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Android-Based Monitoring System for Water Usage Observation and Control

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ABSTRACT

Water is an essential resource that sustains human life, particularly in fulfilling daily domestic needs. However, the availability of clean water in various regions around the world has been declining significantly, which is not proportional to the continuously increasing population growth. This condition necessitates efforts in managing and utilizing water resources efficiently and sustainably. One applicable approach is optimizing water usage in storage tanks through an integrated monitoring and control system. This study aims to design and implement an Android-based monitoring and control system for water usage that is capable of providing real-time information to users. The system is developed by utilizing microcontroller technology and mobile platforms to enhance the effectiveness of water management. The components used in the system development include an Android smartphone as the user interface, Arduino as the main controller, and software tools such as Arduino IDE, Visual Studio Code, and Android Studio. In addition, Firebase is employed as a database and an online data communication medium. The expected outcome of this study is the development of a system that can improve user awareness in conserving water and support more efficient and measurable water resource management.

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I. INTRODUCTION

Water is one of the fundamental human needs and plays a crucial role in supporting various daily activities, particularly for household purposes. Along with population growth, the demand for clean water continues to increase significantly. However, the availability of clean water resources remains relatively limited, requiring efficient management and utilization practices. Water conservation not only contributes to the preservation of natural resources but also reduces household expenses associated with increasing Water Basic Tariffs (WBT). Water resources are among the most essential natural resources for sustaining the lives of all living organisms on Earth. In Indonesia, the continuous growth of the population directly affects the increasing demand for water to fulfill daily needs. Water used for human consumption and household activities should meet specific criteria, such as being clear, clean, and of good quality [1].

Although approximately 71% of the Earth's surface is covered by water, only around 3% of the total water resources consist of freshwater that can be utilized by humans. This condition indicates that the availability of clean water is limited; therefore, effective water conservation and management efforts are necessary [2]. In household environments, people generally use water tanks as storage facilities for clean water reserves to ensure a continuous supply of water.

Current technological advancements provide opportunities to develop systems that support efficient water utilization. Water conservation has become increasingly important to reduce unnecessary water wastage that may increase water supply costs. Furthermore, the proper use of water contributes to ecosystem sustainability and human welfare. One form of water conservation can be achieved through appropriate control of water usage, such as turning off water faucets when they are not in use. This control process can become more effective when supported by continuous monitoring systems for daily water consumption. The use of water reservoirs or storage tanks serves as an important medium for maintaining water availability and ensuring effective water management [3].

Efforts to conserve water can be implemented through regulating the filling process of water storage tanks by designing integrated monitoring and control systems for water consumption. The rapid development of electronic technology can be utilized as a solution to address various problems related to water management in society. Water usage monitoring and control systems can improve the effectiveness and efficiency of water consumption when they are based on daily water usage patterns. In household

environments, water is used for various activities, including bathing, cooking, washing, and other daily needs [4].

Currently, residential buildings are generally equipped with water tanks for storing water supplied by regional water utility companies (PDAM). The use of water tanks provides several benefits, one of which is serving as a backup water source when the main supply is disrupted. In addition, water tanks function as primary storage facilities that help maintain water availability to fulfill household needs. With the availability of water tanks, users do not need to worry about water shortages that may disrupt daily activities.

The system developed in this study utilizes Android technology on smartphones as a medium for monitoring and controlling water usage. Users can monitor water consumption conditions in real-time through an Android application connected to sensors installed in the system. Consequently, users can identify water usage patterns more effectively, reduce water wastage, and optimize the utilization of water resources. Moreover, users can remotely control water flow through the application.

The rapid advancement of information and communication technology has significantly facilitated various aspects of human life. This progress has been supported by technology companies that continuously develop devices and systems based on open-source platforms, including the Android operating system. Android is a platform that enables developers to create various innovative applications that support human needs in different sectors [5].

Research conducted by Zafhran et al. (2020) designed an automatic faucet system based on ultrasonic sensors capable of detecting objects to activate or stop water flow automatically using a servo motor as the primary actuator. The system was also used to control water tank filling in order to prevent overflow. When the water volume falls below the predetermined threshold, the system automatically activates the filling process and stops it once the specified level has been reached. Furthermore, users can monitor water level conditions through smartphones, thereby minimizing water wastage due to user negligence [6].

Research conducted by Kumalasari et al. (2021) stated that conventional water installation and management systems require more effective solutions through the implementation of smart building technology. Smart buildings represent a building automation concept that integrates modern technologies, enabling devices and facilities within buildings to be designed and programmed according to user requirements. This concept allows systems to operate more efficiently, flexibly, interactively, and sustainably. In their study, an Android application was developed as an interface for monitoring and controlling water usage in a smart building environment, which could be accessed through smartphones [7].

Research conducted by Diharja et al. (2021) developed a clean water monitoring and control system based on the Internet of Things (IoT). The system utilized several components, including an Android application, Firebase, and WeMos D1 ESP8266. The sensors used consisted of a pH sensor and a flowmeter to measure water quality and usage volume. The results demonstrated that the system could display real-time information regarding water consumption and associated costs in Indonesian Rupiah. Furthermore, the pH sensor effectively identified water quality characteristics. The average error value between the actual water volume and the predefined setpoint was 1.29%, indicating that the system achieved a relatively good level of accuracy [8].

Based on the background described above, this study aims to design and develop a system that assists household users in monitoring and controlling water consumption effectively. By utilizing advancements in science and technology, the proposed system is expected to provide solutions to water usage problems, improve water consumption efficiency, and support more optimal water resource management.

II. MATERIALS AND METHODS

The research procedure is a sequence of activities conducted systematically and structured to achieve the objectives of the study. This research consists of five stages: analysis, design, testing, implementation, and maintenance. The stages of the research methodology used in this study are illustrated in Figure 1.

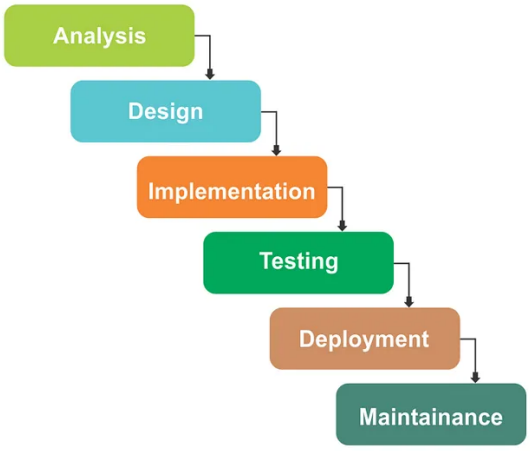

Figure 1. Research Methodology Flowchart [18]

2.1. Analysis

The analysis stage involves an intensive process of gathering requirements to define system needs in a clear and understandable manner. In this study, the analysis phase focused on identifying issues related to

water consumption, particularly the lack of user awareness and control in managing water usage, as well as users' limited understanding of reading water meters for monitoring purposes. One of the primary issues identified is excessive and uncontrolled water consumption. Therefore, relevant data were collected as the basis for developing an Android-based water monitoring and control system aimed at improving water usage efficiency and facilitating real-time monitoring.

2.2. Design

The design stage aims to develop a comprehensive architecture of the proposed system and enhance understanding of the identified problems based on the analysis phase. The software design process includes the development of the architecture for an Android-based water monitoring and control system. The system integrates several technologies, including the Java programming language for application development, Firebase as the database platform, and Android Studio as the development tool.

2.3. Testing

The testing phase focuses on evaluating the system functionality to ensure that the outputs satisfy user requirements. In this study, the software was tested to determine whether it performed according to the intended objectives, specifically in monitoring and controlling water consumption to prevent excessive and inefficient water usage.

2.4. Implementation

The output of this phase consists of one or more product components developed according to established coding standards, including system integration, correction, and testing processes to ensure compliance with the designed system architecture. In this research, the developed software and hardware system was implemented in a residential environment. Furthermore, the proposed system can also be applied in households utilizing water services provided by regional water utility companies (PDAM).

2.5. Maintenance

This stage represents the final phase of the research model after system installation and implementation. Maintenance activities are conducted periodically to ensure that the system continues to operate effectively and efficiently over time.

III. RESULTS AND DISCUSSION

Based on the features incorporated in the designed water discharge monitoring system, the use case diagram of the system can be illustrated as follows:

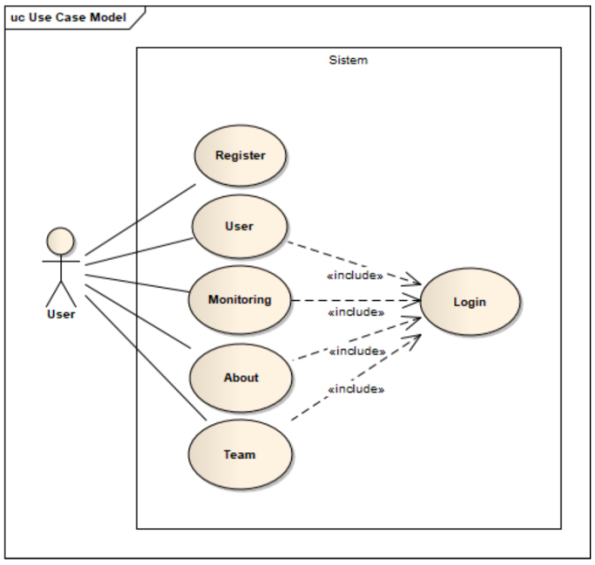

Figure 2. Usecase model for login system

Based on Figure 2, the proposed system involves a single primary actor, namely the user, who directly interacts with the various functionalities provided by the system. This actor is granted access rights to perform authentication through the log-in feature before accessing the available services. The authentication process is carried out by entering a registered username and password. This mechanism is implemented to ensure data security and to guarantee that only authorized users are permitted to access the system's functionalities.

Upon successful authentication, users are directed to the main interface, which provides several submenus designed to support the operational requirements of the system. The Monitoring submenu serves to display water discharge monitoring information, including both real-time measurements and historical data stored in the database. The About submenu provides information regarding the objectives, functionalities, and general description of the developed system. Furthermore, the User Profile submenu is intended to display and manage user account information, including user identity and account settings. The Team submenu contains information about the development team and other stakeholders involved in the design and implementation of the system.

Through the implementation of this access structure and functional organization, the system is expected to facilitate effective water discharge monitoring while simultaneously providing supporting information necessary for the comprehensive operation and management of the system.

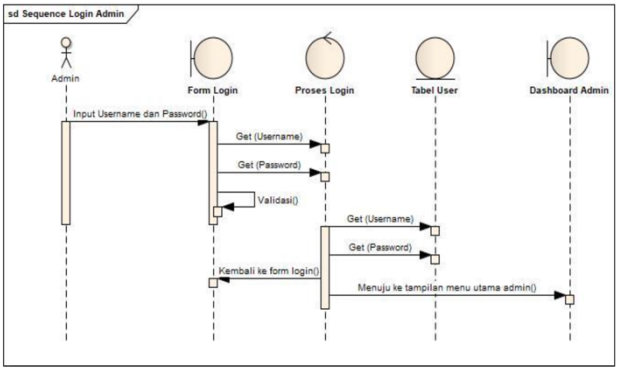

Figure 3. Sequence diagram login system

The sequence diagram of the login system is employed to illustrate the sequence of interactions and message exchanges that occur between the actor and the system components over time. This diagram provides a detailed representation of the authentication process, beginning with the user submitting login credentials, followed by the system validating the provided information, and concluding with the system generating a response indicating either successful or unsuccessful authentication.

In the context of the login system, the sequence diagram serves to visualize the chronological flow of activities among the user, the user interface, the authentication module, and the database. The process is initiated when the user enters a username and password through the login interface. The system subsequently receives these credentials and forwards a validation request to the database in order to verify the submitted information against the stored user records. If the credentials are authenticated successfully, the system returns a positive authentication response and grants access to the main interface according to the user's authorization level. Conversely, if the credentials are invalid, the system generates an error message and prompts the user to repeat the authentication process.

The application of sequence diagrams offers significant advantages during the system analysis and design phases, as they facilitate a comprehensive understanding of the system's dynamic behavior. Such diagrams enable developers to analyze the authentication workflow, identify interactions among system objects and components, and ensure that each stage of the login process is designed in accordance with both functional requirements and security considerations. Furthermore, sequence diagrams serve as valuable technical documentation, supporting system implementation, testing, validation, and future maintenance activities by providing a clear and structured representation of system interactions.

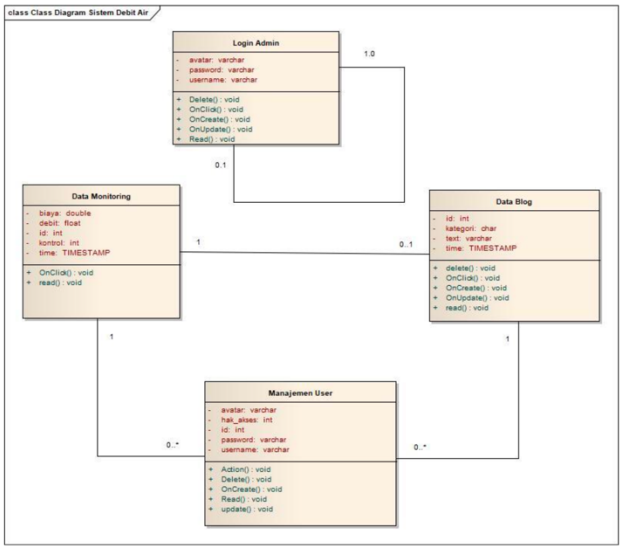

Figure 4. Class diagram system

A class diagram is one of the core diagrams in the Unified Modeling Language (UML) used to represent the static structure of a system. It illustrates the classes that constitute the system, the attributes associated with each class, the methods or operations that define their behavior, and the relationships established among classes. Consequently, a class diagram serves as a conceptual model that describes how system data and functionalities are organized within a software architecture. By providing a structured representation of system components, it facilitates a comprehensive understanding of the system's design and underlying architecture.

In software development, class diagrams are utilized to document the object structure that will be implemented during the programming phase. They assist developers in understanding the interactions and dependencies among system components, including various forms of relationships such as association, aggregation, composition, and inheritance. Through this modeling approach, developers can design a system architecture that is modular, maintainable, scalable, and aligned with the specified functional requirements. Furthermore, class diagrams provide a foundation for object-oriented design by defining the responsibilities and interactions of individual classes within the system.

In the context of a water discharge monitoring system, a class diagram can be employed to represent the relationships among key classes, such as User, Monitoring, Sensor, Database, and Report. The User class is responsible for managing user information and authentication processes, while the Monitoring class handles the collection and processing of water discharge monitoring data. The Sensor class is designed to acquire measurement data from sensing devices, whereas the Database class manages the storage, retrieval, and maintenance of system-generated data.

Additionally, the Report class may be utilized to generate and present monitoring results in a structured format. The relationships among these classes illustrate how information is exchanged, processed, and managed throughout the system, thereby ensuring an organized and coherent data flow.

Therefore, the class diagram plays a critical role in the system analysis and design phases by providing a clear and systematic representation of the system structure to be developed. Beyond supporting implementation activities, it serves as an essential technical documentation artifact that facilitates software development, testing, integration, validation, and long-term maintenance. As a result, the class diagram contributes significantly to improving system quality, consistency, and maintainability throughout the software development lifecycle.

IV. CONCLUSIONS

Based on the design and testing results of the Android-based water flow volume detection and water tank level status monitoring system, the following conclusions can be drawn:

The monitoring system successfully operated according to the planned design. The system functioned effectively by detecting incoming water flow through sensors and displaying water flow volume values as well as the availability status of water levels in the storage tank through the Android application.

The water pump and valve control system also performed effectively. This was demonstrated by the successful activation of the water pump and valve when users interacted with the control buttons provided in the Android application.

The data stored in the database were successfully displayed through the Android application and could be accessed by users for monitoring purposes.

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