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RESEARCH PAPER

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Development of an Expert System for a DO-IT-YOURSELF First-Aid Fault Diagnosis and Resolution of Car-Brake Systems

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Abstract: The condition of the brake system in a motor-car is a very important factor in driving. Many drivers either do not know the warning signs of brake system disorders or cannot help themselves to resolve the simpler ones. We present herein, the models that identify the problems and their solution processes. The data collected from various automobile experts were structured in such a way that they become models, where each problem is linked to different symptoms and correction advices. We developed a diagnostic algorithm, which guided the transformation of the models into a car brake expert system. The program can be installed in a laptop, and overtime, embedded into car dash-boards, to enable drivers conduct FIRST-AID fault rectification routines where the mechanic is not near. This will save time, money, frustration and possibly accident.

***Keywords*:** Computer Model, Fault Diagnosis, First-Aid, DO-IT-YOURSELF, Car Brake Systems.

I. INTRODUCTION

Oftentimes, car drivers get stranded due to minor car faults that can be easily rectified [1]. This may happen in a location where a human expert (mechanic) may not be easily available. It is usually embarrassing when a mechanic fixes a problem for you by doing a very simple thing (such as, tighten the battery head, etc.). You then wish you knew better.

Of all the systems that make up a car, the brake system is one of the most important, as it helps you slow down or stop the car. There is no need to get a car going if you cannot stop it [2]. Servicing your brake system ensures the safety of the driver, the passengers, and other road users. Many people do not know the signs that indicate that the brake system needs maintenance or repair. You may ask, "Why do I need to know, when I can pay a mechanic to figure it out for me?" Consider the telephone conversation in Figure 1.

Car owner:	Hello my vehicle pulls to one side when I step on the brakes.
Mechanic:	This problem usually points to something involving front tyres, front end, or front brakes. The rear system is not really a problem here.
Car owner:	So what do I do?
Mechanic:	Check your two front tyres to see if one has more air than the other.
Car owner:	Yes, one of my tyres appears to have less air.
Mechanic:	Drive slowly to a place where you can pump the tyres and ensure that they are evenly inflated. Alternatively, you can put a spare tyre. If you have done either of these, and you still experience the problem, you can then call me again. That will imply that the problem exists elsewhere. Good luck!

Figure 1: Telephone Interaction between a driver and his mechanic.

Figure 1 is a typical telephone interaction between a car driver and his mechanic. The driver is experiencing a brake problem in a location very far from a mechanic workshop. Considering the time it will take to look for a mechanic, and the dangers the occupants of the car may be exposed to, the driver decides to attempt the correction of the problem by himself (as a FIRST-AID) option. Because he has no idea about what to do, he decides to call his mechanic.

From the interaction, it can be inferred that the driver got the help he needed without physically consulting the mechanic. Personal experiences have also shown that we can be guided, through information, to perform certain processes in car fault rectification, in order to get our car going again. More so, we observe that problems may occur in locations where there are no telephone signals, so that the mechanic may not be reached.

This paper therefore, assembles the simple signs that indicate brake problems to a driver. Computer models of the processes used by motor mechanics in rectifying brake problems have been developed into an expert system to provide help for drivers in critical situations. The process begins with the gathering of all the necessary information required to correct a number of brake problems. The advantage derived here is the contribution of knowledge from several motor mechanics. The expert systems can be installed in laptop computers and mobile phones, which have become relatively affordable. Laptops and mobile phones are portable, and therefore, provide ready information to a driver on demand. Eventually, the systems may become embedded into the dashboards of motor-cars, which makes them readily available.

Consequently, and overtime, drivers will become familiar with the working principles of their brake system, and gradually imbibe the culture to conduct FIRST-AID fault rectification routines where the mechanic is not available. Doing it yourself is about you, your tools, and the courage to save time, money and frustration [2].

II. LITERATURE REVIEW

Diagnosis is a conjecture that certain units in a system are malfunctioning while the rest are functional. The problem is to specify which units we conjecture to be faulty. Diagnosis consists of three key processes; fault detection, fault isolation, and fault identification [3]. The first process, fault detection, is the process of determining that some fault has occurred in the system. The second involves isolating the specific fault that occurred, including determining the kind of fault and the location of the fault. The third process, fault identification, includes determining the size and time variant behavior of a fault. Together, fault isolation and fault identification are commonly called fault diagnosis [4].

According to Katipamula and Brambley in [3], diagnosis can be based on a priori knowledge (e.g., models based entirely on first principles) or driven completely empirically (e.g., by black-box models). First principle model-based approaches use a priori knowledge to specify a model that serves as the basis for identifying and evaluating differences (residuals) between the actual operating states and the expected operating states, and the values of characteristics obtained from the model. Process data driven approaches (i.e. black-box model) use no a priori knowledge of the process, but instead, derive behavioural models only from measurement data from the process itself.

Model-based methods can use quantitative or qualitative models [5]. Quantitative models are sets of quantitative mathematical relationships based on the underlying physics of the processes. Quantitative models consist of qualitative relationships derived from knowledge of the underlying physics.

The qualitative modeling approach is adopted in this paper. Qualitative models use knowledge bases to draw conclusions regarding the state of a system and its components (e.g., whether an operation is faulty or normal [3]. Some qualitative models are obtained by deriving knowledge statements from process history data (such as for expert systems where human experience with a process is used to derive rules governing proper and faulty operations [6].

Qualitative modeling techniques employ casual knowledge of a process or system to diagnose faults. They can further be based on abstraction hierarchies based on decomposition, which is the ability to draw inferences about the behavior of the overall system solely from the laws governing the behavior of its subsystems [6]. The inferences drawn are then represented in a form of Rule-Based-system to derive a set of If-Then-Else rules and inference mechanism that searches through the rule-space to draw conclusion. The rule-based system can be based solely on expert knowledge (which is inferred from experience), or can be based on first principles [7]

The systems described in the previous paragraph are used in developing expert systems, which is a computer transformation of the insights, knowledge, and/or guidance of individuals with expertise in a given field. In developing an expert system, the knowledge of domain experts is usually elicited through interviews with a knowledge engineer, who later enters the collected information into a database (often referred to as a knowledge base [8].

There are fundamentally two different approaches to search fault diagnosis [9]: topographic search and symptomatic search. Topographic searches perform malfunction analysis using a template of normal operation, while symptomatic searches look for symptoms to direct the search to the fault location. We adopt the later approach in this paper.

III. MODEL FORMULATION

Finch and Kramer (1987) represents a plant as a set of interacting subsystems, where each subsystem is categorized as a control system (closed loops) or passive system (open loops) or an external system. Each of these subsystems has an associated function at this level of system description. By comparing the function of a subsystem with the intended function; the hypothesis that a fault is present in the subsystem can be evaluated. The idea is that the failure of the purpose of a higher-level subsystem is due to the failure of the function of one or more of the lower-level units, which is used to identify the subsystem that causes the malfunction. This description forms the background for our model development.

A. *The Solution Process*

Figure 2 depicts the sequence involved in solving a specific problem.

Figure 2. Sequence of solving a diagnostic problem

The system begins by identifying the problem. Looking out for the cause of the identified problem follows next. Finally, based on the observed causes, advice is given on how to resolve the problem. We visited several mechanic workshops in Calabar metropolis in Nigeria, where we conducted interviews with those specializing in the repair of different makes of cars. Our questions focused on brake problems, the symptoms that can be used to identify the subsystem(s) having the problems, and how the problems can be resolved. Beyond the interviews, we took time to observe the sequence of operations adopted by the mechanics. When the process of data collection was completed, the data was refined to remove duplications, and eventually partitioned into three distinct tables (Tables 1-3), representing Problems, Evidences, and resolutions associated with the brake problems.

Table 1: Distinct problems extracted from raw data

DISTINCT PROBLEMS
-Brake pedal goes to the floor -Brake hardly stop the car -Brake pedal is very hard to depress -Brake pedal fades -Brake pedal goes much further down -Parking brake won't release -Brake pedal feels spongy -Brakes grab -One or more brakes lock up -Brakes squeal when applied

Table 2: Distinct Evidences extracted from raw data

DISTINCT EVIDENCES
-Brake fluid is low -Master cylinder is bad -Air in the hydraulic system -Leakage in hydraulic system -Brake pads/shoes are bad -Power brake booster is bad -No vacuum to power brake booster -Some objects stuck under brake pedal -Brakes overheating due to dragging -Brake fluid has wrong colour -Parking brake cables are frozen -Brake line is pinched -Front disc calipers are bad -Parking brake linkage is stiff -Front wheel bearings are bad -Rear wheel cylinders are bad -Brake pads/shoes are contaminated -Parking brake mechanism is broken -Dirt/dust accumulates on pads/shoes

Table 3: Distinct resolutions extracted from raw data

DISTINCT RESOLUTIONS
-Bleed hydraulic system -Replace parking brake cable -Lubricate parking brake linkage -Fill the master cylinder -Replace brake line -Clean and sand brake pads/shoes -Replace rear wheel cylinder -Replace master cylinder -Remove interfering object -Replace fluid type -Replace front calipers -Service brake system -Repair leakage -Replace brake pads/shoes -Replace broken parking brake mechanism -Repack loose wheel bearings -Replace power brake booster bearings -Replace broken parking brake mechanism

The data in Tables 1-3 are at this point structured to produce sets of solution models. Each model is composed of a problem component linked to evidence, which is also associated to a resolution on the same row on the table. The structuring of the data corresponds to a graphical representation of the sequence of identifying and resolving each brake problem. In Table 4, a set of three out of the many brake problems have been presented alongside the evidences and their resolutions. In other words, Table 4 is a sample representation of the knowledge-base for the expert system to be developed.

Table 4: Sample representation of the knowledge-base for developing the expert system

Problem	Evidence	Cause(s)	Resolution(s)
1. Brake pedal goes to the floor when it depressed	i. Brake fluid is very low ii. The master cylinder is bad iii. Air in the hydraulic system iv. Leakage in the hydraulic system	i. Irregular filling of the hydraulic system ii. Master cylinder is old iii. Lack of bleeding iv. Crack in the hydraulic system	i. Fill the master cylinder ii. Replace the master cylinder iii. Bleed the hydraulic system iv. Locate and repair leakage
2. The brakes hardly stop the car or won't hold it at a stop	i. Brake fluid is very low ii. Master cylinder is bad iii. Air in the hydraulic system iv. Brake pads/shoes are worn out	i. Irregular filling of the hydraulic system ii. Master cylinder is old iii. Lack of bleeding iv. Brake pads/shoes are bad	i. Fill the master cylinder ii. Replace the master cylinder iii. Bleed the hydraulic system iv. Replace brake pad/shoes
3.	i. Bad power brake booster	i. Old power brake booster	i. Replace power brae booster

Brake pedal is very hard to push down	ii. No vacuum to power brake booster iii. Brake line is pinched iv. Kid's toy stuck under brake pedal	ii. Absence of vacuum iii. Brake line in locked iv. Eternal object interference	ii. Replace vacuum line iii. Replace brake line iv. Remove interfering object
4.------	i. ---------	i --------	i. ----------

Consequently, each problem component is associated with several models to use. For example, we can have the following models obtained from "Brake hardly stops the car" component of Table 4, as presented in Figure 3.

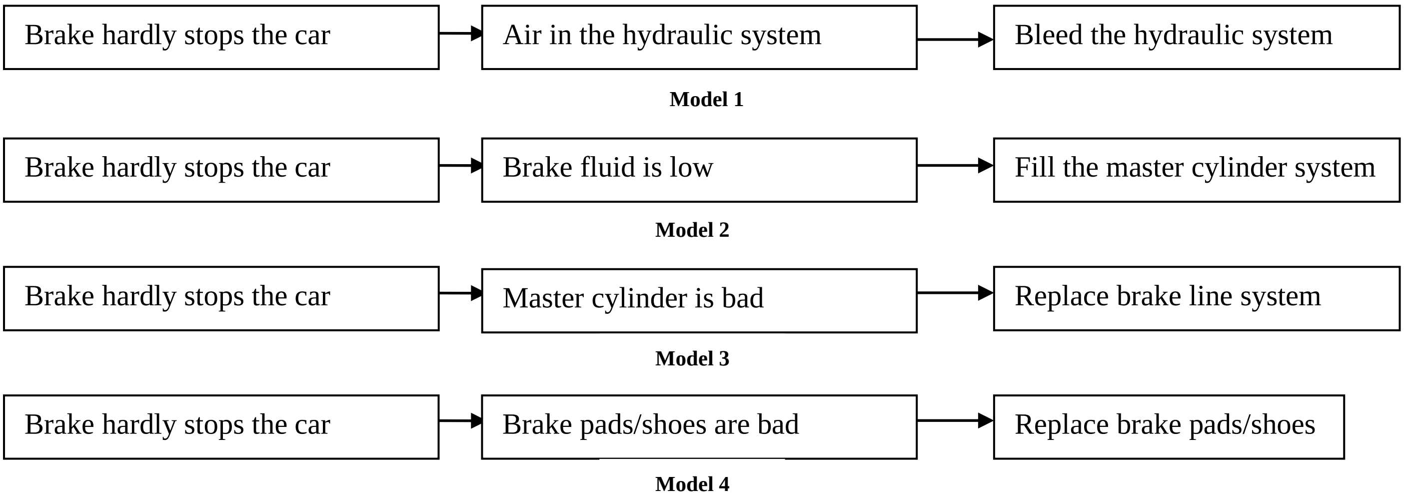

Figure 3: Different solution models for resolving a brake problem

It can be observed from Figure 3 that, in Table 4, the problem component remains the same, while the evidence component varies, and are directly linked to a resolution.

B. *Diagnostic Algorithm*

We formulate an algorithm describing the process corresponding to Table 4. It will be a guide in the development of the car-brakes expert system.

I) Algorithm

Identify the brake problem of interest,

Trace the path of interaction through the subcomponents listed as evidence for that problem as follows:

Evidence = #1
REPEAT
    Match the characteristics of the subcomponent with a corresponding model description for that problem
        IF <a matching model> Then
            Perform the resolution advice corresponding to the evidence
        ENDIF
        IF <problem is resolved> Then
            EXIT
        ENDIF
    Evidence = Evidence + 1
UNTIL <problem is resolved> OR <no more evidence>
STOP

IV. PROGRAMMING THE EXPERT SYSTEM

The system is based on a 3-tier architecture. The first tier, which is the front end is the interface designed using Netbeans IDE 4.0 Beta 2 Java frames and forms. The interface used several controls to provide a convenient platform, which will enhance a user-computer interaction at all times.

The second tier is the application-level interaction. This tier employs the use of the java Virtual machine (JVM) to connect the front end to the back end, through the (JDBC-ODBC) bridge (that is Java Database Connectivity-Object Database Connectivity Bridge). This enables the interface to interact with the database by implementing user-based SQL queries to the database. A query is triggered by clicking on a problem on the interface, followed the OK button. Figure 4 is the interface of the system without a checked option.

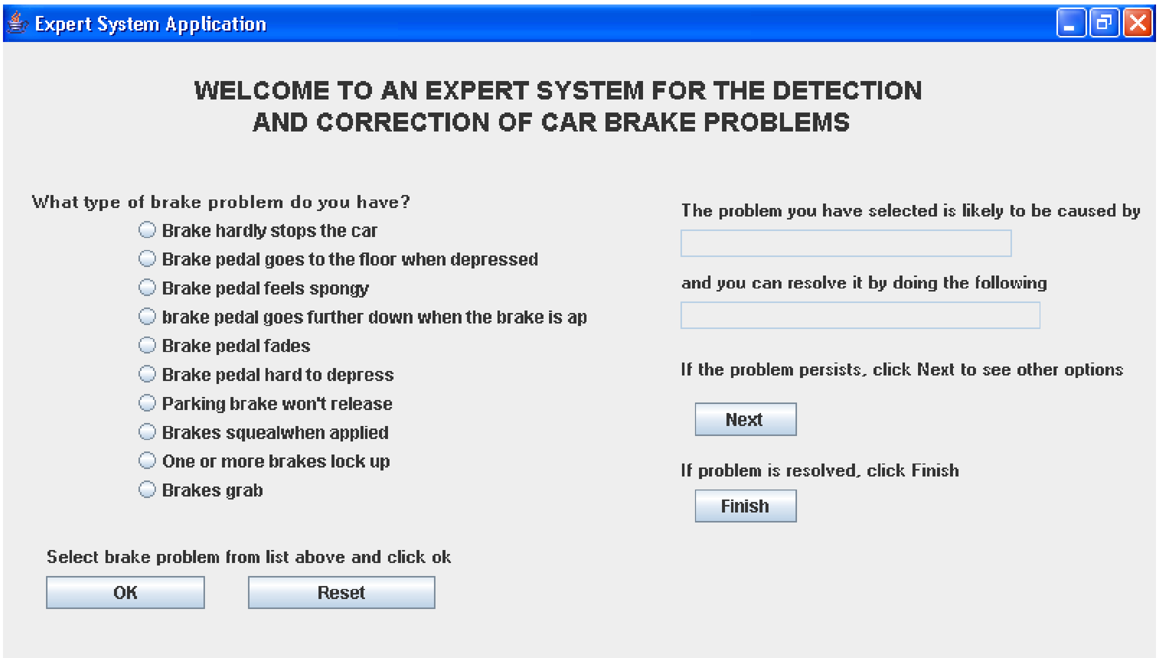

Figure 4: Application interface for the Expert System

The back-end is a Microsoft Access database. The database contains two tables (Problems and EvSolutions), which contain the listed car-brake problems, and the corresponding evidences and resolutions respectively. The problems table contains the fields, <u>Problem ID</u>, and <u>Problem</u>, while the <u>EvSolutions</u> table contains the fields, <u>Problem ID</u>, <u>Evidence</u> and <u>Resolution</u>. There is a one-to-many relationship between the <u>Problems</u> table and <u>EvSolutions</u> table established through the primary key of the <u>Problems</u> table and the foreign key of <u>EvSolutions</u> table; <u>Problem ID</u>. The database is connected to the Java application through a datasource that uses a Microsoft Access driver.

V. DISCUSSION

On executing the application, the problem option group (one of the controls used) is automatically updated by the contents of the <u>Problems</u> table. There are ten (10) problem instances, part of which were presented in Table 4.

A user makes a selection by clicking an option on the problem option group and clicking OK. The expert system queries the database based on the selection made and returns the result of the query (ResultSet) to two arrays (List 1[] for evidences and List2[] for resolutions). The arrays in turn return their values to the interface (on text boxes) to provide a guide to the user on the probable evidence/resolution of the user's car brake problem. At each point in time, the query can be initialiased by clicking the <u>Reset</u> button on the interface, in which case the controls are cleared in preparation for another query.

In Figure 5, a brake problem has been selected from the list of problems.

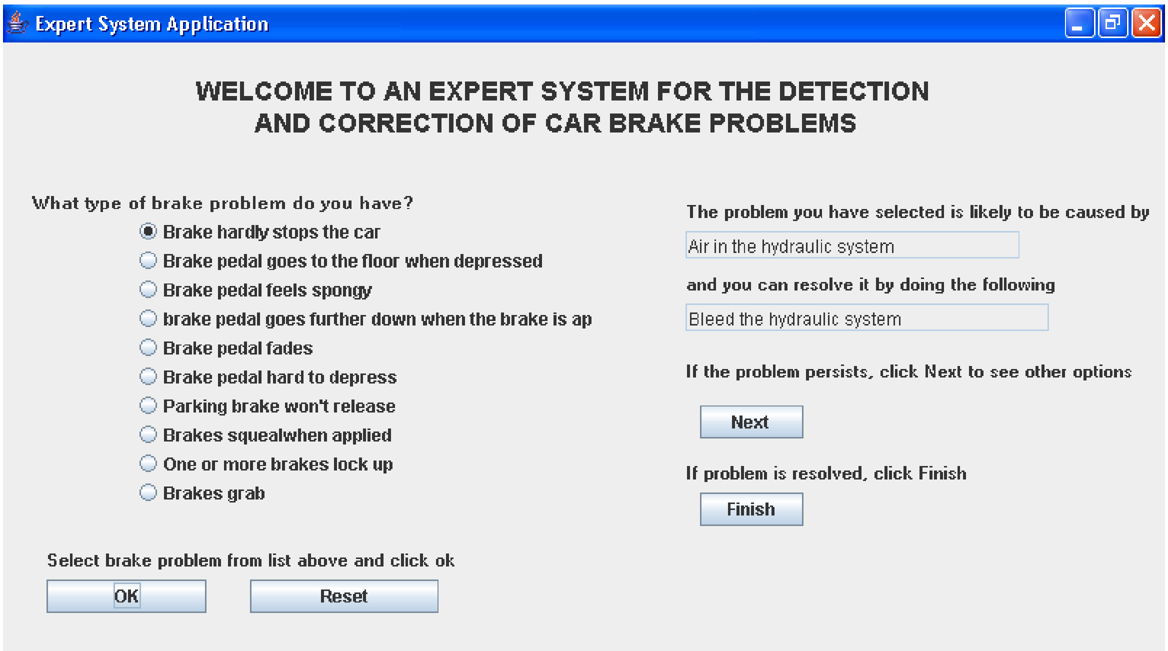

Figure 5: Expert System showing a selected brake problem, evidence and resolution

Automatically, there is an indication of one of the likely causes, as well as how to resolve it. The user is expected to perform the advice. If the problem persists, the program provides the Next button facility, where he should click on, for a fresh set of evidence and resolution advice. The result of clicking on the Next button while the present brake problem remains selected is shown in Figure 6. Figure 7 shows the selection of a different brake problem, with fresh set of likely causes, and resolution strategies.

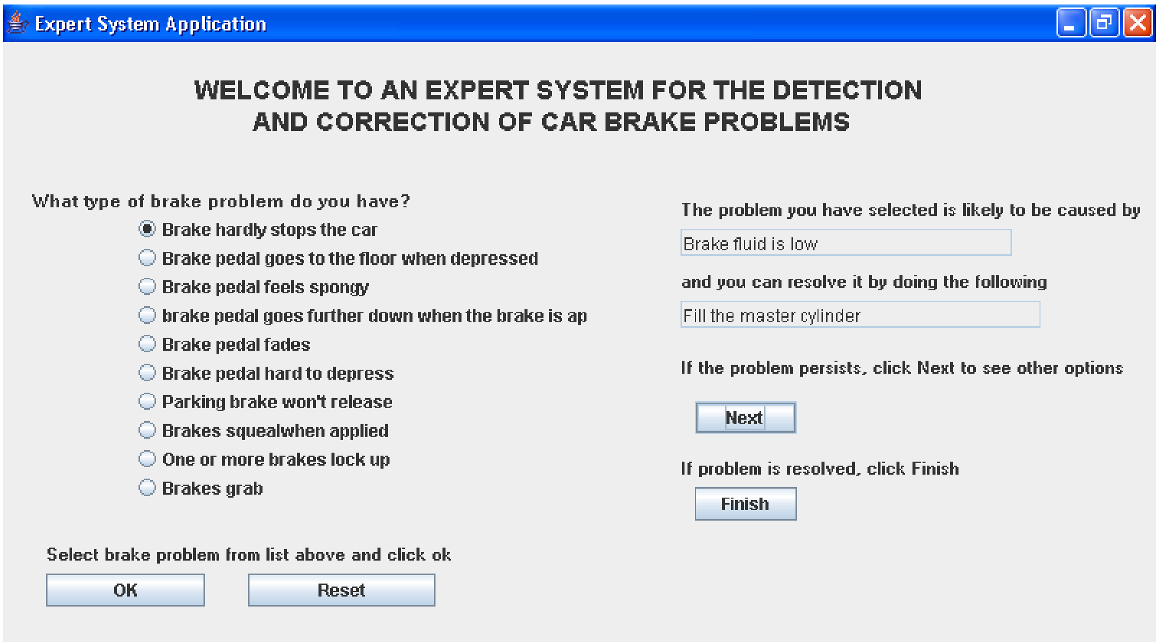

Figure 6: Expert System showing another evidence and resolution of a selected brake problem

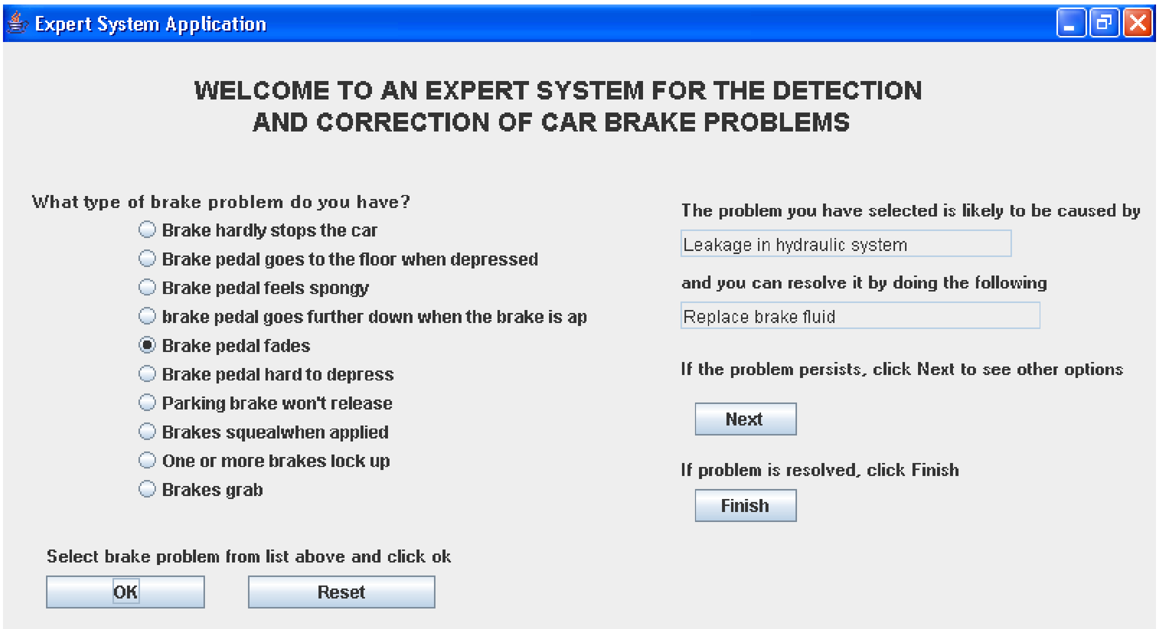

Figure 7: Expert System showing another selected brake problem, evidence and solution.

When the user's problem is resolved, he clicks on the Finish button to complete the operation. The process continues until the user's problem is solved.

VI. CONCLUSION

Normally, a driver will be the first person to notice when there is a brake problem. It is important to be alert and recognize the danger signs. We have listed some of the signs indicating brake problems in this paper. These signs and their resolution advices have been composed into models. The programming tools introduced herein highly simplified the task of transforming our models into an expert system.

The program can be installed in Laptop computers and mobile phones, which can follow drivers around. Overtime, embedded software can be developed out of these models and fused into the dash-board of cars. At this level, the solutions become readily available with the cars. It is our assertion that, the more you know about your car, the more you can attempt to fix some problems yourself, and the more you can protect yourself against unnecessary or inflated bills.

Let us emphasize, however, that we invented these models to provide FIRST-AID strategies when the mechanic is not near. They are made to empower you to try to DO-IT-YOURSELF where and when necessary. Drivers are advised to always consult their automobile mechanic for routine maintenance.

VII. REFERENCES

[1] J. N. Obidinnu, "Enhancement of User Satisfaction and Computer Resource Management Through the Application of Fisheye Interface to Knowledge Engineering Systems", Global Journal of Pure and Applied Sciences, Vol. 13, No. 4, 2007, pp. 585 – 590.

[2] M. Wright, "Your Guide to Auto-Repair", Free Newsletter. Retrieved on 20th December 2007 from: http//autorepair.about.com

[3] S. Katipamula, R. Michael, and K. Brambley, "Methods for Fault detection, diagnosis, and prognostics for building systems", International Journal of HVAC and R Research, Vol 1, January 2005.

[4] J. E. Braun, "Automated fault detection and diagnosis for the HVAC and R industry", International Journal of Heating, ventilating, Air Conditioning and Refrigerating Research, 2009, 5(2): 85-86

[5] R. Isermann and P. Balle, "Trends in the application of model-based fault detection and diagnosis of technical process", Control Eng. Practice, 2019, 5 (5): 709-719.

[6] V. Venkatasubramanian, R. Rengaswamy, K. Yin, and S. N. Kavuir, "A Review of process fault detection and diagnosis, Part II: Qualitative models and search strategies", Computers in chemical engineering, 2013, 27:313-326.

[7] J. Chen and R. J. Patton, "Robust Model-Based Fault-Diagnosis for Dynamic systems", Norwell, Massachusetts: Kluwer Academic Press, 2019.

[8] PECT (Portland Energy Conservation, and Battelle Norwest Division, "Methods for Automated and continuous commissioning of building systems", "ARTI Report ARTI-2/CR/610-30040-01, 2023, Arlington, Virginia.

[9] J. Rasmussen," Information Processing and human-machine interaction", New York: North Holland, 2016.