

# Greenhouse Automation with Artificial Intelligence and Industry 4.0 Integration

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**Abstract**— *ARTIFICIAL INTELLIGENCE (AI) has been a Game Changer in Various Industries and Fields. AI is a sophisticated system that learns over time improving its performance. It is an intelligent control system that normally uses big data to learn and predict the next action.*

*Industry 4.0, it is based on integration of business and manufacturing processes as well as integration of all actors in the value chain. In industry, 4.0 technical aspects of above requirements are met by application of generic concepts of CYBER PHYSICAL SYSTEMS (CPS), INTERNET OF THINGS (IOT) and INTERNET OF SERVICE (Rojko, 2017),(Almada-Lobo, 2016).*

*Greenhouses are framed structures covered with transparent material in which crops can be grown under controlled environment (Nirlipta Ranjan Mohanty and C.Y. Patil, 2018). Greenhouses are an optimal solution for global food crisis and climate changes. By using an AI system to automate a greenhouse is more beneficial than currently available solutions. Traditional methods like using robots, or smart greenhouses still use Remote Control like manual methods, but an AI is able to predict, Inter-communicate and make decisions, these predictions are based on data gathered over time, where these decisions error rate will be lower than human calculations. There are many factors that influence greenhouse production and those factors can impact Production of Greenhouses. For a human it is impossible to analyze all those data but an AI can analyze and calculate all of those factors and provide highly accurate predictions and make decisions, As time goes AI learns about patterns and many factors and improves itself, this will also boost the performance and control of Automated Greenhouses.*

**Keywords:** Greenhouse, Artificial Intelligence, Industry 4.0, Greenhouse Automation, Machine Learning, Neural Networks, Agriculture, Big Data, Arduino.

## I. INTRODUCTION

21<sup>st</sup> Century has many global issues, but a few stands out. The reason for this is that problems and answers for them directly reflects survival of human civilization. In this

research we aim to address two of these issues, Food Shortage and Manpower Shortage (Workforce Crisis).

Food Shortage is a global problem that has caused problems in many industries. The 2018 Global Report on Food Crises provides the latest estimates of severe hunger in the world. An estimated 124 million people in 51 countries are currently facing crisis or food insecurity or worse (the equivalent of IPC/CH Phase 3 or above). Conflict and insecurity continued to be the primary drivers of food insecurity in 18 countries, where almost 74 million food-insecure people remain in need of urgent assistance (“2018 Global Report on Food Crises | World Food Programme,” 2018).

Manpower shortage is a becoming a very concerned problem in 21<sup>st</sup> century. Every economy ‘s ability to compete depends on steady supply of human capital and talent. When that supply is inadequate, imbalances result, creating serious threats not only to the economy but also to social and political stability and future development in every industry. These impacts, moreover, extends beyond borders and becomes global threats (“The Global Workforce Crisis: \$10 Trillion at Risk,” 2014).

AI is the broader concept of machines being able to carry out tasks in a way that we would consider “smart” (Marr, 2016). in this application we use machine learning to implement the intelligent part of the system. Machine Learning is the science of designing and applying algorithms that are able to learn things from past cases. If some behavior exists in past, then you may predict if or it can happen again (MARUTI Techlabs, 2016). By utilizing machine learning we can improve the overall performance of the greenhouse and reduce the error rate considerably.

Modern greenhouse technology deploys automation in agriculture which is now common due to the low costs of electronic components required for its implementation. A lot of efforts have been made by many researchers to automate the traditional greenhouse system. In this system what we aim is to achieve is 90-95%

automated greenhouse. We use Hydroponics Greenhouse. By using an AI Integrated System, we can Automate Plant Growth, Weather Control and Nutrition Control. We Use Sensors to Detect Plant Conditions & Growth, by using Sensor Data AI Controls All the conditions within the greenhouse to be optimal for plants. with sensors provides information used by the control algorithms to modulate ventilation, heating, lighting, moisture, nutrition and every other aspect of the greenhouse. At the same time AI uses these data and past data collected by the it to minimize the errors in Plant Growth and Maximize the Plant Growth and get a higher vest yield. What is important is that even without human supervision system can sustain for longer periods of time. and There is a Web Application to control and monitor the Greenhouse remotely.

## II. METHODOLOGY

The research studied how machine learning being used in modern industry and the agricultural industry. Previous studies have demonstrated that all the systems that uses AI techniques like machine learning and neural networks in agriculture are focusing only on one aspect, where predicting crop yield and does not use it for controlling or management. The main objective of this study is to apply AI techniques like machine learning to every aspect of the greenhouse production by doing so automating the greenhouse and reducing the workforce' needed.

The study is a qualitative approach, since the nature of the research is highly experimental and conceptual at this point, as there are only a few sources to gather data. it was decided to move forwards with a qualitative research approach. As for the data gathering method, record keeping method is used in this study because it makes use of the already existing reliable documents and similar sources of information, by using existing information, we can derive the objective of this research. It is well suited for this kind of study. Record keeping study was used because the focus of the study is more to describe, explain and less for prediction. Document analysis were the main data collection techniques for the study. since the study is still highly conceptual at this point and AI is still growing is the reason for choosing record keeping method. Since the area of the research is still new to the industry there is less information to go by. This is a limitation to data collection, but the research provides solutions for many Issues in agricultural industry and future of AI is proven to be applicable to agriculture and they outweigh the limitations posed by data collection.

## III. LITERATURE REVIEW

In this research, how artificial Intelligence was used in modern industry and in agriculture was studied.

Greenhouses are a solution for many problems in agriculture Industry and global issues. It is a Fact that global food shortage is imminent("2018 Global Report on Food Crises | World Food Programme," 2018) and another global issue that we are facing is manpower shortage("The Global Workforce Crisis: \$10 Trillion at Risk," 2014). To answer to first issue greenhouses are an excellent solution but with that another problem arises, to operate a greenhouse needs special knowledge and skillset not everyone can do the job. With that comes the global workforce crisis, not enough manpower to do the job, to answer these issues a solution is automated greenhouse but there are already automated greenhouses, but not all the way through current solutions available is somewhat automated reason is these available solutions automates one or two aspects like temperature and air ventilation but not all of the aspects of the greenhouse. Another issue is that all of those available systems are smart greenhouse system that still needs considerable manpower and skillset to operate the system("Smart Greenhouse | 2019 Guide to best Sensors and Remote Automated Monitoring Software," n.d.). What we are proposing is a system that can that reduce the needed manpower to 70-90 %. we achieve this by adding an AI System to the greenhouse and letting the AI system handle all the work. AI is not new to the world but in this decade (2010 – forward) we see a rise to it, there are many implementation that uses AI(Adams, n.d.). By using an AI, we can reduce the manpower we use to Nutrient Supply and Environment Control. We can completely remove them and replace the AI system to control the Greenhouse.

As shown in the block diagram (Annexure 1). There are 3 Major Systems to the Artificial Intelligence Automated Greenhouse System (AIAGS),

- Greenhouse
- Processing System
- Web Application

Greenhouse Has 7 Major Sub-Systems Attached to It,

- i. Temperature Control
- ii. Moisture Control
- iii. Humidity Control
- iv. Plant Nutrition
- v. Water & Nutrition Pumps
- vi. Air Ventilation
- vii. Artificial Lighting

Each of these systems has sensors and controls to control their respective Attribute. For these sensors and controllers, we can use Arduino Technology it is non-expensive approach to what is available in market and currently from 2014 onward is becoming somewhat standardized on the market [10].

**Temperature Control,**

Temperature control is an essential part of greenhouse environment control. In here for temperature control greenhouse uses temperature sensors to gather data at certain time intervals. When a temperature fluctuation happens, it activates temperature control system [11]. if it below the desired temperature It will Activate Sprinkler Systems, Air Ventilation Systems, Heat Elements to regulate the temperature to an optimal level. If the

temperature is above the desired level of temperature the system will activate the heat element to bring up the temperature to an optimal level.

#### **Moisture Control,**

As for the moisture control a sensor will detect the moisture levels at a given time intervals and if fluctuations are happening it will activate the Air Ventilation, Heat Elements and Sprinkler Systems to Control the Moisture of the greenhouse [12], [13]. however, this sub-system does not apply to soil-less hydroponic greenhouses.

#### **Humidity Control,**

Humidity is checked by a humidity sensor and it is maintained at an optimal level. The method of controlling humidity regulation temperature via Temperature Control System [13].

#### **Plant Nutrition,**

Since the greenhouse uses hydroponics it is rather easy to control plant nutrition. The system detects nutrition levels using an EC meter in the Nutrition Chamber and Adjusts the Nutrition levels of the plants. An EC meter is a great tool for measuring the strength of hydroponic nutrient formulas. EC stands for electrical conductivity. mineral ions (fertilizers) that are dissolved in the water, the more it conducts electricity. Measuring EC is a great way to determine if there is enough fertilizer in the water to meet the needs of plants. The higher the concentration of fertilizer salts dissolved in water, the higher the EC. The more diluted the nutrient solution, the lower the EC(Harley, 2016).

#### **Water and Nutrition Pumps,**

For Water and Nutrition pumps there are two pumps, one for fresh water and the other one for nutrient pumping. For this setup three tanks are configured one with fresh water, one with nutrients and other with diluted nutrients. When the EC is low on the flow system will detect the values and adjust the nutrients from the nutrient tank, if it is high more water will be mixed into the flow from water tank. The freshwater tank is filtered via a Ultraviolet filter. Diluted nutrient will not be used again and it will be removed when the tank is full(Kläring, 2001; Postscapes, 2018).

#### **Air Ventilation,**

Air Ventilation is controlled by fans around the greenhouse that keep a steady flow of air throughout the greenhouse and controlled accordingly to the situation via the system. Air intake is filtered for bugs and other threats

by a filtration system. Air ventilation system is coupled with a CO<sub>2</sub> Control unit to control the CO<sub>2</sub> levels of the greenhouse(Emeritus William J. Roberts, 2003; "Ventilation System Automation for Small Greenhouses and Indoor Gardens," 2018),("Greenhouse Automation - Temperature, Humidity and Gas Monitoring," 2018).

#### **Artificial Lighting,**

This lighting system uses grow lights as a light source for the plants. This system is a backup system when there is not enough sun light to provide nutrition to the plants. It gets activated by the intensity of sunlight, and gets adjusted by the system accordingly to the time of the day(Kent Gruetzmacher, 2019).

All the above systems have their own sensors and controllers. As for those systems, what is currently available in the market is very expensive, To battle it we can use a simple technology like Arduino (Faris and Mahmood, 2014; Jonathan Enokela and Theophilus Othoigbe, 2015).

The Processing System is divided into three Major Sub-Systems,

- Database
- Decision Support System
- AI (Expert System)

The Database stores all the sensor data it receives and the commands that are issued by the system. The Decision- Support System (DSS) is there to help the user to make decisions regarding control (Vicky Sauter, 2002)of the greenhouse. The DSS provides reports and analysis regarding every aspect of the system.

The AI System or the Expert System is active when the user is not in command of the system. It analyses the real time data with past data and makes decisions. To make these decisions more accurate it needs huge chunks of data or Big Data. When analyzing these large sets of data, machine learning comes into play, machine learning uses complex algorithms that constantly iterate over large data sets, analyzing the patterns in data and facilitating machines to respond different situations for which they have not been explicitly programmed. The machines learn from the history to produce reliable results. The Machine Learning algorithms use Computer Science and Statistics to predict rational outputs(Marr, 2016) the AI system trains itself as it gets used. This constantly improves the performance of the greenhouse.

The Web Application supplies the user with a user interface to interact with the system. Since this is a Web Application user needs an active Internet connection. But it does not require a specific platform to operate[25]. The Web Application will deliver real-time updates and data to the user via the internet using cloud technology. The Web

Application uses cloud to store and forward the data to the system and retrieve the data by same way.

These 3 Major Systems Operates as one System. Because of the machine learning capabilities system will improve over time as data gets collected and analyzed. This system will improve overtime in a steady and faster manner, and it will reduce the manpower needed from 70% up to 95-95% on greenhouse work labor reason for this is that the AI system takes care of all monitoring, Environment Control and Plant nutrition needs via the System Controls. It only needs time to time monitoring and system maintenance.

#### **The AIAGS has 3 Major Functions,**

##### **24/7 Online Greenhouse Monitoring System,**

AIAGS is monitor the greenhouse with the sensors and stores data in a local database and uploads those data in real time to cloud. This is an always online 24-hour process.

##### **24/7 Online Greenhouse Automated Control from Environment Control to Nutrition Control,**

AIAGS is Automatically controls the greenhouse environment and plan nutrition according to monitored results and saves the data in the cloud and a local database. This is an always online 24-hour process.

##### **24/7 Online Web Application and Monitoring System.**

Since the web application receives real time data from the AIAGS via cloud it is always online, and the users can monitor the system externally.

#### **IV. DATA ANALYSIS**

To answer the study questions, based on the data we found in the study briefly presented in the previous section, are now discussed.

**Question:** is it Possible to build a fully automated greenhouse with integration of AI and in accordance with Industry 4.0?

**Factor 1:** the main objective of a greenhouse is environment control and nutrition control so the plants can produce a good crop. So to automate a greenhouse, it is possible using a technology like Arduino according to "An Automated Greenhouse Control System Using Arduino Prototyping Platform by Jonathan Enokela, Theophilus Othoigbe"(Jonathan Enokela and Theophilus Othoigbe, 2015).

"Automation of a greenhouse brings about efficient data acquisition and control of the microclimatic parameters. It also significantly reduces the labor involved in its maintenance thus making the system useful for rural farmers, small scale agriculturists, gardeners, and agricultural researchers."

**Factor 2:** since it is possible to build an automated greenhouse and it is already been done(Faris and Mahmood, 2014; "Greenhouse Automation - Temperature, Humidity and Gas Monitoring," 2018;

Jonathan Enokela and Theophilus Othoigbe, 2015). Another fact is that it is also possible to integrate AI technology techniques to Agriculture. According to "Machine Learning in Agriculture: A Review by Konstantinos G. Liakos, Patrizia Busato, Dimitrios Moshou, Simon Pearson and Dionysis Bochtis".(Liakos et al., 2018) "ML models have been applied in multiple applications for crop management (61%); mostly yield prediction (20%) and disease detection (22%). This trend in the applications distribution reflects the data intense applications within crop and high use of images (spectral, hyperspectral, NIR, etc.). Data analysis, as a mature scientific field, provides the ground for the development of numerous applications related to crop management because, in most cases, ML-based predictions can be extracted without the need for fusion of data from other resources."

According to "Agricultural Crop Yield Prediction Using Artificial Neural Network Approach Miss.Snehal S.Dahikar, Dr.Sandeep V.Rode".(Snehal and Sandeep, 2014)

"crop prediction methodology is used to predict the suitable crop by sensing various parameter of soil and also parameter related to atmosphere. For that purpose, we are used artificial neural network (ANN)."

To factor it in Applying AI techniques like Machine Learning and Neural networks is possible. It is already in use.

**Factor 3:** Industry 4.0 is about integration of business and manufacturing processes as well as integrating all of the actors in a production line. Is Automating a greenhouse and integrating AI technology to it in accordance with industry 4.0. yes, by integrating Greenhouse with AI it achieves integration of all the components within the greenhouse and it uses IOT Technologies(Rojko, 2017).

According to above 3 Factors we can Confirm that it is possible to fully automate a greenhouse by integrating an AI techniques and industry 4.0 concepts.

#### **V. LIMITATIONS AND CHALLENGES OF IMPLEMENTATION**

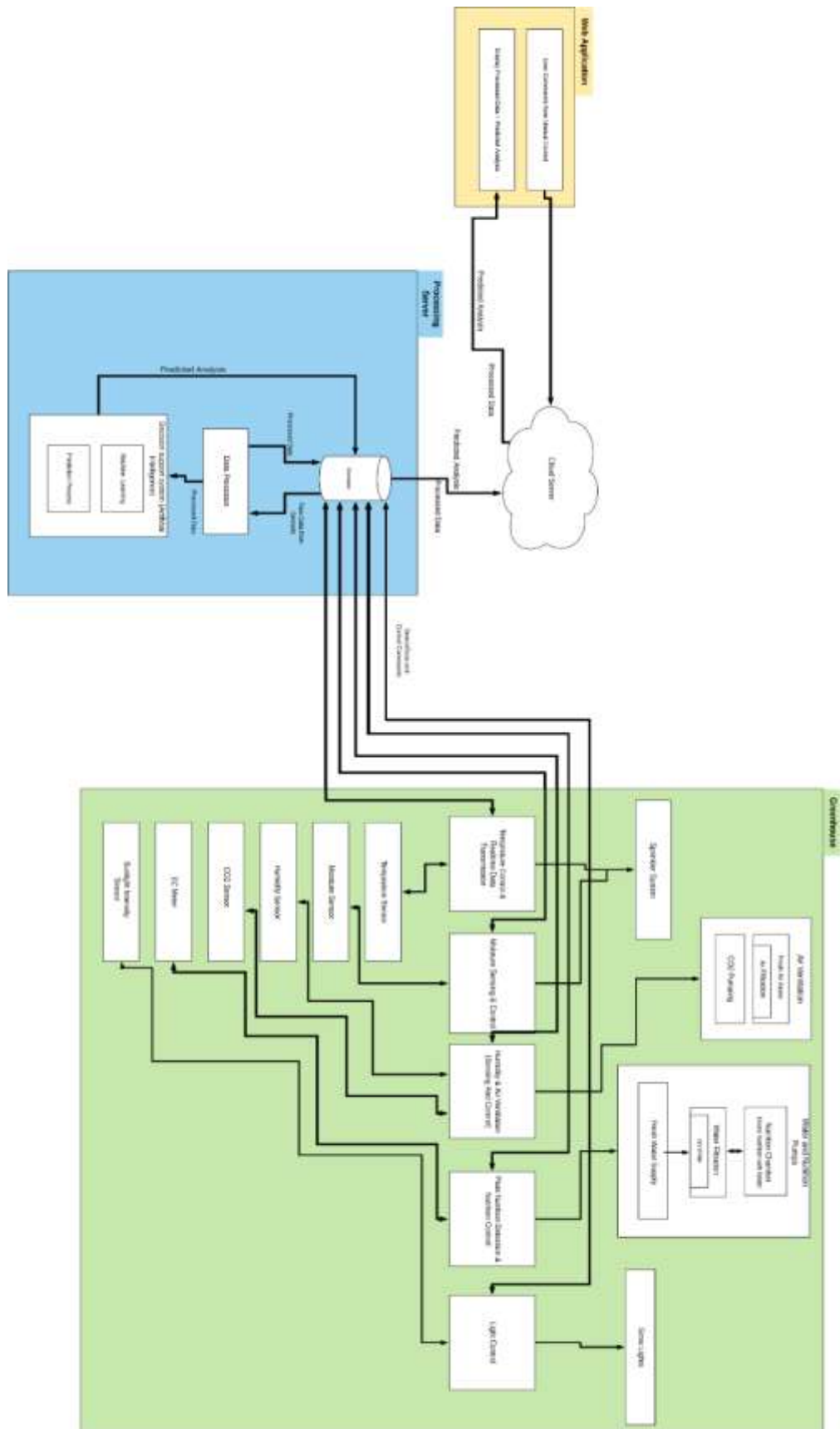
When implementing a project like this there are many issues, since this involves agriculture and Technology it is crucial that both Agricultural and Technological counterparts communicate clearly. A greenhouse is not a cheap investment it is going to be very expensive and implementing a complete system with machine learning is also very costly and highly time consuming. So, it needs to be done after careful planning and consideration. Apart from greenhouse other hardware like sensors and controllers need to be very accurate and precise these types of equipment are very expensive. Since this type of project is never been done before, it is going to be highly experimental implementation and the system uses machine learning it needs lots of data to train the program. As such it is going to be a challenge to get highly accurate data to train the

system. Another challenge is it needs to be accordance with industry 4.0 concepts, since the industry 4.0 is still new around the world it is going to be a challenge to find the right footing in the field.

#### VI. CONCLUSION

Our system enables people to monitor and manage growing conditions of their greenhouse. The use sensor nodes, internet connection, the cloud and the AI system will deliver real-time updates about plants and manage the growth of the plants more efficiently. Since the system uses AI to Control and monitor the greenhouse plants will grow in a more efficient way, it will enable to decrease the manpower 70-90% and as the time goes the more data processing happens the system will improve its accuracy. Implementation of such a system in the field can help to improve the yield of the crops and overall production, and with its quality to cost ratio, it will be affordable to the majority of the agricultural community and also in technological community. If this project were to implemented successfully it will provide solutions to many global issues we face today, from world hunger, Climate change to workforce crisis.

I. Annexure



Annexure 1. Block Diagram of AIAGS  
Source: Author Created

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