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Design and Development of an Android-Based Urban Air Quality Monitoring System

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ABSTRACT

The advancement of transportation technology has redefined the concept of distance and enabled intercontinental travel within a short time, an achievement that was almost unattainable a century ago. While these developments offer convenience and efficiency, they also pose significant environmental challenges, particularly air pollution caused by vehicle emissions, which has become an increasingly urgent global issue. Additionally, noise and humidity problems also affect public health, especially in tropical regions such as Indonesia. With growing awareness of environmental issues, This study aims to design an Internet of Things based air quality monitoring system, temperature, and noise levels. The system is expected to provide real-time reports on environmental conditions, enabling users to access crucial information with ease. By implementing this technology, it is hoped that efforts to mitigate pollution and improve the quality of life can be carried out effectively. The method employed in this study integrates hardware and application development. The findings indicate that the software-processed data can be managed using the Air Quality application, enabling real-time visualization through graphs or circular bar charts.

***Keywords*: IoT, Firebase, System Design, Monitoring System, Environment**

INTRODUCTION

Ad Advancements in transportation technology have significantly redefined the concept of distance. Intercontinental travel can now be completed within hours, a feat that was nearly impossible about a century ago. Motor vehicles have rapidly evolved in their ability to traverse various terrains while enhancing user comfort. Moreover, the public transportation industry has also seen significant progress over the past few decades [1]. Transportation is a crucial role in the economic growth of a region; however, it is also a major contributor to air pollution due to vehicle emissions. This phenomenon presents a global challenge, as increasing pollution levels negatively impact the environment when concentrations exceed permissible thresholds [2]. Nevertheless, the development of transportation technology has also brought adverse environmental effects. Exhaust emissions from vehicles are now the primary cause of air pollution, contributing approximately 70% of total pollution. Unnoticed by many, the air quality that people breathe is gradually deteriorating, with the harmful effects becoming apparent only over time. Awareness of environmental issues caused by non-eco-friendly transportation has only recently begun to emerge [3].

Noise is defined as unwanted sound produced by an activity or operation at specific levels and times. Additionally, humidity plays an essential role in life, particularly concerning health [4]. Humid air and unpredictable climate changes, especially in Indonesia's tropical regions, can lead to various illnesses often influenced by high humidity levels [5]. Several regulations regarding noise have been established in the Republic of Indonesia, including Noise Level Standards. Generally, an acceptable noise level in residential areas is around 55 dB, while the noise threshold is set at 85 dB for an 8-hour exposure period [6]. Given the issues of air pollution, temperature, and noise, this study aims to develop a monitoring system for air quality, temperature, and noise using Internet of Things technology. The system will consist of hardware and a website that provides real-time reports on environmental conditions. Through this website, users can easily access information on air quality, temperature, and noise, utilizing the accessibility offered by IoT. The Internet of Things (IoT) is a concept that continuously enhances internet connectivity, enabling efficient data collection and exchange [7]. IoT connects global infrastructures with communities, offering advanced services by linking physical and virtual objects through internet technologies, allowing devices to communicate with each other. IoT technology typically operates with various sensors tailored to specific needs [8]. The data obtained from these sensors will be encrypted using the Advanced Encryption Standard (AES) method, which, according to [9], is a modern cryptographic method that replaced the insecure 56-bit block Data Encryption Standard (DES) algorithm. This algorithm was chosen based on its characteristics, security level, and cost and implementation considerations. The development of this IoT-based air quality, temperature, and noise monitoring system is expected to simplify the measurement of air quality in ports and other locations [10].

METHODS

This research is an experimental study focused on the development of a device that integrates hardware and software components. The resulting device is a prototype. The following are the steps undertaken in this research:

2.1 Hardware Identification and Design

The primary objective of this stage is to identify and define the hardware requirements necessary for the design process. This step is critical to ensure that all components selected are appropriate and capable of meeting the system's functional requirements. The hardware draft consists of a series of sensors, indicators, and an Arduino Mega Pro Mini microcontroller, which acts as the central processing unit of the system. These components are interconnected through a wireless module to facilitate seamless data transmission between the hardware and the user interface. The sensors are specifically chosen to measure environmental parameters such as air quality, temperature, humidity, and particulate matter levels, while the indicators provide real-time feedback to users. The microcontroller processes the sensor data and manages the communication flow within the system. Following this design, the necessary components or modules are sourced and integrated to proceed with the subsequent steps of the project. This foundational phase ensures that the hardware architecture aligns with the system's intended functionality, providing a solid base for the development of the functional prototype in the later stages of the project.

2.2 System Design

System design is a crucial initial stage in developing a tool. This stage involves comprehensive planning for all aspects of the system, from selecting hardware components to developing the software [11]. A well-thought-out design ensures that the resulting tool not only functions optimally but also effectively meets user needs. The design process includes creating flowcharts, schematics, and detailed user interface designs [12]. The success of this stage significantly impacts the quality and performance of the final tool. An overview of the prototype system is shown in Figure 1.

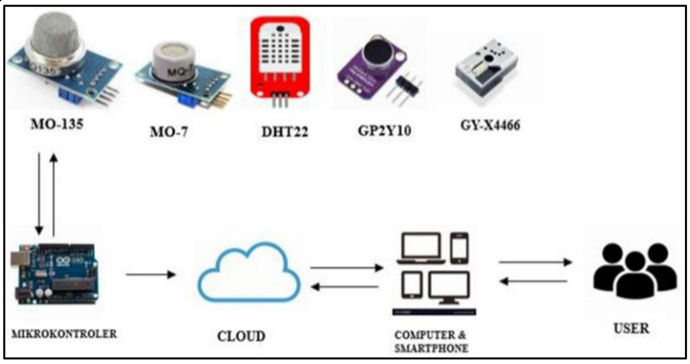

Figure 1. System Overview

Figure 1 illustrates the general structure of the IoT-based air quality monitoring system, utilizing sensors such as MQ-7, MQ-135, DHT22, GP2Y1010AUF, and GY-MAX4466. These sensors detect air quality by measuring pollutants or health-hazardous gases like ammonia, aromatic compounds, sulfur, benzene vapor, smoke, NH3, NOx, alcohol, and CO2. Once the sensors collect data, it is transmitted to the cloud. The cloud, a technology that leverages the internet as a centralized server for data management [10], enables users to run programs without installing applications and facilitates easy access to data and information via the internet. Subsequently, users can monitor air quality in a specific location in real time through a web interface [13].

2.3 Block Diagram

In designing a system, several factors must be considered, including how to construct the tool based on existing theoretical foundations [14]. Before building or designing a system, a block diagram is created. A block diagram is one of the simplest methods to outline the workflow of a system, minimizing errors during implementation [15]. The block diagram of the Android-based environmental monitoring system is shown in Figure 2.

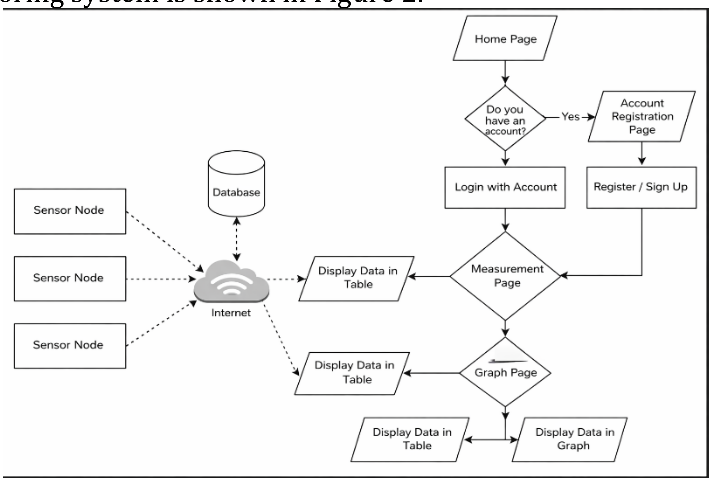

Figure 2. Environmental Monitoring System Block Diagram

In the final stage, simulations are conducted on the hardware and software components to measure vehicle count, air quality, temperature, and noise levels. The hardware includes the Arduino Mega Pro Mini, MQ-7, MQ-135, DHT22, GP2Y1010AUF, and GY-MAX4466 sensors. The software utilized is Arduino IDE for programming tasks executed by Arduino UNO, with data transmitted over the internet to the Air Quality monitoring system application and stored in the Firebase database.

RESULT AND DISCUSSION

In the Results and Discussion section, we will discuss the hardware implementation, software implementation, and the results of the Android application interface design. The hardware implementation focuses on the assembly and configuration of the physical components used in the system, such as sensors, microcontrollers, or input/output devices, which affect the overall system performance. The software implementation covers the development of the application running on the system, including programming and testing the software functionality that interacts with the hardware. Lastly, the results of the Android application interface design will address the user experience (UX) derived from the visual design and interactivity of the application, as well as how well the application meets the needs and expectations of the users. This section will provide a comprehensive overview of the achievements and challenges encountered during the system development.

1. Hardware Implementation

The hardware assembly was carried out in stages, starting with connection sesors to the microcontroller and positioning the sensors appropriately. The arrangement of the hardware component used in the system can be seen in Figure 3.

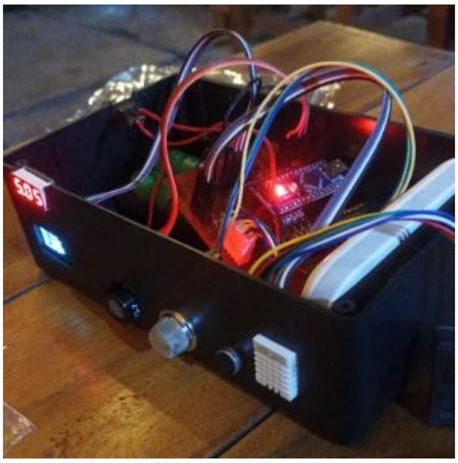

Figure 3 Hardware Setup of the Environmental Monitoring System

In Figure 3, the entire assembled system is connected to Firebase, which serves as the database provider, and an Android application that functions as the medium for displaying information such as vehicle count, air quality, temperature, and noise levels. The development and demand for prototype design have become increasingly essential, as highlighted by Paksi et al. (2023) [16]. This need is driven by the growing requirement for real-time data collection and monitoring in various applications. The prototype for this system has already undergone the creation of a circuit diagram, which serves as a crucial guide for understanding the components involved in the circuit and their proper arrangement, as outlined by Purnomo (2017) [17]. This well-structured design ensures that each element in the system is connected and functions as intended, enabling effective data transmission and display through the Android application.

2. Software Implementation

Software plays a crucial role in this system, serving as an indispensable component. Two primary tools were used in software development: Ardiuno IDE and Android Studio. Arduino IDE: Used for writing and developing program codes that are uploaded to the Arduino Mega microcontroller, enabling the hardware to function according to its puposes. Android Studio: Used for designing and building the user interface of the Android application, ensuring an intuitive and engaging user experience. Using these platforms allows for a structured and efficient software development process. Figure 3 below illustrates the pseudocode developed, offering a clear representation of the program logic and structure implemented in this system.

```
class Homescreen extends StatefulWidget {
}
const Homescreen({Key? key}): super(key: key);
@override
State<Homescreen> createState() => _HomescreenState();
class _HomescreenState extends State<Homescreen> {
final HomeModuleController controller = Get.find();
final AuthenticationModuleController authenticationModuleController =
Get.find();
@override
void dispose() {
Get.delete<HomeModuleController>();
super.dispose();
}
@override
Widget build (BuildContext context) {
return Scaffold(
backgroundColor: Theme. of (context).scaffoldBackgroundColor, appBar:
PreferredSize(
preferredSize: const Size.fromHeight(0),
child: AppBar(
backgroundColor: Color.fromARGB(255, 32, 77, 135), elevation: 0,
), // AppBar ), // PreferredSize
body: SizedBox(
height: Get.height, width: Get.width,
child: PageView(
physics: const NeverScrollableScrollPhysics(),
onPageChanged: (value)
},
controller.currentPageIndexOnMainframe.value = value;
controller: controller.mainframePageController, children:
PengukuranPage(), GrafikPage(),
), // PageView
), // SizedBox
bottomNavigationBar: getBottomNavigationBar(),
```

```
Obx getBottomNavigationBar() {
return Obx(() {
return BottomNavigationBar(
type: BottomNavigationBarType.fixed,
selectedItemColor:
Color.fromARGB(255, 255, 255, 255), //,
unselectedItemColor: greyColor,
backgroundColor: Color.fromARGB(255, 32, 77, 135),
elevation: 6,
currentIndex: controller.currentPageIndexOnMainframe.value, onTap: (value) {
},
controller.currentPageIndexOnMainframe.value = value;
controller.mainframePageController.animateToPage(
);
value,
duration: const Duration(milliseconds: 400), curve: Curves.linearToEaseOut,
items: [
],
BottomNavigationBarItem(
icon: Icon(
Icons.bubble_chart,
color: controller.currentPageIndexOnMainframe.value == 0
? Color.fromARGB(255, 255, 255, 255)
: greyColor,
), // Icon
Label: "Pengukuran",
),// BottomNavigationBarItem
BottomNavigationBarItem(
icon: Icon(
Icons.ssid_chart_sharp,
color: controller.currentPageIndexOnMainframe.value == 1 ?Color.fromARGB(255,
255, 255, 255)
: greyColor,
), // Icon
Label: "Grafik",
```

Figure 3. Air Quality Code

The code snippet is part of a mobile Android application designed for environmental monitoring. The main screen of the application was built using Flutter, a framework that enables the creation of modern, fast, and intuitive user interfaces. One of the key features is the Page View functionality, which allows users to easily switch between two main sections of the app: the "Measurement" page, where real-time environmental data is displayed, and the "Graph" page, which shows graphical representations of the data. To ensure the application's performance and reliability, it needs to undergo thorough testing. As demonstrated in the study by Mashuri et al. (2021) [19], the application must be tested through various experiments to evaluate its functionality, accuracy, and overall user experience.

3.3. Result of Android Application Interfacce Design

The design of the Android application interface focuses on three key elements: the Initial Screen, the Real-Time Data Visualization Menu, and the Data Graph Menu, each of which was crafted to enhance user interaction and provide a clear, intuitive experience.

3.3.1. Initial Screen of the Air Quality Application

The initial screen of the Air Quality application is designed to provide users with an easy entry point, offering options to either log in if they are returning users or register if they are new to the application. This login or registration process is crucial to ensure proper user access, enabling personalized settings and full utilization of the app's features. Figure 4 showcases the intuitive and clean design of the initial user interface, which simplifies the user's decision-making process by clearly displaying options for login or registration. The layout is carefully structured to guide users through the process with minimal effort, using clearly labeled buttons and a straightforward design that enhances user experience and accessibility. This approach ensures that users can quickly begin interacting with the application without confusion or unnecessary steps.

Figure 4. Initial Screen of the Application

Implementation refers to the process of translating a theory, method, or set of concepts into practical application in order to achieve specific objectives and fulfill the anticipated interests of a group, which has been carefully planned and organized in advance [18]. The figure presented illustrates the user interface (UI) of the mobile application developed for air quality monitoring. The application features a simple and intuitive design, emphasizing ease of use to ensure a smooth user experience. It provides login options, allowing users to access the app either through an existing email account or by registering a new account. This design choice reflects the developer's commitment to delivering an optimized user experience, ensuring accessibility for both new and returning users. For the purposes of this study, the login credentials used for testing were Tester1234@gmail.com and the password: Tester1234. This user authentication process is part of the application's effort to provide secure access and enable personalized interactions, ultimately supporting the functionality of real-time air quality monitoring.

3.3.2. Real-Time Data Visualization Menu

The importance of creating a real-time data visualization menu lies in its ability to enhance user comprehension of the application's functionality by presenting complex data in an easily understandable format [20]. The second screen of the Air Quality application is specifically designed to allow users to view and interact with real-time environmental data. This screen provides a user-friendly interface, simplifying the process of interpreting key information such as air quality levels, temperature, and noise levels. The intuitive design ensures that users, regardless of their technical background, can quickly grasp the significance of the displayed data. Figure 5 illustrates this menu, highlighting the various types of data presented and the interactive elements available to the user. These features allow for seamless navigation and interaction, enabling users to access detailed insights and monitor real-time environmental conditions effectively. This approach underscores the developer's focus on improving usability and enhancing the overall user experience, ensuring that the application meets the needs of a diverse user base.

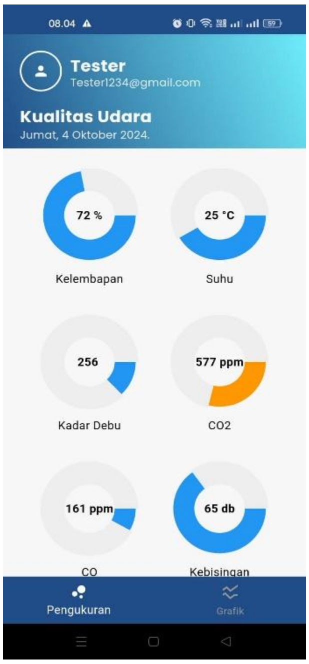

Figure 5. Real-Time Data Visualization Menu

The application effectively delivers up-to-date information regarding air quality, ensuring that users have access to real-time data on environmental conditions. The intuitive interface plays a crucial role in facilitating user interaction, allowing for the easy interpretation of displayed data such as humidity, temperature, and particulate matter (PM) levels. The clear visualization of these parameters empowers users to quickly assess air quality and make informed decisions. Furthermore, the real-time measurement results demonstrate the app's responsiveness and accuracy, reflecting its ability to provide precise data with minimal delay. This responsiveness is essential for applications that require continuous monitoring, as it ensures that users receive timely updates on air quality changes. The app’s real-time performance is a testament to its robustness and reliability, reinforcing its effectiveness as a tool for environmental monitoring.

3.3.3. Data Graph Menu

The second screen of the Air Quality application is specifically designed to provide users with easy access to real-time environmental data. This screen serves as a crucial component of the application, enabling users to monitor dynamic environmental parameters such as air quality levels, temperature, humidity, and particulate matter (PM) concentrations in real-time. The user-friendly interface of this screen simplifies the data presentation, ensuring that users, regardless of their technical expertise, can easily interpret and understand the displayed information. Key features such as clear labeling, color-coded indicators, and intuitive navigation contribute to a seamless user experience, allowing users to focus on essential data without unnecessary complexity. Figure 6 provides a visual representation of this menu, illustrating the diverse types of data available and the interactive elements that users can engage with. These interaction options include toggling between different data views, zooming in on specific metrics, and selecting time intervals for more detailed insights. By offering these features, the application enhances user engagement and empowers users to make informed decisions based on real-time environmental conditions.

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Figure 6. Data Graphs of Measurement Results

The test results demonstrate that the application accurately and reliably displays real-time air quality data, ensuring that users are provided with up-to-date information. The application's graphs offer clear and intuitive visual representations of changes in key environmental parameters, such as humidity, temperature, and particulate matter (PM) levels, over time. These visualizations are not only easy to interpret but also serve as a valuable tool for users to track fluctuations in air quality. The accuracy of the displayed data has been rigorously validated through comparisons with data from established air monitoring stations, revealing strong correlations between the two data sources. This validation underscores the credibility of the application's measurements and its potential as a reliable environmental monitoring tool. Furthermore, the effective visualization of the obtained data plays a critical role in the analysis that users will conduct. By transforming raw data into accessible graphical formats, the application allows users to identify trends, make data-driven decisions, and gain deeper insights into environmental conditions, which is essential for informed decision-making and timely interventions [21].

CONCLUSION

The Air Quality Environmental Monitoring System Application is designed to function optimally, providing accurate and up to date information about environmental conditions. By delivering real time transfering data, the application allows users to monitor air quality, temperature, noise levels measured by the integrated hardware. Furthermore, the application offers an intuitive and user friendly interface, allowing users from diverse backgrounds to quickly comprehend and interpret the presented data. Suggestions and future development is the incorporation of AI and Machine learning algorithms could enchance the app's capabilities by predicting future environmental conditions based on current and historical data. For example, the app could forecast air quality levels or temperature trends, allowing users to plan ahead for environmental fllutuactions. By continually improving the application with these added features, the air quality environmental monitoring system can envolve into a more powerful and versatile tool for individuals and organizations aiming to monitong and protect their enviromnetal surroundings.

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