International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:5, No:3, 2011

Integrated Reasoning Approach for Car Faulty Diagnosis

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***Abstract*—**This paper presents an integrated case based and rule based reasoning method for car faulty diagnosis. The reasoning method is done through extracting the past cases from the Proton Service Center while comparing with the preset rules to deduce a diagnosis/solution to a car service case. New cases will be stored to the knowledge base. The test cases examples illustrate the effectiveness of the proposed integrated reasoning. It has proven accuracy of similar reasoning if carried out by a service advisor from the service center.

***Keywords*—**component; case based reasoning (CBR), rule based reasoning (RBR), decision support systems, diagnosis tool.

I. Introduction

AN automobile is a highly complex collection of various part and components. It is always very difficult to identify the exact problem for the first time. When the car isn't starting, there could be many reasons for it. For instance, the petrol could be empty or the battery could have gone flat. Despite fundamental understanding of a car repair, it still often requires a thorough examination before being able to conclude the faulty area and perform the fixes. The motivation for this research paper stems from the following problems/ opportunities:

A. Complexity of Car System: A car system is complex and there are many parts involved to make the car runs. Knowing the best solution to repair a car problem will be more effective with an organized knowledge of the experts.

B. Expert Systems for Faulty Diagnosis: A good faulty diagnosis system will help the users to learn and understand car problems over the time. Users will also be taught to do basic car inspections if the problem is easier to solve.

C. Repository of Experts' Knowledge: The experts refer to the Service Advisor and technicians of Proton Edar Service Centre. The repository will store all the knowledge gained from the diagnosis process of the system.

D. Reasoning Technique: The system will advise users to find the problem by rules so that the most accurate diagnosis can be determined. It also allows users to retrieve past cases of car problems and adapt it with the new case they are facing.

E. Cost and Relevance: The approach will be able to minimize operation time and cost. There will be improved quality of service, ultimately leading to increased customers' satisfaction.

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In doing so, this research studies the application of case based and rule based reasoning method in assisting decision making. This involves identifying the process to solve a car service problem recall from a previous similar situation or from a matching rule(s), use that knowledge and adapt it and apply to current problem.

II. Literature Review

Case Based Reasoning (CBR) is a decision making technique that reuses past cases stored in a case base to solve a new problem. Usually each case has a case specification part and a solution part [1]. Differs from traditional rule-based systems, CBR is not represented in rules but in examples. CBR is originated from the field of Artificial Intelligence (AI) as their ideas are based almost like how people logically approach the task of solving problem [2]. The ability to utilize specific knowledge of previously experienced, concrete problem cases makes CBR different from other major AI approaches. CBR is the most suitable method to explain why a certain solutions are proposed [3]. CBR process involves four main activities and can best be represented by a schematic cycle which includes the four RE's: Retrieve, Reuse, Revise, and Retain. A case refers to the record of a previous experience or problem.

- Retrieve is the process of querying the case-base to search for previous instances that match [2]. By calculating the similarity of the query (problem) to the case library, the system will retrieve the most similar cases out from the library to match the query.
- In reuse process, the goal is to use the solution of previous case in solving a new problem [4]. The suggested solution must be confirmed by the mechanic that it is the correct solution for the problem.
- The next process is revising the proposed solution [5]. If the solution proposed by the system was an exact or very close for the problem in question, the retrieved case needs no revision and the case-base will not be updated. However, if the retrieved case is not an exact match then the case will be modified thus producing a new case.
- The final stage is retaining the parts of experience likely to be useful in future problem solving [6]. In this stage, the case base is updated by a new learned

case or by alteration of existing case after being revised in the previous process.

In the context of car fault diagnosis, retrieving past cases stored in the case base can reduce the knowledge acquisition task needed to get into the solution of critical car problems [7]. If the CBR is implemented, the knowledge management awareness level becomes higher in Proton organization. The users get to discover new problems and new solutions based on the car faults found thus it increase learning over time. CBR avoids repeating the same mistakes. The system allows retrieval and adaptation made from past cases to predict failures in the future [6], [8]. As CBR reflects human reasoning in real life, it becomes easier to convince users of the validity of each solutions arrived.

An example of CBR for fault diagnosis is discussed in Eremeev and Varshavskiy [8], in the CBR method for real-time expert diagnostics systems. The complex architecture with various interrelations, a lot of controllable and operated parameters and small time for acceptance of operating influences are the major subject that the authors mentioned. A software (Case Libraries Constructor – CLC) is created using Borland C++ to help the system in diagnose and detect operations. K-nearest neighbors' algorithm is being used to find similarity degree of current case situation with past cases the CLC described.

Rule Based Reasoning (RBR) represents the mean of codifying problem-solving knowhow of human intelligence [9]. A RBR is an assessment to derive decision recommendations based on the production of rules [10]. Its approach is suitable mostly for knowledge demanding expert system. The rules are usually represented in the form of:

IF condition is true
THEN draw conclusion or perform action

Frederick [9] points out that RBR incorporates practical human knowledge in condition if-then rules, has the ability to explain a wide of possible difficult problems by selecting relevant rules and combining the results in a suitable way, and explains conclusions by repeating the actual lines of reasoning, then interpret the logic of each rule employed into a natural language. Although researches in AI field developed several alternatives to develop a knowledge-intensive system, only RBR that consistently produce expert problem solvers. In a typical RBR, inference engine and a knowledge base will take place. The knowledge base contains rules and facts while the inference engine work as working memory to explain the rules for user understanding. Rules can be produced from a decision tree. Combination of nodes will bring the user to last node that we deemed as the solution or the THEN part.

Similar to CBR, RBR has its own advantages. RBR represent problem solving know-how in a suitable manner, it modularizes chunks of knowledge, and it makes decision making more intelligible and explainable. RBR uses deductive reasoning approach thus it is widely used by existing expert system [11]. It employs existing domain knowledge as set of rules to suggest with new problem found by user. Al-Taani [12] points out an expert system for car failure diagnosis using set of rules in RBR. An inference engine decides which rules satisfied the facts stored in working memory when an abnormal situation arises in the car. A rule based shell called CLIPS keeps the knowledge in the form of rules. The implementation of forward-chaining rule language in CLIPS has shown a boost popularity and acceptance by end users. In short, the system is practical and can be extremely useful in providing consistent car failure detection. It also reflects characteristics of good expert system such as ample response time, understandability and high performance.

The first reasoning modality successfully incorporated with CBR was RBR [7]. CABARET is among the first CBR/RBR system built in the field of statutory legal domains [13]. The integrated system combines a CBR system with an explanation mechanism which contains the domain theory to perform problem solving tasks. It eliminates the drawback of inductive reasoning of CBR and deductive reasoning in RBR. The interpretation problem of governing rules that often have words or phrases that cannot be defined precisely can be overcome using this system [13]. In computerizing this type of hybrid knowledge representation and the consequent reasoning processes, the system should allow users to pick the best reasoning method to solve new problem [14].

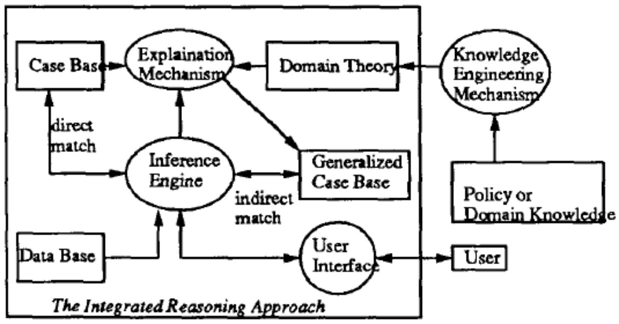

Fig. 1. A Model for Integrated Reasoning Approach [11]

Architecture of the integrated reasoning approach consists of:

- Inference engine as a working memory of RBR and CBR, it also controls explanation mechanism
- Policy or domain knowledge is manipulated by knowledge engineering mechanism to create rules in the domain theory
- Database to store the facts and interactive user interface. User will enter new case via user interface. When a match found between in the database, the system can be deemed as successful. If the diagnosis not successful, user can choose either way of CBR/RBR.

A few advantages that need to be stressed here are the system minimizes effort for fault management process to save cost [15]. Accuracy of results will be stronger [16]. Problem solving capability is improved through the method provided and the explanation mechanism. Flexibility in both reasoned modeling also makes the system more adaptive to survive in dynamic environment.

III. Related Work

A. CAMPER

CAMPER is a hybrid approach of CBR/RBR in nutritional menu planning. A nutritional menu planning system was built to incorporate the strengths of RBR and CBR. CAMPER will replace nutritionist task which is to design daily menus according to certified nutrition guidelines and aesthetic standards for color, texture, temperature, taste and variety. Its database contains of 608 food items, 94 terminals of rules subset and a lots of cases. A “what if” analysis is modeled inside the system allows users to replace food and CAMPER will provides a choice of alternative foods that could similarly fulfill the same role. It displays nutrient effects of each change to a menu. When a new case found, CAMPER has the ability to store the case base menus inside the case base. User needs to understand how CAMPER expands role of the case. CAMPER approach allows user to derive benefit from cases in two different ways: A reusable solution and useful abstraction to define a range of possible solutions.

B. ScheduleCoach

ScheduleCoach is a project scheduler that solves the problem of contractors to compare and contrast their project with many experienced, senior project managers. This system analyzes a project schedule and provides suggestion for revision to create a better prospect of project. It looks for potential schedule errors based on rules and suggests corrections using CBR method. ScheduleCoach benefits the users by its ability to identify errors that have potential to occur and advise revision. Thus it reduces time required by the schedule reviewer to perform his task while maintaining the quality of the review.

IV. Methods

The initial research work was carried out to study the components of case based and rule based reasoning. An interview was conducted at the Proton Service Center to understand the AS-IS processes in place for car faulty diagnostic. The subsequent development of the integrated reasoning system follows a prototyping system development method as shown in Figure 2.

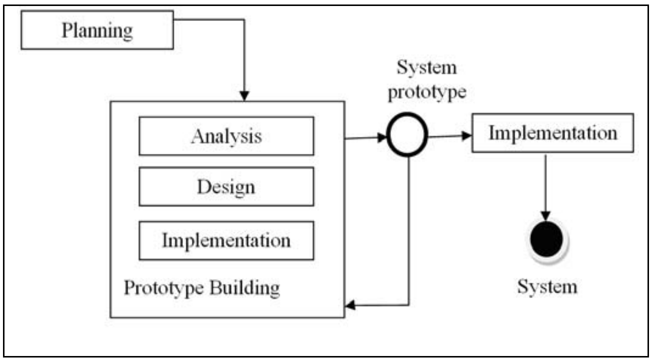

Fig. 2 Prototyping Method

The method presents a repetition of series of activities after the planning phase to produce different versions of prototypes prior to actual implementation. The technology used to develop the system includes Microsoft Visual Basic and Microsoft SQL Server. Figure 3 depicts the framework for the development.

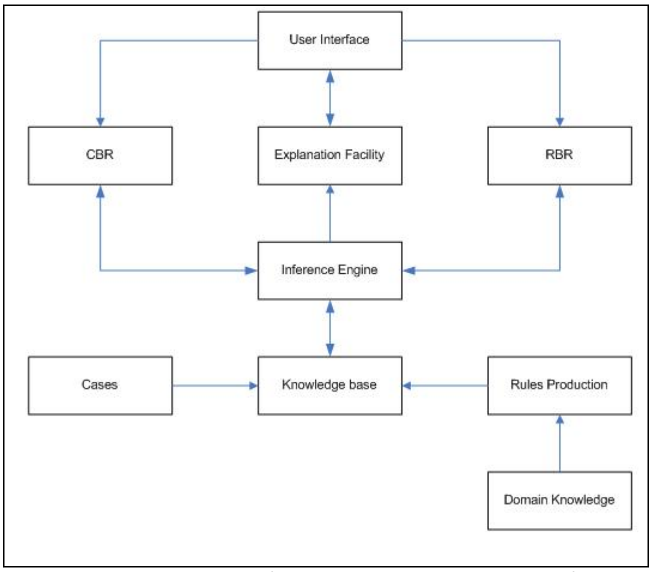

Fig. 3 System Architecture for Integrated Reasoning Method for Car Faulty Diagnosis

The proposed architecture explains the various components such as:

- User interface allows user to register themselves and make an option whether to find a new case using RBR or CBR,
- Explanation facility is the part that explains the user step they have taken to measure a fault of the car that lead to a root cause finding. The cases that found during the retrieval part of past cases will also be presented in the most presentable method here. So that users can understand the explanation given well.
- Inference engine is the working memory of the overall system. It derives proper answers from the case based and rule based using a computing technique (See Figure 4 and Figure 5). The architecture relies on the working memory and database of facts and assertions about car problem. The reasoning production is generated from domain knowledge.

The RBR framework consists of two parts: Measure Module and Real-time Diagnosis. For the measures module, the objective is to detect the measurement taken by the user to find the root cause of a car problem. Each root causes have a set of measures that will lead to it. The system will get the measures input from the user and compare the input in each rule. For the Diagnosis module rule, it will take the result of the measures module and use it as an input to suggest the solution for the patient. It will use the same similar ‘If-Then’ concept.

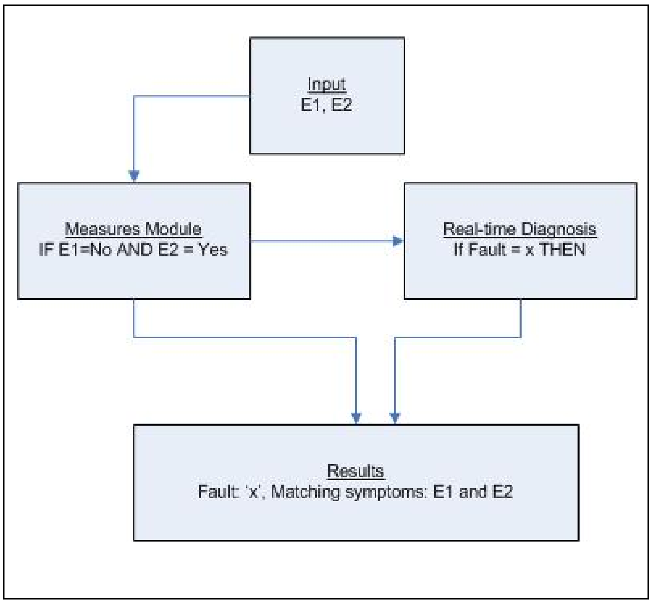

Fig. 4 RBR Framework

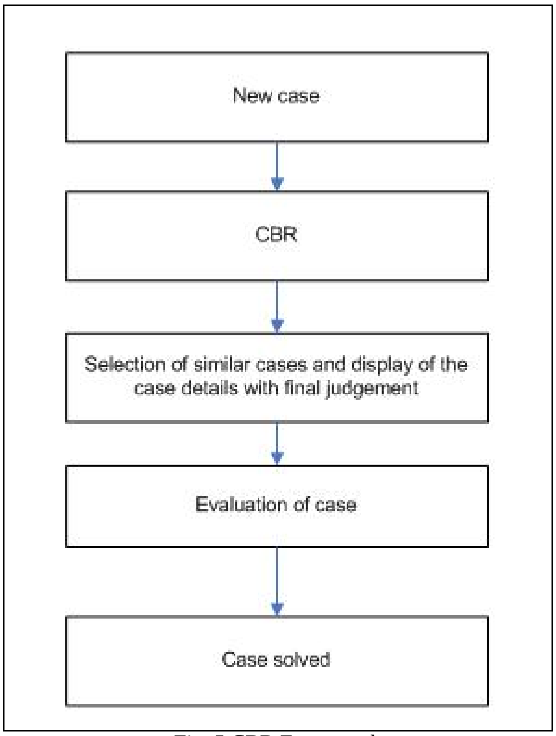

Fig. 5 CBR Framework

The CBR framework will do its basic 4REs' cycle if the user chooses to diagnose a case using this system. A user will query inputs into the system. CBR will retrieve cases inside the case base by looking for the keyword that matches the cases inside it. Then similar past cases and the solution taken will be displayed to the user according to its match strength. The concept of similarity measure allows retrieval process to be fine-tuned to better fulfill its purpose. Now the user can evaluate the past case and adapt it into their query to create a new case. Case indexing is important for future retrieval and comparisons of the cases. The choice of indices is crucial to being able to retrieve the right case at the right time. Thus, the most abstract case attribute chosen is the part and the diagnosis description.

CASE ID: 1
CAR NAME: SAGA
CAR MODEL: 1.3 AUTO
PART: BRAKE
MILEAGE: 11111 KM
DIAGNOSIS DESCRIPTION: Reverse sensor not sensitive; Replace front wiper arm and blade
SOLUTION: To rectify wiring socket; To replace wiper arm

Fig. 6 Example Representation of a Case

V. Results and Discussion

Four interviews were conducted in different Proton service centers in order to better understand the services that Proton offers and systems that they are using - Proton Edar Service Centre Bandar Seri Iskandar, Proton Edar Service Centre Menglembu,, Powertrain Department Engineering Division, Proton Sdn Bhd, and Proton Edar Service Centre Petaling Jaya Section13. According to the Proton personnel from different departments, the current data management system that they are using is the SAP 5.1 system. SAP replaced the previous system used by group-wide Proton Service Centre which is the Enterprise Planning Resource (ERP). SAP able to link data from other department such as Human Resource, Finance, and R&D Department but it is not integrated with other branches database like ERP do.

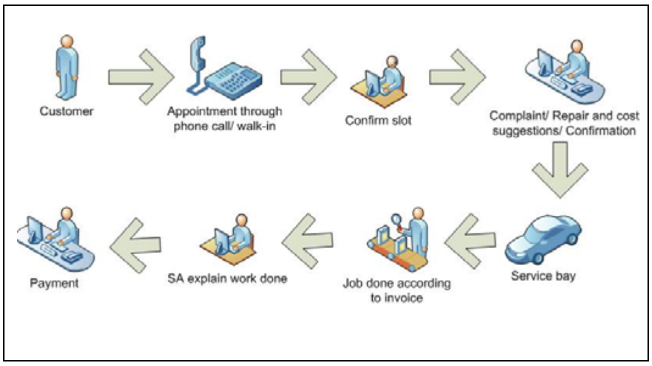

Fig. 7 Proton Service Process

Figure 7 illustrates the process of dealing with car servicing at Proton. To perform a car service at Proton Service Centre, customers will have to book slot appointment by telephone or walk-in. The customer will set the time and the receptionist will confirm the slot. When the customer come in, they will make complains of the car problems to the Service Advisor (SA). Sometimes the customer does not know the detail of the service their car needed, so the SA will inspect the car according to the importance and tell the customer what his findings are. The customer then will be explained about the suggested solutions of each car problems found and the costs of the service. Upon agreement the car will be brought to the Service Bay to be serviced. The SA will bring the invoice of job to be done by the technician at the materials room. SA will get all the parts required as in the report and the technician will precede with car servicing. After all the works are completed, the mechanics will confirm with the SA about the job status and customer will have to make payment at the registration table. The SA will explain the work done and a few tips will be given to the customer to help them care for their car better. Based on the interview findings, it is confirmed that there is still no single system created to manage the knowledge of the people working with Proton that may benefit the Proton customers. The integrated reasoning approach for car faulty diagnosis system will help users itself to capture car fault and solution in the most interactive and cost efficient way.

A. RBR Strategy: A decision tree for finding faults when car cannot start will be converted into IF-THEN rules. User will choose multiple inputs of problems that occurred in their car. A set of measures will be given according to part causing problem. The IF-THEN that has been created beneath the system will generate the possible actual faults that actually occur. The result of the diagnosis should show the measures taken and the solutions for root cause are suggested.

TABLE I. SNIPPETS OF RBR STRATEGY

ID	Rules	Root Causes
R1	E1 = 0, E2 = 1	Solenoid stuck, not powered, missing teeth on flywheel
R2	E1 = 0, E2 = 0, E3 = 0	Jump start or pop start car and check if battery is charging
R3	E1 = 0, E2 = 0, E3 = 1, E4 = 0	Clean battery terminals and connectors, engine ground
R4	E1 = 0, E2 = 0, E3 = 1, E4 = 1	Car parked in neutral, use heavy jumper or screwdriver to bypass starter relay solenoid, test starter
R5	E1 = 1, E5 = 0, E6 = 0, E7 = 1, E9 = 0	For electronic distribution, see model manual for diagnostic checks
R6	E1 = 1, E5 = 0, E6 = 0, E7 = 1, E9 = 1	Check condenser, points or magnetic pick-up, rotor or cap damage
R7	E1 = 1, E5 = 0, E6 = 0, E7 = 0, E8 = 0	Ignition system wiring, Voltage regulator

B. CBR Strategy: If the user cannot find the root cause of car problems using RBR strategy, CBR will take place. Users also can directly choose to diagnose with CBR without experiencing RBR first. CBR provides more detailed prospect compared to RBR. It is because CBR will try to retrieve past cases to find similarity with the new case queried by the user. The case will be retrieved alongside with the solution taken. Thus, CBR helps better in decision making. Cases in CBR is generated from examples of Service Receipt that customer received after making a car service at Proton Service Centre.

Finally, several test cases were performed through testing out with the service advisor personnel and a Proton customer. The user will enter the measures listed in the system. The system is then tested by doing a series of test cases, where several measures are inserted and the diagnoses given by the system is compared to the final diagnosis that the service advisor provided. The results of the test cases through the integrated reasoning method are proven coherent to the service advisor's diagnosis. The following Figure 8 and Figure 9 depict the example of test cases.

TABLE II SNIPPETS OF CBR STRATEGY

ID	Car Model	Part	Diagnosis	Solution
C1	Wira 1.5 Manual	Engine	Engine abnormal sound noise while idle and accelerate; Front right side signal light malfunctioning while use emergency button; Front right side door hard to close	To adjust lay out NGV pipe; To replace hazard switch (Part order); To adjust the door
C2	Waja 1.6 Manual	Engine	Engine or belting area sound noise; Check alignment, balancing and tyre rotation; Check clutch paddle noise	To lubricate belting; To replace worn out tyre; To lubricate and suspect clutch release bearing
C3	Neo 1.6 Manual	Electrical System	Reverse sensor not sensitive; Replace front wiper arm and blade	To rectify wiring socket; To replace wiper arm
C4	Perdana V6 Auto	Steering	Steering wheel area make noise when starting engine; Scratching sound during braking	To replace front steering lower arm; To replace brake pads front

Configured Rules Involved: IF *Starter cranks = No* AND *Starter spins = Yes* THEN *Solenoid stuck, not powered OR missing teeth on flywheel*
Measures Chosen : Starter spins
Final diagnosis provided by user: Missing teeth on flywheel
Diagnoses given by the system : Solenoid stuck, Solenoid not powered, Missing teeth on flywheel
Was the expected final diagnosis given : Yes, there are missing teeth on flywheel

Fig. 8 Example of RBR Test Case

Query by users: Car Name : Saga BLM Car Model : 1.3 Auto Part/System : Engine, Clutch Mileage : 4444 km Diagnosis entered: Engine make noise when idle; Clutch noise
Similar case retrieved: Case 1: Car Name: Wira Car Model : Wira 1.5 Manual Part: Engine, Others Mileage: 7500 km Diagnosis entered: Engine abnormal sound noise while idle and accelerate; Front right side signal light malfunctioning while use emergency button; Front right side door hard to close Solution Done: To adjust lay out NGV pipe; To replace hazard switch (Part order); To adjust the door
Case 2: Car Name: Waja Car Model : Waja 1.6 Manual Part: Engine, Clutch Mileage: 156684 km Diagnosis entered: Engine or belting area sound noise; Check alignment, balancing and tyre rotation; Check clutch paddle noise Solution Done: To lubricate belting; To replace worn out tyre; To lubricate and suspect clutch release bearing
Final Diagnosis Case After Adaptation Car Name: Saga BLM Car Model : Saga 1.3 Auto Part: Engine, Clutch Mileage: 4444 km Diagnosis entered: Engine make noise when idle; Clutch noise Solution Done: To adjust lay out NGV pipe; To lubricate and suspect clutch release bearing

Fig. 9 Example of CBR Test Case

VI. Future Work

The initial stage of this project had given the exposure of understanding of how to develop an integrated rule-based and case-based reasoning. The next part is to capture the diagnostic knowledge from either reading or by interviewing the experts. Using the integrated RBR and CBR allows the system to function immediately, as long as the facts and rules have been stored in the system. The system intelligence does not need to be train. But in order for the system to be accurate, the rules must be developed with the experts of the field, in this case the car experts or technicians.

Acknowledgment

This research paper would not have been possible without the encouragement and support from my family, colleagues, and friends. I would like to express my deepest appreciation to Dr. Fadzil, who continuously and convincingly conveyed a spirit of enthusiasm in regard to research and teaching. Without his strong support, this research would not have been possible. In addition, I am heartily thankful to Mr. Wayn and Ms. Nur Nabihha for their constant encouragement and insights of learning processes. It is a pleasure to thank those who made this study possible.

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