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The Prototype of an Expert Car Failures Diagnosis System with Combining Forward Chaining and Bayes Network

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Abstract— *Today's automotive technology makes use of computers and sensors, as well issues a warning message on the dashboard to alert the car owner to a problem. This study aims to design an expert system to diagnose car failures using the Forward Chaining and Bayes Network methods. This system is specifically designed to use a knowledge base and solutions to diagnose failure Mercedes Benz cars based on Message Indicator Light (MIL). Observations and interviews were conducted with the experts in a workshop, then the rules for forward chaining were compiled, and then Bayes probability was calculated. The results of calculations with these two methods were the same diagnoses and solutions from experts.*

Keywords— *Expert Systems, Car Failure, Forward Chaining, Bayesian Network.*

I. INTRODUCTION

Today's automotive technology makes use of computers and sensors and also issues a Message Indicator Light (MIL) on the dashboard to alert the car to a problem. One MIL can have several different problems and could make a problem for non-authorized Mercedes Benz workshops that do not have adequate diagnostic tools because it can cause misdiagnosis or take a long time to find the correct diagnosis.

Artificial Intelligence through one of its branches, namely the Expert System, can be used to help workshops simplify diagnosis, where this system is associated with an expert or expert in car repair, who can provide failure analysis based on information from customers, see MI, symptoms and physical facts of the car. Thus, a mechanic can solve problems in a car with the help of an Expert System.

The object of this research is the car failure shown by the indicator on the dashboard screen of the Mercedes Benz car, with the Check Engine indicator sample. And to complete the diagnosis using the Forward Chaining method and Bayes probability.

Budiharto (2013) adapted Bayesian approach to develop expert car failure diagnosis system, however the knowledge acquisition for rules production was not written in details. Adekunle (2018) built an expert system for automobile reference and maintenance, however the paper focused on the application without detail in the rules and algorithm process. The most complete design of expert system for fault diagnosis of an automobile was developed by Aijaz ul Haq (2015), which use 3 technique to gather data, which is case base, rules base and frame base.

Forward Chaining is used to represent knowledge, with a search technique that starts with known facts, then matches those facts with the IF part of the IF-THEN rule. Bayes probability is used to ensure that the recommended diagnostic results of forward chaining are correct. Historical car repair data is needed to support Bayes probability calculations

II. LITERATURE REVIEW

A. Forward Chaining

Forward chaining is a search technique that starts with known facts, then matches those facts to the IF part of the IF-THEN rule. If there is a fact that matches the IF part, then the rule is executed. When a rule is executed a new fact (THEN section) is added to the database. Each time there is a match, it starts from the top rule. Each rule may only be executed once. The matching process stops when there are no more rules that can be executed (Sutojo, 2011).

In general, in inference (guess / estimate), the Forward Chaining rules will be tested one by one in a certain order. When each rule is tested, the system will evaluate whether the condition is true or false. In other words, reasoning starts from the facts first to test the hypothesis. Forward chaining is data-driven because inference starts with available information and then conclusions are obtained.

In expert systems, generally, the reasoning method or inference engine is implemented in the form of coding lines in a particular programming language. So it can be estimated that an expert system with some knowledge can only be filled with several experts who have the same inference technique and have the same knowledge base structure.

B. Bayesian Inference

Bayesian inference is the process of fitting a probability model to a data set and summarizing the results with probability distributions on model parameters and unobservable quantities such as predictions for new observations (Gelman et al., 2013).

Bayes probability theory is used to calculate the probability of an event occurring based on the effects obtained from testing. Bayes probability of a relationship between the probability of the hypothesis Ci with the fact (evidence) X that has occurred and the probability that the evidence X with the hypothesis Ci has occurred. This theorem is based on the principle that if there is additional information or evidence, the probability value can be increased, so that the theorem is

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useful for modifying or increasing the existing likelihood value into better evidence-supported information or additional evidence. The Bayes theorem equation is mathematically written as:

$$P(Ci|X) = \frac{p(X|Ci)*p(Ci)}{\sum_{i=1}^{n} p(X|Ci)*p(Ci)} \quad (1)$$

P(Ci|X) = The hypothesis for the probability of Ci is correct if evidence of X is given
p (X|Ci) = The probability of evidence X if it is known that the hypothesis Ci is true
p (Ci) = The probability of a hypothesis without considering any evidence
p (X) = Probability of proof X
n = Number of hypotheses

III. RESEARCH METHODS

The diagram of research methods as follows:

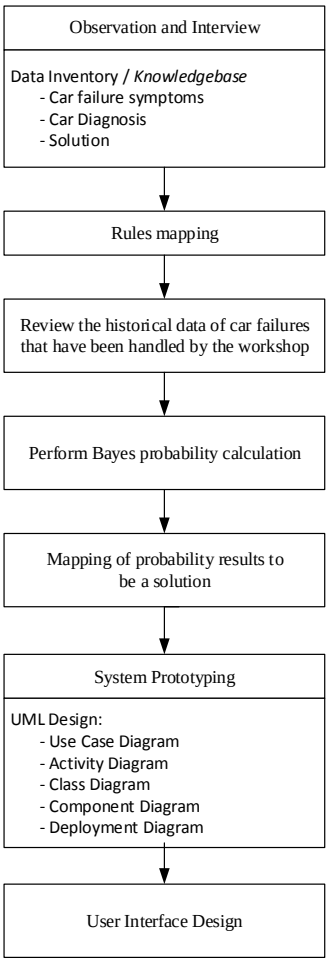

Fig. 1. Diagram of Research Methods

A. Knowledge acquisition

To obtain data, direct observations were made at the research object workshop, as well as interviews with the Service Advisor, the Head of the Workshop, and the mechanic. It was found that there were several cases where each expert had a different diagnosis.

There are 6 stages in carrying out a car diagnosis (Denton, 2017):

1. Verification of the problem: ask the car owner about the problem, have you ever overheated, never ran out of radiator water?
2. Collecting problem information by checking directly with a test drive, checking for dripping water, cracking hoses?
3. Evaluation of existing problems. If there is an overheat and the radiator water runs out, there may be a leak in the radiator or hose.
4. Perform tests to confirm problems. Using a pressure test kit on the radiator, if the pressure is low then there may be a leak.
5. Repair according to diagnosis. Radiator hose replacement.
6. Check again after repair to make sure the problem has been fixed and corrected properly. Perform a visual inspection and test drive.

B. Forward Chaining

Inference (guess / estimate) in the Forward Chaining rule will be tested one by one in a certain order

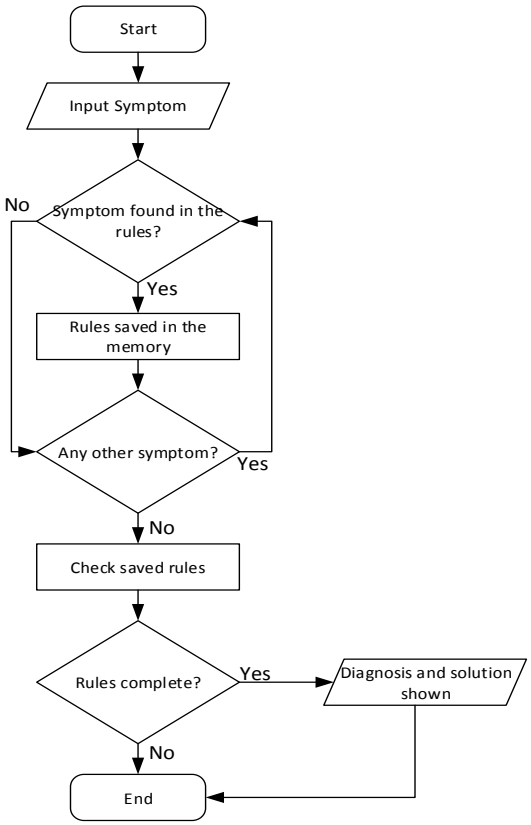

Fig. 2. *Forward Chaining Flowchart (source:* Perbawawati, 2019).

The tables below are the knowledge base of car failures.

TABLE 1. Failure Symptoms Table

Code	Description of Symptoms
G01	*Check Engine Light*
G02	Wasteful Fuel
G03	Engine misfire
G04	Engine idle jerk
G05	The engine won't start
G06	The exhaust fumes were black
G07	Engine off its own occasionally
G08	ESP indicator light on

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TABLE 2. Diagnosis

Code	Diagnosis
D01	Emission Control System Problems
D02	Engine Control Unit Problems
D03	Ignition System Problems
D04	Crankshaft Sensor Problems

TABLE 3. Rules

Symptoms	Diagnosis			
	D01	D02	D03	D04
G01	X	X	X	X
G02	X		X	
G03			X	X
G04	X			
G05		X	X	X
G06	X			
G07				X
G08		X		

C. Production Rules

• Rule 1

If the Check Engine light is on AND the fuel is wasteful AND the engine RPM fluctuates at idle AND the exhaust fumes are black THEN it is the problem with the emission control system (D01)

• Rule 2

If the Check Engine light is on AND the engine does not turn on AND the ESP indicator light is on THEN it is the Engine Control Unit (D02) problem

• Rule 3

If the Check Engine light is on AND fuel is wasteful AND the engine is limping THEN it is an ignition system problem (D03)

• Rule 4

Check Engine starts AND engine limps AND engine often turns itself off AND engine doesn't start THEN it is crankshaft sensor problem (D04)

D. Bayes Probability Calculation

Bayes probability is used to determine the level of uncertainty from the diagnosis resulting from Forward Chaining. Historical data of car failure is needed to determine the weight of the failure diagnosis required in calculating the Bayes probability. During the research period from September to December 2020, there were recorded 57 cars repaired in the workshop, with the following data:

TABLE 4. Historical Data of Car Repaired

Description	No. of car
Failure with an indicator or message appears on the dashboard	17
Failure without any indicators or messages on the dashboard	12
Service and maintenance	28

TABLE 5. Historical Data of Car Failures with MIL

Description	No. of Car
Check Engine Light	10
ESP	4
Battery Indicator	2
SRS/Airbag	1

10 cars that have problems with the Check Engine light indicator appearing, and the details of the failure are shown in the following table.

TABLE 6. Historical Data of Car with Check Engine Light On

Code	Diagnosis	No of Car
D01	Emission Control System Problems	3
D02	Engine Control Unit problems	1
D03	Ignition System Problems	5
D04	Crankshaft Sensor Problems	1
	Total	10

Based on table 6, if the Check Engine indicator light is on, then the probability calculation is as follows:

Probability D01 if the Check Engine light is on:

$$p\ (G01|D01) = \frac{3}{10} = 0.3 \quad (2)$$

Probability D01 regardless of other symptoms:

$$p\ (D01) = \frac{1}{4} = 0.25 \quad (3)$$

Probability D02 if the Check Engine light is on:

$$p\ (G01|D02) = \frac{1}{10} = 0.1 \quad (4)$$

Probability D02 regardless of other symptoms:

$$p\ (D02) = \frac{1}{4} = 0.25 \quad (5)$$

Probability D03 if the Check Engine light is on:

$$p\ (G01|D03) = \frac{5}{10} = 0.5 \quad (6)$$

Probability D03 regardless of other symptoms:

$$p\ (D03) = \frac{1}{4} = 0.25 \quad (7)$$

Probability D04 if the Check Engine light is on:

$$p\ (G01|D04) = \frac{3}{10} = 0.3 \quad (8)$$

Probability D04 regardless of other symptoms:

$$p\ (D04) = \frac{1}{4} = 0.25 \quad (9)$$

The probability the Check Engine light comes on with a fault diagnosis is the Ignition System (D03)

$$= \frac{0.5 \text{ x } 0.25}{(0.3\ x\ 0.25)+(0.1\ x\ 0.25)+(0.5\ x\ 0.25)+(0.3\ x\ 0.25)}$$

$$= \frac{0.125}{(0.75)+(0.25)+(0.125)+(0.75)} = \frac{0.125}{0.3}$$

$= 0.416 = 0.416 \text{ x } 100\% = 41.6\%$

And the probability of the Check Engine light on with a fault diagnosis of the Emission Control System (D01) is

$$= \frac{0.3 \text{ x } 0.25}{(0.3\ x\ 0.25)+(0.1\ x\ 0.25)+(0.5\ x\ 0.25)+(0.3\ x\ 0.25)}$$

$$= \frac{0.75}{(0.75)+(0.25)+(0.125)+(0.75)} = \frac{0.075}{0.3}$$

$= 0.25$

The probability of the Ignition System is higher than the others, 41.6%, thus the conclusion is the ignition system is the issue.

E. Mapping Bayes Probability Results into Solutions

Based on the probability calculation, the system recommends a solution to the problem. The following table of solution data and diagnostic mapping with solutions:

TABLE 7. Diagnosis and solution mapping tables

Diagnosis	Solution			
	S01	S02	S03	S04
D01	X			
D02		X		
D03			X	
D04				X

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TABLE 8. Solution

Code	Solution
S01	• Air mass sensor cleaned or replaced • The Oxygen Sensor is cleaned or replaced
S02	• Engine Control Unit Replacement
S03	• Coil replacement • Spark plug replacement • Replacement of spark plug wires
S04	• Replacement of the crank shaft sensor

Based on the results of the probability calculation, problems with the Ignition System (D03) have the greatest probability, namely 41.6%.

And referring to table, the solution for diagnosing D03 is S03, could be one of those part or all parts problem.

As for symptoms of failure with two indicator lights on, namely Check Engine and ESP, with a diagnosis of D02, the solution is to replace the Engine Control Unit.

F. User Interface Design

The User Interface design of the system as follows:

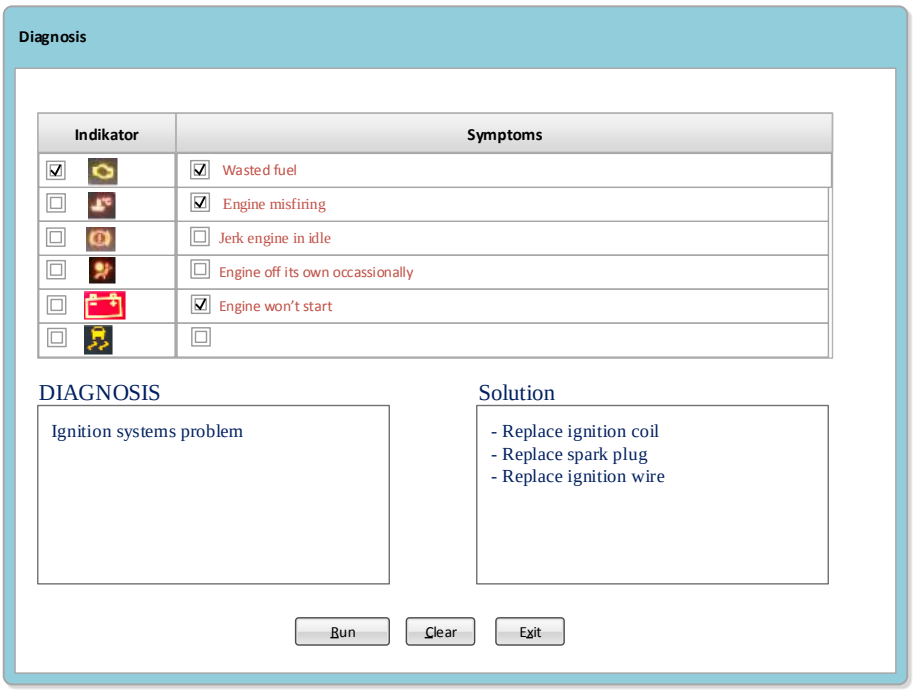

Fig. 3. User Interface Design

IV. CONCLUSION

The application of forward chaining based on facts and data from experts produces an accurate diagnosis in determining car failure. Meanwhile, the use of the Bayes probability provides certainty that the diagnosis taken has the most appropriate possibility. After the diagnosis is obtained, a solution will be issued.

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