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# An Expert System for Laptop Fault Diagnostic Assistance

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**Abstract:** Laptop has always been a very useful tool for studies and most university students own at least one laptop. However, not all university student knows how to diagnose and troubleshoot their laptop when it is not working right. Most university student would rather hire computer technician to fix their laptop even though the solution to their laptop problem is rather simple. As cost of living increases every year, so does the cost of hiring a computer technician. Therefore, an expert system for laptop fault diagnostics was proposed to be developed. The objective of this study is to develop an expert system capable of diagnosing the cause of a laptop problem by analyzing user's answers to the questions displayed by the system. The proposed system would also provide easy to follow solution to the user on how to solve the problem. The methodological approach to developing this system is by following waterfall model. There are five phases in a waterfall model, however only four phases will be executed namely requirement, design, implementation, testing phase. By using this system, user can easily identify possible root causes to their laptop problem by answering few questions related to their laptop problem. On top of that, the expert system will provide appropriate recommendation to the diagnosed laptop problem. Using this system, the time required to diagnose a computer as compared to manual diagnosis will reduce drastically. Most process in manual diagnosis will be automated and handled by the expert system. Lastly, user can save up unnecessary expenditure used to hire a computer technician.

**Keywords:** Laptop, technician

## 1. Introduction

Nowadays, it is normal to see university students carry laptops around regardless of whether the student is undertaking computer science major or not. The laptop has always been one of the most important tools for a student as most students use it on a daily basis. However, regardless of how well built a laptop can be, all laptops are susceptible to faults and errors [1]. Typically, laptop problems can be categorized into two general types, hardware, and software errors. There are several factors which can cause a laptop to function abnormally, for instance, if a laptop is attacked by viruses or malware, when a hard drive is worn out or when the hardware is damaged due to electrostatic discharge [2], [3].

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Usually, when a user found out that their laptop is not functioning properly, their first reaction is attempting to troubleshoot the problem themselves. The method of troubleshooting varies with the type of problem the user encounters [4]. In the case of a hardware failure, the process of troubleshooting starts by examining each hardware one at a time. Once the faulty hardware is found, the hardware will then be replaced with new hardware. However, if the faulty hardware is not found, the process of checking each hardware is repeated until the faulty hardware is found [5]. The problem with troubleshooting a laptop manually is that not all computer owners are well versed in computer troubleshooting [6], [7]. The fact is that not all laptop owners are tech-savvy and thus they might have no idea how to respond when something went wrong with their laptop. On top of that, the time required to manually diagnose a laptop problem is time-consuming and not everyone has the spare time to diagnose each laptop components one at a time [8].

Therefore, the proposed project aimed to develop an expert system using the forward-chaining approach for laptop fault diagnostics to overcome the shortcomings of manual troubleshooting. The expert system will function by analyzing the laptop problem based on the symptoms faced by the user. Once the analysis is completed, the system will provide appropriate solutions to the laptop problem. The importance of the proposed system is to prevent unnecessary expenses from hiring a computer technician. Other than that, the proposed system aimed to reduce the time required to diagnose a laptop.

This work is segmented into sex section starting with the introduction which it is give a background of the work. Section 2 discussed the related work. Whereas, the research methods have been illustrated under section 3. The system design and analysis is presented in section 4. Moreover, the implementation and Results have been presented and discussed under section 5. Lastly, section 6 conclude the work.

## 2. Related Work

This section is split into three parts. The first part will explain the background of the case study. The second part will explain about the expert system and the inference method chosen. The third part will describe the comparison between three existing systems and the proposed system. By definition, laptop fault is when a laptop is not working as intended, which could either caused by a hardware or software failure. Typically, the user found out about a laptop fault when they notice the laptop is not operable or it is not functioning as intended [6], [9]. Laptop fault can be categorized into two categories, which are hardware failure or software failure. The hardest part when dealing with a laptop fault is trying to Fig. out which of the category the fault falls in. This is because two different laptop faults could share similar symptoms, even though one is related to hardware failure and another software failure [10].

The expert system can be defined as a type of computer software that uses a process similar to the way humans think in order to provide people with solutions to problems relating to a particular subject [3]. For a computer system to be classified as an expert system, it must contain 3 major components: a user interface, a knowledge base, and an inference engine [11]. The user interface is a component which allows the user and the expert system to interact. The Knowledge base stores knowledge about an expert's domain. An inference engine is part of the ex-pert system that deduce new facts from existing information [12].

The inference engine is a vital part of an expert system as it plays several important roles, and which is also why it is known as the "brain" of the expert system. The first important role of an inference engine is that it is responsible for combining facts with rules to establish a conclusion. This is done by analyzing and interpreting facts from the user's input and combining them with rules stored inside a knowledge base [13]. However, there are also times when several rules are applicable to a specific scenario. This is where the inference engine second role comes into play. The inference engine will resolve conflicts by directing the user interface to receive more inputs from the user. An inference engine deduces a conclusion based on logic [3], [14]. Inference engine typically employs one of the two following strategies during logic reasoning: forward-chaining and backwards-chaining. The proposed system will utilize forward-chaining as the inference method to diagnose and troubleshoot laptop fault.

An inference engine using forward chaining method determines a decision by collecting facts and comparing it with the inference rules. Forward chaining can be seen as a convergent approach or data-driven approach to logic reasoning as each IF clause rules are tested to see which of them is satisfied by the current facts. When a true value is returned, the subsequent THEN clause is chosen as the conclusion. The purpose of this study is to gain a better understanding of how to develop the proposed system and discover new features from existing systems that have the potential to be implemented into the proposed system [15]. The following are the three expert system that will be reviewed and compared: rule-based computer fault troubleshooter expert system, diagnosis and troubleshooting of computer faults based on expert system and artificial intelligence, and self-learning computer troubleshooting expert system. Four features will be considered during the comparison, namely admin log in the module, troubleshooting module, data modification module and diagnosing module.

According to Table 1, all existing systems do not have the administrator log in feature. Other than that, all existing system only provides diagnosis to the computer problem, however, the systems do not provide recommendations to the diagnosis result. Due to the fact that all existing systems do not have a data modification module, the administrator is not able to update or insert newer expert system rules into the system, which will cause the system to be obsolete in the near future. In short, the proposed system has a more complete functionality when compared to the existing systems.

Two major take-away from the above comparison is that the proposed system comes with troubleshooting module and data modification module. Therefore, the proposed system is an improvement over all the existing systems.

**Table 1 - The comparison between existing systems and proposed system.**

| Features/ System | Fault Trouble-shooter [13] | Hardware Failures [14] | Troubleshooting [15] | Fault Diagnostics |
|---|---|---|---|---|
| Administrator Log in Module | No | No | No | Yes |
| Data Modification Module | No | No | No | Yes |
| Diagnosing Module | Yes | Yes | Yes | Yes |
| Troubleshooting Module | No | No | No | Yes |

## 3. Methods

This section will discuss the methodology used throughout the development of this project. To select the most appropriate model for this project, four types of software development lifecycle models were chosen for comparison and analysis. The selected models are namely waterfall model, incremental model, spiral model and v-shaped model. Table 2 shows the comparison of the four methodology models.

**Table 2 - Comparison of four methodology models.**

| No | Types of Model | Advantage | Disadvantage |
|---|---|---|---|
| 1 | Waterfall Model | Each phase has precise deliverables and a review process | Changing project scope during life cycle is not advisable |
| 2 | Incremental Model | Allows changing of project scope during lifecycle | Each phase is rigid and does not overlap with each other |
| 3 | Spiral Model | Good for large scale project | Costly to implement |
| 4 | V-Shaped Model | Works well with small scale project | Adjusting scope during lifecycle can be costly |

### 3.1 Development Model

Upon conducting an analysis on the four SDLC models, waterfall model was selected as the methodology for this project. The reason why the waterfall model was chosen over the other available models is that the waterfall model offers more advantages and is ultimately a more suitable model for the project at hand. One of the many advantages that the waterfall model offers is that it is easy to be implemented by small-scale projects, especially when the project requirements are well understood [16]. Other than that, due to the rigid nature of the waterfall model, each phase has clear and concise deliverables, which will allow the developer to review and monitor each phase closely [6], [17]. The waterfall model can be broken down into five phases, namely requirement analysis, system design, system implementation, system integration and testing, and system maintenance. However, due to the nature of this project, the system maintenance phase will not occur during the development of this project.

### 3.2 System Development

There are a total of four phases from the waterfall model. As shown in Table 3, each phase has its own tasks and outputs that need to be produced during the entire project development.

**Table 3 - Software development activities and their task.**

| Phase | Task | Output |
|---|---|---|
| Requirement Analysis | Identify problem statement, objectives, scope, and expected outcome.<br>Conduct interview with Mr Ismadi.<br>Collect data regarding the domain study.<br>Write project proposal. | Requirement specification documents.<br>Data related to domain study.<br>Gantt chart.<br>Project proposal. |
| Design | Identify software and hardware requirements.<br>Design user interface.<br>Design database. | System Design Specification Documents:<br>Hardware and software<br>DFD, ERD and flowchart, and System interface design. |
| Impl. | System module coding.<br>Testing each system module. | System modules.<br>Unit test cases. |

| | | |
|---|---|---|
| | | Test case results. |
| Testing | Perform internal testing.<br>Perform user testing.<br>Make amendments.<br>Documents each testing. | Test cases.<br>Test reports.<br>Defect reports. |

## 3.3 Hardware and Software Requirement Analysis

This project is proposed to be executed within a span of 2 semesters. As stated before, the proposed project will be split into 4 phases namely requirement analysis phase, design phase, implementation phase, and system testing phase. Whereas, the hardware requirement refers to the device or hardware component required to execute the project. Software requirements specify the set of programs or operating information used during project development. However, this section describes the implementation environment. It is divided into software and hardware as described as follows.

- Software: the work is run on the Windows 10 with programming tool named Sublime Text, and the most suitable web page design and programing language of HTML, CSS, PHP, JavaScript and MySQL.
- Hardware: the work is implemented by using one laptop with specifications of Intel® Core i5 4210U 1.7 GHz processor, 2.40GHz, and 16 GB RAM.

Table 4 provides an outline on the hardware requirements of the proposed system whereas Table 5 contains information regarding the project software requirements.

## 4. System Design and Analysis

This section discusses in detailed regarding the analysis and design phase of this project. The aim of system requirement analysis is to provide a clear definition of users' expectation of what the system can do. These requirements are analyzed, validated and documented in three parts namely functional requirement analysis, non-functional requirement analysis and user requirement analysis [18], [19]. A functional requirement describes the functions that should be delivered by the developed system. Table 4 shows the functional requirement of the proposed system.

**Table 4 - Functional requirement of the proposed system.**

| No. | Modules | Functionalities |
|---|---|---|
| 1 | Registration Module | The system should allow administrator to register a new account. |
| | | With an administrator account, the system should allow administrator to login to the system by entering the correct combination of administrator id and password. |
| | | The system should alert administrator if either administrator id or password is incorrect. |
| | | The system should redirect user to the main menu if login successfully. |
| | | The system should allow administrator to log out from the system. |
| 2 | Data Modification Module | The system should allow administrator to enter new diagnosis/solution into the database. |
| | | For example, administrator can enter a new topic such as laptop screen category into the system. |
| | | The system should allow administrator to modify existing diagnosis/solution that exist in the database. |
| | | The system should allow administrator to delete existing diagnosis/solution that exist in the database. |
| 3 | Diagnosis Module | The system should display a list of topics associated to laptop faults. |
| | | The system should display the questions that correspond to the topic that user chooses. |
| | | The system should display the cause of the laptop problem that the user is facing by analysing the user's answers. |
| 4 | Troubleshooting Module | The system should provide the correct solution to the diagnosis of the laptop problem. |

Moreover, non-functional requirements describe the quality attributes associated with a system and are not covered by functional requirements. However, the non-functional requirement of the proposed system is illustrated bellow:

- Any interaction between the user and the system should not more than 30 seconds.

- The system should be accessible anytime.
- The system should have minimal and easily understood user interface.
- The system should be able to work on any web browser.
- The system should prevent any unauthorized users from accessing the system.
- Only administrator should be able to add/modify/delete any data in the database.

Furthermore, user requirement is a list of activities that the user expects to do when using the system [20]. From a developer's standpoint, user requirement act as a guideline during development phase on what the software is supposed to do and to avoid missing out on the system's major features. However, the user requirement of the proposed project is illustrated as following:

- Administrators should be able to login to the system by keying in the correct user id and password.
- Administrators should be able to view, add, delete and modify computer fault symptoms and solutions.
- Administrators should be able to view, add, delete and modify computer fault symptoms and solutions.
- Users should be able to select a topic.
- Users should be able to answer questions regarding the laptop fault.
- Users should be able to view the diagnosis and recommendation to the laptop fault.

This section will elaborate on the system analysis for this project. Con-text diagram, DFD diagrams, ERD diagram and flowcharts were designed to represent the system processes. DFD diagrams are further broken down into DFD diagram level 0 and DFD diagram level 1.

## 4.1 Context Diagram

A context diagram is drawn to define the boundary of the system and to identify the relationship between the system and the external entities. The main entities of the proposed system are the administrator and user [21]. Fig. 1 shows the context diagram for the proposed system. Furthermore, two cases have been considered as following:

- In Data Flow Diagram level 0, there are 4 processes, 2 entities and 8 data stores. The name of each process are as follows: 1.0 admin registration process, 2.0 admin login process, 3.0 data management process, and 4.0 diagnose and trouble-shoot process. The two entities are the administrator and user. The eight data stores are tbl_problem, tbl_topic, tbl_question, tbl_rules, tbl_solution, tbl_ruledetails, tbl_tempresponse and tbl_admin.
- Data Flow Diagram level 1 is created to elaborate on the processes in DFD level 0. Based on the DFD level 0 in section 4.2.2, there are only 2 processes that can be expanded into DFD level 1.

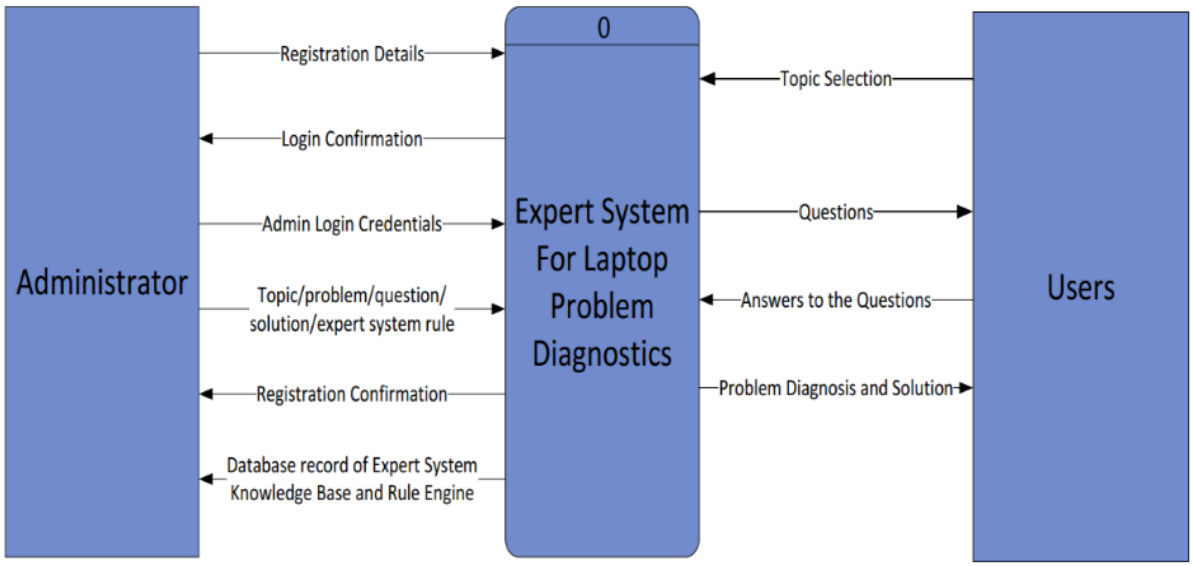



**Fig. 1 - Context Diagram of the expert system.**

The flowchart is the graphical representation of the process flow of a system from start to finish. Two flowcharts are representing the two target users of this system. Fig 2 shows the flowchart design for users. Users can seek a diagnosis for their laptop problem by selecting a topic and answering all the questions

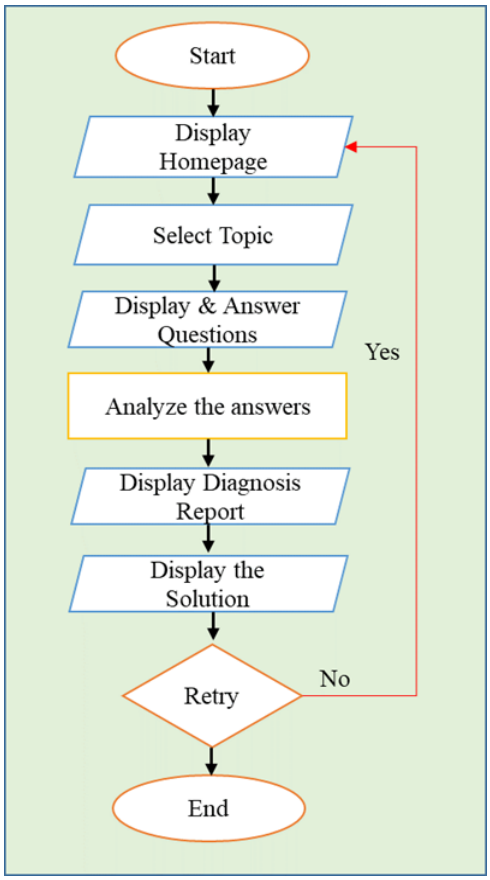



**Fig. 2 - Flowchart design for users interaction.**

## 4.2 Entity Relationship Diagram

Fig. 3 shows the ERD of the proposed system. Tbl_admin manages one or more tbl_topic by inserting, updating and deleting data. For each topic in tbl_topic, there is at least one or more tbl_question and tbl_problem. Each rule in tbl_rules includes one and only one tbl_problem, whereas each tbl_rules contain one and only one tbl_ruledetails. For each tbl_questions, it is included in at least one or more tbl_ruledetails. Tbl_question and tbl_topic are included at least one of more in tbl_tempresponse. Lastly, for each tbl_problem, it contains one and only one tbl_solution, but each tbl_solution can be included by one or more than one tbl_problem.

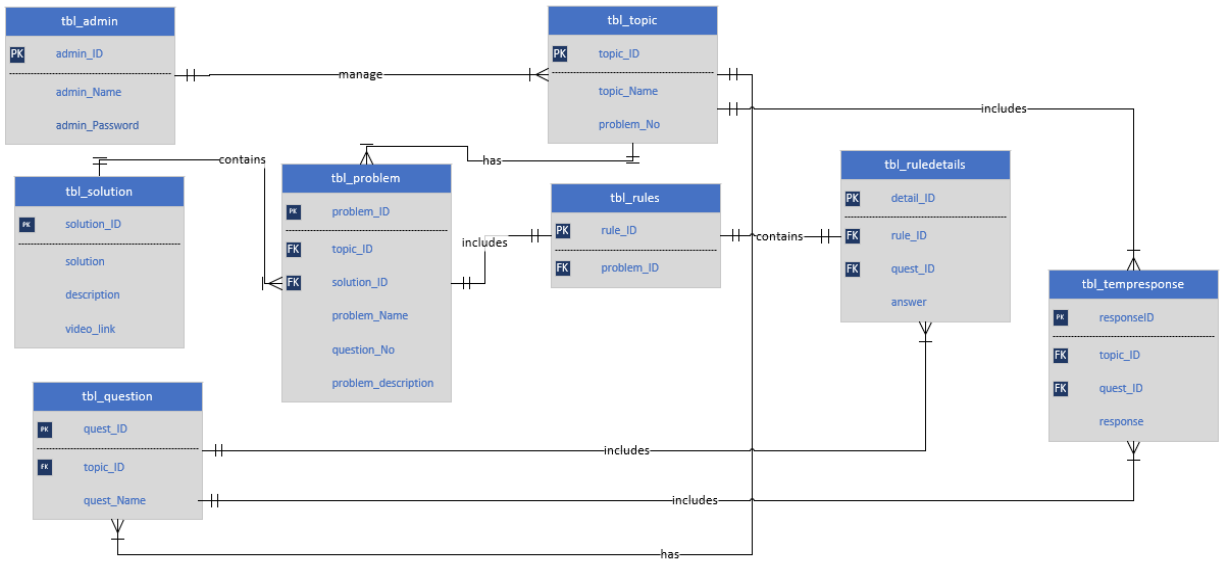


**Fig. 3 - ERD of the proposed system.**

## 4.3 Rule Design

For the proposed system, forward chaining is used as the inference engine to deduce conclusion by collecting facts from the user and comparing it with the inference rules stored in the database. One of the ways of representing the inference rule is by using the decision tree. Fig. 4 shows the decision tree for the audio topic. Inference rule can also be expressed as IF-THEN rules. There are two parts to an IF-THEN rule, the first part, IF, is used to represent the condition, or also known as the antecedent [8]. The second part, THEN, is used to represent the consequent of an event, which is also known as consequent [9].

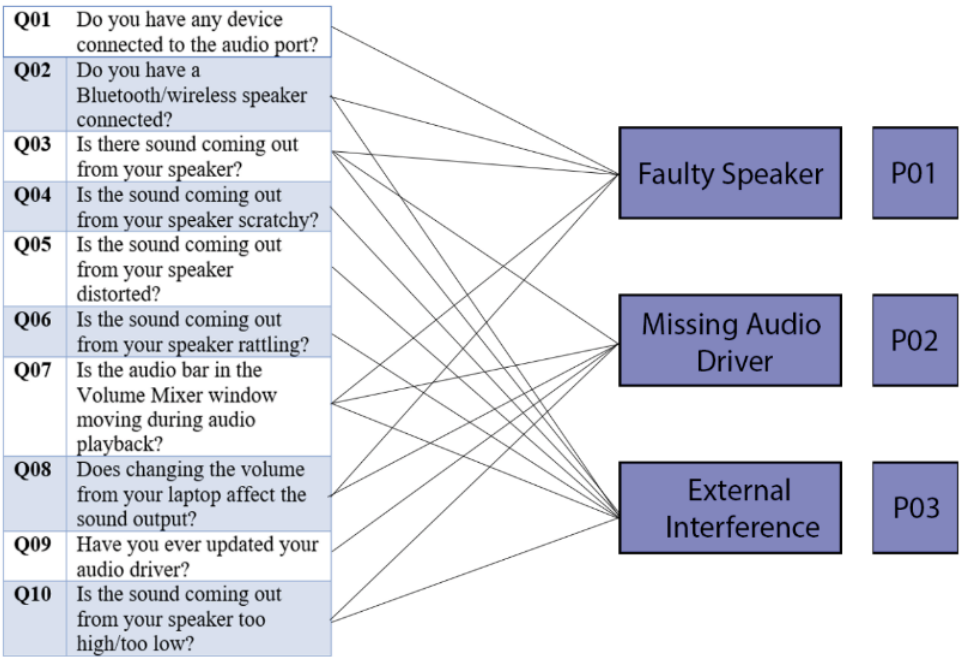



**Fig. 4 - Decision tree for the audio topic.**

## 4.4 Interface Design

This section describes the user interface design for each major processes of the proposed system. The interface is designed using Adobe Photoshop. Fig. 26 to show the interface design for the system.

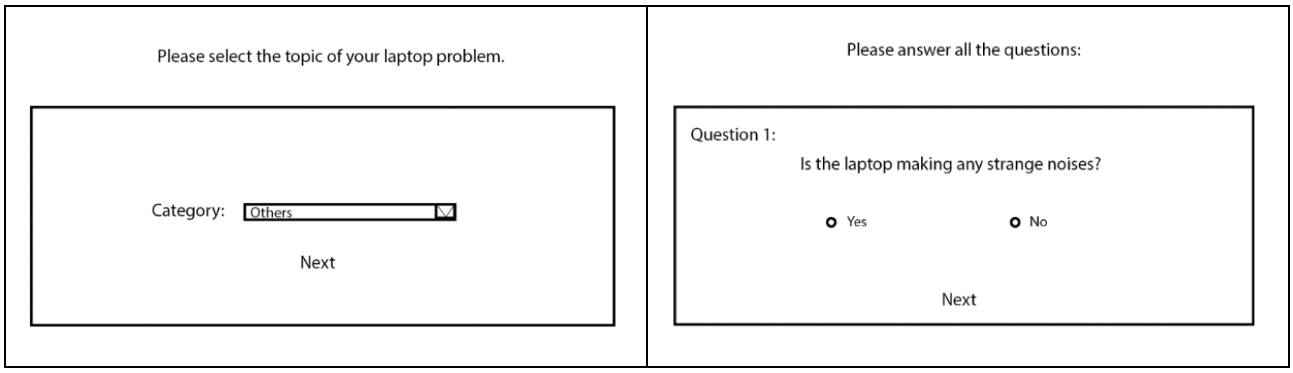



**Fig. 5 - Interface of question display page.**

Whereas, the interface of diagnosis results page is illustrated in the bellow Fig. 555, and the recorded request illustrated in Fig. 6.

| | | |
|---|---|---|
| Root Problem: | | Faulty Storage Device |
| Explanation | : | Storage device are susceptible to wear and tear after several years. A faulty storage device can affect the peformance of your laptop and cause random reboot if the storage device is not replaced. |
| Solution | : | Replace storage device |

| No | Problem | Question | Answer | Edit | Delete |
|---|---|---|---|---|---|
| 1 | Fault audio driver | Is the sound scrappy? | Yes | Edit | Delete |
| 2 | Fault audio driver | Do you have attach device | No | Edit | Delete |
| 3 | Fault audio driver | Is the volume too loud? | Yes | Edit | Delete |
| 4 | Fault audio driver | Can you control the volume? | Yes | Edit | Delete |
| 5 | Fault audio driver | Is your audio device vibrating? | No | Edit | Delete |

**Fig. 6 - Interface of diagnosis result page and display page.**

## 5. Implementation and Results

This section will elaborate on the system implementation according to the requirements specification and design phase mentioned in the previous chapters. In addition, this section will also accentuate on all forms of testing done on the system to ensure system behaviour reflects according to what was documented during requirements specification phase.

The system was designed to be used by two groups of people, namely system administrators and public users. The administrator website will allow computer technicians, who will act as the system administrator, to manage data involved in diagnosing laptop faults. This system will also allow public users to access the website to diagnose laptop fault by answering a series of questions. The software used to develop the system were Notepad++ and XAMPP, whereas the programming languages involved were PHP, HTML, CSS, JavaScript and MySQLi.

The login function is an essential feature of the system to prevent unauthorized users to access the website. Administrators who wish to enter the website must first enter the correct match of username and password. The program code for the login page is stored in the login.php file. Fig. 7 show the user interface of login page

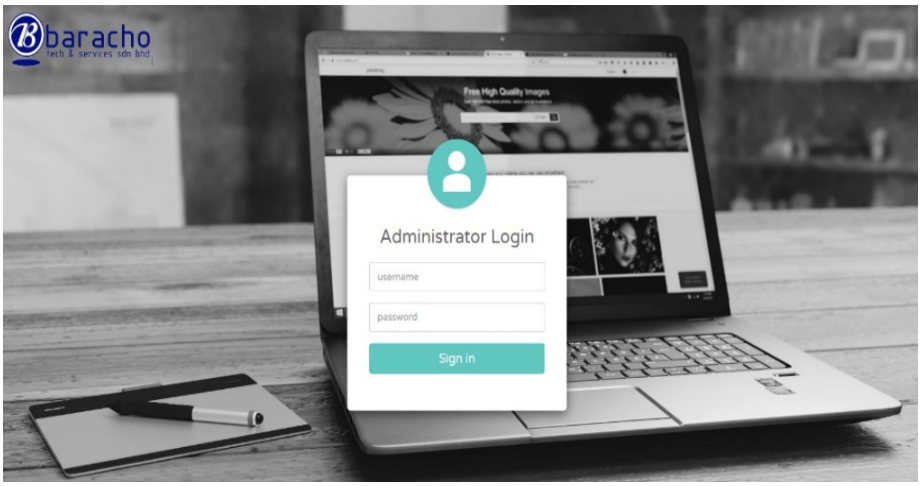



**Fig. 7 - User interface of the login page.**

Account registration can only be done by an authorized administrator who has logged in to the system. This is to prevent a public user from able to access the administrative system just by creating an account. To create an account, the administrator has to enter the new username, password, and confirm password. One of the tasks of an administrator is to insert new diagnostic information into the database. Currently, this expert system can diagnose 11 different lap-top faults from 4 categories. The diagnosis of each laptop faults also comes with its solution. To expand the knowledge base, the administrator can insert the following information: topic, laptop problem, question, solution and rules. Fig. 8 shows the user interface of the insert question page.

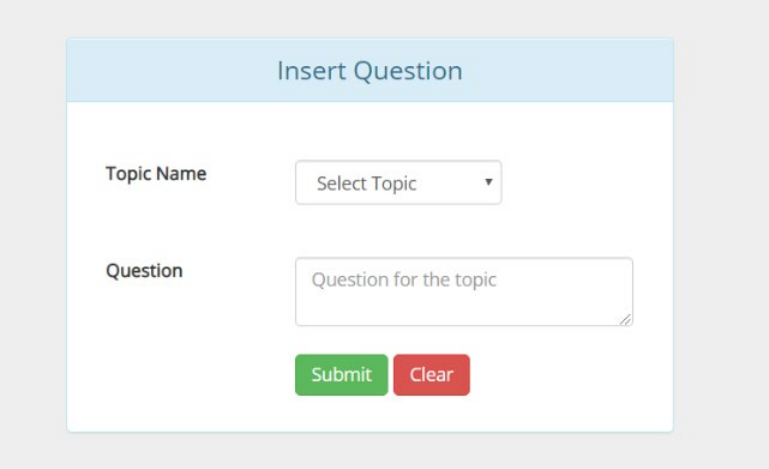



**Fig. 8 - User interface for insert question page.**

Furthermore, all information entered by the administrator can be viewed in the view in-formation pages prepared for each type of data in the knowledge base. Data are organized in tabular format to allow for easy viewing. The searching function is prepared to allow the administrator to look for specific data from a pool of information. The administrator can select the search type from the drop-down list and enter the search value in the search bar. Updating and deleting information have been kept simple as the administrator can perform these actions simultaneously in each view information page. One of the primary functions of this system is to allow the public user to diagnose potential laptop fault. The system will return the potential root problem and the recommended solution to the problem based on the user's response to a series of questions generated by the system. Prior to answering the questions, the user must first select the topic of their problem. Each topic comes with a different set of questions tailored to diagnose the problems that fall in that topic.

Upon answering all questions, the system will produce a diagnostic report that details the findings of the preliminary questions and answers phase. The diagnostic report primarily conveys three information to the users: the probability of the problem, which causes the problem and the recommended action to rectify the problem. The probability of the problem is represented with a numerical percentage and it comes with an explanation of why the problem occurred to educate the user. Recommended action has its own step-by-step procedure and many complex solutions are accompanied by video tutorial so the user can follow along if textual instruction is convoluted. To widen the accessibility of the developed system, the system was developed with mobile users in mind. The website is not only compatible with most desktop and laptops but also designed to be accessible on mobile and tablet.

The final phase of the software development lifecycle focuses on determining whether the developed software will function according to the user's requirements. As per the requirement of this project, the developed software underwent two types of software testing: functional testing and user acceptance testing. This section will cover the result of functional testing whereby the developed software is scrutinized against the functional requirements. During the testing, functions are examined by entering both valid and invalid inputs according to the test plans. The actual outputs for each iteration of testing are recorded and subsequently compared with the expected outcome. Table 5 represent a sample of the test plan for each major function of the developed system.

**Table 5 - Test plan for administrator login and registration function**

| No. | Test Case | Expected Outcome | Actual Outcome |
|---|---|---|---|
| 1. | Fill in valid username and password when logging in. | Redirect to administrator homepage. | Same as expected outcome. |
| 2. | Fill in invalid username or password when logging in. | Error message will pop out warning user about incorrect username or password. | Same as expected outcome. |
| 3. | Fill in valid details when registering new account. | New account added to the database. | Same as expected outcome. |
| 4. | Fill in username that has been entered before when registering. | Error message appear warning user about existing account with similar username. | Same as expected outcome. |
| 5 | Leave username or password empty when registering new account. | Error message appear asking user to fill in all the required textboxes. | Same as expected outcome. |

This section discusses the second form of testing that has been conducted on the developed system. User acceptance testing is a process of proving that the developed system is working as intended for the targeted user. The testing is conducted by distributing the system to a group of randomly selected user and collecting their feedback. The feedbacks are then compiled and arranged in bar charts.

In the case of this project, the testers are consisting of two types of people. The first type of testers is the public users, where 10 students from University Tun Hussein Onn Malaysia are randomly selected to test the public user website. The second type of tester consists of 2 computer technicians from Baracho Tech and Services Sdn Bhd, which will be testing the administrator website. Fig. 9 shows the result of the user acceptance test on the system's graphical user interface. Based on the feedback, most testers show a satisfactory reaction when navigating through the website interface.

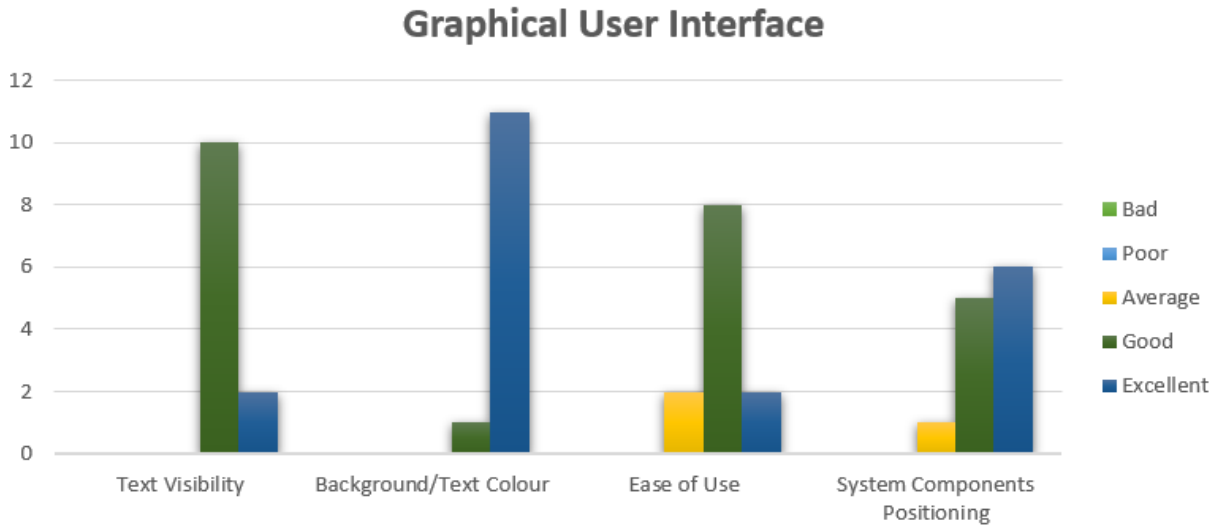
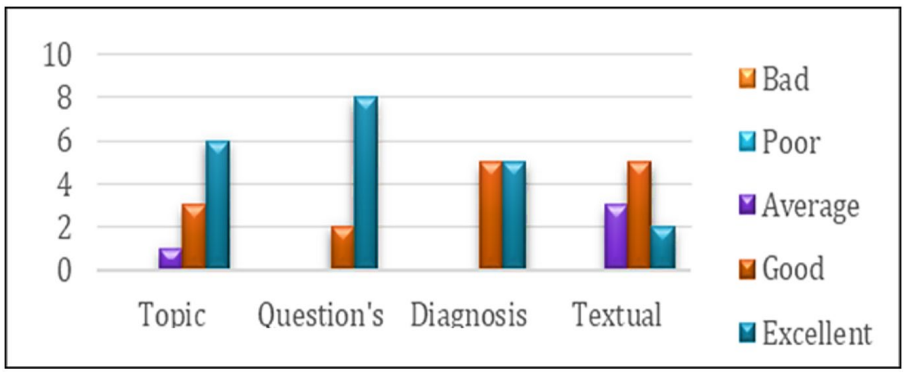
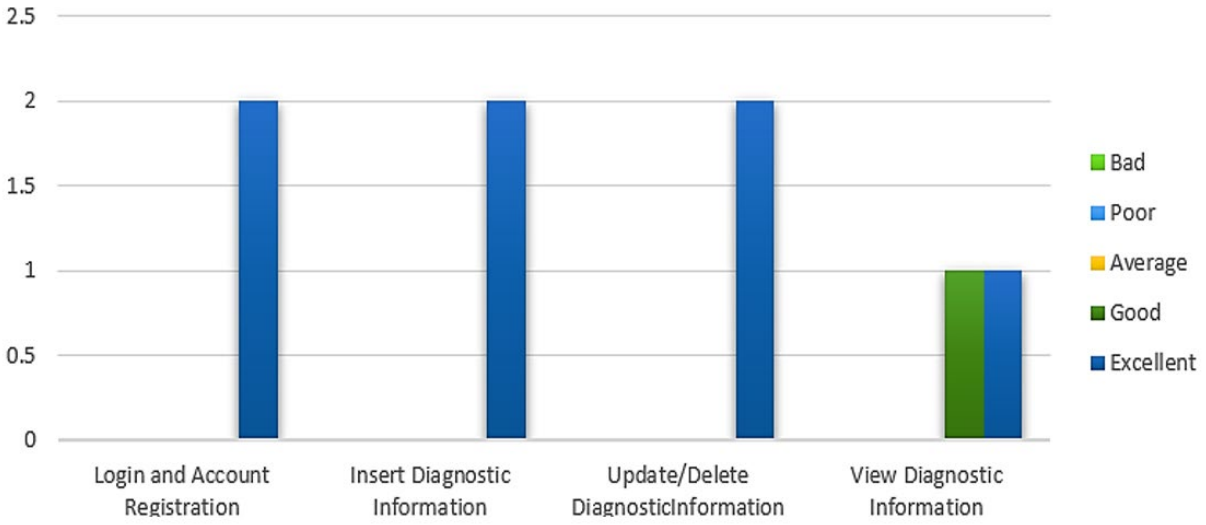



**Fig. 9 - User acceptance test on the system's graphical user interface.**

Fig. 10 (a) and (b) indicates the findings of user acceptance test on the system's functions for public users and administrators. At first glance, testers are generally please about the functional modules of the system. All categories of the test receive very positive feedback from the testers. Other than view diagnostic information, the other three categories receive an excellent rating from both testers.




**(a) User acceptance test**




**(b) Functional testing administration**

**Fig. 10 - User acceptance testing on system's functions (user and administrator).**

## 6. Conclusion

Expert System for Laptop Fault Diagnostics was successfully developed, and it managed to deliver the project's objectives. The system is designed to provide an express diagnosis of potential laptop faults according to the signs that the user has been noticing when using their laptop. Through using this system, the user can expect a quick and accurate way of diagnosing laptop faults, instead of having to perform the diagnosis themselves. User can also avoid unnecessary expenditures in hiring technicians to fix their faulty laptop, and instead follow the step-by-step instructions provided by the system to fix the laptop themselves. Users do not have to worry about whether the diagnosis results are obsolete as the expert system also comes with administrative functions that permit authorized user to update the knowledge base with the newest information. As for future work, more categories of laptop faults can be added to increase the capability of the expert system. A new feature can also be added to allow the user to list out all the symptoms they have been noticing without having to select a topic. This feature allows the system to automatically detect the laptop fault based on the symptoms written by the user. Following on, the system can also utilize artificial intelligence by introducing self-learning technology that allows the expert system to grow in knowledge with each iteration of diagnosis. Lastly, new security measures can be taken such as by making sure the PHP version is always updated and setting up SSL certificates.

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## References

[1] Dahouk, A. W., & Abu-Naser, S. S. (2018). A Proposed Knowledge Based System for Desktop PC Troubleshooting

[2] Fadel, H., Hameed, R. S., Hasoon, J. N., Mostafa, S. A., & Khalaf, B. A. (2020). A Light-weight ESalsa20 Ciphering based on 1D Logistic and Chebyshev Chaotic Maps. Solid State Technology, 63(1), 1078-1093

[3] Zulhilmi, A., Mostafa, S. A., Khalaf, B. A., Mustapha, A., & Tenah, S. S. (2020, December). A Comparison of Three Machine Learning Algorithms in the Classification of Network Intrusion. In International Conference on Advances in Cyber Security (pp. 313-324). Springer, Singapore

[4] Ghani, M. K. A., Mohammed, M. A., Ibrahim, M. S., Mostafa, S. A., & Ibrahim, D. A. (2017). Implementing an Efficient Expert System for Services Center Management by Fuzzy Logic Controller. Journal of Theoretical & Applied Information Technology, 95(13)

[5] Sahin, S., Tolun, M. R., & Hassanpour, R. (2012). Hybrid expert systems: A survey of current approaches and applications. Expert systems with applications, 39(4), 4609-4617

[6] Expert System (noun) definition and synonyms | Macmillan Dictionary", Macmillandictionary.com, 2020. [Online]. Available: https://www.macmillandictionary.com/dictionary/british/expert-system. [Accessed: 29- Sep- 2019]
[7] Ahmed, B. (2020). An Expert System for Engine Excavator Troubleshooting. Journal of Soft Computing and Data Mining, 1(2), 53-61
[8] Ali, A. A., Hameed, E. M., Shareef, S. M., & Khalaf, B. A. (2020). Lion Optimized K-Means Support Vector Machine for Clustering Problems in Cloud Internet of Things Environment. Solid State Technology, 63(6), 4620-4631
[9] Thaeer Hammid, A., Awad, O. I., Sulaiman, M. H., Gunasekaran, S. S., Mostafa, S. A., Manoj Kumar, N., ... & Abdulhasan, R. A. (2020). A review of optimization algorithms in solving hydro generation scheduling problems. Energies, 13(11), 2787
[10] Mostafa, S. A., Mustapha, A., Hazeem, A. A., Khaleefah, S. H., & Mohammed, M. A. (2018). An agent-based inference engine for efficient and reliable automated car failure diagnosis assistance. IEEE Access, 6, 8322-8331
[11] Abu-Naser, S. S., & Hamed, M. A. (2016). An Expert System for Mouth Problems in Infants and Children
[12] Mostafa, S. A., Ahmad, M. S., Mohammed, M. A., & Obaid, O. I. (2012). Implementing an expert diagnostic assistance system for car failure and malfunction. International Journal of Computer Science Issues (IJCSI), 9(2), 1
[13] Sharma, T., Tiwari, N., & Kelkar, D. (2012). Study of difference between forward and backward reasoning. International Journal of Emerging Technology and Advanced Engineering, 2(10), 271-273
[14] Mandal, S., Chatterjee, S., & Neogi, B. (2013). Diagnosis and troubleshooting of computer faults based on expert system and artificial intelligence. International Journal of Pure and Applied Mathematics, 83(5), 717-729
[15] Mustaffa, M. M., Shibghatullah, A. S., Basari, A. S. H., & Hussin, B. (2014, October). Diagnosing Computer Hardware Failures Using Expert System (Rule-Based Technique). In International Symposium on Research in Innovation and Sustainability
[16] Ergado, A. A. (2016). Self learning computer troubleshooting expert system. International Journal of Artificial Intelligence & Applications (IJAIA), 7(1), 45-58
[17] Mostafa, S. A., Mustapha, A., Hazeem, A. A., Khaleefah, S. H., & Mohammed, M. A. (2018). An agent-based inference engine for efficient and reliable automated car failure diagnosis assistance. IEEE Access, 6, 8322-8331
[18] Ragunath, P. K., Velmourougan, S., Davachelvan, P., Kayalvizhi, S., & Ravimohan, R. (2010). Evolving a new model (SDLC Model-2010) for software development life cycle (SDLC). International Journal of Computer Science and Network Security, 10(1), 112-119
[19] Ghani, M. K. A., Mohammed, M. A., Ibrahim, M. S., Mostafa, S. A., & Ibrahim, D. A. (2017). Implementing an Efficient Expert System for Services Center Management by Fuzzy Logic Controller. Journal of Theoretical & Applied Information Technology, 95(13)
[20] Grosan, C., & Abraham, A. (2011). Rule-based expert systems. In Intelligent systems (pp. 149-185). Springer, Berlin, Heidelberg
[21] Ahmed, B. (2020). Wrapper Feature Selection Approach Based on Binary Firefly Algorithm for Spam E-mail Filtering. Journal of Soft Computing and Data Mining, 1(2), 44-52