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An Expert System for Car Failure Diagnosis

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Abstract**—**Car failure detection is a complicated process and requires high level of expertise. Any attempt of developing an expert system dealing with car failure detection has to overcome various difficulties. This paper describes a proposed knowledge-based system for car failure detection. The paper explains the need for an expert system and the some issues on developing knowledge-based systems, the car failure detection process and the difficulties involved in developing the system. The system structure and its components and their functions are described. The system has about 150 rules for different types of failures and causes. It can detect over 100 types of failures. The system has been tested and gave promising results.

Keywords**—**Expert system, car failure diagnosis, knowledge-based system, CLIPS.

I. Introduction

EXPERT systems (ES) are a branch of artificial intelligence (AI), and were developed by the AI community in the mid-1960s. An expert system can be defined as "an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions [1]". We can infer from this definition that expertise can be transferred from a human to a computer and then stored in the computer in a suitable form that users can call upon the computer for specific advice as needed. Then the system can make inferences and arrive at a specific conclusion to give advices and explains, if necessary, the logic behind the advice.

ES provide powerful and flexible means for obtaining solutions to a variety of problems that often cannot be dealt with by other, more traditional and orthodox methods [2]. The terms expert system and knowledge-based system (KBS) are often used synonymously. The four main components of KBS are: a knowledge base, an inference engine, a knowledge engineering tool, and a specific user interface. Some of KBS important applications include the following: medical treatment, engineering failure analysis, decision support, knowledge representation, climate forecasting, decision making and learning, and chemical process controlling [2].

Previous work has shown that systems concerned with car fault detection were very limited. Jeff Pepper [3] has described a proposed expert system for car fault diagnosis called SBDS, the Service Bay Diagnostic System. SBDS is being developed by a joint project team at Ford Motor Company, the Carnegie Group, and Hewlett Packard. SBDS's knowledge base will contain the expertise of Ford's top diagnosticians, and it will make their diagnostic skills available to mechanics in every Ford dealership in North America. This system will guide a human technician through the entire service process, from the initial customer interview at the service desk to the diagnosis and repair of the car in the garage [3].

There are a lot of related expert systems in the literature concerned with diagnostic problems. Daoliang et al. [4] presents a web-based expert system for fish disease diagnosis. The system is now is use by fish farmers in the North China region. Yu Qian et al. [5] proposed an expert system for real-time failure diagnosis of complex chemical processes. Other diagnosis systems are described in [6-9].

A knowledge-based system for car failure diagnosis is presented in this paper. Section 2 gives a brief description of the problem domain. Section 3 presents the proposed system. In section 4, I will give some discussion and finally I will draw some conclusions.

II. Problem Identification

The proposed system divides car failures into three major types:

1. Start-up state, problems that may occur when a person try to start up the car, for example; engine does not work, some sounds noticed, engine works ones and stops. These problems could be due to one or more failures; will happen, the battery needs to be recharged, the dynamo is dead, or the battery is dead.
2. Run-stable state, problems that may occur after starting the car, for example; unburned fuel, cycle on-off, blue gas emitted, avance is very high.
3. Movement-state, problems that may occur while the car is moving; this state also includes problems related to the brake system. Most of movement problems that might occur appears on the car's tableau the proposed system takes advantage of these facilities and use them to diagnose the problem and to gives advice of the solution to the driver. Some of these problems are: oil pressure, water temperature, voltage, and fuel pointer.

If the car is in the start-up state and doesn't start, then the cause could be one of three main reasons: a bad fuel mix, lack of compression or lack of spark. In addition, thousands of minor things can create problems, but these are the main three.

Bad fuel mix: A bad fuel mix can occur in several ways:

1. The car ran out of gas, so the engine is getting air but no fuel.

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2. The air intake might be clogged, so there is fuel but not enough air.
3. The fuel system might be supplying too much or too little fuel to the mix, meaning that combustion does not occur properly.
4. There might be an impurity in the fuel (like water in your gas tank) that makes the fuel not burn.

Lack of compression: If the charge of air and fuel cannot be compressed properly, the combustion process will not work like it should. Lack of compression might occur for these reasons:

1. Piston rings are worn (allowing air/fuel to leak past the piston during compression).
2. The intake or exhaust valves are not sealing properly, again allowing a leak during compression.
3. There is a hole in the cylinder.

Lack of spark: The spark might be nonexistent or weak for a number of reasons:

1. If the spark plug or the wire leading to it is worn out, the spark will be weak.
2. If the wire is cut or missing, or if the system that sends a spark down the wire is not working properly, there will be no spark.
3. If the spark occurs either too early or too late in the cycle (i.e. if the ignition timing is off), the fuel will not ignite at the right time, and this can cause all sorts of problems.

Other Problems: The following problems are also taken into consideration in the system.

1. If the battery is dead, the engine cannot turn over.
2. If the bearings that allow the crankshaft to turn freely are worn out, the crankshaft cannot turn so the engine cannot run.
3. If the valves do not open and close at the right time or at all, air cannot get in and exhaust cannot get out, so the engine cannot run.
4. If someone sticks a potato up your tailpipe, exhaust cannot exit the cylinder so the engine will not run.
5. If you run out of oil, the piston cannot move up and down freely in the cylinder, and the engine will seize.

In addition to the above problems, the proposed method also has dealt with problems that may occur in the following systems: cooling system, air intake system, starting system, lubrication system, fuel system, exhaust system, emission control, and electrical system.

III. Design and Implementation of the KBS

The KBS developed in this work consists of the user interface, the explanation facility**,** the knowledge base, and the inference engine. The structure of KBS is shown in Fig. 1.

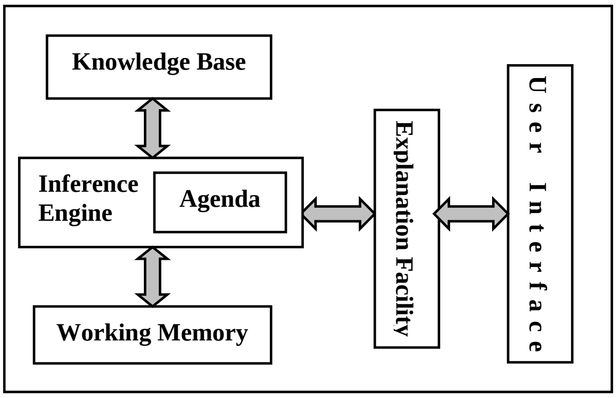

Fig. 1 Structure of the car failure diagnosis system

A. *User Interface*

Communication between the user and the system is done through the user interface which implemented in both Arabic and English languages. The user interface is represented as a menu which displays the questions to the user and the user answers with Yes or No. When the system is started a main menu is displayed on the screen which asks the user to choose one of the three car states (Fig. 2).

Car Failure Diagnosis Expert System

1. **Start-Up state.**
2. **Run-Stable state.**
3. **Movement state.**
4. **Exit the program.**

Enter your selection according to the car state: ----

Fig. 2 Start up menu of then system

B. *Explanation Facility*

Illustrates to the user how and why the system gave a certain cause for the failure, i.e. explains the reasoning of the system to the user.

C. *Knowledge Base*

The knowledge of the system is collected from mechanic experts, specialized books, and from different car websites [13-26]. The knowledge base contains about 150 production rules for different types of car failures and causes.

As a rule-based shell, CLIPS stores the knowledge in rules, which are logic-based structures, as shown in Fig. 3.

```
;Rule No 1 – Run-Stable State
(Defrule Rule1 "gas smile and high avance"
  (Selection 2)
  (Fuel NotBurn)
  (Cycle Ok)
  (BlueGas No)
  (Avance Bad)
=>
    (printout t "Dirt in the
     injections/carburetor or the
     adjustment of ear and gasoline is not good")
    (printout t "Advise: clear
     injections/carburetor and adjust the ear"))
```

Fig. 3 CLIPS representation of a rule

An English counterpart of the above rule in represented in Fig. 4.

```
Rule No 1: gas smile and high avance

IF the selection is 2 "Run-Stable State"
      AND the fuel is not burning well
      AND the engine running cycle is ok
      AND there is no blue gas
      AND the avance is bad
THEN
       There is a Dirt in the injections/carburetor
      or The adjustment of ear and gasoline is not
      good, clear injections/carburetor and adjust
      the ear.
```

Fig. 4 English representation of the rule in Fig. 3

D. *Inference Engine*

When abnormal situation arises in the car, the KBS makes inferences by deciding which rules are satisfied by facts stored in the working memory and executes the rule with highest priority and propose proper correcting solution. The rules whose patterns are satisfied by facts in the working memory are stored in the agenda part of the inference engine. Figure 6 explains the inference process of the system using the rules listed in Figure 5. Figure 7 shows the relationships between the four rules used in this example.

```
Rule 1:  IF  the engine is getting gas,
         AND the engine will turn over,
         THEN  the problem is spark plugs.

Rule 2:  IF  the engine does not turn over,
         AND the lights do not come on,
         THEN  the problem is battery or cables.

Rule 3:  IF  the engine does not turn over,
         AND the lights do not come on,
         THEN  the problem is the starter motor.

Rule 4:  IF  there is gas in the fuel tank,
         AND   there is gas in the carburetor,
         THEN  the engine is getting gas.
```

Fig. 5 Four assumed rules in the agenda

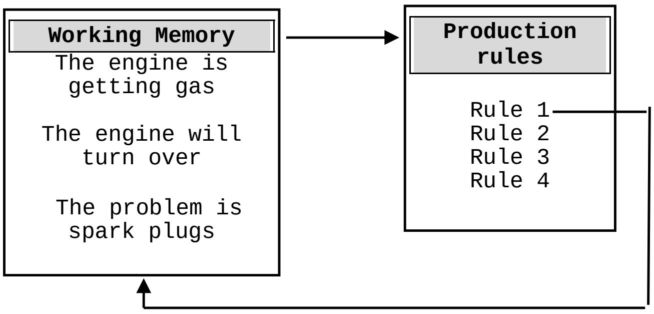

Fig. 6 The production system after Rule 1 is fired

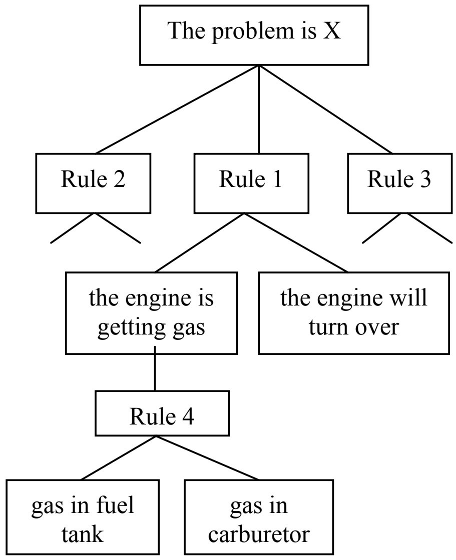

Fig. 7 Example shows relationships among rules

E. *Language selection*

The proposed knowledge-based system is implemented using the CLIPS expert system tool [12]. CLIPS is a forward-chaining rule-based language that resembles OPS5 and ART, two other widely known expert system tools [1]. CLIPS was developed by NASA and it has shown an increasing popularity and acceptance by end users [13]We decided to use CLIPS to implement the KBS of car failure diagnosis system for four reasons. First, the data-driven nature of the domain suggests the use of a forward-chaining inference engine. Second, CLIPS runs in Windows environment, which is the platform of choice among our end users. Third is the availability of CLIPS source code. Finally, CLIPS provides the ability to construct production rules which rely on pattern-matching.

IV. Results and Conclusions

We presented in this paper a KBS for car failure diagnosis. The system consists of four main stages. We implemented the KBS using the CLIPS expert system language. During the test phase of system it never gave wrong diagnosis according to the rules used. The system indicated that a full expert system will be practical and can be extremely useful in providing consistent car failure detection. Further work is needed to improve the system by adding sufficient domain knowledge that represents domain knowledge thoroughly. Plans are underway to convene experts to use the system to assist them in their jobs of car failure detection. The first advantage of using CLIPS is it allowed us to keep the system small, while maintaining speed and ease of programming. The second important advantage of using CLIPS is the suitability of the forward reasoning and matching to the application and representation of the knowledge. No meta-level reasoning was necessary in the system. In summary, the system has the characteristics of good expert systems, such as high performance, adequate response time, understandability, and understandability.

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