

Expert system for motorcycle damage diagnosis using certainty factor and case-based reasoning methods

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ABSTRACT

Motorcycles are the main mode of transportation that requires maintenance due to damage. Unfortunately, damage detection on motorcycles remains traditional, despite the potential for expert systems and artificial intelligence (AI) to facilitate more straightforward diagnosis for both motorcycle users and mechanics. That is why this research aims to develop a system with an expert system approach to diagnose damage to a motorcycle. This research applies the certainty factor (CF) expert system approach and the case-based reasoning (CBR) AI method. The study found that the expert system using the CBR method outperforms the CF method in diagnosing motorcycle damage. The CF expert system method achieves an accuracy performance of 98%. In comparison, the CBR expert system method achieves an accuracy of up to 100%, or can be equated with human mechanics in diagnosing motorcycle damage. The finding implies that CBR can effectively replace human experts in detecting motorcycle damage.

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1. INTRODUCTION

Motorcycles are the most commonly used mode of transportation in Indonesia due to their affordability and practicality [1]. The annual increase in motorcycle use ranks Indonesia at the top of Southeast Asia's list of motorcycle-using countries [1]. In the meantime, automatic motorcycles have become one of the vehicles with high daily performance [2], [3]. Motor vehicles require regular maintenance to prevent damage and ensure optimal performance [3]. Truly, the main complaint is that when a motorbike breaks down, it disrupts the user's activities [4]. So it makes sense if previous researchers suggested that motorcycle drivers should also pay attention to disturbances in their motorcycles [5]. Unfortunately, motorcycle damage detection remains traditional despite the possibility of adopting a computer-based system [6]. However, recent survey research indicates that induction motor failures result in significant performance losses and downtime [7]. Now is not the time to rely on traditional methods for diagnosing motor damage or failure. Transparent decision-making using expert systems and/or AI is essential [7]. Therefore, it is unsurprising that previous researchers have suggested using computer technology to improve motorcycle problem management [3]. In turn, it is necessary to develop an innovative system that facilitates easier repair of motorcycle damage for both motorcycle users and mechanics [8]. That is why this study aims to diagnose motorcycle damage and analyze the accuracy and percentage of diagnostic results using expert system computer intelligence technology.

Case-based reasoning (CBR) is an artificial intelligence (AI) approach to problem-solving [9]. It operates on the principle that similar problems have identical solutions [9], [10]. CBR is a method for predicting or estimating new events based on past case data [9]–[11]. The CBR method helps solve new problems by leveraging knowledge from similar past cases [10]. CBR is one of the most effective methods for leveraging a knowledge base to solve problems [12]. The highest level of similarity from the previous case is the solution to the CBR decision in solving new problems [10], [11]. CBR is the proper method for detecting damage to automatic machines [11].

In the meantime, knowledge-based expert systems help evaluate and process large amounts of data quickly, enabling the replacement of human expertise in responding to and solving specific problems [13]. Expert system CF utilizes rule-based inference engines to diagnose issues [14]. Expert Systems can analyze data in a very significant way to produce results [15]. Expert system have gained trust as problem-solving solutions by acting as specialists and applying knowledge from human experts [16], [17]. In short, expert system CF makes decision based on datasets that contain knowledge from human experts [18]. The CF method is a well-known inference engine that establishes independent causal assumptions [19] and employs a rule-based approach to derive final decisions [16]. However, previous researchers have recognized that system models can solve problems across various fields by favoring expert systems and artificial intelligence [20].

The latest survey research confirmed that none of the previous studies had simultaneously used expert systems and/or intelligent methods in diagnosing motor damage (work errors) [7]. Moreover, considering that CBR is an experience-based historical approach to solving new problems based on the similarity of events, in the sense that CBR in diagnosing (classifying) new cases is completely dependent on historical data (experience) [21]. In addition, consider the rule-based CF method for diagnosing problems that also depends on CF experts and CF users [14]. In other words, both methods have a close way or similarity to human work in diagnosing problems based on their expertise and/or experience. Therefore, this is the primary reason why the study conducted a motorcycle damage diagnosis using the CF expert system and the CBR AI approach.

The expert system approach is very competent in providing certainty based on evidence of events [22]. In cases of uncertainty regarding a problem's analysis, the specialist system approach can be an ideal solution to ensure informed decisions based on existing problem information, as an expert would [23]. Expert systems have gained recognition for their effectiveness in decision-making and problem-solving across various fields [20], [24]. Expert systems are a branch of AI [25] that can mimic human intelligence and expertise [18]. Likewise, as decision-making problems become increasingly complex, CBR, as an AI method, can deliver innovative decision solutions [26]. CBR offers the benefit of leveraging previous dataset solutions for new problem-solving tasks, making it well-suited for scenarios that require contextual understanding and informed decision-making [27]. Furthermore, CBR is an AI that has been widely applied in various domains, including management, medicine, and intelligent networks [28].

The results of this study have implications for knowledge related to the comparison of performance in diagnosing problems between the CF and CBR methods, with the latter being superior. Related to the advantages of CF and CBR, this background provides a basis for selecting and using these methods in this study. This research has novelty because it is research that previous researchers have not carried out in terms of research objects and research methods, including research by researchers [9], [24], [26], [27]–[34] (as shown in Table 1).

In short, reviewing related works confirms that this research addresses a topic that has not been explored by previous researchers. Santosa *et al.* [30] confirmed that the results of chicken disease diagnosis using the Dempster-Shafer method matched those of expert opinion with an accuracy of up to 95%. This prior study tested the proposed expert system on 40 cases. Previous studies have demonstrated that expert systems play a crucial role in empowering chicken farmers to diagnose chicken diseases effectively. This earlier research focused solely on the Dempster-Shafer method for diagnosis. In contrast, this article utilizes the CF and CBR methods.

At the same time, Oliveira *et al.* [28] presented a CBR approach to encourage its use across various fields of science, especially outside of computer science. The previous study provides only a methodological framework for applying CBR beyond the field of computer science. This study differs significantly from the research in this article in its aims, objectives, and methods. Meanwhile, the article by Glukhikh and Glukhikh [31] proposes a framework to support decision-making in complex technological systems. This research focuses on the challenges of utilizing alternative decision-making methods and analyzing similar databases of research subjects with various elements and environmental factors in technological settings. It advocates for the use of comparator-adder neural networks (CANN). This study differs from previous research regarding its methods, subjects, and objectives.

Anggrawan *et al.* [24] proposed a model for early diagnosis of learning disorders in children using the CF and Dempster-Shafer expert system methods. The object of this research article is not learning disorders but rather the diagnosis of motorcycle damage. So, not only does this study employ the CBR method, which the previous researcher did not, but it also has different objectives and research focuses that differentiate it from the previous research. This prior study concluded that the CF method is more accurate than the Dempster-Shafer method for detecting disease types in children. Meanwhile, Ramadan *et al.* [29] introduced a disease diagnosis model utilizing a forward-chaining expert system. Unlike the current article, which employs the CF and CBR methods, the previous study focused solely on the forward-chaining expert system. The earlier research focused on diagnosing poultry diseases rather than motorcycle damage. This study does not present the performance of the proposed expert system application in percentage terms, except to demonstrate that the model built can detect the type of disease affecting chickens by entering the symptoms of chicken disease.

Vandana *et al.* [33] diagnosed poultry diseases using convolutional neural networks (CNN) applied to fecal images. This study develops a model to identify chicken diseases by classifying images of feces exhibiting symptoms of healthy and unhealthy conditions. This prior research does not pertain to the CF or CBR methods, the diagnosis of motorcycle damage, or the development of an application program as described in this study. In the same year, Pradeep *et al.* [26] examined the synergy between CBR methods and explainable artificial intelligence (XAI) to develop an XAI platform. This study examines the alignment of CBR principles with XAI to enhance the transparency of AI reasoning. This previous study differs from the study presented in this article in terms of objectives and research subjects.

Isika *et al.* [32] identified various challenges in finding internships and, therefore, researched the presentation of a platform through the CBR model design to facilitate internship placement. This previous study utilized three datasets from information technology (IT), healthcare, and manufacturing to evaluate the performance of the CBR method in identifying internships. Earlier research on diagnosing motorcycle damage did not use CF methods beyond Dempster-Shafer; therefore, it differs from the research presented in this article. Meanwhile, Yan and Cheng [9] summarized the literature review on the development of CBR and its main challenges. Previous researchers' research on CBR is limited to a literature review rather than a trial research of the method for diagnosing machine damage. In the meantime, Desnelita *et al.* [35] proposed an expert system for diagnosing mental health disorders in adolescents, but their study relied solely on the CF method. In contrast, our article not only addresses a different research objective but also compares the results of CF and CBR methods in making diagnoses.

Table 1. Comparison of our work with several prior related works

Paper	Research category	Research approach		Research object		Performance status
		CF	CBR	Motor cycle	Using application	
[30]	Expert system	No	No	No	No	Achieving a diagnostic accuracy of 95% for chicken diseases using the Dempster-Shafer method.
[28]	AI	No	Yes	No	No	Not disclosing the accuracy performance of the offered models, beyond their potential performance, encourages the use of CBR computer science expertise across various scientific fields.
[31]	CANN	No	No	No	No	This experimental study demonstrates that the proposed neural network architecture outperforms a multilayer perceptron.
[24]	Expert system	Yes	No	No	Yes	The CF method achieves 90% performance, and the Dempster-Shafer method achieves 87%.
[29]	Expert system	No	No	Yes	Yes	Did not do performance testing
[33]	CNN	No	No	No	No	Identifying chicken diseases through fecal images with an accuracy of up to 97.07%
[26]	AI	No	Yes	No	No	The findings of this previous study do not reveal the performance of the results achieved.
[32]	AI	No	Yes	No	No	The accuracy performance of applying the CBR method in this previous study was 79% in the IT dataset, 83% in the Healthcare dataset, and 75% in the manufacturing dataset.
[9]	Literature Review	No	Yes	No	No	Previous researchers did not evaluate the performance of the methods they reviewed.
[35]	Expert system	Yes	No	No	No	This earlier research utilized the CF expert system method to diagnose mental health disorders.
[36]	Expert system	Yes	No	No	No	This study proposes a diagnosis of mental illness with CF.
[34]	AI	No	Yes	No	No	Proposed a model for lung cancer diagnosis using a CBR approach.
Our paper	Expert system and AI	Yes	Yes	Yes	Yes	The CF expert system method achieved 98% accuracy, whereas the AI CBR method achieved 100% accuracy, comparable to human mechanics' ability to diagnose motorcycle damage.

Zolfagharnasab *et al.* [36] was also diagnosed with mental illness with CF. The diagnosis of that study was limited to CF, which differentiates it from the study in our article, which included not only CF but also CBR. The subject of this previous study differs from ours. Tofighi *et al.* [34] proposed an CBR model for the early diagnosis of lung cancer. This study highlighted the significance of detecting lung cancer early through CBR AI. Both this previous study and the current article focus on using CBR for diagnosis. However, the two studies differ in their research objectives. Additionally, the earlier study limited the use of the CBR method and did not compare its results with those obtained with the CF method, a key aspect of our study.

Table 1 presents the study's objectives, method category, research approach, and focus, highlighting the differences between this study and some previous studies. In other words, this study is not a duplicate of prior studies and has a uniqueness that others do not. However, referring to the results of a literature review of several recent related works (as summarized in Table 1), this confirms that our study is not a copy of previous studies, but rather has novel findings. Essentially, our study of motorcycle damage diagnosis is a research that has not been conducted by previous researchers who applied the CF expert system method and AI CBR.

The specific contribution of this research to science is to demonstrate that the CBR method is an alternative method that is useful in making predictions, classifications, or diagnoses with high accuracy, because CBR is increasingly intelligent due to working on case-based experience that is continuously retained in the CBR system. Its contribution to society is helping in diagnosing motorcycle damage based on a system that can assist or replace human experts.

2. METHOD

This study's research method utilizes a flow diagram of the methodology model to develop a damage diagnosis system model for automatic motorcycles (see Figure 1). Data on the type of motorcycle damage tested in the study were from a Honda-brand motorcycle in Mataram, Indonesia.

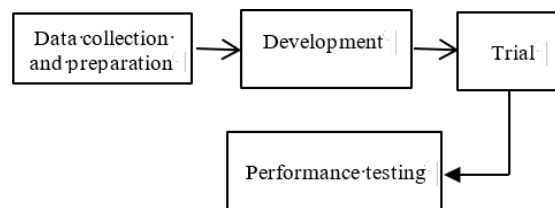


Figure 1. Flow diagram of research method

2.1. Data collection and preparation

Data collection and preparation involve gathering relevant information required for research, specifically focusing on motorcycle damage datasets. The dataset was compiled using secondary data on various types of motorcycle damage sourced from Honda motorcycle service workshops. Direct interviews were conducted with the head mechanic (mechanical expert) at Krida Honda motor Mataram to enhance the completeness of the research dataset. The collected dataset includes 64 symptom entries, 31 damage records, and 50 case lists that have been examined. This information serves as the basis for testing the accuracy and willingness of experts to determine the belief value for each symptom, ultimately producing a percentage value for this study. Tables 2, 3, and 4 provide an overview of the datasets collected and prepared for use in this research.

Table 2. Type of damage

No	Type of damage
1	V-Belt
2	Roller weight
3	Clutch lining
4	Secondary and primary pulley
5	Gear ratio
6	Foot starter
7	Front brake pad
8	Rear brake pad
9	Shock breaker
.....	
30	Lights (lamps)
31	Horn (horn)

Table 3. Symptom dataset

No	Symptom name	Symptom code
1	Weak acceleration	G1
2	Excessive vibration	G2
3	Noise or grinding sound	G3
4	CVT slip	G4
5	Performance decreased	G5
6	The motorcycle does not move even when running	G6
7	Engine RPM unstable	G7
8	Overheating	G8
....		
64	Changed exhaust sound	G64

Table 4. Knowledge base

Damage	Damage symptoms	Weight
V Belt	Weak acceleration	0.8
	Excessive vibration	1
	Noise or friction	0/2
	CVT slip	0.8
	Performance decreased	0.6
	The motorcycle does not move even when running	1
Roller Weight	Weak acceleration	0.8
	Excessive Vibration	0.8
	Noise or grinding noise	0.8
	CVT slip	0.6
	Performance decreased	0.6
	Engine RPM unstable	0.6
Clutch canvas	Weak acceleration	0.8
	Weak acceleration	0.8
	Excessive vibration	1
	Noisy or grinding sounds	0.4
	CVT slip	0.4
	Performance decreased	0.6
....		
		
		
		
		
		
Horn	Horn does not sound	1
	Horn sound is weak or not loud	0.8

2.2. Development

The program code in the research is an application that was developed. The development stage involves designing a motorcycle damage diagnosis system using the CBR and CF methods. The CBR method helps solve new problems by leveraging knowledge from similar past cases [10]. The CBR method involves four key processes: retrieve, reuse, revise, and retain [10]. Retrieval is the step of obtaining cases similar to the current problem. The reuse of previously stored cases addresses the new issue in this step. Revision is a process of modifying and adapting proposed solutions to suit the new situation. Finally, the retain step incorporates the solutions derived from new cases into the case database, updating it with relevant information for future use. The CBR calculation uses (1). S represents similarity (similarity value), with values of 1 (same) and 0 (different), while w represents weight.

$$\text{Similarity (problem, case)} = \frac{S_1 \times W_1 + S_2 \times W_2 + \dots + S_n \times W_n}{W_1 + W_2 + \dots + W_n} \quad (1)$$

The CF method helps overcome uncertainty by enabling more flexible and adaptive decision-making. In (2), (3), (4), and (5) are the CF formulas for calculation. $CF[h,e]$ represents the certainty factor (CF), $MB[h,e]$ represents the measure of confidence in hypothesis h , given evidence e (between 0 and 1). Meanwhile, $MD[h,e]$ measures disbelief in hypothesis h , given evidence e (between 0 and 1). In (3), $CF(H)$ represents the measure of user confidence, while $CF(E)$ represents the measure of expert confidence.

$$CF[h,e] = MB[h,e] - MD[h,e] \quad (2)$$

$$CF(H,E) = CF(H) * CF(E) \quad (3)$$

$$CF_{\text{combination}} CF(H,E)1 = CF(H,E1) + CF(H,E2) * (1 - CF(H,E1)) \quad (4)$$

$$CF_{\text{combination}} CF(H, E)_{\text{old}3} = CF(H, E)_{\text{old}} + CF(H, E)_3 * (1 - CF(H, E)_{\text{old}}) \quad (5)$$

The advantage of the CF expert system is its ability to diagnose various disorders by leveraging expert knowledge and user certainty [37]. CF produces decision solutions with a level of confidence based on hypothetical facts, so it has expertise with a truth-value error between -1 and +1, so its diagnostic performance exceeds the diagnostic performance of the bayes theorem method [38]. On the other hand, CBR plays an important role in AI because it diagnoses problems like human experts do [9], [21], utilizing experience from previous cases to solve new cases [21]. Therefore, the more experience of previous cases that are close and/or similar to new cases makes CBR more expert in diagnosing (providing solutions) new cases, or with more experience of solutions to previous cases, the CBR system's case base becomes wider in diagnosing new cases with correct results [9]. Thus, CF and CBR are two reliable methods for developing diagnostic methods: CF diagnoses based on human expert knowledge and user confidence while CBR diagnoses new cases like humans by utilizing experience from previous cases. In other words, the CF and CBR methods mimic the work of human experts in diagnosing a problem, drawing on their expertise and experience. Therefore, comparing the performance the CF and CBR methods is essential in research. The design of a CBR system does not require rule creation, as CF does, but only requires the collection of previous cases and retrieved cases as precedents to support decisions. This also distinguishes it from machine learning, which provides diagnostic results (predictions) from rules induced from training data against testing data (diagnosed cases). Figure 2 presents the data flow diagram (DFD) of the CF expert system and AI CBR in diagnosing new cases.

The performance tests for CF and CBR in this study used the same damage symptom data. The diagnostic results from CF and CBR were compared with the actual damage observed from the damage symptoms. The differences in the diagnostic performance tests for CF and CBR lie in the stages of the test process and the use of different equations.

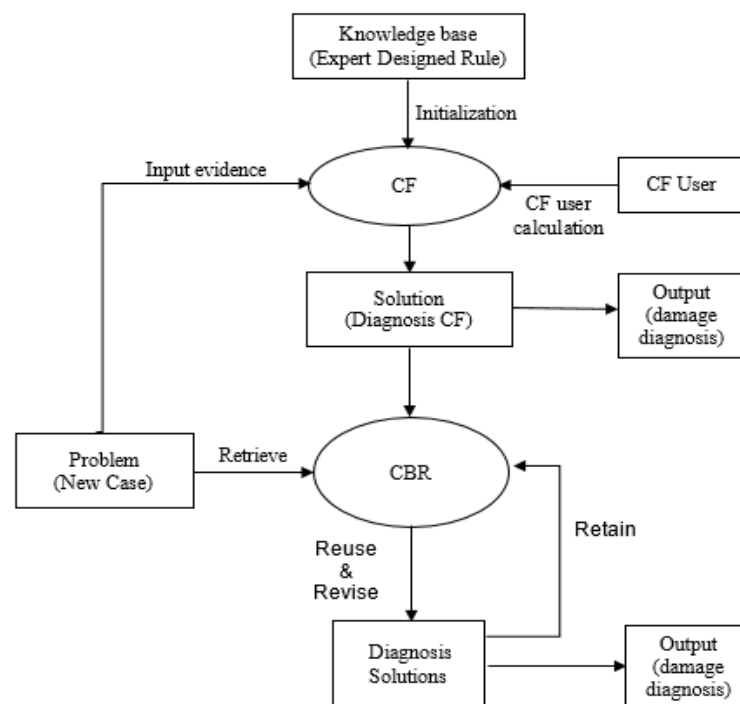


Figure 2. DFD of the CF expert system and AI CBR

3. RESULTS AND DISCUSSION

This section describes the result and discussion (implementation) of the motorcycle damage diagnosis system. The theoretical testing in this study involves manual calculations on cases with 5 symptoms of motorcycle damage. Table 5 presents an example of motorcycle damage and its accompanying symptoms. The diagnostic process consists in comparing diagnostic results from manual calculations with those from the application system.

Table 5. Damage case

Code	Damage symptom
G5	Performance decreased
G13	Fuel consumption
G29	Unstable idle
G31	Check the engine light on
G56	The Engine could not start

3.1. CBR expert system trial

During the retrieval phase, new problem cases (X) are used to search for the most similar cases in the database. This process involves comparing new instances (X) with older cases to identify which older cases best match the new case's characteristics. Table 6 shows an example of the relationship between weight and similarity in old cases. From case X, the similarity between the new case X and the old case of injection (carburetor) is 0.833. The next step is to reuse this step to match the similarity value between manual calculations and system calculations. In this case, manual calculations for new cases yield results similar to those for old cases, specifically Injection or Carburetor, with an accuracy of 0.833 (83.3%). The results on the system also match this accuracy level, at 83%. Thus, the solution provided in servicing is that the fuel system and injectors work well, check fuel pressure; clean and replace fuel filters, check and repair electrical systems and sensors; check and repair wiring and connectors; check and adjust the fuel system; check engine conditions, and use fuel that gets quality recommendations.

Next, the revise process reviews the case data and solutions provided during retrieval if the system does not provide an appropriate diagnosis. The similarity value obtained in the previous test data case example is 83.3%, and it directly displays the resulting solution. Next, after obtaining the resulting solution from the new case, the retain system process saves it as a new entry in the expert system database, along with the type of damage, symptoms, and solutions. This new entry in the database improves the system's ability to solve future motorcycle damage problems of the same type, or it is generally useful in improving the system's ability to solve motorcycle damage problems.

Table 6. Example of weights and similarities of old cases

Old case	Weight	Similarity
The engine will not start	1	1
Idle is unstable	0.6	1
Performance decreases	0.8	1
Fuel consumption is poor	0.8	1
Acceleration is weak	0.8	0
Checking engine light is On	0.8	1

3.2. CF expert system trial

For example, damage 13 (injector or carburetor) has only five symptoms: decreased performance (G5), Wasteful Fuel (G13), Unstable Idle (G29), Check Engine Indicator Light On (G31), and Engine can not be Started (G56), as per Table 7. Table 8 displays the results of the CF expert multiplied by the CF user. Meanwhile, Table 9 shows the combined calculations of G5, G13, G29, G31, and G56. The results of the motorcycle damage diagnosis, with a confidence level of 0.9998 (99.98%), indicate damage to component 13, attributed to a fuel injector.

3.3. Performance testing

The expert system's performance in diagnosing motorcycle damage in this study shows that CBR has higher accuracy than CF. Table 10 presents the results of the performance test conducted for the CBR and CF systems, compared with those of the CF expert. The performance test results showed that the CF method achieved 98% accuracy in diagnosing motorcycle damage. At the same time, CBR had the same accuracy as a human expert in analyzing the type of damage to a motorcycle. The study findings confirm the opinion of previous researchers, such as [12], that CBR is the most effective method for addressing problems. The performance test results for CBR in diagnosing or classifying motorcycle damage achieved 100% accuracy. The high accuracy of the CBR method is achieved through learning from experience, namely, diagnosing new cases by searching for similar past cases and using them as the basis for decision-making solutions. In other words, CBR has the ability to learn (from experience) by collecting new cases over time without having to add new rules.

Table 7. CF expert

Symptom code	CF expert
G5	0.8
G13	0.8
G29	0.6
G31	0.8
G56	1

Table 8. CF expert multiplied by CF user

Symptom code	CF user	CF expert	User and expert multiplication results
G5	0.6	0.8	0.48
G13	1	0.8	0.8
G29	0.6	0.6	0.36
G31	0.8	0.8	0.64
G56	0.8	1	0.8

Table 9. CF combined result

Symptom code	CF calculation
Combination 1	$= 0.48 + 0.8 (1 - 0.48) = 0.896$ or 89.60%
G5 with G13	$= 0.896 + 0.36 (1 - 0.896) = 0.933$ or 93.30%
Combination 2	$= 0.933 + 0.64 (1 - 0.933) = 0.999$ or 99.90%
G5, G13 with G29	$= 0.999 + 0.8 (1 - 0.999) = 0.9998$ or 99.98%

This means that by retaining the CBR process, the experience of diagnosing evidence of symptoms and new cases that have been properly diagnosed allows the dataset to store more experience data, making CBR increasingly intelligent in diagnosing correctly. It is like a medical doctor who has previous experience in treating a particular patient's illness; the medical doctor will become increasingly expert in finding solutions to cure the patient's illness. Besides that, testing the performance of the CBR method in this study is an advantage, as it has not been carried out by previous researchers, either by researchers [26] or [28]. The performance of CBR in this study on the motorcycle damage dataset achieved a superior level of accuracy compared to previous research conducted by [32] which only achieved a performance of 79% in the IT dataset, 83% in the Healthcare dataset, and 75% in the manufacturing dataset.

This study found that CBR has perfect accuracy and is superior to CF. Because the findings of this study demonstrate that CBR's ability to diagnose motorcycle damage is comparable to that of human experts in motorcycle repair, the results of this study also align with the opinion of previous research by [11], which suggests that CBR is the most suitable method for detecting damage to motorcycle machines. In other words, the findings of this study confirm that AI systems facilitate high-accuracy diagnosis of motorbike damage and conclude that expert systems and AI methods have gained recognition for their effectiveness in decision-making and problem-solving across other fields outside of computer science. In addition, this study's findings support previous research [13] showing that systems with expertise can help human experts in addressing and solving specific problems. In short, the method proposed in this study, especially the AI CBR method, achieves very high accuracy and outperforms the CF expert system method, which has been widely used by previous researchers in diagnostic research.

The study results align with the view of previous researchers [26] that CBR, as an AI method, can provide innovative decision solutions. This study's results also confirm that expert systems facilitate high-accuracy diagnosis of motorbike damage. The findings of this study reinforce previous findings [22], [23] that the expert system approach is highly effective at providing decision certainty based on evidence of events, making it an ideal solution for ensuring expert-level decision-making in diagnosing existing problems. The findings of this study, which demonstrate that CBR outperforms existing methods in diagnosing damage to motorbikes and exhibits human-like performance without errors, are novel and have not been reported by previous researchers, including those of [9], [24], [26]-[34].

However, given the wide range of diagnostic methods available, this study's limitations lie in its limited use of the CBR and CF methods and in its comparison of their predictive/diagnostic results. Further research should also incorporate other approaches. The results of this study have implications for understanding the diagnostic performance between CF and CBR methods, with the latter being superior. Future studies could prioritize the diagnostic importance of AI CBR over CF methods, given its superior performance. Furthermore, previous research confirms that expert systems are a branch of artificial intelligence [25] capable of imitating human expertise [18]; our findings corroborate this. Similarly, with

increasingly complex decision-making problems, CBR, as an AI method, can provide innovative decision solutions [26], as demonstrated by our research results.

Table 10. Performance test of motorcycle damage diagnosis accuracy results

No	Symptom code	Expert	Test result		Information	
			CBR	CF	CBR	CF
1	G1, G5, G13, G29, G31	Injector	Injector 79%	Injector 100%	v	v
2	G5, G1, G3, G7, G4	Roller	Roller 81%	Roller 99%	v	v
3	G1, G2, G3, G4, G5	V-belt	V-belt 95%	V-belt 100%	v	v
4	G13, G29, G5, G37, G56	Spark plug	Spark plug 87%	Spark plug 100%	v	v
5	G5, G13, G32, G29	Air filter	Air filter 93%	Air filter 100%	v	v
6	G8, G3, G35, G36	Lubricant (oil)	Lubricant 100%	Lubricant 97%	v	v
7	G8, G34	Cooling system	Cooling system 67%	Cooling system 100%	v	v
8	G63, G2, G5, G4, G7	Clutch plate	Clutch plate 71%	Clutch plate 95%	v	v
9	G43, G41, G42, G29	Throttle gas	Throttle gas 100%	Throttle gas 100%	v	v
10	G16, G19, G20, G22, G18	Front brake pads	Front brake pads 86%	Front brake pads 100%	v	v
11	G16, G19, G21, G23	Rear brakes	Rear brakes 100%	Rear brakes 97%	v	v
12	G61, G62	Horn	Horn 100%	Horn 100%	v	v
13	G59, G60	Lamp (light)	Lamp (light)100%	Lamp (light)100%	v	v
14	G28, G44, G45, G47	Battery	Battery 83%	Relay coil 99%	v	x
15	G48, G47, G49	Alternator	Alternator 100%	Alternator 98%	v	v
16	G47, G50, G51	Regulator rectifier	Regulator rectifier 100%	Regulator rectifier 100%	v	v
17	G52, G46, G53	Fuse	Fuse 100%	Fuse 100%	v	v
18	G54, G55	Switch	Switch 100%	Switch 100%	v	v
19	G56, G37	Ignition key	Ignition key 100%	Ignition key 100%	v	v
20	G46, G28, G57	Relay	Relay 100%	Relay 100%	v	v
21	G28, G37, G58, G5	Ignition coil	Ignition coil 93%	Ignition coil 100%	v	v
22	G28, G37, G40, G31	Engine control M.	Engine control module 94%	Engine control module 99%	v	v
23	G8, G33, G34	Cooling system	Cooling system 100%	Cooling system 100%	v	v
24	G9, G2, G3, G7	Pulley	Pulley 100%	Pulley 94%	v	v
25	G1,G10,G12,G11,G17, G3	Gear ratio	Gear ratio 91%	Gear ratio 98%	v	v
26	G14, G15, G3	Foot starter	Foot starter 100%	Foot starter 96%	v	v
27	G24, G25, G26	Shock breaker	Shock breaker 83%	Shock breaker 100%	v	v
28	G5, G13, G30, G27, G3	Piston cylinder	Piston cylinder 100%	Piston cylinder %	v	v
29	G5, G28, G29, G13, G30	Valve	Valve 100%	Valve 96%	v	v
30	G5, G56, G29, G37, G13	Spark plug	Spark plug 93%	Spark plug 100%	v	v
31	G2, G24, G25	Shock breaker	Shock breaker 83%	Shock breaker 100%	v	v
32	G48, G49	Alternator	Alternator 75%	Alternator 100%	v	v
...					...	...
48	G1, G2, G3, G5, G63	Clutch pads	Clutch pads 86%	Clutch pads 97%	v	v
49	G3, G5, G13, G30	Cylinder and piston	Cylinder and piston	Cylinder and piston	v	v
50	G56, G5, G37, G38	Fuel pump	Fuel pump	Fuel pump	v	v

4. CONCLUSION AND FUTURE WORK

This study found that the CBR and CF expert systems achieve high diagnostic accuracy in diagnosing motorcycle damage. This study demonstrates that CBR achieves an accuracy rate of up to 100% and a CF of 98% in diagnosing motorcycle damage. The CBR method is more accurate than CF for diagnosing motorcycle damage. That means that the CBR AI method is the most suitable for detecting damage to automated machines compared to the CF expert system method. The findings of this study reinforce the opinions of several previous studies, including that CBR is the most effective method for solving problems. The results of this study also support the view of prior researchers who asserted that expert systems are effective for decision-making in problem-solving. The findings also support previous research that systems with expertise can help human expertise in addressing and solving specific problems.

These findings imply that CBR is a useful diagnostic model for replacing human experts in detecting motorcycle damage. The findings of this study offer novel insights that have not been explored using the same method as previous researchers in diagnosing motorcycle damage. The shortcomings of this study are limited to the use of research methods that focus solely on CBR and CF; proposals for further research incorporating other methodological approaches are offered. Besides that, further research is needed across different datasets to determine differences in diagnostic performance between CF and CBR, and to ascertain whether CBR remains superior to CF. It is also necessary to conduct additional research using other AI methods, including machine learning methods.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nvestigation

R : **R**esources

D : **D**ata Curation

O : Writing - **O**riginal Draft

E : Writing - Review & **E**diting

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

DATA AVAILABILITY

The data used in this study can be accessed via the link provided in the subheading titled "Data Collection and Preparation".

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