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Iot Based Smart Garage Application Design For Residential Residences

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Abstract

The rapid development of the Internet of Things (IoT) has encouraged the adoption of smart technologies in residential environments, including garage management systems. However, existing smart garage solutions primarily emphasize remote control functionality while providing limited support for enhanced security, activity monitoring, and user management. This study aims to design and evaluate an IoT-based Smart Garage application that improves both convenience and security for residential users. The research adopts a Research and Development (R&D) approach using the Agile software development methodology. The proposed application integrates remote garage control, real-time status notifications, activity history tracking, user profile management, and biometric authentication through Android Keyguard Manager. System quality was evaluated based on the ISO 25010 standard, focusing on functional suitability, usability, and reliability. The results indicate that the application achieved a functional suitability score of 100%, demonstrating that all implemented features operated according to requirements. Usability testing using the System Usability Scale (SUS) produced an average score of 80, indicating acceptable user satisfaction and ease of use. Reliability testing confirmed stable system performance without failures during continuous operation. The study contributes a secure and integrated smart garage framework by combining IoT-based control, activity monitoring, and device-level biometric authentication within a single mobile application.

Keyword: Smart Garage, Internet of Things, Keyguard Manager, Garage Control, Mobile Application

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INTRODUCTION

Internet of Things (IoT) technology has become one of the most widely adopted technologies for supporting monitoring systems due to its ability to facilitate monitoring activities through applications (Muliadi et al., 2020; Hidayat et al., 2023). IoT has become a major technological trend since the early 2010s, along with the rapid development of 4G and 5G communication networks (Isa & Suhartono, 2024). One of the monitoring systems commonly used today is the installation of Closed-Circuit Television (CCTV) around residential areas, particularly in garages (Herdiansyah et al., 2021). However, CCTV systems have limitations in enhancing security because they generally only record events that occur. In addition, conventional garage doors are often considered impractical and inefficient because they still require manual operation (Hartana, 2023). Therefore, the integration of IoT technology is needed to address these limitations. This is consistent with previous research reported in (Malaravan et al., 2023), which stated that IoT implementation contributes to improved security systems. The operation of IoT-based monitoring systems through applications requires smartphones as the primary access device. Most smartphones are equipped with technologies such as Wi-Fi, Bluetooth, and infrared, enabling users to communicate and transfer data through wireless connections (Anchal & Mittal, 2020). Among these devices, Android smartphones are particularly dominant due to their widespread adoption, with Android being used on hundreds of millions of devices across more than 190 countries (Patta et al., 2023).

However, when discussing security and application-based control, challenges arise in preventing unauthorized access. One of the most commonly used security methods is the implementation of PINs or passwords. Nevertheless, this method provides only limited protection and remains vulnerable when used as the primary security mechanism (Bjelcic et al., 2021). To strengthen security, biometric authentication systems can be incorporated to provide additional protection against unauthorized access (Ariff et al., 2022). According to Daulay, as cited in (Suhartono et al., 2023), fingerprints consist of unique ridge patterns on the fingertips and have long been utilized as an identification method because of their high matching accuracy. Biometric systems therefore have significant potential to replace conventional passwords as identification and authentication mechanisms (Widyaretno & Indriyanti, 2023).

Several previous studies have successfully designed and developed automatic garage systems using various approaches. For instance, the study in (Ariff et al., 2022) developed a smartphone-based remote garage control application integrated with IoT devices. Another study developed an IoT-integrated garage control application with notification delivery through a Telegram bot (Rohadi et al., 2019). Research conducted in (Hartana, 2023) implemented a PIN-

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based authentication system as a security mechanism, while the study in (Pratama & Sunardi, 2020) developed a garage control system using the Blynk application as the user interface.

To bridge the need for both garage accessibility and security, this study focuses on the design of an IoT-based Smart Garage application for residential housing. This research is aligned with the growing trend of smart parking studies that emphasize efficiency and security in parking management systems (Suhartono et al., 2024). Therefore, this study adapts these concepts through the development of a Smart Garage application that not only functions as a garage control system but also enhances user security. The application is designed for Android-based mobile devices and provides an intuitive interface that allows users to control the garage anytime and anywhere. Furthermore, the application is equipped with built-in garage status notifications, garage activity history records, and Keyguard Manager authentication as an additional layer of security.

LITERATURE REVIEW

Previous Research

Table 1. Previous Research

No	Writer	Tittle	Explanation
1	Mohammed Murad, Oguz Bayat, Hamzah M. Marhoon (2021)	Design and implementation of a smart home system with two levels of security based on IoT technology	Smart home system with smart garage automation using a mobile application and internet connectivity
2	Mohamed Imran Mohamed Ariff, Farah Diyana Mohamad Fadzir, Noreen Izza Arshad, Samsiah Ahmad, Khairullizza Ahmad Salleh, Jufiza A. Wahab (2022)	Design and Development of a Smart Garage Door System	Smart garage application with remote control functionality through smartphones and IoT integration.
3	Juniyan Wisnu Rohadi, A Sjamsjiar Rachman, Supriono (2019)	Design of an Automatic Garage Door Prototype Using Morse Code and	Developed an IoT-based garage control system integrated with Telegram

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		Telegram Bot Based on ESP32-CAM	Bot for notification delivery and remote monitoring
4	Bagas Yudhi Pratama, Sunardi (2020)	Monitoring and Control of Home Garage Access using IoT-based Smartphones	Mobile garage control and monitoring system integrated with IoT devices and the Blynk platform
5	Hartana (2023)	Wireless Automatic Garage Door Controller Menggunakan Nodemcu ESP8266	Automatic garage control system with PIN-based authentication for additional security
6	Dibyahash Bordoloi, Surendra Shukla (2021)	Planning And Construction of a High-Tech Garage Door	Smart garage door system with IoT integration and Google Assistant voice commands.

METHOD

This study employed a Research and Development (R&D) approach and adopted the Agile methodology for software development. According to Sugiyono, as cited in (Okpatrioka, 2023), the R&D approach is a research method used to develop a product while simultaneously evaluating its effectiveness. Meanwhile, the Agile methodology enables developers to respond quickly to user feedback, allowing feature modifications to be implemented efficiently through iterative sprint cycles (Tinambunan et al., 2024).

Data Collection and Problem Identification

Data were collected through a review of theories, concepts, and previous studies relevant to the research topic. This process aimed to establish the theoretical foundation of the study and identify variables related to the research problem (Waruwu, 2024). The literature review revealed several gaps in previous studies, indicating the need for further development of existing technologies. The identified gaps included intuitive user interfaces, additional application authentication mechanisms, application personalization, garage status notifications, and garage activity history features.

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System Design

The design phase focused on defining the workflow, structure, and interface of the application to be developed. The system design served as a guideline for the development process by representing the functionality and structure of the proposed system. The design activities included application architecture design, Unified Modeling Language (UML) modeling, and low-fidelity user interface prototyping.

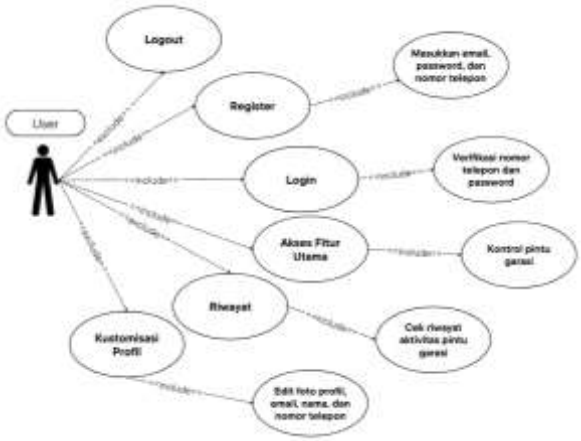


Figure 1. Use Case Diagram

Application Development

During the development phase, the functional and interface designs were translated into a working application using the Kodular platform. Kodular is a web-based development platform that provides drag-and-drop tools through a block-programming approach (Kholifah & Imansari, 2022). The developed application integrated Android mobile devices, Firebase services, and IoT hardware components responsible for garage door operation and monitoring.

System Testing and Data Analysis

Application testing was conducted using the Black Box Testing method. This method focuses on evaluating application inputs and outputs without examining the internal program code (Desyani et al., 2022). The evaluation process referred to the ISO 25010 software quality standard, which provides quality characteristics for assessing system feasibility and performance (Nursahiba & Enda, 2025). Three ISO 25010 quality characteristics were evaluated in this study:

1. Functional Suitability

   Functional suitability testing was conducted to evaluate whether all application features performed according to their intended functions and user requirements (Zahra,

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2025). The assessment involved two expert validators with expertise in software engineering and system evaluation. A Guttman scale was employed, where each feature was rated using binary responses: "Yes" if the feature functioned correctly and "No" if it failed to meet the expected functionality (Suhartono & Susilawatizahraen, 2022). The obtained scores were subsequently converted into percentage values and interpreted using predefined functional suitability criteria ranging from "Very Poor" to "Very Good."

2. Usability

Usability testing was conducted to assess the extent to which the application could be used effectively, efficiently, and satisfactorily by users in achieving specific objectives (Lianto et al., 2023). The evaluation involved 15 respondents, following Nielsen's recommendation that 5–10 users are generally sufficient to identify most usability issues, while at least 15 users can reveal nearly all usability problems within a system design (Handayani & Maria, 2025). The System Usability Scale (SUS) was adopted as the evaluation instrument. SUS consists of ten statements measured using a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5).

Table 2. System Usability Scale Questionnaire

No	Questions
1	I think that I would like to use this system frequently.
2	I found the system unnecessarily complex.
3	I thought the system was easy to use.
4	I think that I would need the support of a technical person to be able to use this system.
5	I found the various functions in this system were well integrated.
6	I thought there was too much inconsistency in this system.
7	I would imagine that most people would learn to use this system very quickly.
8	I found the system very confusing to use.
9	I did not encounter significant obstacles while using this system.

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10	I needed to learn a lot of things before I could get going with this system.

After the respondents data had been collected, the SUS score was calculated according to the standard SUS scoring procedure. Several rules were applied during the scoring process as follows:

a. For each odd-numbered item, the score contribution is obtained by subtracting 1 from the respondent's selected score.
b. For each even-numbered item, the score contribution is obtained by subtracting the respondent's selected score from 5.
c. The final SUS score is calculated by summing the adjusted scores of all ten items and multiplying the result by 2,5.

These scoring rules apply to a single respondent. To obtain the overall SUS score, the average score of all respondents was calculated by summing the individual SUS scores and dividing the result by the total number of respondents. The SUS evaluation categories are based on a scale ranging from 0 to 100, as illustrated in Figure 2.

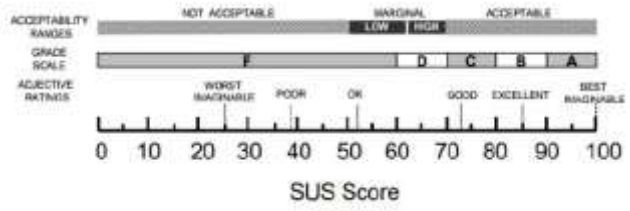


Figure 2. SUS Rating Scale

The SUS acceptability scale is divided into three categories. The first category, not acceptable, ranges from 0 to 50. The second category, marginal, ranges from 50 to 70. The third category, acceptable, ranges from 70 to 100 (Susila & Sri Arsa, 2023). Therefore, the application's usability can be considered satisfactory when the average SUS score exceeds 73 (Bagaswara, 2019).

3. Reliability

Reliability testing was performed to evaluate the system's ability to operate consistently and maintain its functionality over a specified period (Mulyawan et al., 2021). This quality characteristic encompasses several sub-characteristics, including maturity, availability, fault tolerance, and recoverability.

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The evaluation employed the Mean Time to Failure (MTTF) method, which measures the average operational time before a system failure occurs (Verma, 2024). During the testing process, the application was operated continuously within a predetermined observation period while monitoring for system errors, failures, or operational interruptions. The resulting MTTF value was used as an indicator of the application's reliability and operational stability.

RESULTS AND DISCUSSION

Application Features

The research resulted in the development of the Smart Garage application, which provides remote garage control through an Android-based mobile application. The application incorporates several supporting features, including real-time garage status notifications, garage activity history records, profile management, and Keyguard Manager authentication for additional security.

The main application features include:

1. User Registration

   The registration page allows new users to create an account before accessing the application features. Users are required to provide personal information, including email address, phone number, name, and password. The submitted data are stored in Firebase and subsequently used for user authentication. Input validation and error prevention mechanisms are implemented to ensure data accuracy.



Figure 3. Registration Page

2. User Login

   The login page enables registered users to access the application using their phone

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number and password. Upon successful authentication, users are redirected to the main dashboard. Error-handling notifications are provided to inform users of invalid login credentials.

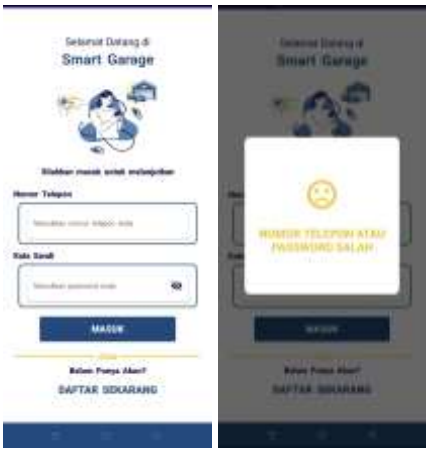


Figure 4. Login Page

3. Keyguard Manager Authentication

This feature provides an additional security layer by utilizing the Android Keyguard Manager. Users must verify their identity through device-level authentication methods, such as PIN, pattern, password, fingerprint, or facial recognition, before performing sensitive actions.

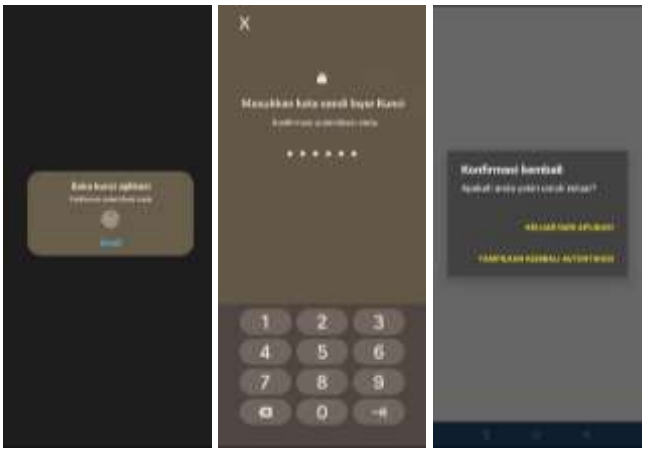


Figure 5. Keyguard Manager

4. Garage Control Interface

The dashboard serves as the main interface of the application and provides personalized greetings based on the user's account information. It also displays garage control instructions and real-time garage status notifications, indicating whether the garage door is open or closed.

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Figure 6. Dashboard Page

5. Activity History Management

The activity history page displays a chronological record of garage-related activities, including door status changes, timestamps, and user identities. This feature enhances transparency and supports activity monitoring, particularly in multi-user environments.



Figure 7. History Page

6. User Profile Management

The profile management page allows users to update personal information, including name, email address, password, and profile picture. To ensure security, profile modifications require successful authentication through the Android Keyguard Manager before changes can be saved.

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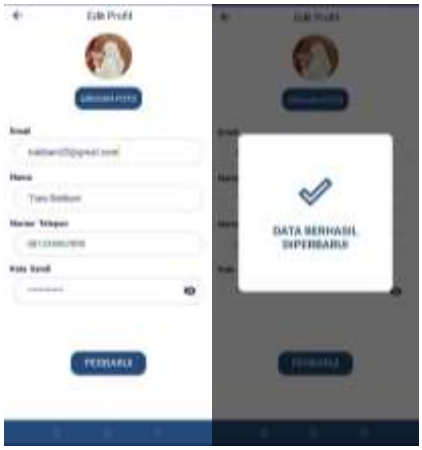


Figure 8. Profile Page

Blackbox Testing

1. Functional Suitability

Based on the results of the functional suitability evaluation conducted by two expert validators, the following recapitulation was obtained:

Table 3. Functional Suitability Evaluation Results

No	Validator	Total Score	Maximum Score	Percentage (100%)	Category
1	Validator 1	23	23	100%	Very Good
2	Validator 2	23	23	100%	Very Good
Total		46	46	100%	Very Good

To determine the percentage of positive responses obtained from the evaluation data, the following formula was used (Basri et al., 2024):

$$Functional\ Suitability\ = \frac{Total\ Score}{Max\ Score} \times 100\%$$

$$Functional\ Suitability\ = \frac{46}{46} \times 100\%$$

Based on the assessments provided by both validators, the functional suitability score obtained was 100%. Referring to the functional suitability interpretation criteria, the developed application falls within the Very Good category, as it fulfills all functional

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requirements specified for the system.

2. Usability

Usability testing was conducted with 15 respondents using a hybrid approach (online and offline) and applying the System Usability Scale (SUS) method.

Table 4. Summary of Usability Assessment

Respondents	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total Score	*2,5
R1	3	4	4	4	4	4	4	4	4	3	38	95
R2	3	4	3	4	3	3	3	3	3	4	33	82,5
R3	3	4	3	3	3	3	3	3	3	4	32	80
R4	3	3	3	3	3	3	3	3	3	3	30	75
R5	3	4	3	3	3	3	3	4	3	3	32	80
R6	4	3	3	3	3	4	3	3	3	4	33	82,5
R7	3	3	3	2	3	2	3	3	3	3	28	70
R8	3	3	3	3	3	3	3	4	3	4	32	80
R9	3	3	3	3	3	4	2	4	3	3	31	77,5
R10	3	3	2	1	3	3	3	3	3	3	27	67,5
R11	3	3	3	3	3	3	3	3	3	3	30	75
R12	4	3	3	3	4	3	3	4	4	4	35	87,5
R13	4	4	3	3	3	4	3	3	3	4	34	85
R14	2	4	3	3	3	3	3	4	3	4	32	80
R15	3	4	3	3	3	3	3	3	4	4	33	82,5
											TOTAL	1.200

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The following formula was used to calculate the SUS score (Bagaswara, 2019):

$$Average\ SUS = \frac{Total\ Score}{Number\ of\ Respondents}$$

$$Average\ SUS = \frac{1.200}{15} = 80$$

After all responses were calculated and averaged, an average SUS score of 80 was obtained. According to the SUS interpretation standard, a score of 80 falls within the acceptable category. This result indicates that the application demonstrates a high level of usability, is easy to understand, comfortable to use, and provides a positive user experience. Therefore, the application can be considered suitable for use from a usability perspective and meets software quality standards based on user perceptions.

3. Reliability

Reliability testing was conducted under two different states and evaluated by two validators. The results obtained for each state are presented below.

Table 5. Reliability Testing - State 1

No	Session Start Time (T0)	Failure Time (Tf)	Uptime Duration (Tf - T0)	Failure Type	Description
1	13:16:57	13:32:46	15 minutes 49 seconds	Failed to connect to IoT	The application was unable to reach the IoT device.
2	13:34:29	13:49:12	14 minutes 43 seconds	Failed to connect to IoT	The application was unable to reach the IoT device.
3	13:50:58	14:08:37	17 minutes 39 seconds	Failed to connect to IoT	The application was unable to reach the IoT device.
4	14:10:25	14:27:03	16 minutes 37 seconds	Failed to connect to IoT	The application was unable to reach the IoT device.

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5	14:28:31	14:44:59	16 minutes 28 seconds	Failed to connect to IoT	The application was unable to reach the IoT device.

The following formula was used to calculate the Mean Time to Failure (MTTF) (Verma, 2024):

$$MTTF = \frac{Total\ test\ time}{Total\ failure}$$

$MTTF = \frac{4.876}{5}$ = 975,2 sec = 16 minutes and 15 seconds

Table 6. Reliabiity Testing - State 2

No	Session Start Time (T0)	Failure Time (Tf)	Uptime Duration (Tf - T0)	Failure Type	Description
1	13:36:00	13:56:00	20 minutes (uptime)	No Issues Detected	The application operated normally.
2	13:34:29	13:49:12	20 minutes (uptime)	No Issues Detected	The application operated normally.
3	13:50:58	14:08:37	20 minutes (uptime)	No Issues Detected	The application operated normally.
4	14:10:25	14:27:03	20 minutes (uptime)	No Issues Detected	The application operated normally.
5	14:28:31	14:44:59	20 minutes (uptime)	No Issues Detected	The application operated normally.

Since no failures were detected during the total simulation period of 100 minutes of continuous operation, the MTTF value for this version exceeded 100 minutes. A comparison between the results of State 1 (before system improvements) and State 2 (after system improvements) demonstrates a significant increase in application reliability, particularly in terms of IoT connectivity. In version 1.0.0 (before improvements), IoT connection failures occurred consistently, resulting in an MTTF of 16 minutes and 15 seconds. However, after the implemented revisions, version 1.0.1 exhibited substantially improved stability, achieving an MTTF greater than 100 minutes without any detected IoT connectivity failures

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during testing. These findings confirm that the implemented improvements effectively resolved the previously identified connectivity issues and significantly enhanced the overall reliability of the application.

CONCLUSION

Based on the findings of this study, it can be concluded that the proposed Smart Garage application successfully implemented IoT-based garage control through a mobile application, enabling users to operate the garage remotely. The application also provides real-time notifications as confirmation of user actions and maintains a comprehensive activity history to support monitoring and transparency. Furthermore, the implementation of Android Keyguard Manager offers an additional layer of security by verifying user identity through device-level authentication mechanisms.

The evaluation results indicate that the application satisfies the selected ISO 25010 quality characteristics. All implemented features functioned as intended, demonstrating excellent functional suitability. The usability assessment showed positive user responses, indicating that the application is easy to use and provides a satisfactory user experience. In addition, reliability testing confirmed that the system was able to perform its functions consistently and operate stably without significant disruptions.

Several improvements may be considered in future research. These include integrating SMS or email notification services to ensure users receive alerts even when the application is inactive, extending application support to the iOS platform, and evaluating additional ISO 25010 quality characteristics using different testing approaches or tools. Furthermore, security can be enhanced through the implementation of One-Time Password (OTP) authentication during the login process to provide stronger protection against unauthorized access.

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