EDITOR IN CHIEF

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FOREWORD

The International Research Conference 2018 of General Sir John Kotelawala Defence University (KDU IRC-2018) was on the 13th and 14th of September on the theme, Securing Professional Excellence through Collaboration. It was held for the 11th consecutive year under the guidance of the Vice Chancellor, Rear Admiral JJ Ranasinghe. The inaugural ceremony of the conference was held at the auditorium of the Faculty of Graduate Studies, under the patronage of the Secretary to the Ministry of Defence, Mr. Kapila Waidyaratne. Many distinguished guests: Tri-service Commanders, members of the Board of Management of KDU, representatives of the Diplomatic Corps, Vice Chancellors of other state universities, senior officers of the Tri-services and the Police, graced the event.

The session was opened by the Vice Chancellor, and he warmly welcomed all the dignitaries and participants. Further, he briefly explained the significance of the theme of the conference and KDU's commitment to fulfill national responsibilities. KDU IRC-2018 awarded honorary professorships to two internationally eminent Sri Lankan born scientists, Professor Mohan Munasinghe and Dr Sarath D Gunapala, in recognition of their contribution to their respective fields of science, and to mankind.

Delivering the keynote address, Mr. Waidyaratne commended KDU for playing a leading role in moulding the future of the military as well as civilian youth who are in pursuit of high quality tertiary education in Sri Lanka. He also stated that KDU contributed immensely to the much needed research and innovation, despite being an excellent institution for learning and disseminating knowledge that empowers the youth by helping them to develop sound attitudes and skills.

KDU IRC - 2018 continued with the tradition of bringing together researchers, academics and professionals from all over the world. This conference particularly encouraged the interaction of scholars to present and to discuss new and current research. Their contribution helped to make the conference as outstanding as it had been. A significant increase in the number of research papers received was noted at this conference. Out of 573 research papers received from both local and international scholars, 370 research papers were selected for presentation through the double blind peer review method. Each paper was reviewed by two independent experts in the field prior to selecting them for either oral or poster presentation. The selected papers were presented in nine research sessions, such as, Defence and Strategic studies, Basic and Applied Sciences, Engineering, Medicine, Allied Health Sciences, Computing, Built Environment and Spatial Sciences, Law and Management Social science and Humanities.

Technical Sessions were conducted on the first day of the conference in each faculty which drew approximately 55 guest speakers internationally and locally. Similarly, on the second day, parallel Plenary Sessions were conducted in the faculties under sub-themes, with the participation of approximately 370 experts delivering speeches related to their respective disciplines. The international guest speakers numbering more than 14 represented countries such as Japan, United States of America (US), United Kingdom (UK), India, New Zealand, Malaysia, Pakistan, Philippines, Burma, Indonesia, Bangladesh and Maldives,

KDU IRC-2018 was a unique research conference due to reasons, such as, international authors were facilitated to present via Skype remaining in their country; articles were automatically uploaded to Google Scholar in order to generate individual citations (H-indexing); the best papers of each category were published in the KDU Journal of Multidisciplinary Studies; and the best oral and poster presentation of each session were awarded.

This book contains proceedings of the sessions conducted under the disciplines of The plenary speeches and selected research papers presented at the technical sessions of the faculty are also included in this book, in addition to transcripts of the speeches delivered at the inaugural session. These Proceedings will no doubt furnish scholars of the world with an excellent reference book. I also trust that this will be an impetus to stimulate further study and research in all areas. I also trust that this would stimulate enthusiasm among scholars to engage in further study and to demonstrate the national and international importance of conducting research. I thank all authors, guest speakers and participants for their contributions.

A conference of this magnitude could not have been realized without the tremendous and generous support of the academic and administrative staff of KDU, who contributed to making it all happen.

Dr. Upali Rajapaksha
Editor
Conference Chairman 2018

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PROCEEDINGS

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Content

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WELCOME ADDRESS

Rear Admiral JJ Ranasinghe VSV, USP, psc, MSc(DS) Mgt
Vice Chancellor

A very good morning to you!

I cordially welcome the Hon. Secretary to the Ministry of Defence, Mr. Kapila Waidyaratne, and I pay my gratitude to you Sir, for accepting our invitation and for being with us today at this 11th International Research Conference of General Sir John Kotelawala Defence University.

Next, I wish to extend a warm welcome to our Keynote Speaker, Prof. Mohan Munasinghe; and the Guest Speaker, Dr. Sarath D. Gunapala, both of whom are very eminent and distinguished Sri Lankan scholars who have made their imprint in the international arena. We are proud of your achievements and we consider your presence here today, as truly encouraging and inspiring us at KDU, as well as for all conference participants.

Let me also warmly welcome the Tri-service Commanders and all the other Members of the Board of Management of KDU.
Also it is my pleasure to welcome Your Excellencies of the Diplomatic Corps; Vice Chancellors of other State Universities; and Senior officers of the Army, Navy, Air Force, and the Sri Lanka Police.

I also wish to extend a warm welcome to all dignitaries, scholars and participants; especially those of you from our friendly countries, who have come all the way to adorn this international conference in Sri Lanka.

Ladies and gentlemen, let me bid all of you present here today a very warm welcome this morning; and extend our appreciation for participating in this important event of our calendar.

We at KDU consider this annual conference very seriously due to several reasons. First, it is instrumental in establishing and strengthening the much needed research culture within the university, and it permeates the same into other universities and higher educational institutions in the country as well as into the industry through collaborations. Secondly, it gives local participants and institutions invaluable opportunities to establish links and networks with international counterparts, which is essential for progression in respective fields of specializations. Thirdly, it directly and indirectly contributes to the national growth and development in the long run. So, we consider this international research conference as an investment for the future.

As you are aware ours is primarily the National Defence University of Sri Lanka and our primary mandate is to produce academically and professionally qualified officers for our defence services, and we have been doing this for the highest satisfaction of the services. But today KDU has identified the need to establish firm civil military relations to face the complexities in national defence today, and hence the commencement of day-scholar programmes has helped us to achieve that goal while reducing the burden of the other state universities in providing adequate higher educational opportunities for our youths. The well-developed infrastructure, state-of-the art facilities as well as the dedicated human resources at KDU are now being meaningfully utilized to extend its services to deserving

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civilian youths to follow standard degree programmes in diverse disciplines, and the success of our achievement is seen in the increasingly higher number of foreign students who join our courses from countries, such as, the Maldives, India, Pakistan, Bhutan, Nepal, Uganda and Japan; along with expatriate students from Australia, Canada and the Middle East.

Ladies and gentlemen, in the modern times, it is essential not to compartmentalize varied fields, but to instill multidisciplinary collaboration among them. Hence relationships with different fields of innovation help to bridge gaps and inculcate professional excellence, which is the challenge of the 21st century. This explains the validity of the theme of our 11th International Research Conference, "Securing Professional Excellence through Collaboration".

KDU IRC is an ideal opportunity for the academia and professionals, to meet, discuss and exchange views in an academic environment. What is special about our conference is that, it is enriched with the participation of many local and foreign academics in varied disciplines; along with individuals from all three armed forces and the Police Department. Therefore, this is the only conference in Sri Lanka that brings together civilian professionals and their military counterparts.

I extend a warm invitation to the local and foreign students, academics and professionals present here today, to present their research findings; engage with other researchers in your field of study; have fruitful discussions and build life-long friendships with each other.

I welcome all to the 11th International Research Conference of KDU.

Have an inspiring and unforgettable day at KDU!

ISBN number: 978-955-0301-48-5

SPEECH OF THE CHIEF GUEST

Mr. Kapila Waidyaratne
President's Counsel Secretary

Good morning, everyone !

Chancellor, Vice Chancellor, Secretaries to the Ministries, Commander – Sri Lanka Navy, Chief of Staff of the Army, Dampath Fernando and the Air Force, Sumangala Dias, Your Excellencies of the Diplomatic Corp, international organizational scholars and other distinguished invitees.

It is my privilege and honour to be present here as the Chief Guest of the inauguration ceremony of the 11th International Research Conference organized by the Kotelawala Defence University, at which I happen to be the Chairman of the Board of Directors of its management. Let me first express my thanks to the Vice Chancellor, and conference organizers for inviting me as the Chief Guest of this very significant event.

Ladies and Gentlemen, as the Defence Secretary and also the Chairman of the Board of Management, I am aware of the outstanding role played by KDU in the tertiary landscape of Sri Lanka. With the donation of this beautiful estate along with the Kandawala mansion by the late General Sir John Lionel Kotelawala, the third Prime Minister of Sri Lanka, KDU was founded in the 1980s as the only tri-service academy in the country to provide much needed university education to the officers of the tri-services. Since then, KDU has come a long way over the last several decades reaching heights that may not have been dreamt at its inception.

For the last thirty years, KDU has produced thousands of graduate officers of very high calibre to lead the Army, the Navy and the Air Force, as highly disciplined and professional forces. In most recent times with its expansion to provide higher education opportunities to deserving civilian students, KDU has earned a name within and outside the country as a university that provides high quality tertiary education in diverse fields in a disciplined environment.

Today, with nine academic faculties, the Southern Campus and the recently established University Hospital, KDU has come to the forefront with determination to serve the nation in the best possible way. Therefore let me congratulate the Vice Chancellor and his able staff for the tremendous job, the excellent job done by them. Also let me take this opportunity to salute the pioneers of the university, specially the late General Sir John Lionel Kotelawala and Deshamanya Late General Dennis Perera, and let me not forget the political leadership of His Excellency the former President, J.R. Jayawardena, for the foresight to establish this University far back in the 1980s. Ladies and Gentlemen, the 11th International Research Conference that we are inaugurating today is a testimony for the significant role played by KDU in the field of higher education of Sri Lanka. As you are aware, it is not at all an easy task to successfully organize an annual conference of this magnitude considering the previous years. This itself indicates the strong commitment and responsibility of KDU to provide opportunities for the all-important task of knowledge creation and dissemination.

As you have already heard, and what I gathered from the Vice Chancellor, every year the number of research

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papers submitted for this conference is on the increase. It is heartening to know that thousands of researchers from all over the country as well as the world consider this conference an appropriate platform to present their papers. Therefore in my capacity as the Chairman of the Board of Management of KDU, I too share with KDU the pride of the leading role played by this defence university in popularizing research, which I believe is an essential, key aspect in the nation's growth.

Ladies and Gentlemen, the conference theme, Securing Professional Excellence through Collaboration, is timely particularly for countries like ours in our quest for appropriate development strategies in the face of new global challenges.

We do need meaningful collaborations across diverse professional bodies, and we cannot be completely looking after our own interests in isolated compartments. So time has come for all professionals to unite in sharing the burden of developing our nation economically, socially and culturally, so that the future generations will have a safer world to live in.

I believe it is our professional responsibility, irrespective of lables of distinction such as scientists, doctors, engineers, lawyers, academics, administrators, military professionals or any other, to find opportunities for innovative collaborations. And in such initiatives we all must reach excellence in our own professional domains and it is in this respect that universities and higher education institutions play an important role.

Ladies and Gentlemen, it is my belief that in this respect General Sir John Kotelawala Defence University is discharging its duty to the nation in a commendable manner. So let me conclude without taking much of your precious time as there are two eminent internationally recognized Sri Lankan intellectuals to deliver key note addresses at this conference. Let me once again thank the Vice Chancellor and the organizers for inviting me as the Chief Guest this morning. And let me also congratulate them for organizing a conference of this nature on a very timely and an important theme. Finally let me wish the two-day conference and both national and international participants a highly productive conference with intellectually stimulating deliberations.

Thank you very much.

ISBN number: 978-955-0301-48-5

KEYNOTE SPEECH

Professor Mohan Munasinghe
Professor of Sustainable Development, Sustainable Consumption Institute, University of Manchester, UK
Founder Chairman of the Munasinghe Institute of Development, Sri Lanka

Good Morning to everybody!

Distinguished Audience, Vice Chancellor, Secretary, Service Commanders, Distinguished Guests Excellencies and of course fellow academics - I'm going to talk to you very briefly about Sri Lanka's sustainable mission and how we can achieve security, peace and prosperity through the green growth path. I would like to emphasize that we are looking for win-win solutions for people, the planet and prosperity for the entire globe. Now let me talk very briefly about the major issues that we face, i.e. threat for global security, and threats, such as, poverty and inequality due to resource shortages, shortfalls in the financial sector, disasters, conflicts and unfortunately weak leadership at the global level.

There is a concept called ecological foot print of humanity, which tells us how much of the planet resources we are using in total. In 2012, we were using one and a half times the equivalent of what the earth can sustainably produce, and by 2030 If we continue our present pattern of development we will need two planets! We know that we have only one planet. Sri Lanka is also exceeding its own ecological balance; it means we are chopping down the forests, polluting the water and so on. Now we have another question. It is the question of over consumption because if you look at who is doing the consumption, the richest people on the planet or the top 20% is consuming 85% of the resources, which is sixty times more than the poorest.

Sri Lanka has a dynamic nonaligned strategy; friend of all and enemy of none, which is something the President emphasized to me very much. The multipolar world order will be hopefully much more dependent on soft economic power rather than military power. And you have many poles of influence in the world. As we move to that, there will be disturbances, but Sri Lanka has a very key geostrategic position, and we can play a role in this. In case of climate change and global warming, there are two key facts which are the most important. The first point is; poor countries in poor groups suffer the most, which is manifestly unfair because the poor countries and the poorer people had the least to do with creating the problem. The problem was mainly created by the rich countries but the poor suffer. The second important point is that we follow this balance inclusive of a green growth path and make development more sustainable.

We can meet the challenge of climate change, as well as, all the other problems like poverty and so on. In the history, we have had many civilizations which lasted thousands of years. Whilst the Han civilization in China, Maurya Gupta Empires in India, Mesopotamian and the Roman Empire collapsed, eventually because of environmental and social factors, mainly over consumption of resources, there will be social divisions between rich elites and poor masses. So, these are very important aspects. We can learn a lot from the past history. If you take for example the hydraulic Systems in Sri Lanka, we had a wonderful

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sustainable vision. For example, we believe that land belongs to the people and all living things while the ruler is only the guardian of the land; and King Parakramabahu had said not even a drop of rain water should flow into the ocean, without serving the man. If you look at the old dam anicuts, you will see that they were positioned exactly where the modern instruments tell us where they should be. They were ecofriendly and we had systems like the Velwidhana system and social system, controlling the flow of water which was extremely sustainable. So we have to be very much aware of these environmental and socio economic factors, scarcity of resources, inequality and conflicts which can also affect our present civilization. It could lead to some process of Barbarization where you have unrestrained market forces combining various problems like poverty, inequality and climate change, which would lead to a total breakdown of the planetary system. We also see the mass movement of refugees and other people which is more and more difficult to control, which is really a threat to global security in the future.

So, we now come to the last hope for mankind in a sense in this era, which is the 2015 sustainable development goals and the UN 2030 Agenda. How can we move forward towards a 21st Century Earth Eco-Civilization for a safer and better future? It is through the Balanced Inclusive Green Growth (BIGG) Path. The "Inclusive Green Growth Path", if you analyze the words- 'inclusive' means social; 'green' means Environment; and 'Growth' means Economy. These three elements are in the sustainable development triangle. And one of the core concepts that are extremely important here is, making development more sustainable. It is a call for empowerment and action. It basically says that sustainable development maybe very mysterious like a mountain peak covered with clouds. But we don't need to be discouraged. We will take one step at a time and climb up the hill, and eventually, we will reach the top. And the important thing here is that you and I, individuals, can make a difference.

We don't need to wait for Presidents, Prime Ministers and others to tell us what to do. Many of us know what we need to do. When we leave this room we switch off the light, we can turn off a tap, we can plant a tree, many things we can do that are extremely sustainable; so empowerment is extremely important. At the company level, we have corporate social responsibility and many other things. At the city level we can practice sustainable cities, and we come to the second core concept which is essentially what I told you before, that we need a prosperous economy specially with many millions of poor people in the world, we need to bring them out of poverty, but we also need to look at the environmental side that is the process of growth. So we don't want to destroy the environment and we need the social side which is the most neglected part. Unless we have social harmony none of the other things will be helpful. We can understand nature quite well, such as, forests, lakes and the air we breathe. But we have neglected social capital, human and cultural capital, and we had a 30 year war which eroded a lot of our social capital, this is the glue that binds the society together. All of us have a major role to play in that.

Just to remind you of the 2004 Tsunami in Sri Lanka, which is a shining example of social capital work. We were in the middle of a civil war, a poor country, one in every five hundred people was affected by the Tsunami, and other countries thought our society would collapse. But we rallied; people went out onto the beaches, voluntarily helped other people and cleared the bodies. There was social capital at work. If you look at the following year, in Hurricane Katrina in 2005 in one city New Orleans, what happened? There was no social capital: there was a complete breakdown of law and order, looting, raping and other things were going on. It was shocking because it's a very wealthy country and a small city. Hence social capital is not necessarily the property of the rich. Poor countries have effective social capital networks; we have it in Sri Lanka; we must build it and we must continue with it. I must also tell you very briefly that we need to transcend boundaries within our own mind; also this is for innovation that is what universities have to do.

Values are extremely important. We have to replace unsustainable values with more ethical values. We need to think in terms of multi-disciplinary issues. We need to think in terms of the whole planet and not just our own backyards. We have to think in terms of long time spans, decades and centuries; and as military practitioners, I'm sure you understand that it should be a long range plan, not just today or tomorrow. And we need to work with all stakeholders, i.e. the Government, not only the Government but also the civil society and businesses. Just to emphasize the question of social values, it is unethical social values that actually drive our society towards injustice, violence, greed and selfishness. That has created the state of what I call not as economic development, but as maldevelopment. We are growing based on debt, poverty, inequality and so on, which is not a very healthy way to go, and that has created what is called the environmental death over-using our planetary sources and also causing climate change. When we deplete our natural resources,

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PROCEEDINGS

there is more conflict. So, you have unethical social values. That is a vicious cycle. If you look at the pattern of wars today, there are no wars on weapons of mass destruction, the wars are all for resources for oil, water and land.

So, this cycle has to be broken, and we have to transcend disciplines to do that, we need to think in multi-disciplinary terms, and we need to bring the civil and business societies to work with the government to push them to strengthen democratic space and provide good governance. So, let me just briefly tell you that climate change is in a precarious situation today. We have 280 parts per million, and the main indicator is the Co2 level in the atmosphere. That was at a safe level 100 years ago or more. Today it's over 400. So, we are exceeding the safe level of Co2, and what will happen is that we will have global warming, we will have more rainfall in wet areas so you have more floods, landslides; and more droughts in dry areas and more deserts; and we will have storms, cyclones and other things in addition to sea level rise and overall temperature increase. So the economic damage over the last 50 years is rising and it's going to continue to rise. We need to survive climate change, specially to protect the vulnerable people, poor children and the elderly, in some parts of the world, such as, small islands like the Maldives, and others which will be completely submerged, and particular sectors and systems like agriculture, coral reefs and so on, but unfortunately we are not doing those things.

Talking of sustainable production, there are two key points to consider. The first one is sustainability and triple bottom line, i.e. finance and economy, environmental and social. Those three have become much more important, it's not only a question of profits any more. The second one is effective usage of resources. If you are producing shoes, if you can produce shoes using less leather, less energy and less water; it is a win–win situation, because you are reducing the burden on the environment, and also reducing your cost. So this is very attractive and now we have technologies, which are win-win. There are many technologies which we have applied, for example, in case of a garment factory in Sri Lanka, MAS Holdings, which shows you how resource efficiency works. We have looked at how carbon and energy are used in the life cycle of the product from raw material to manufacturing, to distribution to use and disposal. The main carbon emissions of a garment come from raw material, not only from manufacturing. What is the lesson for us? If you want to reduce emissions of carbon, you are not going to tinker with the manufactory process; you are going to talk to your procurement officer. The procurement officer must buy raw material from the sources, which uses the least amount of carbon. It is not an engineering problem, it's a procurement problem. So this kind of analysis tells you where the hot spot is.

For energy, the hot spot is in manufacturing and distribution and in final endings. Why? Because people wash garments, that is energy, because of hot water. So these are methods on improving production processes; and let me just tell you that what we are planning here is to have sustainable consumers and sustainable producers working together because what you see in advertising today in the TV is mainly very unsustainable; it tells you to buy more and tells you to buy very unsustainable products. We have to break that side and eventually if we get these sustainable consumers and sustainable producers working together, we can eventually have a sustainable society and use modern tools. Traditional markets fall, so we can have organic markets and other things, where you go and buy the stuff, but for young people, it's online marketing. I'm supporting start-up companies which have huge sustainable online markets. Most young people who are in their twenties do not want to visit a shop; they go to the computer and shop online. So you have to have the tool to do the right thing and through these sustainable markets you can build a sustainable society.

In the sustainable Sri Lanka vision, we have hope for a thriving economy. We don't want to be poor. Being green and inclusive does not mean poor. We want to be prosperous and to lead a high quality life in an advanced stable economy, but it is green; it should be built on our traditional respect for nature, use resources efficiently and in an inclusive society. If you look into cross cutting issues, it has things like values, gender, international relations, security and peace; so all of these are integrated. This is one of the failures of Sri Lanka in every department of the Government. It is up to people like you, thought leaders, who can contribute to bring this integration about.

Let me just finish by saying we need to harmonize the economy, society and environment to build the democratic space in Sri Lanka. We need to work with the business society, civil society, the government, or all working together; and let me just end by reminding you that the situation in Sri Lanka has to be improved quite substantially because inequality has become much worse in the last two decades. Although GDP is growing, it is not reaching down. That is a very important aspect. Spatially also, the western province and so on are much better off than for example - the dry zone. We are not

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investing enough in health; we are not investing enough in education rather low as a percentage of GDP.
There are also other things, for example, the Belt and Road Initiative (BRI). The Chinese government is very important for us strategically. If you want to be an Indian Ocean hub, we have to understand that we are right in the middle of the maritime BRR. So we need to be a friend of everybody and enemy of none. We have two major ports, Hambantota and Colombo right in the middle. So Sri Lanka's geostrategic position allows us to play a key role and the investments in the BRI will also help us to bring that about. But we have an important balancing act to play. And I think, the Foreign Ministry and security forces establishment of the country have a very important role in maintaining that balance and bringing prosperity to Sri Lanka. So, for the defense services you have to be good professionals; as professionals you have to be the best. But you have to also understand the economic, social and environmental dimensions of your job. And you have to broaden your perspective to bring those aspects this is difficult.

Although it is a difficult task, our graduates and others need to narrowly focus on their expertise and to be the best in the world. I think you can do much for building the nation, one nation and one flag, protecting the democratic space. And you have to understand the concept of National Identity. We all are Sri Lankans. We have a role in disaster, this is a peace time role going from conflict to resolution; through education and training, raising the standard of national conduct especially among young people; service to the nation; honesty; integrity; respect for nature and environment; respect for the society; law; tolerance and harmony; discipline; leadership; accountability; effectiveness and impartiality, and all of these values have to be rebuilt. My final message is that we face multiple problems, but we know how to address them. Unfortunately we need to do more; we have to go on the balanced inclusive green growth path. The Indian Ocean is a key area where we can do this. We need also to bottom up leadership; we don't have to wait for global leaders to tell us what to do. I think KDU and the Sri Lanka Defence Services can lead the way to peace and prosperity in the 21st century global civilization.

ISBN number: 978-955-0301-48-5

GUEST SPEECH

Dr Sarath D Gunapala
Solid-state Physicist and Senior Research
Scientist, Jet Propulsion Laboratory, NASA,USA

It's my pleasure to be here today, and I'm going to talk about the exploration of our solar system and beyond in the next thirty minutes or so. I have small stories to make it memorable, and I hope you will enjoy it.

I work at NASA Jet Propulsion Laboratory (JPL). Our main business at NASA is exploration of solar system and beyond, using robotic space-crafts. If you hear anything in the news, such as, going to Mars, Rovers, Jupiter, Saturn or beyond solar system, that is what we do.

We design and build space-craft, and seven minutes after launching we take control of it. With the space network, we can listen to our satellites even beyond the solar system. Two of our satellites, Voyager 1 and Voyager 2, are stationed about sixteen billion miles away, so if you have to send a radio signal at one hundred and eighty six thousand miles per second, it takes twenty six hours to go and then acknowledgement comes twenty six hours later, and it keeps changing.

Our deepest space network system has three antennas set in Basku in California, Madrid in Spain and Canberra in Australia. So when the earth spins, we have 24/7 coverage. Why do we do this? When I fly for a long ride, if my neighbour sitting next to me somehow learns that I am a physicist working for NASA, ten out of nine times, irrespective of gender, colour of skin, religion or ethnicity, they ask, "Are we alone? Is there life in outer space?" Looks like the question, "Are we alone?" is somehow genetically quoted into us. It's fascinating! It's interesting to note as to why we call this a solar system and not an earth system!

For nearly a few million years we believed the earth was flat, we were at the centre and everything and the universe spun around us. Normal people, also called Homo Sapiens; in Latin, homo is "man" and sapien is "wise" – "wiseman"- were very egocentric and less tolerant, so they thought everything was around us; but some people thought otherwise. Some thought there were other worlds, and they were put to silence very quickly by execution. Aren't we glad we live in more tolerant times today? We can say, "It's flat", "It goes around or not", "I don't believe in it", etc. People may argue with you, but not get physical. I'm going to talk about different types of space-craft we use, one example for each satellite class, such as, Voyager, Cassini, Phoenix and Curiosity. Then I'll talk about the hunt for other earth-like planets and recent developments in the search for life in our solar system and beyond.

JPL was formed by the California Institute of Technology in 1936 as a graduate student experiment with the involvement of six students. JPL gave the first orbiting spacecraft called Explorer 1 to the United States of America in 1958. The first two Russian spacecraft were Sputnik 1 and Sputnik 2. We have about 9000 staff, located in Pasadena in California at the foot of St. Gabriel Mountain. In 1940, JPL's first claim to fame was the development of something called jet assisted takeoff, during the World War II, for planes to takeoff at very sharp angles, so in enemy

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territory it was very helpful. In 1950, they developed the first guided missile for the United States Army, and in 1958, they designed the first orbiting satellite called the Explorer. Today, we have thirty one robotical spacecraft, two beyond the solar system and the balance twenty nine are around different planets. The four types of spacecrafts we use today are: Flybys, Orbiters, Landers and Rovers. Sometimes planets align; in that case it is much more cost effective to send one satellite to observe few planets. It happens once in one hundred and seventy six years; they are the major plants: Jupiter, Saturn, Uranus and Neptune. Voyager is a Fly-by. We built two voyagers, Voyager 1 and Voyager 2; and launched them to Jupiter in 1976. Jupiter, the largest planet, is a thousand times larger than the earth and does not have a terrestrial land; instead it's just a gas bowl with many moons. Before sending the Voyager, we knew of only four moons, discovered by Gailio called Galilian Moons, bigger than our moon, but Voyager 1 discovered fifty four moons, so Jupiter has fifty eight moons. It's fascinating! In one of the Galilean moons, we observed a big volcanic eruption. This was the first time we observed a volcanic eruption beyond the earth. All the planets of the solar system are on one plain called the Solar Plain.

Voyager 2 was sent two weeks behind, in case something goes wrong with Voyager 1. Saturn is a magnificent planet, also a gas bowl. It has a fantastic ring system, first observed by an Italian astronomer. Its density is so low, if you can take this serene and beautiful Saturn to the ocean, it will float. Its rings are formed with ice particles; some are like sand pebbles and some are big chunks of ice, as big as ten meters. Close to about sixty moons were observed in Saturn; the biggest moon is Titan, at which temperature is very low and ice water is frozen. Another moon of Saturn is called Enceladus. It is a very small moon covered in ice and it has water-rivers. Hence, it has a lot of interest. Voyager is very interesting. Professor Carl Sagan, Professor of Cornell University, encouraged JPL to put a message if there is any intelligent life elsewhere. So we made a copper record quoted in gold with greetings from fifty five languages including "Ayobowan", one hundred and fifteen pictures, a variety of natural sounds of birds, whales, giraffes, lions, etc., and also President Carter's and the then UN Secretary General Waldheim's message, classical and western music, and also we put a needle and sign language if intelligent life captures it they will figure out how to play it. We put a map of the solar system so that they would know from which planet it came from. We also put sign language indicating where we are and where it came from. It is hoped for someone to find it; similar to in early days when people got lost in the ocean or stranded on an island, they would put a message to a bottle, hoping someone would find it.

The first Lander was launched to Mars in 1975. An Italian astronomer found canals in Mars. So, Hollywood movie makers hypothesized Marshians; little men with big heads, complied with Darvin's theory of evolution. We believed Martians were more brainy. Of course now we know Mars does not have intelligent life, but there could be microbian life.

Curiosity is the largest rover we built; it has ten instruments, cameras and very powerful lasers, which would analyze signals coming from vapour to find out what kind of minerals it has. Curiosity has been working on Mars since 2012, and we are building the next one called Mars 2020, and it will be launched in 2020, it will take eight months to go to Mars. We will launch when Mars and the earth are close, so it doesn't have to travel across the solar system, which would otherwise take years. Mars and earth get close every other year. We are about one hundred million miles away. One Martian year is two earth years. We landed on a crater with a five kilo metre high mound. Why did we select this location? From previous Rovers, Landers and Orbiters there is evidence that Mars has running water. We know on earth, life was formed as soon as it had water. So we thought if Mars has running water, this crater could have water. We wanted to explore whether there are rivers. There were pebbles without jaggered edges, instead they were circular, because for millions of years they would have rolled over. One hundred to two hundred years ago Mars had frozen ice like frozen mud, so in Summer times, it melts. The question is if it had water, what would have happened to it? Scientists believe that when the inner core gets colder and becomes solid, it is called a dead planet as nothing moves, and there is no current and no magnetic field. Therefore, due to blasting of high energy solar wind, the water would have vapourized.

Cassini orbiter launched in 1997 on a journey to Saturn, landed in Venus. Until Cassini, we didn't know Enceladus had rivers. We sent Cassini five miles above the surface of Enceladus. It was a very risky maneuver. We found it has geyzers, everything that a primordial soup needs. Now we know of four places that have water: Mars, Europa (icy moon of Jupiter), Titan and Enceladus. We want to investigate all four. We are very much interested in sending a very specific satellite to Titan to explore the possibility of life. We encourage NASA to fund. Actually NASA funded Europa Clipper Mission last year. Europa

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is one of the large moons of Jupiter discovered by Galilio. In Europa ice cracks all the time, but we don't know the cause. By 2020 we are going to find out whether there is life.

In 2009 we launched the Kepler telescope to find extra planets orbiting around our neighbouring stars. So far we have found five thousand planets. Out of three thousand five hundred of them we found only two earth-like planets; and in one we think there is water. We shouldn't get discouraged; as the Galaxy has two hundred and fifty billion stars. So far we have discovered about two hundred and fifty billion galaxies. If each star has ten planets, there are so many planets more than all the words uttered by human beings in the last several million years; probably one hundred thousand planets in our solar system that can probably have life.

Now we are building a lot of big telescopes for astronomy. The current largest telescope is a ten metre telescope located in Hawaii. We think with large space telescopes we can hopefully find life elsewhere, within our neighbourhood and in the near future. When looking for life, we look around for earth-like blue planets (blue for water), medium in size, hovering around. Bigger stars or giant red stars burnout fast as their life time is short. Medium size stars like us survive longer for about a million years and their biological process is lengthy, so there is plenty of time to evolve.

The building blocks of life are carbon and hydrogen. There is plenty of these in the universe found by NASA's Spitzer space telescope developed about twenty years ago, still in space. Life must be around carbon and water base. Life can come in surprises. Look at life on earth? Take a bird, lion, jelly fish, human, snake and a giant tree. To explain a snake to a person from another planet – how do you explain? We have this animal as long as a rod, no hands, can swallow his prey five times bigger than his mouth, can move two feet per second, can kill a person like me in a couple of hours by biting and injecting some proteins allergic to us, etc. So when we look for life, it can be in different forms, but water and carbon base.

Our ancestors, probably two and a half million years ago, never thought we would walk on the moon; escape the gravity of earth; become the second kind of species, not the first generation, etc. What's happening? Scientists are making new life! A couple of years ago, French scientists made an artificial rabbit. They took the glowing florescent of a jelly fish and mixed and made a glowing rabbit or a luminous rabbit. Now homosepians are creating life. Many cultures or societies in the East and mostly the West thought only God can create life. Homosepians can play the role of God, too! A question for you!

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VOTE OF THANKS

Dr Upali Rajapaksha
The Conference Chairman,
KDU International Research Conference 2018

Honourable Secretary to the Ministry of Defence, Mr. Kapila Waidyaratne, Keynote Speaker, Professor Mohan Munasinghe, Guest Speaker, Dr. Sarath D. Gunapala, Tri-service Commanders, Members of the Board of Management of KDU, Your Excellencies of the Diplomatic Corps, Vice Chancellors of other State Universities, Senior Officers of the Tri-forces and the Police, Our most valued invited guests, Academic and Administrative Staff of KDU Distinguished Ladies and Gentlemen.

It is my privilege to propose the vote of thanks on this occasion. An event of this magnitude cannot happen overnight. The wheels started rolling months ago. It required planning and a bird's eye view for detail. I have been fortunate enough to be backed by a team of motivated and dedicated colleagues, who were willing to take on the completion of tasks beyond their comfort zones.

It is with pride I announce that we received more than 573 manuscripts, from local and international authors, and approximately 350 of them are published. Moving with the times, this year's conference offers great opportunities to presenters, such as the ability to deliver presentations via Skype; and to upload Google Scholar in order to generate individual H-indexing citations.

It is with utmost pleasure I announce that we have also given many opportunities to internal and external undergraduates to share their research findings at our conference, as either poster or oral presentations.

On behalf of KDU, or let me call it fraternity of the one and only Defence University of Sri Lanka, I extend very hearty thanks to our Chief Guest, Honourable Secretary to the Ministry of Defence, Mr. Kapila Waidyaratne; for gracing this occasion. The Support we received from the Ministry of Science & Technology and Bank of Ceylon was immense.

It is my pleasure to acknowledge our gratitude to the Guest Speakers, Professor Mohan Munasinghe and Doctor Sarath Gunapala, for sharing with us their findings and opinions. We are all inspired by your great words. You are an enormous pride to our motherland.

My special thanks go to our Vice Chancellor, Deputy Vice Chancellor Defence and administration and Deputy Vice Chancellor Academic, for your consistent guidance throughout this journey.

Ladies and gentlemen, we thank you for being with us this morning.

Have an inspirational and fruitful day!

PLENARY SESSION SUMMERY – ENGINEERING

The engineering plenary session theme was "Engineering Excellence through Collaborative Researchand Innovation". The session started at 1400 hours at FOE 6-1 hall. The session was chaired by Senior Prof Kapila Perera, Vice Chancellor, University of Moratuwa, Sri Lanka. There were four speakers at the session. They are Prof Nicholas Lawson, Dr Jayalath Edirisinghe, Prof Chandima Gomes and Prof Ruwan Gopura. The first speaker Prof Nicholas Lawson is a Professor in Aerodynamics and Airborne Measurement, National Flying Laboratory Centre, Cranfield University, UK. Prof Nicholas Lawson Presentation at the plenary session is mainly based on Airborne measurement and advanced instrument development methods and insight. According to the speaker, airborne measurement is required in many fields of aerospace, ranging from aircraft development and flight test, to atmospheric sciences. However the application of new advanced methods and sensors to refine instrument design has seen slow adoption by most of these fields. He has explained examples of new approaches, which are used to refine a number of airborne instruments, including the measurement of sideslip angle and angle of attack using traditional instruments and strain and pressure using advanced fiber optic sensors.

The second speaker of the plenary session Dr Jayalath Edirisinghe delivered his speech on Technical and Nontechnical Effects of Road Signing and Markings. Dr Jayalath Edirisinghe is a Head of department & Senior Lecturer, Department of Civil Engineering, University of Peradeniya, Sri Lanka. Dr Jayalath Edirisinghe mentioned that the Highways play an important role for an economic and social development of a country. Due to various technical developments many improvements introduced to highways as well as transportation section contributed to increase the average speed of moving vehicles along roads. For the same reason, time to make decisions while driving also reduced considerably. According to the Dr. Jayalath Road signing and markings improved during last decades with numerous technical and psychological concepts. Materials used, new concepts to address driver attitude, control misbehavior of drivers were few to mention. Modern road signing and markings are there to control drivers mentally as well as physically. As a response to the presentation, audience wants to know what the factors effect drivers are mentally. The latest finding and methods used in the world was explained by Dr. Jayalath.

The third presenter, Prof Chandima Gomes is a Professor in Electrical Engineering, Department of Electrical & Electronics Engineering, Faculty of Engineering, University Putra Malaysia, Malaysia. The third presentation titled as "Engineering Research for a Better Country, Beyond the Seeing Eyes", , Prof Chandima Gomes delivered her speech mainly on why a country invests in universities and research institutes. According to the Prof Chandima Gomes developing the know-how for development and seeking solutions to the issues at national level, rather than providing employment to her adult population. Furthermore "engineering" is specifically designed to produce experts that could address technological needs with short- and medium term solutions. Hence an engineer is expected to keep his eyes open to start from a real problem, and then march towards the best potential solution, in the shortest possible time. Further he stated that researchers, even in the field of engineering, tend to work in their own comfort zones rather than looking for the needs of the nation. He proposed to build up a clear vision and mission that is well-tailored for the country of concern. At the questions and answer period, "What is the his experience in Malaysia" actually Malaysia now moving out from this vicious path Prof. Chandima Gomes stated.

The fourth and last speaker of the session was Prof Ruwan Gopura, Head of the Department Department of Mechanical Engineering, University of Moratuwa, Sri Lanka. He delivered his speech on "Upl ifting Quality of

Living of Physically Weak Individuals: Role of Power Assist Robot Systems". Prof. Gopura explained the background of the presentation and importance of uplifting quality of living of physically weak individuals. "power assist robot systems play an important role to uplift the quality of living of physically weak people in numerous ways", Prof. Gopura stated. He further elaborated how an exoskeleton robot is a power assist robotic system which can be used to rehabilitate patients or assist limbs of physically weak individuals to carry out activities of daily living.At the questions and answer period, Mr. WS Fernando ask on the power requirement of the device." The required power is provide by battery which place in the exoskeleton and it will not be an extra weight for the patients" stated by Prof. Gopura.

After the concluding remarks by the session chair, Senior Prof Kapila Perera the session was concluded and at 1600 hours.

PROCEEDINGS

AERONAUTICAL ENGINEERING AND MECHANICAL ENGINEERING

SESSION SUMMERY

I. INTRODUCTION BY THE SESSION CHAIRPERSON

The session of Aeronautical Engineering and Mechanical Engineering began with a welcome note delivered by the Chairperson, Air Commodore LMSK Leelarathne to greet all the session panelists, judges and the audience. In his address he emphasized on the theme titled, "Securing Professional Excellence through Collaboration" for the Faculty of Engineering at the International Research Conference 2018. In addition, he specially recalled the presentation which was carried out on "Airborne Measurement – Advanced Instrument Development Methods and Insight" by one of the plenary speakers, Prof. Nicholas Lawson, who is a Professor in Aerodynamic and Airborne Measurements at National Flying Laboratory Centre, School of Aerospace, Transport and Manufacturing, Cranfield University, United Kingdom. He specially acknowledged the Rear Admiral Jagath Ranasinghe VSV, USP, psc, Vice Chancellor of General Sir John Kotelawala Defence University, Dr. (Mrs) WCDK Fernando, Dean, Faculty of Engineering and also to Group Captain CJ Hettiarachchi USP, psc, Head, Department of Aeronautical Engineering for inviting him to chair the session. Further, he introduced the sequence of the proceedings, mentioned that there were all together five presentations including one presentation which would carried out via Skype technology. In addition, he recalled the presentation guidelines to the panelists including the time durations for the presentation and question and answers session. He also urged to ask questions from panelists based on their presentations in order to rectify unclear areas in their research.

The Chairperson briefly introduced each panelist before their presentations and also being a senior experienced engineer he also added his views to the discussion at the end of each presentation which showcased the essence of each presentation.

II. PRESENTATIONS BY THE PANELISTS

(a) Mr. Erandith presented a method to develop novel digital video surveillance features to enhance home and business security management. He discussed about a security application which can be used for an automatic human detection with the aid of video streams and surveillance cameras. His research was focused on identify the object motions in real-time video surveillance and passed the message to the user via an alert message.

Mr. Erandith mentioned that the proposed prototype could be used to capture foreground image frames and detect objects using background subtraction. Further he showed that the shape-based object classification could also be used to differentiate human objects from other objects. He proposed that this system could be used as a novel feature of digital surveillance to use security purpose to record the unauthorized physical access, detect and identify the relevant object.

One of the judges inquired the possibility of identifying the animals over humans by this security detection system. Mr. Erandith explained that there are factors that he has used and one is the shape of the object. One of the Senior Lecturer's suggested to remove the background noises before the subtraction carried out for the background. In addition, he commented that what he has done so far is correct based on the theories and he suggested him to read more research papers in order to improve his research further.

(b) Mr. HD Wickramasinghe presented about development of a budget roof fairing using a Computational Fluid Dynamics (CFD) analysis of different roof fairing shapes. He summarized the necessity of their research based on the semi-trailer trucks which are commonly used in Sri Lanka for long distance transportation. He described that these trucks are tend to experience an unfavorable high drag which makes a huge impact in fuel consumption. He described that in order to reduce the drag, semi-trailer truck cabins can be equipped with a roof fairing which provides a perfect air flow over the entire vehicle. He stated that based on their research they were trying to evaluate the efficiency in drag reduction of different roof fairing shapes with the assistance of CFD analysis. Finally, he summarized the results that they were achieved through the simulations. He expressed that there is an impact of the geometry and the deflection angles of the roof fairing to the drag reduction. He suggested that an effective roof fairing shape could be manufactured at a lower cost compared to the roof fairing shapes that are available in Sri Lanka. He concluded his presentation after stating that the final outcomes of this research will be helpful for designers to design more effective roof fairings for semi-trailer trucks with improved drag reduction.

Prof. Lawson asked about the generating about the mesh shapes for this roof fairing and he answered that he has developed many mesh types for the roofing and tailor parts of the truck and selected the best out of all based on the CFD simulations.

(c) Flight Lieutenant Gunawardana presented about designing and development of a flying object for inspection and cleaning of distribution power lines in Sri Lanka. In his presentation he discussed that helicopters and unmanned automated vehicles are being used in developed countries to clean the power distribution lines. He stated that manual inspection and cleaning is the current method use in Sri Lanka. In this research he is trying to develop a UAVs to inspect, detect and rectify the issues occur in distribution power lines in Sri Lanka. The objective of his research is to design and develop an unmanned automated flying object with a robot arm and test its' applicability in inspection and cleaning of distribution power lines in Sri Lanka. He presented the design of the model aircraft and preliminary test results of flying, video transmitting and receiving performances of the Quadcopter. He stated that the inspection system was tested by the visual images transmitted to the ground station and the Quadcopter demonstrated safe flying during the experimental time. Finally he stated that upon completion of this experiment his design could be used in Sri Lanka to detect contaminations and clean distribution power lines.

Prof. Lucas was pointed out about the speciality of this so called quadcopter over the commercially available Quadcopter and he answered that in this developed Quadcopter will consist with a robotic arm which could be used to clean the power distribution lines. Another onlooker inquired about the workability duration of this developed model as it powered by batteries. The speaker stated that the quadcopter can be worked for 45 minutes continuously.

(d) Acting Sub Lieutenant SH Munna, presented on impact of human factors on airline overall maintenance effectiveness as an analysis of major aircraft operators in Sri Lanka. The presenter explained that skill based error and mistakes plays a significant part when it comes to the aviation human factors in maintenance related activities. He discussed the research was focused on the maintenance environments of two of Sri Lanka's leading aircraft operators. He stated that they have focused a civil and military maintenance organization for the research and the relevant information was gathered using a structured questionnaire. He explained that they have found out the skill-based errors have a significant contribution for the overall maintenance effectiveness. Finally, he stated that by identifying the probable causes and use prevailing condition will assist to overcome existing shortcomings whilst improving the maintenance effectiveness.

Prof. Lawson inquired about the factors that they have taken in account with related to the human factors. The speaker replied that they have considered several factors such as fatigue, distraction, interruption and over confidence in their study.

(e) Mr. WTS Rodrigo delivered his research work via Skype. His research work was based on optimal crew planning through variable capacity assignment for commercial aircraft flight line maintenance. He stated that the crew planning and scheduling has been researched intensively as it affects the aviation operational costs substantially. As per him the maintenance crew planning is an integral part of the same where less emphasis paid compared to flying crew scheduling. His research paper presented an optimal framework for commercial aircraft flight *he* it is possible through multi skilled persons whilst having the most appropriate line maintenance labour planning. He has developed a mathematical model in his research and maintenance workforce was used as the main variable and which was applied variably to suit the fluctuating demand. Finally, he stated that the developed model would enable aircraft maintenance planners to identify most appropriate combinations of crew sizes, shift patterns and respective shift staring times to fulfil varying maintenance demand. At the question and answer session Prof. Lawson asked a question which was about possibility of utilizing the same

crew for different type of aircraft in order to optimize the crew members. By answering to that the speaker stated crew combinations and shift schedules with a special emphasis on ease out the maintenance certification constraint, which is a unique condition in aircraft maintenance.

III. CONCLUSIONS

The Chairperson Air Commodore LMSK Leelarathne summarized the session by highlighting the major outcomes in each research presentation and he specially thank all the panelists, judges, rapporteur, organizing panel and also to the audience. In the conclusion remark the chairperson specifically mentioned to continue the presented research work until it comes to a certain standard as several presented research work were in preliminary level yet.

Finally, at the end of the session Prof. Lawson was also shared some of his thoughts related to presenting of precious data in experiments and importance of conducting quality research work.

The follow-up talks after the session between participants and the panelists showed the need to improve understanding of the topics involved.

DEVELOPMENT OF A BUDGET ROOF FAIRING USING A CFD ANALYSIS OF DIFFERENT ROOF FAIRING SHAPES

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Abstract - Semi-trailer trucks are commonly used in Sri Lanka for long distance transportation. These trucks are subjected to an unfavourable high drag which makes a huge impact in fuel consumption. In order to reduce this drag, semi-trailer truck cabins are implemented with a roof fairing which provides a perfect air flow over the entire vehicle. Purpose of this research was to evaluate the efficiency in drag reduction of different roof fairing shapes by conducting a computational fluid dynamics (CFD) analysis. Simulations were done on a 1:1 scaled semi-trailer truck model which was modelled using the blueprint of a commonly used truck model in Sri Lanka. Initial simulation was done without the roof fairing and results were compared with the values of coefficient of drag provided by the manufacturer to improve the accuracy of the research. Different roof fairing shapes were then modelled and attached to above mentioned cabin model and CFD simulations were performed. Subsequent simulations were done using three truck speeds which were 30, 60 and 100 kilometres per hour. The efficiency of each roof fairing was analysed during the post-processing phase after the estimation of the coefficient of drag values. Effect of other coefficients such as coefficient of lift and moment were also considered during the analysis. Results which were achieved through the simulations illustrated a drag reduction excess of 10-25% due to the impact of the geometry and the deflection angles of the roof fairing. Based on the analysis, an effective roof fairing shape was proposed which can be manufactured at a lower cost compared to the roof fairing shapes that are available in Sri Lanka. Final outcomes of this research will be helpful for designers to design more effective roof fairings for semi-trailer trucks with improved drag reduction.

Keywords - CFD, Drag Reduction, Wind Shield

I. INTRODUCTION

Semi-trailer truck configuration was modeled as a 1:1 scaled model based on the most common prime mover which is commercially using in Sri Lanka and simulations were performed. Blueprints provided by the manufacturer were used for solid modeling of the truck and initial simulations were done using only the tractor and trailer configuration without attaching the modeled roof fairing shapes. In tractor-trailer configuration, aerodynamic drag occurs mainly due to the shape of the cabin, transition gap between the tractor, underbody of the truck and rear edge of the trailer (Curry et al., 2012). After confirming the accuracy of the simulated coefficient of drag values with the values provided by the truck manufacturer, the modeled roof fairing shapes were attached, and simulations were done. Simulations were performed for three different inlet velocities using *OpenFOAM* computational fluid dynamics software and the inlet velocities were selected considering the speed ranges in Sri Lanka. The efficiency of the different roof fairings was analyzed in the post-processing based on the parameters such as coefficient of drag, the percentage of drag reduction relative to the truck without the fairing, horizontal deflection angle and vertical deflection angle of the roof fairing. Other parameters such as coefficient of lift and moment were also considered in the analysis phase, for that Navier-Stokes equations were used. A percentage reduction between 10 – 30% was obtained for the different roof fairing shapes and It was found out that vertical deflection angle of a particular roof

fairing provides a higher impact to the drag reduction as well as efficiency. Results obtained from the analysis was used to develop a low-cost roof fairing shape which is more compatible with the Sri Lankan road conditions and the economy. The most prominent parameters highlighted in the analysis such as vertical deflection angle was considered for the development of the new design. It was focused more to keep the curvy surfaces lower as much as possible in order to reduce the cost of machining and tried to keep the machining techniques and material used as simple as possible. The new budget roof fairing design is developed to manufacture using the aluminum material with basic welding techniques and fabrication techniques which are commonly available in Sri Lanka and a cost estimation was also done based on the rates of local manufacturers and suppliers. The design outcome of this research will be helpful in manufacturing a low cost and affordable roof fairing shape for the local market which is more efficient in reduction of drag, other related problems of fuel consumption and economic factors in Sri Lanka.

II. METHODOLOGY AND APPROACH

Performance assessment of the truck with different shapes of roof fairing was done by using following tools:

- Solid modeling
- Mesh generation
- Computational Fluid Dynamics

The blueprints of the cabin of truck were obtained by the manufactures, the 3-D model of the truck and the different shapes of roof fairings were created using *SOLIDWORKS* 2015 and then generated meshes using *OpenFOAM* "snappy hex" tool. Meshes were generated for each roof fairing shape. With the available computational power grid negligence procedure was conducted to find the best mesh that could be used to perform the CFD analysis without interruption. The Mesh generated for the basic truck without roof fairing is shown in figure 1.

Figure 1. 3. D Mesh created by OpenFOAM snappy hex tool

The quality of mesh was a factor for the improve the accuracy of the solution and the computational time. Considering that fine mesh was generated, and inflation layers were added to the near surface of the truck to capture boundary layer interactions accurately. Cell volume details of generated computational domains are given in Table 1.

Table 1. Cell volumes of computational domains

	Basic Truck	DAF SE1643	Volvo FM12	Renault 420 DCI
Cell Volumes	2,572,217	5,961,439	5,428,264	5,779,100

After generating the mesh *OpenFOAM* CFD tool used to run the analysis. K-Omega SST model which is two-equation turbulence model which became more recommending because of its analytical capabilities in ordinary aerodynamic streams. Simulations were run on hired server 8 core 3.0 GHz computer with 32GB RAM, up to 10000 iterations and the solutions converged around 4500 iterations. The process was repeated for each model to all three velocities.

III. RESULTS AND DISCUSSION

In the post processing phase, final results were observed and compared through an analysis of the flow properties. For the analysis, the *ParaView* (5.5 version) post processing tool was used since it has the capability of handling multi-platform data and large-scale data which is important in this analysis. Results obtained through basic long truck without the roof fairing was used to compare coefficient of drag values with each roof fairing. It is important to have a reference value to compare since we used a moderated model for the simulations. (Table 2)

From the simulations it was understood that the vortices which are generated due to flow separation when the flow leaves the rear end of the trailer causes a severe pressure to drop behind the long truck. Due to that a large wake region builds behind the trailer of the long truck.

Long truck is a blunt body which generally creates a high pressure in the front face due to the crashing air molecules in the front face of the cabin due to the movement of the long truck. The trailer which generally has a larger face than the cabin also influences in creating a high-pressure force in the frontal area. These crashing air molecules tend to move up or down or sideways along the front face and

Table 2. Reference values of models

Roof Fairing Shape	Horizontal Deflection Angle (°)	Vertical Deflection Angle (°)	Base Area (m^2)	Perimeter of Base (m)	Coefficient of Drag		
					30kmph	60kmph	100kmph
Without fairing	0	0	3.558	7.695	0.3724	0.3775	0.3766
DAF SE1643	19.77	35.68	2.318	6.021	0.2799	0.2786	0.2778
Volvo FM12	8.66	37.76	2.99	7.012	0.2952	0.2943	0.2933
Renault 420DCI	20.71	15.62	2.709	6.807	0.3296	0.3283	0.328

join other molecules of streamlines which moves along the surfaces of the truck. This accelerates the flow speed along the surfaces which creates the flow separation at the rear end. Simulations were done in three different velocities but the coefficient of drag values remained relatively same even at larger velocities showing that the impact of the velocity is minimum.

Roof fairings are used to reduce the flow separation due to above phenomena. Roof fairings help these crashing molecules to move smoothly over the surfaces of the long truck by reducing its turbulence impact on the streamlines around it. roof fairing with higher horizontal deflection angle sends most of these molecules along the side surfaces of the truck. But from any simulation, a significant effect on drag reduction couldn't be identified due to the high horizontal deflection angle.

Vertical deflection angle sends these molecules above the long truck. When the vertical deflection angle is high it prevents air particles crashing on the top of the trailer (Figure 2). This prevents the probable reverse flow that occurs in the gap between the cabin and the trailer which happens in long trucks without the roof fairing. Roof fairing with a lower vertical deflection angle showed relatively a smaller drag reduction compared to other roof fairings because of the above mentioned reverse flow. Through the simulations, it is understood that the higher the vertical deflection angle higher the drag reduction will be.

Roof fairings which were built with a curvature in the top surface have shown a better drag reduction compared to the other roof fairings. It is also understood that the roof fairings which were built with several layers allow air to be flown in different levels which reduces the air molecules mixing with other streamlines (Figure 3). This reduces the turbulent behavior of the streamlines which leaves the rear of the trailer. From all three roof fairings, the most drag reduction was reported in the roof fairing which has a curvy geometry and a higher vertical deflection angle.

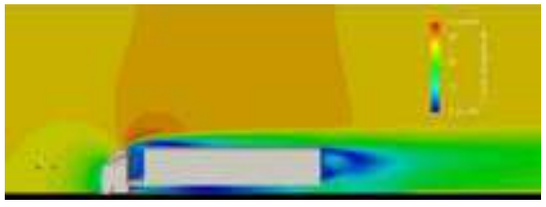

Figure 2. Velocity profile

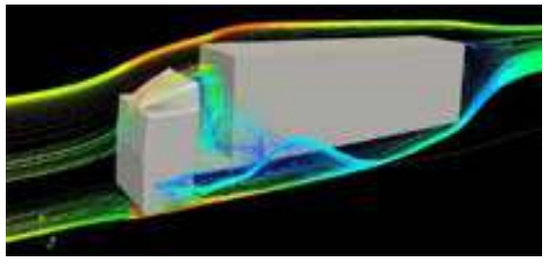

Figure 3. Flow visualization using streamlines

III. CONCLUSION

the analysis, it was understood that the effect of velocity on aerodynamic drag is minimum. Hence velocity doesn't affect at all for the performance of the roof fairing in drag

reduction. Researchers also identified that the reverse flow in between the cabin and the trailer also affects the resultant drag force. It was understood that the vertical deflection angle makes an impact in increasing the efficiency of roof fairings, but the impact of horizontal deflection angle is low. As for the results, the geometry or the shape of the roof fairing made the highest contribution in drag reduction by allowing streamlines to flow smoothly over and in the sides of the long truck. As for the recommendations, researchers are willing to introduce two budget roof fairing designs in near future based on the analytical data obtained through the process.

Researchers propose first roof fairing design (Figure 4) as a budget roof fairing with a higher aerodynamic efficiency that can be afforded by any entrepreneur. In this design, effect of horizontal planes was considered as negligible. This design was prepared by removing the side panels of the roof fairing. A curvy top surface in a vertical angle of 35.68˚ is the prime part of the design which is the same vertical deflection angle of the roof fairing that showed the highest drag reduction.

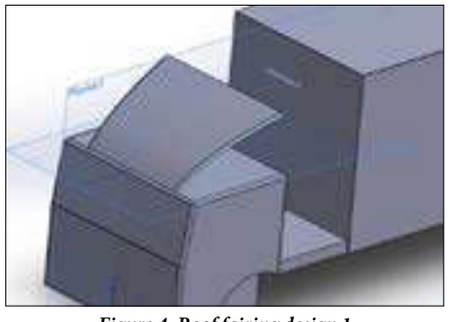

Figure 4. Roof fairing design 1

Design 2(figure 5) was made by taking all the conclusions into consideration. Vertical angle hasn't changed from the earlier one (35.68˚) and the horizontal angle was decided by allowing flow to be deflected just enough to flow along the side surfaces of the trailer. Side panels are designed using a surface arc producing a very smooth deviation of the flow in side panels of the roof fairing. This fairing will be designed using lesser number of sheet materials compared to any other roof fairing that is in the current market. As for the connecting of surfaces researchers propose to use TIG welding method. This welding will allow to use thinner sheet material and it also allows a perfect finish on the surface which will not interrupt the smooth flow over the roof fairing.

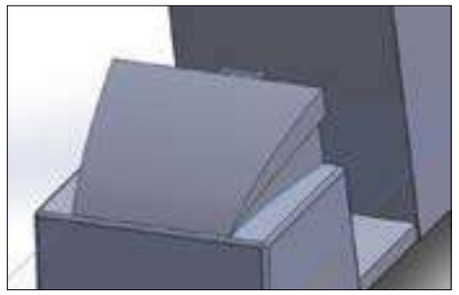

Figure 5. Roof fairing design 2

Performance analysis of the new designs using CFD simulations are ongoing and researchers also plan to develop prototypes and compare the results in future.

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DESIGN AND DEVELOPMENT OF A FLYING OBJECT FOR INSPECTION AND CLEANING OF DISTRIBUTION POWER LINES IN SRI LANKA

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Abstract - Inspection, detection and cleaning are essential for the maintenance of distribution power lines (DPL). Developed countries use unmanned automated vehicles (UAVs) for this purpose. Helicopter usage is efficient but costly and ineffective for developing countries. Manual inspection and cleaning is the current method used in Sri Lanka. Most research on UAVs in the developing world are at experimental level; practical appliances have been slightly neglected. It is possible to use UAVs to inspect, detect and rectify the issues occur in DPLs in Sri Lanka. This can reduce costs, risks and logistic problems of manual inspection and cleaning. Aim of this project was to design and develop an Unmanned Automated Flying Object (with a Robot Arm) and test its' applicability in inspection and cleaning of DPLs in Sri Lankan context. This paper describes the design and preliminary test results of flying, video transmitting and receiving performances of the Quadcopter. Design of the system architecture of the Quadcopter encompasses a flight control system, Xbee module, inspection camera and a robot arm. The flight control system was tested by practical demonstration. Flying route was recorded from the ground station. The inspection system was tested by visual images transmitted to the ground station. The Quadcopter demonstrated safe flying. Minor errors caused in inspection and detecting may be due to sudden winds, poor GPS signals or electromagnetic interference. Testing of the robot arm is still underway. Upon completion of the experiment this Quadcopter can be used in Sri Lanka to detect contaminations and clean DPLs.

Keywords - Quadcopter, distribution power lines (DPL), Inspection

I. INTRODUCTION

Electric power distribution is the final stage in the delivery of electric energy to the consumers. Transmission of electrical energy along large distances is via overhead power lines; heather to referred as the 'distribution power lines' (DPL). Since most of the insulation is provided by air, overhead power lines are generally the lowest-cost method of transmission for large quantities of electric energy.

The demand for electricity in Sri Lanka had risen due to the country's sustained economic growth. There is a growth in the development of the power transmission and distribution projects island wide (Shimomura et al., 2005). All DPLs should be inspected after construction, before energizing the line and throughout the maintenance process. Maintenance of DPLs has become an important issue because too much investment had been put into the power generation sector (Shimomura et al., 2005). It seems maintenance sector has lagged markedly causing various problems such as insufficient capacities in transmission lines, voltage drops and electrical transmission losses.

In spite of frequent maintenance the DPLs often get contaminated with natural causes and human activities. For example branches of the trees, bushing, bird nesting, animal collisions, kites and other objects. Frequent power outages due to salt contamination on DPLs are common in coastal areas; especially in Puttalam, Mannar and Jaffna areas (Wijayathilaka, 2014). Birds cause damage and disruptions in many ways. They build nests on transmission poles, sit on the lines causing long term accumulation of

contaminations by bird droppings, collide with power lines and damage facilities causing much inconvenience in maintenance. On DPLs overhead ground wires are often smaller, and so are more likely to cause bird collisions.

Inspection, detection and cleaning are mandatory components of maintenance of DPLs. Manual inspection and cleaning of DPLs is the only method used currently in Sri Lanka. Wijayathilaka, (2014) stated salt contaminations are flushed away from the insulator surface naturally during the rainy season but not up to the sufficient level as most of the coastal areas in Sri Lanka are dry throughout the year. The presently adopting method is wiping out the insulator surface by hand and wash insulators with mild water (with low conductivity) while interrupting the feeder supply. Manual inspection of tree branches and bushes on DPLs from ground is difficult and ineffective. Removal is currently done by the municipalities using tree trim crews. Manual inspection and cleaning of DPLs is difficult, costly, inefficient and time consuming activity. This requires more man power and it carries huge risk for the maintenance crew. Therefore it is timely important to introduce an alternative way that ease the maintenance of DPLs.

Most of the developed countries use robots, helicopters or unmanned automated vehicles (UAVs) for inspection and cleaning of DPLs (Ceron et al., 2014; Li et al. 2013; Wang et al., 2010; Jones, 2005). There are various types of UAVs used in the field, to name some rotorcrafts and unmanned automated aircrafts. Helicopter usage is costly (Wang et al., 2010), may not be effective and affordable for a developing country like Sri Lanka. But instead this can be carried out using UAVs at a very low cost in most of the situations.

Use of UAVs in DPL maintenance is a novel concept in developing countries in the world. At experimental level popular focus is on design, control, runtime and stability of UAVs (Wang et al., 2010; Li et al. 2013) but the practical appliances of these have been slightly neglected. UAVs are not used within the current system in Sri Lanka. However it is possible to use such method for inspection, detection and rectifying the issues that occur in DPLs. Current study has a significance impact on introducing a new approach that reduce costs, risks and the logistic problems of manual inspection and cleaning of DPLs.

Aim of the main project is to design and develop an unmanned automated flying object (with a robot arm) and to test its' applicability in inspection and cleaning of DPLs in Sri Lankan context. The project is still ongoing, there for this paper only describes the design phase of the model aircraft and preliminary test results of flying, video transmitting and receiving performances of the Quadcopter.

II. METHODOLOGY/ EXPERIMENTAL DESIGN

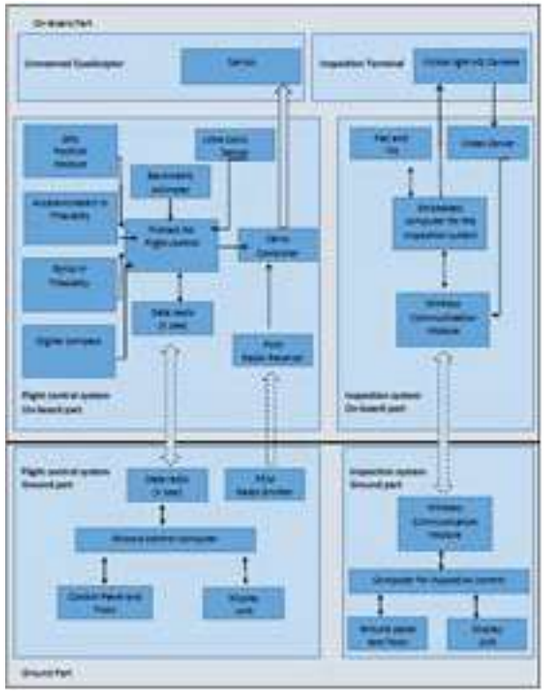

Figure 1: System Architecture of the design (Source: Author)

The model consists of three sub systems; the flight control system, inspection camera system including an Xbee module and a robot arm. The flight system consists of an unmanned flying object (Quadcopter) and a flight control system including an on-board part and a ground part. The computer based on the ground station is for managing flight plans and tasks, manually controlling the Quadcopter and displaying the state parameters of the Quadcopter. Inspection system consists of a HD camera and an Xbee module. The HD camera is used to obtain visible-light images. This can be used to detect visible faults or contaminations on transmission lines. The camera is controlled by the embedded computer at the ground station. The visible-light camera produces both videos and high resolution still images. The videos acquired by the camera are directly transmitted to the ground through the wireless communication modules. The Xbee module increases the reliability of the communication between the aircraft and the ground station. Videos are processed and then displayed on the computer screen. The still images are saved in the storage unit. Figure 01 illustrates the detailed system architecture of the design.

Figure 2: The model aircraft (Quadcopter)

III. EXPERIMENTAL RESULTS AND DISCUSSION

The model aircraft was developed and installed a video data link, HD camera and the Xbee module on it. A practical demonstration was conducted to test the flight control system. The aircraft could fly successfully along a 33kV distribution power line. Total flying distance was about 2 km. Flying route was recorded from the ground station. Practicability of the inspection system was tested by the visual images transmitted to the ground station from the Quadcopter. Figure 2 and 3 show the Quadcopter and the interface of flight control system.

In many developing countries the inspection and cleaning of distribution power lines is mainly carried out manually whereas the developed countries use helicopters and UAVs (Wang et al., 2010). Current project is a novel concept to design and develop a Quadcopter with abilities to inspect, detect and rectify the contamination of DPLs.

Figure 3: The interface of flight control system

This Quadcopter is controlled by a radio- transmitter sending signals to a receiver in the model which in turn actuates servos which manipulate the model's flight controls in a similar manner to a full sized aircraft. We used a flight controlling computers to fly the aircraft autonomously and to stabilize the aircraft. Vision information is a good means of inspection and detecting the errors on DPLs (Wang et al., 2010). There's still room for further improvement of the quality of visual information if used a thermal camera (Wang et al., 2010). Austin and Earp (2004) used a TV camera with 10:1 lens with a thermal camera in their unmanned helicopter in order obtain a better inspection. Design and development of the robot arm is still under way. The experiment will continue to test the practicability of visual system and the robot arm, which is our future work. The project will be completed by September 2018.

IV. CONCLUSION

In conclusion the UAV demonstrated safe flying. Minor errors caused in inspection and detecting may be due to sudden winds, poor GPS signals or electromagnetic interference. Testing of the robot arm is still underway. This UAV can be further improved using a thermal detection camera for thermal detection. Upon completion of the experiment this UAV can be practically used in the current system to detect and clean DPLs in Sri Lanka.

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IMPACT OF HUMAN FACTORS ON AIRLINE OVERALL MAINTENANCE EFFECTIVENESS: AN ANALYSIS OF MAJOR AIRCRAFT OPERATORS IN SRI LANKA

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Abstract - Skill based error and mistakes form a significant part of the effect of aviation human factors as far as maintenance is concerned. Many air and ground incidents have been traced back to have occurred due to lapses that occurred during handling and maintenance of aircraft, which resulted in such human errors. Proper identification of the possibility of such mistakes and errors to occur in a given maintenance environment and finding steps to mitigate the same is crucial in order to increase the effectiveness of the airline's maintenance programme. This research focused on the maintenance environments of two of Sri Lanka's leading aircraft operators. For diversity, a civil and military maintenance organization was selected. Information was gathered by means of structured questionnaire and existing records of aircraft related incidents and occurrences. Quantitative and qualitative analysis of data was conducted. Quantitative analysis was done using SPSS software and comparisons were made between different indicators such workplace design, fatigue, routine violations etc.

It was found that mistakes amount to a higher percentage of errors caused, whilst skill-based errors have a significant contribution as well. Identification of the probable causes and prevailing condition of human factor contributions to maintenance effectiveness will provide insight to the respective organization to find better solutions to overcome existing shortcomings.

Keywords - Human factors, Mistakes, Maintenance effectiveness, Skill Based errors.

I. INTRODUCTION

Smooth functioning of an airline requires arranged contribution from every level starting from pilots to maintenance crews. In order to ensure effective maintenance, manageability and accountability every level is designated with specified task and held responsible for their own deliverables. This research emphasizes on reducing the effects of aviation human factors to enhance airline overall maintenance effectiveness.

Human factors is simply human performance in the working environment. The role of 'Human Factors" include Information about human abilities, human's limitations, flaws along with other characteristics of human and applying it to machines, systems, tasks, equipment, jobs, tools as well as the working environments to produce and also to ensure harmless, comfortable, and effective use of human in aviation.(Graeber, 2017).

The role of human factors in aviation safety cannot be underestimated. One small error caused by poor procedures, maintenance technicians, pilot, air traffic controller or else line manager can result in catastrophic events including the loss of life. In aviation, human factors is dedicated for better understanding on how humans can most carefully and skilfully be integrated with the present and updated technology. That understanding can be put into design, training, policies, or procedures to help human's performance better. An aircraft is just a

machine, and machines sometimes malfunction. Flight attendants and pilots may even fly several times per week even though the airlines companies take all possible precautions to avoid any accidents or incidences. This research will mainly focus on the impact oferrors done by the maintenance engineers and technicians in the aircraft maintenance environment.

A. Research Question

The research questions around which this research is based are presented below:

Primary Question: Does airline's overall maintenance effectiveness depend on mitigation of skill-based error rather than mistakes?

Secondary Questions

a. Is 'skill-based error' the main cause of human error present in airline maintenance organizations?

b. What is the present procedure followed in civil and military airline operating organizations in Sri Lanka to mitigate human errors?

c. What are the recommended procedures for ensuring the expected performance from the maintenance crews for overcoming human errors, mostly skill-based errors?

B. Research Objectives

The main objectives of this paper is to recommend ways for mitigating the adverse effects of aviation human factors of aircraft maintenance crews of maintenance organizations by reducing skill-based errors.

The specific objectives are to find whether the effects of skill-based error affect the maintenance effectiveness of the two main civil and military airline operating organizations in Sri Lanka. Identifying common errors and mistakes done by the maintenance engineers and technicians in the two selected organizations. Finding whether skill-based errors of maintenance engineers and technicians vary due to the age and gender difference and measures could be taken to mitigate effects of human errors to enhance maintenance effectiveness.

C. Research Hypothesis

The research hypotheses are as follows:

Hypothesis 1 : Most of the human errors are occurring due to skill-based errors by maintenance crews in civil and military airline operating organizations in Sri Lanka.

Hypothesis 2 : Human errors due to mistakes have been mitigated to an acceptable level by civil and military airline operating organizations in Sri Lanka.

II. METHODOLOGY

The scope of this research was limited to focus only on skill-based errors and mistakes. There are many elements of skill-based errors that can remain latent for a considerable amount of time and result in a catastrophic form afterwards. The data which has been collected through a series of interviews by the aviation personnel and questionnaire has helped to sort out the common indicators of Skill Based Error.

A. Rationale for Adopting the Method of Research:

The research has been conducted by a detailed survey from military operator and civil operator of Sri Lanka to ascertain the hypotheses. It is a descriptive and causal research and followed the mixed methodology. The sample included aviation maintenance crews, including the engineers and technicians from both organizations. The subjects have been selected on random sampling method and both qualitative as well as quantitative data has collected in the form of survey. Interview of maintenance crews has been taken and used for qualitative subjective analysis. Relevant literatures on the subject is the main sources of secondary data.

B. Conceptual Framework:

The conceptual framework which connects the dependent variables (DV): "Skill-based error" to the independent variables (IV): "Slip of action" and "Memory lapse" and "Mistakes" to independent variables "Knowledge based errors" and "Rule based errors". The independent variables have different indicators. Sorting out these indicators of each independent variable is necessary for the research. The indicators of slip of actions are shown below:

- Workplace design
- Fatigue
- Distraction
- Interruption
- Supervision
- Independent checking
- Over confidence

The memory lapses that can occur amongst the maintenance crews can be found out by the indicators' interruption and distraction of the independent variable slip of actions. Besides age and gender also have their role on memory lapse. It can be faced by the people of almost all ages, but the severity differs from age to age. Though mistakes have not emphasized much in the research; yet, through the questionnaire and interviews it has sorted out whether it contributes more that the skill-based errors. So, to know about the indicators of mistakes is necessary. The indicators of mistakes are given below:

Knowledge based errors and Rule based errors

- Improper application of good rule
- Bad rule

C. Data Collection:

Primary data was collected through a structured questionnaire which was distributed to engineers and technicians of the two organizations. Further, interviews were conducted where areas such as total strength of the maintenance crews, number of qualified personnel, most common incidents that occur day to day, way of mitigation of those incidents, fatigue management, critical situation management and memory lapse occurred amongst the crews were touched upon. Besides, secondary data has also been collected from books, journals, and articles and by brainstorming with the persons related to aviation.

D. Methods of Data Analysis

The responses were obtained on a 5-point Likert scale to ascertain level of agreement to measure each of the indicators. Skill-based errors there were represented by 07 indicators which determine both the slip of actions and memory lapses, while 03 indicators represented mistakes. In skill-based errors, the indicator fatigue had been divided to two categories.

- **Fatigue1** was based on the workplace comfort ability, number of working hours, number of breaks and how often they go on leave.
- **Fatigue2** was based on their health issues and their general lifestyle.

Data was then analysed using SPSS.

III. DATA CALCULATION AND ANALYSIS

The percentage of each indicator of a particular dependent variable (IV) was found using the equation below:

$$\frac{\%\text{ of an indicator}}{\Sigma\%\text{ of all indicators of a IV}} \times 100 = \%\text{ of an indicator in a IV}$$

The results yielded are depicted in table 1.

IV. RESEARCH FINDINGS AND RESULTS

Through data analysis it was found that the majority of skill-based errors of the military operators comes from the indicator Supervision, which is 29.39%. There is a clear difference between what SLAF technicians have stated and what engineers have stated and that is because even though technicians feel that they are always supervised, engineers do not supervise them always unless it is required. In the responses some engineers have said that they rarely supervise, and this is because some of these engineers are quality managers who does not do supervision always anyway. In the civil operator, the mean value of Supervision is 2.4 whereas in the military operator it is 2.8.

Table 1. Summary of Errors

Human Errors		% of errors in military operator		% of errors in civil operator	
Skill based errors		47.47		33.13	
Mistakes	Rule Based	57.24	52.53	71.29	66.87
	Knowledge Based	42.76		28.71	

The second highest percentage of errors was found in independent checking which was 22.91%. The main reason for this is the over confidence of experienced technicians, who tend to have an inertia to refer to maintenance manuals and work instructions while performing work. This finding is further supported through interviews carried with technicians of different levels. It was found that certain engineers are quality managers and do not refer to such documents unless there is a strict need to do so. It was also found that fatigue 1 has added up to a percentage of 17.55% and this is due to excessive working hours and a smaller number of leave the maintenance crew get on a weekly basis.

In case of the civil operators, interestingly the highest percentage of errors found was from the indicator Independent Checking which was 25.34%. Unlike the military crews most of the civilian engineers work in the same department for a longer period of time and they have the tendency of not referring the maintenance manual or perform a check on technicians' work every time they carry out any maintenance activity on an aircraft. The second highest percentage is from the supervision indicator for the same reasons mentioned above. Fatigue 1 also takes a majority part in skill-based errors because of the excessive working hours inside hangars.

Through interviews it was found that the military technicians switched their job roles within the same hangar as well as other technical and even non-technical jobs during their service tenure. Further, since they were not bound by international civil aviation legislation, it was found that the percentage of skill-based error is more in military operators in comparison to the civil operators. Taking all the indicators of skill-based errors into account, the comparison between these two operators is shown in Figure 1.

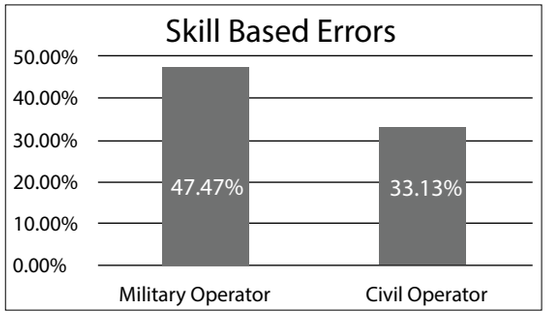

Figure 1. Comparison of skill-based errors between two organisations

Another reason for this result maybe the nature of the aircraft fleet operated by the two organizations. Since the aircraft fleet of the civil operator was frequently upgraded and the maintenance crew need continuous training on new upgrades. The military operator, on the other hand maintains a rather aging fleet of aircraft with little or no upgrades which resulted in comparatively lesser training for the technical crew.

While analysing the data it was also found that, the highest percentage of mistakes in military operator consists of bad rule as depicted in figure 2.

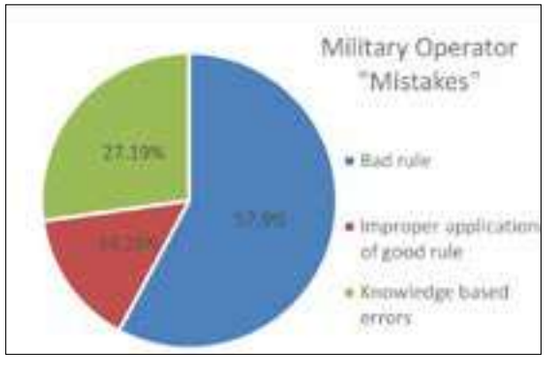

Figure 2. Presence of mistakes in military operator

The reason for this was found out through interviews, to be the presence of redundant rules. Second highest is from the knowledge-based errors which can due to the lack of consistent and higher training. Like military operator, in civil operator also the highest percentage of mistake is from the indicator Bad Rule, followed by improper application of good rule. The reason for this is seen as the flexibility in application of rules, commonly seen with the civilian technicians.

Figure 3. Presence of mistakes in civil operator

A comparison of the mistakes between military and civil operators are shown in figure 4.

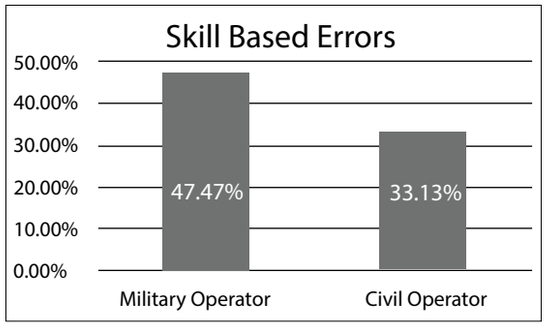

Figure 4. Comparison of mistakes between two organisations

Both rule and knowledge-based errors lead to mistakes and it is found that the civil maintenance crews are more prone to break rules or less effective to adapt with the new rules when applied in case of any emergency or critical situations. On the other hand, as the military personnel undergo through a tough and strict disciplined life, the tendency of breaking rules is less with them in comparison to the civil personnel.

The highest standard deviation is 1.54 amongst the responses for the indicator Fatigue 2 (Based on health issue and general life style) of the civil airline operator. Apart from workplace design and fatigue which are two of the ten indicators, all have their standard deviation under 1.00 which gave the idea that the variation of the responses around the mean response is very less.

The inter-item correlation matrix was generated to depict the relationship among the indicators. For skill-based error taking workplace design as 1.00 and for mistakes, taking knowledge-based errors as 1.00 the correlations of other indicators were found. All the values found were positive which indicates that all the indicators are related to each other in the similar fashion; not reversibly.

Cronbach's alpha reliability test was done to measure the internal consistency of the responses of the participants. When there are less than 10 items and the value of alpha comes greater than 0.5, then the responses are considered to be consistent. (Pallant, 2005). In the research, only the Cronbach's alpha of mistakes of civil operators came below 0.5 (0.496), which was a limitation of the research.

IV. CONCLUSION AND RECOMMENDATION

This research analysed the maintenance environments of two aircraft operating organizations in Sri Lanka. The aviation maintenance crews are the lynchpin in the airline industries. They are the most important personnel who are maintaining the aircrafts and help to fly on time it by hard works. For the better maintenance of the aircrafts they should not commit any human error. As maintenance crews are doing the most important and complex job in a wide variety of ways thus, they must be aware of human factors associated in aviation.

Out of several causes of human errors of maintenance crews, it is found that rule-based error is more common. The first research hypothesis was, "Most of the human errors are occurring due to skill-based errors". However, it was found that the percentage of mistakes is higher than that of the skill-based errors. On the hand, second hypothesis was, "Human errors due to mistakes have been mitigated to an acceptable level by the civil operator and the military operator". But if 50% is considered as the average level, in both the cases the percentages found were higher. Thus, it cannot be concluded that the mistakes have been mitigated at an acceptable level. Within mistakes, the percentage of rule-based errors is more than that of the knowledge-based errors. In the military operator the rule-based errors are comparatively lesser in comparison to the civil operator.

Based on the findings of this research, the researchers have found that despite the immense contribution made by both organizations towards the aviation industry in Sri Lanka, proper utilization of available human and technical resources are not utilized to the fullest potential to achieve better productivity. Improvements to overall maintenance effectiveness can be achieved by inculcating a more disciplined work environment where rules and regulations with regard to technical work are more stringently imposed and facilitating cross training between two organizations to enable mutual development and resource sharing.

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OPTIMAL CREW PLANNING THROUGH VARIABLE CAPACITY ASSIGNMENT FOR COMMERCIAL AIRCRAFT FLIGHT LINE MAINTENANCE

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Abstract - Crew planning and scheduling is researched intensively as it affects the aviation operational costs substantially. Maintenance crew planning is an integral part of the same where less emphasis paid compared to flying crew scheduling. This paper presents an optimal framework for commercial aircraft flight line maintenance labour planning. A mathematical model combined with a management framework named "variable crew assignment" is used to discover optimal crew combinations, shift sizes and shift starting times. Maintenance workforce is used as the main variable and is applied variably to suit the fluctuating demand. The framework is articulated in such a way that it can accommodate different types of aircraft with different maintenance certifications. This optimal framework would enable aircraft maintenance planners to identify most appropriate combinations of crew sizes, shift patterns and respective shift staring times to fulfil varying maintenance demand.

Keywords - Manpower planning, Integer Programming, Variable crew assignment.

I. INTRODUCTION

The contemporary aviation operations have become increasingly complex and dynamic in nature due to the rapid growth of global air travel demand. Attaining optimal productivity through limited resources has become extremely demanding (Jamili, 2017). In a managerial perspective, controlling crew costs are more feasible and practical. Periyar Selvam et al. (2013) describe airline crew cost to be the second largest cost contributor of operational budget. An optimal crew schedule not only enhances the cost benefits but also improves safety and reduces operational delays as well. Gill and Shergill (2004) reveals that more than fifty percent of departure delays are due to operational shortcomings including maintenance.

Unlike the other industries, aircraft maintenance requires highly skilled technicians, special equipment and complicated procedures. Short-term layover maintenance, which is also called flight line maintenance hereafter, is executed at the parking terminals during an aircraft's arrival and departure time interval. Flight line maintenance crew planning is an extremely tough task as it is inhibited by many variables like timetables, personal commitments, labour regulations, and infrastructure capacity limitations. The timetable punctuality alone induces a huge pressure on maintenance schedulers demanding meticulously planned schedules to prevent delays and to ensure optimal resource utilization. In addition, the requirement of maintenance certification further exaggerates the planning complexity. An approved maintenance type certification is vital for every crewmember who conduct aircraft maintenance. This is a strictly observed regulation throughout the industry with zero tolerance.

A. Literature review

Airline crew scheduling has undergone extensive research during past few decades in search of optimal solutions (Ernst, Jiang, Krishnamoorthy, Owens, & Sier, 2004). Due to cost constraints involved, even a minor percentile

saving leads to considerable cost reductions annually (Sasaki and Nishi 2016). Scientific personal scheduling literature trace back to Edie (1954) and Dantzig (1954) where they enumerate a toll booth scheduling problem mathematically.

According to Gopalakrishnan & Johnson (2005) , airline staffing and scheduling problem covers a large span of complexities ranging from aircraft routing, assignment, scheduling, crew rostering, scheduling and assignment. Lavoie et al. (1988) formulate a large-scale set covering problem with many columns where each represents a valid crew pairing. Based on generalized linear programming they propose a continuous relaxation to solve a scenario inclusive of 329 segments of flight legs through column generation method. Ryan (1992) introduces a generalized set partitioning model for aircrew scheduling involving more than 650 constraints and 200,000 binary variables. Yan & Chang (2002) discus cockpit crew scheduling in specific as the salary and remuneration of the pilots covers a significant portion of the overall crew costs. They formulate a set partitioning model and solve it through column generation. Deng & Lin (2011) use ant-colony optimization based algorhythem to solve airline crew scheduling problem with numerous enumerations. Mercier & Soumis (2007) solve the optimal crew-scheduling problem along with aircraft routing and retiming. These three areas are interdependent one each other and linking these constraints together ensures same schedule is used for both aircraft touting and crew scheduling. Kasirzadeh, Saddoune, & Soumis (2014) presents a detailed review on crew scheduling models and methods discussed since year 2014. As highlighted above, a majority of the of the crew scheduling research are allied with complex mathematics and heuristics mainly due to the complex nature (Barnhart & Cohn, 2004).

As per Medard and Sawhney (2007) a majority of the airline crew scheduling problems focus on flying crew and the emphasis applied on ground maintenance crew scheduling is relatively less. The problem setting of the two types are also diverse in nature due to several reasons. Unlike flying crew (inclusive of cockpit and cabin crew), the ground maintenance crew is stationed at the airline's base airport and do not move from one location to another. Further, the requirement of maintenance certification distinguishes the maintenance crew from the flying element. Hence, the general crew scheduling techniques needs adjustments before being applied to ground maintenance crew.

Van Den Bergh et al. (2013) analyse several hard and soft constraints in their three-stage methodology such as legal restrictions, personal preferences and coverage constraints. They first formulate personal rosters for line maintenance using mathematical programming and then second stage evaluates the formulated rosters through discrete event simulation. The third sage ranks the most optimal rosters through data envelopment analysis and the model is validated through a real time case study. Alfares (1999) presents several findings in his study including cyclic roster change from five working days to seven working days and usage of some management strategies involving numeral flexibility, temporal flexibility and functional flexibility. Numeral flexibility proposes use of part-time employees and variable maintenance squad sizes while temporal flexibility proposes different shift starting times.

HoIver, Kasirzadeh et al. (2014), Gopalakrishnan and Johnson (2005), Barnhart and Cohn (2004) argues that mathematical modelling and complex simulations alone do not present the most feasible solutions for crew capacity planning problems. They support the argument with several examples. First, crew scheduling is a combination of crew pairing and crew assignment even though it is addressed unitedly in most literature. Second, many objectives and constraints in popular solution algorhythems are treated approximately due to large size of the problem, complex aviation safety agreements and various contractual rules.

B. Outline

The outline of this paper flows as below. Section 2 describe the problem setting and introduce the concept of "variable crew assignment" where I incorporate a mathematical model for solution. The following sections discuss the initial stage of data analysis and illustrate how to downsize the problem for ease of computation. Section 4 is the case study through which I try to test the model. Section 5 presents the overall conclusion.

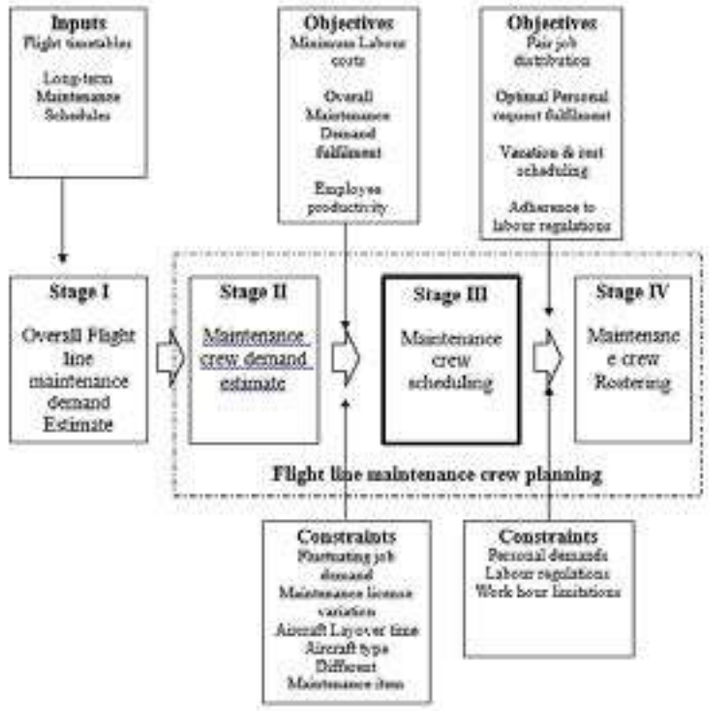

Figure 1. General Research Model

II. PROBLEM DEFINITION AND MODEL FORMULATION

Even though the number of members for a job squad is not assigned, I observed the average number of members in a squad are four in most of the instances. The day is divided to three eight-hour shifts and the excess demand is handled through overtime shifts of eight hours. However, as per the aviation regulations if a crewmember works two eight-hour shifts consecutively it raises several concerns. First, continuous work indulgence of 16 hours is beyond the authorized threshold of 12 hours. Second, the employees is entitled for a 48 hours shift off which deprives his service for almost two days.

C. Variable Crew Assignment Strategy

In view of addressing the above disadvantages, I introduce an innovative concept of varying labor utilization both numerically and duration wise. It is named as "Variable Crew Assignment" (VCA) strategy and will produce better solution for optimal crew scheduling when combined with durable maintenance workload forecasting. First, I formulate a common platform for the VCA strategy and incorporate it with a mixed integer linear programming (MILP) mathematical model. Then I move to validate the model through a case study regarding the sample airline "S". In this model, I try to vary the maintenance labour capacity through three variable channels. They are the number of members in a squad, number of squads in a maintenance group during a specific job duration and the number of shifts a crewmember works.

D. Mathematical Model

A mathematical model is formulated using mixed linear integer programming (MILP) incorporating the above VCA strategy. The primary input for the model is different type of maintenance demand [m_{ia}] for different models of aircraft[A_i] in each job duration(n). Flight line maintenance requirement (in terms of man-hours) for maintenance elements(i) of (a) type aircraft is considered (h_{ia}). The three types of maintenance elements are preflight checks, transit checks and the daily checks. The number of aircraft from (a) type is considered as (p_a).

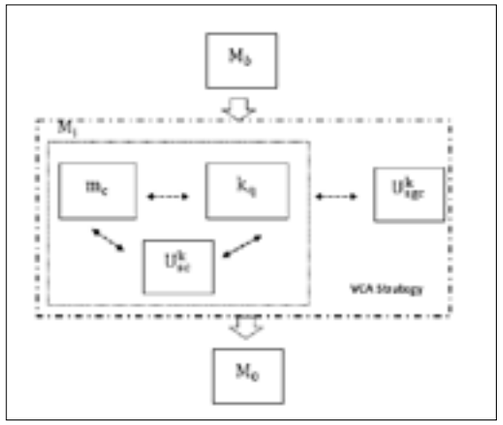

Figure 3. Optimal maintenance crew planning model with intermediate variables

1) Problem Setting

Nomenclature

Algebraic Notations

h_{ia} Maintenance man-hours required for (i) maintenance element of (a) type aircraft

t_a Layover time of (a) type aircraft

G Set of job-squads in a maintenance group during (k) job duration

g Number of job-squads in (G) maintenance group during (k) job duration, where (g ∈ G)

C Set of different job-squad sizes (Number of engineers in a squad) during (k) job duration

c Number of engineers in a job squad during (k) job duration, where (c ∈ C)

Q Set of different shift combinations in a job duration.

q Number of shifts included in (k) job duration starting at (s) shift starting time

A Set of different aircraft types serviced at (k) job duration

a A one type of aircraft requiring (i) maintenance element during (k) job duration where (a ∈ A)

k A job duration with (q) number of shifts

S Set of shift starting times

s Shift starting time corresponding to (k) job duration where (s ∈ S)

d A duration of shift in hours

I Set of maintenance elements

i Type of maintenance element required by (a) type aircraft during (k) job duration where (i ∈ I)

D_{ai}^{k} Maintenance manpower demand estimate to service (A) set of (a) type aircraft during (k) job duration

f Lower bound of the number of type (c) job squads

h Upper bound of the number of type (c) job squad

α Lower bound of the number of shifts in (k) job duration

β Upper bound of the number of shifts in (k) job duration

γ Lower bound of the number of technicians in (c) type job squad

δ Upper bound of the number of technicians in (c) type job squad

W A very large positive value less than (∞) used for the ease of modelling

Z Objective function, which aims to reduce total manpower utilization while catering optimal customer satisfaction.

Auxiliary Variable

L_{sgc}^{k} Amount of manpower provided by (G) maintenance group who start their duty at (s) starting time of (k) job duration with (q) number of shifts

Decision Variables

m_c Number of technicians in (c) type job squad

k_q Number of shifts in (k) job duration

U_{sgc}^{k} Number of type (c) job squads in group (g) whose duty commences at (s) starting time of (k) job duration

The integer-programming model for minimizing the manpower used for line maintenance through variable crew assignment is as below;

$$\text{Min } Z = \sum_{s\in S}\sum_{g\in G}\sum_{q\in Q}\sum_{c\in C} m_c\, k_q\, U_{sgc}^{k} \quad (1)$$

The objective function; Equation (1), minimize the number of technicians in (c) type job squad, number of shifts in (k) job duration and number of type (c) job squads in group (g) whose duty commences at (s) shift starting time of (k) job duration.

$$\sum_{g\in G} L_{sgq}^{k} \geq \sum_{a\in A} D_{ai}^{k} \quad \text{For } \forall g \in G, a \in A \quad (2)$$

Equation (2); represents that the minimum amount of manpower provided by (G) maintenance group who start their duty at (s) starting time of (k) job duration with (q) number of shifts should be able to cover the maintenance manpower demand estimate to service (A) set of different (a) types of aircraft during (k) job duration.

$$\sum_{c\in C}\sum_{g\in G} m_c U_{sgc}^{k} \geq \sum_{g\in G} L_{sgq}^{k} \quad \text{For } \forall s \in S, c \in C \quad (3)$$

Equation (3) ; represents the amount of workload provided by the total number of technicians in (c) type job squad in group (g) whose duty commences at (s) starting time of (k) job duration, has to be higher than the amount of manpower required by (G) maintenance group who start their duty at (s) starting time of (k) job duration with (q) number of shifts. Here it is to be noted that number of technicians in (c) type job squad in group (g) whose duty commences at (s) starting time of (k) job duration ($\sum_{c\in C}\sum_{g\in G} m_c U_{sgq}^{k}$) is difficult to be related to maintenance manpower demand estimate to service (A) set of (a) type aircraft during (k) job duration ($\sum_{a\in A} D_{ai}^{k}$) directly. The auxiliary variable (L_{sgq}^{k}) representing amount of manpower provided by (G) maintenance group who start their duty at (s) starting time of (k) job duration with (q) number of shifts; along with Equations (2, 3) are designed to facilitate this transformation.

$$\sum_{a\in A} D_{ai}^{k} \geq \sum_{i\in I}\sum_{a\in A} h_{ia} \quad \text{For } \forall i \in I, a \in A \quad (4)$$

Equation (4) ; states that total maintenance manpower supply estimate to service (A) set of (a) type aircraft during (k) job duration should satisfy the total Maintenance man-hours demand for (i) maintenance element of (a) type aircraft.

$$\sum_{a\in A} t_a \geq \sum_{i\in I}\sum_{a\in A} h_{ia} \quad \text{For } t_a \geq 0 \quad (5)$$

Equation (5) ; highlights the cumulative aircraft layover time constraint, where the maintenance man-hours required for (i) maintenance element of(A) set of (a) type aircraft should be less than the cumulative layover time of (A) set of (a) type aircraft.

$$f \leq U_{sgc}^{k} \leq h \quad \text{For } f,h \geq 0 \text{ and } h > f \quad (6)$$

Equation (6) ; limits the number of type (c) job squads in group (g) whose duty commences at (s) starting time of (k) job duration to a reasonable range as this is governed by several external factors such as the respective facilities' maintenance capacity, airport slot allocations and different labour regulations.

$$\alpha \leq k_q \leq \beta \quad \text{For } \alpha,\beta \geq 0 \text{ and } \beta > \alpha \quad (7)$$

Equation (7) ; limits the number of shifts in (k) job duration to a feasible range as it is governed by several constraints such as the maximum number of hours a technician could work continuously, minimal economic duration of employment for a paid technician and the complexity faced by the maintenance schedule planner.

$$\gamma \leq m_c \leq \delta \quad \text{For } \gamma,\delta \geq 0 \text{ and } \delta > \gamma \quad (8)$$

Equation (8); limits the number of technicians in (c) type job squad to a feasible range.

$$\sum_{g\in G}\sum_{c\in C} U_{sgc}^{k} \leq W \quad (9)$$

$$U_{sgc}^{k} \geq 0 \text{ ; Where } \forall s \in S, c \in C, g \in G \quad (10)$$

$$L_{sgq}^{k} \geq 0 \text{ ; Where } \forall s \in S, a \in A, g \in G \quad (11)$$

$$m_c, d, n_q, q, p_a, h_{ia} \geq 0 \text{ ; For } m_c, d, n_q, q, p_a \in I \quad (12)$$

Equations (10, 11, and 12) are the non-negativity constraints.

C. Solution Algorithm

1) Problem size

In order to ascertain the problem size I consider the sample airline "S" where it has six different aircraft types and the planning horizon is a seven-day working Week. I compare two models. The first one is the base model M_b, which represents the present crew scheduling method while the other represent the prospective optimal model M_o, formulated with the variable crew assignment strategy. M_b, does not incorporate any variables, it has three shifts, average four member crews and random maintenance certifications. On contrary M_o incorporates all three variable strategies, where c (number of crew in a job squad) h 5 variables (2,3,4,5,6), and q (number of shifts in job duration) has 2 variables (2,3). The variable number of squads in a work groups depend on the number of aircraft types maintained due to the maintenance certification constraint. Each day has six shifts of four-hour duration. If $G_{x,y}$ means the selection of x items from an array of y items, the possible job squad combinations for six aircraft types would be,

$$G_{1,6} + G_{2,6} + G_{2,6} + G_{4,6} + G_{5,6} + G_{6,6} = 63. \quad (13)$$

As there are five different squad sizes and six different shift starting times U^k_{sgc} will have (7 x 6 x 63 x 5) = 13,230 variables and L^k_{sgq} will have (7 x 6 x 63 x 4) = 10,584 variables. This adds up to 23,814 variables and there are some more related to Equations (2, 3, 4, and 5).

2) Interim problem formulation

Practically, solving a MILP (mixed integer leaner programming) problem of this size is complex and consume extended computational time. Therefore, I reduce the problem scope through several arbitrary iterations. In doing so, I observed the contribution of the variable; "number of aircraft types" expand the number of total variables compared to the other parameters as per Equation (13). For an example if the number of aircraft types are 10 to 12, the number of variable U^k_{sc} will almost double. Hence, I tried to decompose the original objective function as below assuming that the total maintenance demand is for a single aircraft type. Then I redefined the main decision variable as below and as a result, the objective function is modified as per Equation (14) where model (M_o) has been adapted by removing aircraft type related variables (A) and (a), and maintenance related parameters (G) and (g), which are related to maintenance certification. The formulation of the first sub-problem is as follows:

U^k_{sc} - Represents the number of type (c) job squads whose duty commences at (s) starting time of (k) job duration where the variable number "g" becomes one type.

$$\textbf{Min } Z = \sum_{s\in S}\cdot\sum_{q\in Q}\cdot\sum_{c\in C} m_c\, k_q\, U^k_{sc} \quad (14)$$

Here, the number of job squads in a maintenance group will be similar and every member is certified to maintain single aircraft type available, as there are no variations. When analysing carefully, I understood that this is the lower boundary of the original problem even though it is not a feasible solution practically. The following constraints also get relaxed by removing variable g and reduces the number of variables. I call this model M_i or the intermediate model.

$$\sum_{\cdot} L^k_{sq} \geq \sum_{\cdot} D^k_i \quad \text{For} \quad a \in A \quad (15)$$

Equation (15); represents that the minimum amount of manpower provided by all equivalent (g) squads who start their duty at (s) starting time of (k) job duration with (q) number of shifts should be able to cover the maintenance manpower demand estimate to service all (a) type aircraft during (k) job duration.

$$\sum_{c\in C}\cdot m_c U^k_{sc} \geq \sum_{\cdot} L^k_{sq} \quad \text{For} \quad \forall s \in S, c \in C \quad (16)$$

Equation (16) ; represents the amount of workload provided by the total number of technicians in (c) type job squad in group (g) whose duty commences at (s) starting time of (k) job duration, has to be higher than the amount of manpower required by (G) maintenance group who start their duty at (s) starting time of (k) job duration with (q) number of shifts.

$$\sum_{\cdot} D^k_i \geq \sum_{i\in I}\cdot h_i \quad \text{For} \quad \forall i \in I, \quad (17)$$

Equation (17) ; states that total maintenance manpower supply estimate to service all (a) type aircraft during (k) job duration should satisfy the total Maintenance man-hours demand for (i) maintenance element of (a) type aircraft.

$$\sum_{\cdot} t_a \geq \sum_{i\in I}\cdot h_i \quad \text{For} \quad t_a \geq 0, \quad (18)$$

Equation (18) ; highlights the cumulative aircraft layover time constraint, where the maintenance man-hours required for (i) maintenance element of(A) set of (a) type aircraft should be less than the cumulative layover time of (A) set of (a) type aircraft.

$$f' \leq U^k_{sc} \leq h' \quad \text{For } f', h' \geq 0 \text{ and } h' > f' \quad (19)$$

$$U^k_{sc} \geq 0\,; \text{ Where } \forall s \in S, c \in C, \quad (20)$$

Equations (19 and 20) are the non-negativity constraints and the revised boundary conditions of U^k_{sc} .

The rest of the equations remain unchanged. The main purpose of this intermediate model is to downsize the problem and to find appropriate number of shifts and the corresponding shift starting times. Then I will fix these optimal values and feed them as input to the main model. It reduce the number of variables related to main objective function and make the solving process easier. This indicate the feasible lower bound of the solution beyond which it will not be feasible to try. It will also reduce the span of probable solutions for the problem.

III. CASE STUDY

Test data collection for the mathematical model validation was done by the flight line maintenance operations of a medium scale South Asian airline with 94 international destinations.

Figure 4. Maintenance manpower demand throughout the day

The computational environment is a ASUS i7 personnel computer. In order to ensure ease of computation, the solution satisfactoriness was set to 10% gap (error margin) from the lower bound obtained by the intermediate modelM_i. Except for few, majority of the problems were solved within the above margin. However if the error margin was downsized, more accurate results would have been achieved in spite of the computational difficulties. The main attributes of the two comparative scenarios are as follows,

Table 1. Main attributes

Attribute	M_b	M_o
Work duration	8 - 16 Hrs	8 – 12 Hrs
People in a Squad	4 (On average)	2,3,4,5,6
Number of Shifts	3	6
Shift Starting times	0000 Hrs,0800 Hrs,1600 Hrs	0000Hrs,0400Hrs, 0800Hrs,1200Hrs, 1600Hrs,2000Hrs

Out of the six shifts highlighted in M_o model, not all shits can be accommodated for an optimal solution due to several practical implications. If an optimal solution is found for one shift, the number of working hours per day will be only four hours, which is an underutilization of the labor resource. In the same essence, if I consider 5-6 shifts at a stretch, it is impractical for an employee to work beyond 16 hours continuously and it is against the industry norms. In order to identify the most appropriate shift schedule, I varied the shifts from two to four. The job durations spanned from 8 hours to 16 hours and the starting times Ire as per table 1. The results highlighted three-shift job duration is optimal in terms of man-hours utilization and there was 4.73% difference between the two-shift duration and three-shift duration as per table 2. The optimal shift starting times are 0400 Hrs, 0800 Hrs, 1600 Hrs, 2000Hrs. As per the computational results, shifts starting at 0000Hrs and 1200Hrs indicates infeasible solutions. These findings harmonized with the maintenance demand distribution (Figure 3) as well. In addition, all results of M_o model appeared to be better than M_b, which is an indication of the proposed model's effectiveness.

Table 2. Shift wise computational results

Number of shifts	M_b*	M_o*	Gap (%)
2	11464	11128	2.93
3	-	**10921**	**4.73**
4	-	11326	1.21

PROCEEDINGS

However, the optimal solution rises a concern. As per M_o model, three shifts means a job duration of 12 hours, which involves overtime payment. Therefore, it is to be highlighted that these results are mainly planning oriented, mathematical conclusions where actual rostering needs further calculations with thorough management involvement. Next, I moved to find the optimal squad size fixing the number of shifts to 3 and the results show a job squad with five members are more feasible than the rest. When compared with the present practice it has a 2.39% increment. Nevertheless, it is to be noted that the next best condition is the four-member squad size, which is in present practice even though the number is not fixed. These results further shows that smaller squad sizes such as two or three member squads are not feasible in terms of man-hour consumption.

Table 3. Squad wise computational results

Members in a Squad	M_o*	M_c*	Gap (%)
2	-	11832	-3.21
3	-	11618	-1.34
4	11464	11442	0.02
5	-	**11191**	**2.39**
6	-	11426	0.03

(*all figures are calculated in man-hours)

Finally, I combined the above optimal values and compared the overall results of the two models. Here the evaluation considered the starting times to be 0400 Hrs, 0800 Hrs, 1600 Hrs, 2000Hrs while the number of shifts varied from 2-4 and the squad size varied from 4 to 6 personnel.

Table 4. Integrated results

Number of shifts	Members in a squad	M_o*	M_c*	Gap (%)
2	4	11464	11386	0.06
	5	-	10968	4.37
	6	-	11410	0.05
3	4	-	11242	1.93
	5	-	**10788**	**5.89**
	6	-	11318	1.27
4	4	-	11412	0.04
	5	-	11314	1.22
	6	-	11492	-0.02

(*all figures are calculated in man-hours)

The results presented an interesting finding as shown in Table 4 and I further manipulated the findings as shown in Table 5. If the four members working on two shifts is signified by$2S^{4m}$, I rearranged the combinations according to the descending order of gap analysis.

These results clearly specify the most feasible combinations in terms of their efficiency compared to the existing system. I understand that most optimal combination cannot be used every time due to some practical

Table 5. Gap Analysis

	Combinations	Gap analysis
1.	$3S^{5m}$	5.89
2.	$2S^{5m}$	4.37
3.	$3S^{4m}$	1.93
4.	$3S^{6m}$	1.27
5.	$4S^{5m}$	1.22
6.	$2S^{4m}$	0.06
7.	$2S^{6m}$	0.05
8.	$4S^{4m}$	0.04
9.	$4S^{6m}$	-0.02

(*all figures are calculated in man-hours)

implications highlighted above and the complexion of the problem varies with the size of the variables. Especially as highlighted early, the number of aircraft types matters a lot. However, this framework is applicable to all scenarios for the planners to discovery the best possible combinations and it highlights a set of optimal combinations depending on the restrictions impose at the enumeration stage. It allows aircraft maintenance capacity planners to compute optimal crew assignment combinations with the appropriate shift starting times.

IV. CONCLUSION

The increasing air travel has augmented the pressure imposed on airline maintenance element. Specifically flight line maintenance, which is an integral part of the latter, has become more and more demanding due to timetable deadlines, delayed arrivals, capacity issues, environmental constraints and manpower issues. In this backdrop, flight line maintenance labor planning has become a demanding task. In addition, it has a direct bearing on critical operational attributes such as costs, safety and punctuality. However, the amount of research on maintenance manpower planning and scheduling is relatively less in comparison to pilot and flight attendant scheduling.

This paper focuses on the above gap while constructing a framework to plan flight line maintenance crew, optimally. I used both managerial insights and computational advantage of mixed linear integer programming and was able to formulate framework with which the maintenance manpower planners could identify the most appropriate crew combinations and shift schedules. Here a special emphasis was paid to ease out the maintenance certification constraint, which is a unique condition in aircraft maintenance. I proposed a novel concept termed variable crew assignment, which is a derivative of several management theories. The VCA strategy has two advantages over other methods. First, one being the crewmembers could maintain more than one type of aircraft during their tour of duty due to multi-skilled group concept. Next VCA assigns as low as possible crewmembers to fulfill the maintenance labour demand during a given job duration.

As any solution, this model too has its limitation. It is designed for planned maintenance and hence cannot handle the robustness in maintenance scheduling. When I solved the equations, I detected some anomalies in our prepositions, which was adjusted during data analysis. I believe this research would lead to many future researches such as robust maintenance scheduling for dynamic short-term lay over maintenance and stochastic maintenance demand forecasting for flight line maintenance demand.

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PROCEEDINGS

ELECTRICAL ELECTRONICS AND TELECOMMUNICATION ENGINEERING

SESSION SUMMERY

The Electrical Electronics and Telecommunication Engineering Session was chaired by Prof JP Karunadasa. He is from the Department of Electrical Engineering, University of Moratuwa. His key areas of research are, electrical machines and drives, power electronics and applications, power systems, and mechatoronics.

SUMMERY OF PAPERS PRESENTED AT THE SESSION

1. Light interface of 3D hand motional Gesture recognition in Human Computer Interaction

The objective of this research paper is to replace traditional human computer interaction methods with rough hand gestures. Technique like smart wearable glove, able to capture gestures more accurately compare to image- based recognition but it disturbs the user's way of living. In this work, introduced more efficient mechanism for human -computer interaction through the optical medium.

Following are the questions which were asked by the audience;

Q: How effective are these hand gestures and the originality of the project?

A: The proposed system is implemented with sixteen photodetectors to capture the basic hand gestures such as up, down, left, right. Also, it could capture the waving hand movement as well. Further, the system uses a combination of basic technology in gestural aspects such as TOF and LiDAR.

Q: With gestures are you hoping to transfer knowledge to the computer or only the movement?

A: From the current situation sixteen basic movements could identified. However, by further enhancements finer details could be identified without complex mathematics or image processing.

Q: Is it possible for you system to operate on electrical appliances?

A: Yes. By using a Wi-Fi module this could be achieved.

Q: What is the accuracy variance between the actual movement and the detected movement?

A: Basic sixteen movements could be determined easily and properly. Intensity levels are used to guide the gestures moving towards and outwards the sensor within the specified frame. Depth information is also calculated to predict the gesture more accurately.

Final Note by the Chair:

The proposed mechanism is a good initiative. However, it could be improved if the technology was diversify to electrical appliances as well.

2. Early warning system for landslides using Wireless Sensor Networks

The project is to develop an effective mechanism of an early warning system to predict the possibility of landslides occurring. This work is carried out to develop a cost-effective early warning system for land slide using WSNs incorporating machine learning.

Following are the questions which were asked by the audience;

Q: How early could a landslide be predicted?

A: The original plan was to predict the landslide the day before but when conducting the research it was found out that since the algorithm is based on Machine Learning, more the data points the landslides could be predicted more accurately even up to few days in advance. However, this concept is yet to be developed by acquiring more data.

Q: How to determine the locations to place sensors?

A: The possible high risk landslide locations are predetermined. The sensors are deployed in such places to monitor the movements of soil layers. However, this prediction mechanism will not be as effective for instant landslides. The main idea is to minimize the repercussions of the landslides.

Q: What is the level of performance in comparison with technologies used in other countries to detect landslides?

A: Since Sri Lanka needs does not have the required capital nor technology to implement satellite imaging the proposed system is more feasible.

Final Note by the Chair:

The project is appreciated as it addresses a current issue in the country. But a timely issue has been addressed. Accuracy and the time length of the warning system is yet to be verified. Therefore, the study needs to be continued further.

3. Low Cost Real Time Temperature Monitoring System for Concrete using Wireless Sensors

This paper discusses the development of low cost real time wireless smart sensor monitoring system to monitor early age concrete temperatures. These wireless sensors are connected to a NodeMcu, which is an open source IoT platform. Temperature measurements are saved and visualized in real time using ThingSpeakTM which is an open source IoT online platform with MATLAB analytics.

Following are the questions which were asked by the audience;

Q: Were experiments conducted in order to compare the accuracy level of the system by using other means of temperature measurement?

A: Yes. Readings of wired and wireless thermocouple measurements were compared with the current system.

Q: Did you test your specimens under various conditions of weather such as keeping under the sun?

A: No. This was conducted at room temperature only.

Q: Did you conduct a cost comparison between the thermocouple system and the proposed system.

A: Yes the proposed system is cost effective according to the research conducted. Further, this could be also to calibrate the thermocouple.

Final Note by the Chair:

Since the proposed method is more cost effective and versatile than the existing systems the research should be carried down to the product level. However, the prototype should undergo additional testing in various weather conditions in order to improve the reliability of the condition.

4. Investigate the Necessity of use of Nuclear Power as an Energy Source in Sri Lanka with Special Concern on Present Nuclear Trend

This research examines the necessity of nuclear energy to Sri Lanka with special concern on nuclear trends which are growing in the country and all over the world. Since, power demand in Sri Lanka has grown at an annual rate of about 6% over the past ten years. Therefore, it is important to increase the total installed capacity through appropriate sustainable power generation combinations such as nuclear power.

Q: Clarify the originality of the research?

A: Only few researches have been conducted on nuclear power generation in Sri Lanka. As stated by the topic the current study highlights the necessity of Nuclear Power generation in Sri Lanka, by analysing past and ongoing foreign researches on nuclear power.

Q: What are the proposed methods for nuclear waste management?

A: This study is more focused on fusion technology which do not produce any residuals.

Q: Isn't produced energy via fusion is much less than consumed energy?

A: Yes. However, if the particles could undergo magnetic forces they would accelerate and therefore the energy produced could be much more.

Q: Are fusion reactors currently available?

A: No, they are still at experimental level however Sri Lanka as a country, should join the ongoing experiments.

Final Note by the Chair:

This survey paper focuses on the feasibility of implementing nuclear power in Sri Lanka. It also addresses an up growing technology in the nuclear power generation arena which is nuclear fusion. Considering the current power demand status in the country alternative power generation methods are required. However, technological restrictions in the proposed system should be addressed.

LIGHT INTERFACE OF 3D HAND MOTIONAL GESTURE RECOGNITION IN HUMAN COMPUTER INTERACTION

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Abstract - Hand gestures play a significant role in Human-Computer Interaction(HCI) where traditional interaction method like Keyboard, Mouse or Joystick induce stress and fatigue to the user when interacting with computing environments. Technique like smart wearable glove, able to capture gestures more accurately compare to image-based recognition but it disturbs the user's way of living. In this proposed light-based technique, simple motions of a hand like up, down, left, right, combine fingers motion like zoom in, zoom out, left rotation, right rotation, forward & Backward will be interfere with light-medium. The reflections of light from hand motional actions capture to process as interaction into computing environment. The technique, interact user's hand motion with Infrared(IR) light medium. And through an array of Photodetectors(IR), the reflected light intensity measure to extract various distances from the array to hand and fingers. The sensor array directly coupled with the processing device, which convert light various intensities into voltages. Through programming and Machine Learning techniques, the proposed method able to identify the gestural aspect of the hand. The technique able to overcome the problems like background conditions, proper exposure towards the camera, start/stop aspect of the gesture and noise in image based HCI techniques. By continuous processing of IR reflections, the method able to identify various hand 3D motional gestures with easily compare to direct and indirect based interaction techniques. The technique easily able to customize for different users' requirements and different environment to support human Computer Interaction. Further, this method supports simultaneous multiple user 3D interaction with the computing environment.

Keywords - Hand Gestures, Light-medium, Interaction, IR, customize.

I. INTRODUCTION

Gesture recognition is the informal way of interacting with computing devices through hand movements and postures (Rajeshri R Itkarkar, Anilkumar V. Nandi, 2016). The identifiable differences in hand motions and relative variations in fingers provide a set of variables as input to the computing devices. The approaches of Vision, Colour and sensor embedded gloves are being used in the field of recognition of gestures in HCI. Vision-based recognition techniques are sensitive to background and lighting conditions and the other glove based techniques, the user has to wear the electronic or colour glove (Hong Cheng,Lu Yang, Zicheng Liu, 2015) all the time to make an interaction, which disturbs the normal ability of work. In 2D vision based recognition techniques, complex mathematics involved in the aspects of segmentation, feature extraction, and recognition process. As an improvement to the 2D vision based recognition of gestures, 3D depth based techniques able to identify depth information of the gesture of sequence, and provides 3D position and orientation (Rajeshri R Itkarkar, Anilkumar V. Nandi, 2016) information of the gesture to the computing environment. Current techniques like Kinect, Leap Motion, and Time of Flight (TOF) sensors able to capture and identify gestures accurately with compare to 2D vision-based techniques.

In the field of robotics, IR based techniques used to measure distances from an object or identification of obstacle along the path when the robot is moving (Yuebin Yang, Guodong Feng, Shaoxian Wang, Xuemei Guo, Guoli Wang, 2013), Also another application of IR is to detect human presence by detection body temperature using Passive Infrared (PIR) sensors. In the distance based sensing and ranging, Light Detection and Ranging sensor (LiDAR) provides the highest accuracy in distance measurement. By using the principle of TOF information in the transmitted and receive signals of light. The LiDAR sensors are heavily used in Smart vehicles and autonomous robots for collision and obstacle - free navigation.

Considering the weaknesses in vision-based, glove based and depth based recognition techniques, and the considering principles of LiDAR, TOF, and Light, the novel proposed method use the falling light intensity measurement on to a photodetector array to identify gestures. Hand motional gestures like up, down, left, right, combine fingers motion like zoom in, zoom out, left rotation, right rotation, forward & Backward motions able to extract after processing of the light fallen on to the photodetector array (Yilong Li, 2016). The proposed method, further support to identify complex gestural behaviour in the light -medium through Machine learning.

II. METHODOLOGY/EXPERIMENTAL DESIGN

Research Methodology based on the study reflection of light at the various region of the hand when gestures in the medium of light. The various gestures from the hands, legs or head able to produce reflections on to single or multiple directions, which in turn able to capture using single or multiple light source & detector arrangement. The reflected light contains the information of different intensity values of the hand and fingers. After processing of reflected light, processer enables to identify the intended gesture (Piero Zappi, Elisabetta Farella, Luca Benini, 2008). The light wavelengths in the electromagnetic spectrum fall into three categories as infrared, visible and ultraviolet. IR wavelengths are not visible to the human naked eye, hence IR the best medium without the strain of fatigue to the eyes. Further IR radiation does not disturb the surrounding environment and there is no interference from other visible light wavelengths.

The behavior of these three bands is similar in nature, for easy visualization of the incident light on the hand, the experimental design made with Light Emitting Diode(LED) and Light Dependent Resistors(LDR). The Light interface and Photodetector array supports to study of the hand(s) simple motions such as up, down, left, right, combine fingers motion like zoom in, zoom out, left rotation, right rotation, waving actions, forward & Backward as probable manipulative gestures into the computing environment. The motions interaction in the light medium captured as reflections on to the photodetector array to process and identify the gesture.

A. Radiance

The proper unit for measuring the delivery of light in space is radiance, which is defined as:

"The amount of energy traveling at some point in a specified direction, per unit time, per unit area perpendicular to the direction of travel, per unit solid angle".

The radiance at the patch is $L(x1,\theta,\varphi)$, then the energy transmitted by the patch into a tiny region of solid angle $d\omega$ around the direction θ,φ in time dt is

$$L(x1,\theta,\varphi)(cos\ \theta 1 dA1)(d\omega)(dt)$$

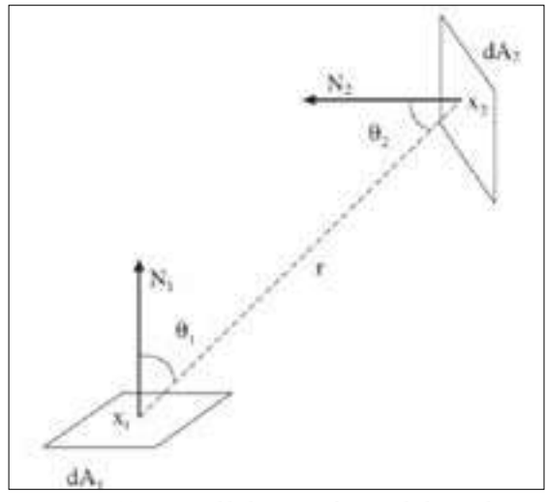

Figure 1: Transmitted light energy from path dA1 to dA2

Figure 1 shows the two patches are located at $x1$, $x2$ with the area of $dA1$ & $dA2$. The radiance leaving $x1$ in the direction of $x2$ is $L(x1,x1 \rightarrow x2)$ and the radiance arriving at $x2$ from the direction of $x1$ is $L(x2,x1 \rightarrow x2)$. In time dt, the energy leaving $x1$ towards $x2$ is

$$E1\rightarrow 2 = L(x1,x1 \rightarrow x2)\ cos\ \theta 1 d\omega 2(1) dA1 dt$$

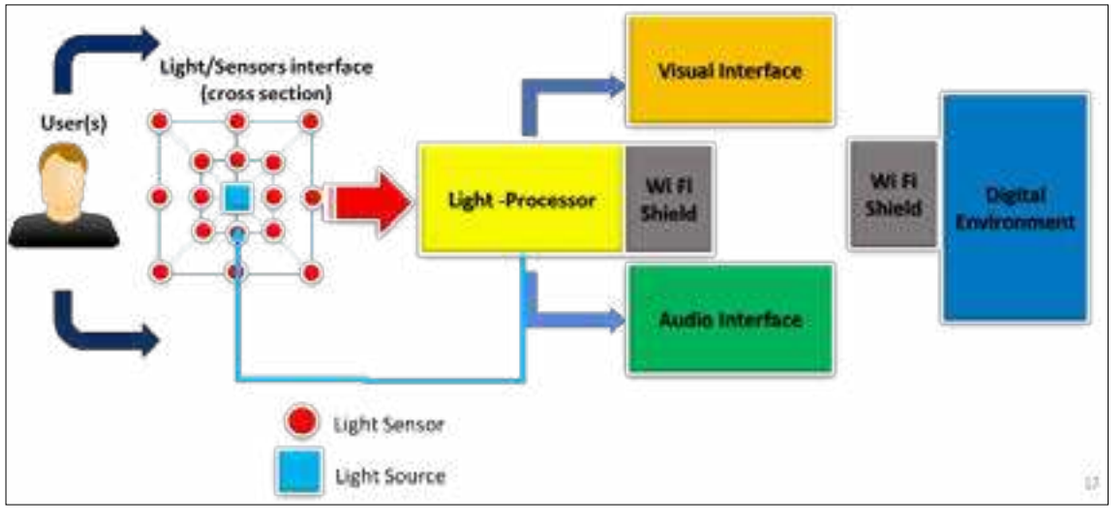

Figure 2: Research Design

where $d\omega 2(1)$ is the solid angle subtended by patch 2 at patch 1 ($d\omega 2(1) = cos\ \theta 2 dA2/r2$)

$$E1\rightarrow 2 = L(x1,x1 \rightarrow x2)\ cos\ \theta 1 d\omega 2(1) dA1 dt$$
$$= L(x1,x1 \rightarrow x2) cos\ \theta 1\ cos\ \theta 2 dA2 dA1 dt/r2$$

B. The Bidirectional Reflectance Distribution Function(BRDF)

To identify the relationship between incoming illumination and outgoing reflected light. The most general model of local reflection is the Bidirectional Reflectance Distribution Function(BRDF). The BRDF defined as the ratio of the radiance in the outgoing direction to the incident irradiance

$$\rho bd(\theta o,\varphi o,\theta i,\varphi i) = Lo(x,\theta o,\varphi o)/\mathrm{Li}(x,\theta i,\varphi i)\ cos\ \theta i d\omega$$

The radiance leaving a surface due to irradiance in a specific direction is given as:

$$Lo(x,\theta o,\varphi o) = \rho bd(\theta o,\varphi o,\theta i,\varphi i) Li(x,\theta i,\varphi i)\ cos\ \theta i d\omega$$

If the transmitting light source (Li) model as a point source using a LED, the reflected light from the gestural hand able capture through an array of photodetectors such as $Lo1$, $Lo2$, $Lo3$,…… Lon. The photodetector array measures different dynamic intensities of reflected light from the palm and fingers. By processing this dynamic information, the system able to identify the gestural aspect of the hand.

Experimental design & study phased out as a light transmitter & Photodetector, processing, visualizing and networking phase. For visualization of the light, a Red colour square LED selected as the light source, which was capable of an emitting radiance power of 10W.

Sixteen number of LDR photodetectors were arranged as shown in Figure 3 to capture the reflection from the hand. The motions like up, down, left, right, combine fingers motion like zoom in, zoom out, left rotation, right rotation, forward & Backward were able to reflect light differently towards the photodetector array. For identification of major directions as Up, Down, Left & Right, the minimum number of four sensors were sufficient (Fig. 3 V2, V4, V6 & V8). Corner placed photodetectors (Fig. 3 V1, V3, V5 & V7) were able to identify the directions in-between Up, Down, Left & Right, and the outer rectangular array of photodetectors support to confirm the selected basic motions of the hand.

Each photodetector connected to the light processor (ArduinoMega 2560 Rev 3) through a 100k variable resistor, which enables to control the intensity level of fallen light on to a photodetector. Based on the light intensity level, processor reading value could be adjusted from 0 to 1023 levels. The sensing array input clarity can be improved by integration of the number of sensor transmitter units and processing using Machine Learning techniques to support more diverse interaction.

The visual interface gives direct feedback to the user's interaction as the action to act upon in HCI environment. In experiment design for verification of interactions, the author has used the sensor to LED, 1:1 mapping technique to identify the affected photosensor. In which each photosensor node mapped to output LEDs to indicate when reflected energy fall on to it.

Experimental design integrated with an audio interface to support vision impaired users to interact with the computing environment through basic hand motions. Vision impaired users' interaction assigned with different tones to identify the hand motion gestural aspect with the HCI environment. Further, through Wi-Fi interface system provides connectivity with the computing environment and support with mobility for the user.

III. RESULTS AND DISCUSSION

For the study of light reflections, interface designed with 16 number of Photodetectors. 8 x 02 photodetectors arranged in squares as shown in figure 2. The measured intensity of reflection light from the hand (right or left) as shown in table 1. In the experimental design, hand motion distance varied from 20cm to 100cm with 20 cm steps to identify the gestural aspect. Each similar motion interaction from the same distance introduced an error, which varied up to ±40 from the measured intensity. Error tolerance compensated through programming to the identification of the gestures.

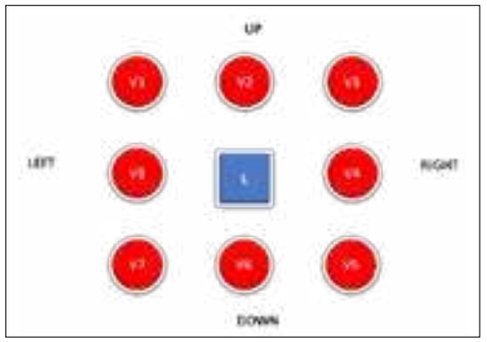

Figure 3: Photosensor Array
Table 1: Individual sample data collected from 20 cm to 100 cm

Table 1 shows the measured intensity data for a user's hand

IV. CONCLUSION

In this work, introduced an efficient method for human -computer interaction through the light based medium. The Interaction technique was able to address the drawback of vision-based interaction and was able to use the principles of light- based depth recognition to support interaction with basic hand motions. Novice to professional users' simply can interact with computing environment using simple motion aspect of the hands, legs or head. By different configuration of Light Transmitters, Photosensor arrays and Machine Learning the method could be developed to support multiuser interaction with more & finer variations of gestures for identification into the system. Further, the light-based interaction able to support differently able people to interacting with computing aspect through the available motion of hands, legs or head.

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Table 1: Individual sample data collected from 20 cm to 100 cm

User	Distance	Hand		Direction of The Hand Motion			Photo Sensor Value							
		Right	Left	Right	Up	Down	V1	V2	V3	V4	V5	V6	V7	V8
1	100 cm		yes				360						380	400
				yes					400	460	410			
					yes		460	500	473					
						yes					402	480	444	
	80 cm		yes				580						566	625
				yes					580	600	612			
					yes		625	680	645					
						yes					633	666	650	
	60 cm		yes				700						695	730
				yes					745	780	715			
					yes		725	740	735					
						yes					712	745	710	
	40 cm		yes				725						740	760
				yes					739	780	745			
					yes		745	760	749					
						yes					710	770	746	
	20 cm		yes				824						880	850
				yes					869	890	873			
					yes		856	875	843					
						yes					848	880	865	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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EARLY WARNING SYSTEM FOR LANDSLIDES USING WIRELESS SENSOR NETWORKS

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Abstract - Landslides occur in many areas in Sri Lanka, and they cause considerable damage to natural habitat, environment, economy and other resources. Monitoring, predicting and controlling are the three major challenges associated with landslides due to the randomness of the event. Yet, developing an accurate prediction mechanism with an effective early warning system has become a need of the hour since the damages and the losses caused by the landslides are intolerable. Although there are expensive and advanced mechanisms deployed in foreign countries to predict the possibility of occurring landslides, such as satellites and radar systems with artificial intelligence capabilities, Sri Lanka finds it difficult to afford them due to the high cost and the advanced technologies used. When compared with the existing high-end systems, a simple wireless sensor network which is capable of identifying the underground movements and soil conditions is a cost effective, practical solution. But, dealing with a large number of variables manually with no proper understanding about their contribution for the occurrence of a landslide is difficult. Machine learning, which is a method used to create complex models and algorithms that lend themselves to predict is a fruitful solution for that issue. This research work is carried out to develop a cost-effective early warning system for land slides using WSNs incorporating machine learning.

Keywords - Wireless sensor network, Machine Learning, Landslide Prediction, Early Warning

I. INTRODUCTION

Landslide can be considered as a main problem which occurs in many areas in Sri Lanka. It causes a considerable damage to the natural habitat, environment, economy and other resources. Landslide monitoring, prediction and managing are the three major challenges associated with landslides due to the randomness of the event. Yet, developing an accurate prediction mechanism with an effective early warning system has become a need of the hour since the damages and the losses caused by landslides are intolerable. So far, many static and dynamic models and prediction mechanisms based on different approaches have been locally tested, validated and improved in various parts of the world. However, a numerous number of problems remain still unsolved hindering accurate prediction of landslide hazards especially when real time forecasting is in concern. In fact, the soil conditions in different parts of the world are much deviated from one another, making it more difficult to adopt one model or a prediction mechanism all over the world. Therefore, more and more studies with the introduction of various factor combinations into modern analytical methodologies are still necessary to come out with more appropriate models.

In the Sri Lankan context, landslide susceptibility maps have been prepared; yet they have no any temporal implications or information about the intensity of

triggering events. Hence, their role in managing a landslide event is very much limited. Due to lack of resources, expert knowledge and research interest, the amount of attempts that have been taken so far for the improvement of models and for the development of real time forecasting methodologies in the country are inadequate.

Identifying the necessity for a locally developed accurate landslide prediction mechanism, the challenge to develop an accurate landslide prediction and early warning system has been taken up by this research. It ultimately delivers an intelligent landslide prediction model which incorporates machine learning capabilities to predict the possibility for a landslide by analysing the actual data obtained from a particular landslide prone area, and an effective early warning system that helps to mitigate loss of lives in future landslides. Further, a Wireless Sensor Network is prototyped and the prediction model plus early warning system is tested with the prototype to illustrate that the suggested system can be practically deployed and functioned in the real world.

II. METHODOLOGY

A. Data Filtering

A large data set which contains sensor readings of landslide prone areas in Sri Lanka for nearly three years was obtained from NBRO (National Building Research Organization), the collected data were filtered and re-arranged into a suitable format.

1) Sensor readings

The data set included sensor readings of five sensor types which had been deployed in Kahagalla, Sri Lanka. The number of sensors deployed, their frequency of data collection and the total duration are mentioned in the table below;

Table 1. Summary of the filtered data

Sensor Type	Number of Sensors Deployed	Frequency of data collection	Total Duration
Rain Gauge	1	1 Day	3 Years
Extensometer	4	1 Hour	3 Years
Strain Gauge	2	1 Day	3 Years
Water Level Meter	1	1 Hour	3 Years
Inclinometer	3	1 Month	3 Years

Source: National Building & Research Organization

2) Issued warnings by NBRO

The data set was matched with the dates where a landslide warning was issued to Kahagalla area. During 2015 to 2016, there had been five warning situations where the people who lived in that area were asked to evacuate.

B. Machine learning function

1) Identifying the machine learning approach

Machine learning is used due to the fact that; it can handle a vast amount of data and parameters. Also it does not require a predefined model. To predict whether a landslide will occur or not, the system needs to provide two outcomes. Because of that; binary classification method can be used to build the machine learning function.

If Y is the output, then;

Y =1; Warning Situation

Y =0; Normal Situation

Since adequate amount of previous data are available for the study, and the data set contains several sensor types, the output datasets can be provided for training the system. Hence, the machine learning approach can adopt supervised learning method. To analyse the relationship between the predictors of this study, logistic regression is selected.

2) Feature Selection

Feature selection is one of the paramount tasks in machine learning. Among the available three main methods to choose the most appropriate feature set; K-Fold Cross Validation method was selected which partitions the original sample into several testing sets. The general recommendation for predictive models is K=10. Hence, it was used in this study as well. Feature selection was conducted under two scenarios;

Scenario 01: Each sensor was considered individually and its contribution for the prediction was measured. Based on the obtained results, different feature combinations were selected to train them.

Scenario 02: "Recursive feature elimination method" was also used to choose feature sets. Instead of taking feature sets from each sensor as one whole group, each feature was taken as an individual feature and measured the success rate of each and every one of them and a feature set with highest success rate was selected.

3) Model Evaluation - Confusion Matrix

In order to evaluate the created models, a "Confusion Matrix", which is the technique used for summarizing the performance of a classification algorithm, was used. The confusion matrix of binary classification is a 2×2 table formed by four outcomes;

True positive (TP) : correct positive prediction

False positive (FP) : incorrect positive prediction

True negative (TN) : correct negative prediction

False negative (FN) : incorrect negative prediction

Accuracy of the models were evaluated using the following measures.

Classification Accuracy

Calculated as the number of all correct predictions divided by the total number of the dataset. The best possible accuracy is 1.0, whereas the worst is 0.0.

Classification Error

Error rate (ERR) was calculated as the number of all incorrect predictions divided by the total number of the dataset. The best possible error rate is 0.0, whereas the worst is 1.0.

Sensitivity

Sensitivity was calculated as the number of correct positive predictions divided by the total number of positives. It is also called recall (REC) or true positive rate (TPR). The best possible sensitivity is 1.0, whereas the worst is 0.0.

Specificity (True negative rate)

Specificity was calculated as the number of correct negative predictions divided by the total number of negatives. The best possible is 1.0 and the worst is 0.0.

False Positive Rate (FPR)

FPR was calculated as the number of incorrect positive predictions divided by the total number of negatives. The best possible FPR is 0.0 whereas the worst is 1.0.

Precision

Precision was calculated as the number of correct positive predictions divided by the total number of positive predictions. It is also called positive predictive value (PPV). The best precision possible is 1.0.

C. Prototype Sensor node construction and Web interface development

A prototype of a Wireless Sensor Network, which consists different sensor types to measure the movement of underground soli layers, pressure and the water level, was created to illustrate that the proposed landslide prediction model and the early warning system can be practically deployed and functioned in an actual landslide prone area.

The sensor types, number of sensors, number of slave nodes and their positioning varies from one site to another depending on the condition of that specific site. Hence, designing of sensor nodes for a particular site and deploying them is recommended to be conducted under the supervision geologists. Yet, the basic structure of the sensor network can be created as follows;

1) Sensor Selection

The sensor types which gave high contribution for the prediction model were selected based on the cost and their availability as prototype sensors.

2) Sensor node construction

Two Sensor nodes and a central node was constructed for the prototype sensor network. Plastic boxes were used to place the microcontrollers, transceiver modules and power supplies. The sensors were fixed on pipes in appropriate ways to get sensor readings and the all nodes were powered by the power banks. The modules and the sensors used for each node are as follows;

Central node / Master node

Node MCU was used as the microcontroller and the Wi-Fi module since it has ESP8266 Wi-Fi module embedded with it. NRF24l01 transceiver module was also used to receive sensor data.

Sensor nodes / Slave nodes

One node was made with 4 Strain Gauges and a transceiver module. The other node contained a Rain sensor, Accelerometer, thin film pressure sensor and a transceiver module.

3) Communication link establishment

The link between master node and slave nodes was a point-to-multipoint link. Slave nodes transmitted data using 2.4 GHz NRF24L01 transceivers. Data packets were sent in character array and a specific character was added at the beginning of the array for identification.

After connecting to an access point, master node transmitted received sensor data form slave node to the web server using ESP8266 Wi-Fi module. Transmissions were delayed by necessary time intervals to minimize the data loss. Slave nodes transmitted data for every 5 seconds and Master node transmitted data for every 20 seconds.

4) Web interface and databases

The web interface was created using a public web server and Bootstrap Framework was used to create the interfaces.HTML 5, CSS, JavaScript and php was used for coding. The web interface contains a logging page and a home page. The home page shows all sensor data in corresponding tables created for each and every sensor type used in the prototype. Page is refreshed for every 5 seconds to update data the tables.

A database with 4 tables was created using MySQL to store sensor data. All tables have columns to show date and time. Last 5 values of the tables are shown on the web page. Chart.js which is a JavaScript library, is used to plot graphs. Last 50 values of the tables in the

Classification Accuracy - 98.1%
Classification Error - 0.1%
Sensitivity - 97.6%
Specificity - 98.8%
False Positive Rate - 0.1%
Precision - 93.2%

MySQL database were used to plot the graphs and it is updated for every 20 seconds. The X axis of the graph indicates the time and the Y axis indicates the corresponding sensor values.

Classification Accuracy - 99.1%
Classification Error - 0.1%
Sensitivity - 100%
Specificity - 98.8%
False Positive Rate - 0.1%
Precision - 99.2%

D. Warning Message Generation

Machine learning function was coded in a php script. Real-time sensor data were given as inputs to the machine learning function. After evaluating the function, if the value is greater than 0.5, a warning message was shown on the web page stating a landslide threat with audio

Classification Accuracy - 99.8%
Classification Error - 0.001%
Sensitivity - 99.4%
Specificity - 99.8%
False Positive Rate - 0.007%
Precision - 99.4%

output. To verify the output, the previously mentioned accuracy measures; that is, Classification Accuracy, Classification Error, Sensitivity, Specificity, False Positive Rate, Precision etcetera were used.

III. RESULTS

A. Feature selection

1) Scenario 01 – Feature Selection using individual sensors

11,876 samples and 126 features were used in feature selection process. Based on individual sensors, eight basic

Feature Set	Sensors	10 Fold Cross Validation Accuracy
1	All the sensors	93.3%
2	Rain Gauge	87.0%
3	Extensometers	98.3%
4	Strain Gauge-1	96.1%
5	Strain Gauge-2	91.2%
6	Inclinometer-1	74.9%
7	Inclinometer-2	77.3%
8	Inclinometer-3	77.3%
9	Ground Water	80.5%
10	Rain Gauge+Extensometers+Strain Gauge	92.7%
.....	.....	.....

Figure 1. Results of the Feature Selection
Source: Experimental data

feature collections were selected. Figure 1 indicates how basic sensor types, selected combinations of the sensors and all the sensors as one group contributes to a successful feature selection process with 10-fold cross validation method.

Extensometer and Strain gauge collections shows higher success rate than other basic features. Surprisingly rain sensor success rate is below than extensometer and strain gauges. Among the several types of combinations tested, Extensometer and Strain gauge combination showed more promising results. Therefore Extensometers and Strain Gauges +Extensometers collections were taken as two feature sets to build two models.

2) Scenario 02 - Recursive Feature Elimination Process

Table 2. Comparison between three models

Measurement	Model 1	Model 2	Model 3
Classification Accuracy	98.1%	99.1%	99.8%
Classification Error	0.1%	0.1%	0.001%
Sensitivity	97.6%	100%	99.4%
Specificity	98.8%	98.8%	99.8%
False Positive Rate	0.1%	0.1%	0.007%
Precision	93.2%	99.2%	99.4%

Source: Experimental data

B. Table updating and plotting graphs

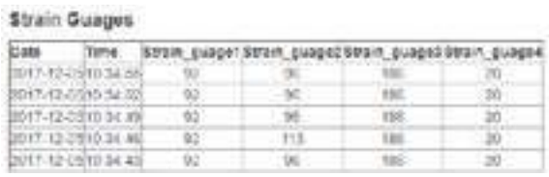

Figure 5. Table updating in Web interface
Source: Experimental data

The X axis of the graph indicates the time and the Y axis indicates the corresponding sensor values.

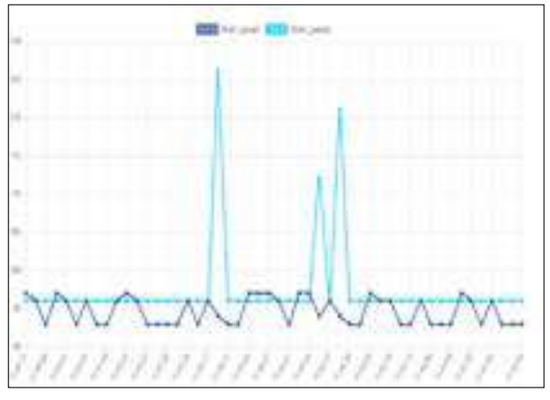

Figure 6. Graph created for two strain gauges
Source: Experimental data

C. Generating warning messages

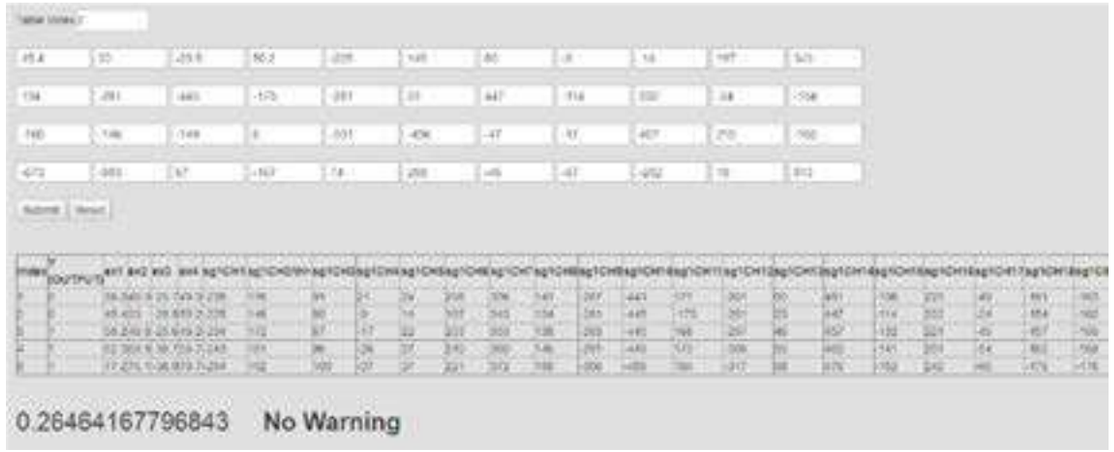

Figure 7. "No Risk" situation
Source: Experimental data

When the system was tested with manually entered data values corresponding to a critical situation the system generates an alert indicating that the system has identified a possibility for a landslide.

IV. CONCLUSION

When considering the past records of natural disasters occurred in Sri Lanka, landslide is a commonphenomenon which has caused intolerable damages to the living beings and properties. Due to the randomness, high uncertainty and the complexity, it is quite difficult to predict the possibility for a landslide and hence, issuing early warnings has become a challenging task. Up to now, the Disaster Management Centre of Sri Lanka adopts a simple method when issuing early warnings for landslides, which is totally based on the amount of rainfall to a particular landslide area. Even though rainfall is considered as one of the two triggering factors of a landslides, relying completely on the rainfall data when issuing landslides is not an acceptable method due to there are more accurate measurable parameters that can be used to predict the possibility for a landslide.

Compared with the existing high-end systems, a simple wireless sensor network which is capable of identifying the underground movements and soil conditions is a cost effective, practical solution. But, dealing with a large number of variables manually with no proper understanding about their contribution for occurrence of a landslide is difficult for human brains. Machine learning, which is a method used to create complex models and algorithms that lend themselves to predict; is a fruitful solution for that issue. Incorporating the cost effective Wireless Sensor Networks and machine learning approaches, developing an accurate landslide prediction and early warning mechanism to minimize anticipated damage of future landslides in Sri Lanka was the ultimate goal of this project.

Achieving the expected outcome and the main objectives, an intelligent landslide prediction model which incorporates machine learning capabilities to predict the possibility for a landslide was developed and tested with the prototype to illustrate the practicability of the suggested system. Since the developed model incorporates the parameters which contribute more than rainfall for the occurrence of a landslide, the accuracy and the reliability of the proposed system is higher and the warnings generated by the system are trustworthy and true when compared to the existing warning mechanism. Depending on all the results of the system, it can be concluded that by deploying a Wireless Sensor Networks in the landslide prone areas with the required sensor types and by using a fine-tuned version (to match with the soil condition of the selected site) of the proposed model to predict the possibility of landslides, the anticipated damage of future landslides in Sri Lanka can be reduced up to a great level.

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LOW COST REAL TIME TEMPERATURE MONITORING SYSTEM FOR CONCRETE USING WIRELESS SENSORS

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Abstract— Structural health monitoring (SHM) has become an inevitable part in a life span of a structure due to its potential to ensure the public safety and to increase the life span of the structure. Monitoring any kind of structures for various parameters, using wireless smart sensors has gained popularity in recent past. This paper discusses the development of low cost real time wireless smart sensor monitoring system to monitor early age concrete temperature in real time. Temperature of two early age concrete mixes (Mix1, Mix2) were measured in real time for 24 hours by using DS18B20 sensors connected with the NodeMcu, which is an open source IoT platform. Temperature measurements were saved and visualized in real time using Thing SpeakTM which is an open IoT online platform with MATLAB analytics. The temperature sensorDS18B20 was selected such that it is suitable to measure temperature readings of the concrete without any interference of the chemical reactions in concrete. Calibration methods and temperature variation with different concrete mixesare also discussed. It could be seen that the wireless temperature monitoring system performed adequately and it can be considered as a better low cost alternative for traditional wired temperature monitoring system.

Keywords - Structural Health Monitoring, Wireless smart sensors, Wireless temperature monitoring system, Concrete, low cost.

I. INTRODUCTION

The safety and durability of any civil infrastructure is mandatory. Structural health monitoring (SHM) is a new paradigm which incorporates automated systems for data acquisition for monitoring, analysing and identification of structural defects (Sun et al. 2010). It enhances the structural safety and significantly reduces lifetime operating costs by early detection of defects for maintenance (Farrar et al. 2007). Data resulting from deploying sensors, could also be used for design optimization, retrofitting and replacement of structures. Dense arrays of sensors were used to monitor structures at the initial stage of the development of such SHM system which was very expensive and non-versatile (Hongki et al. 2010). The attractive features in wireless SHM are real time processing, low cost, easy to install with less space accommodated, and performance similar to that of wired sensing system (Kim et al., 2006). However, such a wireless sensor based real time monitoring system for health monitoring of civil infrastructures has not yet been developed and used in Sri Lanka.

The development of high temperatures in fresh concrete could cause detrimental effects to long-term concrete performance. High concrete temperatures accelerate the rate of hydration and cause the concrete to undergo drying shrinkage cracking(Schindler &Frank Mccullough, 2002). When temperature reduces, the hydration process slows down and concrete does not set properly which would affect the strength of concrete. Increased rate of hydration in thick elements could create higher core temperature within structural element. Higher core temperatures will create temperature differentials when ambient temperature differs from core temperature. Higher temperature differentials could cause cracking, loss of structural integrity, thus shortening the life span by decreasing the strength of the concrete. Higher temperature around 70°C is the key factor for Delayed Ettringite Formation (DEF) which could lead to cracking of concrete with the presence of water in long run and this could be significant when concrete element is larger. Concrete temperature is also used in identification of corrosion of steel reinforcement, which also strengthens the vitality of monitoring temperature.

Main constituent minerals to cement are Tricalcium aluminate (C_3A), Tricalcium Silicate (C_3S),Dicalcium Silicate (C_2S) and tetra calcium alumino ferrite (C_4AF. C_3A) which reacts very fast with water with an exothermic reaction that increases the temperature at a higher rate. In order to slowdown the effect from C_3A, gypsum is added to cement. The presence of OH- and SO_4^{2-} allows the formation of primary ettringite ($C_3A.3CaSO_4.2H_2O.32H_2O$) which is later converted to Mono sulphate hydrate (Dayarathne et al., 2013). Ettringite formation in fresh concrete does not cause any adverse effects because of the plastic nature of concrete. But it can cause significant effect if it forms during hardened stage of concrete. Hence it is important to measure the temperature of concrete at least during first 24 hours to ensure, prevailing temperature of fresh concrete is within the limit 70°C.

II. WIRELESS SMART SENSORS

Wireless smart health monitoring system is a new substitute for the traditional tethered monitoring system (Lynch, 2006). With the introduction of new electronic systems with high processing power and remote sensing ability, wireless monitoring system(WMS) has become an attractive solution for SHM. Noel et al. (2017) compared the advantages and disadvantages of wireless smart sensing method with the traditional tethered method. Traditional wired sensing methods are labour intensive due to its complicated arrangement of long wires, which is a major contributing factor for the higher cost involved. Wired sensing networks usually takes several days to deploy because, running of wires through structure without invasion of space is not an easy task.

Apart from its attractive features, WMS has inherent challenges which is currently overcome with the development technology in electronics and telecommunication. Wireless sensing network has nodes which consists of required sensors connected with PCB, and wireless transmission portion such as Wi-Fi module. These nodes generally run on battery power, which needs regular recharging, thus resulting in regular maintenance requirements. Wireless sensing network has lesser band width compared to wired method, but it does not have significant impact in data transfer because in SHM systems, data transfer rate requirements are lesser. Even with 10bits resolution of data with data acquisition frequency 1kz the data transfer rate would be 125Bytes/s.

$$\frac{1000\ samples}{second} X \frac{10\ bits}{sample} X \frac{1Byte}{8\ bits} = 125\ bytes/s$$

In other words, it would only be 0.125kB/s whereas modern transmission wireless protocols can even transfer in a rate of 100 MB/s. Another main challenge in wireless monitoring is synchronization of data, due to its lesser speed whereas wired monitoring systems are much more reliable as far as synchronization is concerned.

Wireless smart sensing technology suits Civil engineering structures well, due to its easiness of handling and long range transmission of data. The first ever structure with high number of sensor nodes with proper PCB designs and network protocol is Golden Gate Bridge(Noel et al., 2017) which was successfully monitored irrespective of its size. Data were collected at a sample rate of 1 kHz where the sensitivity of accelerometer was 500 μG. The data collected were impressively synchronized with 10 μs jitter.

Since this research only consider one node and the parameter monitored was temperature, there were not any significant invasive disturbances for the readings taken.Silveira and Bonho (2016)implemented a wireless temperature monitoring system using IEEE 802.15.4 (Wi-Fi) protocol where data was successfully transferred in the range of 50m out door and 20m indoor. Using Wi-Fi makes higher data transfer possible. Wi-Fi is suitable for local area networks and it is now incorporated with day to day devices such as smart phones, which makes the data transfer to cloud data base easier and fast. Storing data in cloud not only secures the data but also it allows to monitor the data from anywhere of the world along with analytical graphs and other interactive features.

Wireless smart sensors could be an attractive solution. However, the success of that depends on the way it is connected with sensors, nature of sensors, electronic design, power supply, telecommunication protocol etc. (Norberto B. et al., 2013) describes some main challenges

faced when a wireless temperature and humidity sensing unit was deployed in real structures. In addition to afore mentioned factors there were some other challenges such as inability of temperature sensor to sustain with the alkaline environment and selecting a proper casing for the monitoring system to protect PCB and transmission unit in order to prevent current leakages and short circuiting.

III. METHODOLOGY

SHM includes many common steps irrespective of the parameters and the structures we monitor. The flow chart below (Figure 1) depicts the critical steps in monitoring a structure for a given parameter, which is identified to be critical. In this particular research the flow starts from identification of concrete specimens and ends with the real time online visualization.

Monitoring of temperature of concrete is important in Sri Lankan context because Concrete is widely used in construction industry in Sri Lanka. In this experiment, Fresh concrete samples were selected at their plastic stage. Appropriate mix proportion is essential to meet the concrete strength and the durability requirements. Two types of concrete Sample mixes (Mix1 and Mix2) were selected with different cement contents, in order to observe clear difference in peak temperatures. Cement content of Mix2 was selected such that it is higher than Mix1. Table1 shows the mix proportions of Mix1 and Mix2.

In the next step, proper sensor was selected in order to meet the accuracy level required. Several wireless temperature sensors such as SHT15, SHT21S, SHT71, BOTDR, Raman OTDR, Rayleigh OFDR/OBR, FBG, and DS18B20 were considered. In order to select an appropriate sensor several factors such as cost, ability to perform in severe environments, power supply and range of temperature that the sensor can sustain, were considered. Since the temperature measurements are related to concrete, high accuracy is not required. An accuracy of 0.5°C with the range of 10°C to 80°C is sufficient for monitoring of concrete temperatures.

Temperature sensor, DS18B20 was selected to monitor the temperature because of its casing which ensures the protection from severe alkali environment. This sensor can measure temperatures in the range from -55°C to +125°C (-67°F to +257°F) with ±0.5°C accuracy in the range of 10°C to +85°C. DS18B20 sensor can be powered by an external

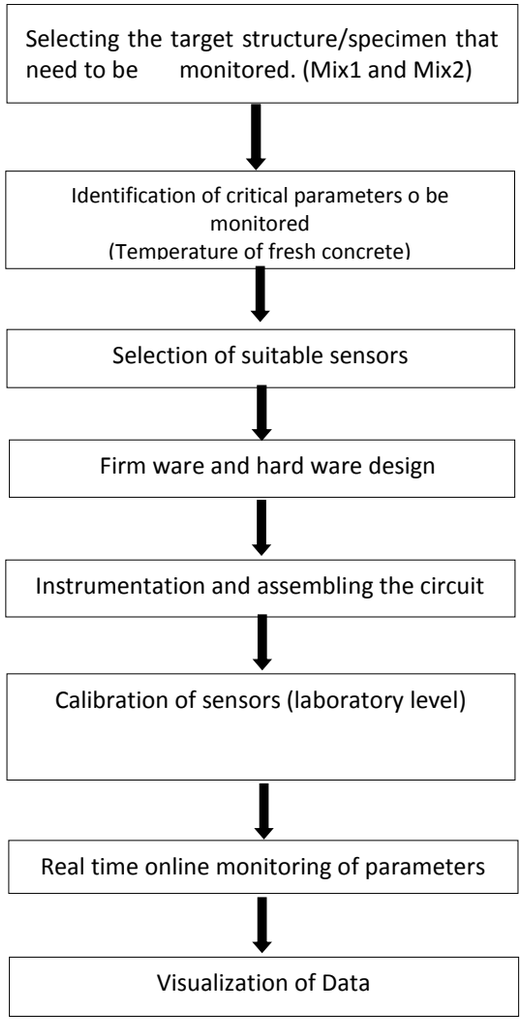

Figure 1: Methodology of the experiment

Table 1. Mix proportion for Mix1 and Mix2.

Material used	Mix1 (kg/m³)	Mix2 (kg/m³)
Cement	385	711
Water	154	284
Coarse Aggregate	1291	1007
Fine Aggregate	859	681

supply on the Vcc pin. External power supply was used to power the sensor because power supply using USB is not reliable in higher temperatures. DS18B20 does not sustain communications due to the higher leakage currents which exist at these temperatures. For applications in which high temperatures are likely, it is strongly recommended to use direct power supply. DS18B20 was very cheap compared to the other aforementioned sensors. Table 2shows the specifications of the DS18B20 sensor.

Table 2. Specifications of DS18B20

Specifications	Range
Voltage supply	3V -5.5 V
Sensing temperature	-55°C ~ 125°C
Accuracy - Highest (Lowest)	±0.5°C
Sensor type	Digital
Mounting type	Surface Mounting

The typical method used in Sri Lanka to monitor temperature of concrete is thermo-couple based data logging system. Thermocouples are tethered with data loggers using wires. This method is very expensive because of the higher cost involved with data loggers and man hours required to install and onsite collection of data.

Figure 2: Typical data logging systems used in temperature monitoring.

Table3 compares the cost involved in both thermocouple based data logging system and WMS used in this research. Another attractive feature in WMS was, it consumed less current at the node level which could also be powered by a battery.

According to the system design, electricity consumption for one sensor operation unit annually is calculated as follows:

Monitoring interval	=	10minutes.
Then per one hour	=	6 data.
Per one day (6 x 24)	=	144 data.
Power consumption per day	=	0.048mAh.
Sleeping mode	=	2.3999mAh.
Annual power consumption	=	893.505mAh.

Table 3. Cost comparison (Main components only) of dense wired method and wireless monitoring method.

Thermocouple based wired data logging system	
Data logger	Rs. 600,000
Thermocouple wire k-Type 4m	Rs. 800
Total	Rs. 600,800
Wireless system	
Sensor(DS 18B20)	Rs.150
Node MCU	Rs.900
Other Circuit components	Rs.800
Total	Rs.1,850

Once the sensor type is selected the circuit was designed with the main components. The main components in the circuit contains sensor, micro controller, communication units and power supply to the circuit. The collected data flows as depicted in Figure 3 below. Instrumentation and assembling the circuit with the actual components carried out after the completion of the circuit design. NodeMcu version 1.0 (*NodeMCU* Documentation, 2018) is selected as a master controller since it contains the specified Wi-Fi module in itself. NodeMcu is programmed using Aruduino IDE (Integrated development environment). Figure 4 shows the connected DS18B20 sensor with NodeMcu. The setup was later encompassed in proper casing. PCB board was not required because of the simplicity of the experiment set up and bread board was used in order to implement the circuit design. Figure5 shows the final product after encompassing circuit where dual data channel was used in order to collect two different flows of data. The yellow colour wire indicates where the

data cable of the sensor should be connected whereas red and black indicate the power supply and ground, respectively. The WMS was calibrated using thermocouple based temperature monitoring system before monitoring concrete temperature. Then, it was used to measure the temperature of Mix1 and similarly another set of 3 wires and a sensor were connected to the system in order to take measurements of Mix2. It was programmed so that the data from each mix could be collected alternatively in 10 minute intervals assuming the concrete temperature does not vary significantly during this interval. Then obtained results were initially established within a local network and an online open source plate form Thingthinkspeak.com (*IoT Analytics - ThingSpeak Internet of Things, 2017*) was used to monitor the temperature variations in real time online. Figure 6 shows both Mix1 and Mix2 samples being monitored for temperature using WMS.

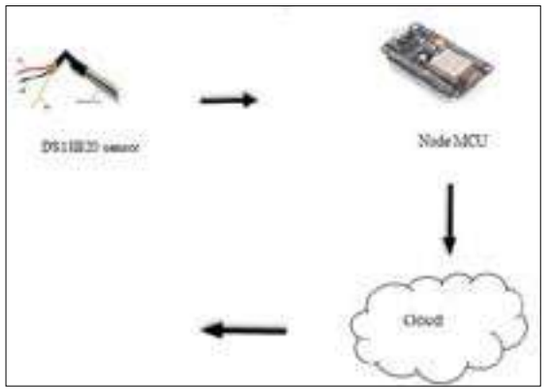

Figure 3: Sensed Data flow

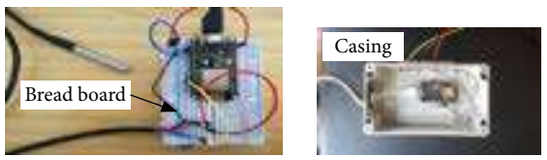

Figure 4.NodeMcu connected with temperature sensor and full setup with casing.

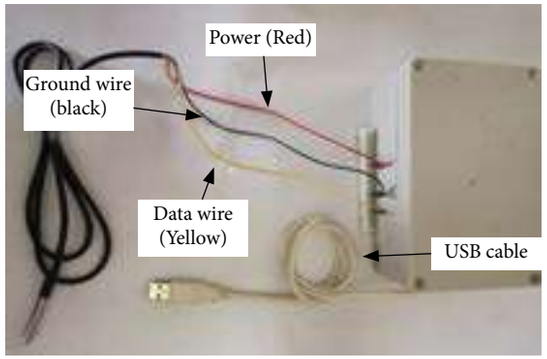

Figure 5. Dual data channel wireless temperature monitoring system.

Figure 6. Laboratory test set up of monitoring temperature of samples using wireless system.

The experiment was carried out for continuous 24 hours in order to monitor the concrete temperature during plastic stage and hardened stage.

IV. RESULTS AND DISCUSSION

Temperature of both types of mixes were visualized in real time in Thingspeak blocks. Then the data were extracted and combined in order to compare. Table 4shows the inner temperature reading of concrete obtained using WMS for both Mix1 and Mix2 for 24 hours, using calibrated wireless temperature monitoring system. Figure 7 shows how the temperature of Mix1 and Mix2 vary against time.

Table 4. Reading obtained using wireless monitoring system(WMS) for 24 hours period

Time (minute)	Temperature of Mix1 (°C)	Temperature of Mix2(°C)
0	30	30.5
120	29.05	29
240	29.31	29.5
360	29.95	31.25
480	30.57	33.15
600	30.75	33.38
720	30.3	32.75
840	29.8	31.25
960	29.5	30.5
1080	29.25	30.12
1200	30.05	31
1320	30.25	31.125
1440	30.2	31.25

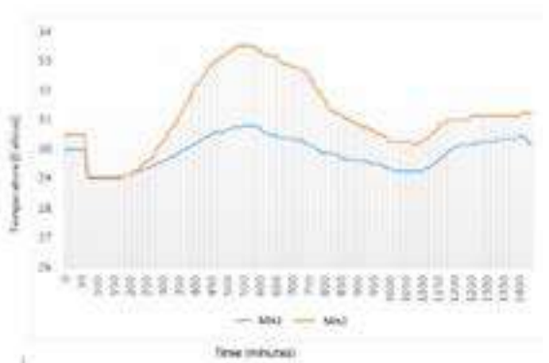

Figure7. Compares the temperature between two grades of concrete.

The results of the calibration tests displayed that the initial temperatures monitored using the DS18B20 and thermocouple based temperature monitoring system was more or less same for both grade of concrete, with a maximum variation of only 0.3 oC throughout the experiment.

As expected, the temperature of Mix2 was always higher than that of Mix1, due to the higher cement content in Mix2.Maximum temperature difference observed was 2.63oC.The absolute maximum temperature measured during the experiment was 33.38 o C (Mix2).The observed temperature rise values were not that significant since the size of tested concrete elements were small in size.

V. CONCLUSION

This paper discussed about a low cost wireless temperature monitoring system for concrete developed using DS18B20 temperature sensor and Nodemcu IoT platform. Data visualization has been carried out on thing speak IoT online application. This system was calibrated using thermocouple based temperature monitoring system at laboratory level. It has been shown that proposed low cost wireless system performed adequately and could be used as a replacement for wired temperature monitoring system.

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INVESTIGATE THE NECESSITY OF USE OF NUCLEAR POWER AS AN ENERGY SOURCE IN SRI LANKA WITH SPECIAL CONCERN ON PRESENT NUCLEAR TREND

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Abstract - The escalation of electricity demand in a country has become an unavoidable factor. Technological development and raising people's living standards are the main reasons for increasing electricity demand. Electricity demand in Sri Lanka has grown at an annual rate of about 6% over the past ten years. Therefore, it is important to increase the total installed capacity through appropriate power generation combinations. Clean, reliable, affordable, balanced and sustainable energy structure by giving priority for renewable energy generation while minimizing the contribution of diesel and coal is the strategy of Government of Sri Lanka (GoSL). The unreliability of renewable energy sources such as solar, wind and hydropower questions their contribution to sustainable energy mix. Concerns about environmental issues have limited the development of fossil fuel power plants. Hence, Nuclear Power Plants (NPPs) can be considered as strong and competitive candidate in Sri Lankan energy industry. Ceylon Electricity Board (CEB) has included their proposal to consider nuclear power plant (NPP) in Sri Lanka after 2030. The higher plant factor, capacity, efficiency, reliability, zero or less emissions of greenhouse gases are the advantages of NPP while high capital and maintenance cost, complexity of technology, possible radiation threat are main disadvantages of NPPs. Political, social, environmental, cultural and economic bottlenecks are mainly connected with complexity of technology. There are many technologies being used for NPPs, but most of them are more complex, costly and accidents-prone. This research examines the necessity of nuclear energy to Sri Lanka with special concern on nuclear trends which are growing in Sri Lanka and all over the world.

Keywords - Nuclear Power, Energy mix, Nuclear trends

I. INTRODUCTION

The energy has played a prominent role in the human evolution throughout the history. Scarcity of electricity power has exaggerated by alarming inevitable power crisis over acquiring, sharing and utilizing energy. Availability, cleanliness, low cost and sustainability are the pillars where energy source exists. Sri Lanka has to pay more consideration to select a viable and sustainable power option as a main power source in the country. All most all the power sources are having advantages as well as disadvantages. In order to achieve the development targets in the country, it is paramount important to have electricity supply adequately with proper generation mix. The significant impact of electricity supply on economic growth of Sri Lanka is inevitable and attested (R Ferguson;W Wilkinson; R Hill, 2000)(R Morimoto, C Hope, 2001). Power saving could be a part of energy management for future Sri Lanka. However, there is a limitation to power saving where as 100 % saving through energy management is not practical. Developed countries such as USA, UK and Singapore are having considerably high per capita electrical consumption rate with more than 7000 kWh where as Sri Lanka is having approximately 600 kWh.

Two main factors to be considered while studying the viability of a source of energy are the '*behavior of the demand*' and other *'alternative options available.'* The requirement of connect additional power sources to

the supply is essential only if the demand in increasing significantly. Over the past 15 years, the demand has increased by 5% annually while in year 2016 and 2017 it has increased by more than 10%. Hence, the demand increment can be considered as a confirmed fact.

Except few options available with mini hydro power plants, hydro power capacity cannot be increased further in the country. There is no possibility of generating electricity power from tidal waves and wind power in large scale. Solar power has become an emerging source of power in the country today. In collaboration with Sri Lanka Sustainable Energy Authority (SLSEA), Ceylon Electricity Board (CEB), Lanka Electricity Company (Pvt) Ltd. (LECO) Government of Sri Lanka (GoSL) introduced the "Suryabala Sangramaya" (Battle for Solar Energy) to motivate people for implement Solar Panels power systems. This project has expected to add 200 MW to the national grid by 2020 and 1000 MW by 2025(Surya Bala Sangramaya, 2017). Even though it is a renewable energy source, the high flickers generate in the system, non availability at night and less reliability has created many uncertainties to depend upon solar power systems. Hence, renewable energy sources are having restrictions to recognize as main power source for a country. The main aim of establishing of SEASL by enacting the Sustainable Energy Authority Act No.35 of 2007 of the parliament of the Democratic Socialist Republic of Sri Lanka is to pave the way for Sri Lanka to gain energy security by protecting natural, human and economic wealth. Embracing the best sustainability practices by generating energy indigenously and use them efficiently are the objectives of the inception of SEASL.

The world today does not promoting fossil fuelled power plants considering their effect on the environment. Being a member country who ratified to "The Convention of the Parties to the United Nations Framework in Climate Change held in 2015" (COP21), Sri Lanka is having obligation to commit to decrease the greenhouse gas emission and take necessary measurements to hold the global temperature well below 2 degrees centigrade, from pre-industrial level. Considering the alternative power source, nuclear power can be considered as a clean and sustainable energy source.

There are several factors to be considered while introducing nuclear power as an energy source to Sri Lanka. Technological, Political, Social and cultural, financial and environmental factors are more important to assess vigilantly prior to introduce nuclear technology as a candidate to Sri Lankan energy mix. The use of nuclear power as an energy source has not been discussed adequately in Sri Lanka's power sector as well as the general public.

Besides the financial constraints that could be a potential barrier, the deterrence over using of nuclear energy is the main barrier to table this topic for further discussion. Without examining the pros and cons of use of nuclear energy in depth, it is unjust to comment on acquiring nuclear energy to fulfill the energy requirement of Sri Lanka. Many different technologies are involved with nuclear technologies. Considering above all, this study has been conducted to examine the necessity of using nuclear power as an energy source in Sri Lanka considering its viability with special concern favorable nuclear trends in the world.

II. METHODOLOGY

The research was a qualitative research. Hence, formulation of hypothesis before hand and testing it was not done. This chapter was dedicated to describe the way this research carried out to derive recommendation and comment on core argument, main and other objectives. The construction of research, sampling methodology, data collection method, data analyzing method are to be discussed in this chapter. The purpose of the methodology was to investigate the quality of the relationship of nuclear energy in Sri Lankan context. Hence, statistical data and numbers were seldom involved. The study limitations such as in-sufficient knowledge were restricted the smooth conduct of the research. Ethical considerations of the research also have discussed.

Before developing the core argument, the history of the nuclear industry with related to energy production sector was studies in depth. This was helpful to have an idea on the development of the sector and rise and falls of the nuclear industry and reasons for such incidents. There were very less and limited studies were found with related to Sri Lanka on nuclear energy sector.

The topic nuclear energy has not been a popular topic among the scholars and academia in Sri Lanka. The laboratory facilities and other infrastructures also were very limited. Sri Lanka Atomic Energy Board (SLAEB) was the main responsible body for promote nuclear related experiments and educations. The main concern of SLAEB has focused on other usages of atomic energy rather than nuclear energy.

On completion of comprehensive study on history, previous researches as well as technology related to nuclear energy, the core arguments and other objectives were derived. This could be considered as the basement of the research.

The study on history was immensely helped to conduct case study on previous accidents and their consequences. Other than accidents, Following factors were studied during research;

- Technological factors
- Economical factors
- Social and cultural factors
- Political factors
- Environmental and Security factors

III. DISCUSSION

A. Energy Sector In Sri Lanka

The average power consumption in Sri Lanka is 35 to 40 GWh in an ordinary day. Concerning the consumption pattern in Sri Lanka, electricity tariff has implemented by CEB. The total installed generation capacity mix in Sri Lanka is approximately 4000 MW by August 2017 and it has estimated to be increased up to 6400 MW by 2025(Ministry of Power and Renewable Energy, 2018) with the rate of 6 % per year during year 2000 to 2015. As a result of motivate public to use of unconventional renewable energy, the percentage of Non-Conventional Renewable Energies (NCR)has increased from 4.1 % in 2007 to 10% in 2016 and is estimated to be 20 % by 2020(Ministry of Power and Renewable Energy, 2018).

The electricity generation has been increased approximately 4% while maximum peak demand has increased approximately 3% per year during this period. (LTGEP, 2016) The annual electricity generation in year 2015 and 2016 are 13,151 GWh and 14,301 GWh respectively. Accordingly, the average growth has increased up to 5.9 % and 8.7% during 2015 and 2016. The system peak demand also has increased in year 2015 and 2016 with 2210.4 MW and 2406.4 MW respectively with 2.5% and 8.9% (PUCSL, 2016). The total installed generation capacity of Sri Lanka by the end of year 2016 was 3,887 WM. There were 239 grid connected power plants owned and operated by government (27) as well as Independent Power Producers (207). The percentages of each producer category in year 2016 in Sri Lanka are as follows.

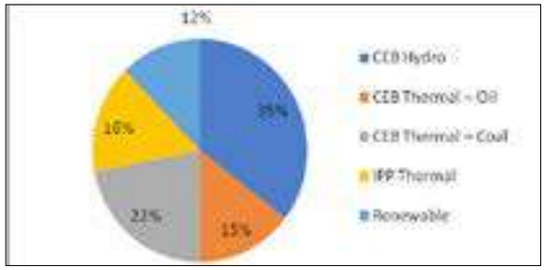

Figure 1. Generation Capacity Mix in WM in Year 2016
Source: Generation Performance Report, 2016
(PUCSL, 2016)

Despite of the higher installed capacity of CEB owned and operated hydro power plant, the power production and contribution of them to the national grid is depend on the rainfalls to the area where reservoir are located. This dependability of largest power producer has threatened the reliability of the power hydro power source and sustainability of the power system in Sri Lanka. The contribution of coal power has been gradually increased from 2015 to 2017 after commissioning of all three coal power plants at Norechcholei in 2014. Total capacity of 1259.3 GWh is available with main three hydro power reservoirs (Mahaweli, Samanalawewa and Laxapana complexes) in Sri Lanka. Since, the total annual power demand in Sri Lanka is approximately 14,000 GWh, the available reservoir capacity is only 08 % of annual requirement. (PUCSL 2016) Hence, the non-availability of rain for catchment area may significantly effect to the stability of the electricity supply of the country. Hence, a sustainable, reliable source to take over the base load of the country is essential for Sri Lanka.

Discussions are in progress to Commercialize Natural Gas discovery in Mannar basin with the initiative of Cairn Lanka Pvt Ltd being the only identified indigenous fossil energy source. GoSL expected to introduce a natural gas power plant to Mannar basin with 1000 kW capacity(Reuters, 2017). However, their quantities and industrial utilization capability have not been verified. Hence, it is of paramount importance to find alternative sources which easily can be replaced with fossil fuels.

B. Nuclear Energy and its Development

The history of nuclear science goes back to the 18th century and in its early stage it was focused on science of atomic radiation. Uranium was discovered in 1789 by German chemist Martin Klaproth and named after the planet Uranus. The atomic energy and nuclear fission was developed in 1895 to 1945.Nuclear reactions are two types. In fission reaction, large nucleus breaks down into two or smaller nuclei losing mass in the process. Two small nuclei react to form a bigger nucleus while releasing a large amount of energy as per Einstein's equation (E = mC2where E for energy, m stands for Mass and C is velocity of speed which is high as 3 x 108 ms-1) in fusion reaction.

As per the two summary reports published by MAUD committee of UK in 1941, the use of Uranium in a weapon and as a source of power using controlled fission reaction was highlighted and no sooner the attention was made harnessing this energy in a controlled manner for energy production (Power Generation) as well as naval propulsion systems. First atomic device test was carried out by USA on 16th July 1945 at Alamagordo in New Mexico with a Plutonium pile. Then USA dropped a U-235 atomic bomb on Hiroshima on the06thJuly 1945 and a Pu-239 device on the 09th August 1945 on Nagasaki. American based "Argonne National Laboratory" in Idaho designed first ever nuclear power plant to produce electricity in December 1951. "Atoms for peace" program was deployed by president Eisenhower in 1953 boosting the interest over researches on nuclear science with relevant to electricity production. This is today considered as the birth of nuclear power (World Nuclear Association, 2018).

C. Different NPP Technologies And Their Availability

At present several technologies used for nuclear power generations have been phased out while adding some new technologies. In Pressurized light water moderated and cooled reactor (PWR) the reactor core heats water, this is not boiled. This hot water then exchanges heat with a lower pressure water system, which turns to steam and drives the turbine. There are 232 reactors available in world (WNA, 2018). In Boiling Light-Water-Cooled and Moderated Reactor (BWR– 75 Nos) the reactor core heats water, which turns to steam and then drives a steam turbine. A pressurized heavy water reactor (PHWR– 49 No.s) is a nuclear power reactor, commonly using un-enriched natural uranium as its fuel that uses heavy water (deuterium oxide D2O) as its coolant and moderator.

Another important technologies use in nuclear reactors is Light water cooled graphite moderated reactor (RBMK), Gas-Cooled Reactor (GCR) and Fast Breeder Reactors (FBR). Advanced Boiling Light-Water-Cooled and Moderated Reactor (ABWR), Advanced gas-cooled reactor (AGR) and Water Cooled Water Moderated (WWER are not commonly used in the world. Focus Fusion reactor which burn deuterium, an isotope of Hydrogen which naturally occurred and can be easily obtained from water is one such alternative. It does not produce radioactive waste and reactors cannot meltdown. It increases the conversion efficiency due to high temperature and having lesser designing and constructing time for a plant. Study on the viability of this developing technology will help Sri Lanka to achieve her nuclear goal in future.

Nuclear plant produces electricity by converting water into steam which rotates a steam turbine coupled to a generator. Uranium fuels are consisting in Solid Ceramic Pellets. These pellets are packaged into long, vertical bundles. The fission or fusion reaction dissipates a huge amount of heat. Before use them in a reactor the ore has to undergone several processes. These are namely, mining and milling, conversion, enrichments and fabrication. All these steps involve with high technology and safety.

D. Comparison of Nuclear Energy with other Energy Sources

- Higher Capacity Factor - Capacity Factor of power plant is important aspect of for base load plant. This indicated the performance of the plant as well as efficiency of the plant. The net **capacity factor** of a **power plant** is the ratio of its actual output over a period of time, to its potential output if it were possible for it to operate at full nameplate **capacity** indefinitely. Further, it is important tool with respect to energy management aspect.

In a year, solar PV plant with 01 kW capacity will generate 2000 kWh while coal or nuclear power plant can produce approximately 7000 kWh/year. This is comparatively very high and having huge margin. The costs of battery pack which can be used for solar power system to store the power also high. Practically it will be difficult to store the solar energy and use them when sunlight is not available.

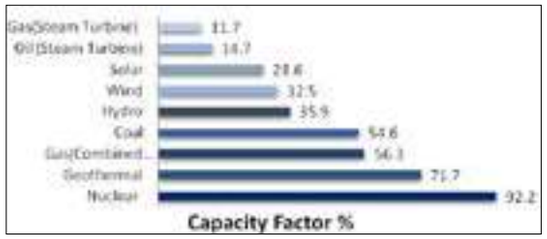

Figure 2. Capacity factors of Power Sources in USA- 2015 Source: US Energy Information Administration (EIA) and Nuclear Energy Institute

- *High Reliability* - Being an Island nation situated in Indian Ocean and very close to the Bay of Bengal the weather conditions are ever changing and unpredictable in Sri Lanka. Hence, the yield of Solar and Wind power also cannot be predicted or assured.
- *Higher Energy Efficiency* - Considering the fuel cost for generation a unit, the cost incurred for other forms of fuel and their quantities are very high. On based on average conversion rates available with Energy Information Administration, the fuel equivalent for electricity generated by 1000 MW reactor at 90 % capacity in one year which sufficient to provide 7.9 billion kWh are as follows (NEI, 2017).

Table 1. Fuel Equivalent for Electricity Generated by 1000 kWh NPP

	Fuel Type	Qty Required to provide 7.9 billion kWh	Unit yield
1	Oil	13.7 million barrel	1 barrel yield 576 kWh
2	Coal	3.4 million tons	1 ton yields 2,297 kWh
3	Natural Gas	65.8 billion cubic feet	100 cubic feet yields 12 kWh

Source: Nuclear Energy Institution, 2017

E. Why Sri Lanka Need Nuclear Power

Considering the disadvantages of fossil fuels and renewable sources, the necessity on NPP for Sri Lanka can be emphasized by examine the necessity of sustainable, reliable power source considering the requirement of Energy Diversity in a country. It is essential to have different type of energy sources for a country to depend the customers from price volatility. Price hike of crude oil was experienced by all over the world during year 2010 where the price of crude oil barrel increased more than $150 per barrel (EIA, USA 2016). The price volatility is common phenomenon for all the fuels. Proper and healthy energy diversity is required to nullify the affect or harm that can be happen to a country due to the rapid or sudden variation of any type of energy source. WNA emphasized the requirement of this mix finding optimal balance between need for human development and the protection of the natural environment. They target for 1000 GWe of new nuclear capacity to be added by 2050 by increasing nuclear power up to 25% of global electricity (WNPR, 2016) from the present share of 10% from world energy production.

A. At present Norechcholai has become the main power producer for the country. It was experienced sudden breakdowns more than 30 occasions as of May 2018 due to various reasons. Once it shutdown, it takes nearly two days to make the plant operational. Due to poor energy mix and limited standby energy sources in the country, power cut was mandate during this period.

F. Co-relation of Economy with Per Capita Electricity Consumption –

As per the research done by R Morimoto and C Hope in 2001 on the impact of electricity supply on economic growth of Sri Lanka, they have calculated that extra economic output of Rs. 88,000.00 to Rs. 137,000.00 for every 1 MWh increase in electricity supply in Sri Lanka in year 2001. Strong correlation between electricity use and economic development has been emphasized by many scholars(R Ferguson et al, 2000). The heavy drought experienced by Sri Lanka in 1996 coused to experienced severe power crisis and economic downfall. Same was experienced in year 2000 and 2001 with frequent power interruptions coused to reduce per capita electricity consumption from 296 kWh in 2000 to 292 kWh in year 2001. The GDP of Sri Lanka also decresed in 2001 up to 15.75 Billion US Dollars from 16.33 Bill$ which was in 2000.

G. Nuclear Trends in the World

As of 27th May 2018, 30 countries are operating 450 reactors with 393,836 MWe total net installed capacities.

Further, 59 new nuclear plants are under construction in 15 countries with two nuclear power reactors are in long term shut down. (IAEA, 2018). The total world electricity load share of nuclear power is 11 percent by 2014 (Nuclear Energy Institute, 2017). By 2016, France is the highest electricity load sharer in the world with 72.3 percent total electricity production of their country are fulfilling by nuclear power. Slovakia, Ukraine, Belgium and Hungary are obtaining more than 50 percent of their electricity using nuclear energy. At present 99 reactors with 34 BWRs and 65 PWRs are operating in USA. Another four plants (Summer 2 and 3 at South Carolina, Vogtle 3 & 4 at Georgia) are under construction. USA President Donald Trump placed nuclear first on America's energy agenda. Their main theme was the Global Energy Dominance of USA based on nuclear energy (NEI, 2017). US ***"Nuclear Energy Dominancy"*** may not restrict within the boundaries of the country. It has spread towards the abroad as well as.

H. Favorability on Nuclear Energy

NEI of USA is conducting 33 years long public opinion tracking program on public favorability to nuclear (NEI, 2017) and found that, the trend has gone up in favor of nuclear energy in long term from 1983 to October 2016 and stable in short term since 2010. According to the survey done by NEI they have found the followings;

- 84% nuclear should be important in future
- 82% agree that, US should take advantage of all low carbon energy sources including nuclear, hydro, and other renewable energy
- 95% agreed it's important to maintain diverse electricity sources. (NEI, 2017)

More importantly above research has found that the plant neighbors are more favorable to nuclear energy than general public. With compare to 27 % which strongly favor to have nuclear energy among the general public, 50% of people who are neighboring to nuclear plant are favor of nuclear energy.

I. Favorable initiatives in Sri Lanka

By establishing SLAEB and revising Atomic Energy Act in 2011 GoSL has shown their interest to develop nuclear technology in Sri Lanka. A pre-feasibility study has started in year 2009 (WNN, 2018) held up temporary due to the Fukushima accident in March 2011(Ranaweera, 2018). Sri Lankan government has included two 600 MWe NPPs by 2032 and 2035 to their Long Term Generation Expansion Plan 2015-2034. Since, the design and construction of nuclear plant takes approximately 10 to 15 years this can be considered as good initiatives.

Sri Lanka government has signed bi-lateral agreement with India in 2015 (WNN, 2015) and discussed with Russia in 2018 on sharing nuclear technology. Further the discussion in progress together with Japan, USA, and South Korea. The arrival of Deputy Director of Russian State Nuclear Cooperation Rosatom Mr. Nikolay Spassky in January 2018 signifies the interest of both countries to work jointly to realize the Sri Lankan dream of establishing NPP at least by 2031. (WNN, 2018).

The delegates from GoSL participated for the first time in the history to 9th session of AtomExpo International Forum in Moscow in June 2017. All giant in Nuclear Industry were participated to this forum and they express the aim of WNA to add 1000 GWe of new nuclear capacity by 2050 by catering 25% of world's electricity requirement. (WNN, 2017). The government has instructed all the higher educational institute to include subjects related to nuclear energy to the curriculum. Accordingly, necessary steps have been taken to amend the syllabuses of Advance Level and educate instructors, lecturers and school teachers on nuclear energy via student/ staff exchange programs with Japan, Korea, USA and UK (Ranaweera, 2018).

The sole authority of regulating the activities related to nuclear industry and radiological activities lies on Atomic Energy Authority in Sri Lanka. The DMC established Nuclear Disaster Early Warning System (NDEWS) in collaboration with AEASL, and has installed the online radiation Detectors of the system in the coastal belt of Sri Lanka from West to North facing to Tamil Nadu. These Detectors have been installed at Kalpitiya, Thalei Mannar, Delft, Kankasanthurai, Trincomalee, Colombo and Galle.

J. Nuclear Neighbors in Asia

The neighboring countries such as India (22 No.s), Pakistan (5), Vietnam (Planed 4, Research 1) and Bangladesh (01 plant to be commissioned in 2023) are equipped with nuclear energy technology. The World Nuclear Association has recognized that Sri Lanka has expressed interest on consider, plan and start nuclear power plant. However, as a country, Sri Lanka has not forwarded country paper on her enthusiasm over nuclear power prospect (World Nuclear Association, 2018). At present India's power generation capacity is approximately 330,260 MW and peak demand is 159,541 MW. It indicates that, India is having 75,000 – 100,000 MW of excessive power. Even with this power surplus, Indian Prime Minter has mentioned their intention to build up further two nuclear power plants at Kudankulam which is 276 km from Colombo. Even though Sri Lanka does not have nuclear plants within the country, the threat of nuclear industry related accidents are possible to whole country.

K. Causes Affected Negatively to Promote Nuclear Energy

The complexity of the technology and possible radiation threat are the main causes affected negatively to promote nuclear energy. The impact of nuclear bombs and nuclear accidents mainly at Fukushima in Japan has slow down the progress of implement nuclear development projects. As a result of this, Sri Lankan government had to abundant the preliminary feasibility study conduct on nuclear energy. Among the other reasons, use of Liquefied Natural Gas (LNG) as an alternative, Negative Cultural and Social factors, Security and environmental threats, negative attitudes of people, policy makers and market forces towards acquiring a new technology such as nuclear energy, site selection difficulties, Negative Environmental Factors, financial and technical barriers, negative Impact of Accidents to Nuclear Energy Sector in Sri Lanka mainly the Fukushima accident in Japan in 2011.

IV. CONCLUSION

The main concern of this report was drawn to the necessity of nuclear energy to Sri Lanka as an energy source and favorable conditions over nuclear technology. The ever rising energy demand in the country is evitable and energy saving methods without hindering the development process of the country will not be a viable solution for this crisis. The history has taught that, when power crisis arises in Sri Lanka, the development process also has been held up or downfallen. Per capita electrical consumption in Sri Lanka is low as 600 kWh and need to improve. It is important to maintain a sustainable and reliable generation mix in a country. Two main factors to be considered while studying the viability of a source of energy are the *'behavior of the demand'* and other *'alternative options available.'* The behavior of Sri Lankan energy sector has emphasized the necessity of sustainable base load taker to the system. All most all the power sources are having advantages as well as disadvantages. Among the other alternatives, nuclear energy is a competitive yet controversial option.

Higher capacity factor, higher plant efficiency, lower unit cost and limited greenhouse gas emission are the main advantages of nuclear energy. New trends in nuclear technology such as plant neighbor's favorability over nuclear plants, increment of plant capacity, increment of security measures, positive concern of investors such Microsoft owner Bill Gates on small scale plants and political backing of political leaders such as Donald Trump and Vladmir Putin are positively impact to promoting nuclear technology.

Technical barriers such as lack resource personnel and skilled engineers and technicians along with financial barriers have negatively impact on promoting and selecting nuclear energy. However, these barriers can be overcome with the assistance of International bodies and foreign investors. Myths and negative attitudes of peoples, lack of political willingness and commitments, and manage the opposition of general public over introducing of nuclear power will be the major issue in Sri Lankan context. How to handle the public opinion will play a key role in this process and educate the general public would be the only option for that. Since, the lead time is very high and requirement of NPP is essential as per the existing situation and future forecasting, Sri Lanka need to accelerate the process early as possible to realize the dream of an indispensable requirement of NPP by 2030.

V. ACKNOWLEDGEMENT

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PROCEEDINGS

PROCEEDINGS

BIOMEDICAL ENGINEERING

SESSION SUMMERY

The session was chaired by Dr. Sarath Guanapala, the Director of the Center for Infrared Photodetectors at the Jet Propulsion Laboratory, California Institute of Technology Pasadena, USA. He is also a Senior Research Scientist, a Principle Member of Engineering Staff, Technology Community Leader, and the Manager of the Infrared Photonics Technology Group at Jet Propulsion Laboratory, California Institute of Technology Pasadena, USA.

The technical session speakers were SR Hewarajage, Mr. MTM Rihan, Ms. MKS Mendis, Dr. Shantha Gamage, Ms. PHK Gamage and Mr. AS Warnakulasuriya.

SR Hewarajage is from Sri Lanka Army Signal Corp and is presently reading his undergraduate engineering degree at the General Sir John Kotelawala Defence University. The title of his speech was 'Smart Device for Close-Monitoring in Elder Care'. The paper is on designing a wearable system for the elderly population to remotely monitor physiological parameters, environmental parameters and for fall prevention.

Mr. MTM Rihan is currently serving as an Engineer in Regional Planning & Optimization, Technology Strategy, Planning & Development at Dialog Axiata PLC. The title of his speech was 'Eigenfaces Based Face Recognition Device for Visually Impaired Persons'. The paper reports the design of a low-cost wearable face recognition system for visually impaired individuals.

Ms. MKS Mendis was a former undergraduate engineering student at the General Sir John Kotelawala Defence University is currently serving as a demonstrator at the Department of Electrical, Electronic and Telecommunication Engineering at the General Sir John Kotelawala Defence University. The title of her speech was 'Comparison on Virus Dynamics Models with Different Functional Responses including Time Delays'. This paper compares different effects on the reproductive rate in four mathematical models modelling virus dynamics using different functional responses incorporating time delays.

Dr. Shantha Gamage is currently serving as a Senior Lecturer of the Department of Physics, University of Sri Jayewardenepura. The title of his speech was 'A computer-based analysis of acoustic properties of Sri Lankan Pirith chants using voiced to unvoiced ratio and probability distribution functions'. The paper is a quantitative approach to analyze the acoustic properties of Pirith chants and states that there is a strong contribution of vocal folds with high vowel pronouncing probability in the analyzed Pirith chants.

Ms. PHK Gamage is reading for a degree in Master of philosophy at the Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, University of Ruhuna. She is currently serving as a Probationary Lecturer in mathematics at Sri Lanka Technological Campus, Padukka and as a visiting lecturer at Open University of Sri Lanka. The title of her speech was 'A unit cell approach to reduce computational time of meshfree based plant tissue models'. The paper is a method that introduces a unit cell to represent several real cells, which can be used as a building block to model plant tissues using meshfree based modeling techniques when low Reynolds number fluid flow conditions is applicable. The technique is aimed at decreasing the computational time required for the simulation.

Mr. AS Warnakulasuriya was a former undergraduate engineering student at the General Sir John Kotelawala Defence University is currently serving as a research assistant continuing his postgraduate studies towards a degree of master of philosophy at the Department of Electronic and Telecommunication Engineering, University of Moratuwa. The title of his speech was 'Braille Blood Pressure Interpreter for Home Blood Pressure Measurement for Visually Challenged Individuals'. The paper is a USB compatible braille interface that can be plugged into a commercially available blood pressure meter for a visually challenged individual to self-measure blood pressure without sighted assistance. The proof of concept reported shows the potential of the system to retrieve and use blood pressure information from a commercially available blood pressure monitor.

SMART DEVICE FOR CLOSE-MONITORING IN ELDER CARE

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Abstract - Elder care is an area in modern society where a series of issues are encountered. There is a feasibility to find solutions pertaining to the issues of elder care by using wearable sensors and telemonitoring devices. This paper will discuss monitoring of critical diagnosis parameters of the elders who are bedridden using Internet of Things (IOT). A survey was conducted to identify the environmental factors which affect the elder care service and the management of sudden accident and making alarm under conditions of emergency. It was identified from the survey that blood pressure, body temperature, pulse rate, heart rhythm and Electro Cardio Graph (ECG) are highly important for diagnosis procedure by doctors. In the same way this parameter can be obtained via telemedicine even though the doctor is a long distance away from the patient. Further, elder care service providers can monitor many elders from a long distance by checking critical environmental factors such temperature, humidity and fall detection by using IOT. All these requirements can be fulfilled by confining all sensors in a wearable jacket.

Keywords - eldercare, IOT, wearable sensors

I. INTRODUCTION

With the rapid development of medical science, desire to live and living restorative standard of human has been expanded in present day society. The dominant part of individuals in the last phase of their life have been living longer with various and frequently complex wellbeing conditions (Han, Ma and Oyama, 2016). Like other nations, elder care in Sri Lanka has been met with numerous basic issues. This paper will talk about the essential issues existing in the elder care and handle the issue with ease using technology available today. Through study it was recognized that IOT and wearable sensors can be used to answer the issues related to elder care. Before presenting the outline plan, this paper will talk about gathering information and essential surveys led by the research group. In the last stage, square outlines, the design of the device and specification will be presented.

II. OUTLINE OF DEPLOYMENT

A. Identification of the required parameters

With the help of wearable sensors network and wireless communication technology, it's conceivable to transmit imperative signs, for example, circulatory strain, beat, body temperature, ECG parameters, and fall recognition cautions starting with one area then onto the next long goal. Further, ecological parameters, for example, temperature, mugginess and gas spillages additionally can be transmitted in same way. These two innovations have been opened a field to new ideas in the restorative science such telemedicine telemonitoring. Before examining the best possible outline framework, it is required to recognize the issues and fundamental parameters for telemonitoring. Along these lines, following advances were brought down amid the underlying phase of the exploration.

Step 1: Identify the Problem

We followed the following two data analysis methods to identify the problems. Those were,

a) Collecting the primary data

b) Conduct the interview with resource personnel.

Some elder care homes (Kottawa, Pannipitiya and Homagama) were visited, conducted interviews with professional expertise in the field. Further, conducted an interview with Dean, Faculty of Medicine, General Sir John Kotelawala Defence University, Ratmalana (KDU); this lead to develop a conceptual paper through assistance of the consultants who are professionals in that field.

Step 2: Literature search and review

Research team went through websites, books and papers that were published by researchers from other parts of the world regarding the Wearable Sensor Network (WSN) technology. It encouraged to work together the recognize issue. After distinguishing issues with the realities found amid the writing review, it was discovered that there is a probability to give an answer for the issues happening in the elder care.

Step 3: Design requirement analysis

Having analysed the primary data and factors collected through the interviews of professional expertise, following issues have been identified by the research team which pertains in the elder care service.

1 Requirement of continuous health monitoring for elders.

2 Elders are highly vulnerable to sudden accidents in the homes.

3 Elders need more nursing care which is comparatively a high cost.

4 Elders always require comfortable and safety surrounding which is difficult to make possible always.

5 Elders require daily reminders from an assistant to fulfil their daily needs.

6 To ensure the mental relaxation and high standard of mental health conditions have been met with lot of difficulties due to their confinement to beds.

7 Elders have always been lacking in communication with others due to loneliness.

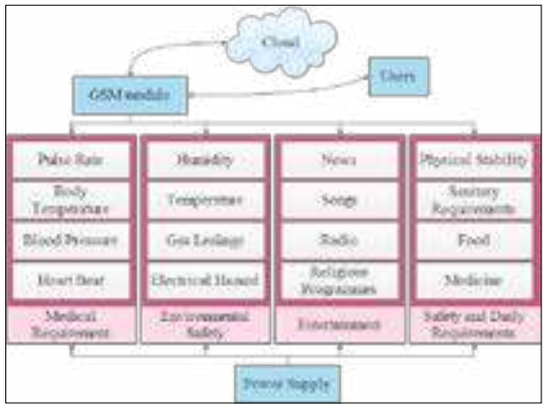

Figure 1. Basic circuit block diagram

B. Design of the monitoring systems

Vital parameters were recognized and specified in the subsystems. Further, it is conceivable to outline a wearable jacket that can be embedded with sensors, control supply and flag handsets. Having met with medical officer, circulatory strain, body temperature, heart beat rate, ECG and Heart Rhythm were chosen to be identified. Further it was necessary to install falling alert, natural moistness and gas spillage recognitions. Each subsystem can be controlled by one power supply through cell phone. At that point the flag handset likewise implanted in the jacket and the flag can be transmitted to the handling interface to change over constant information. Created programming and applications will be utilized by specialists, senior care specialist co-ops another required client for telemonitoring senior care benefit.

C. System components

Eldercare monitoring jacket consists with three subsystems as mentioned in Figure 2. Apart from those, it comprises a unique pneumatic pump which controls movement of the sensor at predefined interims. These predefined interims can be modified by the prerequisite of the clients. The general arrangement incorporates with the cloud server to have database to assist in diagnosis. The pneumatical unit comforts the elder while discharging the sensor during non-checking time. The aggregate schematic chart of the jacket is shown in Figure 2.

1. Health care monitoring system

The monitoring system consists sensors to monitor the blood glucose level, blood pressure, body temperature, pulse rate, heart rhythm and for obtaining ECG. Signals from sensors are required to be amplified and fed to the processing interface. Then processed signal can be provided to the user.

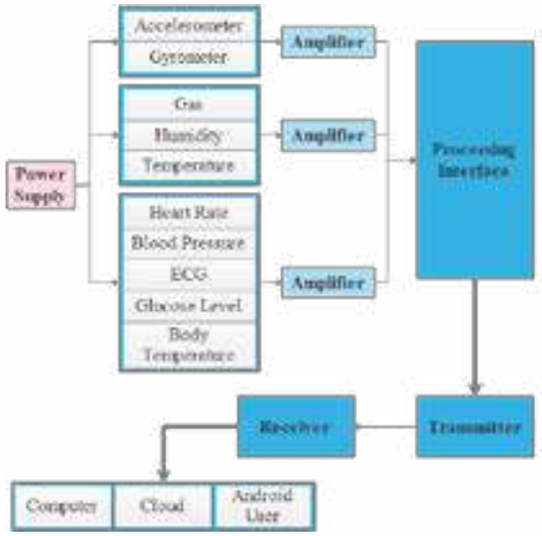

Figure 2. Narrowed circuit block diagram

2. Environment and safety monitoring system

This consists two sensors that monitor the temperature and humidity in the environment and two sensors to monitor any gas leakages. For this ultrasonic sensor and gas detecting sensors are used.

3. Fall emergency alarm system

Elders have the vulnerability of falling. An emergency alarm is made to reduce the high risk of fallen elder. Gyro sensor and accelerometer are used to make emergency alarm.

4. Processing interface

This functions as a converter of electrical signal to a meaningful data. Signals from the sensors are fed to the processing interface. Then this data is fed to the transceiver for telemonitoring. That processing function can be performed by the mobile app. For this, mobile app (software) is designed.

5. User interface (Software)

This consists with software which is developed using Android, JAVA. The users who monitor the system will be able to gather the required information and receive emergency alarms.

D. Overall architecture

The overall architecture of the proposed system is as follows and it consists with basically four connected units. Layer 1 consisted with sensors and Layer 2 consists with processing interface. Then Layer 3 consisted with the connecting devices and the communication link. The final layer that is Layer 4 consists with all the applications and software which provides required information to the users. Further, this layer provides access to cloud server for maintaining database in the future reference

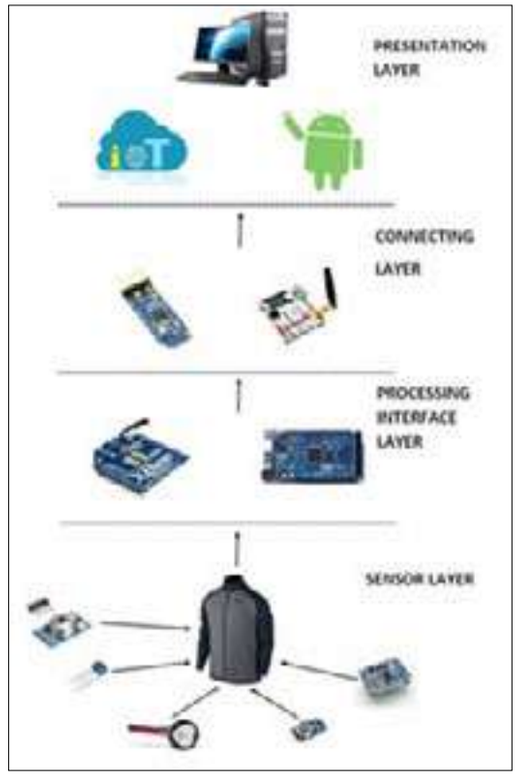

Figure 3. Architectural design for the proposed device

III. PROBLEMS

A. Sensor reliability

It's obvious that, any electronic segment or gadgets are at risk to breakdown or make inconveniences while working. At that point all sensors in the jacket additionally are helpless for any breakdown or risk. At that point, it causes to stop all the observing

frameworks. This can be overwhelmed by utilizing a few sensors for repetition.

B. Users compatibility

Since the system has embedded with four sub monitoring system it required comparably high-power consumption. Then it requires comparably battery with high capacity. Then it causes to increase the weight of the jacket which make uncomfortable to the user. Therefore, sharp designing techniques required to identify the parameters of the battery pack.

C. Security Aspect

The signal transmitting strength of the transmitter will be kept at the low level. Then the unauthorised access can be avoided, and the power consumption also will be at low level. Further, encrypted and decrypted data flowing will be ensured from transmitter end to the receiver end to ensure the security of the data and information.

IV. CONCLUSION

In this paper, it was discussed about some critical issues and problematic area in the elder care service providing in Sri Lanka. Further, it has given a few answers for distinguished most basic issues with the unique direction of restorative specialists and expert senior care faculty. Framework is required to experience with numerous research centre analyses and modern investigations. With aftereffect of that trial, there will be a chance to recognize most troublesome planning issues and it will be useful to discover answer for conquer this. The wearable sensor organizes innovation and telemedicine ideas are quickly creating step by step. With this improvement, this framework likewise can be created in numerous viewpoints and it can be acquainted with the market as a top notch mechanical item.

ACKNOWLEDGEMENT

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EIGENFACES BASED FACE RECOGNITION DEVICE FOR VISUALLY IMPAIRED PERSONS

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Abstract - This paper proposes to develop an embedded system based instrument for visually impaired, it is a wearable device in the form of badge holder of the patent which is designed using Raspberry Pi in addition with visual and hearing sensor. This system works to detect the human faces. With this help user can identify the person in front of the vision sensor. Open CV computer vision and machine learning libraries were used to simulate a system that aids the blind person to recognize his family and friend's facial images that are stored in a database, and if a match is found in the database, the system will announce the name of the person via sound sensor to

the blind person. Further for this system modelling we used various algorithms. Viola–Jones object detection framework as known as Haar-features for face detection, Eigenfaces for face recognition and python text to speech library used for audio output. The simulation considered the recognition of a static facial image (photo) and a live facial image. This system is beneficial in terms of its portability, low cost, low power consumption.

Keywords - visually impaired, Computer vision, Haar features, Eigenfaces, Raspberry pi, Open CV

I. INTRODUCTION

It is estimated that 285 million people globally are visually impaired with 39 million blind and 246 million with low vision [3]. Visually impaired persons adapt to life by using various assistive methods such as the white cane, sensory substitution and electronic devices. Electronic assistive systems use sensors or other methods to avail visually impaired users. They ordinarily focus on providing navigation in indoor, outdoor or both environments. Navigation is usually given through the frameworks which utilize some form of computer vision to recognize obstructions, paths and perform location determination. These frameworks frequently use Global Positioning System (GPS) gadgets and web-based location services while giving route in outdoor environments because of their high precision [4].

While there are several systems for availing the visually impaired people in navigation, there are couple of frameworks which enable them to locate and identify specific objects. Visually impaired persons can be assisted in object detection and recognition using electronic gadgets. These gadgets must be small enough to be easily portable and have the necessary hardware requirements of performing object detection and recognition.

At the point when object recognition is applied to faces, it can be utilized for identification. Face recognition is an appropriate technique for helping visually impaired people in identifying individuals compared to other technique, such as voice recognition [16]. However, this may be difficult or unfeasible in some circumstances Face recognition is the essential means by which people distinguish each other.

This project proposes to develop a wearable device which allows blind and low vision people to interact with society. Using face detection and recognition technology, the device will identify classmates, relatives and colleagues by giving some identity or name for new people. If the same

person appears in front of the user then the name of a person is given as message on earphone.

The remainder of this paper is organized as follows, section II and section III respecting describe system design and working principle. The system analysis and results are explained in section IV. Finally, conclusions are given in section VI.

II. SYSTEM DESIGN

Figure 1 shows the architecture of face recognition system for a visually impaired person. The system detects the face of the person approaching the blind person by a camera. The detected face will be processed by one of the face recognition algorithm Eigenface to find if it belongs to the database of friends and family or not. After the recognition process the system will announce to the blind person the name of that person

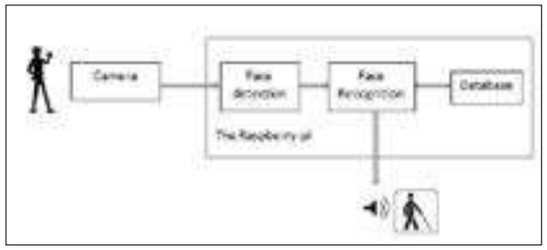

Figure 1. The architecture of face recognition system for a visually impaired person

The proposed face recognition system is designed to capitalize on the portability of mobile devices and provide a straightforward user interface that makes utilization of the system facile for the visually impaired. Key design requisites for a portable system include minuscule gadget size and low weight.

To achieve this goal, a raspberry pi, pi-camera and earphone are habituated to compose a compact and lightweight system. To give an advantageous software

experience to the compact framework, a clear application in an ideally recognizable working framework is required. The open source (Linux) based OS enables an easy to understand application to be produced using worked in accessibility features.

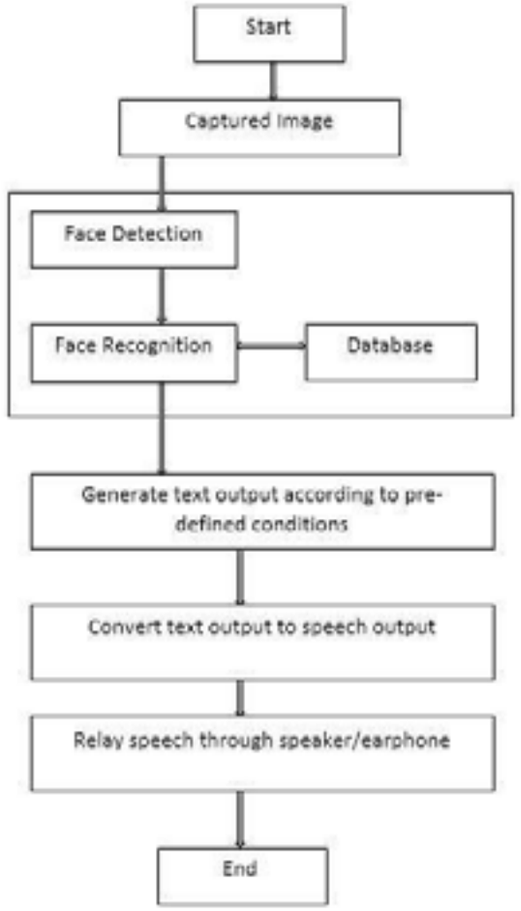

Figure 2. The proposed framework for face recognition system for a visually impaired person

III. WORKING PRINCIPLE

The process of the face recognition is divided into two parts; the training process and the testing process.

The training process starts by preparing the facial training database. This process converts the facial images in the database into matrixes [1]. The face vector will be then computed and the covariance matrix and the eigenvectors will be calculated from it. The eigenfaces with low eigenvalues will then be omitted [2]. From the remaining eigenfaces matrix, the feature weight of each will be calculated and stored as shown in Figure 3

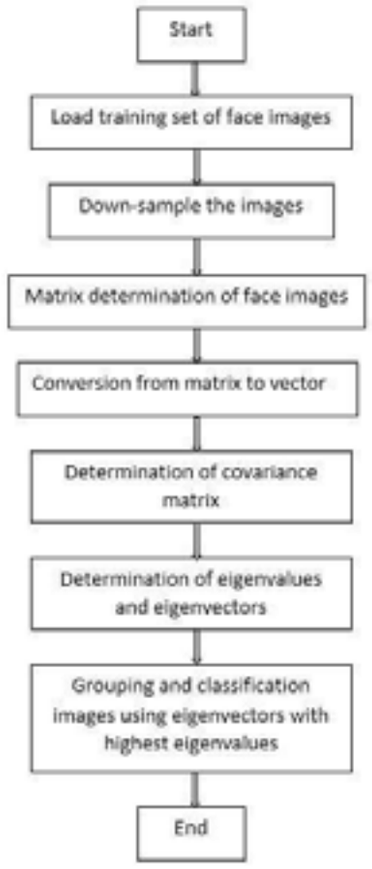

Figure 3. The Eigenface training process

In the testing process an image is captured and inserted into the system to find a match from the database. The eigenface, eigenvalues, and feature vectors of that face are then calculated. The Euclidean distance will then be calculated and the minimum Euclidean distance value will be found from it. The minimum Euclidean distance represents the matching value. The minimum Euclidean value together with a threshold will determine if the image is in the database or not [6] [7].

Developing a computational model of a face recognition is quite arduous, because faces are intricate, multi-dimensional and significant visual stimulant. In mathematical terms, we wish to find the principal components of the distribution of faces, or the eigenvectors of the covariance matrix of the set of face images. These eigenvectors can be thought of as a set of features which

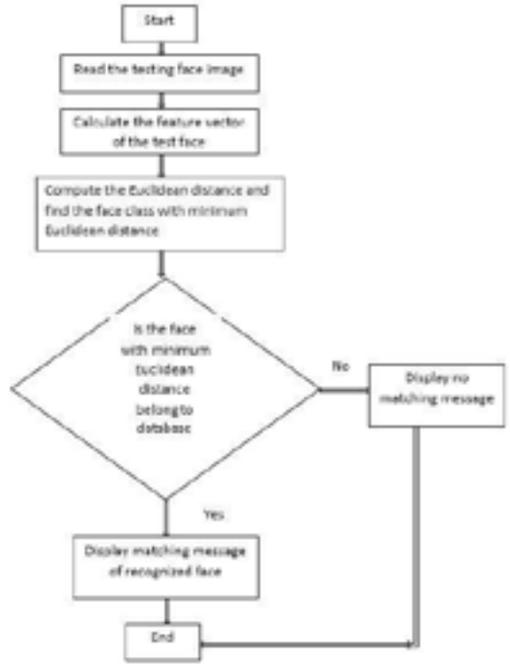

Figure 4. The Eigenface testing process

together characterize the variation between face images. Each image location contributes more or less to each eigenvector, so that we can display the eigenvector as a sort of ghostly face which we call an eigenface [5] [6].

The basic idea of eigenfaces is that all face images are similar in all configurations and they can be described in its basic face images. Based on this idea, the eigenfaces procedures are as follows [1] [2] [5] [6] [15]:

a) We assume the training sets of images are Γ1, Γ 2... Γ m with each image is I (x, y). Convert each image into set of vectors and new full-size matrix (m×p), where m is the number of training images and p is x × y.

b) Find the mean face by:

$$\Psi = \frac{1}{m}\sum_{i=1}^{m}\Gamma_i$$

c) Calculated the mean-subtracted face:

$$\Phi i = \Gamma i - \Psi, \quad i = 1, 2, \ldots, m$$

$A = [\Phi 1, \Phi 2, \ldots, \Phi m]$ is the mean-subtracted matrix vector with its size Amp.

d) By implementing the matrix transformations, the

Vectors matrix is reduced by:

$C_{mn} = A_{mp} \times A^{T}_{pm}$

Where C is the covariance matrix and T is transpose matrix.

e) Find the eigenvectors, Vmm and eigenvalues, λm from the C matrix using Jacobi method and ordered the eigenvectors by highest eigenvalues. Jacobi's method is chosen because its accuracy and reliability than other method.

f) Apply the eigenvectors matrix, Vmm and adjusted matrix, Φm. These vectors determine linear combinations of the training set images to form the eigenfaces, Uk by:

$$U_k = \sum_{n=1}^{m} \Phi_n V_{kn}, \quad k = 1, 2 \ldots, m$$

Instead of using m eigenfaces, m' < m which we consider the image provided for training are more than 1 for each individuals or class. m' is the total class used.

g) Based on the eigenfaces, each image has its face vector by:

$$W_k = U_k^T (\Gamma - \Psi), \quad k = 1, 2, \ldots, m'$$

and mean subtracted vector of size (px1) and eigenfaces is Upm'. The weights form a feature vector:

$$\Omega^T = [w_1 \; w_2, \ldots, w_{m'}]$$

h) A face can be reconstructed by using its feature, Ω^T vector and previous eigenfaces, U_{m}` as:

$$\Gamma' = \Psi + \Phi_f$$

Where

$$\Phi_f = \sum_{i=1}^{m'} w_i U_i$$

IV. SYSTEM ANALYSIS AND RESULT

A coloured face image (see figure 5) is changed over to grey scale image (see figure 6) as grey scale images are more facile for applying computational techniques in image processing

Figure 5. Captured coloured face image

A grey scale face image is scaled for a particular pixel size as 250x250 because many input images can be of different size whenever we take an input face for recognition [11].

Figure 6. Grey scale face image

With a specific end goal to make database, the viola jones algorithm is utilized to distinguish the face, which is captured image by means of web camera or pi-camera. For database distinctive arrangement of conditions must be kept up, for example, different expressions. Pivoted pictures in left and right course and diverse light conditions are additionally considered while influencing the preparation to training set. Measure varieties in an input face image can also change the output therefore input images by fluctuating their size are additionally taken for recognition.

A test image for recognition is tested by comparing to the stored data set. The eigenvectors corresponding to the covariance matrix define the Eigenface (see figure 8) which has a ghostly face like appearance and a match is found if new face is close to these images

In this study for the testing purpose, two database were designed for both static (The database of faces published by research AT&T laboratories Cambridge) and live facial

Figure 7. 4x3 Training set with different angle and expression

Figure 8. Eigenface

images. Figure (9) shows the static facial image database and figure (10) shows the live facial image database captured by pi-camera.

Figure 9. Static image database (The database of faces published by research AT&T laboratories Cambridge)

Figure 9. Live image database

The performance of the both live and static images were tested. A facial image was inserted to the system, to find a match from the database. It can be either live image or static image. Furthermore some simulated test facial images were initially used, they were consist of white, light grey, dark grey shaded and black backgrounds [16]. The test results obtained are shown in the table (1).

Table 1. Test result

Image type	Percentage predicted
Static images	64%
Live images	39%

V. CONCLUSIONS

This project helps visually impaired and blind individuals to identify persons in front of them and makes them independent to live in society. This device works in two modes of operations: Face Detection and Face Recognition. The device that includes face detection, regularized methods for training and testing of individuals in an unconstrained environment. While our device is functional, useful, and robust, there are still some improvements that could be made in the future. In real time atmosphere have more than one person. If all the faces are given same preference then the blind person finds it difficult to identify those faces, so each person has to be assigned some priority for easy recognition. Therefore, the face in front and close to the blind person is very essential rather than the other faces far away from the blind person.

In this project, one of the most requested features of this device was reduced size. With the current state of mobile computing, processors are not fast enough to perform the algorithms utilized by our device in real time. But in the future, several advances could be made to enable this. As technology progresses and mobile processors become more powerful, this could potentially be driven by a smaller device. This device will allow the visually impaired to greatly improve their social interactions with both sighted and blind people. This project puts the visually impaired one step closer towards equality with sighted people in conversation. New technologies will allow people with disabilities to improve their standard of living and put them closer to parity with people without disabilities. Here science, technology, and society intersect providing a better life for the visually impaired people.

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COMPARISON ON VIRUS DYNAMICS MODELS WITH DIFFERENT FUNCTIONAL RESPONSES INCLUDING TIME DELAYS

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Abstract – A virus can be identified as an infectious mediator consisting a core of genetic material and an envelope of protein. The behavior of viruses can be modelled through mathematics, and those viral dynamics can consist a class of differential equations which describe the effect of the virus on uninfected and infected cells, in a body compartment over a period of time. Even though many mathematical models have been proposed for various viral infections, a proper assessment on them has not been done throughout the literature. In this paper, dynamics models with bilinear, Michaelis

Menten, saturated and Beddignton-DeAngelis functional responses have been compared, with respective to the time delays and the basic reproductive rate (0). For the considered models, the populations of uninfected cells, infected cells and free virus were calculated to find solutions for respective infection free and infected equilibriums. By carrying out numerical simulations through literature reported parameter values, the effect of intracellular and maturation time delays on the corresponding reproductive rate of each model was analyzed. Since a reproductive rate, less than unity represents an infection free host, the primary target of the treatments for viral infections is to decrease

the reproductive rate as possible. The graphical representation showed that the model with Beddignton-DeAngelis functional response, possessed a greater capacity in reducing 0, with the effect of time delays. This qualitative analysis on models will have the capability to give the drug producers more significant guidance in recognizing the most appropriate viral dynamics model.

Keywords - viral dynamics, delay differential, reproductive rate

I. INTRODUCTION

A virus can be described as a micro parasite, consisting a core of genetic material, either RNA or DNA and a surrounding envelope of protein, lipid and glycoprotein. It possesses the capability to infect any form of life, including animals, plants and microorganisms (Koonin at el. 2006). Viruses are incompetent of multiplying within them, thus they acquire the assistance of a host cell to be spread. Although certain viruses hold some important functions, substantial amount of viruses including the human immunodeficiency virus (HIV), common cold, influenza, chickenpox, hepatitis A/B/C and human papilloma virus (HPV) are considered to be pathogenic (Zahler 1979).

With numerous researchers finding a way to cure these viruses, virus dynamical modelling has also given a considerable contribution in epidemiology. Even though many mathematical models have been proposed for various viral infections, a proper assessment on them has not been done throughout the literature. Viral dynamics can consist a collection of mathematical models which describe the behavior in the populations of targeted uninfected cells, infected cells and the virus over a period of time. Thus a three dimensional model has been used (Bonhoeffer et al. 1997; Nowak & May 2000) to describe the phenomena as on model (1).

$$\dot{u}(t) = \alpha - \beta u(t)v(t) - ju(t);$$
$$\dot{r}(t) = \beta u(t)v(t) - kr(t);$$
$$\dot{v}(t) = mr(t) - lv(t). \qquad \text{Model (1)}$$

Considering a body compartment, the concentrations of uninfected target cells, infected cells with the aptitude of

producing new virus and free virus at time are represented by , and respectively. The constant (> 0) is the rate which uninfected target cells are recruited to the compartment. (≥ 0) is the constant characterizing the infection of cells. The infected cells produce (> 0) number of free virus in during their life. The constants (> 0), (> 0) and (> 0) denotes the death rates of uninfected cells, infected cells and clearance rate of virus from the system.

In the recent times, there has been an extensive effort in the mathematical modelling of virus dynamics, mainly encouraged by the model (1). These models have been used to study HIV (Li & Ma 2007; Wang et al. 2010; Perelson & Ribeiro 2013; Pradeep & Ma 2014; Pradeep et al. 2015), hepatitis B virus (Ciupe et al. 2007) and hepatitis C virus (Neumann et al. 1998; Chatterjee et al. 2013) among other infections.

In model (1), it has not been considered any of the time delays which occur in the viral progression biologically. In accordance to do the comparison of more realistic virus dynamics models, time delays have been incorporated to compare models with delay differential equations.

The intracellular delay, indicating the time between the viral entry and the new virus production was initially proposed by (Herz et al. 1996) and numerous models representing the intracellular delay were developed later (Li & Ma 2007; Huang et al. 2010; Huang et al. 2011; Pradeep et al. 2015; Pradeep & Ma 2014).

Maturation time delay denotes the time period which the virus acquired after its rise, to develop the ability to infect the target cells. Mathematical models representing the maturation time delay were also developed in the recent years (Huang et al. 2010; Pradeep et al. 2015).

II. METHODOLOGY

In this paper, the followings models, with different functional responses were compared, with respective to the time delays and the reproductive rate (0) which denotes the average number of infected cells produced by one infected cell over the course of its infectious period (Fraser et al. 2009).

In the following models, ≥ 0 is the intracellular time delay while − accounts for the probability of surviving from time − to, ≥ 0 is the maturation time delay while − accounts for the probability of surviving from time − to and the parameters and are positive constants.

1 Bilinear functional response/ Holling type I functional response (Nowak et al. 1997; Nowak & May 2000; Herz et al. 1996; Perelson et al. 1996)

$$\dot{u}(t) = \alpha - \beta u(t)v(t) - ju(t);$$
$$\dot{r}(t) = e^{-k\tau}\beta u(t-\tau)v(t-\tau) - kr(t);$$
$$\dot{v}(t) = e^{-l\sigma}mr(t-\sigma) - lv(t).$$

2. Michaelis - Menten functional response/ Holling Type II functional response

$$\dot{u}(t) = \alpha - \frac{\beta u(t)v(t)}{1+au(t)} - ju(t);$$
$$\dot{r}(t) = e^{-k\tau}\frac{\beta u(t-\tau)v(t-\tau)}{1+au(t-\tau)} - kr(t);$$
$$\dot{v}(t) = e^{-l\sigma}mr(t-\sigma) - lv(t).$$

Model (3)

3. Saturated incidence rate (Li & Ma 2007)

$$\dot{u}(t) = \alpha - \frac{\beta u(t)v(t)}{1+bv(t)} - ju(t);$$
$$\dot{r}(t) = e^{-k\tau}\frac{\beta u(t-\tau)v(t-\tau)}{1+bv(t-\tau)} - kr(t);$$
$$\dot{v}(t) = e^{-l\sigma}mr(t-\sigma) - lv(t).$$

Model (4)

4. Beddignton-DeAngelis infection rate (Wang et al. 2010; Huang et al. 2011; Pradeep & Ma 2014; Huang et al. 2009)

$$\dot{u}(t) = \alpha - \frac{\beta u(t)v(t)}{1+au(t)+bv(t)} - ju(t);$$
$$\dot{r}(t) = e^{-k\tau}\frac{\beta u(t-\tau)v(t-\tau)}{1+au(t-\tau)+bv(t-\tau)} - kr(t);$$
$$\dot{v}(t) = e^{-l\sigma}mr(t-\sigma) - lv(t)$$

Model (5)

Table 1 - Solutions of Infected Equilibria for the above mentioned Models with time delays

Model	R_0	u^*	r^*	v^*
2	$\frac{\alpha\beta m e^{-k\tau-l\sigma}}{jkl}$	$\frac{\alpha}{jR_0}$	$\frac{jle^{l\sigma}}{\beta m}(R_0-1)$	$\frac{j}{\beta}(R_0-1)$
3	$\frac{\alpha(\beta m e^{-k\tau-l\sigma}-akl)}{jkl}$	$\frac{\alpha}{jR_0}$	$\frac{\alpha e^{l\sigma}}{k}(1-\frac{1}{R_0})$	$\frac{jm e^{-k\tau-l\sigma}}{\beta m e^{-k\tau-l\sigma}-akl}(R_0-1)$
4	$\frac{\alpha\beta m e^{-k\tau-l\sigma}}{jkl}$	$\frac{\alpha}{jR_0}(1+bv^*)$	$\frac{jl(R_0-1)}{me^{-l\sigma}(\beta+jb)}$	$\frac{j}{\beta+jb}(R_0-1)$
5	$\frac{\alpha m e^{-k\tau-l\sigma}(\beta m e^{-k\tau-l\sigma}-akl)}{jkl}$	$\frac{lk(1+bv^*)}{j\beta m e^{-k\tau-l\sigma}-akl}$	$\frac{uv^*}{me^{-l\sigma}}$	$\frac{j}{\beta m e^{-k\tau-l\sigma}-akl+jb}(R_0-1)$

III. RESULTS AND DISCUSSION

For all the models, numerical simulations were done using literature reported parameter values, and the following graphs were obtained.

First, the intracellular time delay ( ) was kept fixed at the value of 15, and the maturation time delay ( ) was varied ranging from 0-20, and the deviations of the reproductive rate (0) was attained.

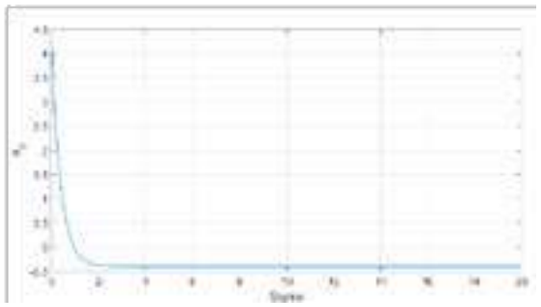

Figure 2 - versus σ for Model 3 and 4

For model (2), 0 deviates from 0-5, for model (3) and model (4) 0 deviates from 0-4.5, and for the model (5), 0 deviates from 0-1.8. These graphical representations verify the fact that model (5) has a greater ability and potential in reducing 0, by reducing the maturation time delay ( ) compared to other models.

Then, the maturation time delay ( ) was kept fixed at the value of 2, and the maturation time delay ( ) was varied ranging from 0-20, and the deviations of the reproductive rate (0) was attained

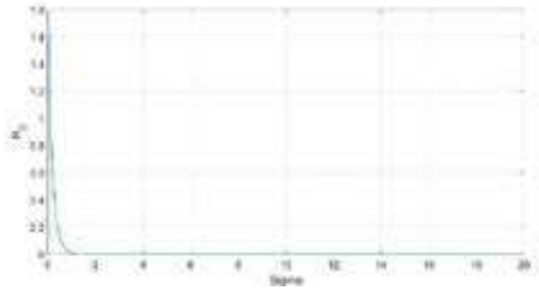

Figure 3 - 0 versus σ for Model 5

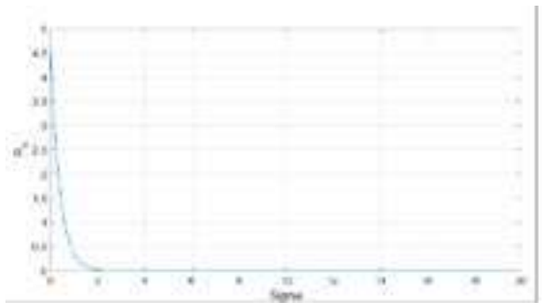

Figure 1 - 0 versus σ for Model 2

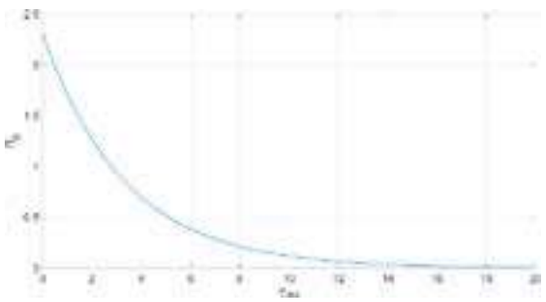

Figure 4 -R_0 versus τ for model 2

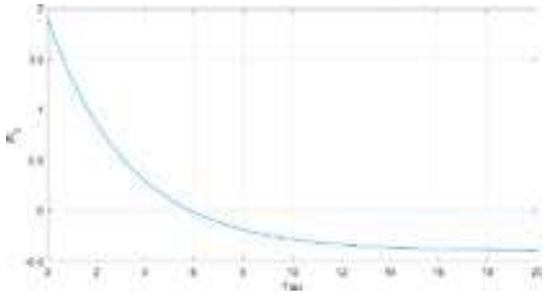

Figure 5 - R_0 versus τ for model 3 and 4

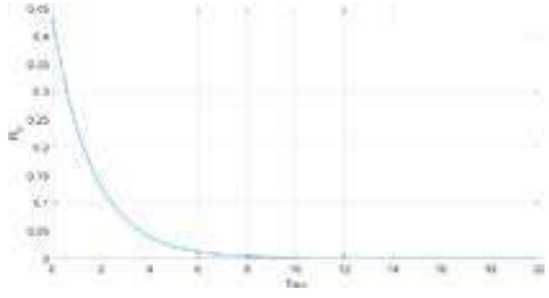

Figure 6 - R_0 versus τ for model 5

IV. CONCLUSION

0 is the limiting factor in determining if the disease has been spread or died out within a host. Thus the reproductive rate should be less than unity in order to recognize as the host is free of infection. Therefore, as to reduce 0, various parameters should be increased or decreased. But, looking at the scenario biologically, it has been identified that the parameters which could be changed by the influence of humans are the intracellular and the maturation time delays. It is certain, from the gained results that the model with Beddignton-DeAngelis functional response carries a greater capacity in reducing 0, with the effect of time delays. Consequently, this comparison can help the drug producers in recognizing the most appropriate viral dynamics model for their identification purposes of parameters more significantly.

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A COMPUTER-BASED ANALYSIS OF ACOUSTIC PROPERTIES OF SRI LANKAN PIRITH CHANTS USING VOICED TO UNVOICED RATIO AND PROBABILITY DISTRIBUTION FUNCTIONS

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Abstract - Pirith is a special type of chanting; believed to be a protective doctrine preached by the Load Buddha in Pali language. Generally, a voice signal consists of the fundamental frequency, F_0 and a series of harmonic frequencies called as formants, F_n. As reported by several other studies, characteristic formant frequency distributions are identified in chanting, contrast to normal speaking. This work is dedicated to developing a phonetic picture on Pirith chants investigating probability distribution of formants and quantify voiced to unvoiced ratio utilizing computer-aided tools. In this study, 25 samples of each Rathana, Karaneeya Metta and Angulimala Suttas recited by male monk chanters were recorded using high precision microphone array and then subjected to splitting of smaller voiced segments of frame length 10*ms* sampling at a rate of 44.1 *kHz*. In the computational speech model, a pre-emphasis filter is applied to the sampled time series of voiced segment to cancel out the effect of glottis. Then frame-by-frame analysis was used with hamming windows and liner predictive coding (LPC) and auto correlation to extract the formant values. Voiced to unvoiced ratio is assessed using zero crossing rate and energy content of the acoustic signal. Results of the Voiced to Unvoiced ratio over 75% of voiced frames in all types of Suttas despite number of monks involved in chanting. Having a high percentage of voiced frames interpret strong contribution of vibrating vocal folds involved in chanting of Pirith Suttas. Further, Probability Distribution Functions (PDFs) of each Sutta is generated and compared for first five formants. Angulimala Sutta and Ratana Sutta show similar patterns in terms of PDFs while Karaneeya Metta Sutta indicates a clear discrepancy demonstrating a unique set of characteristics.

Keywords - Formant frequencies, Voiced to unvoiced ratio, Probability distribution functions

I. INTRODUCTION

Speech production process begins at the point of converting an idea developed in the speakers' mind to a language code. With the aid of articulatory motion and vocal tract movement, the phonemes which are lined up in a set of sequences propagate outside as an acoustic waveform. *Pirith* means protection from all aspects and this protection is to be obtained by reciting or listening to *Pirith suttas*. The practice of reciting and listening to *Pirith suttas* began very early in the history of Buddhist culture.

Voiced to unvoiced ratio (V/UV ratio) indicates the involvement of speech production system with vibration of vocal codes. In this work, we combined the results of zero crossing rate (ZCR) and energy of short time segments of the signal to generate V/UV ratio. In voiced speech, the vibrating glottis generates periodic pulses which are resonate in the vocal tract. However, in the unvoiced speech, vocal chords held open and a continuous air beam flow through them. (Lee and Yoo, 2003). The zero crossing rate measures number of intersections a given signal makes with the time axis per unit time in an amplitude- time plot. Voiced speech shows a low zero-crossing rate due to the excitation of vocal tract by the periodic air flow, whereas the unvoiced speech shows high zero-crossing count as it is produced by the turbulent airflow flowed through the narrowed vocal tract (Bachu et al., 2010). Additionally, the voiced part of the speech has high energy content because of its periodicity.

According to the acoustic theory of speech production, vocal tract is modelled as a non-uniform tube closed at vocal folds and open at the lip end (Stevens and House 1955). Due to varying cross section along the vocal tract, different resonance frequencies (harmonics) are generated in response to varying vocal fold vibrations. Consequently, the complex output voice signal is composed of several harmonics called as formants (Fant,1973).

As reported by Jayaratne 2007, an experiment was performed at Kanduboda International Meditation Centre, Sri Lanka to understand the effect of *Pirith* on human beings. When a sample of human subjects could listen to *Pirith* chants, it is observed that within 10 minutes of the commencement of the chanting, their heart beat reduced, heart pulse amplitude halved and reached to an alpha state similar to what is obtained under a meditative trance. A famous Japanese researcher, Masaru Emoto had provided evidences that human thoughts can affect the molecular structure of water through words, ideas and human vibrational energy (healingsounds.com, Jan 2018).

In the literature, there are evidences a large majority of the studies carried out so far in this discipline, have used a qualitative approach to tackle the problem. Instead, we chose a rigorous but quantitative approach which exploits state-of-the-art computer aided tools such as high- performance computing facilities (supercomputer cluster) to evaluate acoustic properties of a vast range of *Pirith* chants.

II. METHODOLOGY AND EXPERIMENTAL DESIGN

In the analysing process, Samples of *Rathana, Karaneeya Metta* and *Angulimala Suttas* recited by male monk chanters were recorded using high precision microphone array and 25 samples of each *Sutta* were *analysed.* Recorded samples were then subjected to splitting of smaller voiced segments of frame length 10 ms using sampling rate of 44.1 kHz. This specific frame length was selected as vocal tract has fixed characteristics over a time interval of the order of 10 ms.

Fast Fourier Transformation (*FFT*) and Linear Predictive Coding (*LPC*) are techniques used in spectral analysis of the speech. Fast Fourier Transformation(*FFT*) develops a spectrum by decomposing a sound wave into sinusoidal components whereas Linear Predictive Coding (*LPC*) estimates formant frequencies associated with vocal tract.

The formant frequency estimation was performed using computational method as follows. A pre-emphasis filter is applied to the sampled time series of voiced segment to cancel out the effect of glottis. Then *frame-by-frame analysis* was used with *hamming windows* and *liner predictive coding* (*LPC*) and auto correlation to extract the formant values. Speech signal has been modelled as a combination of a source and a filter. Source-filter separation model is use as a fundamental method for formant frequency estimation. The modelled system and its frequency resonances are only considerable in this estimation and Liner Predictive coding (LPC) is used to find the best matching system. The LPC filter is a function with set of filter coefficients. Resonance of the filter is expressed by a pair of coefficient. As in every 10 ms vocal tract parameters are changed, creating new set of coefficients. When applying LPC, a speech sample approximated as a linear combination of past speech samples. Minimizing the sum of squared differences over a 10 ms frame between actual sample and linearly predicted sample, a set of predictor coefficients can be obtained.

According to the discrete-time model,

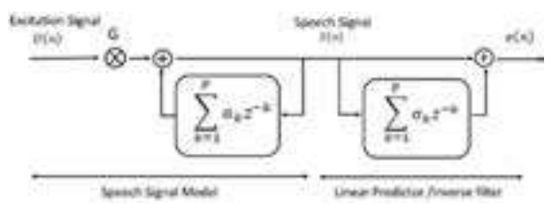

Figure 1- Linear Prediction model and

$$S(n) = \sum_{k=1} \alpha_k S(n-k) + GU(n)$$

where, $S(n)$: Estimated current value, αk : Predicted coefficients, $S(n-k)$: Past samples and $U(n)$: Excitation of vocal folds

Between two pitch pluses $U(n)$ is zero. Therefore, nth speech sample can be written as a linear combination as follows,

$$S(n) = \alpha_1 S(n-1) + \alpha_2 S(n-2) + \alpha_3 S(n-3) \ldots\ldots\ldots + \alpha_p S(n-p)$$

Figure1 demonstrate how the prediction error ($e(n)$) is defined. By minimizing the square of the error $\{e(n)2\}$ filter coefficients can be generated. After finding the locations of the resonance to extract the formant frequencies from the filter, the filter coefficients were treated as a polynomial and solved for the roots of the polynomial.

Voiced to unvoiced ratio is calculated by counting number of frames less than a reference zero-crossing rate and higher than a reference short time energy as voiced frames and others as unvoiced frames according to the algorithm shown in Figure 2. Zero-crossing rate is defined as the ratio between number of intersections given signal makes with time axis to number of sampled data points in the signal. The upper threshold zero crossing rate for qualifying a voiced frame is 0.1, greater than 0.1 but less than 0.3 for a silent frame and over 0.3 for an unvoiced frame. Probability Distribution Function (PDF) based quantitative analysis is carried out to identify the occurrence of formants. First five formant frequencies were extracted from the recorded voiced track with the aid of computer program scripted in MATLAB and corresponding PDFs are determined.

III. RESULTS AND DISCUSSION

MATLAB is used for scripting, calculations and analysis. In the frame by frame analysis, speech signals are divided into a non-overlapping frame of samples.

A. Voiced to unvoiced ratio

Voiced to unvoiced ratio is developed based on the algorithm shown in Fig 1 and corresponding results are summarized in Table 1. All types of chant samples demonstrated over 75% of voiced frames despite number of monks involved in chanting. Periodically vibrating vocal folds cause generation of voiced speech and hence, having a high percentage of voiced frames interpret strong contribution of vibrating vocal folds involved in chanting of *Pirith Suttas*. Usually, in speech, silent regions exist in between voiced and unvoiced regions yet without existence of silent regions the speech will not be

Table 1- Voiced to Unvoiced ratio and percentage of silent frames for Pirith Suttas

Name of the *Pirith Sutta*	Voiced to Unvoiced ratio	Percentage of silent frames
Rathana Sutta	87:1	4.68
Karaneeya Metta Sutta	88:1	2.7371
Angulimala Sutta	76:1	26.64

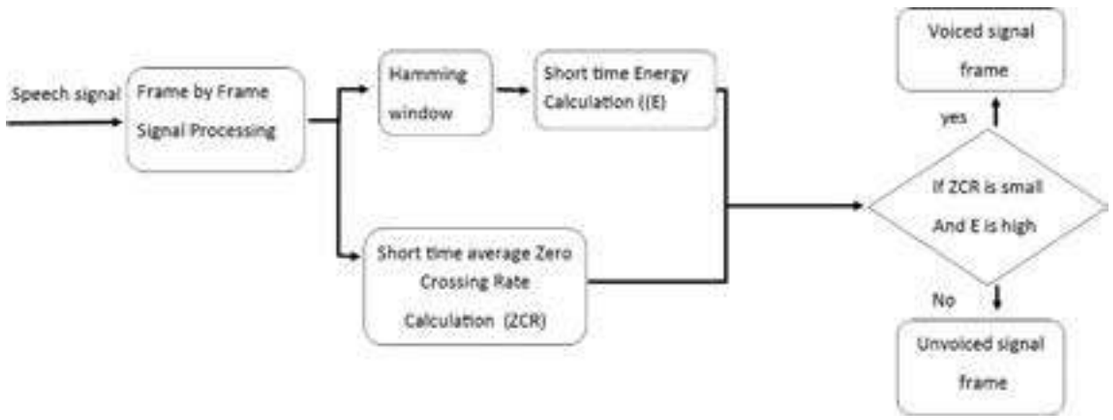

Figure 2 The algorithm to recognize Voiced to Unvoiced ratio

A. Probability Distribution Function (PDF)

In figures 3,4 and 5 the resulting variation of PDFs are shown. In these figures red, gray, black, blue and green solid lines show PDFs corresponding to formant frequency 1, 2, 3, 4 and 5 respectively. In Fig 6 the comparison for all suttas is shown. Plot dot shapes square, round and triangle indicate PDFs related to *Angulimala Sutta*, *Karaneeya Metta Sutta* and *Rathana Sutta* respectively.

Most common features of all Suttas are representing a considerable amount of probability for final three formants and probability of occurring second formant is comparatively lower.

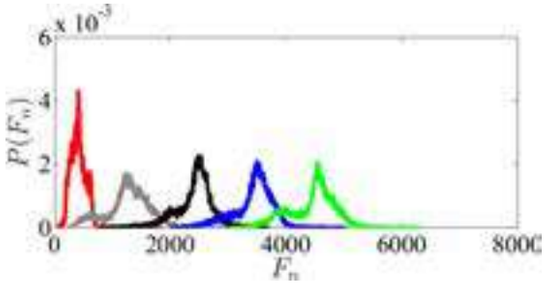

Figure 3. The figure represents probability of format frequencies of first five formants of Ratana Sutta. $\boldsymbol{f1}$, $\boldsymbol{f2}$, $\boldsymbol{f3}$ $\boldsymbol{f4}$ and $\boldsymbol{f5}$ represent by red, ash, black, blue and green colour plots respectively. First formant ($\boldsymbol{f1}$) shows highest probability of occurrence while third ($\boldsymbol{f3}$) forth ($\boldsymbol{f4}$) and fifth ($\boldsymbol{f5}$) formants indicate second highest probability. Second formant ($\boldsymbol{f2}$) shows a considerable low probability and $\boldsymbol{f4}$ shows probability in descending order while $\boldsymbol{f2}$ remains at the least probability

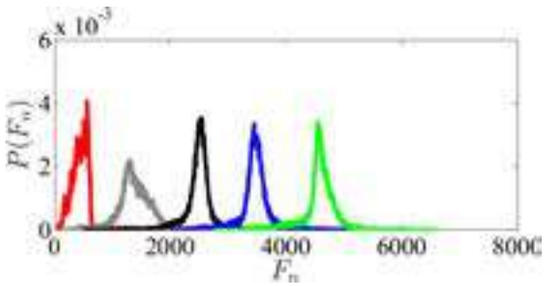

Figure 4. Probability distribution for Karaneeya Sutta as per contributed by first FIVE frequencies, $\boldsymbol{f1}$, $\boldsymbol{f2}$, $\boldsymbol{f3}$ $\boldsymbol{f4}$ and $\boldsymbol{f5}$ represented by red, ash, black, blue and green colour plots respectively. In Karaneeya Sutta $\boldsymbol{f1}$, $\boldsymbol{f3}$ $\boldsymbol{f5}$

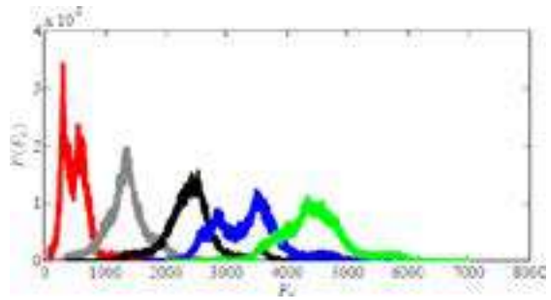

Figure 5. Probability distribution for Angulimala Sutta as per contributed by first FIVE frequencies, $\boldsymbol{f1}$, $\boldsymbol{f2}$, $\boldsymbol{f3}$ $\boldsymbol{f4}$ and $\boldsymbol{f5}$ represented by red, ash, black, blue and green colour plots respectively. Occurring probabilities of formants, decrease continuously from $\boldsymbol{f1}$ to $\boldsymbol{f}$

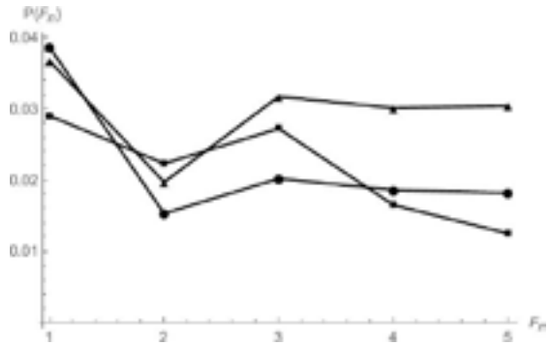

Figure 6. Mean Probability Distribution for all three kinds of Suttas. Plot dot shapes square, round and triangle indicate PDFs related to Angulimala Sutta, Karaneeya Metta Sutta and Rathana Sutta respectively

VI. CONCLUSION

As per deduced from the analysis of voiced to unvoiced ratio, demonstrating over 75% of voiced frames in all Pirith samples reveal a strong contribution of vocal folds in Pirith chanting with high vowel pronouncing probability.

The relative occurrence of each formant frequency varies according to one of the following two patterns shown below:

- First formant, $f1$ shows the highest probability of occurrence while $f3$, $f4$ and $f5$ contribute to probabilities in descending order while $f2$ remains at the least probability of occurrence
- Probability of occurrence of formants, decrease continuously from f to f.

In terms of third and fourth formant frequencies is more related to lip-spreading and to lip-protrusion. As reported previously and can be made much stronger in singing than in speaking. Trained singers can manipulate and by lowering the larynx and elevating the tongue blade to enhance this part of the spectrum and make it heard above an orchestral accompaniment.

As a future work, it would be challenging but rewarding to investigate on corresponding practical effects such as the effect of these properties on blood pressure, alpha-ray emittance of the brain in response to variation of these physical properties.

V. ACKNOWLEDGEMENT

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A UNIT CELL APPROACH TO REDUCE COMPUTATIONAL TIME OF MESHFREE BASED PLANT TISSUE MODELS

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Abstract - Plant tissue modelling and simulation has become one of the popular research topics in the field of computational mechanics. In this regard, numerous numerical modelling techniques are being researched to study real tissue mechanisms with the help of High Performance Computing (HPC). Among such numerical modelling techniques, meshfree methods have a higher capability, particularly in modelling critical plant tissue deformations during drying. However, existing meshfree based models are computationally expensive in modelling real tissues made oat of loge number of cells, limiting their applications in the real world tissues having thousands of cells It is mainly due to the computationally inefficient conventional neighbourhood treatment methods used in above numerical methods. Accordingly, this research oimed to develop o meshfree based unit cell approach which con be used as o bulldog black to model large tissues. Here, a novel Fixed Neighbourhood based SPH (FN-SPH) method was involved to setup a unit cell representing several real cells (seven cells here). Compared to the original tissue with seven cells, the tissue made oat of the unit cell approach resulted in approximately50M of overall computational time reduction, highlighting the capability of this approach in reducing the computational cost in simulating large-scale plant tissues

Keywords - Fixed Neighbourhood based Smoothed Particle Hydrodynamics (FN-SPH), High Performance Computing (HPC), Meshfree Methods, Numerical Modelling, Plant Tissues

I. INTRODUCTION

From the ancient time, drying or dehydration has been used for the preservation of food materials. As moisture escapes from the food material during drying. it undergoes shrinkage and excessive deformations (Bai 2002; Mayor, ?Bowie & Sereno 2011k Compared to the fresh condition, dried version of a given food material usually has a different structure, mechanical properties, nutrients, visual appearance and mouth feel, leading to higher consumer demand. One of the key observations during drying is the structural deformation as influenced by the moisture content reduction and the drying temperature, which leads to heterogeneous tissue morphological alterations (Bai 2002). In order to optimise such dried focd characteristics, it is critical to have a broader understanding of fundamental mechanisms involved (II. C P Karunasena, Gu, et al. 2015b). For this purpose, there have been many numerical models developed so far, which are either based on grid-based modelling methods such as Finite Difference Methods (FDM) and Finite Element Methods (FEM), or meshfree based modelling techniques. In common, these methods have targeted to model the dynamic co-existence of liquid, solid and gas phases, excessive wall deformations and mufti-scale relationship between sub-cellular and bulk plant material deformations (H. C P Kanmasena, Gu, et al. 2015b; Lewicki & Pawlak 2003). However, many recent research findings have revealed that meshfree based modelling approaches are more capable of modelling large tissue deformations during drying, compared to grid based methods (H. C P Karunasena, Gu, et al. 201Sb; H. C P Karunasena, Senadeera, Brawn, et al. 2014a; H. C P Karunasena, Senadeera, Gu, et al. 2014d; Liu et al. 2003). Furthermore, combined grid.based and meshfree methods have also shown promising capability in modelling multi-scale tissue mechanisms (Ghysels et al. 2009; H. C. P. Karunasena et al. 2014c). Also, several types of food • material structures and many advanced physical mechanisms such as case hardening and porosity development during drying have recently been modelled

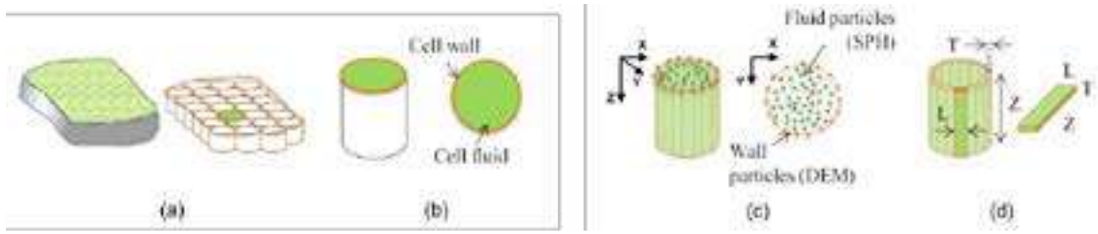

Figure 1. (a) A plant tissue simply represented as an aggregate of cylindrical cells. (b) 2-D model to represent any cylindrical cel (c) Particle scheme used for the 2-D cell model: fluid model based on SPH particles and wall model based on DEM particle (d) discrete elements of the cell wall (H. C. P. Karunasena, Senadeera, Brown, et al. 2014a)

(Bai 2002; H. C P Karunasena, Brown, et al. 2015c; H. C.P. Karunasena et al. 2015a; Van Liedekerke et al. 2011; Rathnayaka Mudlyanselage et al. 2017). Figure 1 presents a basic meshfree based model of a plant cell developed using Smoothed Particle Hydrodynamics (SPH) and the Discrete Element Method (DEM).

However, compared to grid based numerical method; meshfree methods demand higher computational resources and time. Therefore, much attention is currently on improved meshfree based modelling techniques to reduce computational effort. For instance, simulation of the dynamics of a single apple cell just for S ms in real time requires a SDH-OEM based meshfree model to run for at least 200 seconds in a typical personal computer having Intel•CorelMi7.6700, 3.4 GH1 • 8 core processor with 8 GB RAM in Ubuntu. Furthermore, if this model is used to simulate a 1 mm^2 tissue consisting of 178 cells, approximately 10 hours of simulation time would be needed (H. C P Karunasena, Senadeera, Gu, et al. 2014a). If this is so, it may become computationally much difficult to model and simulate a tangible real plant tissue (e.g. 1 cm * 1 cm), having thousands of cells. Accordingly, as the number of cells in a plant tissue increases, the overall computational time increases exponentially, limiting the applicability of current modelling approaches. Anyway, modelling such larger tissue are of much importance to the field since different analysis and predictions are to be done involving realistic tissues of tangible sizes.

In above models, it is commonly observed that more than 50% of the computational time is taken by the All Pair Search (APS) algorithm, which is used for interaction calculations in Nearest Neighbour Particle Searching (NNPS), which is an indispensable part of meshfree based models (Hansani, Karunasena & Sumith 2017; Hansani, Sumith & Karunasena 2016). Although APS is the simplest method to identify neighbour particles, it consumes more time as it checks every particle in the simulation domain for possible neighbourhood interactions, which is repeated in each time step, not like in grid based methods having fixed neighbours (Liu et al. 2003). As a solution, computational time reduction steps have been recently proposed for meshfree based plant tissue models, with the use of Fixed Neighbourhood method (FN) and Cell-Linked List Algorithm (CLLA) (Hansani, Karunasena & Sumith 2017; Hansani, Sumith & Karunasena 2016). However, there are many limitations in these modelling approaches as these models are more focused on micro-scale cellular mechanisms rather than simulating bulk scale mechanisms of larger tissues.

In this background, this research proposes a unit cell approach to conveniently model large plant tissues, which will be described in sections below.

II. NNPS AND FN-SPH BASED SIMULATION

In meshfree methods, Nearest Neighbour Particle Searching (NNPS) is one of the key time-consuming components in the source code of the model. In NNPS, physical properties of a given particle is calculated using the properties of the neighbouring particles. Here, the

neighbouring particles are the ones that are located in a distance less than or equal to *2h from the particle of interest*, where h is smoothing length.

In this work, individual seven cells were taken as a unit cell and simulated as a cluster using APS in SPH. Then the unit cell was setup using the novel Fixed Neighbourhood based SPH method (FN-SPH) also and the two methods were compared both qualitatively and quantitatively. The FN-SPH has characteristics of the grid based methods such as Finite Difference Method (FDM) and Finite Element Method (FEM) and it involves following key steps in its implementation:

1. Place each particle in an enclosed boundary of 3h
2. Store neighbouring particle identities in the computer memory
3. Perform interaction calculations for the above neighbouring particles
4. Run all the iterations and perform all calculations in the model using the selected neighbours

This approach runs under two key assumptions: 1) cell fluid is incompressible and only have low Reynolds number fluid flow conditions, 2) each particle is virtually located in an enclosed circular boundary of radius 3h, where a fixed number of neighbouring particles exist. Therefore, unlike in APS approach, the entire problem domain is not searched during the simulations in each time step, but only the pre-determined neighbouring regions, which is essentially a smaller portion of the whole problem domain (see Figure 2) (Hansani, Karunasena & Sumith n.d.; Hansani, Sumith & Karunasena 2016). This is the main cause for the reduction of the computational time significantly.

III. METHODOLOGY

The FN-SPH based unit cell model was developed based on an existing C++ code (H. C. P. Karunasena, Senadeera, Brown, et al. 2014a), that had been developed for single plant cell simulations. Here, for the convenience of concept validation, a smaller unit cell was involved in this paper, consisting of seven individual cells. In the original model, a single cell was modelled using 96 wall particles and 656 fluid particles. Accordingly, here the unit cell was modelled using 252 wall particles and 1728 fluid particles (see Figure 3) (Hansani, Sumith & Karunasena 2016). Simulations were done using a High-Performance Computer (HPC) having Intel® CoreTM i7-6700, 3.4 GHz × 8 core processor having 32 GB RAM in Ubuntu operating system. Parallel processing was used in the computer code to reduce overall computational time. For visualisation of the model outcomes, the Open Visualisation tool (Ovito), version 1.1.0 was used.

IV. RESULTS AND DISCUSSION

As given in Table 1, when comparing the model outcomes from both approaches, the results are almost same. It implies that the unit cell approach can fundamentally be applied for tissue simulations and predictions.

Figure 4 presents the qualitative results comparing the seven cells and unit cell under varying moisture content. The two set of results indicate that the unit cell has the capability to mimic the gradual deformation and shrinking characteristics displayed by the original seven cell cluster, even with less number of particles and interactions.

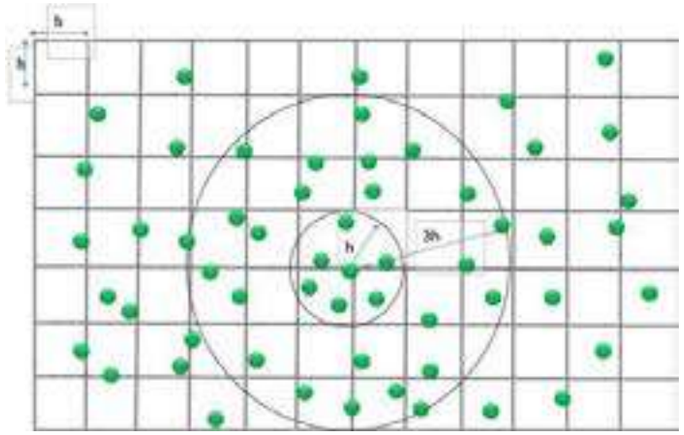

Figure 2. Domain discretisation in FN-SPH based on a circular boundary of radius 3h

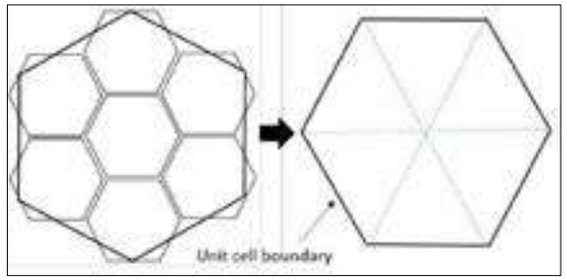

Figure 3. Aggregation of seven cells(left) into a simple unit cell(right)

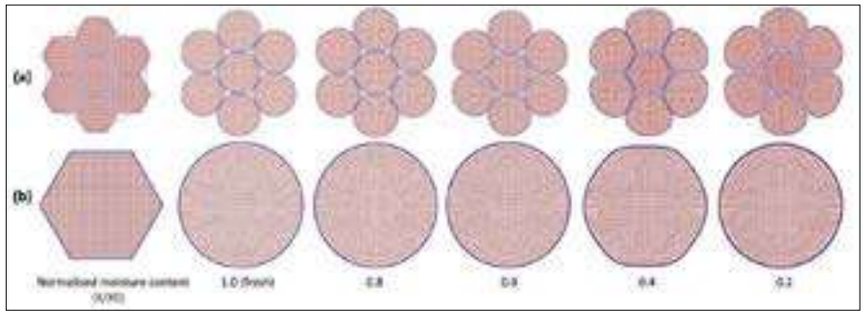

Figure 4. Deformation of a tissue during drying (reduction of the X/X0): (a) a tissue with combined seven cells with APS, and (b) unit cell with FN-SPH used

Table 1. Comparison of model outcomes

Parameter	Tissue with combined seven individual cells	Tissue with the unit cell
Percentage error in model consistency	4.90%	-1.48%
Fluid Final Pressure (kPa)	187.0	189.5
Fluid final density (kgm^{-3})	999.9	999.9
Final stretch ratio	1.0	1.1
Normalized moisture content	1	1
Final cell fluid mass (kg)	2.17389E-09	1.53076E-08
Final cell area (m2)	2.09965E-08	1.47269E-07
Final cell equivalent diameter (μm)	163.5	433.0
Final cell perimeter (μm)	516.4	1360.6
Final cell roundness	0.990	1.000
Final cell elongation	1.008	1.001
Final cell compactness	0.959	0.994
Wall inter-particle force (theory (mN)	1.531	4.111
Wall inter-particle force (SPH) (mN)	1.606	4.050
Wall contraction force due to drying (mN)	-1.452	1.763
Maximum number of interactions per particle	23	29
Minimum number of interactions per particle	14	14
Number of particles with no interactions	0	0
Average number of interactions per particle	17	18

Table 2: Comparison of simulation results of the original tissue model with seven cells using APS, the tissue model with the unit cell approach using FN-SPH method

	A/A0			D/D0			P/P0			R/R0		
X/X0	Seven cells	Unit cell	%Error	Seven cells	Unit cell	%Error	Seven cells	Unit cell	%Error	Seven cells	Unit cell	%Error
1	1	1	0	1	1	0	1	1	0	1	1	0
0.8	0.9363	0.9408	0.481	0.9676	0.9699	0.238	0.9732	0.9699	0.339	0.9885	1.0001	1.173
0.6	0.8594	0.8725	1.524	0.927	0.9341	0.766	0.9403	0.934	0.67	0.972	1.0001	2.891
0.4	0.7251	0.7956	9.723	0.8516	0.892	4.744	0.9027	0.8953	0.82	0.89	0.9926	11.53
0.2	0.6091	0.7619	20.56	0.8301	0.8728	5.144	0.8811	0.8729	0.911	0.8876	0.9999	12.55

Table 2 presents the quantitative values such as the normalized cell area (A/A0), ferret diameter (D/D0), perimeter (P/P0) and roundness (R/R0), against the normalised moisture content (X/X0). Here, X, A, D, P and R are the moisture content, area, diameter, perimeter and roundness respectively while X0, A0, D0, P0 and R0 are the initial values of those properties. It is evident that both results are in very good agreement where the maximum percentage error limiting to 12.5%.

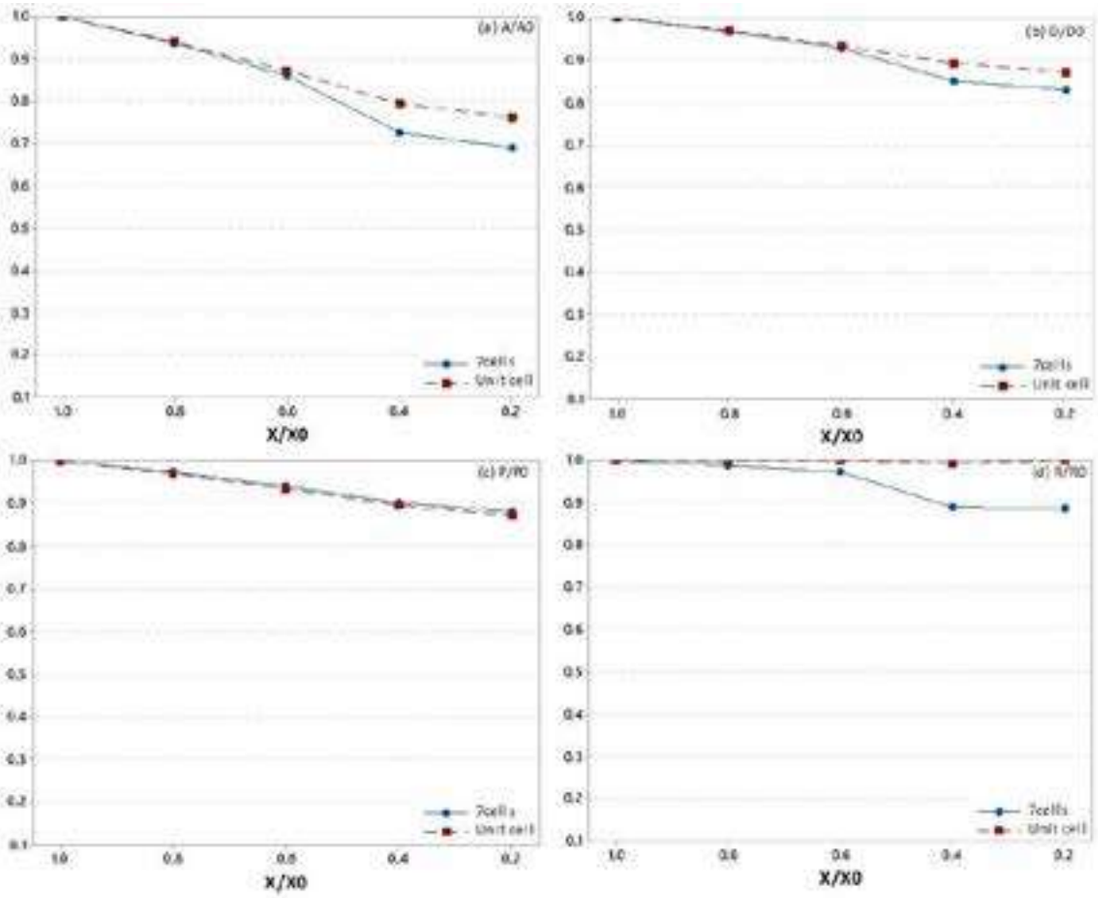

Figure 5. Quantitative results of the simulations of seven cell method and proposed unit cell method comparing with (a) A/A0 - Normalized cell area (b) D/D0 - Normalized cell ferret diameter (c) P/P0 - Normalized cell perimeter (d) R/R0 - Normalized cell perimeter respect to X/X0 – Normalized moisture content

Next, the Figure 6 compares the computational time for both methods. Accordingly, the unit cell approach records an 80% computational time reduction compared to the original model with seven cells. Therefore, the validity of the unit cell approach in order to reduce the computational time is evident. Furthermore, it can be observed that the simulation time is gradually reducing as the cell cluster or the unit cell is getting dried. One of the main reasons for this is the reduced size of the cellular problem domain, where neighbourhood finding become easier since particles are located much closer.

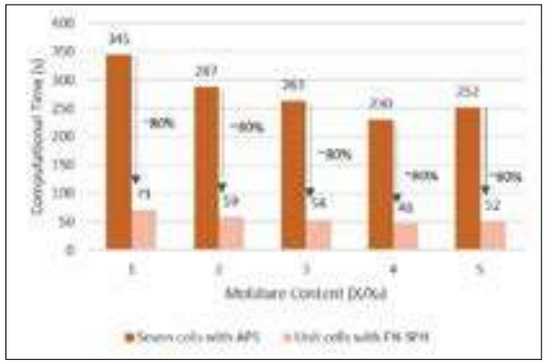

Figure 6. Comparison of the computational time of seven cell and the unit cell implementation. It clearly indicates that the unit cell can reduce the computational time significantly

V. CONCLUSION

This paper presented a unit cell approach by incorporating the FN-SPH approach, which results in about 80% of the computational time reduction compared to original tissue modelling approach involving APS in SPH. The accuracy of predications is also much comparable with the original model predictions. The computational advantage is particularly due to the reduced number of interaction calculations offered by the proposed method, where the whole problem domain is not searched to identify the neighbouring particles, under NNPS in SPH. Accordingly, this can be used in large tissue simulations producing much higher levels of computational advantages. However, the application of the proposed technique is limited to lower Reynold number flow conditions in the fluid flow problem domains, if FN-SPH is used. However, if APS is used instead of FN-SPH for the unit cell approach, the lower Reynold number condition can be avoided, but with additional computational expense. This approach has the potential of applying in many other research areas other than just plant tissue modelling, such as modelling of animal tissues or non-continuum discrete materials in general

VI. ACKNOWLEDGEMENT

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BRAILLE BLOOD PRESSURE INTERPRETER FOR HOME BLOOD PRESSURE MEASUREMENT FOR VISUALLY CHALLENGED INDIVIDUALS

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Abstract -Hypertension has slowly secured its place as the severest disease burden in the world among Global Burden of Diseases (GBD). Hypertension management programs which are employed to control the disease have identified Home Blood Pressure Measurement (HBPM) to be the most efficient blood pressure monitoring tool to effectively control hypertension. This paper presents an innovative, low cost and user friendly universal technological solution for the visually challenged community who are seeking hypertension management programs without compromising the independency and privacy with regard to sensitive medical data. In place of an exclusive and high cost blood pressure meter with Braille output, an external USB compatible tactile interpreter has been proposed and implemented. Systolic and diastolic readings isolated using a commercially available Device Monitoring Software, verifies that such a device is indeed realizable with a micro-controller based tactile feedback system especially designed for this purpose.

Keywords - Blood Pressure, Braille, Hypertension management, Visually impaired

I. INTRODUCTION

The remarkable advent of technology and drastic changes in the human life style has led to an epidemic uprise of several chronic diseases in the recent past. The most severe cause of mortality and disease

burden in the world today is hypertension according to the Global Burden for Diseases (GBD). Home blood pressure measurement (HBPM) is the internationally accepted procedure for a better hypertension management which involves frequent monitoring of blood pressure from home. However, for blind and visually impaired individuals, there exist no reliable and accessible mechanism/approach self-measure, interpret and record blood pressure measurements without the sighted assistance.

According to the World Health Organization as at 2014, estimated 39 million of world population is totally blind while 285 million are visually impaired. Moreover, the Centre for Disability research stated that in the year 2010, estimated 358 000 individuals were suffering from deaf-blindness in United Kingdom alone(WHO, 2014). WHO further revealed that over 82% of the individuals who are living with visual disabilities are aged 50 or above.

Unfortunately, these statistics are estimated to be gradually increasing every year and expected to be doubled by the end of year 2020. With the dawn of the present decade, lifestyle of both sighted and blind individuals have changed dramatically. Hypertension has slowly risen to the top in the Global Burden of Diseases (GBD) as the biggest contributor for mortality and the disease burden in the world. Hypertension, which is often assumed to be a problem in the developed countries is indeed the biggest disease burden in South Asian region too (Gupta, 2016).

The major developments in the field of biomedical engineering towards the visually challenged community during the past were often in rehabilitation (Hersh & Johnson, 2008). That is, development of Electronic Travel Aids (ETAs) and external prosthesis to stimulate visual cortex artificially (Dakopoulos & Bourbakis, 2010; Velázquez, 2010). However, the development of the first exclusive medical device for the visually challenged, the Braille Thermometer (Islam & Mondol, 2014), scientific

community has taken several strides in developing dedicated medical equipment for vital signal measurement for the visually challeneged community. Two proposals have been put forward; the Starp-on blood pressure monitor (Shenzhen, 2013) and the Tensio blood pressure bracelet (Marcel, et al., 2016). Due to design constraints, regulatory limitations, and lower return for cost incurred, these devices have not been commercially realized.

Navigation, distance estimation and obstacle avoidance are the three major obstacles faced by the blind individuals throughout history which lead to limitation of the physical activity level among blind individuals (Maidenbaum, et al., 2014; Velázquez, 2010) while increasing the risk of cardiovascular diseases, like hypertension (Marcel, et al., 2016; Pickering, et al., 2005). Lack of physical activity and contraction of cardiovascular diseases has been established over 30 years ago (Weil, et al., 2002). Now that hypertension has become the deadliest disease burden in the world (Gupta, 2016) there exist a need for a proper and reliable approach for visually challenged to monitor their blood pressure values since Home blood pressure monitoring (HBPM) is considered to be the internationally recommended blood pressure measurement approach for management of hypertension (Weil, et al., 2002; Sattelmair, et al., 2011)

The internal market and consumer protection committee of the European Union has passed regulations stating that products and services available in consumer markets must be accessible to disabled individuals including the blind(Europa, 2017). However, the existing home blood pressure monitors lack accessibility for visually challenged individuals. This paper thus presents a simple, reliable and an accessible approach through technological innovation that will help improve the quality of life of visually challenged individuals through participating them in hypertension management program by empowering independent measurement of blood pressure while protecting their medical privacy.

II. METHODOLOGY

The objective of the research study was to develop an accessible approach that helps a visually challenged individual to self-measure blood pressure without sighted assistance. It was identified that without developing an exclusive blood pressure meter for the visually challenged, it is far more effective and meaningful in developing a standard blood pressure monitor compatible electronic reader that could convey blood pressure readings to the visually challenged using Braille, the universal language of the blind community. This electronic Braille display was named as "Braille Blood Pressure Reader" (Figure 1) by us since it is capable of more than just displaying blood pressure. The device when connected to a standard blood pressure meter via the USB port and blood pressure data with regard to systolic and diastolic blood pressure could be tactually displayed using electronic on a braille calibrated rotary display when correct protocol is adhered to. In other words, Braille blood pressure reader device can tactually convey blood pressure readings to the visually challenged, electronically store and create a data log of blood pressure readings, end of measurement signalling and measurement error signalling.

A. Architecture Overview

In the present study, three servo motors rotating on top of a braille calibrated display of raised dots would function as the actuator mechanism of conveying systolic and diastolic blood pressure values to the blind and visually impaired. When a blood pressure measurement is read by the Arduino board, the Servomotors will turn clockwise along the braille calibrated display. The shaft will point towards a braille number. By dragging the finger along the shaft and onto the braille number, blind person would be capable of reading blood pressure values independently.

Keeping a track of blood pressure variation during a given period of time plays an integral part in any hypertension management program. In order to facilitate that, each and every blood pressure reading taken during that time period needs to be recorded with data and time. Hence, a memory log of such records is proposed and implemented in this study using SD Card module. A memory log of the measured blood pressure readings play an important role in allowing the physician to evaluate and derive conclusions about the hypertension level of the patient, activity/effect of drugs prescribed and the progress/recovery of the patient in terms of hypertension management. Arduino SD card module will implement the function of memory logging.

A suitable mechanism that allows the visually challenged user to monitor and record their blood pressure without any errors of measurement or errors of calculations/processing is essential. In the case of such errors, the user must be notified to take the blood pressure back again. Moreover,

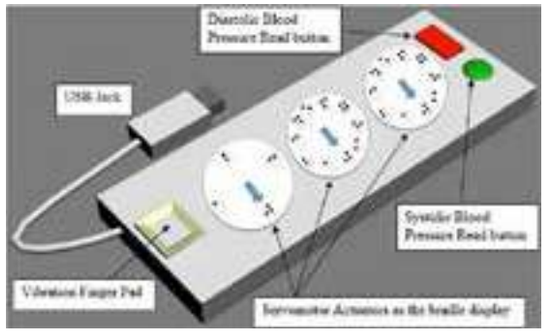

Figure. 1. The 3DsMax model of the proposed Braille blood pressure reader

user has to be notified of the end of measurement of blood pressure by the blood pressure monitor so that he can stop following measurement protocols and start reading blood pressure. These two functions of signalling is implemented using an Arduino vibration motor module.

Arduino will function as the brain of the braille blood pressure reader device. It is responsible for processing and manipulation of acquired data through USB port to derive systolic and diastolic pressure values in Braille. Hence, arithmetic and logic functions related to data acquisition are conducted by Arduino. Apart from that, Arduino is also responsible for actuation of the three servo motors, writing blood pressure data to SD card, controlling of vibration motor pad upon acquired USB data from the blood pressure meter.

Since, Arduino follows serial communication protocol it strictly follows the Master/Slave communication model where the master (host) controls the communication between the two devices whereas slave (also known as device) act upon the instructions, commands or requests of the master device. Slave cannot initiate communication with host nor can it end an existing communication. Hence, without the acknowledgement of the master, slave device cannot send to or receive data from the master. Since almost all Arduino devices are slave devices, a special

Arduino shield in the name of Arduino USB host had to be utilized in order to initiate and maintain communication with the blood pressure monitor to acquire data related to systolic and diastolic pressures.

As it was established that developing an exclusive blood pressure meter in braille exclusively for the blind/visually

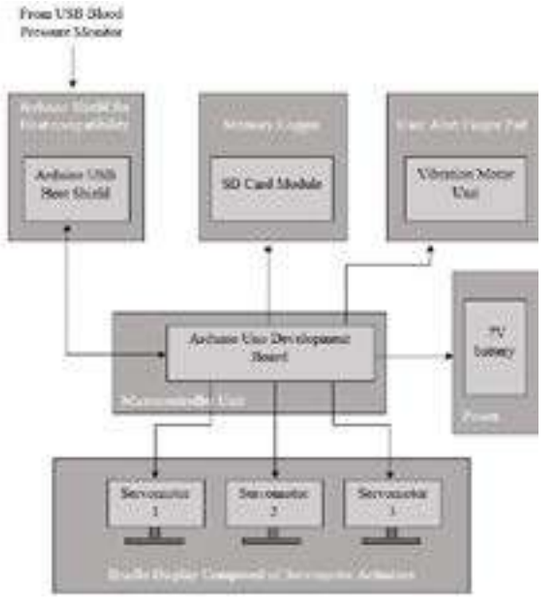

Figure2. The system architecture of the Braille Blood Pressure Reader

impaired community is an expensive and unrealizable solution. Hence, a standard blood pressure meter which has been inspected, tested and approved by a renowned global institution like Food and Drug Administration (FDA), Conformité Européene (CE) or British Hypertension Society (BHS) was selected upon the consultation of cardiologists from the Sri Jayawardenapura General Hospital, Sri Lanka. It was decided that Contec 08A blood pressure monitor which is approved by FDA and used for home blood pressure measurement by individuals with no visual complications as a standard tool for blood pressure measurement to be used for the Study.

B. Development of prototype model

The entire study was designed in five phases. In phase 1 Literature survey and collection of data was conducted. Phase 2 was about developing the conceptual design and implementation. In phase 3 the Braille Blood Pressure Reader hardware components were developed. Phase 4 of the study primarily focused on data acquisition from the Contec 08A blood pressure meter and processing of data to derive meaningful information. The final phase of the study was developing the Braille blood pressure reader prototype by integrating all the independent components together

Figure3. Initial Testing Prototype Model of the Braille Blood Pressure Reader developed on a breadboard using three Servomotors

C. Data acquisition from the blood pressure monitor

First step of the data acquisition phase of prototype development was to confirm whether the blood pressure data with regard to systolic pressure and diastolic pressure could be obtained from the blood pressure monitor to the computer. Then, the obtained data was analyzed to identify the type and mechanism of data flow in and out of the device. The Contec 08A blood pressure monitor was connected to the computer via a USB port. Device Monitoring Studio 7.05 software was used to analyze the data acquired from the blood pressure meter. ELTIMA USB analyzer software was used to verify and validate the data obtained from the Device Monitoring Studio. Device Monitoring Studio was first programed to identify the USB device class of the blood pressure monitor. The USB device class determined the type and mode of communication protocol used by the blood pressure meter to exchange information between the device and the host.

Blood pressure measurements were taken from the blood pressure monitor and these readings in the blood pressure meter memory (EEPROM) were imported to the computer through Device monitoring studio software. The data transferred between the computer and the device during communication were also recorded using Device Monitoring Studio in two data visualization modes, namely; Structure View and Raw Data View. Structure view mode allowed visualizing acquired data identifying the target data packets and filter out required data packets based on their type and/or other distinct feature. Raw data mode allowed visualization of ingoing and outgoing data between the computer and the blood pressure monitor in two separate part-windows.

In order to develop a communication platform which allowed the Arduino to talk to the blood pressure meter and effectively transfer/acquire the systolic and diastolic blood pressure data, communication channels had to be established first between the blood pressure meter

EEPROM and the Arduino microcontroller. In order to facilitate this, the communication between the computer and the blood pressure meter had to be replicated between the blood pressure meter and the Arduino through the Arduino Host Shield. Hence, identification of other data packets like, handshake packets, control transfer packets and device descriptor request packets, device descriptor transfer packets had to be clearly identified. Device monitoring studio platform could be programed to filter out the required data packets in concern from other data packets when developing the communication platform.

D. Processing of acquired data to derive meaningful information

After obtaining blood pressure data via the Device Monitoring Studio 7.05 in Structural view and Raw Data view modes, observations were made on the type of data, length of data packets that was given out by the blood pressure monitor. Each blood pressure record obtained as a 16-bit hexadecimal data stream was conveniently filtered out using the structure view. The aim of this phase of the study was to distinguish the data packets containing the systolic and diastolic blood pressure values from the rest of the data packets. This was followed by extraction of those data packets from the obtained data stream to be displayed via the braille tactile display.

In order to isolate the required data string containing systolic and diastolic blood pressure values, first, incoming data packets were filtered out from the outgoing data packets using the Device Monitoring Studio 7.05. Thereafter, payload data packets were filtered out from the header packets, metadata packets, transfer request packets, descriptor request packets and other types of data packets using the Structure view mode. Using Packet View mode, only the data packets related to bulk/interrupt transfer were isolated from the rest of the data packets. This was done because payload packets are always a part of bulk/interrupt transfers. After filtering out the bulk/interrupt transfer packets, Structure view mode was used to identifying all the payload data packets from the remaining bulk/interrupt data packets. Payload data contained actual data communicated between the device and computer while the rest of the data packets were used to establish the connection between the device and the host computer.

PROCEEDINGS

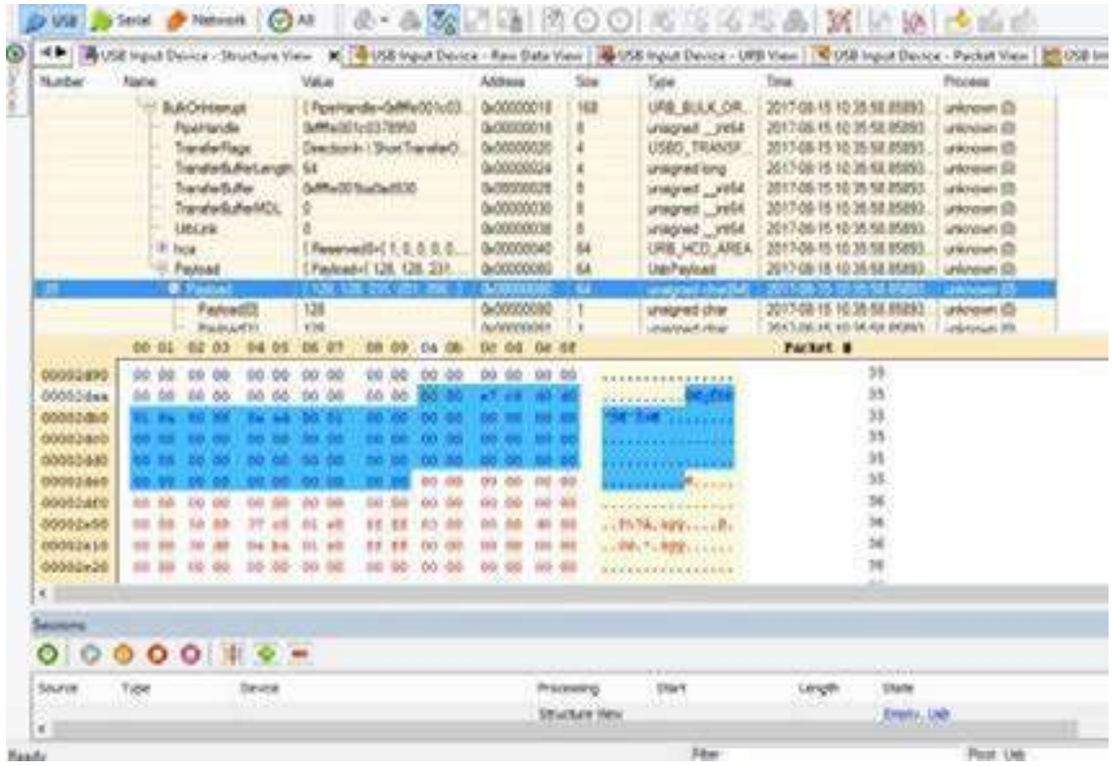

Figure 4. Part of Structural View mode in Device monitoring studio that was used to acquire raw data packets employed in communicating with the computer

F. Braille Actuator System

A rotary braille display was developed by using SG90 servo motors (Figure 5). Three servo motors was used to display units value, tens value and hundreds value respectively of diastolic and systolic blood pressure in mmHg. Servo motor displaying units values and tens values were programed to rotate from 0 to 9 during a full rotation. Hence, the angle between two integers was 36º. Remaining servo motor which was responsible of displaying hundred's value was modified to rotate only from 0 to 3 during a full rotation. The angle between two integers in hundred's scale was 90º. As a result, the maximum value which could be displayed using the three servo motor braille display assembly was 399 mmHg and the lowest value was 000 mmHg.

III. RESULTS AND DISCUSSION

A. USB Device Class

Device Monitoring Studio 7.05 device class was identified to be USB Human Interface Device (HID). USB HID class contains many predefined functions that allows them to be used across many platforms with no or very limited number of restrictions in communication protocol (Axelson, 2015). The cross-platform adaptability and minimum number of restrictions play a crucial role in data acquisition and developing communication protocol between the Arduino and the blood pressure meter.

B. Type and amount of the data packets that were transferred during data acquisition

When data acquisition was conducted with only one blood pressure reading was available in blood pressure meter memory, it was observed that 44 data packets were interchanged between the blood pressure meter and the computer. When the data transfer was conducted with two blood pressure readings in the blood pressure meter memory, total of 50 data packets were observed to be interchanged. During one cycle of data interchange, twenty data packets were observed to be transmitted per second between blood pressure meter and the computer within three milliseconds.

We observed that a total of 1618 bytes were transmitted from the device to the host (computer) during one transmission cycle of which 850 bytes were read from the device and a constant number of 768 bytes were written to the device It was also observed that a total of 3 milliseconds were required to prepare the host and the device to initiate communication between the two. As a result. It was clear that data are transferred at more than reasonable speed to convey the blood pressure effectively. As the waiting time to receive the Braille tactile response is below one second, the effectiveness of the device in delivering the feedback was considered to be acceptable.

C. Identification of Payload packets

Out of the data packets that were interchanged during data acquisition payload packets were identified by programing the acquired data in Structure view mode of the Device monitoring studio (Table). It was observed that payload packet data in packets 11, 19, 27, 31, 33, 42, 44 remained constant for each and every blood pressure reading taken during any time of the day. Variations were observed in the payload packet 35 in each of the blood pressure transfer suggesting that packet 35 could carry the data about systolic and diastolic blood pressure values for the particular measurement.

D. Blood Pressure data processing

When the blood pressure meter is concerned the data that is stored in the blood pressure meter memory for each and every measurement were clearly identified. They were; Systolic Blood Pressure (SBP) in mmHg, Diastolic Blood Pressure (DBP) in mmHg, Pulse rate, Mean Atrial Pressure (MAP) in mmHg, date of measurement and time of measurement. We concluded from the acquired data that the final data string of data were in the following order.

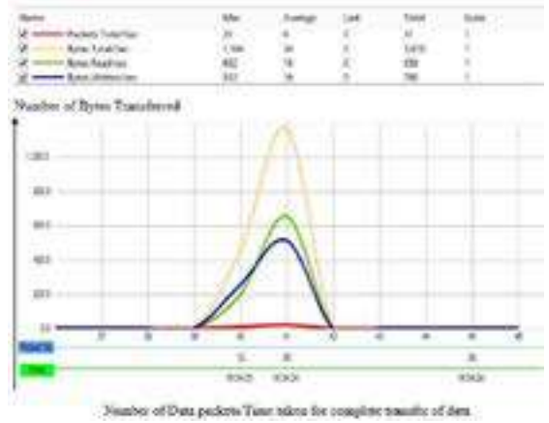

Figure 5. Number of Bytes transferred vs Packet number/Time graph obtained from the Device Monitoring Studio

Table1.Type of data in a typical data transfer between the computer and the blood pressure monitor

1	Class specific request	21 09 00 00 00 00 00 00
2	Get Descriptor	80 06 02 03 09 04 02 04
3	Descriptor from device to Host	09 02 53 00 04 00 42 00 03 00 03 00 72 00 42 00 65 00 4C 00 65 00 63 00 74 00 72 00 6F 00 6E 00 69 00 63 00 73 00
4	Acknowledgement and send Data request	23 01 13 00 14 00 42 00 31 00 32 00 20 00 41 00 76 00 78 00 74 00 6D 00 20 00 69 00 69 00 6E 00
5	Interrupt or Bulk transfer	Out of the 44 data packets that were transferred, 17 of them were interrupt or bulk transfers that had variable values from reading to reading. Hence, they are not mentioned here..
6	Acknowledgement	23 01 13 00 14 00 42 00 31 00 32 00 20 00 41 00 76 00 78 00 74 00 6D 00 20 00 69 00 69 00 6E 00

Table 2. All the payload packets transferred during data transmission between device monitoring studio and blood pressure monitor

Payload packet number	Raw data string obtained (converted to decimal format)
Packet 11	65, 2, 65, 16, 0.....
Packet 19	65, 2, 65, 16, 0.....
Packet 27	72, 65, 2, 17, 1, 0 .....
Packet 31	74, 67, 1, 0, 0 .....
Packet 33	70, 65, 128, 128, 129, 130, 0.....
Packet 35	Data obtained in this payload packet varied in each transfer.
Packet 42	70, 65, 128, 128, 129, 130, 128, 128, 128, 128, 128, 129, 0.....
Packet 44	70, 65, 128, 128, 129, 130, 128, 128, 128, 128, 128, 129, 0.....

Figure 6. Order of blood pressure measurements in the packet 35 of the blood pressure data string

IV. CONCLUSION

The system has already been designed and implemented to a satisfactory level, yet few more tests, verifications and implementations are yet to be conducted. As of now, the Braille blood pressure reader is optimally functional using Arduino IDE, Serial monitor in a computer. All the peripheral devices including servomotor actuator system, SD card module, and vibration motor module have been tested and verified for their functionality separately. It should be noted that the results of the braille blood pressure reader system is encouraging. The results speaks for the efficiency and uniqueness of the implemented system in its ability to interpret the blood pressure readings to the visually challenged. Apart from showing systolic and diastolic blood pressure values, the system is also capable of storing the blood pressure readings and alert the user of end of measurement and error if encountered. This system does not require any special skills or training before use. It is portable and simple in design. Use of a microcontroller control and logic system has ensured that the device is inexpensive and affordable to any user. Using a raspberry pi microcomputer, as a control and logic device would have made implementation much easier yet the cost would be too high.

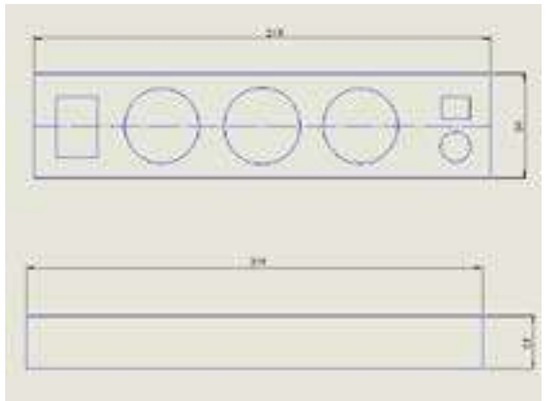

Figure 7. Physical dimensions of the blood pressure reader device in the initial prototype

V. FUTURE WORK

Currently, the blood pressure reader could be fully controlled using computer and Arduino IDE and serial monitor platform. However, development of an Arduino program to establish, completely control the blood pressure meter and finally display the reading is still under development stage and is yet to be realized. The problem was the unavailability of proper Arduino libraries for the Arduino USB Host shield. Furtherly, clinical trials were not carried out using blind test subjects to test whether they can easily interpret blood pressure values using the Braille blood pressure reader. Hence, by conducting clinical trials with blind test subjects could emphasize the actual effectiveness of the device in interpreting blood pressure data in everyday life.The Braille blood pressure reader has been developed only for the Contec 08A blood pressure meter. It has not been tested nor implemented with other types of USB compatible home blood pressure monitors. Hence, its applicability across different blood pressure meter platforms is yet to be identified.

VI. ACKNOWLEDGEMENT

The authors acknowledgement the support and guidance from all the academic and non-academic staff of the Biomedical Engineering Degree Program in General Sir John Kotelawala Defense University. Special thanks goes to the biomedical engineering batch of intake 31.

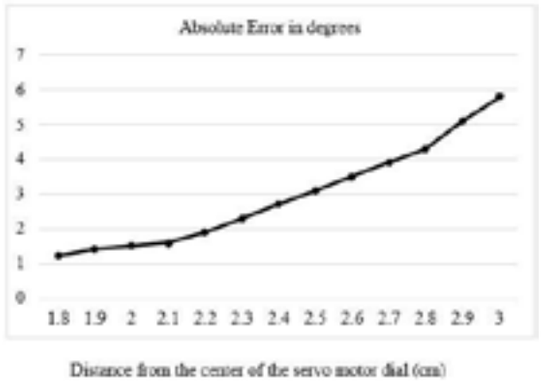

Figure 8. The graph of absolute error in degrees vs the Distance from centre of the servomotor dial

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Poster Session Paper

UPPER LIMB MOTION RECOGNITION BASED ON ELECTROMYOGRAPHY SIGNALS AND SUPPORT VECTOR MACHINE

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Abstract - The increasing requirements of the society to help physically disabilities, the old and the injured individuals to avoid many difficulties to do their day-to-day activities and increase their living condition. The upper limb forearm rehabilitative device has been expected to have a better solution for them. Because the traditional recovery system takes much time to get recovery. In this research, Surface electromyography (sEMG) signals were used as the intention command to movement identification of the upper limb forearm. Six types of major wrist movements collected by placing electrodes on four appointed muscles. Feature extraction was conducted under the Time Domain (TD) Statistical features. Mean Absolute Value (MAV) concluded to be the best feature extraction method for the classification, and it has higher accuracy and the low computational power than other statistical features in order to operate as real-time. The Support Vector Machines (SVM) is designed to conduct classifications task and the model was trained by using a linear classifier. The model operated as a real-time working device and trained the model using 128 features of 128ms. The prediction speed of the model was ~330 obj/sec. The whole process of the model was taken only 131.030ms. The study has obtained zero error rates via the confusion matrix.

Keywords: sEMG; Time Domain; Support Vector Machine; Upper limb

I. INTRODUCTION

The fast-growing science and technology play a significant role in the current society. A diverse range of technologies are launched to the world every day with the more and more new developed features. Humanoid robotics interfaces have always been a very interesting topic in the field of science and technology [1]. The signals which are the human body muscle generate known as the Myoelectric signals (MES). Myoelectric signals contain rich information [2] from which can detect user's intention in the form of a muscular contraction, using surface electrodes [3]. It is clear that amputees or disabled people can generate repeatedly, but gradually varying, myoelectric signal patterns during different levels of static muscle contraction or dynamic limb motion. These patterns used in a control system, known as a myoelectric control system (MCS), to control rehabilitation devices or assistive robots.

A large number of upper limb loss amputees seen in the world due to various accidents, sports injuries. The humanoid assistive robotic hands in the market could provide limited amputees. The reason of that, the most humanoid assistive robotic hands can adopt only for the ones who could give a command with a joystick or a keyboard. These types of hand control robotics are the most popular devices in the world of robotics. Such cases like this, hand free humanoid assistive robotic hands become more and more important.

The study intends to acquire the myoelectric signals of the hand muscles by using surface electrodes through a signal acquisition device. Then the filtered raw data should classify to move properly under the user's intention. The feature extraction is essential to improve the performance of the classifier, and for feature extractions, there can find three main feature in different Domains. Time Domain, Frequency Domain and Time-Frequency Domain [3-5]. The study intended to research the Time Domain. Many researchers have mentioned that the Time Domain contains the better interpretation for the EMG signal analysis.

When it comes to the feature extractions, there are many statistical features were based on the Time Domain. Such as mean absolute value (MAV), Variance (VAR), Standard Deviation (STD) Root Mean Square (RMS) and etc. [1, 2, 4]. Among the all these, this study intended to find the best accuracy statistical feature to apply for the prosthetic device. Moreover as a classifier, support vector machine (SVM) is commonly utilized [6-8].

II. EXPERIMENTAL PROTOCOL

First of all it is important to identify the wrist movements which are used further in this research.

A. Myoelectric Signals

Myoelectric signals are contain abundant information about the intention of a particular individual and also called a motor action potential, is an electrical impulse that produces contraction of muscle fibers in the body. The skeletal muscles that control voluntary movements. The signals have frequencies ranging from a few hertz to about 300 Hz, and voltages ranging from approximately 10 microvolts to 1 millivolt [9]. Myoelectric signals are the Electrical manifestation of the neuromuscular activation associated with a contracting muscle and formed by physiological variations in the state of muscle fiber membranes.

EMG is an Electrodiagnostic technique to measure muscle responses or electrical activities which are produced by the skeletal muscle [7]. The techniques can record and analyze myoelectric signals. Myoelectric Signals also knew as the EMG signals ones captured from the Muscles using the Electromyography.

B. Forearm Muscles

There are five muscle which helped the forearm to move the wrist, hand, and fingers. These muscles are Flexor carpi radialis, Palmaris longis, Flexor carpi ulnaris, Flexor digitorum superficialis and Extensor carpi radials longus. However, the Palmaris longis muscles are not always present. It is a small tendon in between the flexor carpi radialis and the flexor carpi ulnaris (Fig 7). Doctors have discovered that this muscle is absent in about 14 percent of the population.

So considering all these factors, there are four essential muscles which are very important for acquiring EMG signals.

C. Wrist Movements

This study utilized six basic wrist movements for recognition of Biosignals. Six wrist movements used for this study and movements types are respectively, flexion, extension, radial deviation, ulnar deviation, normal and close. It is exactly as per the images below (Fig 1 - 6).

Fig 1. Flexion

Fig 2. Extension

Fig 3. Radial deviation

Fig 4. Ulnar deviation

Fig 5. Normal

Fig 6. Close

D. Appling Electrodes to Muscles

The (Table 1) describes how electrodes associated with each muscles in upper limb.

Table 1. Applied electrodes

Hand muscles	Electrodes (Channels)
Flexor carpi ulnaris	1
Flexor digitorum superficialis	2
Flexor carpi radialis	3
Extensor carpi radialis longus	4

E. Data Segmentation

The study collected data from 20 people for the six wrist movements. Each data record was 512ms in duration (512 points for each channel), resulting a 512x4 matrix of segmented signals. For each type of action picked up 60 sets of data, which 30 groups were for the training datasets, and other 30 groups were for the testing datasets. These datasets are also known as trails. Moreover, the data inside the trails are called features.

III. FEATURE EXTRACTION

A. EMG Features

If these raw signals send directly for the EMG classification, the accuracy of the signals may decrease. Therefore extracting features of the EMG signals have been essential. Various types of EMG features were used to improve the performance of the classifier. Proceeding with Time Domain [4] is better since it's easier and it does not take more time like Fourier transform.

B. Time Domain Features

1) Time Domain: Extracting features of the Time Domain is usually quick and easy compared to the other two domains. Since these features were calculated based on the raw EMG time series, Time Domain do not need any other transformations [10]. Time Domain features extracted under many statistical features. Such as STD, MAV, RMS, and VAR. Extracted features mention in all below via diagram (Fig 8 - 11).

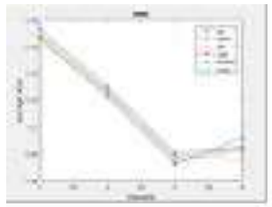

Fig 7. RMS

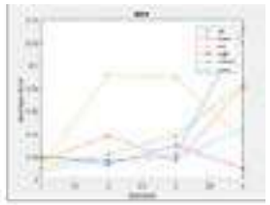

Fig 8. MAV

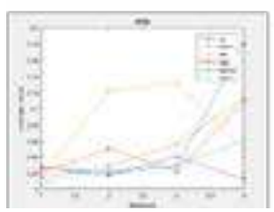

Fig 9. STD

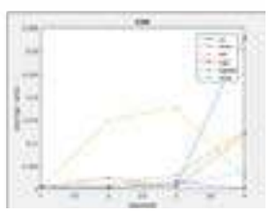

Fig 10. VAR

Different motion result gives different muscles the information about different channel that should be distinct, and it returns each channel ought to express particular character in muscles.

In order to get quick results, it is better to test extract features by reducing time frame. At the beginning, extracted features from 512 feature of 512ms. The testing was done using 256 features of 256ms and 128 features of 128ms.

The next step was data classification utilizing extracted features. In order to create a model machine learning, and MATLAB used for this study.

IV. DATA CLASSIFICATION

Data classification is the process of organizing data into categories for its most effective and efficient use. A well-planned data classification system makes essential data easy to find and retrieve.

Classification learner is an application on the MATLAB machine learning toolbox. It has the capability of training models to classify data. Utilizing the application can explore supervised machine learning. The app can explore the data, select features, specify validation schemes, train models, and assess results.

A. Support Vector Machine (SVM) for Classifications

The support vector machine is a classification method which is widely used for data analyzing and pattern recognition [8]. The SVM helped to create hyperplane between two or more data sets to recognize the class. SVM is base on the concept of decision planes that define decision boundaries and use supervised learning model, which has capability of analyzing large data sets in order to recognize a pattern. Classification is always done based upon the training and test datasets. The classifier separates two or more data sets into respective groups with a line known as a linear classifier. However, most of the classification tasks are not that simple to separate with a line.

B. K-Fold Cross Validation

K-Fold Cross Validation is the widely used cross-validation type in machine learning. The machine itself will partition the original given training data set into k equal sub-sets. Each Subset was called a fold. The value of the k takes any value as per the user's necessity. This research used 5 folds cross-validation. There were 5 subsets, and each subset included 20% of the full data, and 5 experiments conducted.

V. EXPERIMENTAL RESULTS

The four signals are acting differently for the same wrist movement. For example, the (Fig 12) shows wavelets of all four signals on the extension. The maximum amplitude for the specific movement is available in channel 4.

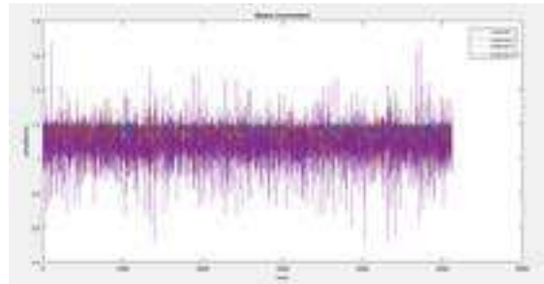

Fig 12. Extension signal

The below figures belongs to the flexion. As in the (Fig 13), the channel 4 has maximum amplitude in flexion. Therefore can get the result that the 4th channel gives precious information about the flexion.

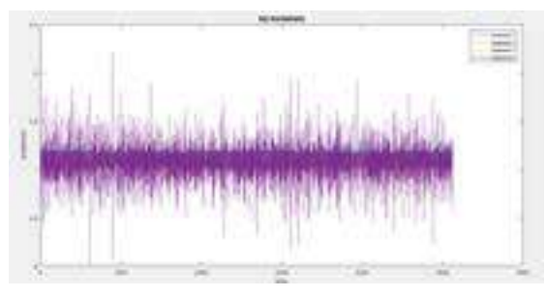

Fig 13. Flexion signal

The below figures belongs to the Radial deviation. As in the (Fig 14), the channel 2 has maximum amplitude in Radial deviation. Therefore can get the result that the 2nd channel gives precious information about the Radial deviation.

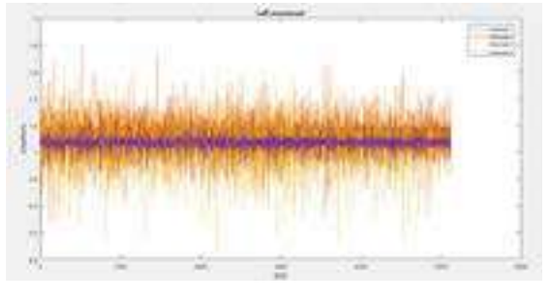

Fig 14. Radial deviation signal

The below figures belongs to the ulnar deviation. As in the (Fig 15), the channel 3 has maximum amplitude in ulnar deviation. Therefore can get the result that the 3rd channel gives precious information about the ulnar deviation.

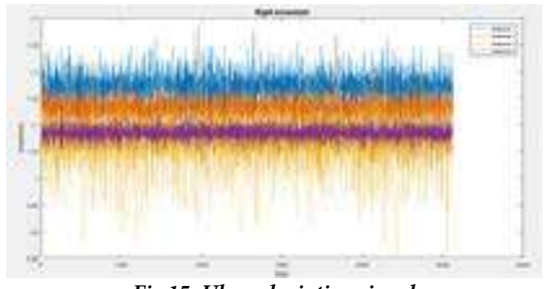

Fig 15. Ulnar deviation signal

The below figures belongs to the normal movement. As in the (Fig 16), the channel 4 has maximum amplitude in normal movement. Therefore can get the result that the 4th channel gives precious information about the normal wrist movement.

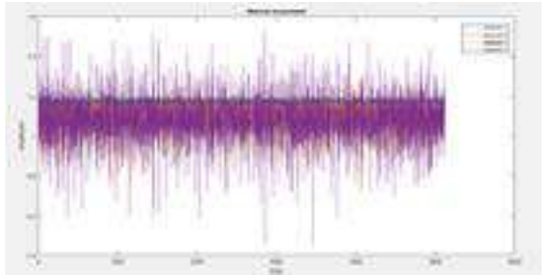

Fig 16. Normal movement signal

The below figures belongs to the close movement. As in the (Fig 17), the channel 4 has maximum amplitude in close movement. Therefore can get the result that the 4th channel gives precious information about the close wrist movement.

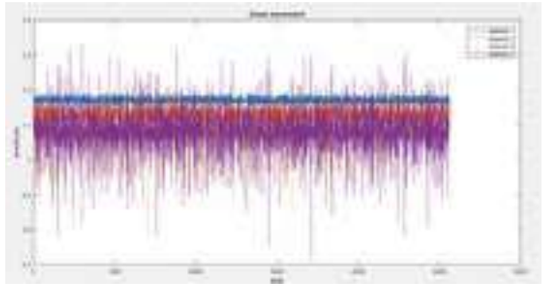

Fig 17. Close movement signal

For each wrist movement, there is a specific channel which has maximum amplitude. That means each four channels provide abundant information for the specific wrist movements. The below table (Table 2) contain the average values of four different Time Domain statistical features in four channels and the variation for six wrist movements.

Table 2. Average values

	Channels	STD	VAR	RMS	MAV
Flexion	1	0.02648	0.00070	1.16538	0.02008
	2	0.02064	0.00043	1.12223	0.01590
	3	0.02816	0.00079	1.07224	0.02095
	4	0.18050	0.03282	1.09181	0.13249
extension	1	0.02014	0.00040	1.16738	0.01592
	2	0.05013	0.00251	1.12493	0.0382
	3	0.02219	0.00049	1.07431	0.01577
	4	0.10839	0.01179	1.08297	0.08042
Radial de'	1	0.01347	0.00018	1.16312	0.01062
	2	0.12127	0.01477	1.12716	0.09152
	3	0.13203	0.01769	1.07915	0.08987
	4	0.04859	0.00238	1.07539	0.03487
Ulnar de'	1	0.02721	0.00074	1.17270	0.02069
	2	0.01694	0.00028	1.13028	0.01319
	3	0.04029	0.00162	1.08082	0.02991
	4	0.01230	0.00015	1.08466	0.00953
Normal	1	0.01409	0.00020	1.16865	0.01096
	2	0.02938	0.00086	1.12605	0.02178
	3	0.05517	0.00305	1.07693	0.03814
	4	0.11249	0.01269	1.08551	0.08393
Close	1	0.00843	7.12E-0	1.17041	0.00681
	2	0.02297	0.00052	1.12819	0.01751
	3	0.02944	0.00092	1.07795	0.01726
	4	0.06035	0.00365	1.08384	0.04456

Data were used to scatter plots diagrams of wrist movements according to each feature extraction type. Feature extractions were done in Time Domain in this study. The statistical feature extractions were graphed using scatter plots of six specific wrist movements are as follows (Fig 18 - 21).

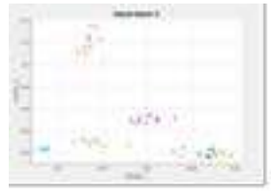

Fig 18. STD Plot

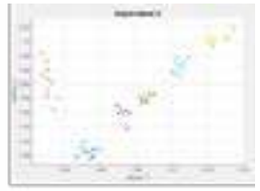

Fig 19. RMS Plot

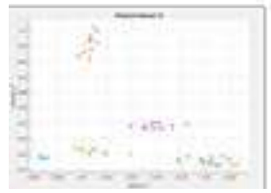

Fig 20. MAV Plot

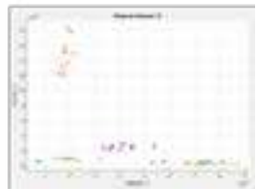

Fig 21. VAR Plot

In order to acquire signals with more speed accuracy was tested again by reducing features and time (Table 3).

Table 3. Accuracy testing by reducing the time

No. of Features and milliseconds	STD	MAV	RMS	VAR
512	100%	100%	100%	100%
256	100%	100%	100%	100%
128	100%	100%	100%	100%

Since the specific research under the supervised learning, the research has shown the accuracy of the model using this confusion matrix. The specific confusion matrix is shown below (Fig 22).

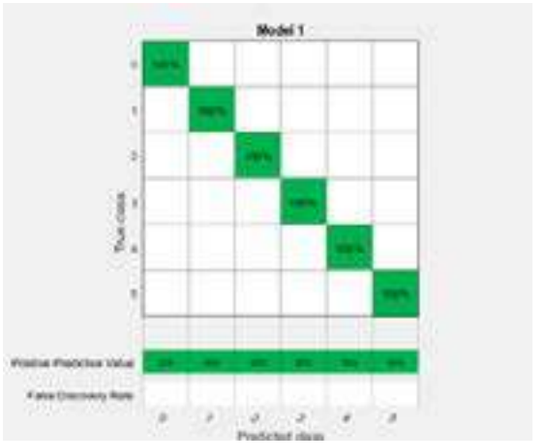

Fig 22. Confusion matrix of the developed model

As in the above (Fig 22), true classes 0 to 5 represent the actual wrist movements and in the predicted classes represent the predicted wrist movements. According to this confusion matrix the accuracy of the model is 100% and there are no errors at all. Therefore the model is running at 0 error rate.

VI. CONCLUSION

The study has successfully developed a wrist movement recognition system using Biosignals. All the experiments and tests obtained the intended accuracy of 100%. Six different wrist movement (extension, flexion, radial deviation, ulnar deviation, normal and close) studied under EMG signals of four different channels. Performance of each channel according to the specific wrist movement is clearly shown by the result.

To do classification is essential to extract the features. Feature extractions on the Time Domain and the algorithms used as STD, RMS, MAV and the VAR. From all these statistical features, MAV demonstrates as the best feature for the classification. Since its' higher accuracy and the low computational power in order to operate as real time.

Classifications explored through SVM experimentation. SVM was the most suitable application for data classification in this research. The model trained under the linear classifier since it is the most primary classification process. Finally, the results have shown that the all testing dataset were obtained 100% of accuracy with 100% of motion identification.

However, for a real-time working system, the time duration for the whole process should be within 300ms. When it comes to the model which was developed, it takes EMG signals of 128 mili-seconds specific to the wrist movement. Moreover, the speed of the model to identify the specific wrist movement is ~330 obj/sec.

Since it takes only 131.030ms for whole process of the model, which was developed and the specific model can apply to a real-time working system successfully.

The current model was developed by using SVM. For the future works, to develop the existing model by using the Hidden Markup Model (HMM) with SVM and model works as a hybrid model. Using hybrid model expect to get high accuracy for the very small movements of the upper limb.

ACKNOWLEDGMENT

I wish to express my sincere gratitude for my academic supervisor Mr. R.L Dangalla Lecturer, Faculty of Applied Sciences, for the encouragement and the enormous support that you have given to me to make my effort success.

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Poster Session Paper

A REVIEW ON ULTRASOUND IMAGE PRE-PROCESSING, SEGMENTATION AND COMPRESSION FOR ENHANCED IMAGE STORAGE AND TRANSMISSION.

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Abstract - Imaging is one of the key medical diagnostic tools to observe internal organs and soft tissues. One such tool is ultrasound scanning, which is highly utilized in gynecology and echo cardiogram. This is due to the number of advantages of ultrasound scanning, such as being non-invasive, free of radiation, economical and real-time. However, access to ultrasound scanning facilities remain limited due to the scarcity of human and physical resources. Therefore, developing technologies to remotely perform ultrasound scans using mobile devices to extend medical imaging facilities to rural and less accessible areas is becoming an interesting research area. This requires efficient compression of ultrasound scan footage in order to facilitate real-time transmission over a mobile network. Careful selection of the Region of Interest (ROI) is essential to compress ultrasound footage efficiently. Yet, it is a challenge due to distributions of various intensities depending on the imaging conditions, boundary ambiguities and speckle noise.

This review paper highlights state-of-the-art technologies for the careful selection of ROI of ultrasound images to facilitate ultrasound image pre-processing, segmentation and compression. Furthermore, the paper proposes directions for future research to develop existing methods. It is envisaged that these technologies will pave the path to develop new technologies that would enable better patient care in the future.

Keywords: Ultrasound images, Region of interest (ROI), Image segmentation, Image compression, Speckle noise removal

I. INTRODUCTION

Medical imaging is a heavily utilized technique by medical officers to visualize internal anatomy without opening the body. Among various medical imaging techniques such as CT, PET, X-Ray, Gamma etc ultrasound is one of the key techniques used for organ and soft tissue imaging due to several reasons. Ultrasound is a non-invasive imaging technique which is free of radiation. Additionally, it provides the real-time imaging possibility. Compared with other medical imaging techniques ultrasound is a low cost technique. Transmitting and storing the ultrasound medical images is important to overcome geographical distance barriers faced by patients and to assist medical trainees/ interns. That is, reducing the travel time and cost, getting the specialists' opinions on real time, avoiding the exposure of patients to microorganisms in crowded medical centers and assisting the patients in complicated situations who cannot be transferred (Kaur & Wasson, 2015; Mofreh et al., 2016; Lee et al., 2005). Additionally, storing the medical images in Hospital Information System (HIS) helps to keep the records of patient history and they can be used as an e-learning resource for medical trainees/ interns. However, maintaining the high quality of the medical images which are large in size is important while storing and transmitting the medical images. High bandwidth is required to transmit large size images which has a negative impact on cost and the time. Moreover, transmission of the data in rural areas is difficult where the network quality can be a barrier (havada et al., 2014).

To overcome the above mentioned obstacles, new techniques for pre-processing, segmenting and compressing of the medical images have been discussed and experimented over a decade.

Medical ultrasound images are inclined to have speckle noise which affects the image quality and the diagnosis process negatively. Therefore, it is important to remove speckle noise from the image in pre-processing steps.

Usually, in a medical image, only a small area contributes for the diagnosis. Hence, maintaining the high image quality in that area is sufficient until it does not lead to any erroneous diagnosis. Accordingly, image segmentation is carried out to extract the important area which is called region of interest (ROI) from the image. Next step is compressing the image to achieve more efficient image storing and transmitting. As mentioned earlier, maintaining the high quality in ROI is sufficient to preserve the diagnostic data. Therefore, in compression process carrying out lossless compression in ROI and lossy compression in the other areas of the image is acceptable until it does not affect the diagnostic process negatively.

In this review paper, de-speckling filters which have been used in pre-processing the image is discussed in section II. In section III, introduction to Region of Interest is given. In section IV and section V, image segmentation techniques and image compression techniques have been discussed respectively. In section VI, analysis parameters which can be used to do a qualitative analysis of results have been discussed. Finally, the paper is concluded and future directions have been given.

II. PRE-PROCESSING OF THE ULTRASOUND IMAGES

Despite the fact that ultrasound images provide many advantages such as being economical, radiation free, real time etc., ultrasound images are corrupted by various types of noise which affect the visual quality negatively as these are low resolution images which are constructed by using reflection of ultrasound waves. However, speckle noise shown in Figure 1, is significant in ultrasound images and it might cause negative impact on post-processing steps such as image segmentation and image compression.

Speckle noise is a combination of additive and multiplicative noise which is statistically independent from the original image. Image with speckle noise can be given by the mathematical equation given in eq 1.

$$g(m,n)=f(m,n)*u(m,n)+(m,n) \qquad \text{eq 1}$$

g(m,n) – corrupted image f(m,n) – original image

u(m,n) – multiplicative noiseη (m,n) – additive noise

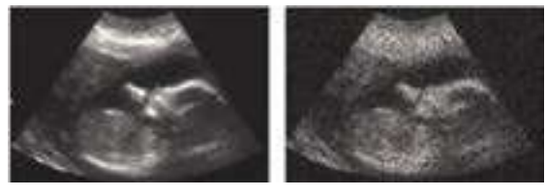

Figure 1 . Comparison between Fetal Ultrasound Image with a Fetal Ultrasound Image Degraded by Speckle Noise (Source : Latifoglu, 2013)

As speckle noise degrades the image quality and affects the diagnosis process negatively, it is important to de-noise ultrasound images, prior to diagnosis. De-speckling ultrasound images is an active research area in recent years. (Attlas, 2014; Jaybhay and Shastri, 2015)

There are various filtering techniques which have been used to remove speckle noise from medical ultrasound images namely, wiener filters, median filters, adaptive filtering techniques and transform based techniques including Fourier transform, Hilbert transform and wavelet transform.

A. Weiner Filter

Weiner filter which is known as least mean square filter in generally, has capability to minimize overall mean square error. Accordingly, this linear filter smoothen the image depending on the variance of the images. Additionally, Weiner filtering is one of the best methods to filter out both multiplicative and additive noise. (Rajesh, 2016).

B. Median Filter

Median filtering is another best known filtering techniques which have been used to remove speckle noise from an image. Median filters preserve the edges of the image while removing the noise.

C. Discrete Wavelet Transformation

In Discrete Wavelet Transformation (DWT) sampling is carried out in a discrete way as it name implies. DWT has a variable window size. Accordingly, time efficiency of DWT is high compared to Fast Fourier Transformation (FFT) as scaling can be performed.

DWT provides one more important advantage when processing medical images. It can be applied to the medical image in such a way where the transformation time duration taken for Region of Interest (discussed in latter sub topic) is greater than time duration taken for Non-Region of Interest to improve the time efficiency and preserve the important data in the area of Region of Interest.

Attlas and Guptha analyzed a de-speckling filtering model which includes median filter and Weiner filter along with DWT approach separately. Quantitative and qualitative results had proved that application of DWT along with median filter and Weiner filter improves the image quality compared with application of median filter and Weiner filter along to an image. (Attlas and Guptha, 2014)

III. REGION OF INTEREST

Each and every area of a medical image does not contribute to the clinical diagnosis equally but a very small area in the image is sufficient enough to make the diagnosis in most of the cases. Accordingly, medical image can be divided into three different areas namely, region of interest (ROI), Non-ROI and the background as shown in Figure 2. Extracting Region of Interest from a medical image is the process of image segmentation. Moreover, it is important to carry out an efficient image compression.

Region of interest is the smallest area in the medical image. Yet, it is the most important and considerable area as it contains the most critical information in the medical image (Kaur & Wasson, 2015).

Determination of ROI by manual, automatic or semi-automatic techniques is an active research area at present (Janaki and Tamilarasi, 2012; Norouzi et al., 2014).

Figure 2 . Different Regions in a Medical Image (Source: http://www.nova-medical.com/ultrasound-3d.htm)

IV. ULTRASOUND IMAGE SEGMENTATION

As mentioned earlier, segmentation is the procedure of extracting region of interest from the image. It is one of the important steps in medical image analyzing process. It helps to improve the time efficiency and cost efficiency in the coming steps of the analysis process.

There are several image segmenting techniques. Most of these techniques depend on the region or edge properties of an image. Under region based methods, thresholding based methods and region-growing based methods are the relatively popular as they are simple and efficient.

A. Thresholding based techniques

Simply, thresholding is the process of division of the pixels in the image into two as foreground and background depending on the threshold value selected according to the need. Pixels which are having greater or equal intensity to threshold value, are the foreground pixels. Pixels which are having less intensity than threshold value are the background pixels.

i. Global Thresholding

This is the one of the simplest methods of image segmentation. In global thresholding, foreground of the image is extracted from the image easily by assigning a threshold value. Yet it fails when the image background is not a constant and object is having different intensities in its pixels. In such cases, global thresholding might work for some regions in the image but fails in other regions.

ii. Variable Thresholding

Variablel thresholding provides different threshold values to different regions in the image. Initially, image is divided into sub-images statistically based on the mean, standard deviation, mean along with standard deviation etc. Then, thresholding is applied separately to each sub-image. Finally, they are merged to obtain the result. Variable thresholding can be categorized into two as adaptive and local thresholding. In adaptive thresholding, threshold value is a function of neighborhood X and Y. In local thresholding, threshold value is not a function of neighborhood X and Y but depends on them. This method is suitable for the images which are having varying backgrounds. However, this process takes time than global thresholding.

iii. Otsu's Thresholding

One of the critical disadvantages of thresholding is the manual selection of threshold value based on visual impact which is a subjective selection. To overcome this issue, methods such as Otsu's thresholding have been introduced where threshold value will be selected by an automatic process.

Thresholding provides the advantages such as being the simplest and less complicated method. However, thresholding is highly dependent on peaks. In addition, spatial details of the pixels are not considered when segmenting the image.

B. Region Growing Based Techniques

In the region growing based techniques, segmentation starts at a seed point and region grows depending on the intensity value of the neighboring pixels. The main disadvantage of region growing based techniques is the difficulty of selection of seed point. Manual selection of the seed point depends on the person's ability and it might leads to erroneous results. Selection of seed point by automatic or semi-automatic processes are active research areas recently (Norouzi, 2014; Kaur and Kaur, 2014)

Region growing techniques work best when the intensities of the objected to be detected is uniform and different from the background. This method is more immune to noise. But this is less time efficient and cost the memory too.

C. Edge Detection Techniques

Boundary properties dependent or edge detection based methods are another type of commonly used segmentation method. These methods depend on the rapid intensity changes in the image. There are different edge detection based methods which can be used to extract the region of interest from an image such as Canny edge detection method, Sobel-Feldman operator, Laplacian edge detection, Robert cross operator etc. In these methods, first the edges are detected and then they are joined together to form the object. The main disadvantage of this technique is that, it cannot be used where multiple edges are presented.

D. Partial Differential Equation Based Segmentation Methods

As these methods are relatively fast, they can be used in time critical applications. There are two main purposes of using PDE. Non-linear isotropic diffusion filter is used to enhance the edges and convex non-quadratic variation restoration is used to remove noise. Main disadvantage of this method is computational complexity.

E. Artificial Neural Network Based Segmentation Methods

These methods are based on the working principal of human brain. Neural networks are constructed of large number of nodes which are having particular weight in each. ANN based segmentation methods do not require complex computational programs. However, they are time in-efficient as they take time to train. (Yogamangalam and karthikeyan, 2013; Kaur and Kaur, 2014)

Recently, ultrasound image segmentation got much attention in the research field and novel advanced approaches have been introduced to segment the images.

Schmidt-Richberg et al. has proposed a new technique which integrates the information of the image with voxel probability maps generated by a fovFCN (Fovea Fully Convolutional Network) architecture based on deformable shape models. It is applied to 3D fetal ultrasound images to measure fetal abdominal circumference. The results of the experiment had shown that combination of fovFCN and deformable shape models performs better with mean-error of 2.24mm (Schmidt-Richberget al., 2017).

V. ULTRASOUND IMAGE COMPRESSION

Image compression is based either on irrelevancy reduction or redundancy methods. Frequently, both of the methods are used alongside with each other to improve the efficiency. There are two types of image compressions namely, lossless image compression and lossy image compression. Lossless image compression is used where critical data exists as in such cases, loss of information is not acceptable. Though the lossy compression is efficient in terms of time, memory requirement and cost in image storing and image transmission, it causes the data loss of the original image. The information of the original image may or may not be preserved. However, this is acceptable where the data of the original image is not critical. Lossless image compression is highly utilized in medical image compression as the data of a medical image is very critical. (Mofreh et al., 2016 & Anastassopoulos et al., 2002) Nevertheless, in some medical applications lossy compression of the full image or part of it is accepted until it doesn't lead to any erroneous diagnosis (Amri et al.,2017).

Most of the time, maintaining high image quality only in the ROI is sufficient (Gokturk et al., 2001). Accordingly, high compression ratio is acquired while maintaining high image quality by utilizing ROI-based compression where both lossy and lossless image compressions are performed. Initially, medical image is segmented into two as ROI and non-ROI. Then lossless compression is performed on ROI region and lossy compression is performed on non-ROI region (Janaki and Tamilarasi, 2012).

Hence, available bit budget can be non-uniformly distributed among ROI and non-ROI regions to enhance the efficiency of image compression. Comprehensively, bits of the ROI region are placed in higher bit-planes than the bits of rest of the image (Anastassopoulos et al., 2002).

VI. ANALYSIS PARAMETERS

Quality assessment of the pre-processed, segmented or compressed images is performed through analyzing various image parameters. There include,

1. Maximum Absolute Error (MAE)
2. Mean Square Error (MSE)
3. Root Mean Square Error (RMSE)
4. Signal-to-noise Ratio (SNR)
5. Peak Signal-to-noise Ratio (PSNR)
6. Compression Ratio (CR)

Maximum Absolute Error (MAE) is one of the most common objective performance measurements. It can be calculated by using eq 2 where F(I,j) is the original image and f(I,j) is the reconstructed image.

$$MAE = max(\left|F(i,j) - f(i,j)\right|)$$

Mean Square Error (MSE) is the second moment of the error function between the reconstructed and original image. To calculate MSE, eq 3 should be applied. M x N is the image size.

$$MSE = \frac{1}{M \times N}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}[\{F(i,j) - f(i,j)\}^2]$$

Root Mean Square Error (RMSE) is the square root of MSE as given in eq 4.

$$RMSE = \sqrt{MSE}$$

Signal-to-noise Ratio (SNR) can be calculated using the following formular given in eq 5

$$SNR = 10log\left[\frac{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left\{F(i,j)^2\right\}}{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left\{\left|F(i,j) - f(i,j)\right|^2\right\}}\right]$$

The ratio of the highest signal power to the undesirable noise power is the Peak Signal-to-noise Ratio (PSNR). To enhance the performance, higher PSNR should be assigned. PSNR can be calculated using the equation given in eq 6.

$$PSNR = \frac{20log_{10}(maximumpixelvalue)}{\sqrt{MSE}}$$

Compression Ratio (CR) is simply the ratio between the numbers of bits in original image and the compressed image. CR can be calculated using eq 7.

$$CR = \frac{Numberofbits(size)oftheoriginalimage}{Numberofbits(size)oftheoriginalimage}$$

(Mofreh et al., 2016; Anandan&Sabeenian, 2016; Attlas, 2014; Jaybhay&Shastri, 2015)

VII. CONCLUSION AND FUTURE WORKS

Ultrasound is one of the key imaging techniques used due to it's non-invasive nature, being free of radiation, real-time viewing possibility, being economical etc. Remotely performing ultrasound provides accessibility in consulting medical experts to patients in remote and less accessible places. Selection of Region of Interest (ROI) of the ultrasound image (Image segmentation) and image compression are two most important steps in the above mentioned process. However, automatic selection of the ROI is still a challenge due to speckle noise presents in ultrasound images which affects the image quality negatively. Therefore, it is important to pre-process the ultrasound images prior to image segmentation and image compression.

Ultrasound diagnosis is not based on only one picture but on sequences of images or a video. Therefore, it is important to carry out researches to identify active region in the ultrasound image sequence or in the video which we need to pre-process, segment and compress. Moreover, real time image transferring is another active research area where we can pay attention. Time efficiency and cost efficiency of the process is required for a better patient management.

This review paper analyzes the methods which can be used to pre-process, segment and compress ultrasound images. This analysis will be useful in implementing better pre-processing, segmentation and compression in medical ultrasound images to facilitate better patient management.

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PROCEEDINGS

CIVIL ENGINEERING

SESSION SUMMERY

CIVIL ENGINEERING – SESSION I

The technical session was chaired by Prof. Wasantha Mampearachchi, a professor in the Department of Civil Engineering of University of Moratuwa. The technical session speakers were, BMN Mendis, KAS Dilruk, KDP Damsara and TMNO Tennakoon.

The first speaker, Mr. BMN Mendis is currently working in S-Lon Lanka (Pvt) Ltd as an Assistant Maintenance Engineer. His presentation was on "Evaluating the Existing Conditions of Borupana Road and Identifying Measures to Reduce the Traffic Congestion". Based on his study, aiming at reducing the traffic congestion of Borupana road, he recommended that Borupana road should be widen to a four lane highway system. Further, he has identified three wheelers as a major factor causing congestion.

The second speaker, Mr. KAS Dilruk talked on "Factors Affecting Pedestrian Visibility at Night Time for Motor Cyclists". He has identified several factors affecting pedestrian visibility at night time and developed a statistical model to describe visibility distance in relation to the identified factors affecting pedestrian visibility.

The third speaker, Mr. KDP Damsara who is currently working as an instructor in the Civil Engineering Department of KDU presented his research work under the title "Introducing a New Traffic Operational Strategy to Minimize Congestion on Galle Road; Dehiwala – Wellawatta". In this research work, level of service calculations have been done for both Marine drive and Galle road using traffic survey data and a new bus route plan for Dehiwala intersection have been proposed.

The last speaker of the session was Mr. TMNO Tennakoon who is currently working as a Planning Engineer in International Construction Consortium. The title of his presentation was "Feasibility Study for a Shuttle System on Kandawala Road from KDU to Galle Road". He explained the methodology adopted in his study which is mainly based on a questionnaire survey. Further, he explained the analysis of data and presented his recommendations regarding a shuttle system for Kandawala road.

CIVIL ENGINEERING – SESSION II

The technical session was chaired by Prof. Jagath Manatunge, a professor in the Department of Civil Engineering of University of Moratuwa. The technical session speakers were, TANT Perera, MCL Peiris, EMPWME Werapitiya, NM Hakmanage and NP Seneviratne.

The first speaker, Ms. TANT Perera is currently working as a Demonstrator in the Computer unit of Faculty of Agriculture, University of Ruhuna . Her presentation was on "Characterization of Indoor and Outdoor Air Quality in Terms of Non-Methane Hydrocarbons of Sri Lanka". She mentioned that as per the experimental results, highest concentration of Non Methane Hydrocarbons (NMHCs) was reported in indoor locations compared to outdoor locations. Further, she revealed that semi urban indoor locations reported the highest significant average concentrations of NMHCs while rural locations reported the lowest average amount of NMHCs concentrations.

The second speaker, Lt. MCL Peiris who is currently working as a Senior Civil Engineer in Sri Lanka Navy Eastern Naval Area talked on "Influence of Vertical Greeneries to Gain Marks in Green Rating Systems for Multi-storied Buildings in Sri Lankan Context". In his presentation, he compared three most commonly used green rating systems in Sri Lanka and explained the scoring given by each rating system to vertical greenery. He concluded by saying that considerable percentage of points can be obtained with the positive effects of the vertical green façades.

The third speaker was Lt. EMPWME Werapitiya who is currently working as a Civil Engineer in Sri Lanka Navy Eastern Naval Area. Title of his presentation was "Seeking Professional Excellence in Water Management: Case Study on Trincomalee Water Supply Scheme". Based on his research work, he presented a substitution plan for water transmission and distribution considering the future demands of Naval Dockyard and Trincomalee town area.

The fourth speaker, Ms NM Hakmanage who is currently working as a Demonstrator in the Department of Statistics and Computer Science, University of Kelaniya presented her research work under the title "Time-Series Analysis of Monthly Rainfall Data for the Nuwara-Eliya District, Sri Lanka". She elaborated on the unit root study conducted on average rain fall of Nuwara eliya district since 1996 to 2015. Further she mentioned SARIMA (1, 0, 0) (1, 0, 2) (12) as the best model for forecasting rainfall in the selected region.

The last speaker of the session was Mr. NP Seneviratne who is currently working as a Civil Engineer in China Machinery Engineering Corporation. The title of his presentation was "Use of Activated Carbon (AC) to filter wastewater to treat landfill leachate". Based on his research work, he mentioned that AC has ability to trap micropollutants due to its high porosity. Further he compared the performance of quarry dust, sand, clay as well as AC in filtering wastewater.

FACTORS AFFECTING PEDESTRIAN VISIBILITY AT NIGHT TIME FOR MOTOR CYCLISTS

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Abstract - In Sri Lanka, most of the motorbike-pedestrian accidents happening in the night time are due to the insufficient visibility of pedestrians. Even though number of researches has been carried out globally regarding improving pedestrian visibility at night for other vehicles, unfortunately few researches have been carried out for motor bikes. In this study, factors affecting the recognition of pedestrians at night such as clothing colour of the pedestrian, rider's age, rider's gender and head light beam condition of the motor bike are considered. For this study white, black, green and red colours were considered as pedestrians clothing colour and four age groups of riders were taken into account. Moreover, head light beam condition of the motor bike was also regarded as head or dim. Experiment was carried out to find the visibility distances in relation to above mentioned factors and data collection method was time duration method and visibility distances were calculated with the help of measured time duration and speed of the motor bike. Experiment was carried out for constant speed of 30 kmph. Findings revealed that the rider's pedestrian recognition distance is affected strongly by the clothing colour of the pedestrian, head light beam condition of the motor bike and rider's age. Rider's gender does not affect pedestrian recognition distance strongly. It was also revealed that Black pedestrian clothing cannot be identified by the rider at a long distance in comparison to other colours. Meanwhile, green and red pedestrian clothing were identified in average distances. Findings showed that white can be identified by the rider at a longer distance than any other selected colours. Furthermore, statistical models were derived for visibility distance in the functions of considered factors.

Keywords- Pedestrian visibility, road safety, motorcyclists

I. INTRODUCTION

Most of the night time motor bike to pedestrian accidents will occur when riders fail to recognize the pedestrian at a reasonable distance. Because rider need some time to apply the brake which is called as 'perception-reaction time'. Within this reaction time period, motor bike moves a certain distance. So that there can be happen a collision. To avoid this situation, rider must have to recognize the pedestrian at a reasonable distance In Sri Lanka, most of the roads are deadlier at night rather than day time. Because in many areas in the country has no enough light condition to recognize a pedestrian at a reasonable distance.

The most efficient way to enhance the pedestrian visibility at night is by increasing the environmental lighting by means of street lights. It will help riders to recognize the pedestrians at a reasonable distance. But when it comes to rural areas where traffic congestion is relatively less, but vehicle speed limit high places, street lights are not common, and it is very much impractical to install. In that context, the aim of this research is to find out the contribution of other factors which affect to the pedestrian visibility at night. This research is going to be carried out to find out the relationship between recognition distance and the affecting factors.

Since there are many factors which affects to pedestrian visibility at night, I have selected only four major factors to this study. They are clothing colour of the pedestrians, age of the rider, gender of the rider and head light beam condition of the motor bike. In this study I have given the priority to the pedestrian's clothing colour in this study.

II. LITERATURE REVIEW

A study conducted by Rachel Rosenberg (2010) to practically examine the hypothesis which was predicted that there would be a main effect for head light intensity such that higher illumination intensities show larger estimated distances compared to lower intensities and also it was predicted that there would be no interaction between clothing and head light intensities on the estimated recognition distance. For this study he had considered 4 different head light beam conditions such as max, high, medium, low and four different pedestrians clothing colours. The considered clothing colours are street, black, white and retro-reflective vest. This study mainly focused on a situation in which a pedestrian is walking along a road way. To increase the accuracy of the results, pedestrians were randomly assigned and walking order of the pedestrians was varied (Rosenberg 2010).

48 participants were taken to this study and a set of questions were given to participants to evaluate their estimation. A mixed model 4 X 4 ANOVA revealed a main effect of clothing, indicating that when averaged across the 4 headlight intensity groups a significant difference in estimated recognition distance among the 4 clothing types was present. Data collection method was direct length measurement using road 4 tracer.

A research which was done by David Shinar in 1984 to examined the relationship between pedestrians' actual night time visibility and their estimated visibility distance with respect to head light beam, reflective tag and glare light. For this research he has taken 19 participants. Methodology of that research is similar to the current research and here he has collected time durations to calculate the visibility distances since vehicle speed was kept constant at 36km/h. His data analysis method was also same as the Rosenberg's study. Data analysing method was two-way analysis of variance of visibility condition i.e. actual vs. estimated visibility distance (Shinar 1984).

Newstead and D'Elia has carried out a study to identify the relationship between vehicle accidents and the vehicle's colour. Their study location was Victoria and West Australia. Here they have considered two independent variables such as vehicle colour and light condition. D'Elia investigated 17 vehicle colours. They are black, brown, blue cream, gold, green, fawn, grey, mauve, maroon, orange, purple, red, pink, silver, yellow, and white. As I above mentioned, they have considered two light conditions, consisting of daylight condition and combined dawn and dusk conditions.

According to the results of his research for the daylight condition, blue, red, silver, gray and black vehicles had the highest crash risks in ascending order. Also, for the dusk and dawn condition, silver and black vehicles had the highest risk in ascending order at 5 percent significance level (AngeloD'Elia 2010).

Another similar research found which was done by Patrick Rosopa about accuracy of drivers' judgments of pedestrian conspicuity while facing varying degrees of headlight glare. He also carried out an experiment using 21 participants. He has selected the participants by considering driving experience and their gender. In this study two independent variables were manipulated within-subjects. Patrick Rosopa has considered about two pedestrian clothing colour and three different glare intensities. The field study was done in an open two-lane roadway with relatively low traffic density. All the Participants in experiment have given a response keypad which connected to a laptop. When the particular response button was pressed, the distance between the test vehicle and the glare vehicle or pedestrian location was calculated with the help of the measured vehicle speed. The test vehicle had maintained a constant speed of 35mph. (Rosapa, et al. 2012).

III. METHODOLOGY

To carry out this study the location was selected by considering the street lights availability and the traffic congestion. Experiment was planned to do in a relatively less traffic congestion area at night. Sitinamaluwa-Aluthwewa-Mulana road was selected for this study since there is no any street lights and have relatively low traffic congestion at night. Moreover, this road is an unlighted road. It was helpful to reduce the disturbance which can be occurred by environment lights. Because study was planned to carry out in dark environment condition and the only lighting condition as motor bike's headlight beam. This road is 3.5m width and there is no any significant building or anything which disturb the experiment and both side of the selected road section were coconut crops.

Here only considered four pedestrian clothing colour for the study. They are black, red, green and white. These colours were selected for this experiment because in Sri

Lanka these colours are widely used as clothing colours. For this study, used that above mentioned four different colour t-shirts and same dark blue colour bottom for every pedestrian as their clothing condition. Same time no any gloving or shining jewelleries or watches worn during the experiment.

For this study only considered two main headlight beam conditions which are called as head and dim. Environment light condition used as dark surrounding, without street lights and any disturbing light source.

The participants were selected by considering their age and their gender. Seven male participants and three female participants were selected for the experiment. Moreover, these participants were divided in to four age categories such as 15-29, 30-44, 45-59 and 60-74 years of age groups. All participants have valid Sri Lankan driving license and all are having minimum four years of driving experience.

This experiment was planned to do with a same motorbike for all the participants. Because there can be different light conditions for different bikes. Because of that reason the visibility distances which measured in the study would be deviate. So, using a same bike for every test ride can avoid that error. Since here considered about the gender of the participants, a common motor bike which can operate by male and female participants had to be selected. Therefore, a scooter was selected as experiment vehicle.

The experiment was carried out and collected the data in above mentioned location by considering previously discussed factors. When it comes to the procedure of this experiment first of all, collected the details of every participants such as age, gender and driving experience. Then randomly selected two participants, one as rider and other one as pedestrian. Next kept the pedestrian with a certain clothing colour at a clear point of the road and the other participant was asked to ride the motor bike at the speed of 30 km/hr and maintain the constant speed as much as possible. And also head light beam condition also kept as head or dim condition. When rider confidently see the pedestrian, he or she may have asked to press the horn and same time the stop watch was started. Stop watch was operated by another person in the motor bike back seat. After motor bike passed the pedestrian, rider again sound the horn and, time duration between two horn sounds was measured by the observer in back seat.

Similarly, the same procedures were carried out for the different pedestrian clothing colour and different head light beam conditions. All participants were involved into the same procedures. Same time the pedestrian's location was changed for every test ride because if the pedestrian placed on an exact location the rider may expect the pedestrian from there for every test ride. So, it will affect to find the real visibility distance. Moreover, pedestrian clothing colour was changed without informing the rider. So, the rider did not know what the pedestrians clothing colour is until he really see the pedestrian. There need to be done eight test rides for each participant and all together 80 test rides were done. The test rides were recorded by a quality video camera and time durations were measured by a stop watch.

IV. RESULTS AND DISCUSSION

To find the relationship between age and the visibility distance I have divided all the test results in to four age categories. The age categories are 15-29 year, 30-44 years, 45-59 years and 60-74 years. All groups have given a representing code number 1 to 4. There was at least one participant for each age group.

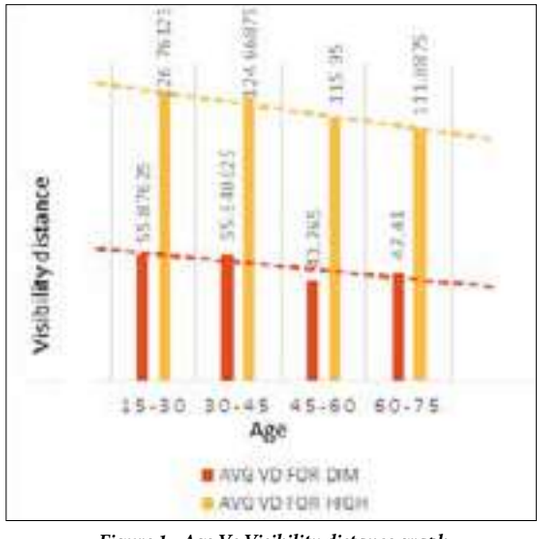

Figure 1. Age Vs Visibility distance graph

To find the relationship between gender and the visibility distance I have separated the test results in to male and female. There were three female participants and seven male participants. Since I wanted only to identify the relationship between gender and visibility distance I did not considered any other factors except the gender. Here I have given two code values for these two groups, No 1 as female and no 2 as male.

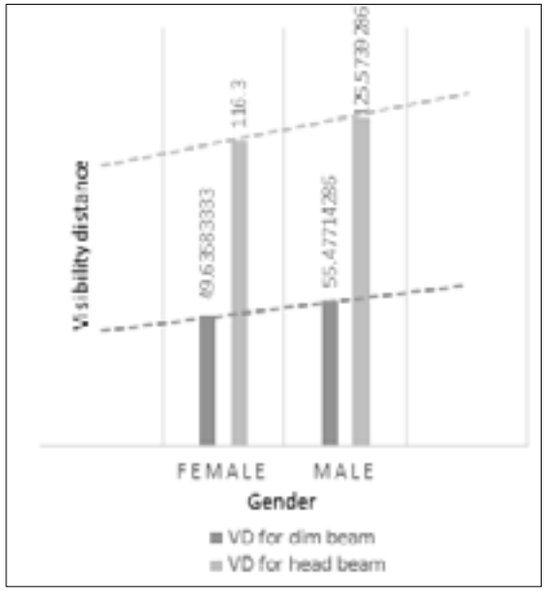

Figure 2. Gender Vs Visibility distance graph

In this research four different types of pedestrian clothing colours were considered. For each colour, average visibility distance was calculated. The colour code values were given in the ascending average visibility distance order. Values were given from 1 to 4. Black, green, red and white respectively 1, 2, 3 an4. These procedures were carried out for high and low beam conditions separately.

After carry out the descriptive analysis it was identified as all four factors have a linear relationship between visibility distances. A function for visibility distance was derived in terms of those four factors using multi regression theory. The multi regression analysis was carried out by using Microsoft office excel software. Visibility distance is selected as the dependent variable and all other four factors (rider's age, rider's gender, head light beam condition of the motor bike and pedestrian clothing colour) selected as independent variables.

Y=(-4.97"X1")+(9.62"X2")+(11.75"X3")+(69.63"X4")-52.17

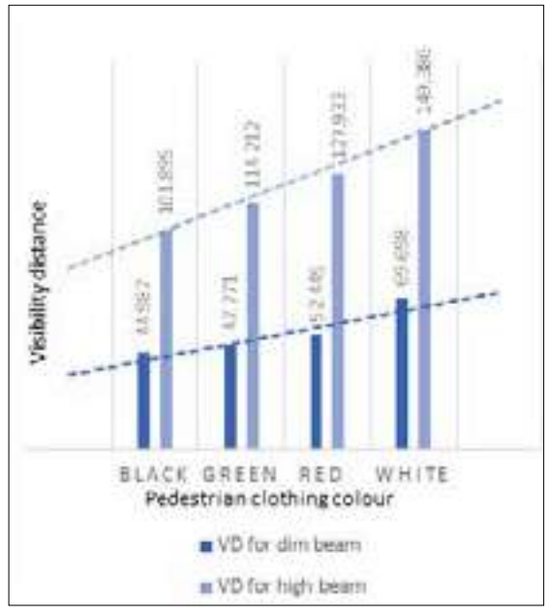

Figure 3. Pedestrian clothing colour Vs Visibility distance graph

In this statistical model Y is representing as the visibility distance in meters." X1", "X2" , "X3" and "X4" the independent variables." X1" Is representing as given value for the age groups. It varies from 1 to 4. Age 15-29 as 1, 30-44 as 2, 45-59 as 3 and 60-74 as 4." X2" Represent a given value for gender groups and it has only two groups which no 1 for female and no 2 for male." X3" Represents the given value for the pedestrian clothing colour. Since I only used four clothing colours for this study its value is varying from 1 to 4 and value 1 for Black colour group, 2 for green colour group, 3 for red colour group and 4 for white colour group. The last independent variable "X4" is representing as the given value for the bike's head light beam condition. Here I only considered two main light conditions which are head light beam and dim light beam. Values given as 1 for dim light beam and 2 for head light beam.

To check the accuracy of the model there selected twenty test results and their estimated visibility distances randomly. When selecting those twenty test results it had taken ten test results for dim light beam and ten test results for head light beam. After that selected actual visibility distances were plotted on a graph against their estimated visibility distances by the developed statistical model.

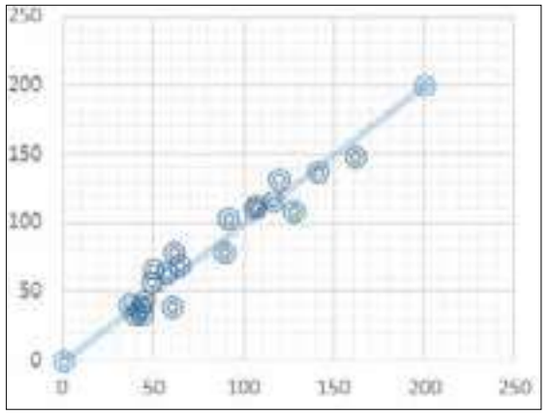

Figure 4. Actual visibility distance Vs Estimated visibility distance graph

Above derived statistical model results show that predicted pedestrian visibility distances have no any significant deviation with actual pedestrian visibility. There were few outlier data and those data were removed from the model to increase the accuracy of the model.

The visibility distance estimating model was derived with the assumption of linear variation between visibility distances with each factor. Also, due to the time limitation a limited number of participants and limited numbers of pedestrian clothing colours were used for this study. It could mainly affect the final output. Because it could have some errors in the assumption of linear variation with limited number of data. There could be some other multi regression variation between each factor. Other than that, experiments were conducted in four different days with same weather condition and same light condition.

This study mainly focused on the factors which affect pedestrian visibility at night for motor cyclists. The results strongly demonstrate that the clothing colour of pedestrian, head light beam condition of the motor bike, age and the gender of the rider significantly affect the visibility distance of pedestrian in night times. Moreover, the graphs which were developed against visibility distance and above considered factors, all the considered factors has a linear relationship between visibility distances.

The clothing colour of the pedestrian is the most significant factor which highly affect to pedestrian visibility at night among all other considered factors. Black colour pedestrian clothes had the lowest recognition distance among the considered four colours. Green colour and red colour had no significant low or high recognition distance. When compared to other colours white colour had a significant recognition distance. Head light beam is also had a significant effect on recognition pedestrians at night. Moreover, pedestrian clothing colour is highly affect visibility distance when using head light beam more instead of using dim light beam. Overall, changing from low beam to high beam improved visibility distances in all cases.

In two head beam conditions, rider's age was a good contributing factor of visibility distance. It could be possible when age increasing means the rider getting older. Normally with the age, people' eye vision decreases. By this effect age may affect the visibility distances significantly. When compared to the age factor, gender factor is not affect to the visibility distance significantly.

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V. CONCLUSIONS

- When considering the results of the regression analysis, Developed statistical model is accurate enough to estimate the pedestrian visibility distance with relevant to considered factors. Since the R square value was 0.91, accuracy of the developed model was ensured.
- Rider's pedestrian recognition distance is affected strongly by the clothing colour of the pedestrian, head light beam condition of the motor bike and rider's age. Rider's gender does not affect pedestrian recognition distance strongly.
- Black colour pedestrian clothing cannot be identified by the rider at a long distance than other colour. Meanwhile green colour and red colour pedestrian clothing can be identified in average distances. White colour can be identified by the rider at a longer distance than any other selected colours
- White colour dress is safer in night for pedestrians and people who wear black should be aware of their visibility to the vehicles in night. Moreover, not wearing dark colour cloths at night increases pedestrians safety
- In high beam condition, clothing colour was the most highly affecting factor in the recognition of pedestrian in night
- In low beam condition or high beam condition, rider's gender was not a significant factor in recognition of pedestrian in night
- Riders age is also highly affect to the pedestrian's visibility at night. Older age riders should aware about the speed of the motor bike at night time due to low recognition distance
- Overall, changing from low beam to high beam improved visibility distances in all cases

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INTRODUCING A NEW TRAFFIC OPERATIONAL STRATEGY TO MINIMIZE CONGESTION ON GALLE ROAD; DEHIWALA – WELLAWATTA

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Abstract- The increase in private traffic demand coupled with a number of issues such as reduced utilization of high occupancy vehicles, lack of capacity of public modes of transportation, inefficient road capacity leads to highly congested roads in Colombo city. Traffic control infrastructure has led to a degradation in the speed of vehicles on the roads of Colombo city resulting in higher operating costs for vehicles and greater congestion and pollution throughout the city. This study intended to suggest proposals to reduce the traffic congestion on Galle road by introducing designing and planning strategies ensuring optimum utilization of Marine Drive. Level of Service (LOS) estimations on Galle Road and Marine Drive clearly indicated that the traffic condition in Galle Road in the section from Dehiwala to Wellawatte, was very poor during peak times. It can be seen that traffic control measures that have already been undertaken, have not answered this traffic congestion problem completely. Even though Marine Drive has been introduced as a solution for this traffic congestion, which has resulted in reducing traffic, should be optimized to take maximum advantage of it. Field observations and Level of Service estimations indicated that the level of utilization of Marine Drive to avoid traffic, was poor. In this case, three proposals have been introduced by this study which are, structural design of Marine Drive extension from Wellawatte to Dehiwala, bus route plan accompanied with re- routing of long distance bus services and intersection plan for Dehiwala junction. Findings and proposals of this project will be helpful to minimize traffic congestion in Galle Road during peak times, at the same time reducing the negative social, economic and environmental impacts.

Keywords- Congestion, Traffic Management, Marine Drive

I. INTRODUCTION

Colombo is named as the commercial capital of Sri Lanka which consists most of the Trip attraction points such as government and private offices, Shopping malls, Hospitals, Hotels, and Schools. The main harbour of the country is also located in Colombo Metropolitan Region (CMR).

However, it has been identified that there is a mobility issue within the Colombo Region. Average travel speed in CMR is limited to 17 km/h. Furthermore it is reduced to 12 km/h in Colombo Municipal Council (CMC). (JICA, 2015) Clearly at these service levels, economic growth is likely to slow down.

According to the JICA (2014) report 1.9 million daily passengers enter the CMC limits each day using 7 corridors: namely, Negombo Road (A3), Kandy Road (A1), Low level Road (B435), Malabe Road (A0-B240), High level Road (A4), Horana Road (B84) and Galle Road (A2). Other than that, 10 million passenger trips generated within the CMR daily. But the problem is with the increase of population, number of private vehicles entering the city is increasing because the public transport share is gradually declining from 65% (1985) to 47% (2013) on the roads (JICA, 2014).

When considering the Galle Road, a huge traffic flow is generated in the morning peak as well as in the evening peak in between Dehiwala and Wellawatta section. Congestion ends in Wellawatta when four lanes are given in one direction and it becomes a one-way road. Marine Drive should be effectively used in order to reduce the traffic congestion on Galle Road.

Considering all those factors, further studying and creating an effective urban plan is highly needed at this moment. For that, all the factors affecting the traffic congestion need to be considered in order to give an effective solution.

The main objective of this study is to identify possible alternatives to improve level of service on Galle road during peak hours with the use of road improvements and new traffic plans.

Structural design of Marine Drive extension from Wellawatte to Dehiwala, bus route plan accompanied with re- routing of long distance bus services and intersection plan for Dehiwala intersection are the proposals which have been introduced by this study.

When deciding a solution, it should have sufficient validity to match with future demand (Wells, 2017). Therefore, demand forecasting is also very important. Megapolis master plan is one of the key projects which will generate more traffic in CMC city limits in the near future. Therefore, it has been considered in this study too.

There are two main issues in current transport conditions in Galle Rd corridor. Even though, Galle Rd corridor has the highest railway modal share among the seven corridors, it has poor availability of feeder services to travel between railway stations and the Galle Rd corridor. The other issue is, the bottleneck in Galle road at Dehiwala fly-over section which generates more traffic in peak hours. In order to eliminate that, bus route plan accompanied with re- routing of long distance bus services and intersection plan for Dehiwala junction has been considered in this study.

II. METHODOLOGY

Galle Road and Marine Drive were the main two roads considered for this study. Initially the Level of Services of the above two roads have been estimated according to Highway Capacity Manual 2000 (HCM 2000).

Intersection turning movement counts have been carried out in selected two locations in order to estimate the traffic volumes in Galle Rd and Marine Dr. These data have been used to identify the peak hour where the maximum flow occurred. The influence of large vehicles on vehicular traffic flow have been identified through converting them to passenger car units (pcu). The length of the sampling period depends on the type of count being taken and the intended use of the data recorded.

Bus volume survey was carried out to analyse the number of busses entering the Colombo city via Galle Corridor and to identify the variation of their capacity with the demand. The long distance busses and short distance busses have been recorded separately along with their cluster type and the number of seats occupied. The location for the bus volume survey was decided as Dehiwala junction (under the flyover) due to the proper visibility, space, and ease of counting. Separate survey form was prepared to record the route, time, cluster type and occupancy level etc. This survey was carried out for both directions that is from Colombo to Dehiwala and from Dehiwala to Colombo. Data collected from bus volume survey has been classified into hourly basis and route basis. Bus demand per each hour is calculated thereby and the count of demand is defined according to a certain criterion of value adopted. The buses travel across the provincial boundaries were considered as long-distance buses and they were sorted out separately. The total passenger demand of long distance buses has been calculated in hourly basis. The data of the long-distance buses has summarized in hourly basis, taking the bus count and the calculated passenger demand as shown in the following table.

Intersection turning movement counts were taken to collect traffic data which was required for LOS determination of the Marine Drive and Galle Rd. Surveys has been conducted in both morning peak and evening peak for selected two locations. From the preliminary site visits, the most effective places to take turning movement counts were identified. These locations were selected based on higher frequency of utilization and less difficulties in counting.

Location 01: In Galle road, near Frazer Avenue (one of the most congested intersection in the Galle road as per the preliminary site observations).

Table 1: Evaluation of passenger loadings for long distance buses (Dehiwala to Colombo direction)

Hour	Number of buses	Total hourly demand
7:30-8:30	23	1115
8:30-9:30	37	1591
9:30-10:30	25	981
10:30-11:30	23	863
11:30-12:30	24	1079
12:30-13:30	22	700
13:30-14:30	20	686
14:30-15:30	21	610
15:30-16:30	17	537
16:30-17:30	20	687
17:30-18:30	22	933
18:30-19:30	20	606
Total for 12 hours	**274**	**10387**

Location 01:

Figure 1: Turning movement at location 1

Collected data for 15 minutes time intervals were used to evaluate hourly traffic volumes which were required for LOS calculations. Level of Service was estimated according to the HCM 2000. The Geometric data of the Marine drive and Galle road were obtained from RDA and CMC respectively. Required vehicular flow data were gathered through the traffic surveys and free flow speed was estimated using the base free flow speed which has been taken by considering the speed limits given for the roads with the adjustments given in HCM 2000.

Location 02: In Marine drive near the Ramakrishna Road

Figure 2: Turning movement at location 2

Galle road morning peak LOS calculations are shown as follows as a sample. Collected data for 15 minutes time intervals have been evaluated in order to find out the peak hour factor.

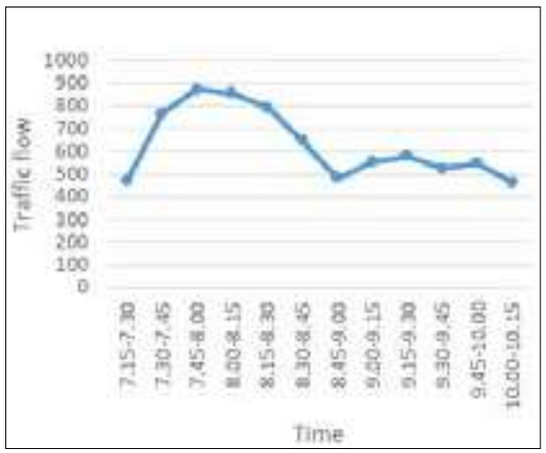

Figure 3: Traffic flow - Galle Road (Dehiwala to Kollupitiya)

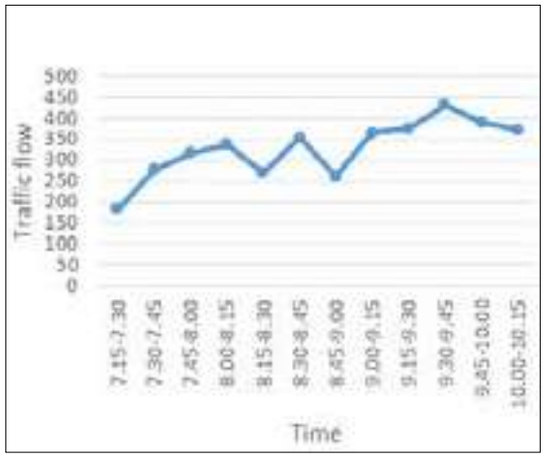

Figure 4: Traffic flow - Galle Road (Kollupitiya to Dehiwala)

From figure 3 and figure 4 peak 15 minute volume and peak hour factor can be calculated as table 2.

Table 2: Peak hour factor calculation

For both directions	
Peak hourly volume	4080
Peak 15min volume	1195
Peak hour factor	0.853556

Then the LOS has been calculated as shown in the table 4 and it has been shown in table 3.

III. RESULT AND DISCUSSION

From Table 3, it can be seen that the traffic condition in Galle Road during peak hours is heavily congested compared to Marine Drive. As a solution, extension

Table 3: Existing LOS details of Galle Rd and Marine Drive

Direction	Dehiwala to Colombo	Colombo to Dehiwala
hourly peak vehicle volume (veh/h) in one direction (V)	2965	1570
number of travel lanes in one direction (N)	2	2
driver population factor (fp) - for commuter traffic	1	1
Peak Hour Factor (PHF)	0.854	0.854
decimal portion of trucks/buses – Pt	0.069	0.16
decimal portion of recreational vehicles – Pr	0	0
passenger car equivalents (trucks/buses) – Et	1.5	1.5
passenger car equivalents (recreational vehicles) – Er	1.2	1.2
heavy-vehicle adjustment factor (fHV)	0.967	0.926
15-minute passenger-car equivalent flow rate (pc/h/ln) - vp	1796	993
base free-flow speed (mi/h) – BFFS	75	75
Lane width (m)	3.3	3.3
Adjustment for lane width (km/h) (Exhibit 21-4) – fLW	3.1	3.1
Lateral clearance from the right edge of travel lanes (m)	0.25	0.25
Lateral clearance from the left edge of travel lanes (m)	0.75	0.75

Direction	Dehiwala to Colombo	Colombo to Dehiwala
Total lateral clearance (m)	1	1
Adjustment for lateral clearance (km/h) (Exhibit 21-5) - fLC	3.93	3.93
Adjustment for median type (km/h)(Exhibit 21-6) – fM	0	0
No of access	122	38
Length of the road segment (km)	5.8	2.2
Access point density (No. of access points/km)	21	17
Adjustment for access-point density (km/h) (Exhibit 21-7)- fA	14	11.3
estimated free-flow speed (mi/h) – FFS	53.97	56.67
Average passenger car travel speed (km/h) – S	74.6	56.67
Density (pc/km/ln) – D	24.1	17.5
From Exhibit 21-2: Level of Service	E	D

Table 4: LOS calculations

Road	Time	Maximum density (D)	LOS
Galle Road			
Dehiwala to Colombo	Morning peak	24.1	E
	Evening peak	20.1	D
Colombo to Dehiwala	Morning peak	17.5	D
	Evening peak	25.6	E
Marine Drive			
Dehiwala to Colombo	Morning peak	20.4	D
	Evening peak	14.5	C
Colombo to Dehiwala	Morning peak	9.2	B
	Evening peak	16.4	D

of Marine Drive up to Dehiwala intersection has been designed to cater a new traffic plan which was tested for its potential to reduce the congestion in Galle road during peak hours.

It can be seen that the vehicles passing the Dehiwala junction without using flyover make much traffic on the Galle Road. It has been identified that the main reason for this traffic is the restriction for buses and other heavy vehicles to use the flyover. After the extension of Marine drive up to Dehiwala, Station road will be used as the main access to Marine drive. Proposed extension of Marine drive will connected to Dehiwala junction as a two lane road.

Currently there are more trip attraction points on Dehiwala junction such as Banks, ATMs, textile shops market, post office, apartments. So that land acquisition might be a massive problem. According to the new implementation, land from Northern side of the station road up to 100m from the junction may have to acquire since several movements will occur towards the station road. Currently bus stops are occupied on the Galle road near to the flyover. With new proposal the bus stop for the long distance busses towards Colombo will be moved to the station road. All the other vehicles travel towards Colombo and Galle will use the flyover except buses and the traffic flow indicate by green colour in the below figure will always flow without any interruption. Then the flow indicated from blue, yellow and red will flow respectively with the control of the traffic lights. With proposed Marine drive extension, all the long distance busses travelling towards Colombo will be directed to the Marine drive. So that width of the station road may not be enough for the traffic flow. Hence the proposed land must be acquired for station road expansion.

With the Marine Drive extension, all the vehicles coming from the Marine Drive directly move towards Dehiwala junction. Near to the Dehiwala junction it is preferred to control the entrance of vehicles to Galle road by traffic lights because crossing of Galle road will increase the traffic condition. All the long distance busses which travel towards Colombo will be shifted to the extension of Marine drive from Dehiwala intersection. Bus Stop for long distance buses will be located on Station road in order to avoid the generation of traffic due to loading and unloading. Passengers who needs to travel on Galle road whose destinations are located along the Galle road can be shifted to the buses of route numbers 100, 101, 154, 155 from Dehiwala. Long distance buses will travel through the Marine Drive with limited stops near the railway stations situated along the Marine drive. Ultimately it will reduce the travel time for the public bus users who travel towards Colombo Fort and it will promote the use of public vehicles in the city.

The access roads connecting the Marine drive and the Galle road has been selected by considering the visual observation and land use patterns of the area. Following Figure illustrates the access road restriction plan for the proposed extension of Marine Drive. Marine Drive extension will be four lane road and Frazer Avenue road is two lane road. Senanayake road, Ferlaine road, Rodrigo Lane and Gregory Lane can used to enter to the Marine Drive due to the residential Availability. If the vehicles need to access the Galle road, they can use the Station road.

According to the proposed plan Station Road and Frazer Avenue roads are open for both ways. De Alwis Place and Muhandiram Lane can also be used to enter the Galle Road. These alternative roads can reduce the amount of traffic entering to Dehiwala intersection from Marine Drive at once. Peter's Lane is a short distance dead end road and it can be used only by residents. Due to limited availability of space in all roads, it is effective to use minor access roads as one way roads. Frazer Avenue can be used as a two way road because of the availability of space. This traffic plan has been proposed by visual observation considering the lane width of the particular connectors and to minimize conflicts in turning movements at junctions. It has also concerned about the existing residencies of those minor access roads and less impact for them.

Table 5 indicates the number of lanes, lane width and right of way (ROW) of the connecting roads.

Table 5: Details of connecting roads

Road Name	No. of Lanes	Lane width (m)	ROW (m)
Frazer Avenue	2	2.6	2.0
Rathnakara Place	2	2.6	0.5
Intium Place	1	4.0	0.5
Albert Place	1	5.0	0.5
Camble Place	1	2.7	0.5
2nd Lane	1	4.2	0.5
Peters Lane	1	4.0	0.5
Muhandiram Lane	1	2.5	0.0
Vandwart Place	1	3.9	0.5
De Alwis Place	1	1.5	0.0
Fair line Road	1	3.5	0.5
Rodrigo Lane	1	2.5	0.5
Gregory Lane	1	2.0	1.0
Station Road	2	3.3	3.5
Senanayake place	1	3.9	0.5
Ramanathan Ave	2	3.0	0.5

V. CONCLUSION

The traffic congestion in Galle Road in the section from Dehiwala to Wellawatte in the peak hours have resulted numerous negative social, economic and environmental impacts in the recent past. LOS studies of this study prove that the need of a proper transport plan in order to cater the future traffic generation with the mass development of the city. It can be seen that traffic control measures that have already been undertaken, could not answer this traffic congestion problem completely. Therefore, this study was focused on introducing a new traffic operational strategy to minimize congestion on Galle Road by optimum utilization of Marine Drive. Three measures have been introduced that ensure the effective use of Marine Drive in order to reduce the traffic congestion on Galle Road. Which are;

- Design of Marine Drive extension from Wellawatta to Dehiwala intersection
- Bus Route Plan accompanied with re-routing of long distance bus services

- Intersection plan for Dehiwala intersection where the new access road for the Marine Drive extension would be located.

With the proposed solutions, it will reduce the travel time of the road users specially who use public transport services for travelling. It will ultimately increase the use of public transportation and reduce the number of vehicles entering the Colombo city. If the proposed transport plan will be implemented with the help of relevant authorities, it will ultimately reduce traffic congestion in Galle Road during peak times, and at the same time reducing the negative social, economic and environmental impacts.

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INFLUENCE OF VERTICAL GREENERIES TO SCORE POINTS IN GREEN RATING SYSTEMS FOR MULTI-STORIED BUILDINGS IN SRI LANKAN CONTEXT

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Abstract - Green rating systems have become more significant factor to enhance green construction practice and saving energy of a building. Vertical greens and its influence on green rating systems to score more points, is the key concern of this research. Especially the vertical greenery component which gives more benefits to the facility by make use of natural processes such as temperature control, Indoor air quality and lighting of a building as previous studies have proven. It will significantly influence green rating systems to score more points to reach higher ratings.

This research compare three most commonly used green rating systems in Sri Lanka and how those influenced by the vertical greenery to reach high scores. Three Green Rating Systems, namely, GreenSL® Rating System for Built Environment, GM ENRB :2017 (BCA Green Mark for Existing Non Residential Buildings) and LEED V4 for Building Design and Construction are evident to be mostly used rating tools in Sri Lanka. Considerable percentage of points can be obtained with the positive effects of the vertical green façades, both direct and indirect methods, with above three rating systems, especially in energy saving, greenery, air quality aspects.

Application of comprehensive vertical greenery will result in significant difference between in and out temperature of a room and help to increase the thermal comfort and some other aspects too. Mainly this improvement can score more points in all three rating systems in varying degrees. GM ENRB: 2017 score card related to aspects in concern shows reasonably high possibility of scoring more points compared to and Green SL and LEED rating tools. Among latter two tools least potential is with LEED, which seems assessing more indirect influences with respect to technical aspects concerned in the study.

Keywords - Vertical greenery; Energy consumption; Thermal comfort; Rating systems

I. INTRODUCTION

Presently different types of rating systems were introduced to measure sustainability in the constructions. Further, the different types of green assessment systems were introduced by different countries and organizations considering different aspects and conditions etc. This paper aims to find out the influence of vertical greenery to score points in green rating systems. The specific objectives are: 1) select key benefits (direct and indirect) of vertical greenery through literature, 2) discover how likely to score more points directly and indirectly due to the effects of vertical greenery 3) identify the weightage adopted in vertical greenery aspects to score points in green rating systems; 4) evaluate vastly achievable green score containing green rating system, by comparing GreenSL® Rating System for Built Environment, GM ENRB :2017 (BCA Green Mark for Existing Non Residential Buildings) and LEED V4 for Building Design and Construction, scoring more points in vertical greenery aspect in Sri Lankan context.

The term "green" emphasis, environmentally friendly practices ranging from building design to final site landscaping. In a local research it has been found that, "Through the preliminary survey, it has been identified the general benefits of vertical greening such as air quality improvement and its velocity changes, ecological aspects and its attractive appearance, protection against driving rain and sun radiation, sound absorption and noise reduction, social impact, cost effectiveness and energy saving. And there are risks of vertical greening such as moisture problems, damage and deterioration, maintenance."(N.M, 2012)

Studies have shown that vertical greenery systems are able to reduce thermal heat transfer by several Celsius degrees into the building which in turn reduces energy consumption for air conditioning. Presently this green features are included in green tools and rating systems and are in the process of familiarizing and test run in Sri Lankan context.

II. SIGNIFICANT OF THE RESEARCH

Since studies have shown that mainly vertical greenery systems are able to reduce thermal heat transfer into the building which in turn reduces energy consumption for air conditioning and giving many more other benefits such as increasing green cover/area of a building, shading effect, increasing indoor air quality, aesthetic appearance of a building, etc. This paper contains a general analysis of direct and indirect influence of vertical greening systems (plants or vegetation against a façade) and their behaviour with positive effects to score points in commonly using three Green Rating systems in Sri Lanka as GreenSL® Rating System for Built Environment, GM ENRB: 2017 (BCA Green Mark for Existing Non Residential Buildings) and LEED V4 for Building Design and Construction to score more under vertical greenery aspect in Sri Lankan context

III. LITRATURE SURVEY

In the literature survey, initial intension was to define the vertical greenery and discuss direct & indirect positive effects of vertical greenery. The benefits those can be gained due to the effect of the vertical greenery are mainly; thermal effectiveness and reduction of energy consumption for air conditioning. Vertical green gives thermal comfort to the building. "Vertical vegetation, in addition to green roofs, can cool buildings in tropical and subtropical climates through their impact on shading the building, adding to exterior wall insulation, evaporating moisture from the growing substrate and transpiring moisture from leaf surfaces"(Wong, 2010).

Literature survey emphasis, a general introduction of vertical greening systems and its behaviour in relation to enhance thermal comfort with reduction of the energy consumption for air conditioning in buildings. "Increased air temperature can be expected to be particularly problematic in urban areas, where temperatures already tend to be a few degrees warmer than the surrounding countryside. This difference in temperature between urban and rural areas has been called the 'urban heat island effect'(Badrulzaman Jaafar, 2011). Other than the the aesthetical value, a green envelope can improve the urban environment conditions and the living conditions of the inhabitants. As mentioned above unstable and increasing energy prices, concern over environmental impact and occupant health and comfort are the drivers of green buildings today (Honeywell). A green envelope can intercept the radiation and thus reduce the warming up of hard surfaces; great quantities of solar radiation are adsorbed for the growth of plants and their biological functions(Krusche, 1982).

Vertical vegetation can cool buildings in tropical and subtropical climates through their impact on shading the building, adding to exterior wall insulation, evaporating moisture from the growing substrate and transpiring moisture from leaf surfaces(Wong, 2010). Few parameters may affect the amount of the vertical vegetation's improvement in energy performance aspect. Some examples are choice of vegetation, growing medium, and extent of wall coverage, water availability, geometry and direction, thickness of the vegetation, type of façade etc. A study conducted in Germany by (Bartfelder, 1987) shows a temperature reduction at the green façade in a range of 2-6 °C compared to the bare wall.

As per results obtained by a metropolitan scale survey in Tokyo suggests, temperature reduction by 5-8°C at facade wall surface (Shibuya K, 2007). A study conducted in Germany (Bartfelder, 1987) shows a temperature reduction at the green façade in a range of 2-6°C compared to the bare wall. Greenery also reduces the cooling loads through better insulation and shading. According to Dunnett (Dunnett, 2004) every decrease of the internal building temperature with 0.5°C may reduce the electricity use with 8% for air-conditioning. And it is estimated (Akabari, 2001) that 5-10% of the current demand of cities is used to cool buildings and the electricity demand is increased for increment of every 1°C.

Another study in Singapore (Wong N.H., 2009) with vertical greening types shows a maximum reduction of 11.6°C. As (Eumorfopoulou, 2009) states a cover vegetation kept a daily room temperature 2°C cooler on average. And Alexander suggests that the surrounding air temperature can be decreased by a maximum of 8.4°C in an urban canyon in humid Hong Kong on a hottest day of the month(Alexandri, 2006). As per a local case study "minimum of 17.5% of electricity use for air conditioning can be reduced by obtaining a 3.50C of temperature reduction" (Peiris1, 2014) "Vertical green vegetation can be adopted as a counter measure of reduction of indoor temperature and reduction of energy consumption for air conditioning in Sri Lankan context" (Peiris1, 2014). The studies of Cheng (C.Y. Cheng, 2010) living wall modular panels reduced the daily cooling load by 1.45kWh and internal surface temperature by 2°C.

Benefits of vertical greenery according to study of Chiang and Tan (Chiang and Tan, 2009) are presented in Table 01.

Table 2. Benefits of vertical greenery

Category	Benefits
Aesthetic	• Greener skyline as part of city branding. • Visual relief from urban environment. • Enhance architectural designs; create iconic landmarks in the city. • Screen and isolate views. • Enhancing public spaces.
Environment	• Reduction of the Urban Heat Island effect and regulating of the microclimate. • Improving the air quality by absorption of pollution and dust as well as reducing the greenhouse effect by CO_2 absorption. • Enhancement of biodiversity through addition of natural habitats within the city. • Vertical green affect to reduce direct sunlight coming to the building, improve air quality, provide insulation, protect the wall against driving rain. • Improving rain water retention. • Therapeutic effects of plants and landscape. • Increase the green coverage of a city.
Economic	• Reduction of cooling loads through better insulation and shading. • Improving acoustic insulation. • Increasing property values. • Protection of building facade

LEED predominantly evaluates environmental factors including Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, and Indoor Environment Quality categories (Dat Tien Doan a, Ali Ghaffarianhoseini a, Nicola Naismith a, Tongrui Zhang a, 8 July 2017). As some studies shown (Lizawati Abdullah, Norhaslina Jumadi, Roshdi Sabu, Huraizah Arshad, Faza Fayza Mohd Fawzy, 2015) 61 % for energy efficiency, 22% environmental protec¬tion , 4% for Indoor environmental quality and 4% green features and innovations, have been weighted in BCA Green Mark rating system.

IV. IMPLEMENTED PROCESS

During this study, GreenSL® Rating System for Built Environment, GM ENRB :2017 (BCA Green Mark for Existing Non Residential Buildings) and LEED V4 for Building Design and Construction to score more in vertical greenery aspect in Sri Lankan context were analyzed in detail. The rationale to select these rating systems is based on considering GM ENRB :2017 (BCA Green Mark for Existing Non Residential Buildings) and LEED V4 for Building Design and Construction, well-known leading ones alongside GreenSL® Rating System for Built Environment, which in comparison is a relatively

new system that has recently released its latest version and Sri Lanka has subsequently seen a significant increase in the number of registered green buildings. This research has been carried out as a literature based work. Positives impacts of vertical greenery has been found out and compared with the areas which can be adopted to gain more points in each rating system to find out what would be the most possible scoring (points) rating system in Sri Lankan context, with the use of vertical greenery.

V. DATA ANALYSIS

A. Direct and indirect impacts of vertical green as per literature survey

- Aesthetic appearance
- Lighting and shading effect
- Screen and isolate views.
- Indoor temperature reduction/indoor thermal comfort
- Reduction of the Urban Heat Island effect and regulating of the microclimate.
- Improve indoor air quality
- Increase indoor Oxygen level
- Enhancement of biodiversity through addition of natural habitats within the city.
- Protection against driving rain
- Sound absorption and noise reduction
- Save considerable amount of energy using for air conditioning of the building
- Therapeutic effects of plants and landscape.
- Increase the green coverage of a city.
- Protection against Sun radiation
- Increase urban greening
- Exterior wall insulation
- Improving rain water retention.
- Improving acoustic insulation.
- Increasing property values.
- Protection of building façade

B. ENRB :2017 (BCA Green Mark for Existing Non Residential Buildings)

The Building and Construction Authority (BCA) Green Mark scheme is a green building rating system introduced for the tropical climate. This has been launched in 2005. BCA Green Mark sets parameters and establishes indicators to guide the design, construction and operation of buildings towards increased energy effectiveness and enhanced environment performances. (BCA) Green Mark for Existing Non-Residential Buildings, GM ENRB: 2017, is the 4th edition and Green Mark aims to derive sustainability outcomes and enable to develop a high quality and environmentally sustainable built environment for current and future generations to come. Criteria have structured into five sections, and total points awarding was 165. Possible ratings are as follows;

Green Mark Platinum	70 and above
Green Mark Gold PLUS	60 to < 70
Green Mark Gold	> 50 to < 60
Green Mark Certified	Compliance with all pre-requisite requirements

C. LEED V4 for Building Design and Construction

LEED is a voluntary standard developed by USGBC (US Green Building Council). It was first launched in 1998 with a pilot version (LEED 1.0) LEED is considered as the most widely adopted rating scheme based on the number of countries, For this research LEED V4 Building Design and Construction 2018 has been selected. LEED evaluates environmental factors including Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, and Indoor Environment Quality categories. Whole of the building's lifecycle could be evaluated based on the criteria from Building Design and Construction, Interior Design and Construction, Building Operations and Maintenance, Neighborhood Development manuals. LEED has total points of 124.

D. GreenSL® Rating System for Built Environment

The GREENSL® Rating System of Green Building Council Sri Lanka (GBCSL) was launched in 2010 in Sri Lanka. Prerequisites and credits in the GREENSL® Rating System for Built Environment address eight domains;

- Management (MN)
- Sustainable Sites (SS)
- Water Efficiency (WE)
- Energy and Atmosphere (EA)
- Materials and Resources (MR)
- Indoor Environmental Quality (EQ)
- Innovation and Design Process (ID)
- Social and Cultural Awareness (SC)

Total score of GREENSL® Rating System is 100 points and the Certifications from the GREENSL® Rating System for Built Environment will be awarded according to the following range;

Certified	40 - 49 points
Silver	50 - 59 points
Gold	60 - 69 points
Platinum	70 points and above

E. Comparison of rating systems and points that can be scored against positive effects of vertical greenery.

Table 03. Comparison of rating systems against points that can be scored with vertical greenery

GM ENRB: 2017 BCA Green Mark scheme for existing non-residential buildings	EED v4 for Building Design and Construction	GREEN$^{SL^{®}}$ Rating System
Greenery Provision (GnP) (2.5 Points)	Sustainables sites (SS)On-Site restoration (01–02 points)	Optimizing occupant comfort And Energy Efficiency (01 Point)
Vertical Greenery Applicable greenery areas on building façade (01 Point)	Nonroof and Roof (02 points)	Heat Island Effect, Non–Roof (01 Point)
Façade Performance Applicable to all air conditioned buildings (02 Points)	Energy and atmosphere Whole Building Energy Simulation (09 Points)	Optimize Energy Performance (01-10 Points)
Air Conditioning System Operating Efficiency Unitary Air-conditioner (08 Points)	Building envelope, opaque: roofs, walls, floors, slabs,doors etc (01 point)	Ozone Depletion (01 Point)
Air Distribution System (04 Points)	Green power and carbon offsets (01 point)	Outdoor Air Delivery Monitoring (01 Point)
Natural Ventilation (01 Point)	Carbon Dioxide Monitoring (01-02 points)	
Energy Efficiency Practices And Features (02 Points)	Thermal comfort (01 point)	Optimizing occupant comfort and Energy Efficiency (01 point)
Thermal Comfort (01 Point)		Heat Island Effect, Non–Roof (01 point)
Temperature Contro (0.5 Point)		Optimize Energy Performance (01-10 points)
Indoor Air Quality (IAQ) Management (02 Points)		Ozone Depletion (01 point)
Outdoor Air Control (01 Point)		Green Power (01 point)

GM ENRB: 2017 BCA Green Mark scheme for existing non-residential buildings	EED v4 for Building Design and Construction	GREENSL® Rating System
Demand Control Ventilation (02 Points)		Resource Reuse (01 point)
Biophilic Features (01 Point)		For at least 10% of Total Value of Materials (01 point)
Advanced green (01 Point)		Thermal Comfort, Design (01 point)
Thermal Comfort with Elevated Air Speed (01 Point)		
Points 40	**Points 18**	**Points 17**

Total points that can be scored from above three rating systems against positive effects of vertical greenery as follows;

Table 04. Percentage & points scoring form each rating system against the vertical greenery

	Points	Percentage of total points
GM ENRB: 2017 BCA Green Mark scheme for existing non-residential buildings.	40	24.2%
LEED v4 for Building Design and Construction	18	14%
GREENSL® Rating System	17	17%

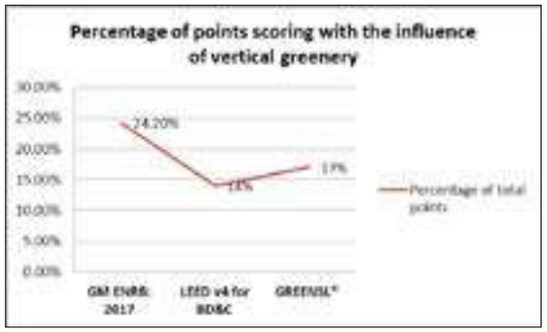

Figure 1. Percentage of points scoring with the influence of vertical greenery

VI. RESULTS AND OUTCOME

A. Discussion

According to the literature survey, to reduce a single degree of Celsius of room temperature, using a split air conditioner, requires almost 5% of its total energy consumption per day (considered as the minimum possible energy reduction). As per literature 3.50C maximum inside temperature reduction is possible with green façade, which can reduce 17.5 % of electricity use for air conditioning (split air conditioner).

The prime result of vertical greenery layer in multi-stored buildings is the thermal comfort. The conclusions from the research are as follows;

- According to the referred literature minimum of 17.5% of electricity use for air conditioning can be reduced by obtaining a 3.5^{0}C of temperature reduction.
- Vertical green can be adopted as a counter measure for reduction of indoor temperature and reduction of energy consumption for air conditioning in Sri Lankan context.
- Green facades and green vegetated walls can improve the environment and air quality in cities which are having less green coverage.
- Regarding the heating, less heat accumulation occurs in the case of a vertical green vegetated surface, it is therefore a wise choice to apply greened surfaces especially in warmer climates.
- Among the three selected rating systems, ENRB :2017 (BCA Green Mark for Existing Non Residential Buildings) is the most possible point scoring rating system with the use of direct & indirect effects of vertical greenery (with a considerable percentage up to 24.2% from total points).
- Least potential is to score more points in LEED with the use of vertical greenery, since the tool is more advanced and area of interest is covered in many indirect aspects.
- GreenSL® Rating System for Built Environment has some similarities with, ENRB :2017 (BCA Green Mark for Existing Non Residential Buildings) since both green tools are assessing closely similar climatic conditions.

Recommendations

From this research, it has been found that, the use of vertical greenery systems on multi-stored buildings can support to improve its thermal comfort mainly and various other green aspects and those impacts support to score more points in rating systems. Further, comparatively high percentage of points can be scored from regional tools. Hence, regional tools give more similar results, it is recommended to use regional tools having similar context or background for local assessment requirements.

Since, it has been observed that a significant percentage of points can be scored with the effects of vertical greenery from rating systems, it is recommended to introduce separate section/sub aspects in rating systems including appropriate criteria to evaluate/identify/quantify positive impacts related to vertical greenery.

Recommendations for Further Researches

- Evaluation of effectiveness of horizontal greenery to score points in rating systems related to Sri Lankan context.
- Improving Local Green Rating tools comparing with leading rating systems in the world.
- Thermal effectiveness of the plants used in horizontal and vertical greening systems in relation to Sri Lankan context.
- Thermal effectiveness of the greenery systems related to climatic conditions in Sri Lanka.
- Appliances of green wall systems in different aspects for different building types.

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SEEKING PROFESSIONAL EXCELLENCE IN WATER MANAGEMENT: CASE STUDY ON TRINCOMALEE WATER SUPPLY SCHEME

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Abstract - The Naval Dockyard Trincomalee is considered as the most strategic and important Naval Establishment of the Sri Lankan Navy. Naval Dockyard Trincomalee was established by the British, during the colonial era. Trincomalee naval water supply scheme was constructed in 1942 to accomplish the water requirement of naval Dockyard and Trincomalee town area. Although this system is more than 75 years old, it provides purified water requirement of Naval Dockyard and few other users within Trincomalee town, even today. The raw water source is Kalamatiyankulam reservoir, which has capacity of 47,029,300 Cubic meters. The water transmits to the Andamkulam purification plant only through the gravitational force and the energy increment by reducing the diameter of pipe. Similarly, the purified water also distributes to Naval Dockyard and other surrounding areas. The entire process is free from pumping, though the pumping station has been designed in original drawings. At present, water demand of Naval Dockyard has increased due to the rapid expansion of military infrastructure with the community.

The objective of the study is to analysis the sustainability of the Trincomalee naval water supply scheme with emerging demand of water. This study concerns direct relationship of the current water demand with existing water supply in order to the factors such as flow rate, wastage, etc. Whilst, analysing the best feasible solution for improvement of existing scheme will be determined based on the quantitative data such as rainfall, population, and flow rate. Furthermore, possibility of contributing to the national water distribution network through state agencies will also be analysed as the conclusion of this study. Finally, the paper presents to a substitution plan for water transmission and distribution considering the future demands of Naval Dockyard and Trincomalee town area. This study focuses on how best to collaborate professionalism to the social demand with view of balancing and sustaining the water resources.

Keywords - water resource management, sustainability, substitution plan

I. INTRODUCTION

Sri Lanka Naval Dockyard was established in Trincomalee by the British in the colonial era and it is surrounded by the Port of Trincomalee which is one of the largest natural harbour in the world. Naval Dockyard Trincomalee could be considered as the most strategic and important Naval Establishments of Sri Lanka Navy (SLN). SLN, being a professional body and first line of the defence of Sri Lanka, required to play a major role to safeguard the territorial water.

The existing Naval water supply scheme has been constructed in 1942 during colonial area and the system is more than 75 years old as to date and provides purified water for approximately 15,000 population consist of people inside dockyard and outsiders in Trincomalee area. This water supply system is the only reliable source of water available for the Naval Dockyard to meet the water demand.

This system consists with three main components. Main intake of Kalamatiyakulam reservoir, Andankulam purification plant and SLN Dockyard sump.

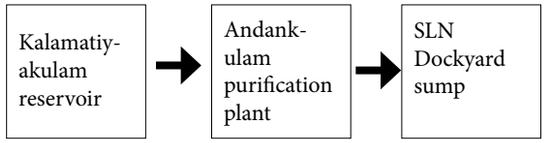

Figure 1: Main Components

The Kalamatiyankulam tank also known as NavalHeadwork's reservoir, had been built by the British in 1942 and situated in Thambalagamuwa area in the Trincomalee district. The path commences to the right of the Palampataru junction, which is located 22 kilometres away from Trincomalee town on the Trincomalee -Kandy road. This reservoir with a capacity of 47,029,300 m3 of water, standing 162 feet above the mean sea level, with 2,840 foot long bund.

The total catchment area is 25Sq.miles. Further 25'6" is the maximum water level of this tank .The main diversion point which is located in the Puliuththukulam (Near to the Thambalagamuwa border) from that point control the water flow into two directions ,One flow towards the Morawewa reservation and the other flow towards the Kalamatiyankulam tank. The way of water flow to the Kalamatiyankulam tank is shown below.

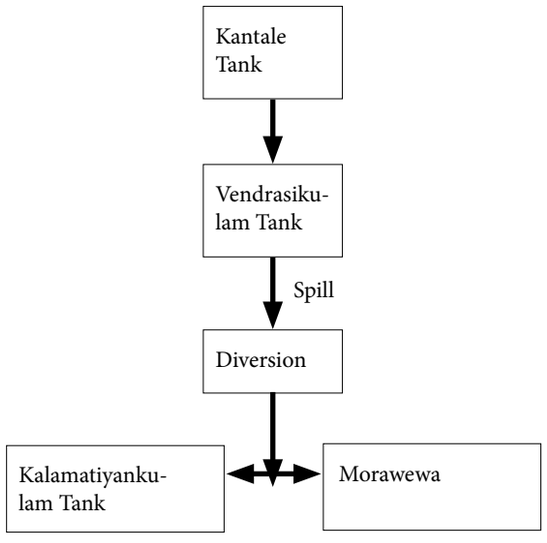

Figure 2: Main diversion path

The water main starts from tank form intake well. Main intake well consists with three draw off and variation of these draw as follows,

At Spill level (155 MSL)	-	3,800	Ac ft
At Top draw off (148.75 MSL)	-	2,200	Ac ft
At Middle draw off (138.75 MSL)	-	600	Ac ft
At Bottom draw off (131.75)	-	91	Ac ft

This water supply system conveys water through the combination of gravitational force and the energy increment by reducing the diameter of pipe. Kalumatiyankulam tank to Andankulam treatment plant, covering approximate 17 Km flow through slope of 06 inches to 1Km which conveys water through gravity without any pumping. Approximately 4500m3of raw water per day received to water treatment plant at Andankulam. Then, the raw water purified under conventional water treatment process (Aeration, coagulation, flocculation, sedimentation, filtration and disinfection.)

Currently, 4000m^{3}of treated water daily distribution to SLN Dockyard and Trincomalee town .Naval water supply system provides treated water for important government institutes such as General Hospital , 22 Brigade SLA Camp, Court complex, police stations , Sri Lanka ports Authority , Government school and approximately 250 domestic dwellers. At present, water demand per day at Naval Dockyard is existing demand of water cannot be met from National Water supply & Drainage Board at Trincomalee.

However, the present water volume received to Andankulam purification plant is not sufficient to cater the present water demand in drought season due to restriction in the opening of sluice valves to prevent a burst of water line due to ageing of water main.

It has been revealed that most parts of the water main are in deteriorated condition, resulting frequent repairs to the water main. The systems adopted and practiced to repair the water main are conventional, complicated and not accommodative with available tools/spares and takes much time and wasted of man power unnecessarily with this repair work. Moreover then a water main is damaged/ leaked that will cut off water supply to Naval Dockyard and Trincomalee town area for 03 to 04 days until completion of the repair. Further, fittings and accessories requirement for repair maintenance are limited and not freely available in the market. The water main is mainly constructed with

cast Iron pipe (CI), Hume pipes and Galvanized Iron pipes (GI) and tends to deteriorate with age and aggressive subsoil condition exists. Frequent breakages in raw/ water cuts to facilitate repairs.

II. LITERATURE REVIEW

As per the formulating Guidelines for Reservoir Sustainability (Kent C., Sean K., Randle T., 2015), it shows that reclamation has to be done for the reservoirs and channel system where the lifetime is exceeding 60 years. It also highlights that reclamation is essential for the reservoirs more than 80 years old. In this case, both the reservoir and channel system are over 80 years. Even though still the system works considerably good manner, without proper attention to the infrastructures of the system, the effectiveness of water management will be negatively affected by this fact.

In Local Water Management of Small Reservoirs: Lessons from Two Case Studies in Burkina Faso (Sally, H.; Lévite, H. and Cour, J., 2011) has shown that not only maintenance, but land use patterns in the catchment area will be crucial factors in effective and sustainable management water. In case of Kalamatiyankulam reservoir, the land use of catchment area is nominated as a sanctuary. Therefore it can be expected almost consisting amount of inflow of water for coming years where which is sufficient for supply the demand for Trincomalee Naval base and for civil organizations too. Still, through proper repairs in the channel system which the water being transported to Trincomalee this massive amount of water can be used with minimum wastage.

The Sustainability of Water Supply Schemes (Abebe, 2008) shows that not sufficient repairs have led the reservoirs to chaos and therefore it has become an element for poor sustainability and service delivery in water management. In this case also, it is a clear fact that wastage of water due to leakages in channel system is far greater than wastage of water due to improper usage. When it comes to level of service, practices adopting in water management cannot influence this factor considerable where the only solution lies on the other option.

In Design of Sustainable Water Distribution Systems In Developing Countries (Kalanithy Vairavamoorthy, Ebenezer Akinpelu, Zhuhai Lin, Mohammed Ali) developed international guidelines for the design of urban water distribution system in developing countries which help to sustain adequate and safe supplies. This was a new approach to the design of distribution system in developing countries. Conventional approach to network analysis was described and discussed with respect to their suitability for simulating conditions of water shortage. Alternative approach design had been developed by utilizing formal optimization techniques to ensure the maximum uniformity in supply. There were required modification model such conditions. Modified network analysis simulation tool had been developed by identifying required modification. This simulation tool had been verified by field survey data.

In the case study Sustainability of Community Water Supply Systems Managed by Water User Committee (Kalyani, 2014) which was totally based on assessments carried out in the field, observations notes, household survey and discussion with members of water user committee, it was discovered that all the water supply systems are smoothly operating and providing quality drinking water without financial, technical or institution problems with in water supply system and the community.

III. METHODOLOGY

- Study relevant documents to find out the catchment areas of Kalamatiyankulam reservoir.
- Analyse rainfall data of eight consecutive years.
- Calculate the runoff coefficient using Khosla's formula.
- Develop the mass curve using the obtained results and find out the possible demand.
- Find out the residential and non-residential demand in Naval Dockyard.
- Suggestions for water transmission and distribution considering the future demand in Naval Dockyard and Civic organizations in Trincomalee area.

IV. RESULTS AND DISCUSSION

Khosla's formula method (Subramanya)

$R_m = P_m - L_m$

Month	T ^{0}C	Rainfall (P_m)(cm)	Monthly Losses (L_m)	Monthly Runoff (R_m)
Jan	26.5	21.826	12.72	9.11
Feb	27	16.376	12.96	3.42
Mar	28	7.64	7.64	0
Apr	29.5	3.997	4	0
May	30.5	9.798	9.8	0
Jun	30.5	0.144	0.14	0
Jul	30.5	5.379	5.38	0
Aug	30	10.483	10.48	0
Sep	30	9.416	9.42	0
Oct	28.5	30.026	13.68	16.35
Nov	27	39.457	12.96	26.5
Dec	26.5	48.279	12.72	35.56
	202.821		90.94	

$$\frac{\text{Annual Runoff}}{\text{(Annual Rainfall}} = \frac{90.94}{202.821} = 0.448 \approx 0.45$$

Table 2: Calculation of mass curve

Month	Rainfall (P_m) (mm)	Runoff Rainfall Ratio	Catchment area (Mm^3)	Monthly Runoff inflow Volume	Monthly Evaporation (Mm^3)	Monthly Flow Volume (Mm^3)	Accumulated Volume (Mm^3)
Jan	218.26	0.45	67.99	6.68	0.37	6.31	6.31
Feb	163.76	0.45	67.99	5.01	0.37	4.64	10.948
Mar	76.4	0.45	67.99	2.34	0.37	1.97	12.915
Apr	39.97	0.45	67.99	1.22	0.37	0.85	13.768
May	97.98	0.45	67.99	3.00	0.37	2.63	16.395
Jun	01.44	0.45	67.99	0.04	0.37	0	16.4
Jul	53.79	0.45	67.99	1.65	0.37	1.28	17.675
Aug	104.83	0.45	67.99	3.21	0.37	2.84	20.512
Sep	94.16	0.45	67.99	2.88	0.37	2.51	23.023
Oct	300.26	0.45	67.99	9.19	0.37	8.82	31.839
Nov	394.57	0.45	67.99	12.07	0.37	11.7	43.541
Dec	482.79	0.45	67.99	14.77	0.37	14.4	57.942

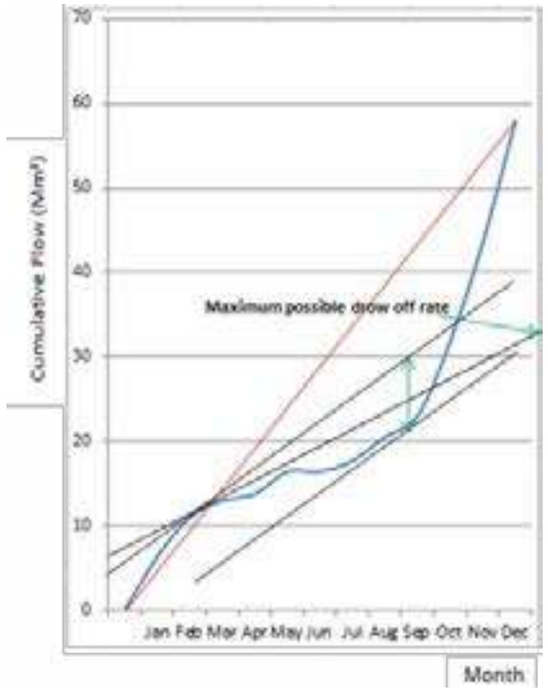

Figure 3: Mass curve

Uniform maximum draw off throughout the year with no spill over the spillway $= \frac{(57.612)}{365}$

$= 0.158\ Mm^3/day$

Existing Reservoir capacity $= 3800$ Acre feet

$= 4.687224 \times 10^6$

$= 4.69$ Mm3

After September reservoir begins to spill,

Hence maximum possible draw off rate

$$\frac{36.2 - 7.58}{365} = 0.078 \text{ Mm3/day}$$

Consider 75% maximum possible draw off rate $= 0.0588$Mm3/day

Current daily demand $= 5000$ m3/day

$= 0.005$ Mm3/ day

Consider 25 % maximum possible draw off rate $= 0.0195$ m3/ day

Current daily demand improve 3 times,

$= 0.015$ Mm3/ day

Current demand x 3 < 25% Maximum possible draw off

$0.015m^3/day < 0.0195m^3/day$

As a result of the operational study carried out in the research, it was discovered that the possible demand is sufficient for more than three times of current demand. But due to expired life time of the raw water main which is more than 80 years old, it is observed that repairing of the system is not much economical and not reliable compare to the replacing line. When compared to gravitational force, it does not requires any other power source for distribution of raw water main from Kalamatiyankulam reservoir to Andamkulam purification plant, which is an added advantage for economic management of water distribution. Still it is highlighted to improve the water purification capacity of Andamkulam purification facility including more number of sedimentation tanks as well as rapid sand filters. If not the total amount of possible demand cannot be utilized unless otherwise. Replacing the purified water distribution line is also paramount important for reducing the wastage and for increased efficiency of the distribution system. Compared to renovation of the distribution system, it is much economical to replace the line as the existing distribution line is having a period of service of more than 80 years to date.

Even though renovation of Andamkulam water treatment plant and replacement of water distribution system implemented, still it won't affect as long as the water sump facilities may improve. In this case,the study could able to identify abundant water tanks (Fort Frederick – 2500m3, Chainabay - 450m3 and Clappenburg - 450m3etc.) which is related to the Trincomalee water supply scheme. Rehabilitation of abundant tanks a better solution for the water management compare to the evaluated possible outflow from the reservoir. Therefore for sustainable and water management system, which is sufficient for more than three times of the existing demand, renovation and replacement of existing facilities is a must and it can be considered a probably the greatest investment for the future supply of water demand in eastern region of Sri Lanka.

V. CONCLUSION

An operational case study is carried out for selecting possible demand of Kalamatiyankulam reservoir. This provision of water to meet the domestic water demand of Trincomalee area, as well as ships and craft of Trincomalee harbour also considered. A compact non-linear optimization formulation for the reservoir outflow is derived by using basic calculation assumption and mass curve analysis. The result of analysis emphasized that possible maximum water demand (0.078Mm3/day) able to reach more than three times compared to the current demand (0.005 Mm3/ day). Similarly increasing the quantity of water management become paramount important with seeking excellence of professionals. Replacing raw water and purified water distribution mains which able to operate under the gravity flow with saving significant amount of energy and cost. This study concludes how to collaborate professionalism to the social demand with view of balancing and sustaining the water resources.

VI. ACKNOWLEDGEMENT

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TIME-SERIES ANALYSIS OF MONTHLY RAINFALL DATA FOR THE NUWARA ELIYA DISTRICT, SRI LANKA

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Abstract - One of the most important climatic element is Rainfall, that directly influences on the agriculture. As a real world practice, the rainfall data has a seasonal trend with short term and long term oscillations; especially, monthly rainfall forecasting is significant to make decisions in management of agricultural scheme and manage daily human activities.

In this current study monthly average rainfall of Nuwara eliya district, Sri Lanka since 1996 to 2015 were considered. According to the unit root study, original observations are non-stationery. So, we moved 1st difference for further study. Furthermore, Seasonal Autoregressive Integrated Moving Average (SARIMA) model was fitted for analyzing and validation 228 monthly observations. According to minimum Akaike information criteria (AIC), SARIMA (1, 0, 0) (1, 0, 2) (12) is selected as a best model for forecasting rainfall in this selected region.

Keywords - AIC, Rainfall, SARIMA models, Unit root

I. INTRODUCTION

Going back to the association of water, it is the source of all life on Earth necessary for maintaining daily life activities. Rainfall is a most significant way for maintaining the land water level. However, the need for accurate rainfall predictions is readily apparent when considering the many benefits such information would provide for river/ riverbed control, reservoir operations, flash flood watches, etc. Furthermore, among climatic factors, rainfall is considered as the one of the most important climatic factor that affect in agriculture field. As a result, not only to planning and management of agricultural scheme but also to management of water resource systems, monthly rainfall forecasting plays a major role.

Harrison et.al (2014) carried out a study to forecast monthly rainfall data for the function relates to the level data in oscillatory of 12 periods. Furthermore, they adjudged stationary by the Augmented Dickey Fuller unit root test and correlogram gives an indication of stationarity as well as an involvement of the presence of a seasonal moving average component of order one and a seasonal autoregressive component of order two. These fundamental conditions with autocorrelation structure suggested a three multiplicative seasonal autoregressive Gadaref rainfall station in Sudan by using SARIMA methods. Their autocorrelation integrated moving average (SARIMA) models, namely: (0, 0, 0) (0, 1, 1)12 , (0, 0, 1) $x(0, 1, 1)^{12}$ and (0, 0, 1)$x(2, 1, 1)^{12}$.

C. C. Nnaji et.al (2013) carried out a similar study based on SARIMA to forecast Nigeria's rainfall patterns. The Box-Jenkins methodology was used to build ARIMA model for the period from November 2003 to October 2013 with a total of 120 data points and suggested that SARIMA (1, 1, 1) $(0, 0, 1)^{12}$ is best for forecasting rainfall data under the seasonality. In a similar study, develop a trend analysis to

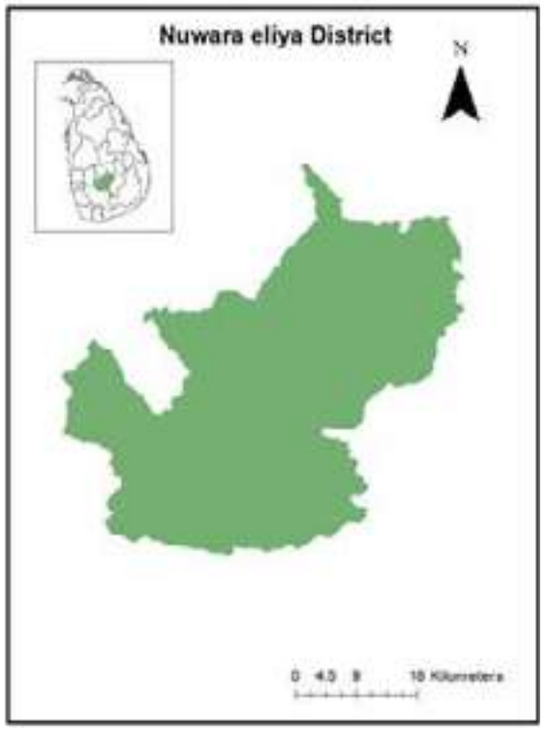

Figure 1: Map of Nuwara eliya District

forecast rainfall deficit in the Blackland Prairie of Eastern Mississippi for a period of 120 years of annual, seasonal, and monthly periods.

Brath, et.al (1997) used time series analysis techniques in order to predict short-term rain fall for flood forecasting. For this study, linear stochastic Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA) models, were used to express the future rainfall as a linear function of past data. By considering about the results we can see that the use of time series analysis techniques for rainfall forecasting may allow an extension of the lead-time up to which a reliable flood forecast may be issued, introducing a very quick prediction based on past data directly in the format required by the rainfall-run off transformation model. The current study attempted to develop linear stochastic models such as multiplicative seasonal autoregressive integrated moving average (SARIMA) and GRACH models for forecast monthly rainfall in Nuwara Eliya, Sri Lanka. The main objective of this study is to perform an analysis the monthly characteristics within the monsoon seasons and to show how these characteristics can be linked to the general circulation such that physical meaning for the cause of rainfall variability can be found. Furthermore, using 21-year period data, aims of this study is ascertaining the presence and range of Self-Organized Criticality in the monthly rainfall pattern of Nuwara eliya.

II. MATERIALS AND METHODS

In this research, our main objective was to find a model to efficiently forecast the monthly rainfall in Nuwara Eliya by applying Box and Jenkins method.

a. Data

For this study, average monthly rainfall data of Nuwara eliya district was considered from period 1996-2015. The rainfall gauge contains 240 observations. We have used 228 observations for build appropriate of Auto regressive moving average model and 12 observations are rest for validation procedure. The average monthly data of Nuwara eliya district show the highest density of the rainfall in period June- November. Thus most of the peaks were reached in October and November months.

b. Modeling by SARIMA

The combination of autoregressive (AR) and moving average (MA) models called ARMA which should be used for forecasting stationery time series. If the time series observations are non-stationery, then we can allow the stationery condition using differencing. Thus the general non seasonal model of ARIMA is shows with 3 parameters such as ARIMA (p, d, q) where p is the order of AR and q is the order of MA and d is the differencing order.

Non seasonal ARIMA model can be written as

$$\emptyset_p(B)\nabla^d Y_t = \theta_q(B)\varepsilon_t \quad \text{-----(1)}$$

Where $\emptyset_p$ and θ_q are the polynomials of order p and q respectively and ε_t is the white noise term. If the time series is with seasonally, the Box-Jenkins (1976) proposed a SARIMA model. In short SARIMA model described as ARIMA (p, d, q)×(P,D,Q)$_s$ which is

$$\emptyset_p(B)\varphi_p(B^s)\nabla^d\nabla^d{}_s Y_t = \theta_q(B)\vartheta_q(B)_s\varepsilon_t \quad \text{-----} \quad (2)$$

Where p and q is the non-seasonal autoregressive and moving average orders and d is the number of regular differencing and P and Q is the seasonal autoregressive and seasonal moving average orders respectively. Also, D is the seasonal differencing order. It is based on the least squares optimization criteria.

c. Model Selection

The fitting of model (2) begins with order selection. The seasonality period can detect using time series plot or correlogram of the object. For this section, rainfall is seasonal time series with s=12 months. The non-seasonal and seasonal AR orders p and P are estimated by the non-seasonal and the seasonal cut-off lags of the partial autocorrelation and similarly, Q and q can determine using seasonal and non-seasonal ACF cut-off points. The minimum **Akaike information criteria (AIC)** values gives the most effective models. For this study, the econometric software Eviews-8 and R-software was used for all analytical work.

d Model Validation

Model validation provides the efficiency of the model while forecasting. Model validation totally based on mean absolute percentage error (MAPE). The value of MAPE classify as follows.

Table 5: MAPE classification

MAPE	Judgment of Accuracy
< 10%	Highly Accurate
11% to 20%	Good Forecast
21% to 50%	Reasonable Forecast
> 51%	Inaccurate forecast

III. RESULTS & DISCUSSION

e. Preliminary analysis

Fig. 1 shows that the time series plot of the original observations from period 1996-2015. The data patterns indicated that series is stationary and the mean of the time series is relatively constant with respect to the time. We were performed unit root test and evaluated the original series are stationery over time. Unit root test results are given below.

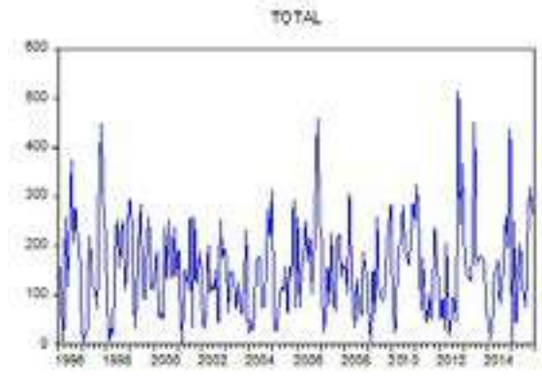

Figure 2-Time series plot of the original observations

Table 2: Unit root test

Null Hypothesis: TOTAL has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=14)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-11.69503	0.0000
Test critical values:	1% level	-3.457630	
	5% level	-2.873440	
	10% level	-2.573187	

*MacKinnon (1996) one-sided p-values.

After testing unit root test, we were concluded original series is stationery. Obviously rainfall data shows seasonal time series with s = 12 months. Figure 2 shows the clear seasonal pattern in 12 months' period. Since data should be seasonal in 12 months' time period.

Thus Figure 3 Shows the ACF graph of observations.

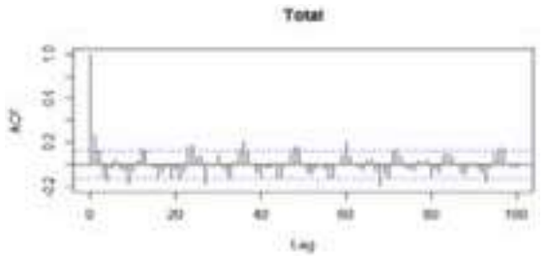

Figure 3-ACF plot of observations

Table 5: Hetroskedasticity test

Hetroskedasticity Test: ARCH

F-statistic	0.131918	Prob. F(1,212)	0.7168
Obs*R-squared	0.133080	Prob. Chi-Square(1)	0.7153

f. Model Selction

Table 3: model selection Results

Model	AIC
SARIMA(1,0,0)(1,0,1)[12]	11.67333
SARIMA(1,0,0)(1,0,2)[12]	11.66028
SARIMA(2,0,0)(0,0,1)[12]	12.066

Next step is the model selection. Thus we were selected most suitable model for the rainfall forecasting. Model selection was totally based on minimum AIC value. The Table 3 shows the AIC values of selected models and suggested that SARIMA (1,0,0) (1,0,2) (12) model is best for future predictions.

g. Diagnostic checking Recidual Autocorrolation test

After selecting a best model, checked the residual to conform the significant autocorrelation using a Breusch-Godfrey serial correlation LM test. The Table 4 Breusch-Godfrey Serial Correlation LM Test results conclude that residual has no autocorrelation.

Table 4: Breusch-Godfrey Serial Correlation LM Test results

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	2.115486	Prob. F(2,209)	0.1231
Obs*R-squared	4.262026	Prob. Chi-Square(2)	0.1187

Thus we were test whether residual contain constant variance or not. We were used hetroskedasticity test to test this assumption. Table 5 shows the results of Breusch-Godfrey Test.

Table 5 shows the homoscedasticity test results concluded that residual has constant variance. Usually we say that residual has homoscedasticity. Thus also this results implies that residual haven't ARCH effect.

VI. CONCLUSION

This current study explored the presenting time series analyses for average monthly rainfalls in Nuwara Eliya district. In presence of strong seasonality in every 12 months, we used the SARIMA model for forecasting the average monthly rainfalls in Nuwara eliya district from January 1996 to December 2015. The minimum AIC criterion results suggested SARIMA (1, 1, 0) (1, 0, 2) [12] is a best model. Model MAPE is 4.4%. It may be used for forecasting process and the forecasted values can be used for planning and managing future decisions of this region. This model is considered appropriate to predict the monthly rainfall for the upcoming years to assist decision makers establish priorities for water demand, storage, distribution and cultivations.

V. ACKNOWLEDGEMENT

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Poster Session Paper

SUSTAINABLE WATER SUPPLY MANAGEMENT SYSTEM FOR PANAGODA ARMY CANTONMENT

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Abstract - Sustainable water management is identified as an important strategic approach to minimize unnecessary costs and for proper utilization of water resources. The Panagoda army cantonment was established five decades ago and current water supply system has deficiencies to cater the demand of water users. Due to malpractices of users massive wastage of water supply has been observed. This study focused on the identification of the status-quo of the water management system in the cantonment. Then to be identified the customer's perspective on the current water management system in the cantonment and identified proper way to improve current water management system. The high value of water invoices and electricity invoices were received for the monthly usage. By introducing new water management, it will be possible to reduce the cost of water usage and cost of electricity usage that use for the pump operation. There are 4 Directorates, 7 Regiments, 31 Units, Army Base Hospital and Army Physical Training School operating at the cantonment and data has been collected from selected 19 establishments which are consist with higher no of staff. During the study qualitative and quantitative data was collected by using the questionnaire and evaluate the quantitative data by using Statistical Package for the Social Sciences (SPSS) software version 23. Both descriptive and inferential statistics were determined. According to the qualitative data, current status of the water management system was evaluated and recommendations were formulated. The conceptual framework consisted of sustainable management approaches such as environmental Sustainability, Affordability, Quality, Health and Safety, Reliability, and Responsibility of the operation. Those five independent variables were correlated with the dependant variable of customer satisfaction. Each independent variable was gathered in two perspectives such as customer expectation and the satisfaction of the aspect. Each factor was plotted to identify the gap area. It is recommended to carry out in-depth study to minimize loss and improve the current system to the sustainable way.

Keywords: Environmental Sustainability, Affordability, Quality, Health and Safety, Reliability and Responsibility.

I. INTRODUCTION

The Panagoda army cantonment consists with the various corps and residential area where as seven regiments and thirty-one units. Because of higher water demand of different units and other establishments, daily water consumption is about 4000 m3 and 50% of the consumed water is released as wastewater in a an appropriate way to the environment. This situation had led to environmental pollution in and around the cantonment area. Therefore, it is very much essential to treat the wastewater and efficiently utilized for nondrinking requirements at the army cantonment such as watering, washing, etc.

As per the observation made by the Garrison Engineer of Panagoda, the army is paying approximately Rs 6.5 million to National Water Supply and Drainage Board per month. There is a considerable gap can be observed when it is compared with the number of water consumers and the consumption of water per month. That emphasis the usage of water is higher than the requirement.

II. OBJECTIVES OF THE STUDY

a. To study the status-quo of the water supply management system of Panagoda army cantonment through a consumer survey.

b. To identify the areas for improvement of the water supply management system of Panagoda cantonment.

c. To identify the consumer satisfaction on each factor of the water supply management system and develop the suitable system to uplift the current system.

d. To propose practical and sustainable system to existing water supply management system of Army cantonment of Panagoda.

III. RESEARCH QUESTION

The research question of this study was based on how to improve the water supply management system of the Panagoda army cantonment in a sustainable way. Therefore, it is necessary to implement under mentioned factors:

a. Reduction of energy cost.

b. Treating of waste water and efficient use of treated water.

c. Cost- Benefits of Investment for the sustainable water management should be analysed.

IV. LITERATURE REVIEW

A. Sustainable Water Management

The sustainability is expressed as the involvement of all stakeholders to achieve better consumption with their involvement for maintenance, recovery, continual support to deliver high-quality service for all (Carter et al., 1999). Sustainability of the water supply is identified as a critical aspect throughout the world. Sustainability was defined as a vital factor in water infrastructure management activities and focused not only on maintenance cost but also on customer satisfaction as essential to implementation and smooth functioning of it (Han et al., 2015).

Sustainable water management was defined as avoidance of losing social welfare in the use of water, and efficient use was the way to achieve sustainability as well as proper pricing scheme identified as a useful method for practical use of water (Bithas, 2008). Shortages in water supply in droughts were critically observed and not enough to meet water demand due to shortfalls in precipitation and stream flows in addition to lack of quality water to consume (Werick and Whipple, 1994). Water consumption in future will be faced to more complex and dynamic situation, and sustainable water management strategies are involved to identify through effect analysis on the vulnerability and adaptation possibilities in future (Haasnoot et al., 2011)

B. Water As A Basic Need For A Human Resource Of The Organization

Water is the basic need of the living creatures, and mainly humans are consuming water for maintaining the biological reactions happen in the body. Also, water is consumed for the cleaning purposes like bathing and washing, and it is highly required for the maintaining health of each person. The primary water requirement is expressed as a fundamental right and supported by the international law (Gleick, 1998).

C. Sustainable Water Supply Approaches

Army water security strategy was published in 2011 by United States Army Environmental Policy Institute stated that significant goal areas as sustainability, reduce the demand of water, maintaining infrastructure integrity and security (Koch and Kodack, 2012). Growth of populations and uncertainties in climatic changes will create intense demands on water resources in the future and holistic approaches and integrated management principles will be necessary to develop sustainable systems and prevent disasters (Bouwer, 2000).

Rainwater harvesting was neglected by the policymakers due to lack of awareness and also not popularized due to high initial cost for average households. However, it is a sustainable way to maintaining and operation of the system to fulfill the drinking water standard through proper awareness programs (Ariyananda, 1999). Rainwater harvesting systems were operated around 15,000 units at Sri Lanka, and improvement of the system was explored (Ariyananda, 1999; Fenghua, 2006). Rain water harvesting is the simple process. However, it can be harvested from any clean roof surface and should be purified or not before consumption due to the hygiene of the system, including the collecting surface, pipelines and tanks (Ntale & Moses, 2003).

D. Importance Of Renewable Energy Usage

Sri Lanka is a ideal country to use solar energy. The average annual of solar radiation in Sri Lanka was estimated as 4.5 - 6.0 kWh/m2/day and cost for power generation was determined as Rs 22 - 25 /kWh (Keswani et al., 2017).

Copmpratively captital investment to be beared for the installation of solar system is higher than the prevelant expences of Coal (Rs. 9 -15 / kWh) which will be reduse in the future due to the advancement of the process thorugh scientific inventions. (Keswani et al.,2017). However after intallation of solar sytem, recurrent expenditure is lower than the prevelant expenses of Coal.

IMPORTANCE OF PERSPECTIVE OF WATER CONSUMER'S VIEW

The current management practices are based on human-centric approaches, and consumer service is playing critical concern on disciplines of marketing, quality management, and sustainable management approaches. The essential requirement of safe, reliable, affordable and accessible water supply is not achieved in developing countries (Hunter et al., 2010).

Water demand management is identified as a critical subject, and economical pricing is needed to the satisfaction of consumers as well as covering up the relevant cost of the operation. Water pricing is also found as the trade-off between the purpose of financial sustainability through cost recovery and consumer satisfaction (Savenije and Van Der Zaag, 2002).

V. METHODOLOGY

Conceptual frame work as shown in fig 1. below is compatible with the literature review

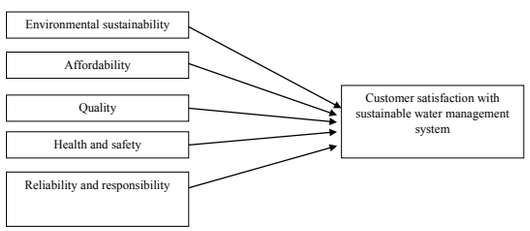

Fig .1 Main factors which affect customer satisfaction

VI. FORMULATION OF EMPIRICAL MODEL

$$Y_i = f(X_{1i}, X_{2i}, X_{3i}, X_{4i}, X_{5i},) \text{ err}$$

where

Y = Vectors of productivity

X_{1i} = Vectors of Environmental sustainability

X_{2i} = Vectors of Affordability

X_{3i} = Vectors of Quality

X_{4i} = Vectors of Health and safety

X_{5i} = Vectors of Reliability and responsibility

i = Organization

err = error factor

VI. SAMPLE PROFILE

There are many army establishments which are functioning under Panagoda army cantonment and questioner was distributed among the selected establishments by considering the higher strength. Accordingy 193 quetioner were collected among 300 distributed quetioners as the sample.

VII. DATA COLLECTION METHOD

The questionnaire was prepared and distributed to the consumers at army cantonment, Panagoda. As a pilot study 30 copies of a questionnaire were distributed and final questionnaire was streamlined accordingly. Then 300 copies of the questionnaire were distributed to different corps and institutions established in the cantonment. All questions were based on a Likert scale 1 to 5 (Strongly agree =1, Agree =2, Neutral=3, disagree = 4, Strongly disagree = 5) and data were entered to Excel sheets before analyzing using SPSS.

VIII. DATA ANALYSIS

The regression method was used to analyze the relationship between the independent variables and the dependent variable. Descriptive and inferential statistics were used to analyze the data. Collected data were statistically analyzed, using the SPSS version 23. Representations like tables and charts were used to ensure smooth and quick interpretation of data.

IX. RESULTS AND DISCUSSION

A. Results

Table 1: Overall satisfaction with the water supply management system rated by the respondents.

Satisfaction	Percentage		
	Total	Male	Female
Highly dissatisfied	2.11	1.58	0.53
Dissatisfied	8.42	7.89	0.53
No idea	17.37	16.32	1.05
Satisfied	61.05	54.21	6.84
Highly satisfied	11.05	11.05	0

A relatively higher number of respondents stated that the water supply system operated at a satisfactory level and no difficulties were encountered. However, some of the respondents genuinely stated that there are unresolved issues in the system. A major lapse of the current system was the insufficient amount of supply and the few respondents had faced difficult situations as some times they don't have water for the fulfillment of basic needs.

Irregular water supply was observed mainly after 1700 hrs to 2000 hrs on working days. Hence most of the people living in the cantonment faced a critical situation in fulfilling their basic needs. They stated that the supply pressure of the water is lower and not up to the satisfactory level. They also observed that several issues on the current system and have to introduce the remedies. Stated issues of the current system given as follows and need to get necessary actions to improve the current water supply system.

i. Not sufficient number of storage tanks in cantonment, no water tanks to collect water for bathing purposes, and water distribution pipelines are not up to the standard.

ii. Continuous water wastage occurred due to water leakages of old cast iron pipes, fittings, valves and taps.

iii. Delaying of taking actions to repair the water supply at the breakdown of supply.

iv. Mud and particulate matter in water.

v. Irregular water supply.

B. Discussion

Considering the statements of respondents and the personal observation at the army cantonment, following suggestions are produced to improve the current water supply system.

i. New storage tanks to be established.

ii. Repair the current pipeline and replace the old cast iron pipes.

iii. A continuous supply of water.

iv. Introduce water showers for bathing purposes and mitigate water wastage at bathing.

v. Quick actions on repairs on the breakdown.

vi. Using quality fittings.

vii. Introduction of tube well and efficiently distribution.

viii. Water supply at peak hours of usage in the sufficient volumes.

ix. Improve the water pressure and uninterrupted supply.

x. Knowledge dissemination and new rules enforcement to minimize water waste and sustainable usage to the consumers.

xi. Water supply with control measures.

xii. Daily inspection and maintenance.

X. CONCLUSION

a. The current water supply system should be improved for the perspective of sustainable manner. The current cast iron pipelines should be replaced by the PVC pipes and fittings.

b. Wastage of supplied water was observed in the bathing and cleaning operations and it is recommended to use gate-valves for the bip-taps. Therefore conserve water in the tap closing operations.

c. Further it is recommended to demolish ground water tanks which is built for bathing purpose and introduce water showers for bathing for all personnel.

d. Effluent treatment should be carried out in an appropriate manner. Wasting of the water and other resources should be identified and mitigate unnecessary waste and leaks.

e. The satisfaction of the consumers of the water supply system should be improved more with respect to affordability and health and safety aspects. Those aspects are considered as basic needs and dissatisfaction of the consumers may happen when not meeting their requirements. However, all five aspects had high negative gaps. Consumers are expecting more and satisfied less on all five aspects. Therefore, need of improvement of the system is identified. Customers are satisfied with the status-quo of water supply system. however, they seek more improvement.

f. Harvesting of solar energy and rainwater harvesting are identified as feasible alternatives for sustainable water management approaches and have comparable significance on the improvement of the current system as well as minimizing the unnecessary public expenditure.

g. It is recommended to have a deep study to minimize loss and improve the current system to the sustainable way and analysis the cost benefit.

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Poster Session Paper

URBANIZATION AND SOLID WASTE MANAGEMENT CHALLENGES: A REVIEW OF LITERATURE

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Abstract The aim of this study is to find out the Challenges of urbanization and Solid Waste Management urbanized city areas in developing countries most of these urbanizing cities and also a commercial hub, providing employment opportunities and accelerating the pace of urbanization, resulting in a corresponding increase in municipal solid waste (MSW) generation. Solid waste management is a one of main challenge for the any developing city and its authorities in developing countries mainly due to the increasing generation of waste, the burden posed on the municipal budget as a result of the high costs associated to its management, the lack of understanding over a diversity of factors that affect the different stages of waste management and linkages necessary to enable the entire handling system functioning. With the rapid urbanization of a developing city and Municipal waste is a term coined to the solid waste produced by the people and the society in their day to day operations. Secondary data was collected from books on this subject matter, publications, research studies, journals, and websites published by the local and foreign intellectuals of the subjects. It presents rich data results from literature review methods. This study describes and evaluates the present state of municipal solid waste management in municipal council area and identified the challenges face due poor management of the solid waste. Finally also summarizes the proposed policies and initiatives of the solid waste management in any urban council to improve the existing MSW management system in order to find the feasible solution for overcome the challenges.

Keywords: Municipal Solid Wastes, Municipal Solid Waste Management, Integrated Solid Waste Management. Solid Waste Management Strategies. Municipal Council

I. INTRODUCTION

Municipal waste is a term coined to the solid waste produced by the people and the society in their day to day operations. In other terms, these are also called as domestic waste. In order to study the analysis of waste management, it is very important to define what it is: Waste analysis is the detection of waste creeks, their origins, their composition and their destinations which is often accomplished through waste audit or assessment procedure. For example industrial waste varies in their composition and it is in more concentrated form which contains hazardous materials than compared to that of municipal solid waste and therefore it requires technologies and specific handling procedures In both categories, there exists major opportunities for prevention and resource recovery. There are variety of methods for disposing solid waste which vary globally which includes methods like dumping in open space, sanitary landfilling, incineration, and composting. Sanitary landfilling is prevalent in many developed countries, while in underdeveloped or less developed countries it is rare. In developing countries, low cost methods like dumping in open spaces, appears more acceptable than the other disposal methods. Despite the huge environmental problems, it is considered the main disposal method of urban solid waste in many of the cities.

II. OBJECTIVES

Objectives of the literature revive under the Title of Urbanization and Solid Waste Management Challenges are as follows.

i. To explore current state of waste management process.

ii. To recognize the Key performance indicators to measure waste management success.

iii. To examine main practical and strategic challenges of the waste management practices.

iv. To develop constructive remedies that can be adopted on a strategic basis for the identified issues to improve municipal waste management efficiency.

III. METHODOLOGY

The conceptual frame work for the challenges affecting successful solid waste management in developing cities had been prepared and this had been restructured to focus around the literature and empirical proof acquired. Further moving forward, hypothesis have been created for the study and these excessively have been justified focused around literature and empirical proof. Also it will specifically explain the methodology, the sample size, data collection, research design and other tools used in the research

IV. LITERATURE REVIEW

To Explore Current State Of Waste Management Process municipal solid waste is a term usually applied to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region. MSWM refers to the collection, transfer, treatment, recycling, resource recovery and disposal of solid waste in urban areas. MSWM is the most important service a council provides. Accordingly, most of the low-income countries as well as middle-income countries, MSW is the largest single budget item. Accordingly, solid waste is usually the one service that falls completely within the local government‘s purview. There, MSW includes wastes generated from residential, commercial, industrial, institutional, construction, demolition, process, and municipal services. Some studies, only consider residential waste as MSW, and in high income countries, only 25 percent to 35 percent of the overall waste stream is from residential sources. Country wide SWM infrastructure is weak, equipment is old and ill maintained, absenteeism is extremely high among municipal waste collectors, and resources that are spent are often misspent on duplication of efforts or corruption. There are many possible reasons why projects fail to meet the expectations and good intentions of the implementers. The report, and much of the literature researched, attributes the low success to lack of coordination, inadequate political will, too many players, jealousy among agencies and villagers, mistrust of new ideas, and resistance to change. As is true in other developing countries suffers from a lack of financial and human resources to obtain and implement expensive technologies, and has a shortage of skilled experts. Though the literacy rates in developing countries are extremely high, graduates are completing higher education without gaining practical, applicable skills and experience.

To Recognize the Key Performance Indicators to Measure Waste Management Success. Integrated Solid Waste Management (ISWM) is a comprehensive waste prevention, recycling, composting, and disposal system. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention, recycling and composting, and combustion and disposal in properly designed, constructed, and managed landfills. Further, Integrated Waste Management (IWM) is an approach that is most compatible with an environmentally sustainable development. It refers to the complementary use of a variety of practices to safely and effectively handle municipal solid waste. The strategy used to develop an integrated waste management system is to identify the levels at which the highest values of individual and collective materials can be recovered. The most favourable is reduction, which suggests using less to begin with and reusing more, thereby saving material production, resource cost, and energy. The least desirable is land filling. The approach not only aims at maximizing recovery of reusable and recyclable materials, but also reduces pollution and protects human health and the environment. The purpose of the waste management hierarchy is to make waste management practices as environmentally sound as possible. The waste management hierarchy has been adopted in various forms by most industrialized countries. The hierarchy is a useful policy tool for conserving resources, for dealing with landfill shortages, for minimizing air and water pollution, and for protecting public health and safety. In many developing countries, some aspects of this hierarchy are already in place, since traditional practices revolving around waste prevention reuse, and recycling are established.

To Examine Main Practical and Strategic Challenges of The Waste Management Practices In any developing country, urban areas are identified as Municipal council (MC) and urban council (UC) areas. Waste collection and disposal is happening in all the above MCs and UCs. It is estimated that large amount of tons/day of solid waste are generated in a city. The most common practice in almost all municipalities in developing countries are open burning, land filling (not technical) and open dumping of wastes. These methods are not considered as environmental friendly. About 85 % of collected waste is subjected to open dumping. Further, there are very good SWM system has been established in most of the councils. However, operation, maintenance, monitoring and evaluations are not properly implementing by these local authorities which leads for so many solid waste issues in urban areas. Further, today SWM issues are become a major environmental problem and also a national issue. To maximize resource recovery with a view to minimizing the amount of waste from disposal To minimize adverse environmental impacts due to waste disposal to ensure health and well-being of the people and on eco-system. Further, a major activity that bounded from the National Policy is the setting up of the Waste management Program to solve the solid waste problem at the national level, with the concept of reusing the resources available in the collected garbage to the maximum before final disposal.

To Develop Constructive Remedies that can be Adopted on A Strategic Basis for The Identified Issues to Improve Municipal Waste Management Efficiency At the present, solid waste management depends solely on collection and disposal method. These conventional methods need to be changed and should promote alternative techniques such as reduce, reuse and recycle the waste. And also, the Sri Lankans' the most popular and the easiest method of disposal; land fill technique must be the last option. Proper financial support should be given for the SWM to improve the infrastructure facilities, such as operating new equipment, technologies, training the staff and implementing awareness programs so on. Eradication of conventional mixed waste disposal. Developing the mechanism to separate waste at the source of generation and collecting those separated waste by local authorities without mixing them. Public education and participation is an important aspect in the context of current socio-economic pressures and complexities. It also envisages creating institutional methods to engage the city residents in municipal planning and decision making. Social awareness programs for home-level waste reduction, reuse and composting are also needed. Urban waste management will be easier and more effective only if the local authority can develop institutional mechanisms to promote sustainable partnerships with different stakeholders of the city such as the residents, civil society organizations and the private sector. Proper record keeping methods are needed. Currently, councils do not provide vital information required by the administrators and planners to understand the ward-specific, lane-specific quality and quantity of generated waste. It does not even provide leading information to plan the cadre and vehicle deployment effectively. Hardly any records exist that can indicate the types and volumes of different waste to help planners determine the different recycling modes and processes that can be used. Further, councils can collaborate with the Department of Education, the Central Environment Authority, Universities, other related agencies and NGOs, to conduct city wide public education activities to raise the environmental awareness levels of the public and the city residents in order to obtain their cooperation to implement the SWM Strategies, for doing researches in this context. Need human resources and also technical knowledge in LAs to coordinate both consumers and producers to promote the use of sustainable consumption and production though 3R and 5R and other SWM techniques. Develop alternative approaches like Waste to Energy[c] ensuring that these facilities are designed to maximize the environmental, financial and social benefits At the end, solid waste management should be an adaptive management approach with monitoring, identifying challenges and finding solutions to overcome those challenges. Accordingly, responsible parties should continue to adapt and evolve their solid waste management operations and infrastructure and create more resilient and adaptable systems. Further, as one of the main problems, a country like Sri Lanka facing is funding for these activities (Development of infrastructures) and failure to pay adequate attention for solid waste management. In this regards, mechanism should be developed for funding these activities such as main focus should be given to public and private sector participation.

V. JUSTIFICATION OF LITERATURE REVIEW

In the overall outcome it can be noted that through local and international literature a vast degree of lack in the sufficient measures connected to the waste management issues can be recognized and integrated to the research methodology. It was help to identified to explore current state of waste management process and with that it was help to derive to examine main practical and strategic challenges of the waste management practices in any developing country. Along with those factors and considerations finally this review was help to identify develop constructive remedies that can be adopted on a strategic basis for the identified issues to improve municipal waste management efficiency.

VI. DISCUSSION

Environmental problems may also be reduced by converting as much waste as possible into a solid product instead of washing the waste away into the wastewater. In general solid waste is fairly easy to control, requires less energy and is cheaper than wastewater treatment. In a few developed countries, environmental problems have led to the formulation of high quality standards for discharged water. To meet these standards, a combination of anaerobic and aerobic is required, often coupled to nutrient removal systems.

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AIRBORNE MEASUREMENT – ADVANCED INSTRUMENT DEVELOPMENT METHODS AND INSIGHT

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Abstract— Airborne measurement is required in many fields of aerospace, ranging from aircraft development and flight test, to atmospheric sciences. It involves the use of aircraft mounted instruments to measure quantities ranging from simple parameters such as pressure and airspeed, to more complex quantities such as atmospheric aerosols and solids. Although well-established traditional methods are available to design instruments in the airborne environment, the application of new advanced methods and sensors to refine instrument design, has seen slow adoption by most of these fields. The following paper presents examples of new approaches, which are used to refine a number of airborne instruments, including the measurement of sideslip angle and angle of attack using traditional instruments and strain and pressure using advanced fibre optic sensors. An example of the application of these methods to aerosol measurement is also discussed. In most cases, it is concluded instruments can be readily and quickly refined using these new techniques, including computational fluid dynamics. New sensors also offer potential improvements in the measurement of many airborne measurands.

Keywords - airborne sensor test, CFD, fibre optic sensor

I. INTRODUCTION

Airborne measurement is a critical requirement in the design and testing of aircraft and it still relies on traditional methods including pressure and vane measurement (Wuest 1980; van der Linden and Mensink 1977). It also plays a vital role in the field of airborne science where bespoke instruments are typically mounted on the fuselage or wings of an aircraft (McBeath 2014).

In a typical aircraft instrument, which may measure critical items such as airspeed or altitude, corrections are applied to the basic instrument to ensure the required levels of accuracy are met in flight (Reasor et al 2015). However, in some cases in airborne test platforms, limitations on where the instrument can be fitted can lead to undesirable performance of the instruments and specialised corrections are generally required (Bennett et a1 2017a; Bennett et al 2017b).

In the last 20 years, computational fluid dynamics (CFD) has seen rapid development in the aerospace sector

(Anderson 1995; Jameson & Ou 2011; Lawson et al 2017). This has allowed complex corrections to be applied to airborne instruments by using the CFD model of the full aircraft and instrument installation along with flight test data (Lawson et al 2013; Lawson et al 2014; Bennett et a1 2017a; Bennett et al 2017b; Reasor et al 2015).

Further advancements in sensor technology are also now offering new opportunities in airborne test and aircraft design (Boden et al 2013). In particular fibre optic sensors

which can measure pressure (Rao 2006), strain (Rao 1999) and displacement (Kissinger 2018) have been applied to a number of airborne platforms and offer a number of advantages including their footprint, resolution and installation (Lawson et al 2016, Lawson et al 2017, Bennett and Lawson 2018)

The following paper presents examples of the application of CFD to airborne instrument development and also presents example of applications of advanced fibre optic sensors to airborne measurement.

PREPARATION OF THE MODELS

A key part of the process in modelling the airborne test system is to obtain a fully scaled CFD model. In nearly all cases, a solid model will not be available to generate the CFD solution. Original Equipment Manufacturers (OEMs) do not release this data except with significant restrictions or unless the intellectual property output during the project was protected. Also many airborne research platforms are old airframes and are likely to have been designed without access or with limited access to computer aided design (CAD).

Therefore the best approach in these circumstances is to generate the solid model from a laser scan of the aircraft. Not only does this method ensure a full scale solid model is obtained, but it also ensures that any features which are key to the airborne platform, e.g. pods or blisters or other mounts, are also captured in the solid model. A typical process required to obtain a solid model is outlined below in Figure 1.

In the first stage of the process, the aircraft must be prepared before scanning to ensure the minimum number of changes to the solid model following the scan. So for example, the ideal situation is to have all the instruments on the aircraft that which correspond to the airborne test.

Also the instruments must ideally be configured in the same condition as expected for the test. Control surfaces must be set to typical flight angles as they may also have an impact on the flow field around the instruments.

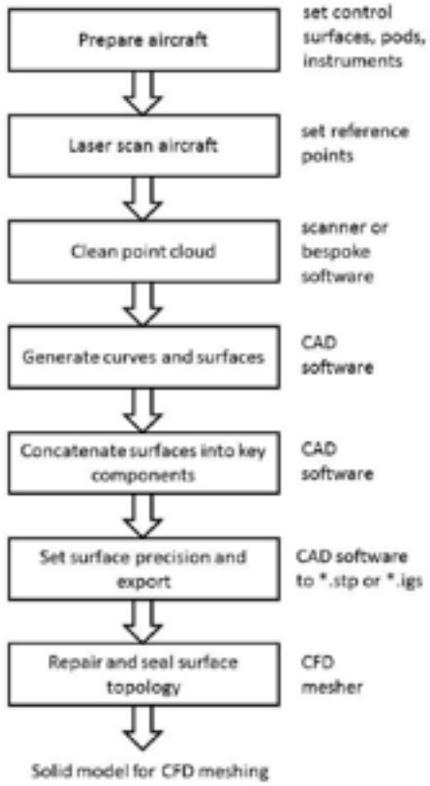

Figure 1. Process used to obtain a solid model for CFD from an airborne test airframe

During the scanning process, a further consideration is the position of reference points or mirrors for the scanner. Generally the laser scanner systems rely on photogrammetric reconstruction and a number of reference points in 3D space are required around the aircraft. For larger aircraft, this may require a greater volume than the hangar space available or where the aircraft is stored. In this situation, the aircraft must be scanned outside. There can also sometimes be issues with windows and canopies on the aircraft as the scanner will not receive a reflected signal. In these circumstances, all windows on the aircraft may need preparing with a removable powder or paint, which does not compromise the integrity of the window materials. Typically due to the optics of the scanner, the resolution of the scanner is fixed as a percentage of the range of distances being scanned. Hence, larger aircraft will result with larger absolute errors in the scanned geometry, but for the purposes of the CFD model, unless an instrument is positioned in a critical area, such as a transition region, these small geometric errors can be tolerated in the overall model.

Following the laser scan, the output is generally in the form of a point cloud which must be cleaned and prepared for export. In some situations, an assumption about the aircraft geometry is made and only half the aircraft is scanned with the point cloud being reflected about a reference line, before export to the CAD software.

Once the point cloud is imported into the CAD software, unless bespoke or specialised functions are available, surfaces must be individually generated by the CAD user by selecting areas of the point clouds to define curves. This reduced functionality can be found with academic licences for software such as CATIA or AutoCAD. If the point cloud is imported directly into the CFD meshing software, this can also cause issues as it is harder to control the surface mesh characteristics with this kind of approach. Therefore the selection and definition of curves is a time consuming process and is open to interpretation by the CAD user, to ensure a representative set of surfaces are prepared. Generally when this process is complete, to ensure fidelity of the overall surface model, there will be a significant number of surfaces which will need concatenation into less, key surfaces for the solid model, for example the fuselage, the wing top and bottom and the tail plane surfaces. At this stage, it is also important that the instrumentation under study for the model has sufficient fidelity, to ensure the local flow physics around the instrument is captured. In the author's experience, concatenation functions on most common CAD packages will provide a good reduced surface model for the CFD.

In the final stage of the CAD preparation, a suitable tolerance must be set for the export of the model into either IGES or STEP format. If these tolerances are not set correctly, when the CAD data is imported into the CFD meshing software, gaps will exist between some of the surfaces which will cause issues with the meshing. Providing these holes or gaps are not substantial, most meshing software such as Ansys ICEM CFDTM can automatically repair these holes using basic topology functions.

The following sections will now describe examples of the application of solid and CFD models to the design and refinement of airborne test instrumentation. For the Bulldog and BAE146 aircraft, a Leica ScanStation 2 was used with Leica Cyclone software to obtain the point cloud to develop the solid models.

BULLDOG AIRBORNE TEST MODEL

In the following example, a design of air data boom is modelled on the Bulldog wing by using CFD. To simplify the modification, the boom is mounted off the leading edge of the port wing with the sideslip angle and angle of attack vanes positioned less than one wing chord away from the leading edge (See Figure 2). This vane position results in a measurement error due to the effect of the upwash of the wing. The most significant error is in angle of attack and at higher angles of attack near the stall.

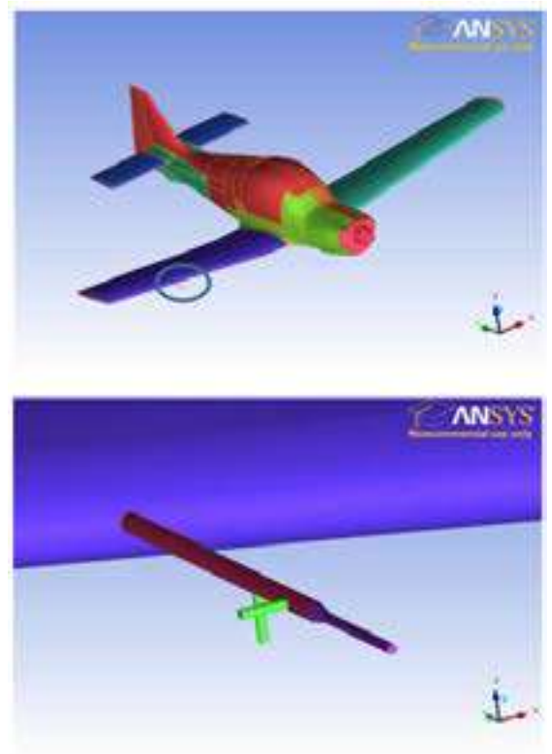

Figure 2. A CAD view of the air data boom on a Bulldog aircraft

As shown in Figure 2, the boom geometry is carefully modelled up to the vane and the flow characterised at the vane position through a range of angles of attack and sideslip. Here each vane is assumed to follow the local flow component and therefore the vane itself is omitted from the geometric model. This approach not only simplifies the CAD solid model but also simplifies the CFD mesh adjacent to the vanes.

In this case, the mesh and an example of the solution are shown in Figure 3. The effect of the upwash on the vane region of the databoom is clearly seen.

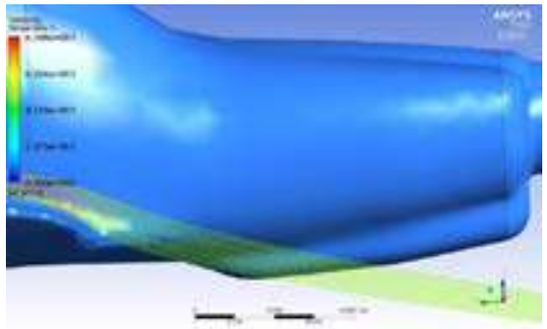

Figure 3. A CFD solution of the air flow over the data boom on a Bulldog aircraft

The results successfully characterise the upwash angle over the test conditions before the stall. Validation of the CFD is through previous published generic charts of upwash angle generated by potential flow solutions and modified lifting line methods outlined by Rawlings (1981). Figures 4 - 6 shows the CFD results predict the measured angle of attack as double the true value, where the measurement of sideslip angle show negligible error over the full range of angle of attack or sideslip angle measured. Further results show an improvement in the error when extending the boom position away from the leading edge and a degradation of error when positioning the boom closer to the leading edge. From this modelling, functions can then be developed which predict the error throughout the range of boom conditions and these functions can be incorporated into the measurement process to correct the data either during or after the flight test campaign.

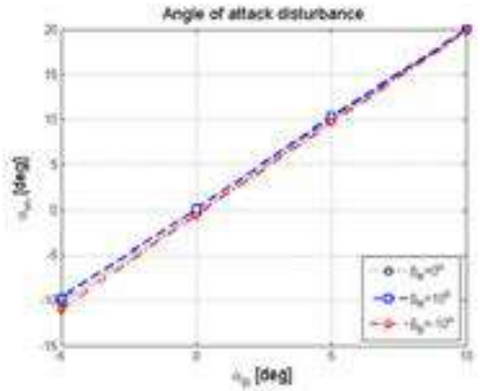

Figure 4. Effect of upwash on the measured angle of attack on the Bulldog air data boom over a range of sideslip angles

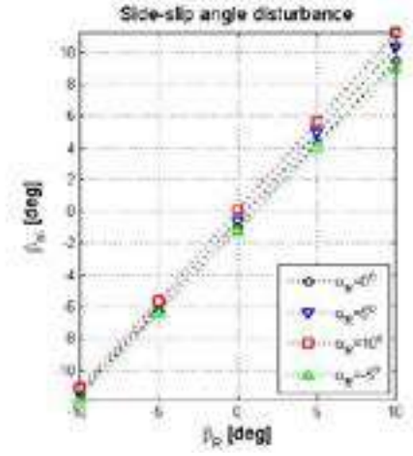

Figure 5. Effect of upwash on the measured angle of sideslip on the Bulldog air data boom over a range of sideslip angles

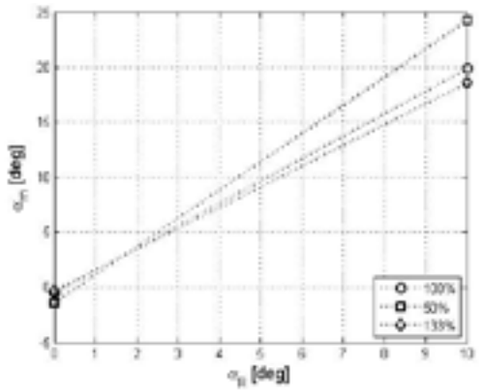

Figure 6. Effect of air data boom position on the measured angle of angle on the Bulldog data boom at zero sideslip angle

From this CFD data a calibration model can be developed based on linear behaviour which takes the form:

$$(\ , \ ) = (\ , \ ) + (\ , \ ) \qquad (1)$$

where is the real angle of attack, m is the measured angle of attack, m is the measured sideslip angle, k is the angle of attack calibration coefficient and k is the sideslip calibration coefficient.

IV. JETSTREAM AIRBORNE TEST MODEL

A further example of the application of CFD to minimise instrument measurement errors involves the development of a detailed model of a set of sideslip vanes and angle of attack vanes, positioned on the nose of the Cranfield University Jetstream aircraft. In this case, to simplify the certification process, the set of vanes were installed on the top and side of the aircraft nose and a flight test was used to estimate the vane angle characteristics (See Figure 7). The CFD mesh for the model is also shown below where the refined mesh around three vane positions can be seen (Figure 8).

The CFD model of the nose region, which also included an angle of attack vane, allowed characterisation of the vane angles through a matrix of flight conditions. In the figure below (Figure 9), which shows the local streamlines in the region of the nose, it is clear the presence of the nose is inducing an error between the true angle of attack, defined through the far field and the measured angle of attack defined by the local streamline.

This relationship also depends on sideslip angle and vice-versa. Therefore using the range of range of angle of attack and sideslip simulated in the CFD model, a relationship can be developed between angle of attack and sideslip angle as measured by the three vanes and the true sideslip and angle of attack that the aircraft was flying.

Figure 7. Jetstream 31 angle of attack and sideslip vane installation

Figure 8. Jetstream 31 angle of attack and sideslip vane CFD mesh

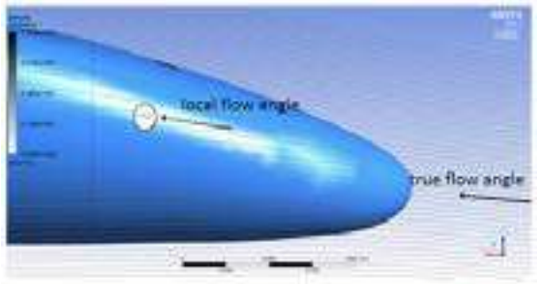

Figure 9. Jetstream 31 flow visualisation in the vane region showing the difference in true and measured angle of attack

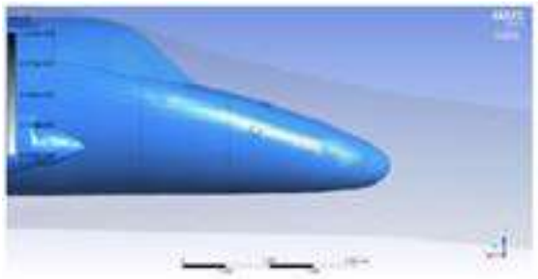

Figure 10. Jetstream 31 flow visualisation in the vane region

Using this relationship, a true angle of attack and sideslip for any flight condition can be estimated under any flight condition. This CFD model of the nose vanes was then checked using independent flight test data taken from an inertial reference unit mounted inside the aircraft.

As the modelled system now uses three measured sources to estimate two true values, a more complex relationship is used which takes the form:

the fan face and the flow conditions at the nearest canisters studied with and without the jet. In this case no significant changes in local pressure coefficient or flow angle were found and so the remaining solutions used empty nacelles.

= +13+22+3+4 53+62+7+8 (2)

= +93+102+11+12 133+142+15+16 (3)

= +173+182+19+20 213+222+23+24 (4)

where the constants k1 – k24 are obtained through correlations of the CFD data and flight test data. Therefore for any value of m or m, the equations can be solved to yield the true values and from the vane data.

V. BAE146 AIRBORNE TEST MODEL

A final example of the application of CFD to study instrument installation effects was the development of a detailed model of the wing booms found on the Facility for Airborne Atmospheric Measurement (FAAM), which is a BAE Systems 146 aircraft (McBeath 2014). This aircraft has been fitted with underwing pods on the outboard section of each wing. Each underwing pod contain 4 standard particle measuring Systems (PMS) sized canisters which allows the aircraft to carry a range of atmospheric sampling instruments.

A full scan of the aircraft was undertaken using the Leica ScanStation2 and as outlined previously a solid model was developed for meshing in ICEM CFD. The solid model from this process, which includes the canisters in a basic configuration, is shown in Figure 10.

The CFD solutions studied were both viscid and inviscid and with and without the influence of the jet engines in the nacelles. In the former case, viscid and inviscid models showed little difference in the behaviour of the local flow around the canisters due to the high Reynolds numbers of the airborne test conditions. Therefore inviscid models were chosen for the remaining study to save computational time and resources. With inclusion of the jets, there was concern that the engines would influence the local flow around the most adjacent canisters. Therefore a representative pressure ratio and mass flow was set up in the nacelle as a pressure jump condition at

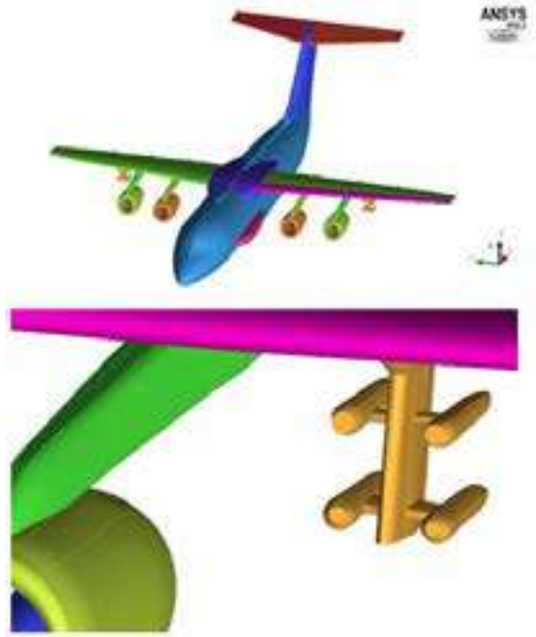

Figure 11. BAE146 solid model showing underwing pods and canisters

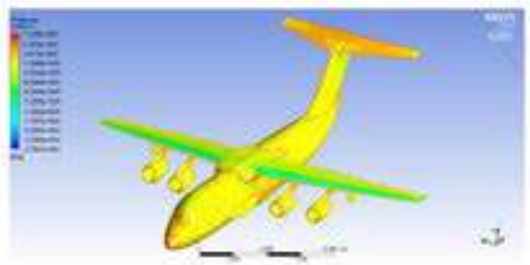

Figure 12. BAE146 pressure field at science speed (6o angle of attack and 107m/s, ISA SL)

Flow solutions for the inviscid case at ISA sea level and test conditions with an angle of attack of 6o and a true airspeed of 107m/s (zero sideslip angle) are shown in Figures 12 - 14. Although the pressure field around the aircraft is as expected, examination of the local flow direction on the canisters shows significant deviation from freestream both with respect to the angle of attack and sideslip angle. The view from the bottom of the aircraft (see Figure 14) shows a substantial crossflow on the canisters. Analysis has found flow deviations of up to 5 degrees from probe reference lines.

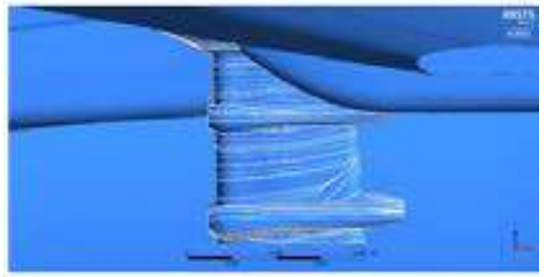

Figure 13. Surface flow visualisation of underwing pods and canisters

Figure 14: . Flow visualisation of underwing pods and canisters

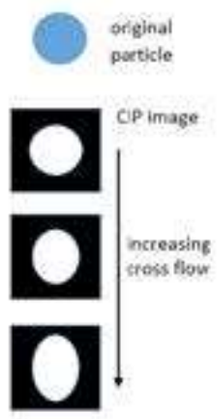

Figure 16. Effect of cross flow component on cloud imaging probe (CIP) liquid particle image

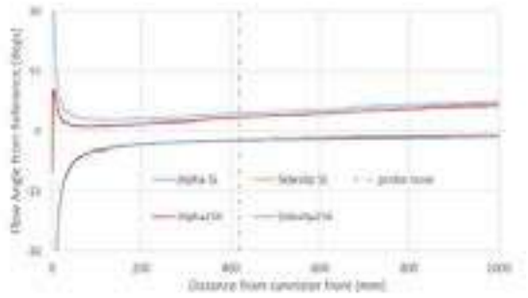

Figure 15. Flow angularity forward of bottom outer canister with typical instrument probe nose position

Such flow deviations from the probe reference lines and the associated cross-flows adjacent to the probes can induce errors in the measurements from the probes. As an example, a cloud imaging probe (CIP) on the aircraft uses instantaneous profile images of the particles through the probe volume, to estimate particle size. Cross flows into the probe measurement volume will distort the particle shape as they pass through the imaging volume (see Figure 16). Liquid particles in clouds which may start as a spheroids in the freestream will be distorted into an ellipsoid. Depending on the probe algorithm, this distortion will induce an error in the size estimation. Figure 17 confirms this crossflow effect on particle size from real airborne data taken from the FAAM aircraft in a recent flight test campaign. The probe is a model DMT CIP100-2. Therefore in certain measurement scenarios, the CFD data will allow a correction to be developed for these types of measurements.

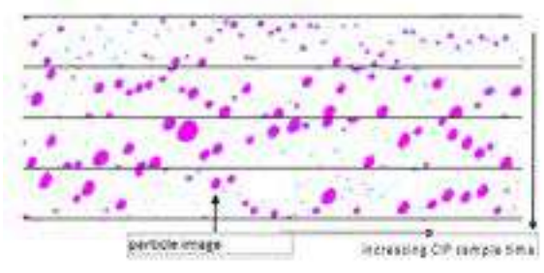

Figure 17. CIP image sequence from the Facility for Airborne Atmospheric Measurements (FAAM) at science speed (courtesy G. Nott and C. Reed, FAAM)

VI. ADVANCED MEASUREMENT SENSORS

Fibre optic sensors are now mature enough to allow their application in aerospace environments (Lawson et al 2016, Lawson et al 2017, Bennett and Lawson 2018). In particular, interrogators which are aerospace approved, for example which meet a Mil Std or CS-25, offer new opportunities to test fibre optic sensors in flight. Recent work by Cranfield University has proven pressure and strain measurement by using a Bulldog aerobatic light aircraft (see Figure 18). The basic sensor suite is shown in Figure 19 and a sample of data taken during an aerobatic manoeuvre shows the response of the sensor under high normal g-loads (see Figure 20). The key challenges in the current sensor designs are removing temperature sensitivity from the system, particularly for the pressure sensors, which are based on Fabry Perot methods.

Potentially these sensors can be integrated into more advanced aircraft composite structures, to offer real time monitoring of structure characteristics, including shape and also health monitoring for longer term analysis of the

structure. Future advances in pressure sensors, in addition, offer the potential for control flow on the aircraft.

sensor path length to resolution or signal to noise, therefore allowing multiple sensors to be placed over a large structure, without degradation of sensor performance.

Work continues at Cranfield University in this area of instrumentation development, with a potential flight test of fibre sensors on a CS-25 category aircraft expected in the next 2 years.

Figure 18. Cranfield University Bulldog airborne test platform

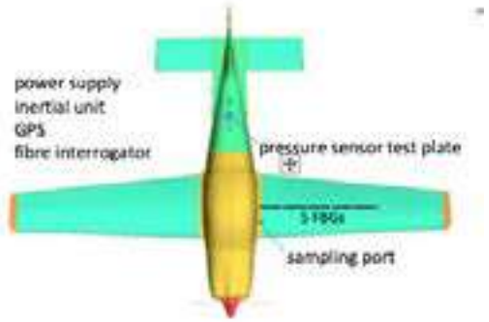

Figure 19. Cranfield University Bulldog overview of advanced instrumentation suite

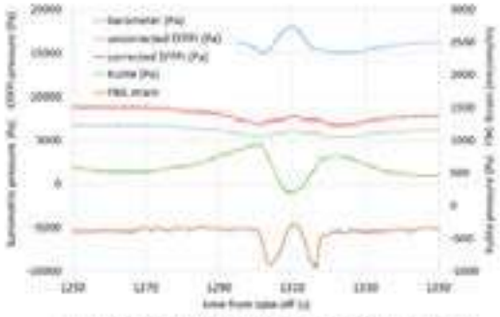

Figure 20. Flight test fibre optic data taken during an aerobatic manoeuvre in the Bulldog aircraft

The flow chart in Figure 21 gives a summary of fibre optic sensors systems which can be combined to study parameters ranging from temperature to shape. In general, Fabry Perot sensors are adapted to measure pressure, fibre Bragg gratings (FBGs) measure strain and fibre segment interferometry (FSI) measures displacement. In the latter two cases, these measurand can be used to estimate object shape such as for a wing in flight. A major advantage of these sensors is also immunity from electromagnetic interference and virtual independence of

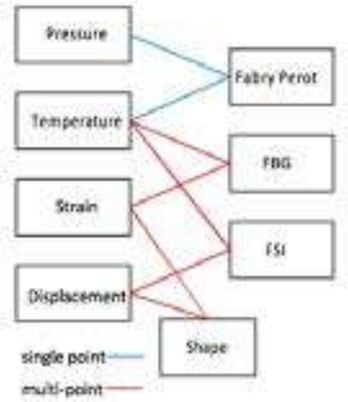

Figure 21. Fibre optic sensor measurands and methods

VII. CONCLUSIONS

This paper has presented examples of new approaches to develop and refine sensors and instruments for use in airborne test. The application of computational fluid dynamics (CFD), combined with detailed solid models of the aircraft, now offer the potential to optimise instruments and sensors on the aircraft, ahead of any airborne test. These methods can also be retrospectively applied to an aircraft to improve or offer correction methods to the sensors and instruments, thus reducing instrument error and increasing instrumental and sensor performance.

Examples of advanced fibre optic sensors for airborne test have also been presented and their advantages discussed. This technology is now mature enough to give detailed and integrated measurements in airborne test and future aircraft designs.

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