Knowledge Based Expert System for Defect Identification and Rectification in Engine and Steering Control Systems of Fast Attack Crafts

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Abstract:Cognitive systems deal with symbolic manipulations on knowledge and it's stored as rules, theories etc. State-of-the-art fault detection methods are equipment and domain specific and non-comprehensive. However, possessing domain knowledge and human reasoning can be applied for fault detection by having a thorough understanding of the associated system and its surroundings. This study introduces a complete semantic framework for fault detection and diagnostics (FDD) in system simulation and control of an indigenously designed engine and steering control system for Fast Attack Crafts (FAC) by the Sri Lanka Navy. The suggested technique includes the construction of knowledge base for FDD purposes using rules and offers increased functionality of such systems using inference-based reasoning to extract information about operational anomalies. Hence, an Expert System (ES) has been designed as a solution for defect identification and rectification (DIDR) challenge for the indigenously designed Naval Propulsion and Steering Control (NPSC) System onboard FACs.

Keywords: Defect Identification and Defect Rectification, Expert System, knowledge base, inference-engine, user interface

1. Introduction

With the development of early cognitive systems over the years, ES have gained widespread recognition in a variety of domains like technical, medical and social fields. An ES is a knowledge-based system that simulates expert cognition in order to solve important issues in a certain subject of expertise. Hence, an ES can be utilized for domain specific problem solving in areas such as analysis, classification & interpretation, diagnosis & debugging, monitoring & control, designing, planning & prediction etc. All these applications have been practically applied with ES solutions.

It is a computer software that imitates a human expert in a given subject by using explicitly expressed knowledge and computational inference techniques. As a result, ESs typically consist of three key components: a knowledge base, an inference engine and an user interface. The knowledge base contains a set of facts, procedures, knowledge etc. The inference engine which has the reasoning technique is the power of an ES. Several problem solving strategies are used in such intelligent reasoning like search, forward and backward chaining, conflict resolution, uncertainty handling. User Interface provides access to developers or users to handle inputs and outputs to the ES through an interface such as Natural Language Processing (NLP), chatbots, asking questions via voice and text etc.

In the domain of DIDR of a mechanical system, several diagnoses in technological processes have been created. Model-based approaches, knowledge-based approaches, qualitative simulation-based approaches, neural network- based approaches and traditional multivariate statistical techniques are among these strategies.

The research has been focused on DIDR of engine and steering control system designed as NPSC which has been installed onboard FACs. An ES has been designed in this study for DIDR of the NPSC system and has to be accessed when a fault alarm arises in the system. A user friendly interface has been designed for easy interaction with the system.

A. Problem Statement

The NPSC system which is indigenously designed and developed by Sri Lanka Navy is an advanced engine and steering control system based on programmable logic controllers (PLC). A marine grade control system is vulnerable to get defected out at sea. While a FAC is patrolling out at sea, there is less possibility for the seamen to identify the technical defects with their general knowledge. Hence, the craft has to come alongside a pier for technical expertise assistance by keeping the primary task at sea non-addressed. This has been identified as a major issue since task of a FAC corporates with security, operational and finance matters directly. Proper FDD implementation can enable proactive DIDR before they have a major negative impact on the operating system's safety, security or efficiency. Hence, an in house solution was found to address the matter by introducing a system which acts as an ES for DIDR.

B. Objectives and Scope

This study has focused on the use of expert knowledge in the domain of defect identification and rectification of engine and steering control systems for an Expert System. The applied ES is proposed for the indigenously designed NPSC system. Whenever a defect occurs in the system, a fault alarm is indicated on the designed Human Machine Interface (HMI). Hence system operates on specific/narrow areas only. Officer in Command (OIC) of a FAC out at sea will be the client. Hence, in any defect regarding NPSC system, he can get consultation from the ES for defect identification and rectification.

The ES is designed to ask various questions according to the error reading in alarm format and comes to the precise conclusion based on forward chaining. Processing incomplete information has been achieved by asking questions at the forward chaining process. Further, this system provides alternative solutions to identify the defects when forward chaining questioning happens. Further this provides certainty factor of a final conclusion but it is required to train the system with several clients with their point of view on defect identification and experience to get the best certainty factor. This FDD system also recommends further actions for rectification process rather giving the exact answer to the root cause of the defect and it gives reasons for final conclusions as well.

2. Literature Review

ES development for fault diagnosis in maritime environment has being most popular due to the requirement of fault detection and diagnosis while at sea is critical and essential. Automatic fault diagnosis is an artificial intelligent problem solving application and a variety of intelligent algorithms have been applied in this area. Among these methods, rule based ES is one of the most widely used methods.

An ES for power system fault diagnosis in a ship has been developed by Chao Liang in 2020 where Frame structure is used to describe the power system connections between various parts of the ship in knowledge presentation. ES uses production rules to describe the specific fault and combine the ideal of fuzzy inference to dealing with the uncertainty in fault diagnosis at the same time.

Designing of an ES for diagnostics and estimation of steam turbine components has been completed with conditional probability to diagnostics and state estimation of steam turbine technological subsystems' components. The ES is based on Bayes' theorem and permits one to troubleshoot the equipment components, using expert experience, when there is a lack of baseline information on the indicators of turbine operation.

Fault diagnosis for marine engines was developed by Xiaojian in 2017 known as belief rule-based (BRB) system where each subsystem has its distinctive outputs and uses the evidential reasoning approach for inference. This novel modeling approach can be applied to identify fault modes that may co-exist. In essence, the group of BRB subsystems is used to model the nonlinear relationships between the fault features and the fault modes in marine diesel engines.

Xin-Yu Shao, in 2009 has developed ship engine room automation novel system named ES for Aided Conceptual Design of Ship's Engine Room Automation (ESACD). With the support of the constructed Ship Data Warehouse System, two core subsystems Configuration Selection Assistant (CSA) and Design Scheme Decision Assistant (DSDA) are included in ESACD. A promising approach integrating Fuzzy c-means algorithm (FCM) and Rough Sets Theory (RST) to extract configuration rules from the stored data is adopted in CSA.

An ES for ship automation has been developed by Zbigniew Kowalski in 2001. The shell ES Exsys Developer was used to create the ES and which is characterized by a rule-oriented representation of knowledge, backward and forward chaining inference methods, various confidence modes to handle uncertain reasoning including fuzzy logic and possibility of co- operation with other software and databases. The databases were made using the MS Access software also known as a Knowledge Based.

Many online and offline ES development tools such as Exsys, Exsys logo, Corvid, Corvid logo, Exsys RuleBook, Exsys RuleBook logos , ES Builder, What I Need to Know (WINK) etc have been designed by worldwide companies.

3. Expert System Structure

The standard ES architecture has been used in designing the ES as depicted in figure 1. The domain expert is the Electrical Engineer who has the technical knowledge of the NPSC System. Expert knowledge is thus acquired in the knowledge base. The reasoning techniques are configured in the inference engine. Exsys Corvid runs the inference engine at the backend and provides a local host window as the User Interface to be accessed by the client.

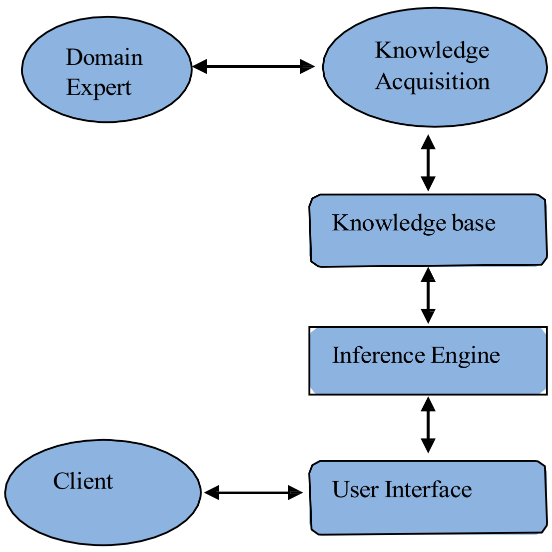

Figure 1. Used ES Archetecture

4. Implementation

The designed ES has been developed using Exsys Corvid tool. It is an offline executable program which is ideal for utilizing out at sea where internet is absent. The designed ES is capable of handling under mentioned 14 Nos. of fault alarms which are identified as probable to occur out at sea in the engine and steering control systems of a FAC.

- No cooling water flow alarm
- Engine Lub oil temperature high alarm
- Low level in cooling water tank alarm
- Engine cooling water temperature high alarm / shutdown
- Gear box Lub oil temperature high alarm
- Gear box Lub oil pressure low alarm / shutdown
- Engine Lub oil pressure low alarm / shutdown
- Engine exhaust temperature high alarm
- Engine charge air temperature high alarm
- Engine sea water pressure low alarm
- Low level in engine Lub oil alarm
- Engine over speed shutdown
- Crank case over pressure shutdown alarm
- Bucket/nozzle system malfunction

The stand alone system is carried in the wheel house of the FAC and can be accessed at any time. Nearly fifty root causes have been identified for the above mentioned alarm types. The knowledge base includes the domain knowledge of an expert to clarify the root causes that have guided for the fault occurred. The client or the end user need to enter the fault alarm/s at the user interface of the ES. Then. all possible root causes are forwarded to the client through forward chaining process. Finally, client can interact with the ES and follow the recommendations given by it to rectify the defect by the boat's crew itself out at sea. In addition, the recommendations include alternative solutions to try by the repair team.

5. Performance Evaluation

It is common for a defect to occur out at rough seas and battle environment. But, to determine a certainty factor by the system itself or manually, many iterations of defect identification and rectification has to be undertaken by the ES. Since, defects do not occur in such frequency, defects are created intentionally and ES is followed in order to assign a certainty factor to the specific alarm rectification solution provided by it. Same methodology was carried out for all defects by several clients.

Table 2. Certainity Factor Table

Defect No	Defect Alarm	Defect root cause	Certainty Factor
1	No cooling water flow alarm	Water Cooling Flow Level not adequate	95
2		Ground Fault/ Wire Break	80
3		Flow Switch Defective	89
4		Defect in the PLC System	84
5	Bucket/ nozzle system malfunction	Wire break in feedback potentiometer	95
6		Steering solenoids defective	99
7		Power Supply Module defective	96
8		Feedback potentiometer defective	84
9		Solenoid Driver defective	85
10		PLC System Defective	80
11		Wire break/ ground fault	97

Certainty factors were assigned manually based on the probability of correct solutions recommended by the ES for any given fault alarm and samples are tabulated in Table 1. Certasininty factors have been obtained for 49 Nos. of defect root cuases which may give defects under aforementioned defects.Thus calculated certainty factors are summarized in Figure
2 for easy visualization. It can be observed that the calculated certainty factor for all root causes lie above 80%. Hence, the performance of the ES can be assessed and concluded as successful.

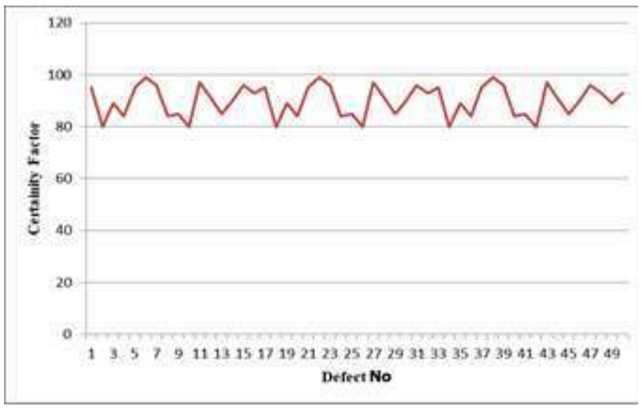

Figure 2. Certainity Factor Summary

6. Conclusion

The research paper has been based on creating a Knowledge Based Expert System to determine the defects which are probable to occur out at sea in the indigenously designed Naval Propulsion and Steering Control System of FACs. An offline ES tool named ―Exsys Corvid‖ has been used to design the standalone system. Pre-identified probable defects in the knowledge base have been used to reason the root causes by the ES. Since, the end user is not a technically expert personal and no provision is available out at sea for physical Defect Identification and Rectification, the designed ES is a timely solution to minimize life threat and cost.

The outcome of the designed ES has been evaluated with the aid of the Certainty Factor and concluded to be satisfied.

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