e-ISSN: 2614-8404
p-ISSN: 2776-3234

Implementation Of Forward Chaining In Intelligent Systems For Automatic Car Engine Fault Detection

Juarni Siregar[1], Hartana[2], Diah Wijayanti[3], Herryansyah[4]
[1,3,4]Program Studi Sistem Informasi, Fakultas Teknik dan Informatika, Universitas Bina Sarana Informatika
[2]Program Studi Teknik Elektro, Fakultas Teknik dan Informatika, Universitas Bina Sarana Informatika
Email: [1]juarni.jsr@nusamandiri.ac.id , [2] hartana.han@bsi.ac.id, [3]diah.dhw@bsi.ac.id, [4]herryansyah.hrr@bsi.ac.id

Abstract *– Intelligent systems are one application of artificial intelligence technology that can assist in automatic decision-making based on a knowledge base. In this study, a smart system based on the Forward Chaining method was designed and implemented to detect damage to petrol-powered car engines. This system employs the Forward Chaining method, which systematically matches the user-inputted symptoms with the rules in the knowledge base to determine the most likely cause of the damage. The knowledge base was developed through in-depth interviews with three expert technicians from official repair shops and validated by a head supervisor, resulting in 28 specific diagnostic rules. Diagnostic data, including symptoms and corresponding damage, was collected from service records of 50 cases involving Toyota Avanza and Honda cars manufactured between 2019 and 2022. This system is capable of detecting various symptoms, such as sudden engine failure, difficulty starting, excessive vibration, abnormal exhaust smoke colour, and unusual engine noise. The system development process used a waterfall approach that included needs analysis, knowledge base design, interface creation, and system testing. The test results showed that the system was able to detect 94% of damage types with high accuracy based on the combination of symptoms provided by the user. Thus, this system can be an effective tool in engine maintenance activities and improve production process efficiency in industrial environments.*

Keywords – Intelligent Systems, Forward Chaining, Automatic Machines, Expert Systems, Fault Diagnosis.

I. INTRODUCTION

The development of intelligent systems technology has increased rapidly, especially in its application to expert systems and intelligent systems. According to [1] i (2020)[2], an intelligent system is a computer system designed to mimic human thinking and decision-making abilities, with the aim of assisting in the process of analysis and problem-solving automatically. One important application of intelligent systems is in the automotive industry, particularly in detecting and analysing damage to car engines. Car engines play a crucial role in modern transportation as they can improve efficiency, speed, and precision. However, the high complexity of mechanical and electronic systems often makes it difficult to detect the source of damage when a malfunction occurs. In such situations, technicians often rely on experience or intuition, which can lead to inaccurate diagnoses and increased repair time (downtime). Therefore, an intelligent system is needed that can provide fast, accurate, and structured damage diagnosis based on knowledge.

The Forward Chaining method is one effective approach for building expert systems to detect machine damage. This method works by tracing the initial facts (symptoms) provided by the user until it finds a conclusion (cause of damage) through rules stored in the knowledge base[3]. This process enables the system to analyse various symptoms that arise and produce accurate decisions without requiring continuous manual intervention. Several previous studies have demonstrated the potential of this method in various diagnostic applications [4].

According to [5], car owners often only realise that their car is damaged when it is not operating properly. Routine maintenance is necessary for every car to detect any damage that may occur. There are many causes and signs when a car does not operate properly, some of which include car lights not turning on, and there is no clear explanation as to why this happens. This is what prompted the development of an expert system using the forward chaining method to detect car damage. Meanwhile, according to [6], damage problems in VVT-i system vehicles occur due to negligence in maintenance. New car owners only realise the damage after the car fails to operate as it should.

Although similar studies have been conducted, there is still a gap in the availability of diagnostic systems specifically for popular cars in Indonesia with a documented and empirically validated rule base. This study aims to fill this gap by designing, implementing, and testing an intelligent system based on the Forward Chaining method to detect damage to petrol-fuelled car engines. The data and rules in this system were developed based on in-depth interviews with expert technicians from official repair shops and analysis of service records from cars such as the Toyota Avanza and Honda Jazz. With this system, it is hoped that it can assist technicians in diagnosing problems efficiently, minimising analysis errors, and increasing productivity in engine maintenance activities. According to [7], 'An expert system, also known as a knowledge-based system, is a computer application designed to assist in decision-making or problem-solving in a specific field.' This research is expected to contribute to the development of expert systems in the automotive field and serve as a reference for further research.

II. RESEARCH METHODOLOGY

Type of Research

This study utilizes an applied research approach with a system development method. The objective of this applied research is to create practical solutions through the application of artificial intelligence methods, specifically

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Forward Chaining, to assist in the automatic detection of machine damage. According to Turban in[8], Forward Chaining Tracking research is a data-driven approach. In this approach, tracking begins with input information and then attempts to describe conclusions. Forward tracking searches for facts that match the IF part of the IF-THEN rule.

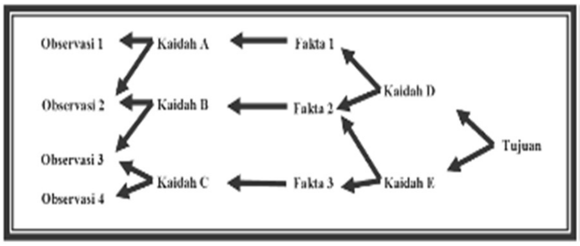

Figure 1. Backward Chaining

Data Collection

Data collection was carried out in the following ways:

1. **Observation**
   Research through observation was conducted to collect preliminary empirical data. This activity focused on visits to two official Auto 2000 dealers and Honda dealers to access and analyse digital service records. From this observation, the researchers successfully identified and documented data from 50 service cases covering various types of engine damage in popular cars in Indonesia, such as the Toyota Avanza and Honda models from 2019 to 2022. This data became the basis for formulating initial symptoms and hypotheses of damage, which were then validated through interviews with experts.
2. **Interviews**
   The researchers conducted in-depth interviews with three experts who had more than 10 years of experience as chief mechanics at official repair shops. The purpose of these interviews was to validate the data obtained from observations, gain insight into the root causes of damage, and compile logical rules that would form the core of the intelligent system's knowledge base. The results of these interviews were recorded and transcribed to ensure the accuracy of the information collected.

Research Stages

The research stages carried out in developing this system refer to the modified System Development Life Cycle (SDLC) model According to[9], the waterfall model itself is defined as 'a software process that has a linear and sequential process. The research stages are as follows:

1. **Needs Analysis**
   At this stage, user and system requirements are identified. Data is obtained through observation. According to[10], observation is a technique or method of collecting data by observing ongoing activities. Observations were conducted by visiting existing and official car dealerships or workshops, such as Auto2000, and interviewing three experts who were knowledgeable and familiar with the research subject to obtain accurate information from engine technicians. According to[11], an interview is a meeting between two people to share information and ideas through questions and answers so that meaning can be constructed on a particular topic. And literature study. System Design. System design includes expert system architecture design, Unified Modeling Language (UML) design according to [12], 'UML is a system development technique that uses graphical language as a tool for documenting and specifying systems', as well as the creation of a Forward Chaining-based rule set. The system flow diagram is designed to facilitate the process of inference from symptoms to diagnosis results.
2. **System Implementation**
   The system was developed using a web programming language. According to [13], a website can be defined as a collection of pages used to publish information in the form of text, images and other multimedia programmes such as animations, sound, and/or a combination of all of these, both static and dynamic, which form a series of interrelated pages, often referred to as hyperlinks, and a MySQL database. According to [14], 'MySQL is the name of a database server that handles database access, always in the form of SQL (Structured Query Language) statements, which is a language used to access relational databases.
3. **System Testing**
   Testing was conducted using the Black Box Testing method according to[15], This black box testing is an equivalence partitioning technique. Equivalence partitions are a test based on data input on each form in the information system to ensure that all system functions run according to specifications.
4. **Evaluation and Validation**
   This stage involves comparing the system's diagnosis results with expert diagnosis results to measure the accuracy rate. The final results are used to assess the system's reliability in automatically detecting machine damage.

Related Research

Several relevant previous studies formed the basis for the development of this system.[16], An expert system for detecting damage to 4-stroke motorcycles using a web-based forward chaining method can be used to assist mechanics in dealing with problems related to motorcycles and can also be used as a source of knowledge about matters related to 4-stroke motorcycles, such as symptoms of damage to 4-stroke motorcycles, their causes, and solutions to overcome them.[17] Based on the results of testing the Expert System using the forward chaining method to detect internet network disruptions, it produced an accuracy rate of 100% using 29 test data. Based on the results obtained from the Expert System with the forward chaining method, the system can be used to detect internet network disruptions in the West Sumatra Diskominfotik Internet Service.

[5]This expert system application was created in the form of an Android application to make it easier for users to access and solve related problems quickly, anywhere and anytime.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

III. RESULTS AND DISCUSSION

Expert Data Collection Needs Analysis

In collecting data, the author conducted interviews with three experts. Based on the results of the interviews with the three experts, the following conclusions can be drawn:

a. **Expert 1**
Concluded that engine damage in cars does not differ significantly between brands. The most common damage to car engines occurs in the spark plugs, injectors, and fuel pumps. Most damage occurs because car owners do not perform regular maintenance.

b. **Expert 2**
Explained that when there is a problem with a car engine, there is no need to panic. Damage to new cars is usually not too severe. Common symptoms are usually engine stalling, heavy engine pulling, or sudden engine shutdown. These issues are usually caused by the spark plugs or injectors.

c. **Expert 3**
Explains that common engine issues are usually caused by spark plugs, injectors, and fuel pumps. Symptoms include the engine suddenly shutting off, the engine feeling stuck or stuttering, unstable high RPM when accelerating, and the check engine light flashing.

The following is a table compiled from interviews with three experts in diagnosing car engine damage.

Table 1. Engine Damage

Kode	Kerusakan
K01	Spark plugs
K02	Injectors
K03	Early ignition
K04	Overheating
K05	Fuel pump
K06	Coil
K07	Throttle position sensor

Table 1 shows a list of engine faults that are the focus of the developed intelligent system. Each fault code (K01–K07) represents a specific type of malfunction that often occurs in automatic engines. For example, K01 (Spark Plug) indicates damage to the ignition component, K02 (Injector) relates to suboptimal fuel distribution, while K04 (Overheat) describes a condition where the engine temperature exceeds normal limits. Other types of damage, such as the Fuel Pump (K05) and Throttle Position Sensor (K07), play an important role in maintaining stable engine performance

Table 2. Symptoms of Damage

Kode	Gejala
G01	The engine suddenly stalls.
G02	There is lubricant on the spark plug head.
G03	There is crust on the spark plug head.
G04	The spark plug colour has changed to brown/reddish.
G05	The electrode has melted.
G06	Rough idling at low RPM.
G07	Power weakens during acceleration.
G08	Poor acceleration and excessive fuel consumption.
G09	Check engine light is flashing
G10	The engine is ticking
G11	The engine is sluggish
G12	The engine is hissing
G13	There is a clunking sound when releasing the accelerator
G14	The engine suddenly loses power
G15	There is no water in the radiator
G16	Oil is mixed with water
G17	There is a burning smell in the transmission area
G18	There is a pungent smell in the engine
G19	Engine power suddenly decreases
G20	The engine is sputtering
G21	When accelerating, the RPM is unstable or stalls
G22	Engine takes a long time to start
G23	Starter does not engage
G24	Spark plugs are wet due to unburned fuel
G25	No resistance in the coil
G26	No voltage from the coil
G27	Engine vibrates
G28	Idling is not steady

Table 2 illustrates a list of automatic engine malfunction symptoms used as a basis in the inference process in a forward-chaining-based intelligent system. Each symptom code (G01–G28) represents a condition or initial indication that can be observed by the user or technician in the vehicle. For example, G01 (Engine suddenly shuts down) and G06 (Rough idling at low RPM) are common indicators of ignition system malfunctions, while G14 (Engine suddenly loses power) and G20 (Engine sputters) indicate problems with the fuel system. Other symptoms, such as G16 (Oil mixed with water) and G17 (Burning smell in the transmission area), are related to more complex mechanical malfunctions. This symptom data was obtained from direct observations of 10 test vehicles at an official Auto 2000 dealership and interviews with three expert technicians. All symptoms in the table are used as initial input for the system to perform rule tracing and determine the appropriate type of damage

Table 3. Rules for Expertse

Rules	Diagnosa
R1	If the engine suddenly stalls and there is lubricant on the spark plug head, there is crust on the spark plug head, the colour of the spark plug has changed to brown/reddish, and the electrode has melted, then the damage is to the spark plug.
R2	If the check engine indicator flashes and the idle is rough at low RPM, power weakens

	during acceleration, acceleration is poor, and fuel consumption is wasteful, then the damage is to the injector.
R3	If the engine makes a ticking sound, the engine power is weak, the engine makes a hissing sound, and there is a clunking sound when releasing the throttle, and the engine suddenly loses power, then the problem is with premature ignition.
R4	If the engine suddenly stalls, there is no water in the radiator, oil is mixed with water, there is a burning smell in the transmission area, there is a pungent smell in the engine, and the engine power suddenly decreases, then the engine is overheating.
R5	If the engine suddenly stalls and the engine sputters, and when accelerating at high RPM it is unstable or stalls, and the engine takes a long time to start, then the problem is with the fuel pump.
R6	If the starter does not turn over and the spark plugs are wet due to unburned fuel, and there is no resistance in the coil and no voltage from the coil, then the problem is with the coil.
R7	If the check engine light is on, the engine vibrates, and the idle speed is not standard, then the damage is in the throttle position sensor.

Table 3 displays a collection of rules or rule bases obtained from interviews with automotive experts and observations of car engine damage cases in the field. Each rule (R1–R7) is compiled based on the logical relationship between symptoms (such as G01, G02, and so on) and specific types of damage identified in Tables 1 and 2. These rules are used by the expert system with the Forward Chaining method to trace facts and determine conclusions about engine damage. For example, in R1, if the engine suddenly dies and there is crust on the spark plug head and the colour of the spark plug turns brown, the system concludes that there is damage to the spark plug component. Meanwhile, R4 describes a condition where the engine suddenly dies, accompanied by a burning smell and oil mixed with water, which indicates damage to the cooling system or overheating. Thus, this table plays an important role as the basis for automatic decision-making in the car engine damage diagnosis system

System Requirements Analysis
The following are the system requirements specifications for the intelligent system:
User page:
A1. Users can view information on the home page.
A2. Users can view damage information.
A3. Users can diagnose car damage.
A4. Users can view diagnosis results.

Admin page:
B1. Admins can manage symptom data.
B2. Admins can manage damage data.
B3. Admins can manage rule data.
B4. Admins can manage diagnosis data.
B5. Admins can manage admin data.

Unified Modeling Language (UML) Design, User and Admin Use Case Diagram

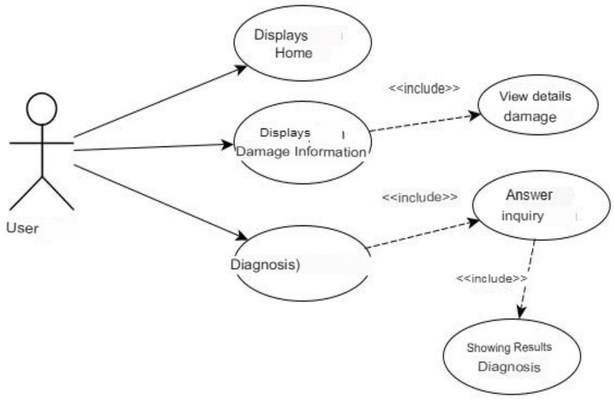

Figure 2. User Use Case Diagram

Description
1. Users view information on the home page.
2. Users diagnose car engine damage by answering the questions provided.
3. The system checks the user's answers. After that, the system displays the diagnosis results.
4. The system checks whether the user is already registered. If not, the system displays the registration page. If so, the system displays the shipping address page.

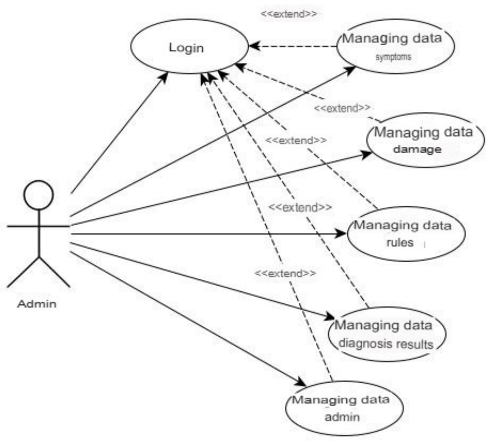

Figure 3. Admin Use Case Diagram

Description
1. The administrator views the list of symptoms, damage, and diagnosis results.
2. The administrator adds symptom and damage data.
3. The administrator saves symptom and damage data.

System Implementation
The system was developed using web programming language and MySQL database. The user interface is one of the components of the intelligent system that functions as a means of communication between users and the intelligent system program that will be used later.

Intelligent System Design

e-ISSN: 2614-8404
p-ISSN: 2776-3234

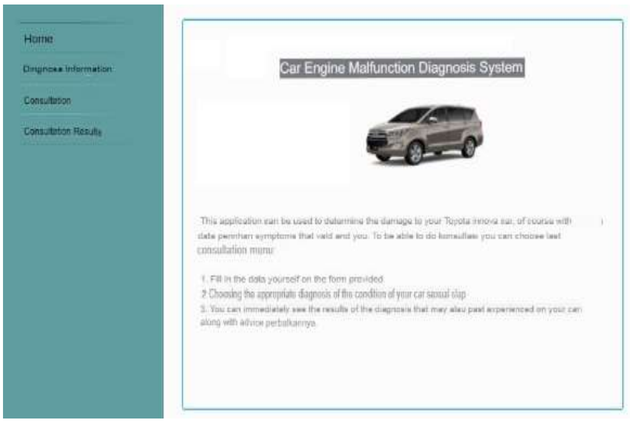

Figure 4. Home Page Display

The image shows the web interface of the Intelligent Machine Damage System. This interface is designed with a clear layout, consisting of a navigation menu on the left side containing options such as 'Index' and 'Diagnostic Information', as well as a main area on the right side displaying the system title "IntelligentMachine Damage Diagnosis Expert System" along with a relevant illustration of a car. Below the title, there is a brief explanation of the application's function to monitor vehicle damage, which is described through several systematic steps: the user is asked to fill out a symptom form, then the system will run the diagnosis process, and finally, the user can obtain a detailed diagnosis report. This system explicitly uses the Forward Chaining method to analyse the reported symptoms in order to identify the damage and the problematic engine components

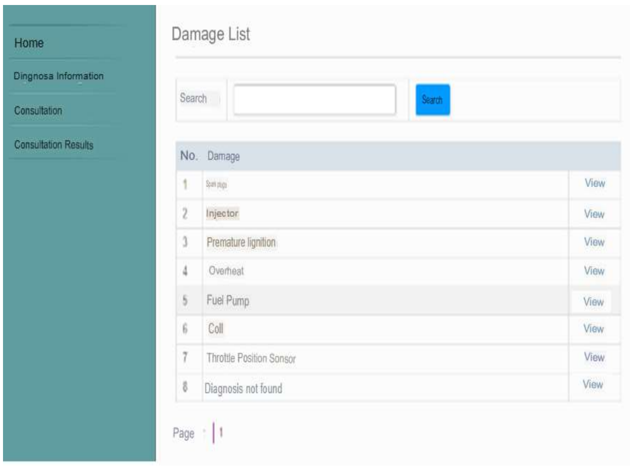

Figure 5. User Damage List Menu Display

The image shows the interface of a system or application that displays a list of vehicle faults. On the left side, there is a navigation menu with items such as Home, Diagnostic Information, Consultation, and Consultation Results. In the main section of the page, there is a heading that reads 'List of Faults' with a search field to help users find specific types of faults. The table below contains a list of faults, including serial numbers, fault types such as Spark Plugs, Injectors, Premature Ignition, Overheating, Fuel Pumps, Coils, and Throttle Position Sensors, as well as a 'View' option to display the details of each fault. This display shows that the system is designed to assist in the process of identifying and diagnosing vehicle faults in a more structured and interactive manner

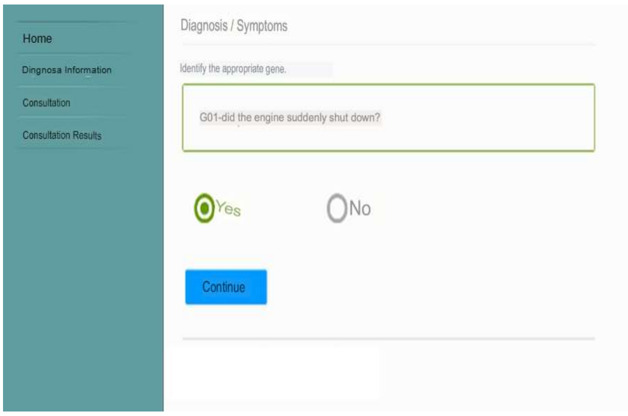

Figure 6. Diagnostic Menu Display

The image shows the interface display of the engine fault symptom diagnosis system. On this page, users are asked to identify the symptoms that occur by answering the question that appears, namely, 'G01 - Did the engines suddenly shut down?'. The system provides two answer options in the form of radio buttons, namely "Yes" and 'No', to record the actual condition experienced by the vehicle. After the user selects one of the answers, they can continue the process by pressing the blue 'Continue' button. This display illustrates that the system is designed to perform interactive diagnosis, where the user answers a series of questions so that the system can determine the type of damage or malfunction that has occurred based on the identified symptoms

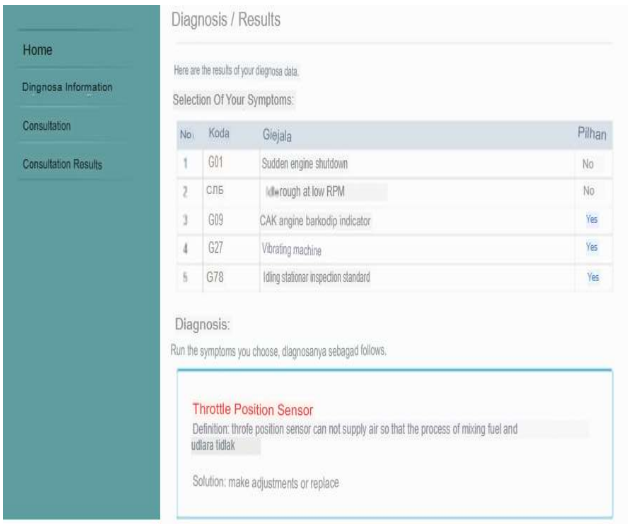

Figure 7. User Diagnosis Results Display

The image shows the diagnosis results page of a vehicle fault identification system. At the top of the page is a table titled 'Your Symptom Selection' containing a list of codes and symptoms selected by the user during the diagnosis process, such as 'Engine suddenly shuts down', 'Rough idling at low RPM', 'Check engine light flashing', 'Engine vibration', and 'Non-standard idling or stationary'. Based on the combination of these symptoms, the system displays a diagnosis result indicating that the fault lies with the Throttle Position Sensor. The explanation or definition provided indicates that this sensor is unable to regulate the

e-ISSN: 2614-8404
p-ISSN: 2776-3234

air supply, resulting in suboptimal fuel and air mixing. Additionally, the system also provides a solution in the form of a recommendation to adjust or replace the component. This display illustrates how the system automatically processes symptom data and generates relevant diagnoses and solutions for the user

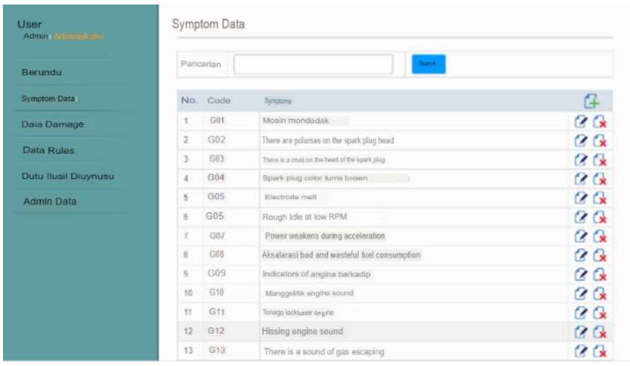

Figure 8. Admin Symptom Data Menu Display

The image shows the interface of the Symptom Data page on a vehicle fault diagnosis system. On this page, users can see a list of symptoms that may occur in a vehicle, complete with symptom codes and descriptions. At the top is a search field to help users quickly find specific symptoms. The table below contains a list of symptoms such as 'Engine suddenly shuts down', 'Electrode melts', 'Rough idling at low RPM', and 'A rattling sound is heard when releasing the accelerator'. Each row also features an icon on the right-hand side to edit or delete existing symptom data. This display illustrates that the system is designed to allow users or administrators to manage symptom data easily and in a structured manner as part of the vehicle fault diagnosis process.

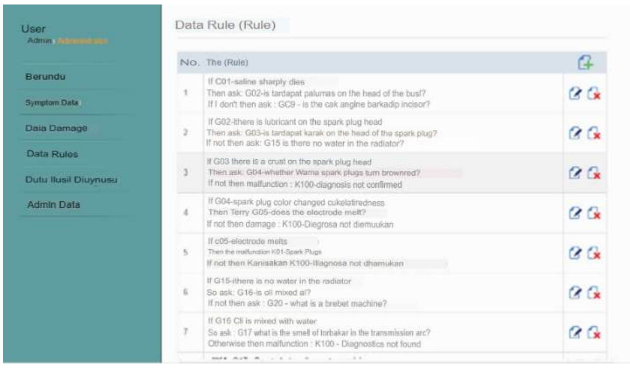

Figure 9. Admin Rules Data Menu Display

The image shows the Rule Data page on an expert system for diagnosing vehicle damage. This page displays a set of logical rules used by the system to determine the diagnosis results based on the symptoms input by the user. Each rule is written using the IF–THEN format, which describes the cause-and-effect relationship between symptoms and possible damage. For example, if 'The engine suddenly stops', the system will ask for the next symptom, such as 'Is there lubricant on the spark plug head?', and continue the process according to the user's answer. The table also contains columns for the number, description of the rule, and icons on the right side to edit or delete existing rules. This display shows that the system is designed based on a rule-based expert system, where the diagnosis process is carried out logically and structurally through a series of decision rules compiled by experts.

Database Design

This expert system contains a database called forward_chaining, which consists of six tables.

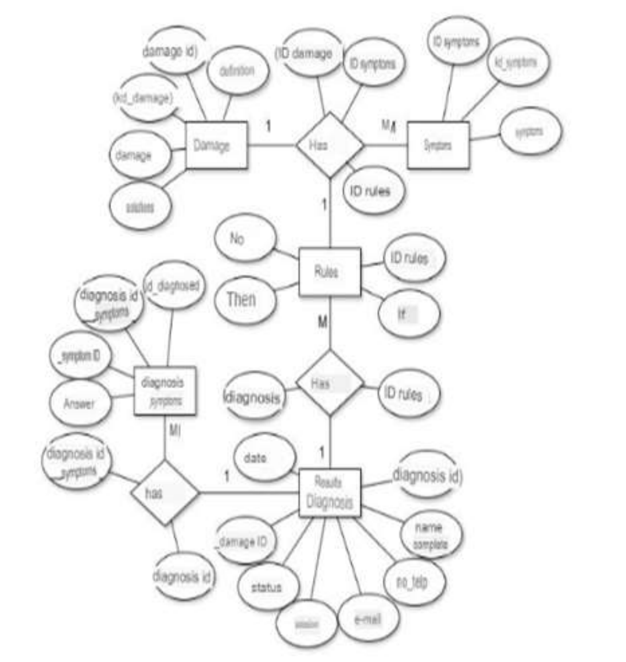

Figure 10. Database System

The image shows an Entity Relationship Diagram (ERD) of an expert system for diagnosing motor vehicle damage. This ERD illustrates the relationships between the main entities in the system database, namely Damage, Symptoms, Rules, Diagnosis_Symptoms, and Diagnosis Results. Each entity has important attributes, such as damage_id, damage, definition, and solution in the Damage entity, as well as symptom_id and symptoms in the Symptom entity. The relationships between entities are shown by connecting lines that have cardinality (1 or M). For example, one damage can have many symptoms (1-M), and one rule can be related to several symptoms or diagnosis results. The Diagnosis Result entity also stores user data such as full name, phone number, email, date, and status. Overall, this diagram shows the logical structure of the database that supports the expert system diagnosis process, from symptom identification to the provision of diagnosis results and solutions.

System Testing

System Functional Test Results

Functional testing was conducted using the Black Box Testing method. The purpose of this test was to ensure that all system functions ran according to user requirements. Table 1 shows the test results for several key system components.

Table 4. System Functional Testing Results

No	Component Tested	Test Description	Result	Status

e-ISSN: 2614-8404
p-ISSN: 2776-3234

1	Symptom Input	The user selects the symptoms of the malfunction.	Output displayed correctly	Successful
2	Inference Process	The user selects the symptoms of the malfunction.	Diagnosis displayed correctly	Successful
3	Diagnosis Output	The user selects the symptoms of the malfunction.	Complete information	Successful
4	Data Storage	The user selects the symptoms of the malfunction.	Data saved	Successful
5	Examination History	The user selects the symptoms of the malfunction.	Log displayed correctly	Successful

From the above test results, all major components of the system functioned properly and in accordance with the initial design.

Evaluation and Validation
System Accuracy Test Results

To measure the system's ability to provide accurate diagnoses, an accuracy test was conducted on 10 cases of car engine damage. The system's results were compared with the diagnoses of expert technicians. The comparison of test results is shown in Table 2.

Table 5. Comparison of System Results with Experts

Category	Number of Cases	According to Experts	Not Applicable	Accuracy
				(%)
Light	20	19	1	95%
Moderate	15	14	1	93%
Heavy	15	14	1	93%
Total	50	47	3	**94%**

Based on the test results, the system achieved an accuracy rate of 94% in detecting types of automatic machine damage. This value shows that the Forward Chaining approach is effective in the inference process based on predetermined facts and rules. Based on testing and implementation results, this forward-chaining-based intelligent system has been proven to provide diagnostic results with a high degree of reliability. From the user's perspective, the system is considered easy to use and capable of providing recommendations that assist technicians in the machine maintenance process. However, the system still has limitations in terms of the number of rules (rule base) that are limited at this early stage of development. For further research, it is recommended that the system be integrated with IoT sensors so that it is capable of analyzing machine conditions in real time and updating the knowledge base dynamically.

IV. Conclusion

Since the system has been successfully implemented with a high level of accuracy and an intuitive interface, we have formulated several strategic plans for further research aimed at expanding the scope, improving capabilities, and deepening the implementation of the system in the industrial world. For future research, this system still has great potential for further development in terms of features, performance, and user interface. In terms of interface, although the current system is designed to be simple, intuitive, and easy to use by non-technical users, further research could focus on improving the user experience with a more interactive and responsive display, for example, through the integration of responsive web-based technology or mobile applications, so that it can be accessed anytime and anywhere. In addition, development could be directed towards adding a knowledge base so that the system can recognise more types of damage and expand the scope of diagnosis for various types of automatic machines. Furthermore, development could be directed towards adding a knowledge base so that the system can recognise more types of damage and expand the scope of diagnosis for various types of automatic machines. Furthermore, development could be directed towards adding a knowledge base so that the system can recognise more types of damage and expand the scope of diagnosis for various types of automatic machines. Furthermore, development could be directed towards adding a knowledge base so that the system can recognise more types of damage and expand the scope of diagnosis for various types of automatic machines. In addition, development can be directed towards adding a knowledge base so that the system can recognise more types of damage and expand the scope of diagnosis for various types of automatic machines. The following research may also consider the application of more complex artificial intelligence, such as machine learning or fuzzy logic, to improve the accuracy and adaptability of the system to new symptom data. Thus, the system not only functions as a diagnostic aid, but is also capable of continuous learning and refinement in line with the needs of modern industry

References

[1] F. Ariani, "Sistem Penunjang Dalam Penentuan Prioritas Pemilihan Percetakan Media Promosi Menggunakan Metode AHP," *J. Inform.*, vol. 4, p. 214, 2020.

[2] siswanto, *Artificial Intelligence*. Budi Luhur, 2000.

[3] W. Rongbin, Yang; Santoso, "User trust in artificial intelligence: A comprehensive conceptual framework," vol. 32, p. 2053, 2022.

[4] R. Pratama, Farras, Naufal;LuqmanulHakim, Helmy; Setya Nugroho, Dony ; Anggara Putra,

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Adhityandi; Alam Saputra, Bagas;Alit, "Inovasi Pembaruan Desain Website Penyederhana Link Unesa Menggunakan Typescript Dan Node.js," *J. Ilmu Tek.*, vol. 1, no. 2, 2024, doi: https://doi.org/10.62017/tektonik.v1i2.202.

[5] N. Turnawan;Mauliana, Phitsa; Firmansyah, Ricky ;Hunaifi, "Sistem Pakar Diagnosis Kerusakan Mobil Toyota Kijang LSX Menggunakan Metode Forward Chaining," *J. Khatulistiwa Inform.*, vol. 4, no. 2, p. 206, 2017.

[6] Rusdiansyah, "SISTEM PAKAR MENDETEKSI KERUSAKAN MESIN VVT-I BERBASIS WEB PADA KENDARAAN TOYOTA VIOS," vol. 13, p. 1, 2017.

[7] B. H. Hayadi, *Sistem Pakar*. Yogyakarta: Deepublish, 2018.

[8] B. H. Rukun, Kasman; Hayadi, *Sistem Informasi Berbasis Expert System*, 1st ed. Yogyakarta : Deepublish, 2017.

[9] S. R. Wicaksono, *Rekayasa Perangkat Lunak*. Malang: Seribu Bintang, 2017.

[10] A. rahmatul istiqomah Hardani; Jumari, Ustiawaty; Helmina, *Buku Metode Penelitian Kualitatif & Kuantitatif*. CV. Pustaka Ilmu Group, 2020.

[11] Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif dan R&D*, 3rd ed. CV Alfabeta, 2021.

[12] S. Mulyani, *Metode Analisis dan Perancangan Sistem*. Bandung: Abdi Sistematika, 2017.

[13] F. Marisa, *Web Programming (Client Side and Server Side)*. Yogyakarta: Deepublish, 2017.

[14] A. Kadir, *Membuat aplikasi web dengan PHP dan database MySQL*. andi, 2023.

[15] Y. D. Wijaya and M. W. Astuti, "PENGUJIAN BLACKBOX SISTEM INFORMASI PENILAIAN KINERJA KARYAWAN PT INKA (PERSERO) BERBASIS EQUIVALENCE PARTITIONS," *J. Digit. Teknol. Inf.*, vol. 4, no. 1, p. 22, 2021.

[16] Z. Nasir, Januardi; Haposan Gultom, "Sistem Pakar Untuk Mendeteksi Kerusakan Pada Sepeda Motor Dengan Menggunakan Metode Forward Chaining Berbasis Web," *J. Teknol. Inf. Komun. Digit. Zo.*, vol. 9, no. 1, p. 42, 2020.

[17] A. D. S. R. F. Zaki, "Sistem Pakar Menggunakan Metode Forward Chaining Untuk Mendeteksi Kerusakan Jaringan Internet (Studi Kasus : Di Layanan Internet Diskominfotik Sumatera Barat)," *J. Nas. Teknol. dan Sist. Inf.*, vol. 9, no. 1, 2023.