A Rule-Based Expert System for Automobile Fault Diagnosis

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Abstract— Diagnosis of car fault is a complicated process that demands a high level of knowledge and skills. For this reason, automobile users require skilled automobile technicians for diagnosing a fault detected in their automobile and for maintenance. However, some faults are minor and will not require the services of skilled mechanics. An automated system that can help automobile users in diagnosing and fixing common automobile failures will be of paramount importance. Expert systems are widely used in such fields as medical and trading for providing advice from a knowledge base database. However, fewer studies have used expert systems for automobile fault diagnosis that can be used by automobile users. The aim of this research is to develop an expert system for automobile fault diagnosis for automobile users. The knowledge base was acquired through interview and observation. The system was evaluated, and the results show that an expert system can be used for automobile fault diagnosis by automobile users. This will enable automobile users to be able to identify the fault in their automobile, fix it if it is a minor fault or take it to the necessary technician where necessary.

Keywords— Expert system, automobile fault diagnosis, artificial intelligence, automobile mechanic, knowledge base.

I. Introduction

Over the years, automobiles have become an essential part of our lives. Automobiles are the primary means of transportation. However, as machines, automobiles are prone to different degrees of failure. Being complex machines, the services of trained experts are usually sort out when there is an automobile failure. This might not be always comfortable for automobile users, for example, the failure can be on a highway. In addition, many automobiles' problems can be a result of minor faults that do not necessarily require the services of a trained professionals, but the automobile users are unaware and lack the technical know-how. An automated system that can help automobile users in diagnosing and fixing common automobile failures will be of paramount importance.

With the tremendous advancements in computing technologies like Artificial Intelligence (AI), building intelligent systems capable of emulating human reasoning with high accuracy is possible. One way of building such systems is using an Expert System. The terms Expert System and Knowledge-Based System (KBS) are often used interchangeably. An expert system is a system that provides an expert-level diagnosis based on domain knowledge to replace or complement human diagnosis [1]. Expert systems have a variety of applications and have widely been used in different diagnostics systems. For example, in medical diagnosis [2-3], in the diagnosis of formation damage caused by organic scale deposits and surface-active agents [4], and in different automobile parts fault diagnosis [5-9].

In this paper, we focus on the design and implementation of a KBS expert system for automobile fault diagnosis. From the literature, machine learning-based and statistical-based approaches have been applied for car fault diagnosis [6-8]. Similarly, KBS has also been proposed for car fault diagnosis [10-11]. Expert systems are reliable, accurate and cost-effective [2-3] and [11]. However, due to the ever-changing specifications, the knowledge base and approaches used in car fault diagnosis also needs to be constantly improved. Consequently, improving the expert systems' inferencing capability and diagnosis accuracy remains a viable area of research.

The system proposed targets automobile users and covers general faults in specific automobile models, and as such different from existing systems that mostly targets trained personnel and covers specific automobile parts like gearbox and brake systems. In essence, this paper has the following contributions: identified the common faults in specific automobiles using qualitative methods and proposed an expert system that can help drivers and inexperienced mechanics in diagnosing common faults found in an automobile.

The remainder of this paper is organized as follows: Section II discusses the related works, Section III highlights the research methodology, Section IV presents the results and discussion, while Section V concludes the paper.

II. Related Works

Expert systems are computer programs derived from a branch of computer science called Artificial Intelligence (AI), that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions [2]. Expert systems served as an expert with enough knowledge with both data and rules associated with a particular problem within the computer. Expert systems have a variety of applications and have widely been used in different diagnostics systems.

Early studies on automobile fault detection expert systems date as back as 1998. Gelgele & Wang [12] proposed an expert system for engine fault diagnosis named Expert Engine Diagnosis System (EXEDS) using knowledgePro, an expert system development tool. The purpose of the EXEDS was to assist auto mechanics in fault diagnosis of engines by providing a systematic and step by step analysis of failure symptoms and offering maintenance or service advice.

In later studies, Al-Taani [10] proposed a knowledge-based automobile fault detection system. The proposed KBS was implemented using the CLIPS expert system tool with a forward chaining inference engine. CLIPS store's the knowledge in rules form, which has logic-based representation as well as the production rules. Communication between the user and the system is done through the user interface, where the system gives diagnosis result with an illustration. The KBS contains about 150 rules for different types of automobile failures and causes.

Wang & Yin [8] This paper presents a fault diagnosis method for the automobile suspension system based on possibilistic c-means clustering and Fisher discriminant analysis aiming to detect and isolate the spring fault with different fault intensities. The pure data-driven characteristic enables this method to serve as a non-line monitoring method for the suspension system. Without any model information or fault features known in advance, the proposed scheme detects and verifies a spring fault by PCM and fault lines in the first step while isolates and labels the fault by pair-wise FDA in the second step.

Jegadeeshwaran & Sugumaran [6] illustrated the procedure of the fault diagnosis of the hydraulic brake system using the vibration signals from the brake fault simulator experimental setup, with the following simulated fault conditions: air in the brake fluid, brake oil spill on disc brake, drum brake pad wear, disc brake pad wear(even)-inner, disc brake pad wear(even)-inner and outer, disc brake pad wear(uneven)-inner, disc brake pad wear(uneven) – inner and outer, reservoir leak, drum brake mechanical fade. Hence an extensive study is needed to find the optimum number of features. The effect of the number of features was also studied, by using the decision tree as well as Support Vector Machines (SVM).

Mostafa et al. [11] proposed an agent-based inference engine for developing an Automated Car Failure Diagnosis Assistance (ACFDA) system. The ACFDA system assists the car driver to take the initiative and try to fix the car or at least learn the car condition.

III. RESEARCH METHODOLOGY

The methodology used in this study is a composition of all the methods, materials, procedures, and techniques used to achieve the research objectives. The proposed system conforms to the standard process of expert system development, which involves knowledge acquisition, knowledge representation and inference, and a specific user interface [2].

A. Knowledge Acquisition

For this study, both primary and secondary data were used to acquire sufficient data for the knowledge base of the proposed system. Primary data include 1) Observations from car garages, car drivers, and the mechanics as well as the activities they carried out during car repairs. 2) Interview with some mechanics and car drivers to acquire a better understanding of the activities that were not clear during the observation session (see Appendix I for the questions). Whereas secondary data from relevant books, the internet, journals, and other relevant documents. The knowledge base constructed here forms one of the most important components of the Expect system. The knowledge acquired in this study was focused on automobile fault diagnosis at the following stages: start-up state, run state and movement state as identified by [10].

B. Knowledge Representation and Interference

Knowledge Representation (KR) is the second phase of developing an expert system. The way in which knowledge is encoded affects the speed of the inference engine. Several knowledge representation techniques can be used for different activities. In this study, we used a rule-based approach which is composed of production rules. Rule-based is an approach that contains information obtained from a human expert and represents that information in the form of rules, such as IF-THEN. For example, to diagnose an automobile's start-up-state problem, the following rules are applicable:

> "If ? motion starter gives sound is Yes and
> ? motion starter sound is normal Yes and
> ? fuel thank empty is NO
> then ? fuel pump damaged is Yes.

The rules can then be used to perform operations on the data in order to reach an appropriate conclusion. These inferences are essentially computer programs that provide a methodology for reasoning about information in the rule base or knowledge base, and for formulating conclusions. Knowledge inferences are essentially computer programs that provide methodologies for reasoning about information in the rule base or knowledge base, and for formulating conclusions.

C. User Interface

User Interface stage that is responsible for the proposed system's interface design which includes: input, database, and output design of the proposed system (see Fig. 1).

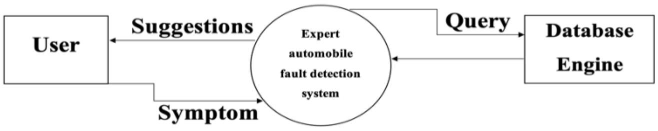

Fig. 1 Dataflow Diagram of the Expert automobile fault detection System

The input to the new system is designed to accept car fault symptoms from a user by entering the signs observed in the car. The system is designed in such a way that the user has the responsibility of inputting the symptoms, and the car registration form provided which contains the plate number, car type, name of the customer, the amount deposited, date, and address and car fault. The database or knowledge base is frequently queried to get the stored information which is in the form of a list of cases of possible car problems that include the problem type, the causes, symptoms, and the possible solutions. Microsoft Access was used for the database design. A sample data for the knowledge base is shown in Table 3 in Appendix II.

1) Unified Modelling Language (UML)

Unified Modelling Language (UML) is a graphical language that allows people who design software systems to use an industry-standard notation to represent them [13]. Use-case diagram was used as shown in Figure 2 to demonstrate the functionality and interaction between the user and the system. The system has three actors: the user, the admin, and the knowledge base database engine.

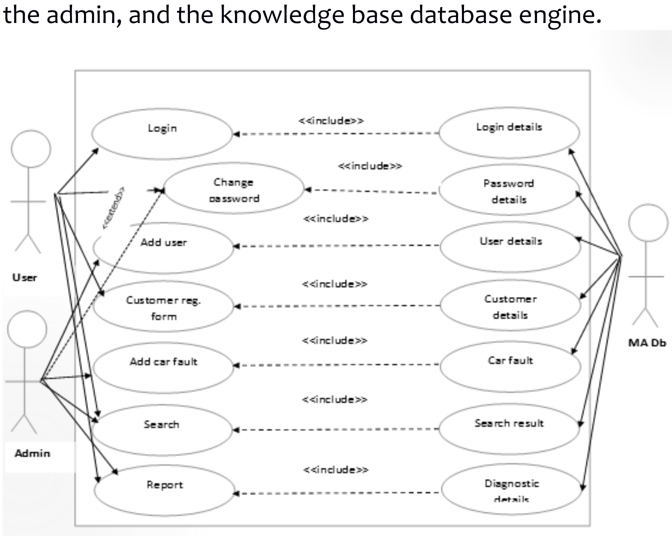

Fig. 2 Use case diagram showing the interaction between the user and the system.

D. System Implementation

The realization of the designed phase of the system was implemented using Visual studio.NET and Microsoft Access. Microsoft Access was used to create and manage the database file. It covers three aspects which are: diagnose common faults in automobiles, suggest a possible cause of the problem, and suggest possible solutions. The system requirements are a computer with keyboard, RAM capacity of 512mb and above, processor speed of 1.8GHz and above on processor Pentium IV.

1) Description of the Developed System

This section describes how the developed system works and how it responds to the user actions, as well as interfaces of the implemented system. The system is structured in such a way that each subsystem is selected and executed independently. The task is divided into several modules, which come together to give the solution to the problem. The modules are as follows: Login Module, Main Interface, Registration, Change Password, Fault/Knowledge Database, User, and Diagnosis. A brief description of each of the modules is given in Table I.

TABLE I
MODULES OF THE DEVELOPED SYSTEM AND THEIR DESCRIPTION

Module	**Description**
Login Module	This consists of entries for username and password in which if entered correctly, takes you into the main interface.
Main Interface	The main interface consists of five respective modules. The menus are as follows: registration, change password, fault, user and diagnosis.
Registration	This is a car registration module that allows users to store faulty car records in a database. These records help in keeping the information of the customer. It consists of the plate number, car type, customer name, the amount paid, address, phone number and date.
Change Password	Is the window that enables users to change the existing password by filling the spaces for username, password, new password and confirm new password. The entries can be saved into the database when the change button is clicked, and the cancel button terminates the process as usual.
Fault/Knowledge database	This program enables the users to add or modify the entries in the knowledge database. It allows users to add or modify car type, problem, symptoms, causes and solutions.
User	New user can be added to the database by clicking on the user module, the form has spaces for accepting full name, username, password and confirm password. The create button store the record in the database and cancel button terminate the process.
Diagnosis	This is the module that takes care of diagnoses on the car to detect the fault and display the generated report. It consists of a search engine for inputting the symptoms observed in a car.

IV. Results and Discussion

The result of the study is made up of the expert system developed. The system has input forms that is composed of mainly two forms: Car Registration Form and Knowledge Database Entry Form (see Fig. 3 and Fig. 4).

Fig. 3 Automobile registration form

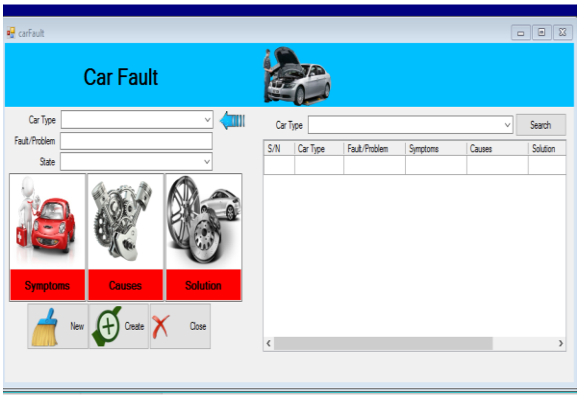

Fig. 4 Knowledge-base entry form

The system developed also has an output form that was designed in such a way that it conveys meaningful information to users. It provides the users with an output that helps as a tool in planning and decision making. Table 2 shows a description of the developed system.

TABLE II
MODULES OF THE DEVELOPED SYSTEM AND THEIR DESCRIPTION

Variable	Meaning
Plate Number	Registration Number of the car
Car Type	The make of the car
Customer Name	Name of the car owner
Amount Paid	Cost of repair
Address	Address of the customer
Phone	Phone number of the customer
Date	Date the car was brought to the workshop
Problem	Car fault
State	Problem state
Symptoms	The faulty signs observed from the car
Causes	The causes of the fault
Solution	Repair options

The system was tested using a list of test cases. The main importance of system testing is to ensure that the system performance is as intended and meets the defined objectives. The testing was carried out in three stages which are: module testing, integration testing, and system testing. Module testing was carried out to ensure that information properly flows into and out of each of the program module. Integration testing was carried out to ensure there is a smooth interaction between the modules of the system. System testing was also conducted to evaluate the performance of the entirety of the system. The system was tested according to eight test cases and the results show that the system works as intended. The eight test cases are listed as follows:

1. Test (1): to confirm that the car registration form is working correctly.
2. Test (2): to verify workability of car registration record form.
3. Test (3): to confirm that the user can change the password successfully using the change password form.
4. Test (4): to verify that adding a new car fault form is working correctly.
5. Test (5): to verify workability of add car fault record form.
6. Test (6): to confirm that a new user can be added successfully using the user form.
7. Test (7): to confirm that the diagnosis form is working successfully using the diagnosis form.
8. Test (8): to verify that the diagnosis/search form is working successfully.

Fig. 5 and Fig. 6 show screenshots from the implemented system. All the tests have shown the system to works as intended.

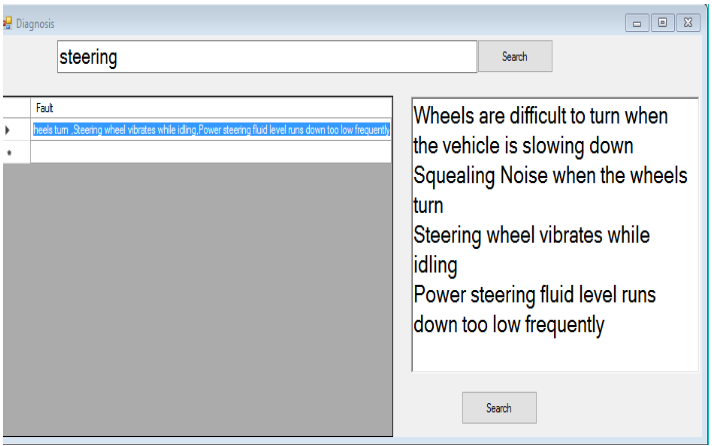

Fig. 5 Result of the test (1).

Test Result (1): to confirm that the diagnosis form is working successfully using the diagnosis form.

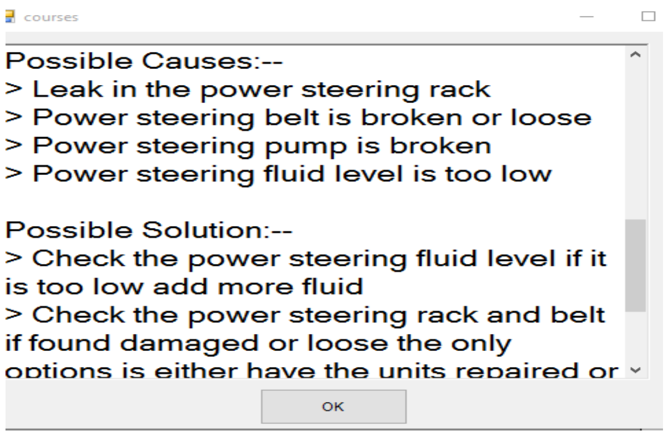

Fig. 6 Result of the test (8).

Test Result (8): to verify that the diagnosis/search form is working successfully.

V. Conclusion and Future work

In this research, we proposed an expert system for automobile diagnosis. The proposed system is helpful to automobile users in diagnosing faults in their automobiles with possible solutions for minor faults. It can also recommend the type of technician needed for faults that require such. The system is helpful as a tool for training automobile technicians. The knowledge-based for the system was based on interview and secondary data collected from journals and textbooks. The system was tested, and the results show that the system works as intended. Future work involves discovering more methods to enrich the knowledge base.

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Appendix I

INTERVIEW QUESTIONS

1. What are the causes and symptoms of suspension problem in automobiles model A – E?
2. What are the causes and symptoms of hard steering wheel problem in automobiles model A – E?
3. What are the causes and symptoms of transmission problem in automobiles model A – E?
4. What are the causes and symptoms of fuel injector problem in automobiles model A – E?
5. What are the causes and symptoms of electrical problem in automobiles model A – E?
6. What are the causes and symptoms of overheating problem in automobiles model A – E?
7. What are the causes and symptoms of Starting problem in automobiles model A – E?

APPENDIX II

TABLE III

SAMPLE DATA FOR KNOWLEDGE-BASE: SUSPENSION PROBLEM

Causes			
		Respondents	**Percentage**
	Bad roads	12	40
	Expired and uneven tire wear	4	13.3
	Damaged or oily shocks	10	33.3
	Substandard parts	4	13.3
	Total	**30**	**100**
Symptoms			
	Abnormal sound when applying brakes or moving on a rough road.	18	36
	Car does not go straight; driver finds it hard when changing lanes.	5	10
	The car shocks and struts look greasy or oily	5	10
	Driver begins to feel every bump.	22	44
	Total	**50**	**100**
Possible Solutions			
	It could be a loose brake pads or worn-out shocks if either of the two replaced. Inspect shocks regularly, leaks, cracks and other damages, replaced if necessary, with original parts	13	43.3
	If the struts are leaking and a broken spring is found, replace the strut it also makes sense to replace both springs at the same time.	5	16.7
	Check the shock absorbers if damaged replace. Check the condition and pressure of the tires, balance uneven tire wear and replace expired tires with good original ones.	12	40
	Total	**30**	**100**