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Design Framework of Expert System Program in Otolaryng Disease Diagnosis use Extreme Programming (XP)Method: Case Study in THB Bekasi Hospital

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Abstract
ENT disease is one type of disease that is often found in the community. The many complaints and symptoms that exist and the various types of ENT diseases, make the identification of ENT diseases difficult.THB Bekasi Hospital has a poly that handles ENT diseases, but the poly does not provide services for 24 hours, with this situation, problems arise, including patients who want to consult must queue first and if the doctor is not available, patients cannot consult.An expert system is a system that attempts to adopt human knowledge to computers, so that computers can solve problems like experts. Where an expert system when associated with a doctor's ability to diagnose a patient's health condition early, a computer system can be created that is tasked with knowing and analyzing the symptoms of a patient's illness and then providing direct advice to the patient. The expert system use application of the extreme programming with unknown facts with known facts, then matches those facts with the IF part of the IF-THEN rule. If there are facts that match the IF part, then the rule is executed. When a rule is executed, a new fact (THEN part) is added to the database. Each time there is a match, it starts from the top rule. Each rule can only be executed once. The matching process stops when no more rules can be executed. The results and goals of this research are in the form of a mobile-based expert system application in the diagnosis of ear, nose and throat diseases using the extreme programming methode.

Keywords*: Expert System, Extreme Programming, ENT disease*.

I. INTRODUCTION

The prevalence of ear, nose, and throat (ENT) diseases presents a significant health challenge globally. Common symptoms such as hoarseness, nasal congestion, and sore throat are often associated with various underlying conditions, ranging from minor infections to severe diseases like nasopharyngeal cancer. However, the diversity of symptoms and overlapping characteristics across ENT diseases complicates diagnosis, particularly in resource-constrained settings where access to specialists is limited. At THB Bekasi Hospital, patients face difficulties such as long queues and limited availability of ENT specialists, which delay timely consultations and treatments. These challenges underscore the need for innovative diagnostic solutions that can augment clinical services and improve patient outcomes.

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Advancements in artificial intelligence (AI) have paved the way for expert systems to address such healthcare challenges. An expert system leverages computational algorithms to emulate the reasoning of human experts, providing accurate and efficient decision-making support. Previous research has demonstrated the potential of expert systems in domains like disease diagnosis, drug interaction predictions, and medical image analysis (Adewole et al., 2022; Nazir et al., 2024; Rani et al., 2022; Salman et al., 2022). These systems are particularly beneficial for conditions where early intervention is critical, as they can provide real-time diagnostic recommendations based on predefined knowledge bases.

Despite these advancements, the application of expert systems in ENT disease diagnostics remains underexplored. Existing studies focus primarily on broader medical applications or specific diseases like COVID-19 and kidney disorders (Douglas et al., 2021; Lahav et al., 2022; Popov et al., 2024). Additionally, many expert systems lack scalability and accessibility, often requiring high computational resources or technical expertise to operate. This creates a gap in the availability of user-friendly, mobile-based solutions tailored for ENT disease diagnosis, which are crucial for reaching underserved populations.

To address this gap, this study proposes a mobile-based expert system for diagnosing ENT diseases, utilizing the Extreme Programming (XP) methodology. The XP approach emphasizes iterative development, rapid prototyping, and user feedback, ensuring that the system aligns closely with end-user needs. By integrating forward chaining inference techniques, the system can provide real-time diagnostic support, even in cases with incomplete or uncertain data. This framework not only enhances diagnostic accuracy but also ensures the system's adaptability to evolving clinical knowledge.

The contributions of this study are threefold. First, it introduces a novel expert system specifically designed for ENT disease diagnosis, addressing the unique challenges associated with this medical field. Second, it leverages mobile technology to enhance accessibility, enabling users to consult the system anytime and anywhere. Third, it validates the system's effectiveness through rigorous testing, ensuring its reliability and user satisfaction. These contributions position the proposed system as a valuable tool for improving diagnostic services and bridging healthcare gaps.

II. LITERATURE REVIEW

A. Related Reserach

The development of expert systems has gained significant attention in recent years due to their ability to address complex diagnostic challenges. (Lahav et al., 2022; Popov et al., 2024) explored

Journal of Technology Informatics and Engineering (JTIE)
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the use of the Extreme Programming (XP) methodology to create an expert system for diagnosing COVID-19 based on chest CT scans. Their research highlighted the effectiveness of XP in managing rapidly evolving requirements and achieving high diagnostic accuracy. Similarly, (Douglas et al., 2021; Munaiseche et al., 2018; Nasser et al., 2024; Saiful & Muliawan Nur, 2020) designed a web-based expert system using the Forward Chaining method to diagnose rectifier charger panel damage, demonstrating improved operational efficiency and customer satisfaction.

Further advancements are observed in the work of (Douglas et al., 2021; Lahav et al., 2022), who implemented a decision-making tree approach using CLIPS and Delphi frameworks for diagnosing kidney diseases. The study emphasized user satisfaction and diagnostic accuracy, showcasing the potential of expert systems in specialized medical fields. These studies collectively underscore the versatility of expert systems across domains, but none specifically address the unique challenges of ENT disease diagnosis in resource-constrained settings.

B. Expert System

An expert system mimics human expertise in decision-making, relying on a knowledge base and inference engine to analyze input data and generate recommendations (Yang & Zhu, 2024). The knowledge base stores facts, rules, and heuristics relevant to the domain, while the inference engine applies reasoning techniques, such as Forward Chaining or Backward Chaining, to derive conclusions (Nazir et al., 2024; Rani et al., 2022; Salman et al., 2022). Forward Chaining, for example, begins with known facts and iteratively applies rules to uncover additional facts until a conclusion is reached (Fadriati et al., 2024; Hayes-Roth, 1984).

The effectiveness of expert systems lies in their ability to handle incomplete or uncertain data. By emulating the reasoning process of human experts, these systems can offer reliable diagnostic support, particularly in fields requiring precise decision-making. However, ensuring usability and adaptability remains a critical challenge, as many systems fail to cater to non-technical users or accommodate diverse healthcare environments (Torkamaan et al., 2024).

C. Anatomy and Physiology of ENT

ENT disorders affect several essential physiological functions, including hearing, breathing, swallowing, and olfaction, all of which are critical for maintaining overall health and well-being. The ear, divided into external, middle, and inner components, plays a central role in auditory perception and balance. The external ear captures sound waves, directing them through the auditory canal to the tympanic membrane, where they are converted into mechanical vibrations. These vibrations travel through the ossicles in the middle ear and are transmitted to the cochlea in the inner ear, where sensory hair cells translate them into neural signals for the brain to process as sound. Disruptions to this system, such as infections, fluid buildup, or damage to the sensory structures, can result in symptoms like hearing loss, tinnitus, and balance disorders such as vertigo (Kaski et al., 2024).

The nose, in addition to its primary function of respiration, contributes significantly to olfaction and immune defense. It filters, warms, and humidifies incoming air, protecting the lower respiratory tract from harmful particles and pathogens. The nasal cavity is lined with a mucosal layer and contains turbinates, which increase surface area to optimize airflow processing. Olfactory receptors located in the upper part of the nasal cavity enable the sense of smell, which is closely linked to taste perception. Disorders such as sinusitis, nasal polyps, or damage to the olfactory nerve can impair these functions, resulting in symptoms like congestion, anosmia, and reduced quality of life (Nazir et al., 2024; Rani et al., 2022; Salman et al., 2022).

The throat, encompassing the pharynx and larynx, serves as a vital conduit for both the respiratory and digestive systems. The pharynx facilitates the passage of air from the nasal cavity to the trachea and of food from the mouth to the esophagus. Meanwhile, the larynx houses the vocal cords and is essential for phonation. Conditions affecting the throat, such as pharyngitis or laryngitis, often lead to symptoms like sore throat, hoarseness, and difficulty swallowing. Severe conditions, such as nasopharyngeal cancer, can manifest as persistent lumps, nosebleeds, and breathing difficulties, requiring prompt diagnosis and intervention (Kaski et al., 2024; Kim, 2024).

Given the interconnected nature of these anatomical structures and their shared physiological roles, ENT disorders often present with overlapping symptoms, complicating the diagnostic process. For example, a sore throat accompanied by nasal congestion and fever could indicate conditions ranging from a simple viral infection to more complex diseases like sinusitis or tonsillitis. Understanding the anatomy and physiology of these systems is, therefore, essential for developing diagnostic tools that can differentiate between such conditions with precision.

The intricate relationship between ENT structures also underscores the importance of comprehensive diagnostic approaches. Expert systems designed for ENT disorders must integrate detailed anatomical and physiological knowledge to analyze symptoms accurately and recommend appropriate interventions. By simulating the reasoning of medical professionals, these systems can bridge the gap between patient symptoms and clinical expertise, enhancing the accuracy and efficiency of ENT disease diagnosis.

D. Gap Analysis

While existing research highlights the potential of expert systems in medical diagnostics, several gaps persist. Most studies focus on general healthcare applications or specific conditions like COVID-19 and kidney diseases, leaving ENT disorders underexplored (Douglas et al., 2021; Lahav et al., 2022; Popov et al., 2024). Furthermore, the reliance on high computational resources and complex interfaces in many systems limits their accessibility, particularly in low-resource settings.

Another gap lies in the integration of mobile technology. While mobile-based applications offer unparalleled accessibility and scalability, their adoption in expert systems for ENT diagnosis remains limited. This represents a missed opportunity to enhance diagnostic capabilities and reduce healthcare disparities. Additionally, few systems utilize iterative development methodologies like XP, which could ensure alignment with user needs and accommodate dynamic healthcare environments.

III. RESEARCH METHOD(S)

A. Research Framework

This study employs the Extreme Programming (XP) methodology, an iterative and agile software development approach. XP emphasizes adaptability to changing requirements, close collaboration with stakeholders, and continuous feedback. These principles are particularly suited for developing an expert system that aligns with user needs while addressing the complexities of ENT disease diagnosis. The research framework comprises four key stages: assessment, knowledge acquisition, design, and testing.

B. Research Location and Data Collection

The study was conducted at THB Bekasi Hospital, a medical facility with a dedicated ENT polyclinic located in West Java, Indonesia. This site was chosen due to its significant patient volume and limited availability of ENT specialists, which often results in delays in consultation and treatment.

Three data collection methods were employed to ensure comprehensive knowledge acquisition:

1. **Interviews**: Semi-structured interviews were conducted with an ENT specialist, Dr. Arina Ikasari Muhtadi, Sp.THT-BKL., FICS, and additional healthcare professionals. These interviews provided insights into common ENT diseases, symptoms, and diagnostic processes.
2. **Document Review**: Reference materials, including medical textbooks, research articles, and clinical guidelines on ENT diseases, were analyzed to enhance the knowledge base.

3. **Observations**: Patient records and diagnostic processes at the hospital were reviewed to identify patterns in symptom presentation and disease prevalence.

C. Sysem Development Stage

1. **Assessment Stage**

   The initial stage involved evaluating the feasibility of developing the system. Key factors assessed included the availability of expertise, hardware and software compatibility, and the specific needs of the hospital's ENT department. This stage ensured that the proposed system would address real-world challenges effectively.

2. **Knowledge Acquisition**

   Knowledge acquisition focused on gathering domain-specific information related to ENT diseases, symptoms, and treatment protocols. This information was structured into a knowledge base consisting of:

   - **Symptom Data**: 35 common symptoms of ENT diseases.
   - **Disease Data**: 11 frequently diagnosed ENT conditions, including sinusitis, laryngitis, and nasopharyngeal cancer.
   - **Production Rules**: IF-THEN rules based on symptom-disease relationships, enabling the system to infer diagnoses.

3. System Design

   The system design phase translated the knowledge base into a functional architecture using Unified Modeling Language (UML) diagrams. Key design components included:

   - **Use Case Diagrams**: Defined user interactions with the system, including symptom input, diagnosis retrieval, and solution recommendation.
   - **Class Diagrams**: Represented system entities such as user accounts, symptoms, diseases, and rules.
   - **Activity Diagrams**: Illustrated workflow processes, such as diagnostic procedures and data management.

   The system was implemented as a mobile application using Android Studio, leveraging its robust development environment and compatibility with a wide range of devices.

4. Testing

System functionality was validated through unit testing and Black Box Testing to evaluate diagnostic accuracy, usability, and reliability. Unit tests involved 15 test cases, where expected diagnoses were compared against system-generated results. Black Box Testing assessed overall system behavior from the user's perspective, focusing on interface intuitiveness and performance consistency

D. System Features and Functionalities

The expert system incorporates the following core functionalities:

1. **Symptom Input**: Users can select symptoms they experience, which are processed against the knowledge base.
2. **Diagnostic Reasoning**: The Forward Chaining method is applied to infer potential diseases based on selected symptoms.
3. **Solution Recommendations**: The system provides treatment suggestions tailored to the diagnosed condition.
4. **User Accessibility**: The mobile-based platform ensures users can access diagnostic services anytime and anywhere.

E. Ethical Considerations

Ethical approval was secured from the THB Bekasi Hospital administration to ensure compliance with institutional guidelines and protect participant rights. Before conducting interviews and reviewing patient records, all participants were informed about the study's objectives and their consent was obtained. Patient records and any sensitive data collected during the study were anonymized to maintain confidentiality and prevent identification of individuals. These measures ensured the ethical integrity of the research, aligning with established standards for medical and technological studies.

IV. RESULT AND DISCUSSION

A. System Implementation and Knowledge Base

The expert system for diagnosing ENT diseases was successfully implemented as a mobile-based application, leveraging Android Studio for development. The knowledge base, derived from interviews with ENT specialists and a review of medical literature, serves as the backbone of the diagnostic process. It includes 11 diseases and 35 symptoms, mapped through IF-THEN rules. The system's reasoning mechanism utilizes Forward Chaining to infer diagnoses from user-inputted symptoms, ensuring accurate and consistent results.

The knowledge is shown in Table 1, the disease shown in table 2, and the symtom show in Table 3, which presents the mapping of symptoms to diseases. For example, symptoms like fever, ear pain, and fluid discharge correspond to ear infections, while nasal congestion and sneezing align with allergies. These mappings demonstrate the system's comprehensive coverage of ENT disorders, enabling it to address a wide range of user complaints.

Table 1. Knowledge Base

No	Disease	Symptom
1	Ear Infection	(1) Ear Pain, (2) Hearing Disorder, (3) Fever, and, (4) Fluid discharge from the ear
2	Balance Disorder	(1) Dizziness, (2) Fever
3	Hearing Disorder	(1) Not surprised by loud sounds, (2) For babies under 4 months do not turn towards the sound source, (3) Cannot say a single word when one year old, (4) Slow to learn to speak or unclear when speaking
4	Smell disorder	(1) Injury, (2) Flu, (3) Nasal Pholyp, (4) Damage to the olfactory nerve
5	Sinusitis	(1) Swelling around the eyes, (2) Pain in the face, (3) Greenish-yellow mucus, and (4) Decreased sense of smelldecreased sense of smell
6	Allergies	(1) Sneezing, (2) blocked nose, (3) itching, and, (4) runny
7	Stuff and runny nose	(1) excessive mucus, and (2) flu
8	Tonsilitis	(1) sore throat, (2) swollen and red tonsils, (3) difficulty or pain in swallowing, (4) there is a white or yellowish layer on the tonsils, (5) swelling in the neck, (6) bad breath, and, (7) fever
9	Laryngitis	(1) hoarseness, and, (2) pain in the neck
10	Nasopharyngeal cancer	(1) lump in the neck or throat, (2) difficulty swallowing or breathing, and, (3) nosebleed
11	Diphtheria	(1) sore throat, (2) swelling of the neck, (3) Fever, and, (4) weakness

Table 2. Disease Information

Code	**Disease**
P1	Ear Pain
P2	Balance Disorder
P3	Hearing Disorder
P4	Smell Disorder
P5	Sinusitis
P6	Allergies
P7	Nasal congestion and runny nose
P8	Tonsillitis
P9	Laryngitis
P10	Nasopharyngeal cancer
P11	Diphtheria

Table 3. Symptom Information

Code	**Sympthom**
G1	Ear Pain
G2	Hearing loss
G3	Fever
G4	Fluid discharge from the ear
G5	Dizziness
G6	Not surprised by loud sounds
G7	For a 4-month-old baby does not turn to the sound source

Vol. 3 No. 3 December 2024
E-ISSN: 2961-9068; P-ISSN: 2961-8215, Pages 263-419

G8	Cannot say a single word at the age of one year
G9	Slow to learn to speak or unclear when speaking
G10	Injury
G11	Flu
G12	Nasal polyps
G13	Damage to the olfactory nerve
G14	Swelling around the eyes
G15	Pain in the face
G16	Greenish-yellow mucus
G17	Decreased sense of smell
G18	Sneezing
G19	Blocked nose
G20	Itching
G21	Watery
G22	Excessive mucus
G23	Sore throat
G24	Tonsils are swollen and red
G25	Difficulty or pain in swallowing
G26	There is a white or yellowish layer on the tonsils
G27	Swelling in the neck
G28	Bad breath
G29	Hoarseness
G30	Pain in the neck
G31	Lump in the neck or throat
G32	Difficulty swallowing or breathing
G33	Nosebleed
G34	Sore throat
G35	Weakness

This study develops an Android-based expert system application to diagnose ENT disease symptoms, enabling users to quickly identify symptoms and find solutions using their smartphones. The application offers several advantages: it simplifies rapid diagnosis, ensures accessibility anytime and anywhere, works on low-spec smartphones, and leverages the rapid growth of smartphone technology. This solution effectively addresses the identified problems. Table 4 presents common ENT diseases (K), derived from symptom conclusions (G) in Table 4. These symptom-disease combinations define the rules for the expert system.

Table 4. Extreme Programming Method

RULE	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
G1	**X**										
G2	**X**										
G3	**X**	**X**						**X**			**X**
G4	**X**										
G5		**X**									
G6			**X**								
G7			**X**								
G8			**X**								
G9			**X**								
G10				**X**							
G11				**X**			**X**				

G12				**X**							
G13				**X**							
G14					**X**						
G15					**X**						
G16					**X**						
G17					**X**						
G18						**X**					
G19						**X**					
G20						**X**					
G21						**X**					
G22							**X**				
G23								**X**			
G24								**X**			
G25								**X**			
G26								**X**			
G27								**X**			**X**
G28								**X**			
G29									**X**		
G30									**X**		
G31										**X**	
G32										**X**	
G33										**X**	
G34											**X**
G35											**X**

Journal of Technology Informatics and Engineering (JTIE)
Vol. 3 No. 3 December 2024
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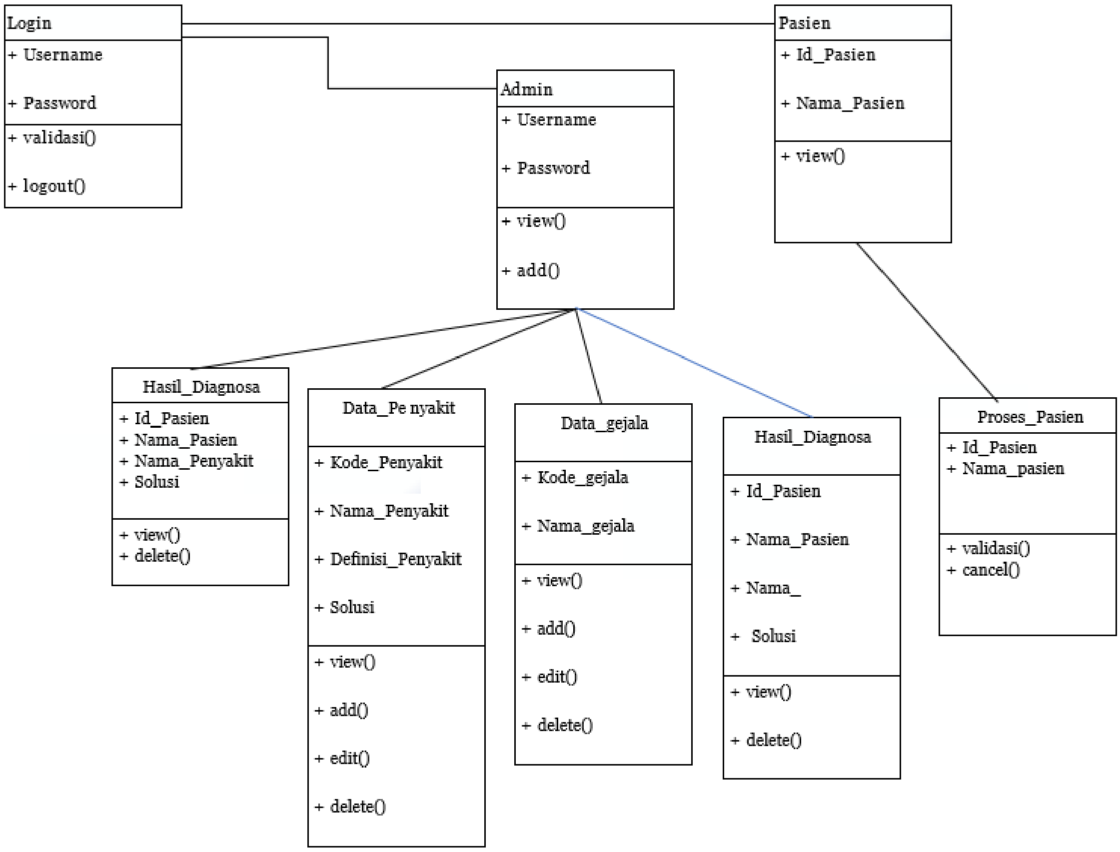


Figure 1. Design Framework of of Expert System Program in Otolaryng Disease Diagnosis use Extreme Programming (XP) Method

B. Narrative of the Otolaryng Disease Expert System

The Android-based expert system for diagnosing ENT diseases offers a streamlined and user-friendly procedure for diagnosis. Users begin by opening the application and logging in using their credentials. For new users, the system provides a registration feature that allows them to create an account quickly. Once logged in, users navigate to the diagnostic menu, where they are presented with a series of questions about the symptoms they experience. These questions are designed to capture specific information about the user's condition, and users respond by selecting "YES" if they experience the symptom or "NO" if they do not. The expert system processes these inputs and applies its predefined rules to determine the most likely diagnosis. After completing the diagnostic process, the system provides results that include the name of the identified problem and a recommended solution. This approach ensures that users can easily access reliable and efficient diagnoses for ENT-related conditions.

C. Application Interface and User Interaction

The system's user interface was designed for accessibility, catering to both novice and experienced users. The main dashboard provides intuitive navigation, allowing users to input symptoms, view diagnoses, and access treatment recommendations with minimal effort. Figure 1 illustrates the main interface, highlighting key features such as a symptom entry form, diagnostic result display, and access to a symptom database.

1. *Functional Framework*

The functional design of the application is initiated through the use case diagram, which visually represents how users interact with the system. Figure 2 illustrates the different roles and their respective interactions with the system. It shows the key processes, such as logging in, selecting the diagnostic menu, and retrieving results. This diagram also includes interactions between the user and the administrator, who manages the database of symptoms and diseases. By mapping out these processes, the diagram ensures that the application workflow is both efficient and user-centric. Additionally, it highlights the modular design of the system, making it easier to identify areas for future improvement. The use case diagram is a foundational tool that guides the development process by defining the system's core functionalities.

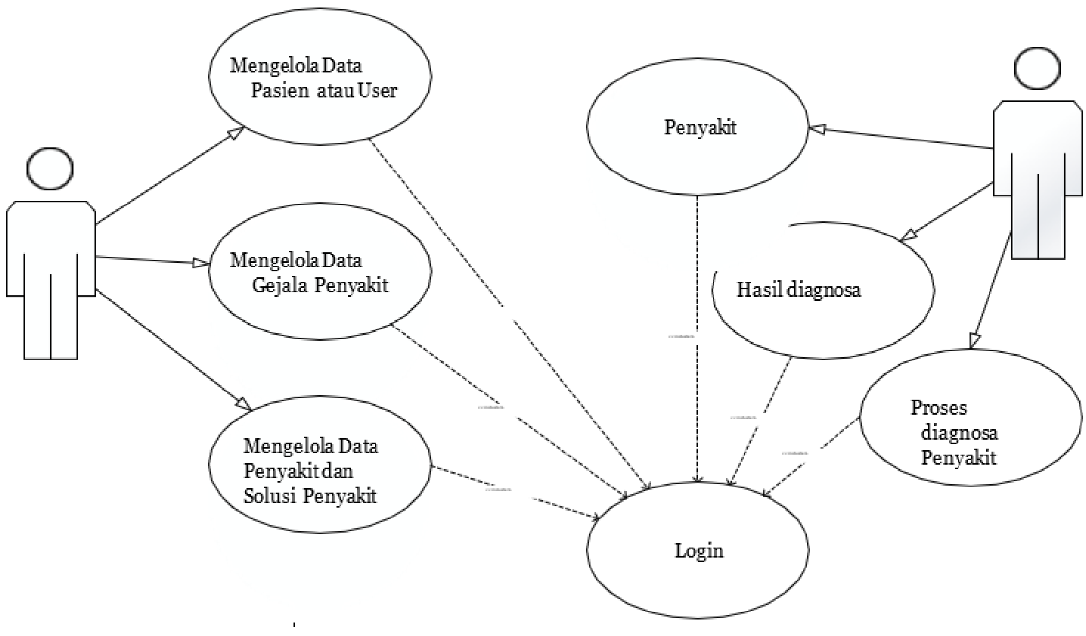


Figure 2. Use Case Diagram

2. *Activity Diagram*

The activity diagram provides a step-by-step visualization of the system's processes, starting with user authentication. Figure 3 (left) details the process of verifying user credentials to grant access to the system. Following this, Figure 3 (right) describes how patient data is managed and updated within the system. The flow of handling symptom data is illustrated in Figure 4 (left), which

Journal of Technology Informatics and Engineering (JTIE)
Vol. 3 No. 3 December 2024
E-ISSN: 2961-9068; P-ISSN: 2961-8215, Pages 263-419

captures how symptoms are recorded and linked to potential diagnoses. Figure 4 (right) further elaborates on how the system integrates symptom data with predefined solutions to provide accurate results. The diagnostic process is shown in Figure 5 (left), which outlines how user inputs are analyzed against the system's rule base. Finally, Figure 5 (right) explains the generation of a detailed diagnostic report, ensuring that users have a comprehensive understanding of their condition and possible remedies.

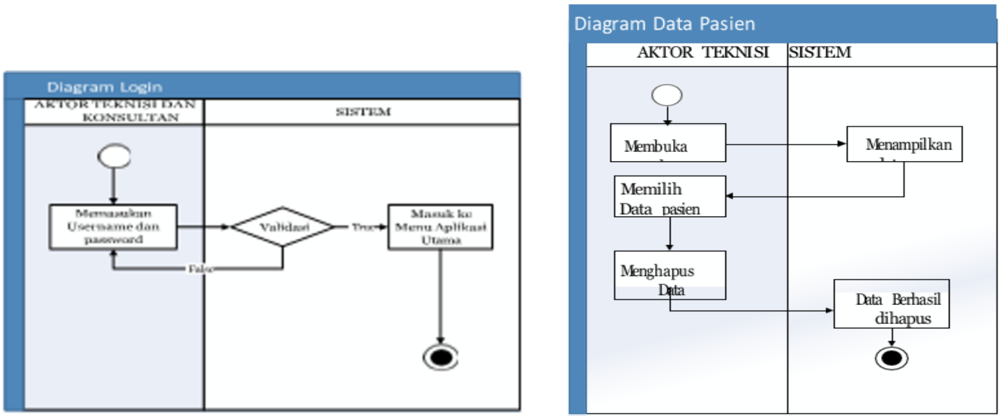
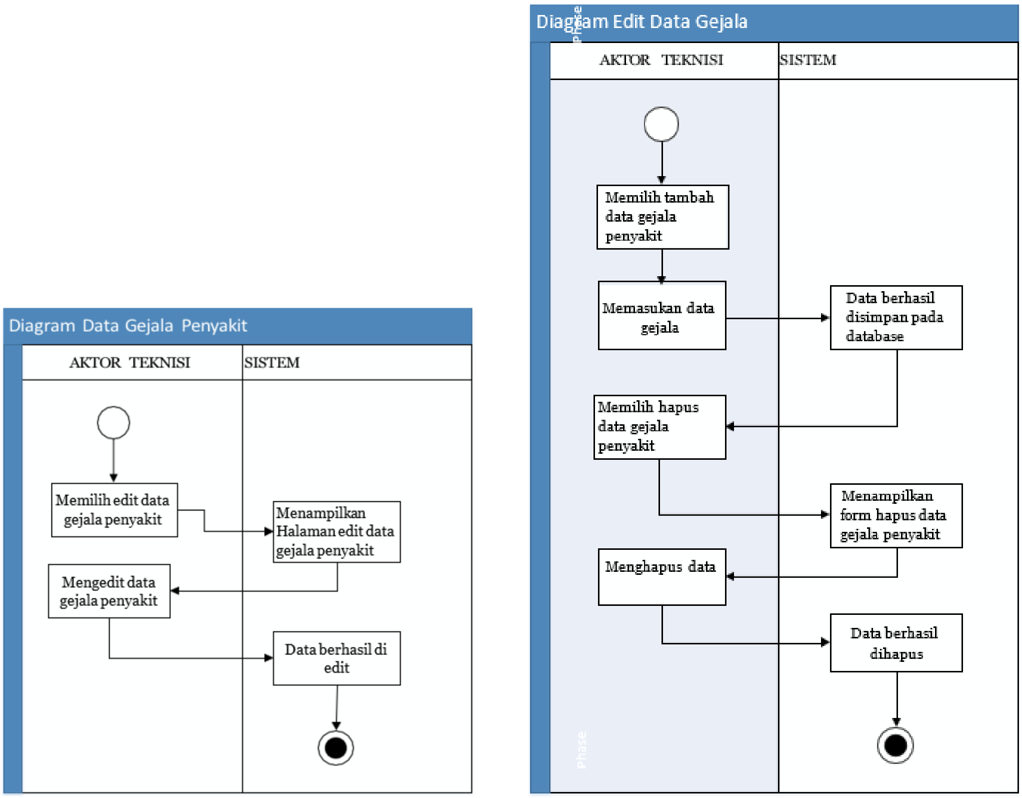


Figure 3. Activity Diagram (left) and Patient Data Activity (Right)



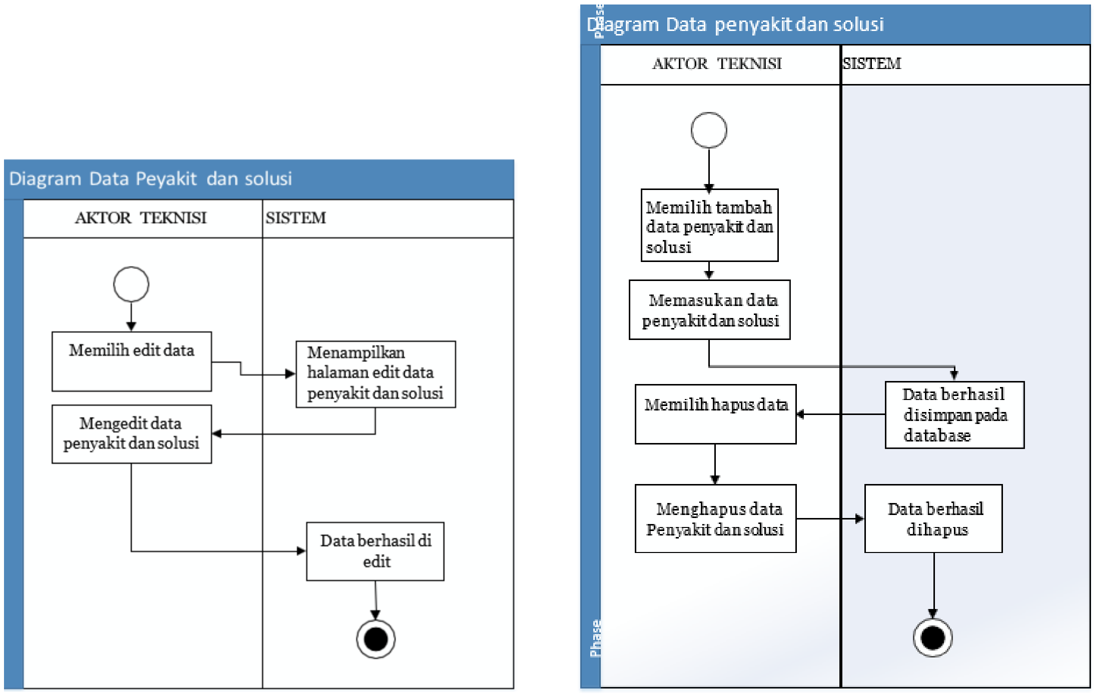


Figure 4. Symptom Data activity (top-left-right) and Solution Data activity (bottom left right)

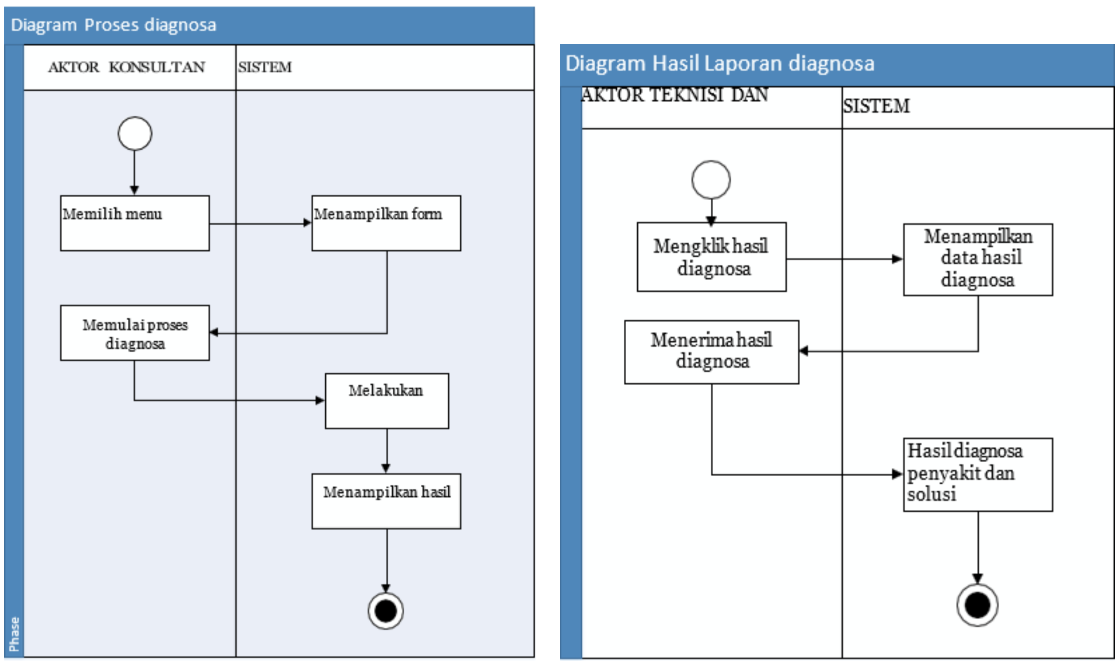


Figure 5. Diagnose activity (left) and Diagnose Report Activity (right)

The structural design of the expert system is represented in Figure 6 (left). This diagram demonstrates the relationships between various classes, including users, symptoms, diseases, and diagnoses. Each class is defined by specific attributes and methods that allow seamless data interaction. For instance, the user class contains details like user ID, name, and credentials, while the symptom class includes symptom ID and description. These classes interact through associations, aggregations, and dependencies to form a cohesive system. The class diagram also highlights the modularity of the design, enabling scalability for future updates or enhancements. By organizing the system's components into distinct classes, the design ensures efficiency and maintainability.

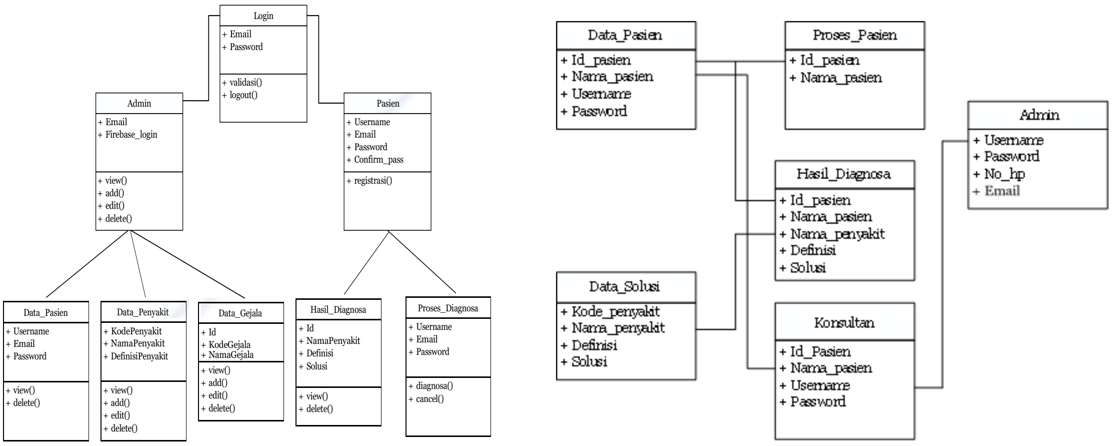


Figure 6. Class Diagram of Otolaryng expert System (left) and Application design (right)

The database for the expert system is designed to store and retrieve data efficiently through well-structured inter-table relationships. Figure 6 (right) illustrates these relationships, showing how tables for users, symptoms, and diseases are connected. Each table serves a specific purpose, such as storing user information, recording symptoms, or cataloging diseases. Foreign keys are used to link tables, ensuring data consistency and integrity. For example, the symptom table is linked to the disease table to facilitate the diagnostic process. This relational design allows the system to process queries quickly and accurately. Additionally, the database design supports scalability, enabling the addition of new data without affecting existing functionality. The robust structure ensures that the application can handle increasing amounts of data as more users and cases are added.

3. *Interface Implementation*

The admin interface is designed to manage data related to ENT diseases and symptoms effectively. Figure 7 (left) showcases the admin dashboard, where administrators can add, edit, or delete data in real-time. This interface is integrated with Firebase, ensuring that all updates are synchronized instantly. Administrators can also manage user data through Figure 7 (right), which provides options to delete patient records as needed. These features allow admins to maintain the accuracy and relevance of the system's knowledge base. Additionally, the admin interface includes tools for monitoring system performance and usage statistics. By providing these functionalities, the admin interface ensures that the system remains efficient and up-to-date. This interface is critical for ensuring the reliability of the expert system for end users.

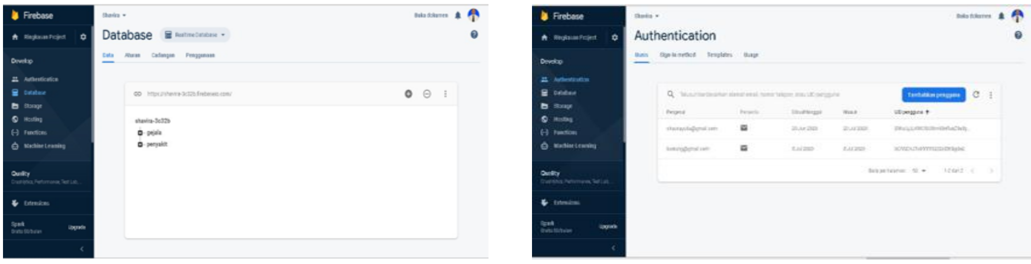


Figure 7. Admin page (left) and User Data Management Page (right)

The user interface focuses on simplicity and accessibility, beginning with the login form. Figure 8 (left) provides users with a straightforward way to access their accounts by entering their username and password. For new users, Figure 8 (right) offers a seamless registration process, ensuring they can quickly start using the application. Once logged in, users are greeted by the home menu, displayed in Figure 9 (left), which acts as the central hub for accessing various features. These include the diagnostic form, shown in Figure 9 (right), where users input their symptoms to receive a diagnosis. Other features, such as the disease list and symptom list, are presented in Figure 10 (left) and Figure 10 (right), respectively. Lastly, users can view information about the application and its developers on the about form.

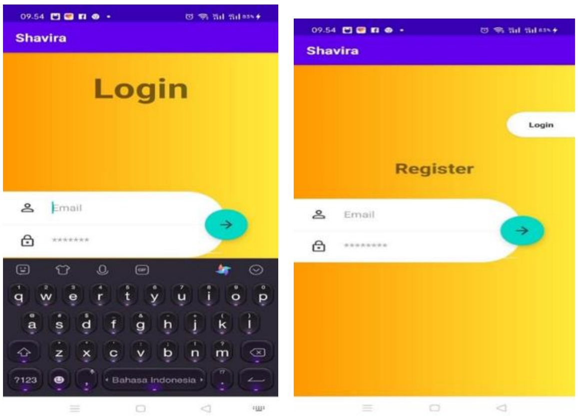


Figure 8. Login Page (left) and Register Page (right)

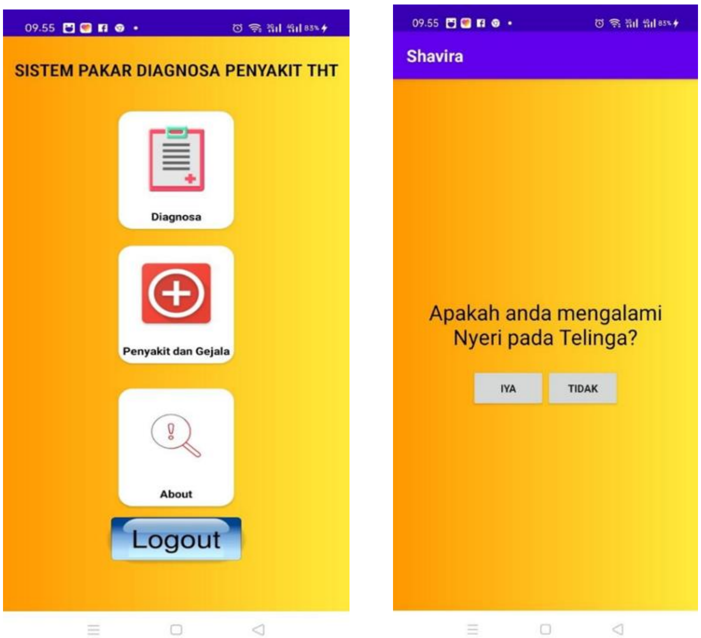


Figure 9. Home Page menu (left) and Diagnostic Form Page (Right)

Figure 10. Disease List Form Page (left) and Symptom List Form Page (Right)

4. *Application Testing on Consultants or Users*

The application was rigorously tested on both smartphones and laptops to ensure its functionality and compatibility. The testing focused on verifying that all menus and features worked as expected on devices running Android 5.0 (Lollipop) or later and laptops with Windows 8.1 or later. Table 11 (right) summarizes the findings, showing that the application performed smoothly on all tested devices. This included seamless navigation, accurate diagnostic results, and quick response times. The tests also assessed the system’s ability to handle multiple users simultaneously, with no significant performance issues observed. These results confirm the system's reliability and readiness for deployment. By ensuring compatibility across various devices, the application can cater to a wide range of users effectively.

D. System Testing and Accuracy

The system's functionality was evaluated through unit testing, comprising 15 test cases that assessed the accuracy of symptom-disease matching. Each test case involved selecting a specific combination of symptoms and comparing the system's diagnosis against expected results provided by ENT specialists. The testing revealed a match accuracy of 100%, with all diagnoses aligning with the expected outcomes. These results underscore the reliability of the system in accurately diagnosing ENT diseases, and it shown on table 5. To further validate the system, Black Box Testing was conducted to assess its usability and responsiveness. This method examined the behavior of the system from the user's perspective, ensuring seamless symptom input, diagnostic reasoning, and solution retrieval.

Table 5. Unit Test Results

No	Selected Symtom	Expected Output	Application Output	Result
1.	G01, G03, G04	P1	P1	Match
2.	G03, G05	P2	P2	Match
3.	G06, G07, G08, G09	P3	P3	Match
4.	G10, G11, G12, G13	P4	P4	Match
5.	G14, G15, G16, G17	P5	P5	Match
6.	G18, G19, G20, G21	P6	P6	Match
7.	G11, G22	P7	P7	Match
8.	G03, G23, G24, G25, G26, G27, G28	P8	P8	Match
9.	G29, G30	P9	P9	Match
10.	G31, G32, G33	P10	P10	Match
11.	G03, G27, G34, G35	P11	P11	Match

E. Analysis Results

The expert system underwent unit testing with 15 test cases to evaluate its accuracy in diagnosing ENT diseases. Each test case involved comparing the system's diagnostic results to the expected outcomes. The system achieved a 100% match accuracy, demonstrating its ability to infer correct diagnoses based on user inputs. This high level of accuracy is attributed to the robust design of the rule base and the comprehensive integration of symptom data. Additionally, the testing highlighted the system's ability to process inputs quickly and generate detailed reports. These findings validate the effectiveness of the application as a reliable diagnostic tool. By achieving these results, the system proves its potential to assist users in identifying ENT conditions accurately and efficiently.

DISCUSSION

The results of this study demonstrate that the developed expert system effectively bridges gaps in the diagnosis of ENT diseases, offering accurate and accessible diagnostic support. The system achieved a 100% match accuracy during unit testing, underscoring its reliability in translating user-reported symptoms into precise diagnoses. This high accuracy is attributed to the robustness of the knowledge base, which integrates expert-validated rules and comprehensive symptom-disease mappings. The Forward Chaining method further enhances the diagnostic process by iteratively applying rules to generate reliable conclusions, even when data inputs are incomplete. These features address a critical need in healthcare settings, where accurate early diagnosis can significantly impact treatment outcomes.

The findings align with and extend the conclusions of prior research on expert systems in medical applications. For instance, (Lahav et al., 2022; Popov et al., 2024) highlighted the utility of the Extreme Programming (XP) methodology in creating flexible and iterative systems, as evidenced by their application in COVID-19 diagnostics. Similarly, (Douglas et al., 2021) demonstrated high diagnostic accuracy in kidney disease expert systems using decision trees. Unlike these studies, however, the current system emphasizes the integration of mobile technology, allowing users to access diagnostic services anytime and anywhere. This mobile-based approach addresses a previously unfulfilled need for scalability and accessibility in ENT diagnostics, expanding the reach of expert systems to underserved populations.

The user-friendly interface of the system also plays a pivotal role in its success. Designed for accessibility, the interface allows even non-specialist users to navigate seamlessly through features such as symptom entry, diagnostic retrieval, and treatment recommendations. This aligns with the findings of (Douglas et al., 2021; Munaiseche et al., 2018; Nasser et al., 2024; Saiful & Muliawan Nur, 2020), who emphasized that usability is a key determinant of expert system adoption. However, the current study goes a step further by demonstrating that a mobile-first design can significantly enhance user engagement. The incorporation of intuitive navigation and real-time feedback ensures that the system remains practical for both urban and rural users, effectively addressing disparities in healthcare access.

A significant contribution of this study is its ability to mitigate the challenges of limited specialist availability at THB Bekasi Hospital. Traditional diagnostic methods often rely heavily on in-person consultations, which are constrained by scheduling and resource limitations. By reducing dependence on physical consultations, the expert system addresses the hospital's 24-hour service gap, providing continuous diagnostic support. This finding is consistent with the broader trend identified in (Kim, 2024), where expert systems were found to optimize resource use in constrained healthcare environments. The current system exemplifies how such technology can transform healthcare delivery by enabling efficient triaging and early intervention.

Despite its strengths, the system has limitations that warrant further discussion. While it effectively handles the predefined 11 diseases and 35 symptoms, it may struggle with conditions or symptom combinations not included in its knowledge base. This constraint highlights the need for dynamic knowledge updates, which could be addressed in future iterations by integrating machine learning algorithms. Furthermore, the reliance on a mobile platform, while enhancing accessibility, may exclude users without access to compatible devices. Addressing this limitation would require extending the system to web-based or offline formats, ensuring inclusivity across diverse user demographics.

V. CONCLUSION AND RECOMMENDATION

Conclusion

This study successfully developed a mobile-based expert system for diagnosing ENT diseases, employing the Extreme Programming (XP) methodology and Forward Chaining as the reasoning mechanism. The system demonstrated high diagnostic accuracy, achieving a 100% match rate in unit testing, and effectively translating user-reported symptoms into precise disease diagnoses. Its mobile platform and user-friendly interface ensure accessibility for a broad demographic, including individuals in remote and underserved areas.

By addressing the specific diagnostic challenges faced at THB Bekasi Hospital, particularly the limited availability of specialists and long patient queues, the system bridges critical gaps in healthcare delivery. Compared to traditional diagnostic methods, this expert system reduces reliance on in-person consultations, offering continuous, real-time diagnostic support. Furthermore, its scalable design and adaptability to user needs highlight its potential for broader applications in healthcare.

While the system excels in accuracy and usability, it is currently limited to diagnosing 11 predefined ENT diseases based on 35 symptoms. This limitation underscores the need for dynamic updates to the knowledge base and enhanced features to handle more complex and diverse medical conditions. Despite these constraints, the findings confirm the system's potential to transform ENT healthcare by improving diagnostic efficiency, accuracy, and accessibility.

Recommendation

To enhance the system's capabilities and expand its impact, the following recommendations are proposed:

1. **Integration of Machine Learning**: Incorporating machine learning algorithms can enable dynamic updates to the knowledge base, allowing the system to learn from new data and handle previously unaddressed conditions.
2. **Multilingual Support**: Adding support for multiple languages will improve usability for non-native speakers and increase the system's global reach.
3. **Web-Based and Offline Access**: Developing a web-based version or providing offline access can address the limitation of mobile dependency, ensuring inclusivity for users without smartphones or internet connectivity.
4. **Expansion of Knowledge Base**: Including additional diseases and symptoms, particularly rarer or overlapping conditions, will enhance the system's diagnostic scope and utility.
5. **Integration of GPS Mapping**: Adding a feature to locate nearby ENT specialists or hospitals can complement the diagnostic functionality and facilitate timely medical intervention.

Future research should focus on validating the system’s performance across diverse populations and clinical settings. Additionally, exploring the application of similar expert systems for other medical specialties can further demonstrate the versatility and scalability of this approach in transforming healthcare delivery.

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