Development of an Intelligent Car Engine Fault Troubleshooting System (CEFTS)

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Abstract

The mass production and wider use of automobiles and the incorporation of complex electronic technologies all indicate that the control of faults should be an integral part of engine design and usage. This paper discusses an expert system application for troubleshooting car engine faults using Auto-mechanic workshops in Calabar metropolis of Cross River State-Nigeria. The method of fact-finding called knowledge acquisition which is an expert system approach to extract facts was adopted in order to achieve good judgment in the use of heuristics among experts. The results are represented as a set of IF – THEN judgments that expert mechanics can rely mostly on in the troubleshooting process. The system depends on an automated matching process between symptoms and procedures. The paper developed a new prototype named Car Engine Fault Troubleshooting System (CEFTS) using C++ programming platform. The purpose of the developed prototype is to assist motorists and auto mechanics in fault troubleshooting of car engines by providing systematic and step-by-step analysis of failure symptoms and offering maintenance or service advice. The result of this development is expected to introduce a systematic and intelligent method in car engine troubleshooting and maintenance environments and also provides a troubleshooting framework for other researchers to work on.

KEYWORDS: Expert System, knowledge base, troubleshooting, inference engine, knowledge acquisition, artificial intelligence**.**

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1. Introduction

In today's highly advanced society, computers affect our lives twenty-four hours a day. The use of computer in diverse activities of human endeavours is increasing in our society today, as awareness of the capabilities of the computer increases [1].

Almost all the activities carried out by humans are stressful. From time immemorial, man has learnt to reduce stress by developing new technologies which to a very large extent reduce stress to the barest minimum, if not completely eliminated [2].The application of computer is prominent in getting things done with high precision [3]. Like every other area of human endeavour, computers are now being applied in various fields, automobile industries inclusive.Auto mechanics have all along been seeking for effective means of improving their services to their clients and technological aid using expert system is no doubt one of these means. Expert system is an intelligent computerprogram that uses knowledge and inference procedures to solveproblems that are difficult enough to require significant human expertise for their solutions [4]. Expert systems provide powerful and flexible means for obtaining solutions toa variety of problems that often cannot be dealt with by other,more traditional and orthodox methods [5].

The mass production and wider use of automobiles and the incorporation of complex electronic technologies all indicate that the control of faults should be given an integral part of engine design and usage [6]. Today, Artificial Intelligence (AI) technology is widely suggested for systematic troubleshooting of faults where the amount of well-defined diagnosis knowledge is vast and the sequence of steps required to identify the fault is very long.

There are many things that can affect eng performance. Today's cars are more complicated than t ever were. Electronic components and computers make th more fuel efficient, but they also make them m complicated and difficult to troubleshoot. A lot of thi that made an engine run bad twenty years ago, still hold today. The electronics make the engine run, but under

those electronics the engine hass basically remained the same. Before one try and troubleshoot any problem, there is need to check the basics. "The engine needs spark, fuel and air to operate and nine times out of ten; it is a simple and basic problem" [7].

Therefore, thepurpose of this study is to develop an expert system application for car engine faults troubleshooting and to transform the expertise of the human expert (auto-mechanics) into an intelligent Car Engine Fault Troubleshooting System (CEFTS) using expert system technology.

2. Problem Definition

Has one's car ever broken down in the middle of a long distance journey, and the motorist do not know what to do? Then, after several minutes of indecision, the motorist starts looking for a mechanic workshop. A mechanic follows the motorist, touches the distributor, and asks the motorist to start the car. The motorist jump into the car, reluctantly turn the ignition key, and then the engine starts. The mechanic then declares that the problem is solved, that the motorist should pay him and continues with the journey. How does the motorist feel? It must be a mixture of excitement and anger within him/her. This is the kind of scenario people go through on several occasions. For this reason, it becomes necessary to automate car engine troubleshooting procedure, so that car owners or motorists can begin to have a level of knowledge, which will enable them solve certain car engine problems personally.

In dealing with car engine problems and troubleshooting, mechanics are those who can help to solve them. But sometimes we donot have enough time to see the mechanics and maybe the distance is quite far, and we are in a hurry. Therefore we need instance help and solution. So it is believed that the use of expert system can be beneficial in this situation by giving a temporary and instance guides to motorists and car owners.

The following situations are the factors that initiated this study, so as to find a way of developing expert system application that can be useful in such situations.

i. Lack of knowledge by car owners or motorists to handle the easier car engine problems.

ii. Lack of knowledge by car owners or motorists to communicate the exact nature of their car engine problems to the mechanic.

iii. Inaccurate diagnosis of car engine problems by the Mechanic.

iv. Frequent occurrence of incidents on the highway, due to regular car engine malfunctioning. Some of the problems that may arise from this include delay in meeting up with appointments; one's integrity can be affected; extortion for a quick fix; exposure to robbery attack; etc.

3.0 Expert Systems

An expert system or knowledge-based system is a computer program that is designed to mimic the decision-making ability of a decision-maker(s), that is, expert(s) in a particular narrow domain of expertise [8].Expert systems are computer applications which embody some non-algorithmic expertise for solving certain types of problems. For example, expert systems are used in diagnostic applications servicing both people and machinery. They also play chess, make financial planning decisions, configure computers, monitor real time systems, underwrite insurance policies, and perform many other services which previously required human expertise [9].

The primary intent of expert system technology is to realize the integration of human expertise into computer processes. This integration not only helps to preserve the human expertise but also allows humans to be freed from performing the more routine activities that might be associated with interactions with a computer-based system [10].

Any successful decision-making is strongly dependent upon various capabilities that include the effective acquisition, storage, distribution, and sophisticated use of the knowledge of the human experts in the field. In the context of computer-aided systems for monitoring and information processing, these capabilities would be achieved through developing an expert system [11].

The author in [4] had also said that the most successful application of Artificial Intelligence (AI) in decision making so far is the development of Decision Support System (DSS), particularly expert system, which is a computer program that act as a 'consultant' or 'advisor' to decision makers.

Expert System has been applied in many ways and various fields which are meant to make human's life simple and even easier. The application of expert systems technology in the domain of environmental management is particularly appropriate in order to preserve and disseminate efficiently valuable and scarce expertise at reasonable costs. The Landfill Restoration Plan Advisor (LRPA) is an expert system designed for use in the planning of sanitary landfill restoration [12].

In medical domain, expert system seems to be really helpful which can assist both doctors and patients, and has been applied in several cases. The efficacy of expert system towards healthcare is demonstrated by discussing an on-going in-house Tele-Healthcare project TIDE—

Tele-Healthcare Information and Diagnostic Environment. TIDE aims to ensure a continuum of healthcare throughout the life-time of the individual. Technical realization of TIDE involves a confluence of information technologies – artificial intelligence (expert systems, case-based and commonsense reasoning), medical informatics, multimedia, Internet and database technologies [13].

The author in [14] described a proposed expert system for car fault diagnosis called the Service Bay Diagnostic System (SBDS). This system has the ability to guide a human technician throughthe entire service process, from the initial customer interviewat the service desk to the diagnosis and repair of the car in the garage.

The author in [15] proposed and designed a decision model forcar fault diagnosis in which an expert system is utilized to helpinexperienced mechanics and drivers.

The authors in [16] proposed and developed an expert system for diagnosis heavy duty diesel engine that can be used to detect malfunctions in the engines andgive recommendation of corrective actions.

4.0 Troubleshooting

Troubleshooting is the process of finding and correcting faults in machinery. Troubleshooters are those who carry out fault tracing and fault correction in a machinery [17].

There are several standard techniques that can be used to troubleshoot problems. Using the tools and documentation provided with the hardware and software is a good starting place. Once users have familiarized with these materials, they can begin identifying the problem and testing the affected features to determine the exact cause. Problems can be caused by issues as diverse as incompatible hardware, outdated drivers, loose connections, incorrect configurations, or other issues. Users can use a variety of resources to isolate the problem and determine if it is a known issue with a documented solution [18].

There are better ways to tackle intermittent. One is to wait until the intermittent has become a more frequent or continuous problem. It's always easier to diagnose a part that has failed than one which is only misbehaving. But that approach may not sit well with a customer who wants you to fix their problem now. Most people want dependable transportation that starts every time and runs reliably. They don't want to risk being stranded or breaking down somewhere. So if they want you to fix it now, they would better be prepared to pay for the diagnostic time it takes to track down the cause of the intermittent [19].

The authors in [20] proposed 10 steps for Universal Troubleshooting Process as follows:

i) Prepare
ii) Make damage control plan
iii) Get a complete and accurate symptom description
iv) Reproduce the symptom
v) Do the appropriate corrective maintenance
vi) Narrow it down to the root cause
vii) Repair or replace the defective component
viii) Test
ix) Take pride in your solution
x) Prevent future occurrence of this problem

5.0 Car Engine Dynamics

It is a common phenomenon that no one will ever admit that he/she is a bad driver.One might have met people that admit being bad tennis players, bad skiers or football players or even bad losers. Never will anyone admit he/she is a bad driver. There must be some psychological reason behind this but that is not really the subject matter here. The mere purpose is to present the physics behind a car's road holding character.

All full time 4 wheel drive cars share some common characteristics in their handling and road holding abilities. A car's handling ability is most easily judged when cornering at high speeds. There are mainly three types of cornering behaviours[21]:

Under-steer, which denotes a car's tendency to exit the curve by following a trajectory whose radius is longer than the corner's. When a car under steers the driver has to steer more than he'd normally have to in track the corner's radius to follow the corner

- **Over-steer**, is characterized by the tendency of a car to follow a radius that is shorter than the corner's. When a car over steers the driver has to steer less than he'd have to, and sometimes counter-steer, in order to track the corner's radius
- **Neutral**, a behavior in which a car follows naturally a curve's radius

Ideally all cars should display a neutral cornering characteristic. Then again we are not living in an ideal world, are we? In real life most full time 4 wheel drive cars display a cornering character that varies while inside the corner. The car has a tendency to under-steer when entering the corner, a neutral behavior in mid-corner and an over-steering tendency when exiting the corner [21]. This, of course, is greatly dependent on parameters such as the car's power output, chassis rigidity, suspension design and dimensioning, torque distribution between axles and is mostly noticed on cars with a power output in excess of 200Bhp. Usually, the

more power a car disposes the more the above handling pattern is true.

It is believed that all handling behaviors described herein are applicable in "close to the limit" situations which are to say close to the limit of grip and are mainly valid on high friction surfaces, that is, dry tarmac. Additionally these handling characters are valid when no major driver intervention or artifacts are used, that is, no hand brake use, lift-off, braking or manual differential locking.

According to the author in [7], every car has a natural tendency for one of the above mentioned road holding characteristics depending on its architecture (mass distribution, engine position, driven wheels, inertia, overhangs, turbo lag time .

Engine dynamics consists of three engine efficiency topics which include volumetric efficiency, thermal efficiency and mechanical efficiency [7].

The engine is the heart of the car, but instead of pumping blood, the engine pumps air and fuel. The engines main function is to convert air and fuel into rotary motion so it can drive the wheels of the car. Only a few basic things are necessary for the engine operation.

1. Fuel (To be exact proper air /fuel ratio, normally it is about 14/1)
2. Spark (in appropriate moment)
3. Proper timing (the ignition of the compressed air /fuel mixture must take place at exactly the correct instant)
4. Compression in cylinders (the phase in which a combination of fuel and air is compressed in a cylinder before being ignited) plus, to start the engine, the battery, the starter and the starter circuit should be okay.

If the engine would not start there is no magic – one of these theories is probably missing, most often it is a spark or fuel related problem, but often it could be versimple things like dead battery.

6.0 Research Methodology

The development of the Expert System on Car Engine Troubleshooting is based on the methodology that has been adopted from several existing methodologies for different applications especially in the field of computer science, software engineering, knowledge engineering and multimedia, since this expert system will be an integration of these technologies.

A detailed survey of expert systems was conducted and an observational methodology sometimes adopted. The method of fact-finding called knowledge acquisition which is based on the Artificial Intelligence approach, to extract facts was also adopted. Interviews and research review was also adopted to extract facts for this study. In the study and development of this expertsystem, the methods used for knowledge representationis Production System (production rule). In theproduction rule, there are one or more rules that aredesigned to solve one problem.

The research also depended on published and unpublished literatures on expert systems, intelligent knowledge based systems, troubleshooting and car engine dynamics when it becomes necessary from the internet.Finally, an implementation driven methodology was also employed to illustrate the software tool resulting from this study.

6.1 System Architecture

This expert system was structured based on the concepts of reasoning which emulates the human's problem solving strategies as shown in figure1

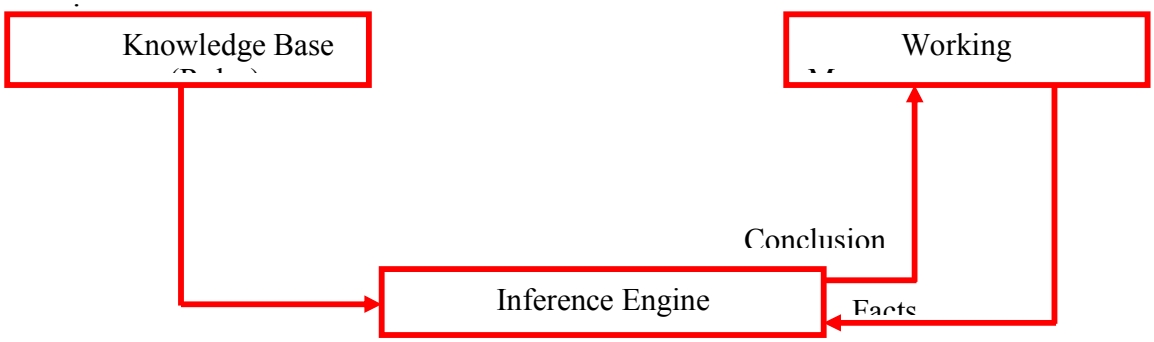
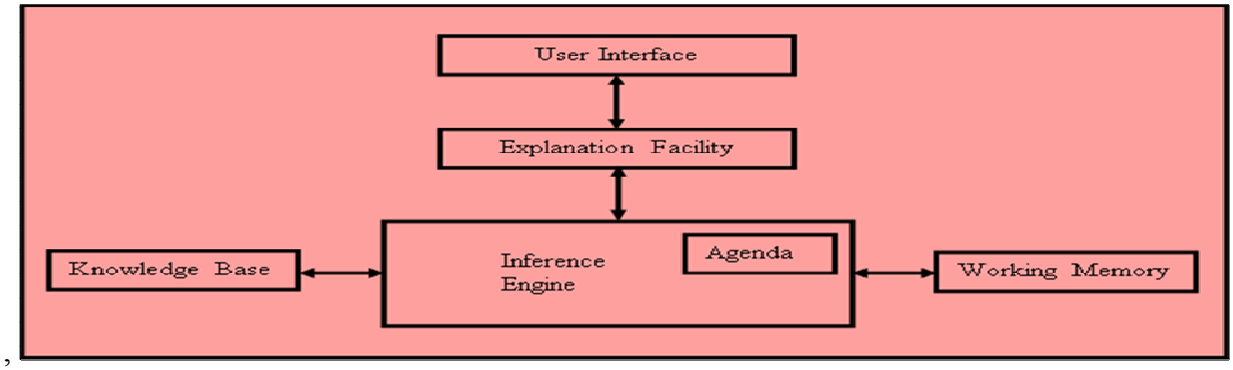


Figure 1: Structure of the Expert System's Problem Solving

6.2 Design of The Expert System

The Expert System developed in this study consists of the user interface, the explanation facility, the knowledge base, and the inference engine. The structure of the expert system is shown in Figure 2



, Figure Fig. 2: Structure of the Car Engine Fault Troubleshooting System (CEFTS)

6.2.1 Main Menu Design of the Proposed System

Communication between the user and the system was accomplished through main menu which is implemented in English language. The interface is characterized of a menuwhich displays the questions to the user. When the system is started, a menu is displayed on the screen, prompting the user to select one out of some enumerated car conditions. After the selection, the user answers with a 'Yes' or 'No'to preceding cross-examinations

Figure 3 shows the main menu of the proposed system.

Figure 3: Main Menu of the Car Engine Fault Troubleshooting System

6.3 Knowledge Base of the Proposed System

Table1 clearly shows contents of the knowledge base of the proposed system which consists of the car engine problems, evidence(s) or symptom(s), cause(s) and resolution(s).

Table 1: Contents of the Knowledge Base of the Proposed System

PROBLEMS	EVIDENCE	CAUSE(S)	RESOLUTION(S)
1. The engine hesitates	-The air filter is bad	-The air filter is dirty	-Replace the air filter
	-The spark plugs are worn-out	-The spark plugs are old and dirty	-Clean or replace spark plugs
	-The ignition wires are worn-out	-The ignition wires are bad	-Replace ignition wires
	-There is water in the gasoline	-Irregular filling of the gas tank	-Drain the gas tank and flushed with fresh gas and refill
	-The fuel filter is clogged	-The fuel filter is bad	-Replace fuel filter
	-The catalytic converter is clogged	-The catalytic converter is bad	-Replace catalytic converter
2. The engine surges or misfires while moving	-The carburetor choke is not properly set	-The carburetor choke is bad	-Check the choke plate and ensure that it is opening completely
	-The engine is too hot while moving	-The cooling system is faulty	-Check and repair cooling system
	-The fuel pressure level is too low	-The fuel pressure regulator is bad	-Replace fuel pressure regulator
	-The ignition timing is wrongly set	-Irregular ignition timing	-Adjust ignition timing
	-The fuel filter is partially clogged	-The fuel filter is bad	-Replace the fuel filter
	-Leakage in the vacuum	-Crack in the vacuum	-Check and replace vacuum lines
	-The EGR valve is stuck open	-The EGR valve is bad	-Replace EGR valve
	-The fuel injectors are dirty	-The fuel injectors are bad	-Clean or replace fuel injectors

3. A hissing sound is heard from the engine	-The engine is overheating	-The cooling system is bad	-Check and repair cooling system
	-The exhaust system is plugged	-The exhaust system is bad	-Check and replace exhaust system
	-The vacuum is leaking or disconnected	-The vacuum lines are bad	-Reconnect or replace vacuum lines
	-Leakage in the vacuum device	-Crack in the vacuum device	-Replace vacuum device
4. Whirring sound is heard from the engine that gets worse as the engine speed increases	-Low power steering fluid	Bad power steering fluid	-Check and refill power steering fluid
	-The alternator's bearings are bad	-Old alternator's bearings	-Replace the alternator
	-Bad water pump	-Old water pump	-Replace water pump
	-Bad power steering pump	-Old power steering pump	-Replace power steering pump
	-Bad air conditioning compressor	-Old air conditioning compressor	-Replace air conditioning compressor
5. Engine seems to use more fuel than normal and there is a strong gas odour coming from the car.	-Leakage in the fuel lines	-Crack in the fuel lines	-Replace or repair fuel lines
	-The fuel injectors are leaking	-Crack in the fuel injectors	-Replace injectors
	-Gas cap is missing or bad	-Old gas cap	-Replace gas cap
	-The fuel pressure level is too low	-Bad fuel pressure regulator	-Replace fuel pressure regulator
6. Engine does not want to increase its speed	-Dirty air filter	-Bad air filter	-Replace the air filter
	-The air filter is clogged	-Bad air filter	-Replace air filter
	-Wrong setting of ignition timing.	-Irregular ignition timing	-Adjust ignition timing
	-Catalytic converter is clogged	-Bad catalytic converter	-Replace catalytic converter
	-Water is the gasoline	-Irregular filling of the gas tank	-Drain the gas tank and flushed with fresh gas and refill.
	-Fuel pump is shot	-Old fuel pump	-Replace fuel pump
7. Engine backfires when you press the gas pedal.	-Slipped camshaft timing belt or chain	-Bad timing belt or chain	-Replace timing belt or chain
	-Wrong setting of ignition timing	-Irregular ignition timing	-Adjust ignition timing
	Burnt or broken valve and camshaft	-Bad valve and camshaft.	-Replace valve and camshaft
	Spark plug wires are placed on the wrong spark plugs	-Incompatible spark plugs	-Check firing order and place the wires on the correct spark plugs
8. Engine hesitates, and a popping is heard from the engine	-The air filter is dirty	-Bad air filter	-Replace the air filter
	-The ignition wires are bad	-The ignition wires are old	-Replace the ignition wires
	-Distributor cap or rotor glazed	-Overheating of the rotor	-Clean/sand the rotor
9. Engine makes a	-Valves need adjustment	-No valves adjustment	-Check and adjust valves
	-The engine's oil	-Old oil pump	-Check and replace oil

tapping noise when idling	pressure is low		pump
	-Bad hydraulic valve lifters	-Old hydraulic valve lifters	-Replace valve lifters
	-Push rods bent or worn out	-Bad push rods	-Replace push rods
10. Engine makes a ticking noise	-Valves adjusted wrongly	-No valves adjustment	-Check and adjust valves
	-There is sludge in the engine	-Restriction in oil flow and bad oil filter	-Flush engine, replace oil filter and fill with new oil
	-Bad hydraulic valve lifters	-Old hydraulic valve lifters	-Replace valve lifters
	-Engine's valves are stuck	-Engine's valves are old	-Check valves and repair
	-Push rods bent or worn out	-Bad push rods	-Replace push rods

6.4 Flowchart of the Proposed System Figure 9 shows the system flowchart of the proposed car engine fault troubleshooting system

(CEFTS).

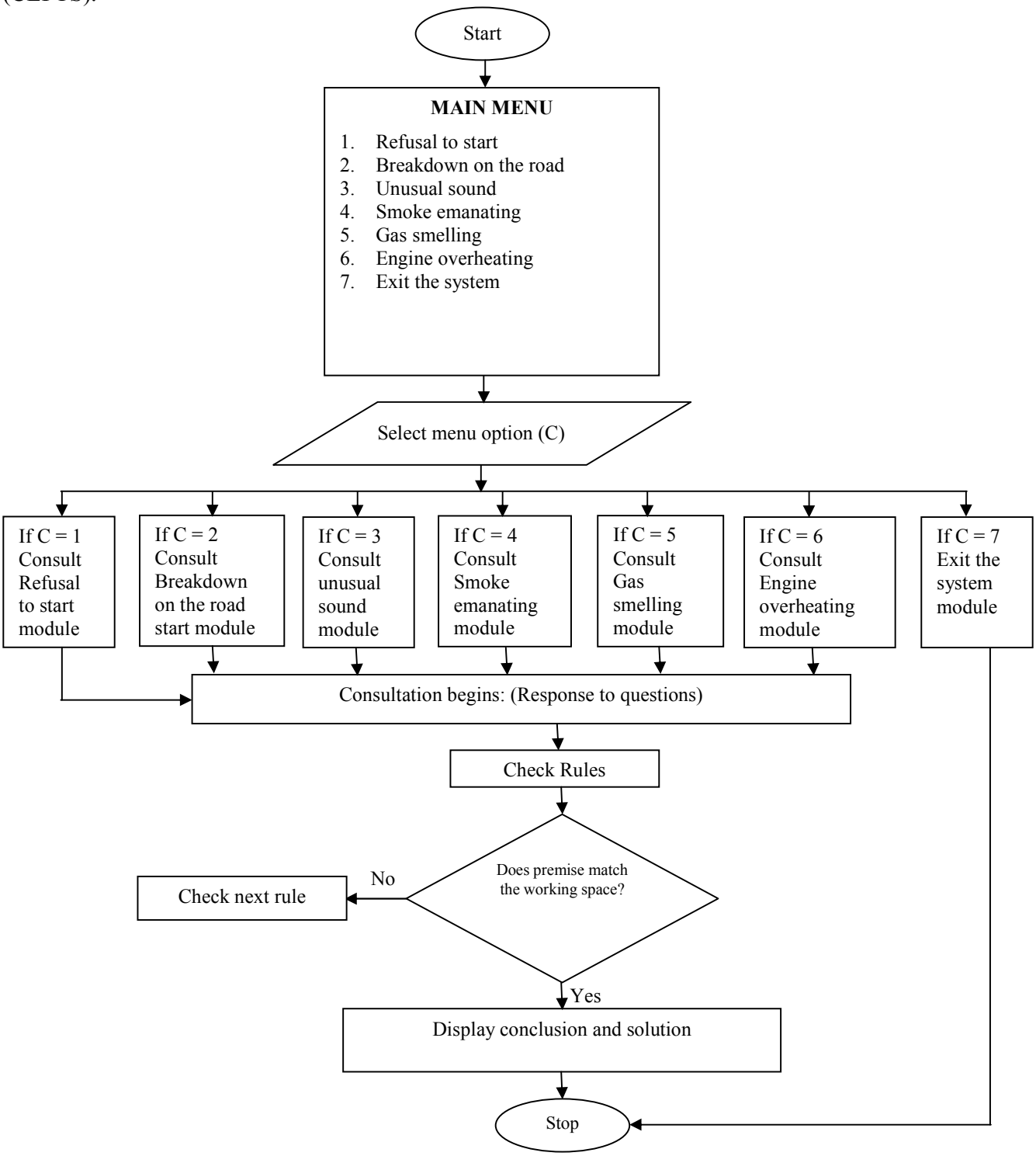


Figure 4: System Flowchart for the Proposed CEFTS

6.5 Advantages of the Proposed System

Generally, the proposed system can help inexperienced mechanics or drivers in troubleshootingcar engine faults. In addition, the system has the following advantages: Prevent the loss of customer and income. If mechanic's repair shop makes a wrong diagnosis, the customer will be reluctant to come back to the repair shop. With this system, the situation can be avoided.

i) The system can give temporary assistance to motorists who are in need of instance help, due to the limitation of time and distance.
ii) The system serves as a troubleshooting tool for training inexperienced mechanics and it will improve their productivities. Having this system may allow mechanics do more work in less time as the system will give instance guides and systematic step-by-step procedure on how to resolve the car engine problems.
iii) The system performs reasoning over the representations of human knowledge and as such can help reduce the need for scarce skilled mechanics. The repair of car engine requires a high level of expertise. With this system, inexperienced mechanics can be guided to find the fault.
iv) The system is capable working without stopping. As a human, expert mechanic will be tired if he works continuously.

7.0 Result and Discussion

A prototype of a troubleshooting system using expert system technology was developed and implemented, which emulates the human mechanic expert in resolving car engine problems. The system includes the common problems that can occur and the possible causes of those problems as well as the method(s) for resolving them. It is important to state that the system does not eliminate the consultant of a human expert (the mechanic)

The developed system provides a communication tool that connects the user with the system. It displays the questions in English to be answered by the user and shows the corresponding results.The system poses a set of questions to the user to beanswered and system decomposition is made based onuser responses.The events and the collected data for each troubleshooting process are retained in the system database to beanalyzed and exploited in enhancing the knowledgebase and constructing new rules for future use.Explanation section is provided to help ad guide the user in the troubleshooting process and on how to implement therepair tasks. See figures 5 – 9

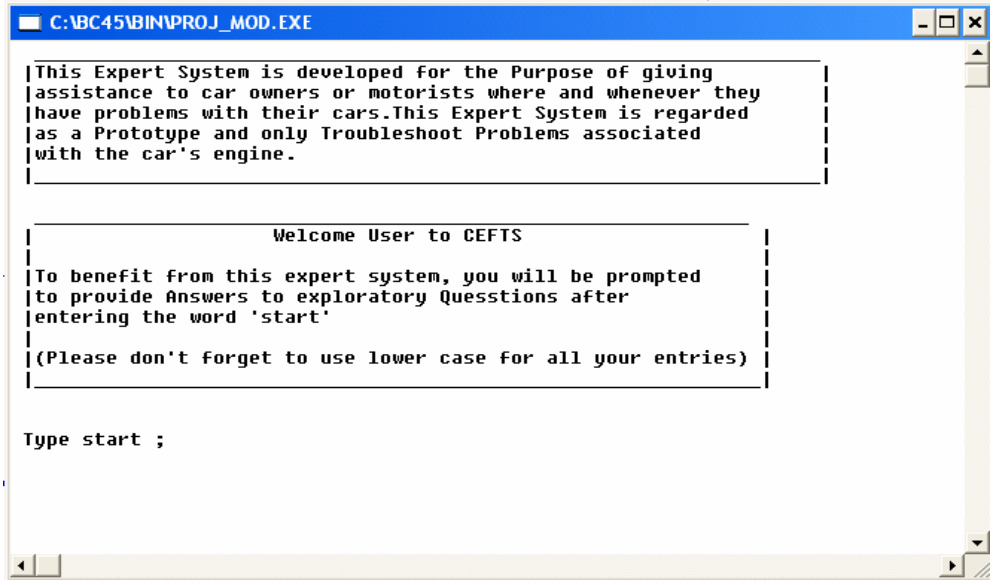


Figure 5: Welcome page of the Proposed System

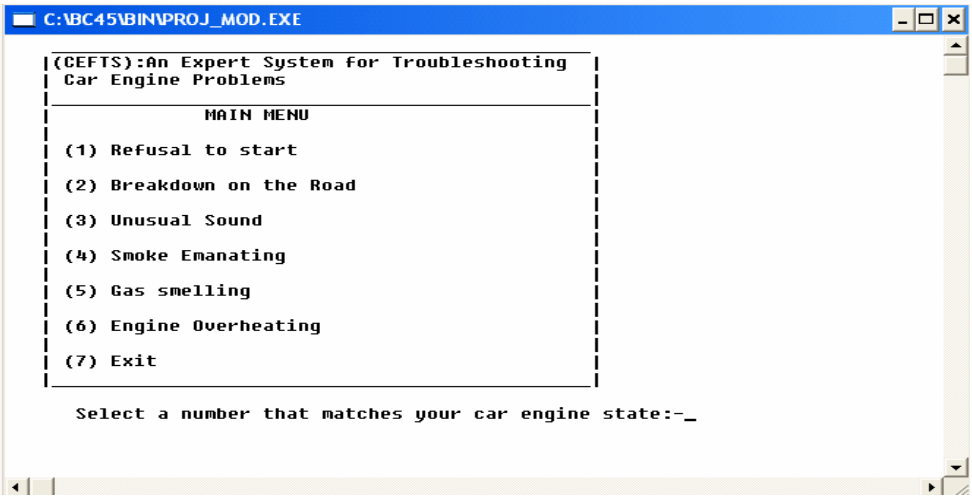


Figure 6: Main Menu of the Proposed System

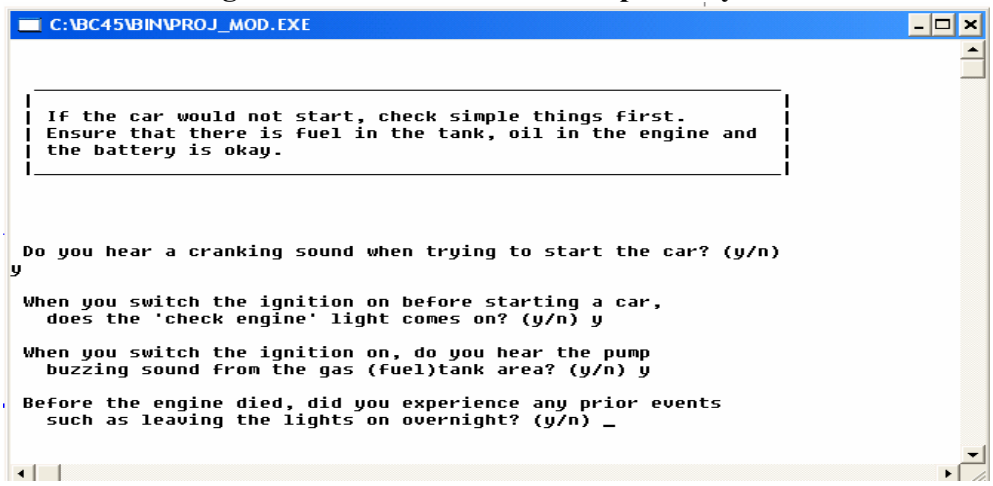


Figure 7: Questions and Answers Section for Option 1 (Refusal to start)

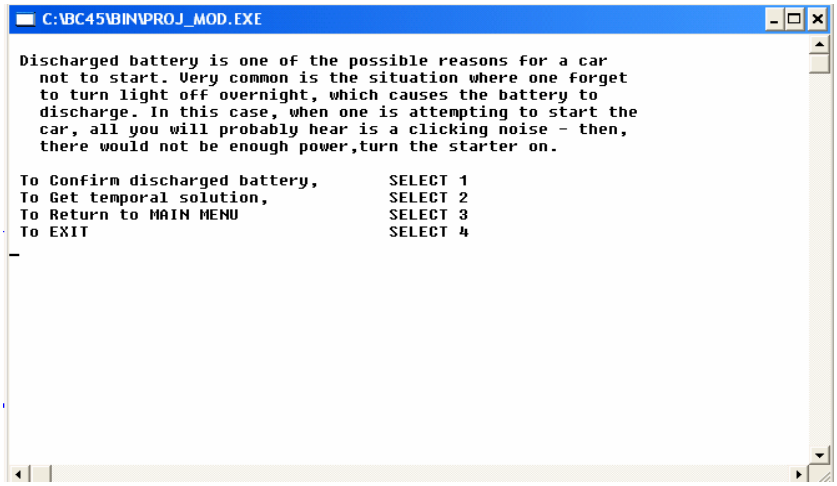


Figure 8: Resolution to Option 1 (Refusal to start)

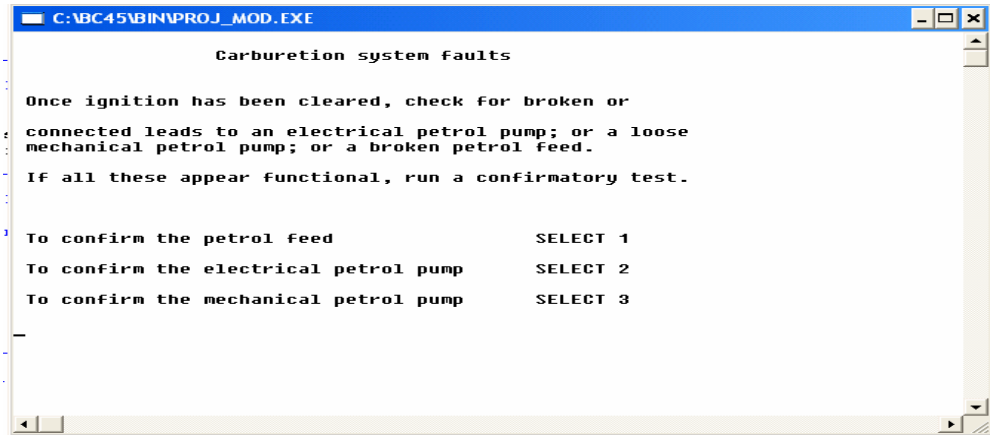


Figure 9: Tracing Carburetion System Faults

.0 Conclusion

In this paper, an Expert System for troubleshooting car ngine faults was developed and implemented. The system vas implemented using the C++ programming language latform. During the test phase of the system it never gave vrong diagnosis according to the rules used. The system ndicated that a full expert system will be practical and can e extremely useful in providing consistent car engine ault troubleshooting. Further work is needed to improve he system by adding sufficient domain knowledge that epresents domain knowledge thoroughly. Plans are nderway to convene experts to use the system to assist hem in their jobs of car engine faulttroubleshooting.

Preliminary validation of the program revealed that sing rule-based expert system to troubleshoot car engine roblems is faster, accurate and more efficient than the anual approach.

The study has positively contributed to a **culture** whereby car users can begin to acquire a level of knowledge in the comfort of their homes andor offices, through the computer program developed in this study, and are able to resolve certain car problems.

Finally, the study is significance as it is a **pioneering** effort, geared towards introducing a new area of application for expert systems.Furthermore, the prototype developed in this study is original, and can help other researchers carrying out further studies in this direction. It is believed that this effort will generate further research efforts in this direction, especially to have the implementation of a complete car troubleshooting expert system and further work is also needed toimprove the system by adding sufficient domain knowledgethat represents domain knowledge thoroughly

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