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Development of Septic Tank Monitoring System through Sensor Technology and Augmented Reality

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Abstract

Septic tank is a dumping place for human waste. However, the presence of septic tanks can also cause many diseases and dangers to the environment. Leaking or overflowing septic tanks can threaten the surrounding environment. This research aims to design and develop a system that can monitor the volume and gas levels in septic tanks to prevent hazards caused by uncontrolled septic tanks. The researcher utilized MQ-4 sensor and JSN-SR04T distance sensor to detect volume and gas in septic tanks. In order to retrieve data from the sensor, a microcontroller is required that uses ESP 32 as a liaison between the sensor and Blynk. Blynk is used as a connecting application between augmented reality and microcontrollers. Data sent from Blynk was then retrieved through the Blynk API and can be displayed on augmented reality using Unity's Vuforia SDK. The researcher employed the prototype method in this study to design the application prototype. This application can run smoothly and provide accurate data on the volume and gas in the septic tank. Thus, this monitoring system can help to prevent environmental and human health damage caused by uncontrolled septic tanks.

Keywords: Augmented reality, prototype application, sensors, septic tank, monitoring system.

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1. Introduction

Septic tank is a dumping place for human waste (Susilawati &; Sitohang, 2020). Groundwater is the main source of fresh water that is often used for household, agricultural (irrigation), and industrial purposes (Emeka et al., 2021). Groundwater can become contaminated due to an overflowing septic tank that can no longer accommodate its contents, leading the discharge of the septic tank to come out into the ground. In addition, groundwater can also be contaminated due to the septic tank’s non-waterproof base, allowing sediment to infiltrate into the ground (Dewi Yusnisa Putri et al., 2022). Septic tanks are made and placed on the ground to accommodate human waste in each household. There are many diseases in septic tank, such as diarrhea, tyhus, muntaber, dysentery, worms, and itching (Di &; Tanjung, 2022).

Septic tanks also store gases that are harmful to human health (Jayaraman et al., 2020). The gas in the septic tank usually contains methane, carbon dioxide, ammonia, hydrogen sulfide, and traces of carbon monoxide (Revanth, 2021). Gas in this septic tank occurs due to the natural decomposition of waste and mixtures formed by slurries leading to the production of toxic waste that releases harmful gases (Asthana &; Bahl, 2019). Gases in septic tanks can also cause explosions. This explosions are very dangerous and can damage buildings around and also people around the septic tank (Hasan et al., 2020).

In order to prevent leakage, overfilling, and gas release in septic tanks, the researcher designed a monitoring system using AR (Augmented Reality) and IoT (Internet of Things) technology to send data between devices. IoT (Internet of Things) is a connected technology to collect data and share data to operate and perform in accordance with the task given [9]. Data that has been retrieved from sensors on IoT is then sent using APIs on Blynk Cloud to AR (Augmented Reality) devices. It is a system that supports interaction between users, digital content, and the real world. Therefore, the ability of AR (Augmented Reality) displays virtual images while maintaining transparency is essential (Xiong et

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al., 2021). The AR (Augmented Reality) devices receives data then display the data received from IoT (Internet of Things) devices to the users (Ellyzabeth Sukmawati et al., 2022).

This research aims to develop a prototype of a septic tank monitoring application using the JSN-SR04T distance sensor and MQ-4 sensor to detect gas. The data transfer from the sensors to augmented reality is facilitated by the ESP32 device. The augmented reality implementation is achieved using the Vuforia SDK on Unity. The prototype was tested using the SUS (System Usability Scale) method as part of the evaluation. This system is a reliable and cost-effective psychometric tool with proven validity and high reliability (Vlachogianni &; Tselios, 2022).

2. Research Methods

This research methodology employed the prototype method, which involved the development and design of system in general (Pressman, 2019). The prototype method used five steps, incuding analyzing system requirements, creating a basic design, developing prototypes (implementation), evaluating and improving prototypes, and also carrying out implementation and maintenance (Marques &; Da Cunha, 2019; Prakoso &; Wellem, 2022). In the specific context of designing a septic tank monitoring system using AR, the following stages were undertaken: problem identification, conducting system needs analysis, system design and implementation, system testing, and conducting research conclusions (Prakoso &; Wellem, 2022). During the prototype testing phase, the application employed System Usability Scale (SUS) due to its established validity and reliability in testing a prototype (Vlachogianni &; Tselios, 2022).

3. Results

The first stage carried out is the problem identification and gathering requirements from literature studies on previous research related to septic tank monitoring systems through Arduino. At this stage, it is found that harmful gases in the septic tank that could threaten the workers involved in septic tank pumping, tand the remaining waste in the septic tank is difficult to detect even though suctioning had been carried out.

The second stage is to conduct simple designs, such as flowcharts and application block diagrams. Flowchart is an overview of application design workflow (Indrianingrum, 2020). The form of the application flowchart can be seen in Figure 1 which describes the application workflow (Flowchart).

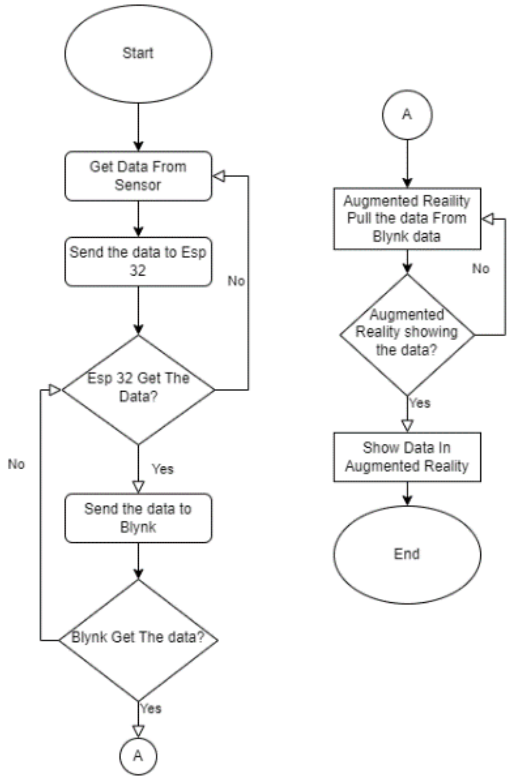

Figure 1. Flowchart septic tank monitoring application using Augmented Reality

Block diagram is a method that can explain the overall work of the tool (Rahmanto et al., 2021). In Figure 2, the block diagram illustrates a system using ESP32 along with distance sensors and gas sensors to monitor the volume of contents of the septic tank and the damage level of gas inside. The data generated by the sensor is then sent to the Blynk cloud, and the data are sent to Unity through the cloud of API Blynk. The data are accessible through Augmented Reality applications owned by application users.

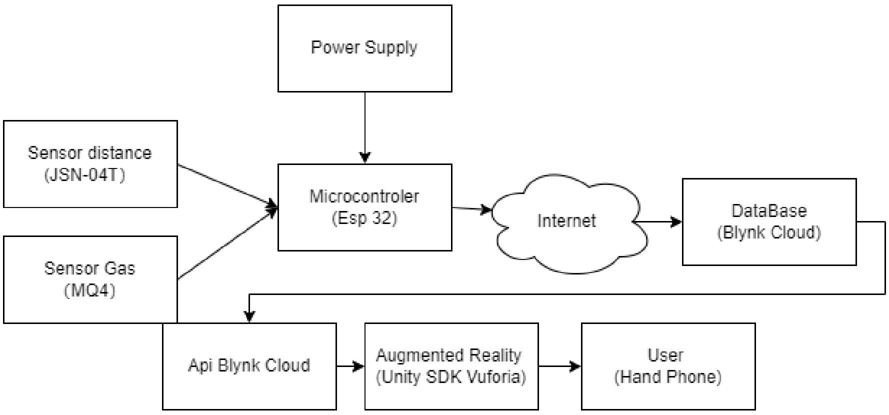

Figure 2. Block Diagram septic tank monitoring application using Augmented Reality

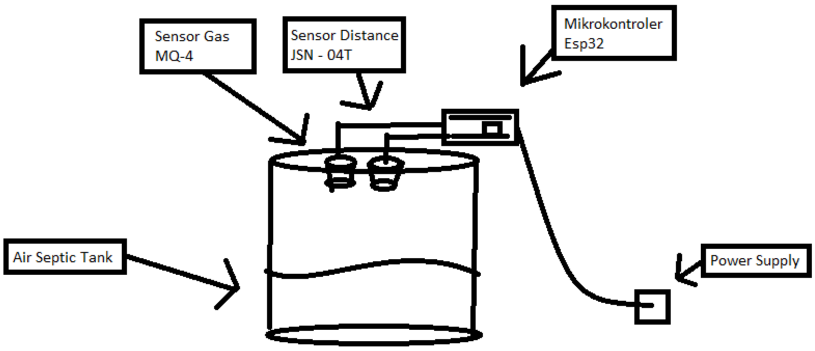

Figure 3. Design of septic tank monitoring application prototype for microcontrollers and sensors.

Figure 4. Prototype form of septic tank monitoring application

The third stage is to make a prototype design in order to understand the placement of sensors and microcontrollers in the septic tank monitoring application using Augmented Reality. The design results can be seen in Figure 3.

In Figure 3, this design shows sensors and microcontrollers placed on top of the septic tank cover to detect the presence of harmful gases and the water volume in the septic tank. The microcontroller is used as a sender of data to Blynk, which will then be forwarded to Unity's Augmented Reality application and presented to the user.

Table 1. Data of 15 respondents who answered 10 questions of System Usability Scale.

No	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	5	1	5	1	5	1	5	1	5	1
2	4	2	5	1	4	1	4	2	5	2
3	4	5	5	2	4	1	5	1	5	1
4	3	1	4	2	4	1	3	1	3	1
5	2	1	3	2	4	2	4	1	5	1
6	5	1	5	4	4	3	4	3	4	5
7	4	1	4	1	5	1	5	1	5	1
8	5	1	5	2	4	1	4	1	4	2
9	5	1	5	1	5	1	5	1	5	1
10	3	3	3	1	2	3	3	2	4	2
11	4	2	4	4	4	2	4	2	4	2
12	4	1	5	5	4	1	5	1	5	2
13	5	2	5	1	4	1	5	1	5	2
14	4	1	4	2	5	2	5	1	4	1
15	2	2	3	1	4	1	4	2	3	1

The fourth stage involved the implementation of the septic tank monitoring application prototype, which can be seen in Figure 4.

In Figure 4, it can be seen that the gas sensor and ultrasonic distance sensors are placed on the septic tank lid to detect the contents inside the septic tank and any gas leaking from it. The data obtained from the sensor is then sent to Blynk, then the data from Blynk is retrieved through the Blynk API and displayed in AR applications, as shown in Figure 5.

In Figure 5, it can be seen the sensor results are sent and then displayed in the AR application. The volume of septic tanks in the tests carried out showed 60%, while the volume of septic tank gas showed 44%.

The fifth stage of this test aims to conduct system usability testing (SUS) since this system has been tested for validity and reliability in testing a prototype (Vlachogianni &; Tselios, 2022). Fifteen respondents have been collected to test the prototype application. Each participant filled in a questionnaire consisting of ten numbers, where each number has five answer choices, and each of which has a different value (Kaya et al., 2019). The rating scale started from number one, which means 'strongly disagree' to number five which means 'strongly agree'. Each number on the questionnaire comes with a questionn, including: 1) I think I will use this system, 2) I feel the system has unnecessary (complicated) features, 3) I think the system is easy to use, 4) I think I need technical support to be able to use this system, 5) I found the various functions in this system well integrated, 6) I think there are too many inconsistencies in this system, 7) I imagine most people will learn to use this system very quickly, 8) I find this system very complicated to use, 9) I feel very confident using this system, and10) I need to learn a lot of things before I can use this system.

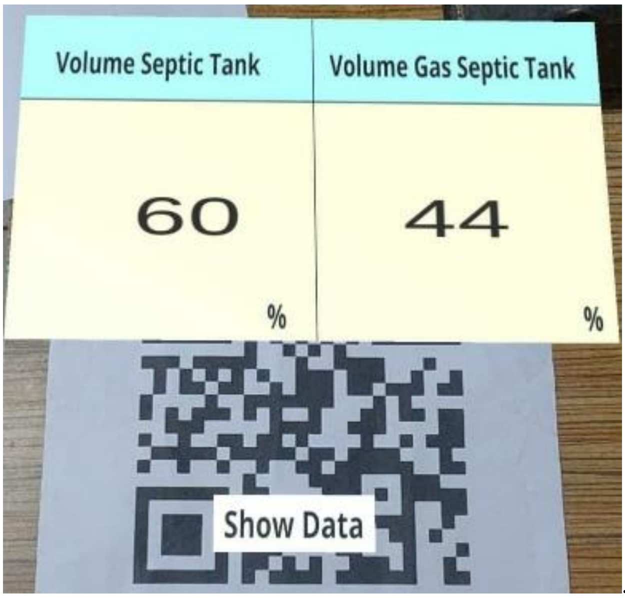

Figure 5. Augmented reality application using Unity with the Vuforia SDK

Table 2. Data of 15 respondents who have been calculated according to System Usability Scale.

No	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	4	4	4	4	4	4	4	4	4	4
2	3	3	4	4	3	4	3	3	4	3
3	3	0	4	3	3	4	4	4	4	4
4	2	4	3	3	3	4	2	4	2	4
5	1	4	2	3	3	3	3	4	4	4
6	4	4	4	1	3	2	3	2	3	0
7	3	4	3	4	4	4	4	4	4	4
8	4	4	4	3	3	4	3	4	3	3
9	4	4	4	4	4	4	4	4	4	4
10	2	2	2	4	1	2	2	3	3	3
11	3	3	3	1	3	3	3	3	3	3
12	3	4	4	0	3	4	4	4	4	3
13	4	3	4	4	3	4	4	4	4	3
14	3	4	3	3	4	3	4	4	3	4
15	1	3	2	4	3	4	3	3	2	4

After testing the prototype application and filling out questionnaires by 15 respondents, the results of data analysis show that most respondents felt the system is easy to use and has well-integrated features, but some respondents consider that the system is too complicated and requires technical support for its use. The complete results can be seen in Table 1.

The collected data was then processed through the System Usability Scale (SUS). For each question on odd order, the value obtained is subtracted by one. For example, if a question gets a score of five, then the score will be reduced by one, to four. As for each question on even order, five is subtracted by the value obtained. For example, if a question gets a value of one, then five is subtracted from one to four. The results of Sytem Usability Scale measurement can be seen in Table 2.

After calculating the System Usability Scale, then the calculation of the average value was carried out using the formula in Figure 6.

The next stage was to add up the values of even and odd numbered questions for each respondent. Then, the result is multiplied by 2.5. After that, the average value of all values that have been multiplied by 2.5 is calculated for each respondent. The result of the average value calculation can be seen in Table 3.

$$\bar{x} = \frac{\sum x}{n}$$

$\bar{x}$ = average score
Σx = SUS total score
n = total respondents

Figure 6. The average value is calculated using the System Usability Scale formula.

Based on the calculation of the average score of each respondent, a value of 82 is obtained which indicates that the application is running and can be used properly. The determination of application quality can be seen from the achievement of an average value above 68. If you get a number below 68, it means that there are problems that can affect the usability system.

Table 3. Data of 15 respondents who have been calculated according to the System Usability Scale.

No	Sum	Value (Sum x 2.5)
1	40	100
2	34	85
3	33	83
4	31	78
5	31	78
6	26	65
7	38	95
8	35	88
9	40	100
10	24	60
11	28	70
12	33	83
13	37	93
14	35	88
15	29	73
Average		82

4. Discussion

A septic tank is an underground facility used for the collection of human waste in every household. If the waste leaks from the septic tank, it can cause damage to the surrounding environment due to the presence of the diseases and harmful gases in it (Emeka et al., 2021; In &; Cape, 2022; Jayaraman et al., 2020). Therefore, regular monitoring of human waste and gas levels in the septic tanks is necessary to avoid environmental damage and maintain human health around the septic tank. In this research, a prototypepe application has been developed to detect gas and volume in septic tanks using the MQ-4 sensor and JSN-SR04T ultrasonic distance sensor. The sensor data were collected by the ESP32 microcontroller and transmitted to Blynk. Subsequently, the data from Blynk were retrieved through the Blynk API to Unity, where the Unity application utilized the Vuforia SDK databases to display AR images on the dashboard when the application is directed to a displayed the QR-code. The implemented application carried out a system usability scale test stage to be able to find out whether the application can run properly or not. The usability scale system is used as a reliable and validated tool to evaluate prototypes (Vlachogianni &; Tselios, 2022). The prototype of this application has been tested using a usability scale system (SUS) and obtained a score of 82 from 15 respondents, indicating that this application can run and can be used properly and effectively.

5. Conclusion

In managing septic tanks, it needs to be considered properly, as improper handling can lead to septic tank overflow, which can contaminate groundwater and generate harmful gases, such as methane and hydrogen sulfide which can endanger human health. One solution to prevent problems in septic tanks is by implementing a monitoring system for volume and gas using MQ-4 and JSN-SR04T sensors, along with augmented reality. This application can assist septic tank owners in monitoring the condition of the septic tank in real-time and preventing potential problems. The results of the System Usability Scale testing indicate that this application runs well, with an average value above 68. Therefore, the utilization of a monitoring systems can serve as a solution to protect the surrounding environment and human health.

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