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An Expert System for Engine Excavator Troubleshooting

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Abstract: Due to the rapid development in urban and rural area nowadays, the use of engine excavator is also increasing. However, currently there are no specific system to provide engine excavator diagnosis and troubleshooting. Engine excavator diagnosis and troubleshooting is only depending on human expert. Most existing systems only offer general information on excavator problems. Therefore, in this work, an expert system that aids users to do engine excavator troubleshooting with repair method recommendation solution was proposed. Engine excavator troubleshooting expert system enable users to do engine excavator troubleshooting via online. In this work, development is Knowledge Engineering which consist of six important phases has been used. The significance of this work is to provide the user the ability to use the troubleshooting features and get the expert recommendation solution from this expert system.

Keywords: Expert system, engine excavator, problem assessment

1. Introduction

Currently, according to the innovative development, the truck mix, and the tractor excavator are used in mining. The main factor is to choose rational hardware as it is a mega-equipment and requires significant expense. Besides, the use of inappropriate instruments can adversely affect and lose a huge amount of money [1]. In this direction, it is necessary to choose hardware carefully to avoid unforeseen accidents, and the most reasonable and high caliber must be solved and selected.

Master frames are computer programs that characterize some non-algorithmic mastering to take care of certain types. For example, master frames are used in analytical applications that customize the two people and hardware. They also play chess, decide the choice of money, design computers, study constant frameworks, ensure protective access, and perform many different administrations that require newer human skills [2]. Fig. 1 shows a general technique for the functioning of an expert system framework.

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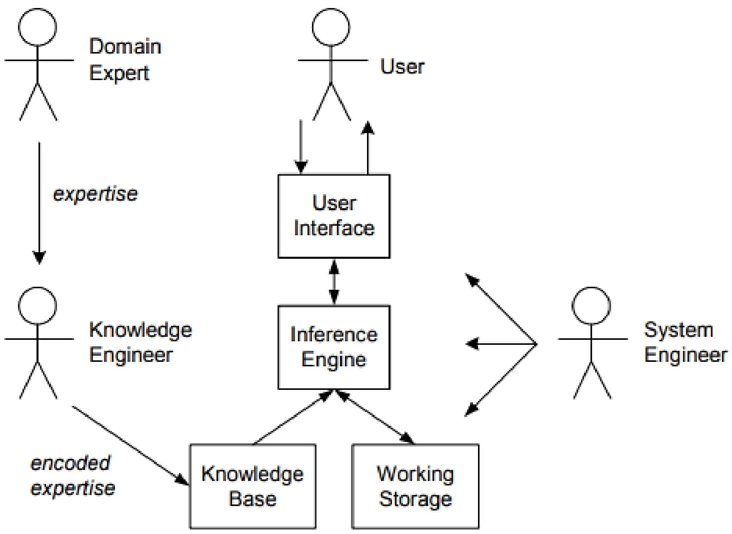

Fig. 1 - General framework of engine excavator troubleshooting [2]

In this work, a special framing method is used to complete the decision of a processing machine in the research. Expert System (ES) is a computer framework that mimics the dynamic ability of the human master in a limited domain [3]. The necessary methods of artificial intelligence for such a field must be able to mimic the analytical cycles of the human mind. Master frameworks have huge applications in all respects, including the clinical conclusion, deficiency detection, research, answering questions, mechanical cycle control, atmospheric determination, disappointment research production, selection assistance, and dynamics [4].

Excavator is used in most construction destinations. It is a piece of heavy development equipment consisting of an explosion, a stick, a bucket, and a car on a rotating platform [5]. Its diversity and beneficial effects make it famous. An operator uses pedals and switches to push the machine back and forth and steer the vehicle. Diesel engines are commonly used in significant applications such as in trucks, portable development machines, conveyors, and marine impulses [6], [7]. Then, the engine excavator is focused to troubleshoot this proposed system. An expert system for troubleshooting the engine excavator may assist the users to have a better understanding of maintenance or repair their engine excavator [8].

The target user who is benefiting from this proposal are excavator owners and experienced and novice excavator mechanics. Therefore, potential users such as excavator mechanics, excavator beginner mechanics, excavator mechanic trainee, and owners may benefit from this expert system. Excavator has many parts but the system only troubleshoots that in the engine of the excavator [9], [10]. A diesel engine excavator is focused to troubleshoot. On the other hand, the system only available in English.

This paper is segmented into six sections, starting with the introduction which gives the background of the work. Section 2 presented the most related work. Furthermore, the research methods have been illustrated in section 3. Whereas, the implementation has been demonstrated in section 4. Moreover, the results and discussion have been discussed in section 5. Finally, section 6 concludes the work.

2. Related Work

Excavators are important parts of building site work. Alongside their wider use and mass production, demand is increasing for excavators. Nevertheless, currently, there is rarely a specific system to provide engine excavator diagnosis and troubleshooting, engine excavator diagnosis, and troubleshooting are only depending on the human expert. Most existing systems only offer general information on excavator problems. Existing websites also offer limited resources on the engine excavator. The most related work has been discussed as below:

In the previous work of Mostafa et al. [6], the objectives of ES for the creation of a model for the detection of a vehicle and the requirements for the development of knowledge-based systems (KBS) for this model were presented. It also shows the transformation of the ES to the improvement of the Car Failure and Malfunction Diagnosis Assistance System (CFMDAS). In any case, the improvement of CFMDAS faces many difficulties to gather the information necessary to build the database and make the conclusion. In addition, locating faulty vehicles requires very special skills and experienced technicians, which are generally rare and expensive to obtain. Leaders like CFMDAS can therefore be of great help in helping mechanics spot disappointments and prepare for goals. Besides, capturing and storing important information about this area enables more accurate and shorter models. Also, Nabende and Wanyama [7] introduced a simple primary framework for diagnosing HDDE problems that rely on Bayesian Network Technology. The use of

Bayesian networks has improved knowledge about the confusing cycle of HDDE diagnoses. In addition, we were able to identify the vulnerability in search engines and integrate the learning functions into the main framework.

Previous work by Kirmanli and Ercelebi et al, [11] created a special framework for the identification of tractor excavators and trucks in surface mines. Hydraulic excavators and trucks are increasingly used in mining. Hydraulic excavators are widely used, especially when energy transport to regions is difficult and for small-scale mining. This article describes a special supervisor who will select the ideal configuration for trucks to minimize the production cost per unit and meet specific limitations such as topographic, geotechnical, and mining requirements. The framework consists of four modules: user interface, rules and techniques, information bases, and activity module. The main framework for this test is created in the KappaPC shell. Supports a climate oriented towards MS Windows innovation.

Prasad et al. [12] developed an expert system in Visual BASIC 6 to select materials for various engineering applications and integrating it with the quality function deployment (QFD) technique while taking into consideration the voice of the customers for a product with its technical requirements. The applicability of the developed QFD-based expert system is validated with the help of two existing material selection problems and then, it is used to select the most appropriate material for excavator's blades, and lining material for brake and clutch.

This frame is a standard base frame for studying engine ground movement. In the main framework based on a standard, information is called a set of rules. Each standard defines a link, suggestion, sequence, technique or heuristic and has the structure IF (condition) THEN (action). As soon as the condition of the standard is fulfilled, we say that the standard is triggered and that the performance part is executed. This is a framework that is an online framework that can be used on the Internet. The guidelines of the proposed main framework are so arbitrary that they stand out. However, according to the above discussion, it is observed that an expert system can aids users to do engine excavator troubleshooting with the repair method solution. Also, it is allowing the expert system to be used as online and troubleshooting aids for users.

3. Research Methods

The research design system understands how different people will collaborate. It characterizes a cycle in which space specialists and research designers assemble an information base. This knowledge base is spoken in an information visualization language with appropriate tools. Languages, dialects, and tool devices depend on information presenting ideal models [15], [16]. All six eliminations will be transmitted by this technique as shown in Fig. 2.

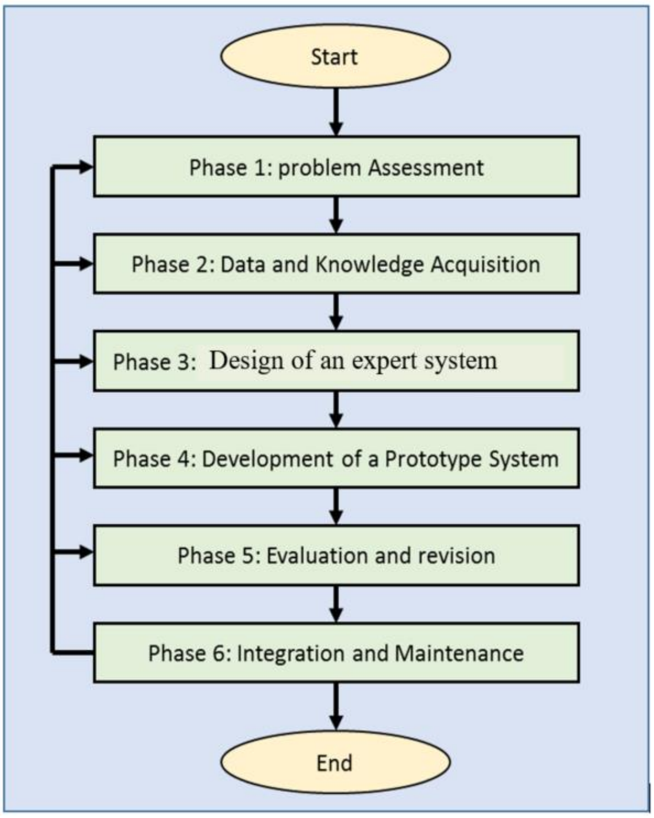

Fig. 2 - The process of Knowledge Engineering [6], [14]

The proposed system is an attempt to troubleshoot an engine excavator. However, the first phase is to identify the problem type. Furthermore, domain knowledge in such problems can often be represented by production rules, and thus a rule-based expert system is suitable for this project. In this data and knowledge acquisition phase is gathering and analyzing both data and knowledge [15]. During this phase, related resources such as journals, books, repair and troubleshooting manuals, and related websites that concern with the proposed system are reviewed. Three existing systems are compared to the proposed system to gather information about the existing system. Apart from that, symptoms of engine excavator, troubleshooting methods, and recommendation solution methods are collected from the domain expect [16], [17]. A formal interview was done with the expert, Lai Gen Huang to have a deeper understanding of the domain knowledge. It is a product support specialist from Sime Darby Industrial SDN.

The development of a prototype system phase is to choose a tool for building an intelligent system and test the prototype with test cases. The modelling is to organize the flow of processes in the intelligent system. the modelling includes Flow Diagram, Context Diagram, Data Flow Diagram (DFD), and Entity Relationship Diagram (ERD) are illustrated to show the flow of the system.

The proposed system needs to provide more rules for handling the cases of engine excavator. After that, the fourth phase is to develop the user interface that is to delivering information to a user. The user interface should make it easy for users to obtain any information needed.

The fifth phase is the evaluation and revision of the system. This phase is to ensure the quality and functionality of the proposed system. Test cases and test plans will be designed to discover errors in the system. The test plan will be designed for every interface to test the input and output of the system. The final output of this phase is the completed system of the proposed system. Table 1 is to show the IPO (Input, Process, and Output) of all the phases.

Table 1 - The IPO role of each phase

Phase	Input	Process	Output
1	Identify Problems Characteristics Search for a suitable participant Specify project objectives Determine the needed resource	Identify Problems Characteristics Search for a suitable participant Create the project's objectives Research on intelligent system and engine excavator	• Confirmed Troubleshooting • Confirm domain expert
2	Collect and analyze data	Documents such as journals website Interview with expert	• Collect info. • Summary of interview
3	Collect a tool to build an intelligent system Design and implement prototype Test the prototype with test cases	Determine the appropriate intelligent system Build and test the prototype	• Expert system is chosen • Stability
4	Prepare a complete design of a full–scare system Develop user interface Develop the compare system	Plan and schedule Design interface Implement the system	• Gantt chart • Process model • System interface
5	Identify the system criteria Revise the system as necessary	User acceptance test	• User feedback • Validate system

This section also discusses the rules of the proposed expert system. The proposed system consists of 63 rules. Table 1 is illustrated partial rules in the system. The partial rules of the system are summarized below:

- Inspect the fuel system and check the control and wiring for abrasion and pinch points. Repair the connector or wiring and/or replace the connector or wiring. Make sure all the seals are in place properly and make sure the connectors are connected. Next, clean the plugged air filters or replace the plugged air filters. If the problem is not resolved, check the circuit protection.
- Ensure that all of the seals are properly in place and ensure that the connectors are coupled. Inspect the fuel system, check the fuel tank for debris or foreign objects which may block the fuel supply. And then, check the filtered fuel pressure while the engine is being cranked. Replace the fuel. Verify that the repair eliminated the problem.

- Thoroughly inspect the ECM connectors J1/P1 and J2/P2. Inspect all of the other connectors for the circuit. Then, check the ECM connector (Allen head screw) for the proper torque. Ensure that all of the seals are properly in place and ensure that the connectors are coupled. The steps are shown in the below rules of Fig 3.

```
IF engine shuts down YES
    THEN problem in electronic connectors
IF problem in electronic connectors YES
    THEN restrictions in the inlet air
IF restrictions in the inlet air YES
    THEN recommendation.
IF engine shuts down YES
    THEN problem in electronic connectors
IF problem in electronic connectors YES
    THEN restrictions in the inlet air
IF restrictions in the inlet air No
    Then fuel quality is not okay
IF fuel quality is not okay YES
    THEN recommendation
IF problem in electronic connectors YES
    THEN restrictions in the inlet air
IF restrictions in the inlet air YES
    THEN recommendation.
    -
    -
    -
```

Fig. 3 - Samples of the rules of the expert system

4. System Implementation and Testing

This section describes the functions and modules in the Hypertext Pre-processor (PHP), JavaScript, and MySQL are used to develop the system. The application is connected with the MySQL databases. Connection with the database is important because it enables the system to access data stored in the database. The functional partial coding will be explained in the following subsections.

The implementation of the troubleshooting question serves as an important function of the proposed system. Users answer a question on the screen and click on the submit button until a final result is displayed. The question is displayed one by one on each page to generate the result.

System testing is performed after the implementation phase is completed. It is performed to ensure that the system meets the expectation in terms of usability and functionality based on system analysis and design. The testing process is divided into two main testing types which are functional testing and user acceptance testing. However, testing the system in a test plan will allow the developer to detect errors within a smaller range of the system. This will ease the correction process for the developer. Table 2 shows the test plan for the login page.

The user acceptance testing was conducted in the JWC Tractor Industry, the owner of the JWC Tractor Industry, and experienced excavator mechanics is the domain expert (Lai Gen Huang) in Sime Darby Industrial Sdn. Bhd. There were a total of twenty users who took the user acceptance test. System testing was successfully conducted. The actual outputs are similar to the expected results. Comments and suggestions from the user acceptance testing are gathered and adopted to improve the system in the future.

Table 2 - Test plan for login page

Test Cases	Expected Output	Actual Output
System display login column	Displays username and password text boxes.	As expected output
Password text box encodes entry	Should have a symbol like '*' displayed in the password text box.	As expected output
Blank username or blank password	It will display the sentence "please fill in this field"	As expected output
Enter correct username and password	Success login	As expected output
Enter a correct username with the wrong password	Unsuccessful login	As expected output
Enter wrong username and correct password	Unsuccessful login	As expected output
Login without entering username and password	Error is displayed	As expected output

This function carries out the troubleshooting part of the system. After the user answers the question then click the submit button to go to the next question until the final result is presented. Table 3 shows the test plan for troubleshooting.

Table 3 - Test plan for troubleshooting page

Test Cases	Expected Output	Actual Output
Display troubleshooting page	Display page with the question with radio b two-buttons for submitting and exit.	As expected output
Click the "Submit" button	The following question displayed or display result for a recommendation.	As expected output
Click the "Exit" button	Exit to home page	As expected output
Produce the correct result for a recommendation	Based on the user answer to display the recommendation	As expected output

5. Results

In this section, the user interface, results, and expert system results have been presented. Fig. 4 shows the interface of the troubleshooting page. Furthermore, users can select the vocabulary in the select box then the system will display the explanation based on vocabulary. This function can run during the troubleshooting process.

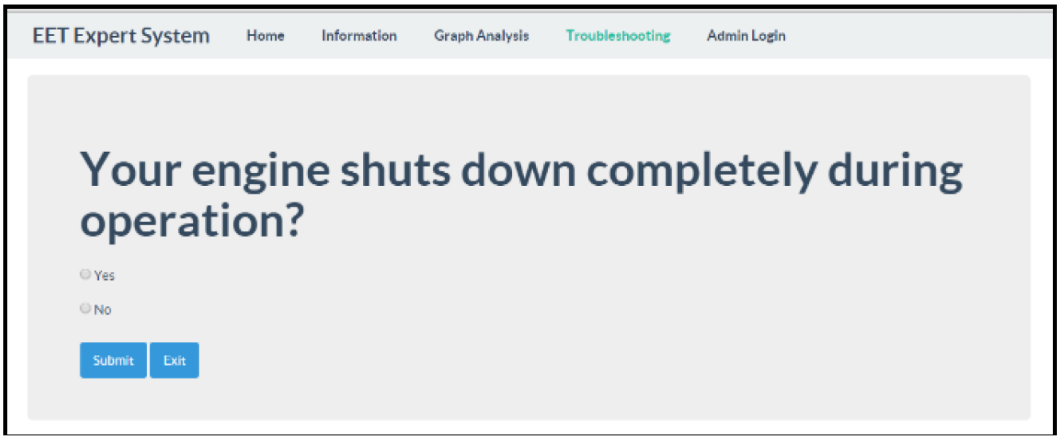

Fig. 4 - Interface for troubleshooting page

After the troubleshooting process, the recommendation is generated on the recommendation page. Fig.5 displays the interface for the recommendation page.

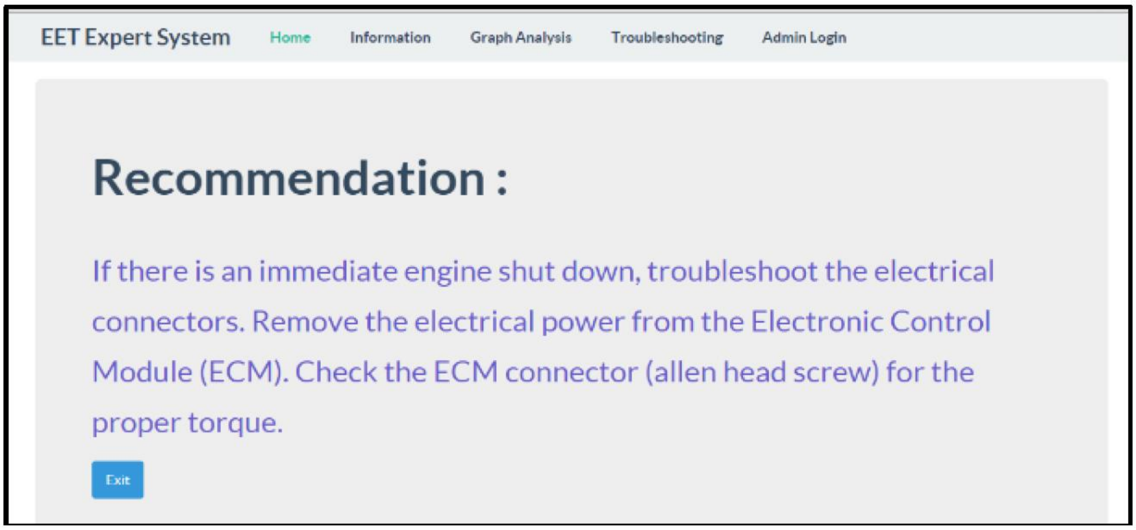

Fig. 5 - Interface for recommendation page

System is able to generate the graph analysis based on the result that have been chosen from users. The frequency of the graph analysis is up-to-date. Figure 6 is illustrate the interface for statistics for troubleshooting results.

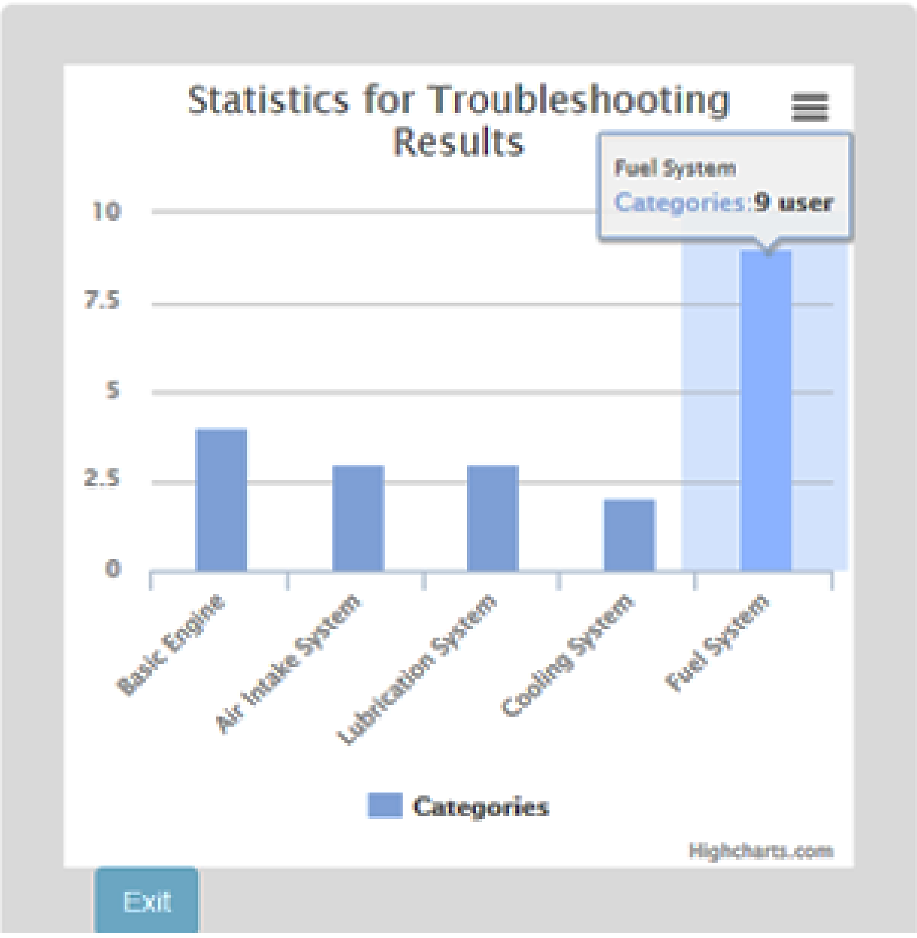

Fig 6 - Interface for statistics for troubleshooting results

Moreover, the system can generate graph analysis based on the result that has been chosen from users. The frequency of the graph analysis is up-to-date. For the administrator, information management allows the administrator to view, add, edit, and delete the data from the database. The interface for the administrator information management page is illustrated in Fig. 7.

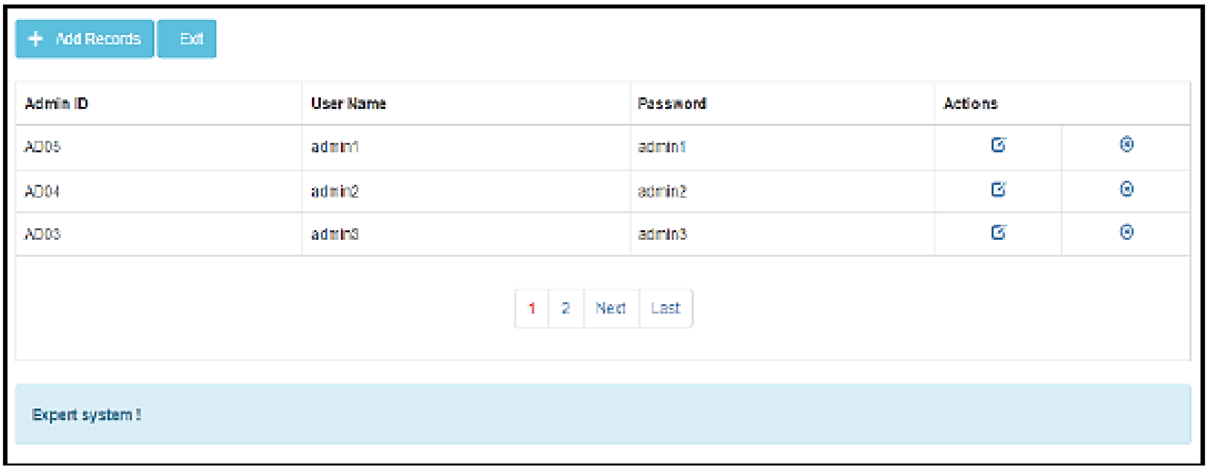

Fig. 7 - Interface for administrator information management page

Subsequently, as the above discussion, this work comes to an ending point, there are few discussions about the system will be done. Some advantages can be identified through the feedback from the respondents during User Acceptance Testing. The analysis from the respondents shows that most of them are satisfied with the overall functions of the proposed system. Analysis for Functional Requirement Graph is shown in Fig. 8.

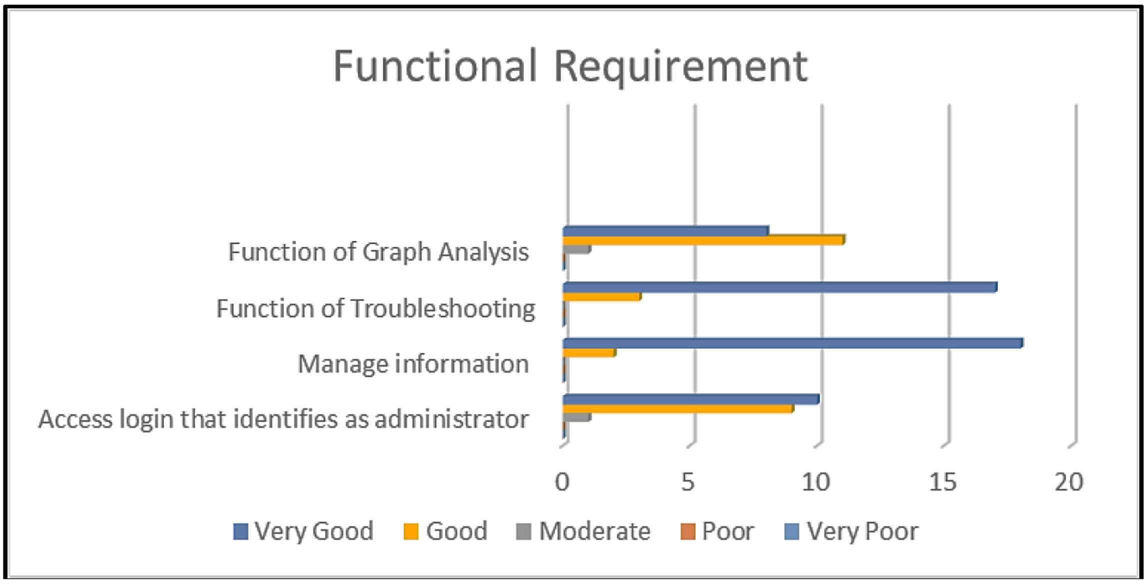

Fig. 8 - Functional Requirements Graph

Although the function of graph analysis and access login that identifies as administrator received moderate vote most of the respondents support that the functional requirement of the system is suitable for the system. However, the proposed system has achieved the objectives, however, there are still limitations in the actual system. For example, the system only displays the current question to users and users cannot view the next question on the troubleshooting page. Users are only able to view the next question when users do the troubleshooting.

6. Conclusion

Expert System for Engine Excavator Troubleshooting offered many benefits, including increased efficiency, and troubleshooting tools for diagnosing engine excavator problems. The advantage of the system is users able to use the troubleshoot features and get the expert recommendation solution from this expert system. This expert system can be used as a reference to assist mechanics to make efficient and accurate decisions. In conclusion, the system has been successfully developed, underwent testing, and proved to have achieved the goals, objectives, and scopes. The actual system is tested to ensure that it fulfils the requirement of the system and check all the functions are working as expected output. Although there are a few limitations in this system, the further effort can be done to make it serve the public in a better way.

Acknowledgement

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