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A Mobile-Based Expert System for Glaucoma Diagnosis Using the Naive Bayes Algorithm

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ABSTRACT

This study aims to develop a mobile-based expert system application for early diagnosis of glaucoma using the Naive Bayes algorithm. The application is designed to help users recognize early symptoms of glaucoma, provide preliminary information, and increase public awareness to reduce the risk of vision loss or blindness. The application was developed using the Dart programming language, the Flutter framework, and Firebase as the database platform. The research method employed is Research and Development (R&D), utilizing the 4D development model, which consists of four stages: Define, Design, Develop, and Dissemination. To evaluate the functionality and effectiveness of the application, both black-box testing and expert validation were conducted. The Naive Bayes algorithm implemented in the application demonstrated a high accuracy rate of 97.50%, indicating strong reliability in recognizing symptom patterns and producing appropriate diagnostic predictions based on user input. Furthermore, the System Usability Scale (SUS) was used to assess the application's usability, yielding a high average score of 97.5%, reflecting excellent ease of use and user satisfaction. In addition, content validation by subject matter experts resulted in an average feasibility score of 98.07%, indicating that the application is highly suitable for public use in supporting early screening and diagnosis of glaucoma.

INTRODUCTION

Glaucoma is a chronic visual impairment caused by damage to the optic nerve and is recognized as the leading cause of irreversible blindness worldwide. The disease typically progresses without noticeable symptoms in its early stages, resulting in many individuals being unaware of their condition until it reaches an advanced stage. According to the World Health Organization (2023), glaucoma affects approximately 3.5% of the global population aged 40–80 years, and its prevalence is projected to rise to 111.8 million by 2040. In Indonesia, data from the Ministry of Health shows that glaucoma cases are steadily increasing, with global figures reaching around 76 million in 2020 (Al-Hikmah et al., 2024).

Public awareness of glaucoma remains significantly low. Many individuals are unaware of the symptoms, delay medical consultation due to limited access to healthcare, or lack knowledge regarding the disease. Observational data from the Eye Clinic of ST Madyang General Hospital recorded 43 diagnosed glaucoma cases between 2023 and 2024. However, a study by Liu et al. (2023) indicated that nearly 50% of glaucoma patients are unaware they have the disease, suggesting that the actual number of cases could be twice as high as currently reported.

Advancements in information and communication technology have led to the emergence of digital health solutions, including expert systems capable of simulating medical expert reasoning. Mobile-based expert systems, in particular, provide accessible, fast, and cost-effective tools for preliminary disease screening. For accurate decision-making, such systems require robust classification algorithms (Suardi, 2022). One of the most suitable is Naive Bayes, a probabilistic classifier known for its efficiency and high accuracy even with limited datasets (Martantoh & Yanih, 2022).

Previous research has demonstrated the effectiveness of expert systems using the Naive Bayes algorithm for glaucoma diagnosis. Rahman et al. (2021) compared Naive Bayes and the Certainty Factor method, showing better accuracy in symptom classification using Naive Bayes. Niati & Sitohang (2022) confirmed the applicability of Bayesian theory for glaucoma detection, while Febrianto et al. (2024) achieved 93.42% accuracy using Gaussian and Bernoulli Naive Bayes models.

However, most existing studies are limited to web-based applications or simulations and have not been implemented on mobile platforms for real-world usage. Additionally, few have been applied in clinical settings within Indonesia, where early detection tools are critically needed. Therefore, this study aims to design and develop a mobile-based expert system for glaucoma diagnosis using the Naive Bayes algorithm, with a case study conducted at ST Madyang General Hospital.

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LITERATURE REVIEW

This literature review examines previous studies related to expert systems and the Naive Bayes algorithm in the diagnosis of glaucoma. It aims to understand the methods used, their advantages and limitations, and to establish a foundation for the system developed in this study.

A heuristic evaluation was conducted with 25 participants from diverse backgrounds. Severity ratings were analyzed using a standard scale, where scores ≥1 indicate usability issues. As shown in Table 4, the highest ratings were for Aspect 9 (0.97) and Aspect 10 (0.98), related to error recovery and help/documentation.Participant feedback highlighted the absence of a contact feature as a key issue, limiting user support and communication. It is recommended that this feature be added to the system design. Other aspects received satisfactory scores and do not require major improvements (Yasir et al. 2023).

A comparative study examined the use of Naive Bayes and Certainty Factor methods in early glaucoma diagnosis. The results indicated that Naive Bayes effectively classified symptom data based on training datasets, while the Certainty Factor method achieved 96% diagnostic accuracy by combining expert CF values with user inputs (Rahman et al., 2021).

Bayes' Theorem was applied to develop an expert system for glaucoma diagnosis, demonstrating effective implementation in detecting glaucoma based on patient symptoms and showing strong potential as a decision-support tool for medical practitioners (Niati & Sitohang, 2022).

An expert system integrating Backward Chaining and Simple Additive Weighting (SAW) was developed to identify and prioritize causal factors of eye diseases such as glaucoma, astigmatism, hyperopia, and myopia. Backward Chaining was employed to trace symptom-cause relationships, while SAW assigned weights for factor ranking. Testing on 45 patient cases showed 91% accuracy, with errors mainly due to data limitations, subjective weighting, and inference rules. This system supports early clinical decision-making by helping physicians focus on the most significant contributing factors, thereby improving diagnostic consistency and efficiency (Wiguna et al., 2025).

A qualitative study investigated factors contributing to delays in seeking care among patients with primary glaucoma, revealing that a lack of awareness of early symptoms often led to irreversible vision loss. These findings highlight the urgency of developing accessible tools for early diagnosis (Liu et al., 2023).

A comparative study evaluated the performance of Gaussian and Bernoulli Naive Bayes algorithms in diagnosing eye diseases at the Eye Clinic of RSI Jemursari Surabaya. The Gaussian model achieved an accuracy of 93.42%, while the Bernoulli model reached 90.79%, demonstrating the effectiveness of Naive Bayes variants in medical classification tasks (Febrianto et al., 2024).

A study analyzed public sentiment toward diabetes using the Naive Bayes Classifier on Twitter data, applying the Knowledge Discovery in Database (KDD) methodology with preprocessing steps such as text cleaning, tokenization, and stemming. From 4,802 collected tweets, 4,369 were included in the final dataset. The model was tested under various training-to-testing ratios, with the best performance at a 90:10 split, achieving 81% accuracy, 80% precision, 81% recall, and an F-score of 80%. The findings confirmed the effectiveness of Naive Bayes in classifying public opinion, which was predominantly negative and reflected widespread concern about diabetes (Susilo et al., 2025).

METHOD

Research Design

This study employed a Research and Development (R&D) approach using the 4D development model (Define, Design, Develop, Disseminate). The research was conducted at the Eye Clinic of ST Madyang General Hospital, Palopo, from December 2024 to May 2025.

In the Define stage, observations and interviews were conducted with ophthalmologists and nurses to identify key issues in glaucoma diagnosis. Based on the analysis, a solution was proposed in the form of a mobile-based expert system application using the Naive Bayes algorithm to assist early glaucoma detection.

The Design stage involved system architecture planning, user interface design, and algorithm development. In the Develop stage, the application was built and underwent expert validation and usability testing. Expert validation used a Likert scale to assess material feasibility, while user testing employed the System Usability Scale (SUS) method to evaluate the application's ease of use and acceptance.

Finally, the Dissemination stage included deploying the application for real users and planning for ongoing maintenance. System modeling used UML diagrams including activity, class, and sequence diagrams, while data management was structured through Firebase-based database design (Maydiantoro, 2021). The visual representation of the 4D development model is shown in Fig 1 (Riani et al. 2023).

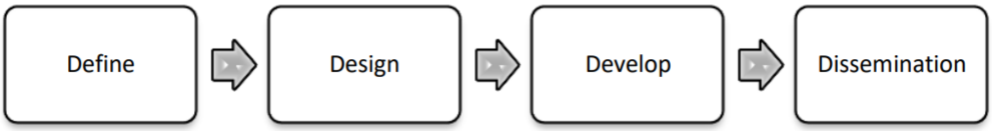

Fig 1. 4D Model

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Naive Bayes Algorithm

Naive Bayes is a method used to predict the likelihood of future events based on previously observed data or past experiences (Rahman et al., 2021). For the implementation and testing of the model, Google Colab was utilized as a cloud-based programming environment. The dataset was randomly divided using the train_test_split function, applying a specific proportion between training and testing data to ensure the generalization capability of the Naive Bayes model on unseen data. The data was split with a ratio of 80% for training and 20% for testing.

X_train, X_test, y_train, y_test = train_test_split(
X, y, test_size=0.2, random_state=42, shuffle=True, stratify=y)

System Usability Scale Method

The System Usability Scale (SUS) is an evaluation method used to assess the feasibility and usability level of an application based on user perception. This method consists of ten statements rated on a five-point Likert scale, ranging from strongly disagree to strongly agree. SUS is designed to provide a quantitative overview of how easy, efficient, and satisfying a system is to use. The formula for calculating the response weights in the SUS evaluation is as follows (Kurniawan et al. 2022).

$$SUS\ Score = \{(S1-1)+(5-S2)+(S3-1)+(5-S4)+(S5-1)+(5-S6)+(S7-1)+(5-S8)+(S9-1)+(5-S10)\}*2,5 \quad (1)$$

Validation by Subject-Matter Experts

This stage involves further development of the previously designed product, both in terms of the application and the algorithm. Content expert validation was conducted to assess the accuracy, relevance, and functionality of the expert system for glaucoma diagnosis, based on feedback from medical professionals. The purpose of this validation is to ensure that the developed application meets clinical standards and real-world needs before being released to the public. The validation was carried out by two experts—a certified ophthalmologist and a nurse—using an evaluation instrument based on a 4-point Likert scale, with the following options: Strongly Disagree (1 point), Disagree (2 points), Agree (3 points), and Strongly Agree (4 points) (Halah et al., 2024).

RESULT

Functional Requirements

This research aims to develop a mobile-based expert system application to assist the public in independently diagnosing early symptoms of glaucoma. The application utilizes the probabilistic Naive Bayes algorithm and is developed using Android Studio (version Ladybug 2024.2.1) with the Dart programming language. Firebase serves as the database platform, with server integration supported by Railway and GitHub. The application's functional requirements include several interconnected features designed to support user interaction and system usability. These features allow users to register a new account, log in to the system, and access the homepage or dashboard. Users can input the symptoms they are experiencing, upon which the system provides a diagnosis result. Additionally, users can view the history of previous diagnoses, access and edit their profile information, and modify application settings. The system also offers access to information about nearby hospitals and allows users to securely log out.

Application Interface Visualization

The user interface of the expert system application for glaucoma diagnosis based on the Naive Bayes algorithm includes main menu components such as Home, Register, Login, Diagnosis, History, and User Account, along with additional features like Settings and Nearby Hospital Information. The entire interface is designed to be user-friendly and to support interactive self-assessment of early glaucoma symptoms. Users who already have an account can log in to the application by entering their registered email and password. Upon successful login, they will be directed to the main page to access the glaucoma diagnosis featur. The login page interface is shown in Fig 2.

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Fig 2. Login Page

After logging in, users are directed to the homepage as the initial display of the application. This page presents the latest articles and news related to glaucoma from trusted sources, displayed in a vertical layout to facilitate navigation. The homepage interface is shown in Fig 3.

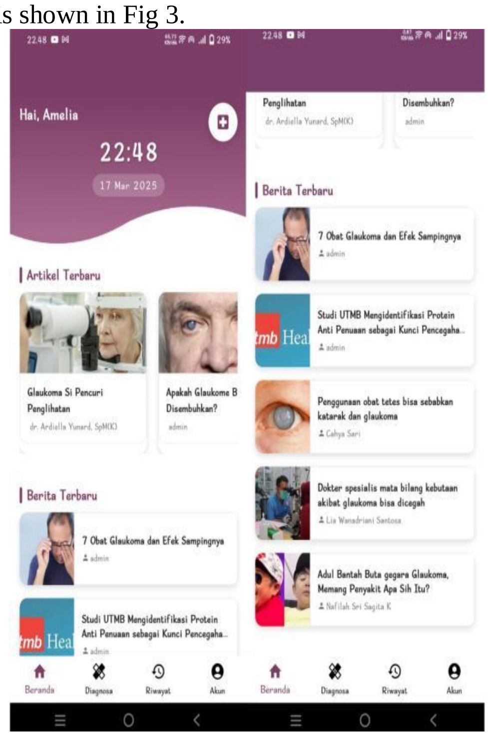

Fig 3. Homepage

The main menu of the application is the diagnosis page. Before inputting symptoms, users go through an auto-filled registration process. The diagnosis page interface is presented in Fig 4.

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Fig 4. Diagnosis Page

On this page, the expert system powered by the Naive Bayes algorithm processes the symptoms selected by the user to generate a diagnostic result. This algorithm applies a probabilistic approach based on previously trained glaucoma case data. Once the user selects symptoms from the list, the system automatically displays a prediction. The symptom input interface is shown in Figure 5.

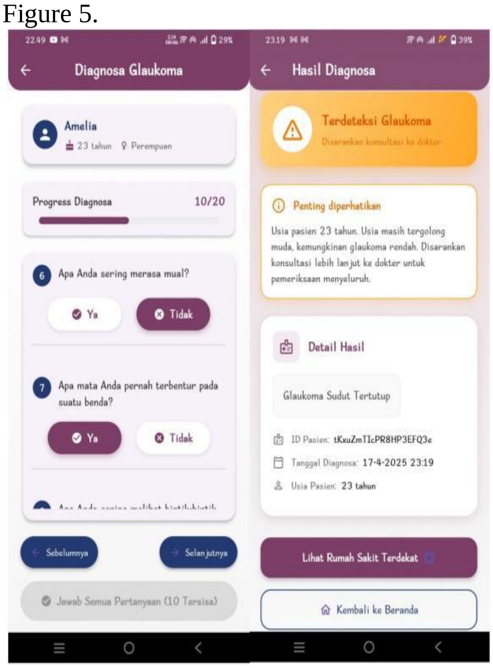

Fig 5. Symptom Input Page

This page displays a list of hospitals in Palopo City based on proximity to the user's location, complete with names and addresses. It can be accessed through the homepage menu or appears automatically if the diagnosis result indicates glaucoma. This feature assists users in locating the nearest healthcare facilities. The interface of this page is shown in Figure 6.

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Fig 6. Nearest Hospital Recommendation Page

System Usability Scale

The expert system application for glaucoma diagnosis was implemented at the research site, specifically at the Eye Clinic (Poli Mata) of RSU ST Madyang, Palopo City. An evaluation was conducted involving ten respondents, consisting of patients and general users, to assess the extent to which the application meets user needs in independently performing early glaucoma diagnosis. Respondent data is presented in Table 1.

Table 1. System Usability Scale Results

Respondent	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**	**×2,5**
	Hh	Hh	Hh	Hh	Hh	Hh	Hh	Hh	Hh	Hh		
Respondent1	4	4	4	2	4	4	4	4	4	4	38	95
Respondent2	4	4	4	2	4	4	4	4	4	4	38	95
Respondent3	4	4	4	2	4	4	4	4	4	4	38	95
Respondent4	4	4	4	2	4	4	4	4	4	4	38	95
Respondent5	4	4	4	2	4	4	4	4	4	4	38	95
Respondent6	4	4	4	4	4	4	4	4	4	4	40	100
Respondent7	4	4	4	4	4	4	4	4	4	4	40	100
Respondent8	4	4	4	4	4	4	4	4	4	4	40	100
Respondent9	4	4	4	4	4	4	4	4	4	4	40	100
Responden1t0	4	4	4	4	4	4	4	4	4	4	40	100
Average Score												97,5

Table 1 shows an average SUS score of 97.5, placing the application in the "Best Imaginable" category, with a Grade A and an "Acceptable" rating. These results indicate high usability, convenience, and user satisfaction, confirming the system's readiness for broader use.

Validation by Subject-Matter Experts

Expert validation followed the Health Technology Assessment (HTA) approach, covering acceptability, accessibility, and feasibility. Two domain experts—an ophthalmologist and an eye clinic nurse from RSU ST Madyang—evaluated the system using a 4-point Likert scale to assess content accuracy and functionality. Results are shown in Table 2.

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Table 2. Expert Validation Results

Assesment Aspect	Result		Total
	v1	v2	v1+v2
Acceptability			
1. The application presents glaucoma symptom information that reflects real clinical conditions.	3	3	6
2. The diagnosis results align with logical medical reasoning.	4	4	8
3. The application is acceptable as an early diagnosis tool in healthcare settings.	4	4	8
4. The use of the Naive Bayes method in diagnosis is relevant and medically acceptable.	4	4	8
5. I believe this application can support public education on glaucoma.	4	4	8
Accessibility			
6. The application is easily accessible to users from various backgrounds.	4	4	8
7. The language used is understandable by both general users and medical professionals.	4	4	8
8. Menu navigation and features are clear and not confusing.	4	4	8
9. No special training is required to use the application.	4	4	8
Feasibility			
10. The application can be used in clinical practice or as a decision support system.	3	3	6
11. Implementation does not require high costs or special infrastructure.	4	4	8
12. Time needed to operate the application is efficient for daily clinical practice.	4	4	8
13. The application is feasible for early glaucoma screening in the general population.	4	4	8
Total			102

The number of items in the validation form was 13, assessed by 2 validators. Each item had a maximum score of 4, resulting in a maximum possible score of 13 × 2 × 4 = 104. The total score obtained from the validators was 102. Therefore, the expert validation percentage is calculated as (102 / 104) × 100% = 98.07%, indicating a very high level of feasibility and content validity.The content validation conducted by two experts resulted in a score of 98.07%, which falls into the "highly feasible" category. This percentage indicates that the content and functionality of the glaucoma diagnosis expert system meet the eligibility standards based on expert assessments and are considered suitable for use by users in conducting early glaucoma diagnoses independently.

DISCUSSION

The glaucoma expert system application is designed to be intelligent, user-friendly, and easily accessible to anyone. This is evidenced by a user score of 97.5, categorized as *Best Imaginable* on the Adjective Rating scale, rated *A* on the Grade Scale, and classified as *Acceptable* on the Acceptability Score. One of the application's key strengths lies in its use of the Naive Bayes algorithm, which processes symptom data probabilistically to estimate the type of glaucoma. This algorithm was trained, tested, and validated using Google Colab, achieving an accuracy rate of 97.50%. Furthermore, the application's diagnostic accuracy was validated by medical experts, with a content validation score of 98.07%.

By employing this approach, the system adapts to new data patterns, enhances diagnostic accuracy, and streamlines the diagnostic process without relying on complex manual rules. The expert system functions as a digital ophthalmologist, combining medical knowledge with algorithmic analysis to produce logical and measurable diagnostic outcomes. This greatly assists users in understanding their eye condition independently.

Ease of access is another advantage, as the mobile-based application is available on Android devices and can be used anytime and anywhere. It also features a hospital recommendation system based on user location, providing a list of nearby ophthalmology clinics in Palopo, including details on eye care services, doctors' names, and visiting hours.

However, the application has several limitations. The number of symptoms and glaucoma classifications included is still limited, as the training data were sourced primarily from common cases in the research location.

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Additionally, the application requires an internet connection to function, which may be a challenge in areas with limited connectivity. It also lacks direct consultation features with ophthalmologists. Therefore, the diagnostic results should be considered preliminary and not a substitute for professional medical examinations. Users are still advised to consult healthcare professionals after using the application.

CONCLUSION

Based on the design, implementation, and testing phases, this study successfully developed a mobile-based expert system application for glaucoma diagnosis using the Naive Bayes algorithm. The application was built using Flutter and Dart in Android Studio, integrated with Firebase as the database and deployed via Railway and GitHub. The Naive Bayes algorithm analyzed user-input symptoms probabilistically and achieved an accuracy rate of 97.50% from 198 test data. Key features—such as symptom input, diagnostic results, history tracking, and nearby eye hospital recommendations—support users in performing early detection of glaucoma independently and effectively.

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