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An Expert System for Automobile Repairs and Maintenance

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Abstract

Most of the car owners have inadequate knowledge on detecting faults from symptoms manifested and developed from their vehicles. These faults require the presence of an auto mechanic. To aid this knowledge inadequacy and temporarily substitute the auto mechanic especially in times of their unavailability, this paper developed an expert system – a computer system that emulates the decision-making ability of a human expert. This system aids the car owners in repairing and maintaining their cars. It was designed to solve complex problems by reasoning about knowledge base which is represented primarily by if-then rules. The expert system was made using Microsoft Visual C# programming language as it is an object-oriented type and has supports for generics and functional programming paradigms. For easy interaction with the user, graphic user interface (GUI) of the system was created using window presentation framework (WPF) from Microsoft in order to achieve fluid and vector based on the interaction of the system with the user. During the process, this system worked accurately according to the various classes of fault presented to the programmer. Furthermore, this could save time and energy of car owners and human expert in diagnosing, repairing and maintaining their vehicles.

Keywords*:* automobile, diagnosis, expert system, fault detection, maintenance

1. Introduction

At present, transportation technology is growing fast. However, many car owners and drivers have less knowledge on detecting and diagnosing faults in their cars. Automobile problem or fault detection is a complicated process which demands high level of knowledge and skill (Kadarsah and Eri, 1998).

As a result, there is a need for frequent maintenance as well as time to repair if necessary.

Automobile maintenance and repair are performed by human experts (auto mechanic) and expert system. An expert system can be defined as an intelligent computer program that uses knowledge and inference procedure to solve problems that are difficult enough to require significant human expertise for their solutions (Giarratano and Riley, 2004). Chakraborty (2010) defined it as an interactive computer-based decision tool that uses both fact and heuristics to solve difficult decision-making problem base on knowledge acquired from an expert. An expert system employs human knowledge captured in a computer to solve problem that ordinarily require human expertise (Hope and Wild, 1994). In an expert system, there is always transference of knowledge from human expert to a computer. This is normally represented by facts and rules in the systems. Advice and proof for any problem in a specific domain for the users upon their requests can be provided by the system (Ahmad and Al-Taani, 2005).

Basic vehicle maintenance is a fundamental part of an auto-mechanic work in modern industrialized countries. While for others, they are only consulted when a vehicle is already showing signs of malfunction. Preventive maintenance is also a fundamental part of an auto-mechanic job, but this is not possible in the case of vehicles that are not regularly maintained by an automechanic. One misunderstood aspect of preventative maintenance is scheduled replacement of various parts which occurs before failure to avoid far more expensive damage. Hence, it helps to ensure that replacements of parts are done before poising problems for the automobile.

With the rapid advancement in technology, the auto-mechanic job has evolved from purely mechanical to include electronic technology. Because vehicles today possess complex computer and electronic systems, auto-mechanics need to have a broader base of knowledge than in the past. Due to the increasingly labyrinthine nature of the technology that is now incorporated into automobile, most automobile dealership and independent workshop now provide sophisticated diagnostic computers to each technician, without which they would be unable to diagnose or repair and maintain a vehicle (Ngure, 2013). In the modern era, the automobile has become increasing difficult to repair without basic technical and computer-based knowledge. The computer and electronic driven elements of the vehicles have changed the nature of the automobile mechanics.

In this paper, an expert system was designed for fault detection analysis in automobile based on the efficient utilization of the past experiences of the owners. This expert system is ought to give a temporary assistance to those users who are in urgent need of an instant help. Automobile fault diagnosis expert system using fault tree-neural network ensemble-based knowledge was developed by Youjun *et al*. (2011). Fault tree analysis was employed to form expert rules for easy faults, whereas the neural networkbased method was adopted as a diagnostic model for faults that are difficult to find specific expression between failure mode and fault reasons (Youjun *et al.*, 2011). The application of a mobile Vehicle Expert System (mVES) was developed by Asabere and Kusi-Sarpong (2012) for solving vehicular problems. The work suggested that minor faults that involve starting and cooling systems can be solved by using mVES.

This work aims to provide an alternative to the human expert method in automobile maintenance and repair for more effectiveness and convenience by modeling an expert system for automobile repair and maintenance through the use of an artificial intelligence programming. However, this application is limited to recognizing and diagnosing five broad groups or classes of car faults for repair and maintenance – engine induced faults, power transmission train faults, clutch-related faults, battery faults and brake induced faults.

1.1 The Expert System

According to Anjaneyulu (1998), expert system encodes human expertise in limited domain by representing it using if-then rules. This article explains the development and application of expert system in an automobile workshop to save the time and energy of human system. Expert systems are part of larger area of artificial intelligence (Giarratano and Riley, 2004; Anjaneyulu, 1998). It is important to state based on literature search that expert system had found applications in various fields. Deschamps and Fernandes (2000) designed an expert system to diagnose periodontal diseases. In another study which aims to minimize the error encountered in welding when fatigue sets in, Adekunle *et al.* (2014) developed a software that will aid robotic welding at a lower cost and could be operated by anyone. Likewise, Huang *et al.* (2001) developed an expert system based on fault tree analysis for lubricating dewaxing process.

An expert system for real-time failure diagnosis of complex chemical processes was developed (Qian *et al.*, 2003). Ahmad and Al-Taani (2005) developed an expert system for car failure diagnosis by implementing a knowledge-based system using C Language Integrated Production System (CLIPS). Adekunle *et al*., (2016) developed a prototype expert system for assistance in welding. An expert system for diagnosing fault, repairing and maintaining electrical machines was developed by Kontargyri *et al*., (2007). In the application of injection molding of plastic parts, Steadyman and Pell (1995) employed expert system in the engineering design. Moreover, for the simulation model for casting metal substructure of a metal-ceramic crown design, an expert system was developed by Matin *et al*., (2017). The utilization of expert system software engineering approach in determining the performance of gas turbine engine in generating electricity was performed by Ipadeola *et al*., (2014). Expert system software was developed by Akinnuli and Olaleye (2013) to carry out the technical diagnosing of the causes of overheating in a bulldozer engine model D60s-6 Komatsu products.

1.1.1 Components of an Expert System

A typical expert system consists of five components as shown in Figure 1.

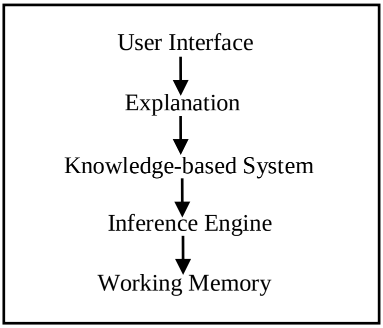

Figure 1. Component of an expert system (Anjaneyulu, 2007)

The knowledge base and the working memory (WM) are the data structures which the system uses. The inference engine is the basic program which is used. The explanation system answers questions from the user and provides an explanation of its reasoning.

1.1.2 Knowledge Engineering

Knowledge engineering or acquisition is the process of extracting knowledge about the domains in which the expert system is being created. Typically, this knowledge is obtained from a human expert in the domain. This knowledge is normally in the form of heuristic knowledge which the expert gains through experience over a period of time. Knowledge engineering is the biggest bottleneck in the development of expert systems.

Depending on the complexity of the domains, knowledge engineering could take anywhere from a few days to a few years. Expert system tools have been created to provide support in the creation of this knowledge and carry out checks on the completeness and correctness of the knowledge represented in the system.

2. Methodology

An expert system shell can be viewed as an expert system minus the domain knowledge. The analogy would be the different between a database tool and a database system. It allows knowledge of a domain to be encoded in a specific format and put into the system to create expert systems for different domains. The advantage of using a shell is that it avoids the need for computer programming and allows the developer to focus only on the domain knowledge. This enables even non-computer professional to create expert systems.

This study aims to design and develop a system that can detect different classes of faults a car based on available information and can recommend a possible solution. The basic steps in solving the problem are as shown in Figure 2.

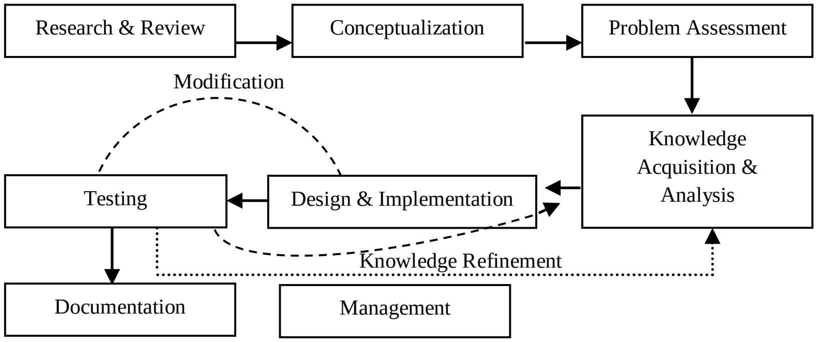

Figure 2. System's development methodology

2.1 Computer Characteristics and Software Function

The system was designed to work as a desktop application. Any system configuration capable of running Windows Vista was capable of running the application. The system transferred the class of fault taken as input to the knowledge base and then to the inference base for causes and solutions. The system took the class of fault from the user as input before giving the causes and solutions based on the available information. The system was expected to give accurate recommendations. In case of non-existence or unexpected events, the system provided a general solution. A vast amount of information concerning mechanical faults of a car was available, stored in the knowledge base and accessible for the inference engine to work on. The system was designed to acquire and store additional faults to the knowledge base in future.

2.2 Domain Identification

The systems aimed at diagnosing common faults or problem in a car and give a possible solution that can be applied if the fault has been verified to be correctly determined. It was designed to use the available information about the car's current state like symptoms and error codes, if available, to arrive at solutions through a careful analysis of the supplied information. The system, therefore, needed a way of keeping its knowledge that can be retrieved when the system was running. This need was serviced by a database system to allow for a flexible storage and retrieval of data.

2.3 Knowledge Acquisition

Knowledge is the key success in the performance of an expert system. Acquisition of the desired knowledge for the problem domain was obtained from intelligent human experts. Car symptoms were different from the components responsible for the fault and other undesired situation in the search for acquiring the symptoms or causes. Comprehensive study of the entire car system fault profile from the expert was carried out. Also, detailed and comprehensive documentation of the real-life methodology of a car diagnosis, repairs and maintenance procedures by the human expert was done. The expert was queried and adequate explanations were given to solve the problems. This was first documented. Finally, other relevant data information were reviewed and utilized as part of the knowledge acquisition procedures through reading of the relevant automobile textbooks and journals.

2.4 Problem Analysis

The domain for this expert system diagnosis car faults could be characterized by fault/malfunctioning of engine or other parts and mismanagement or poor maintenance of the car. For this application, car faults were classified into five broad groups/classes namely engine induced faults, power transmission train faults, clutch related faults, battery faults and brake-induced faults. Problems associated with each group were varied. Each problem was identified by specific features such as faulty mode or error mode, which is the way they behave when faulty. The fault may be caused by human expert due to bad maintenance and usage or by delayed servicing of the car or depreciation on the parts. Mostly, the faults are to occur when the car is exhausted; thus, causing a breakdown or damage of some parts or the whole car system. The system was developed using Microsoft Visual C# programming language. It is an object-oriented type safe, strongly typed and has support for generics and functional programming paradigms. It is a C-family language with a clean and elegant syntax that allows for easier development and manipulation of complex systems. The graphical user interface of the system was designed using WPF from Microsoft in order to achieve fluid and vector based on interaction of the system with the user.

2.5 Database Design (Knowledge Base Creation)

The relevant information was obtained from the repair. Repertoires of knowledge were used to build the database. Microsoft SQL server was used to develop the database because the software was designed to allow easy access. It can also easily be modified and retrained. The database is also flexible such that new information can be added.

2.6 System Analysis and Design

This involved the design of the system through the use object-oriented analysis and design. The system was designed to capture relevant information from the problem domain in order to update the knowledge base. This was then queried by the inference engine upon the request of the user. The system was designed with a GUI for easy interaction of the user with the system. The design consisted different components including user interface, inference engine and knowledge base.

2.6.1 User Interface Design

This was the subsystem of the expert system that facilitated the interaction between the user and the expert system. It also acted as an intermediary between the user and the entire system. The user interface for this system was designed using WPF and GUI framework. The interfaces contained in this system were splash screen, main form interface, automobile information interface and user request interface.

The splash screen provided the user with the welcome or homepage of the whole system with a multimedia design of the system on it. The user login interface was used to prevent unauthorized user from using the system. In it, the user supplies name and the password for necessary authentication.

The main user interface gave the user the options of choosing the work to be done at that time – whether it was updating of the database or the diagnosing of faults.

The automobile information interface deals with the update of automobile information based on the car type, classified faults and symptoms. The administrator had the sole access to this page because it contained delicate information about the knowledge base i.e. update or removal of the information in the knowledge. Hence, there was an authentication through the use of an administrator password.

The user request interface provided the user with the options of five classes of faults that the system is working on. It allowed the user to choose from the list of possible symptoms available to each class fault and click the diagnose option to allow the expert system the opportunity of proffering a solution. It provided the user with the opportunity of determining the method employed in retrieving the results – either through the direct search method or the statistical prediction method.

The inference engine was concerned in combining together an appropriate line of reasoning which led to probable solution. It determined the solution by comparing the facts obtained from the analysis of the problems with supposed working mode of the car system. The inference engine imitated the specialist's reasoning process through the utilization of a problem solving strategy. The inferences were drawn by matching the if-part of the rules with the known facts in the working memory and placing back the result to the working memory.

The inference engine design was implemented in the program using if-then rules. These rules are given as algorithm using pseudo-code and flowchart design representations (Figure 3).

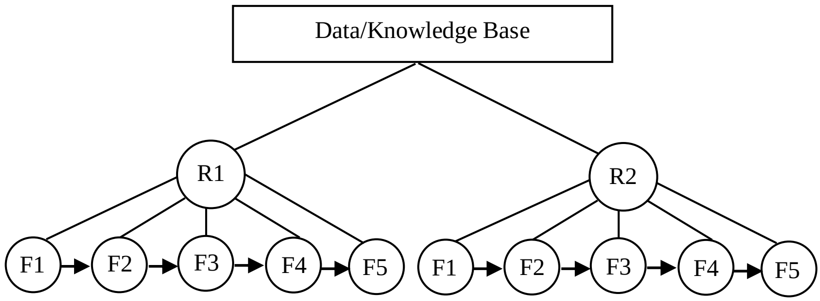

Figure 3. Search engine method (R: Record; F: Field; F1: Car type; F2: Class fault; F3: Symptom; and F4: Diagnosis)

Some of the if-then (if: symptoms; then: cause) rules employed in the expert system developed are listed below.

Rule 1: if key ignition to start the vehicle is turned on and engine fails to crank, then check the battery and battery terminals of the vehicle should be cleaned and tightened appropriately.

Rule 2: if rule 1 is followed and vehicle still fails to crank, then confirm the fuel/ gas level of the vehicle if it is enough.

Rule 3: if rule 1 is followed and there is enough fuel/gas but the engine still fails to crank, then switching operation should be checked.

Rule 4: if the engine refuses to crank after the application of rules 1, 2 and 3, then contact an experience automobile personnel as the vehicle's fault/problem might be likely a major electrical problem.

Rule 5: if there is bad, slow running jet block for carburettor and there is lack of fuel supply, then change the fuel pump.

Rule 6: if the fuel pump is changed and the problem still persists, then check and change the fuel pump fuse.

Rule 7: if the fuel pump fuse is replaced and there is no solution yet, then replace the slow running jet with the help of experienced automobile personnel (recommended).

Rule 8: if the vehicle is turned on and the engine cranking is slow and fails to cause spark, then check the vehicle's battery.

Rule 9: if rule 8 is followed and the vehicle's battery is weak, then charge the battery.

Rule 10: if rules 8 and 9 are followed, the engine still cranks in a slow manner and fails to cause spark, then the starter needs to be checked or tested.

Rule 11: if the starter is tested to be working perfectly, then the battery should be replaced.

Rule 12: If rules 8, 9 and 10 are followed, the engine still cranks in a slow manner and fails to cause spark, then the battery needs to be replaced because it is weak and starter needs to be replaced. The expertise of experienced automobile personnel is required.

Rule 13: if the vehicle is moved and jerking while in gradual motion, then spark plug and contact set problems are suspected in the engine and should be checked.

Rule 14: if the spark plugs and the contact set are checked and fixed, and the vehicle still jerks while in gradual motion, then major fault could be the cause. The assistance of experienced automobile personnel is required.

Rule 15: if there is an unusual increase in the temperature of the vehicle while driving, and the engine is overheating, then check water level in radiator for possible leakages, and check the fan of the radiator if it is still working.

Rule 16: if after the water level and radiator fan are checked which found to be working properly, and there is no radiator leakage, but the temperature of engine remains as high as before causing engine to overheat, then stop the vehicle, open the bonnet and let the engine cools for some time before restarting it.

Rule 17: if there is no solution to vehicle cooling system and vehicle engine maintains high temperature using rules 15 and 16, then fault is likely to be major. The service of experienced automobile personnel is sought.

Rule 18: if the radiator is leaking and/or the radiator fan is not functioning, then seek the help of experienced automobile personnel. It is a major fault.

Rule 19: if there is loss of oil over time and presence of blue smoke or sniff smell of burning oil, stain under the engine compartment such as red fluid (transmission fluid), green or orange fluid (coolant) and brown fluid (engine oil), then check for oil leak from engine valve gasket, oil pan, oil seals, oil drain plugs, oil filler cap, or bad connection, which can be the cause. The assistance of experienced automobile personnel is required.

Rule 20: if the vehicle is ignited and unusual exhaust smoke is emitted, then notice carefully the color of the smoke as this might be due to incomplete fuel combustion, burning engine oil, vaporization of coolant and presence of water in the combustion chamber.

Rule 21: if the exhaust smoke is noticed and black or gray smoke is observed, then this could be due to the clogged air filter, malfunctioning of carburetor and choke/fuel injection, and leaking oil in the exhaust system. It is recommended to seek the assistance of experienced automobile personnel.

Rule 22: if the smoke is noticed and blue smoke is observed, then there is oil leakage in the combustion chamber, worn piston rings, valves or cylinder. It is recommended to seek the assistance of experienced automobile personnel.

Rule 23: if the exhaust smoke is noticed and white smoke is observed, then there is vaporization of coolant and/or water in the combustion chamber which might be due to cold engine, leakage in head gasket or cracked block or cylinder head. It is recommended to seek the assistance of experienced automobile personnel.

3. Results and Discussion

In this paper, expert system software for repairs and maintenance purposes for automobile was developed. During the testing phase of the system, wrong diagnosis was not detected based on the rules used. The expert system was practicable and enormously useful in providing consistent car repair and maintenance alert. Figure 4 indicates the welcome screen of the expert system.

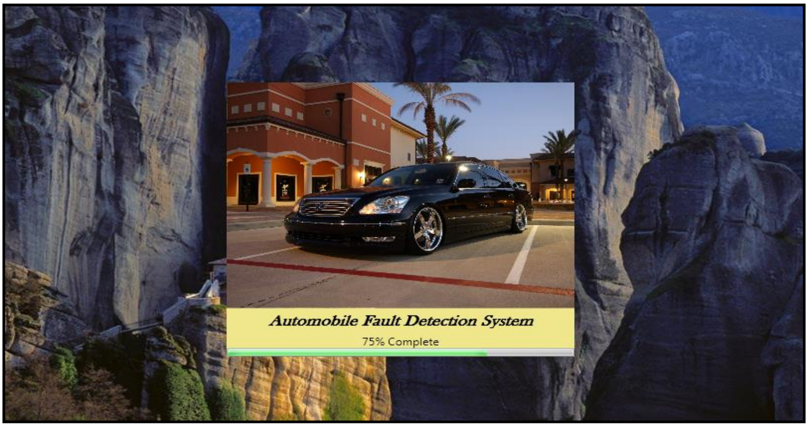

Figure 4. The expert system's splash screen

By clicking on any of the suggested faults as shown in Figure 5, a drop down menu of the symptoms responsible for the fault are displayed as shown in Figure 6. The possible cause of the symptoms clicked upon is displaced alongside the possible solutions as displayed in Figure 7. For instance, when a fault like knocking down is clicked, dropped down menu indicates various symptoms to be checked are displayed. Assuming that bad slow running jet block for carburettor is clicked, the possible causes of the symptom are displayed such as lack of fuel supply, incorrect gear selection for automatic gear box. When lack of fuel supply from the possible causes is clicked, the solutions to be employed are displayed. The solutions include change of fuel pump, change of fuel pump fuse and replace slow running jet. Hence, a car owner who is in possession of this new expert system is able to understand the cause of the fault and take the decision to give aid to it. This is as shown in Figure 7.

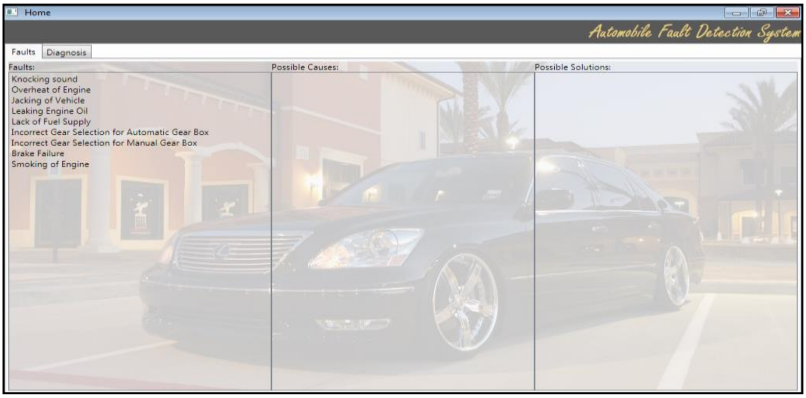

Figure 5. The expert system's fault solution interface

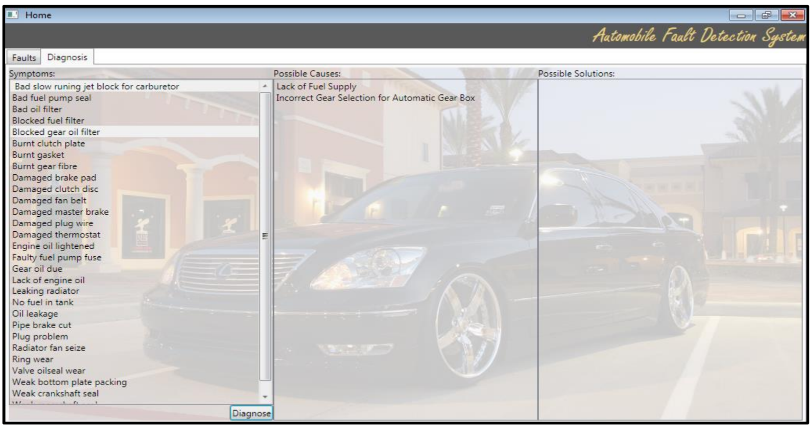

Figure 6. The expert system's diagnosis interface

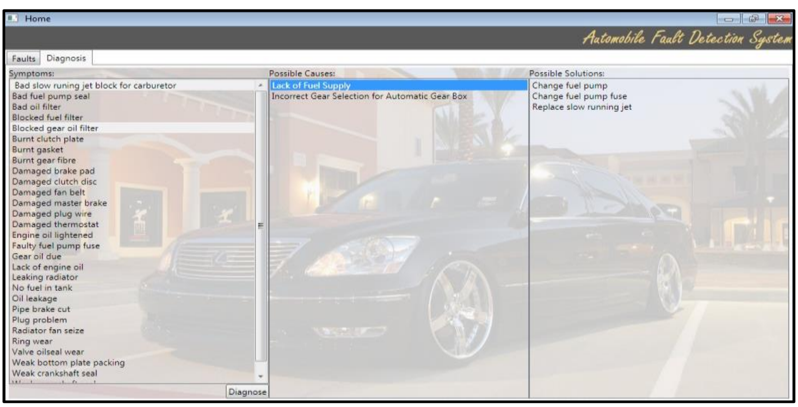

Figure 7. The expert system's sample solution page

4. Conclusion

The expert system was designed in order to detect various automobile problems instead of using human expert system (auto mechanic). There is a need for maintenance and repair as well as time is deemed necessary. Expert system is an interactive computer-based decision tool that uses both fact and heuristics to solve difficult problem base on knowledge acquired from an expert. Expert system is used where there is no available auto mechanic in a particular period of time. By giving the car owners necessary solution, this expert system helps them to troubleshoot the faults detected through the manifested symptoms. Also, this gives a temporary assistance to the car owners who are in need of an instant help – especially those who are in haste and have no enough time to wait for human expert to come to repair the damage. Further, this system enables people to get closer to the world of computerization and technology. Moreover, having this system may allow auto-mechanic to do more work efficiently, which could generate more revenue. Finally, the system has the characteristics of a good expert system because of its high performance, responsiveness and user-friendliness.

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