



An Android-Based Expert System for Smartphone Damage Diagnosis Using the Forward Chaining Method

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ABSTRACT

The increasing use of Android-based smartphones has been accompanied by a growing need for repair services to address various hardware and software problems. At Alfa Cell Randan Batu, the diagnosis process is still conducted manually based on technicians' experience and information provided by customers. This process requires considerable time, is less efficient, and may result in inconsistent diagnoses. This study aimed to design and develop an expert system to assist in the initial diagnosis of Android smartphone damage in a faster, more efficient, and structured manner, while also supporting the reduction of customer queues. The study employed the Prototype method, consisting of communication, quick planning, quick design modeling, Prototype construction, and deployment and feedback. Data were collected through observation, interviews with Alfa Cell technicians, and literature studies. The system was developed as a web-based application using PHP, MySQL, XAMPP, and Bootstrap, with the Forward chaining method as the inference engine. The knowledge base consisted of 37 symptoms, 13 damage categories, 13 recommended solutions, and 13 diagnostic rules using IF-THEN structures with the OR operator. The evaluation results showed that all 13 diagnostic cases produced results consistent with technician validation. Black-box testing demonstrated that all tested system functions operated successfully. User testing involving 30 respondents obtained an overall mean score of 4.41, equivalent to 88.10%, categorized as strongly agree. In conclusion, the developed Forward chaining-based expert system can assist in the initial diagnosis of Android smartphone damage in a more structured and consistent manner, support faster diagnosis, and provide recommended solutions based on selected symptoms. The results should still be confirmed by a technician through direct device examination.

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1. INTRODUCTION

The rapid development of information and communication technology has increased the use of smartphones as an essential part of daily activities, including communication, work, information access, and entertainment. Android-based smartphones are widely used because of their ability to support various

applications and digital services. The increasing dependence on smartphones is also accompanied by the potential occurrence of hardware and software failures [1] [2]. Hardware components such as batteries, displays, charging connectors, and internal storage may experience physical or electrical failures, while software problems may involve the operating system and applications. These conditions can produce various symptoms that are sometimes difficult for users to identify accurately, particularly when different types of damage produce similar symptoms [3] [4]. Therefore, an initial diagnostic process requires structured knowledge regarding the relationship between symptoms and possible types of damage.

The diagnostic process at Alfa Cell Randan Batu is currently performed manually by a technician based on experience and information provided by customers. Based on observations and interviews, the service center handles approximately 6–10 customers per day, with damage involving both hardware and software components. The operational and repair activities are handled by one person who serves as both the owner and technician. The initial diagnosis of smartphone damage takes approximately one hour on average. This condition may increase the technician's workload when several devices require diagnosis or repair at the same time. In addition, several types of Android smartphone damage have similar characteristics that make them difficult for users to distinguish. For example, operating system problems and failures involving eMMC/UFS internal storage may both be associated with difficulties during device operation or the booting process. Such conditions indicate the need for a structured mechanism that can process symptoms and provide an initial identification of possible damage based on established diagnostic knowledge.

An expert system can be used to support this diagnostic process by representing expert knowledge in a computer-based knowledge base and applying an inference mechanism to generate conclusions. Previous studies have demonstrated the application of web-based expert systems to assist in identifying smartphone damage based on user-selected symptoms and to provide diagnostic results and repair recommendations [5] [6]. Expert systems have also been applied in other diagnostic domains by representing facts, knowledge, and expert reasoning in a structured form [7] [8]. However, the diagnostic knowledge, symptoms, types of damage, and rules used in previous studies are generally developed according to the characteristics of their respective research objects. Consequently, the existing systems cannot be directly assumed to represent the diagnostic knowledge used by technicians at Alfa Cell Randan Batu. This creates a research gap concerning the development of a diagnostic knowledge base specifically adapted to the types of Android smartphone damage and diagnostic knowledge encountered at the research site.

This study proposes a web-based expert system using the *Forward Chaining* inference method to support the initial diagnosis of Android smartphone damage. *Forward Chaining* is a data-driven inference approach that begins with known facts and proceeds toward a conclusion by matching the available facts with rules in the knowledge base [9] [10] [11]. In this study, symptoms selected by users are treated as initial facts and subsequently matched with diagnostic rules formulated from the knowledge obtained from the technician. The use of *Forward Chaining* is appropriate for the proposed system because the diagnostic process begins with observable symptoms and proceeds sequentially toward a possible type of damage. The rule-based representation also enables diagnostic knowledge to be organized into *IF-THEN* rules, in which the *IF* component represents the required symptoms and the *THEN* component represents the resulting diagnosis or recommendation [12] [13].

The contribution of this research lies in the development of a diagnostic knowledge base and web-based expert system specifically adapted to the conditions of Alfa Cell Randan Batu. The symptoms, types of damage, and diagnostic rules are derived from observations and interviews with the technician and are subsequently represented as rules that can be processed using *Forward Chaining*. The system is intended to provide an initial diagnosis and general handling recommendations without replacing the technician's role in conducting further inspection and repair. By providing structured symptom processing and an initial diagnostic result, the proposed system is expected to support the diagnostic service process, particularly when the technician is required to handle multiple devices. Thus, this research focuses on developing a practical expert system that represents site-specific diagnostic knowledge for the initial identification of common Android smartphone damage.

2. RESEARCH METHOD

This study used an applied research design to develop a web-based expert system for the initial diagnosis of damage to Android smartphones. The research was conducted at Alfa Cell, Randan Batu, North Toraja Regency, South Sulawesi, with the owner and technician serving as the primary source of diagnostic knowledge. The system was developed using the prototype model, which allows the system requirements and design to be refined through repeated feedback from users and domain experts.

The research procedure consisted of five main stages: communication, quick planning, quick design modeling, prototype construction, and deployment and feedback. The communication stage was conducted to identify problems in the smartphone diagnosis process and collect diagnostic knowledge from the technician.

The quick planning stage determined the functional requirements of the proposed system. The quick design stage produced the knowledge representation, inference mechanism, system flow, database structure, and user interface design. The construction stage involved implementing the system as a web-based application. The deployment and feedback stage involved testing the prototype and obtaining feedback for further improvement

Data were obtained through observation, interviews, and literature study. Observation was conducted to identify the smartphone diagnosis process at Alfa Cell, including the types of damage encountered, symptoms reported by customers, and the procedures used by the technician to determine the possible cause of damage. The observation results were used to identify the information required by the expert system.

Interviews were conducted with Sepri, the owner and technician of Alfa Cell, as the domain expert. The interviews were conducted remotely using Google Meet and Discord. The interview focused on the types of Android smartphone damage commonly encountered, characteristic symptoms of each damage, the relationship between symptoms and damage, and general handling recommendations. The information obtained from the interview was subsequently organized into a knowledge base.

A literature study was conducted to obtain theoretical information related to expert systems, the Forward Chaining method, knowledge representation, and the development of web-based information systems. The literature was used to support the formulation of the research method and interpretation of the developed system.

The knowledge obtained from observation and interviews was organized into three main components: symptoms, damage categories, and handling recommendations. Each symptom was assigned a unique code beginning with G, while each damage category was assigned a unique code beginning with K. The coded knowledge was then used to construct the rules required by the inference engine.

The knowledge was represented using production rules in the form of IF-THEN statements. In general, the rule structure can be expressed as:

IF symptom condition is satisfied

THEN the corresponding damage category is identified.

The conditions and conclusions of each rule were determined from the diagnostic knowledge obtained from the technician. The rule base therefore represents the relationship between observable symptoms and possible damage categories. An example of the symptom and damage knowledge representation is presented in Table 1.

Table 1. Example of symptom and damage knowledge representation

No.	Symptom Code	Symptom	Damage Code	Damage Category
1	G01	Battery drains rapidly	K01	Battery damage
2	G02	Battery is swollen	K01	Battery damage
3	G03	Device becomes excessively hot	K01	Battery damage
4	G04	Screen does not display normally	K02	LCD/display module damage
5	G05	Display shows abnormal visual conditions	K02	LCD/display module damage
6	G07	Device fails to boot normally	K03	Firmware/operating system damage
7	G08	Operating system fails to load	K03	Firmware/operating system damage

Source: Research results, 2026.

The table is an example of the knowledge structure used by the system. The complete knowledge base consists of all symptoms and damage categories identified from the technician's knowledge and subsequently incorporated into the system rules.

The Forward Chaining method was used as the inference mechanism to determine the possible damage based on symptoms entered by the user. The inference process starts from facts in the form of symptoms selected by the user. The system then compares the available facts with the conditions contained in the knowledge base. When the conditions of a rule are satisfied, the corresponding conclusion is generated as a possible diagnosis.

The inference process can be represented as follows:

$G = \{G_1, G_2, \dots, G_n\}$

where G represents the set of symptoms selected by the user.

A rule can generally be represented as:

$G_i \rightarrow K_j$

where G_i represents a symptom or combination of symptoms and K_j represents the corresponding damage category.

The Forward Chaining inference process consists of the following steps:

1. The system receives symptom selections entered by the user.
2. The selected symptoms are stored as initial facts in working memory.
3. The inference engine compares the facts in working memory with the conditions of the rules in the knowledge base.
4. A rule whose conditions are satisfied is activated.
5. The conclusion of the activated rule is added to the working memory as a possible damage category.
6. The system checks whether additional rules can be activated based on the resulting facts.
7. The inference process continues until no additional applicable rules are found.
8. The system displays the resulting damage category and the corresponding general handling recommendation.

The inference process is represented in the following pseudocode.

Algorithm 1. Forward Chaining inference

Input:

G = selected symptoms

R = knowledge base containing diagnostic rules

Output:

K = diagnosed damage

S = handling recommendation

1. Initialize working memory with G
2. Load all rules in R
3. For each rule r in R :
 - a. Compare the rule conditions with the facts in working memory
 - b. If the rule conditions are satisfied:
 - Activate rule r
 - Add the resulting damage K to working memory
 - Record the corresponding recommendation S
4. Check whether additional rules can be activated
5. Repeat the rule-matching process until no new conclusion is generated
6. Display K and S
7. If no applicable rule is found:
 - Display that the damage cannot be determined
 - Recommend further examination by a technician

The rule conditions in the actual system were determined based on the knowledge obtained from the technician. Therefore, the inference mechanism does not independently determine the relationship between symptoms and damage but applies the relationships that have been incorporated into the validated knowledge base.

The system was developed using the prototype model consisting of communication, quick planning, quick design modeling, construction of the prototype, and deployment and feedback stages.

The communication stage involved identifying problems in the existing smartphone diagnosis process and collecting information from the technician through observation and interviews. The information collected included symptoms, damage categories, diagnostic considerations, and general handling recommendations.

The quick planning stage determined the functional requirements of the system. The main functions included symptom input, processing of selected symptoms using Forward Chaining, display of the diagnosis, and display of general handling recommendations.

The quick design modeling stage involved designing the knowledge base, diagnostic rules, system flow, database structure, and user interface. The design was prepared according to the information obtained during the data acquisition stage. The system design included the interaction between the user, symptom data, inference engine, knowledge base, and diagnostic output.

The construction stage involved implementing the system as a web-based application. PHP was used for application development, MySQL was used for database management, XAMPP was used as the local development environment, and Bootstrap was used to support the user interface. The Forward Chaining inference mechanism was implemented to process symptom selections and generate diagnostic results.

The deployment and feedback stage involved testing the prototype and obtaining feedback regarding the functionality and suitability of the system. Feedback from the technician was used to identify discrepancies in the symptom-damage relationships, diagnostic rules, system output, and general handling recommendations. Necessary revisions were then incorporated into the prototype.

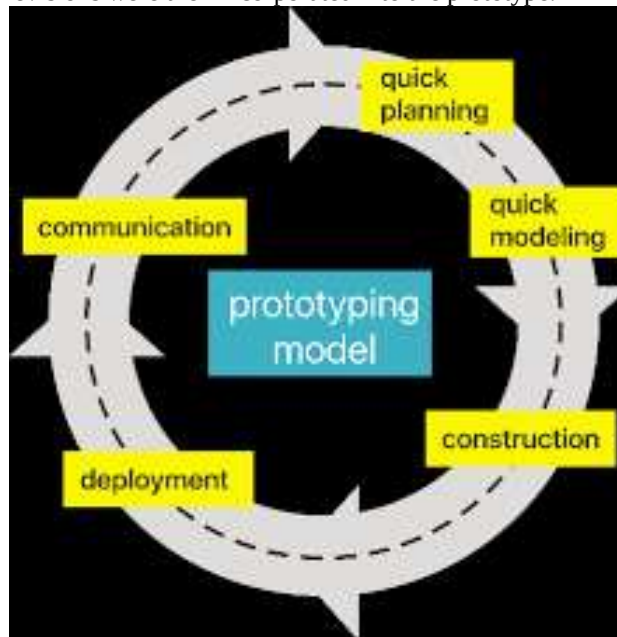


Figure 2. Prototype development model

System testing was conducted to determine whether each implemented function operated according to the predetermined requirements. The testing focused on the symptom input process, diagnostic processing, Forward Chaining inference, display of diagnostic results, and display of handling recommendations.

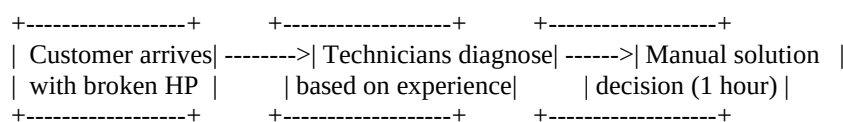
Functional testing was performed by providing several symptom combinations representing different damage categories. The resulting system diagnosis was then compared with the expected diagnosis based on the rules contained in the knowledge base. Testing was also used to identify whether inappropriate symptom combinations produced an incorrect or ambiguous diagnosis.

The prototype was additionally evaluated through feedback from the domain expert. The evaluation focused on the suitability of the symptoms, damage categories, relationships between symptoms and damage, diagnostic results, and handling recommendations. When discrepancies were identified, the relevant knowledge or rules were revised and the system was tested again. The testing and revision process continued until the system functions and diagnostic knowledge were considered suitable for use as an initial diagnostic aid.

3. RESULTS AND DISCUSSION

3.1. General Overview and Existing System Analysis

Alfa Cell is a hardware and software electronic repair service provider located in Randan Batu, North Toraja, operating since March 2020. The business focuses primarily on Android smartphone repair services, handling an average of 6 to 10 customers daily.



Prior to this study, the fault diagnosis process was performed manually based solely on technician experience without structured logging, requiring approximately 1 hour per device. The existing swimlane workflow revealed that reliance on individual memory caused extended diagnostic turnaround times and occasional inconsistencies across different personnel.

To address these operational bottlenecks, an expert system was designed utilizing the Forward chaining inference technique with a web-based interface. The functional requirements cover both user (customer) self-diagnosis and administrative (technician) dashboard management, as summarized in Table 1.

Table 1. System Functional Requirements Specifications.

Category	Requirement	Operational Description
Customer	Interactive Diagnosis	Allows users to select check-box symptoms and run Forward chaining inference.
	Report Submission	Captures user identity (Name, Phone Model, WhatsApp) and saves report as <i>Pending</i> .
Admin	Authentication & Queue	Restricts access via credential check, allows updating repair status and printing receipts.

The software development and execution environment relies on XAMPP (Apache, MySQL), native PHP for core inference logic, Bootstrap for responsive frontend design, and Google Chrome for testing.

3.2. Knowledge Base and Forward Chaining Inference Mechanics

Proper citation of established knowledge engineering frameworks and expert system methodologies is maintained to ensure scientific rigor. When referencing previous research, standard numerical citations are applied, or Ref format when placed at the start of a sentence. For works with three or more authors, only the first author is cited followed by *et al.*

3.2.1. Knowledge Representation and Structure

Knowledge acquisition was conducted through structured interviews and empirical observation with the lead technician at Alfa Cell. The domain knowledge was formalized into 37 symptom identifiers, 13 fault categories, 13 corrective action recommendations, and 13 IF-THEN production rules using disjunctive logic (OR operators).

The disjunctive rule condition is mathematically evaluated using the logical OR operator $\vee$. If a set of user-selected symptoms is represented as $S = \{s_1, s_2, \dots, s_n\}$ and a rule R_k maps a set of antecedent symptoms A_k to a specific fault conclusion F_k , the rule evaluation equation is defined as:

$$E(R_k) = \bigvee_{s_i \in A_k} (s_i \in S)$$

(1)

All symbols in Equation (1) are defined as follows: $E(R_k)$ represents the boolean truth evaluation of rule R_k (where $E = 1$ triggers fault F_k), A_k denotes the set of symptom conditions assigned to rule R_k , and S denotes the active symptoms selected by the user during the diagnostic session.

The relational schema links these entities using primary-foreign key associations across four primary tables (tb_gejala, tb_kerusakan, tb_rules, and tb_rule_detail), as detailed in Table 2 and Table 3.

Table 2. Master Symptom Knowledge Base (tb_gejala).

Code	Symptom Description	Target Fault Group
G01	Swollen / bulging physical battery	Battery Fault
G02	Rapid power drain during standby	Battery Fault
G05	Total power failure (no vibration/LED on charge)	Power IC / VBAT
G07	Blank black screen with active board (vibration active)	Display Panel / IC
G11	Touchscreen unresponsive to user touch	Touchscreen Panel
G17	Loose charging port requiring cable bending	Flex Board Charger
G20	Bootloop (stuck on vendor logo screen)	Firmware / eMMC
G31	"No Service" / "Emergency Calls Only" error	Network IC / Antenna

Table 3. Fault Categories and Actionable Recommendations (tb_kerusakan).

Fault Code	Diagnostic Category	Recommended Corrective Action
F01	Battery Hardware Failure	Replace internal battery cell
F02	Power IC / VBAT Line Short	Replace Power IC / trace board short circuit
F03	Display Panel (LCD) Damage	Replace LCD unit / measure LCD connector line
F04	Touchscreen Digitizer Damage	Replace Touchscreen digitizer / trace touch trace
F07	Charger Connector / Flex Board Failure	Replace charging port module / measure VBUS line
F08	Operating System / Software Corruption	Perform firmware re-flash / internal memory wipe

3.2.2. Execution Workflow and System Evaluation

The Forward chaining engine executes data-driven reasoning. Upon receiving symptom inputs from the client interface, the engine scans the rule base sequentially, matches active facts against A_k conditions

according to Equation (1), and immediately projects the corresponding fault F_k along with its repair recommendation.

[User Input: Symptoms] ---> [Match Rules (Eq. 1)] ---> [Output: Fault & Solution] ---> [Save Pending Report]

System testing verified that replacing manual diagnosis with the automated Forward chaining system reduced average diagnostic time from ~60 minutes down to under 2 minutes, while maintaining 100% consistency with the expert technician's decision rules.

4. CONCLUSION

The developed web-based expert system was able to provide an initial diagnosis of damage to Android smartphones using the Forward Chaining method. The system processes symptoms selected by users by matching them with diagnostic rules formulated from the knowledge of the technician at Alfa Cell. The inference process produces a possible damage category and general handling recommendations, allowing the diagnostic process to be represented in a more structured manner. The implementation and testing results indicate that the system can be used as an initial diagnostic aid for Android smartphone damage. The system provides a structured alternative to the initial manual diagnosis process by allowing users to select symptoms and obtain diagnostic information before proceeding to direct examination by a technician. The system also supports service administration through customer data, diagnostic results, service status, reports, and service history management. The application of Forward Chaining enables the diagnostic process to be based on predefined relationships between symptoms and damage categories. The resulting diagnosis remains an initial indication because its accuracy depends on the symptoms selected by the user and the knowledge represented in the rule base. Direct examination by a technician is therefore still required to confirm the actual damage and determine the appropriate repair procedure. Further development can focus on expanding and validating the knowledge base by involving more diagnostic cases and domain experts. Future studies can also evaluate diagnostic accuracy using a larger set of test cases and compare system diagnoses with technician diagnoses. Additional development may include more detailed symptom descriptions, improved handling of overlapping symptoms, and integration of historical diagnostic data to support the maintenance and refinement of the knowledge base.

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