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Portable Construction Maps (PCM) using location fingerprint positioning algorithm for construction worker safety

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ABSTRACT

The existence of a work from home policy does not seem to have a substantial impact on construction workers. Cases of work accidents on infrastructure projects during the Covid-19 pandemic experienced a significant increase. The number of work accident insurance claims in the first semester (January-June) 2020 reached 108,573 cases. An increase of 128% over the same period in the previous year. One of the steps from the construction site to minimize the occurrence of work accidents is by marking dangerous locations or limiting them with a yellow line. The supervision is carried out by the Occupational Health and Safety division which supervises every worker by using hearing and sight senses. However, this supervision is deemed less effective and efficient considering the number of work accidents that continue to increase over time. Therefore, a worker location monitoring system based on an indoor positioning system called Portable Construction Maps (PCM) using a location fingerprint positioning algorithm for construction worker safety was developed with the Waterfall method. The development of this system uses the algorithm Location Fingerprint as a method for estimating the location of workers in a construction building. Each worker will bring a device called the Worker Tag, in which there is an ESP 32 microcontroller with WiFi and Bluetooth module, which is used to capture WiFi and Bluetooth signals and calculate the Received Signal Strength Indication (RSSI) which will be sent to the server to be processed using the location fingerprint algorithm. In addition, in the worker tag, there is also a passive buzzer that is used to alert workers if they enter a dangerous area.

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1. Introduction

The existence of a work from home policy does not seem to have a substantial impact on project workers [1]. Cases of work accidents on infrastructure projects during the Covid-19 pandemic experienced a significant increase. BPJamsostek data shows that the number of work accident insurance claims in the first semester (January-June) 2020 reached 108,573 cases. An increase of 28% over the same period in the previous year [2].

The lack of supervision and awareness of construction workers in prioritizing work safety and security (K3) has also contributed to work accident cases. Efforts shown by the government to reduce the number of work accidents include conducting

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socialization and inviting companies to apply K3 norms [3].

However, work safety instructions have been conveyed by K3 supervisors to every worker. Similarly, safety talk or promise to comply with safety and security procedures. Nevertheless, not a few workers are ignorant of this procedure [4]. On the other hand, the limited number of supervisors is not commensurate with the number of workers who need to be supervised [5].

One of the steps from the construction site to minimize the occurrence of work accidents is by marking dangerous locations or limiting them with a yellow line [6]. The supervision is carried out by the K3 division which supervises every worker by using hearing and sight senses. However, this supervision is deemed less effective and efficient considering the number of work accidents that continue to increase over time [7].

There are various ways to monitor the location of workers, one of which is using worker ID scanning manually when workers enter an area. However, this is less effective because each area requires a tool to scan worker ID [8]. Workers who have to scan ID when entering an area make workers less focused on their work. The occurrence of queues of workers to perform ID scanning also reduces work productivity [9].

Based on the problems that have been described, more effective and efficient technology is needed in carrying out worker supervision in the infrastructure construction process. The technological innovation presented as a solution to meet these needs is Portable Construction Maps (PCM) Using Location Fingerprint Positioning Algorithm for Construction Worker Safety, a map-based construction worker management system indoor. PCM has a focus on improving the safety of construction workers.

The working principle of PCM replaces GPS with Wi-Fi and Bluetooth Beacons which are installed on each floor of the construction building to provide a passive signal to workers who have used the Worker Tag. The algorithm used in determining the accuracy of the location of workers is using Location Fingerprint Positioning (LFP). The product that will be made is the Worker Tag as a Received Signal Strength Indication (RSSI) scanner around workers. The Local Server will forward the data obtained from the Worker Tag to the cloud service where the data will be processed using the LFP algorithm to determine the location of the workers. In addition, the application has also used the web for monitoring workers and serves as the dashboard's main admin.

2. Method

The development of a Portable Construction Maps system is carried out using the Waterfall method are shown in Fig.1. This development method was chosen because it has a sequential process from analysis to maintenance and each stage of the process has its specifications so that a system can be developed as desired or on target [10]. In addition, in this development method, each process cannot overlap each other so there is no confusion in system development.

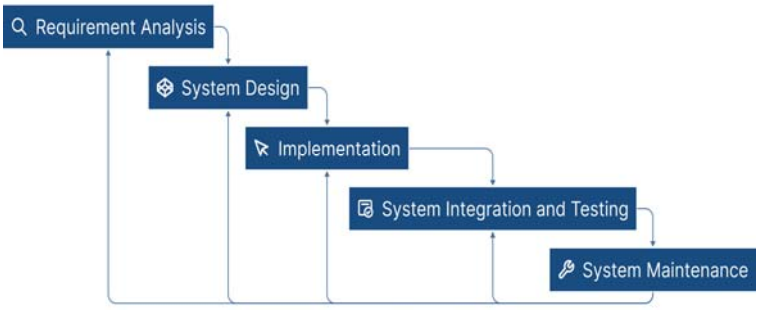

Fig. 1. Waterfall Method

2.1. Requirement Analysis

Gather further information on system development through literature study. This is intended to avoid the incompatibility of needs analysis in the development of system prototypes [11]. The requirements in question are prototype components in the form of hardware, software, algorithms, and libraries that are used to support the creation of the Portable Construction Maps system.

2.2. System Design

At this system design stage, a prototype design is carried out to provide an overview of the architecture or a series of prototypes and the working principles or system procedural algorithms to help provide a complete picture of the things that must be done [12].

2.3. Implementation

Implementation is done by starting a program for the prototype Portable Construction Maps system. Programming is done by referring to the system flowchart design that has been made. The process of making a Web App program using the PHP programming language and using the Laravel framework. For backend services that handle the processing of worker location data, use a programming language Golang and Python wrapped in the FIND3 framework where data will be processed using the location fingerprinting algorithm to determine the location of workers based on RSSI data around workers. Whereas for Worker tag implementation using C++ language.

2.4. System Integration and Testing

At this stage, the device components are combined with hardware and software programs so that they become an integrated system in the form of a prototype. After the prototype Portable Construction Maps system is formed, tested the level of accuracy of detecting the location of "people", alarm system, and range the use of the Worker Tag on the system prototype that has been successfully created.

2.5. System Maintenance

At this maintenance stage, improvements will be made regarding deficiencies found when testing the prototype Portable Construction Maps system. In addition, adjustments were made to the prototype of the Portable Construction Maps system to improve system performance.

3. Results and Discussion

3.1. Location Fingerprint Positioning Algorithm

Location Fingerprint Positioning Algorithm is used for processing raw data from RSSI (Received Signal Strength Indication) in a certain area which is then converted into information about the location in the form of ID and location name. This algorithm consists of 2 phases are shown in Fig.2, namely the offline phase and the online phase. During the offline phase, the fingerprint database collects data from a predetermined location/area. To determine the position, the nearest fingerprint location is searched based on predetermined metrics, this is called the online phase.

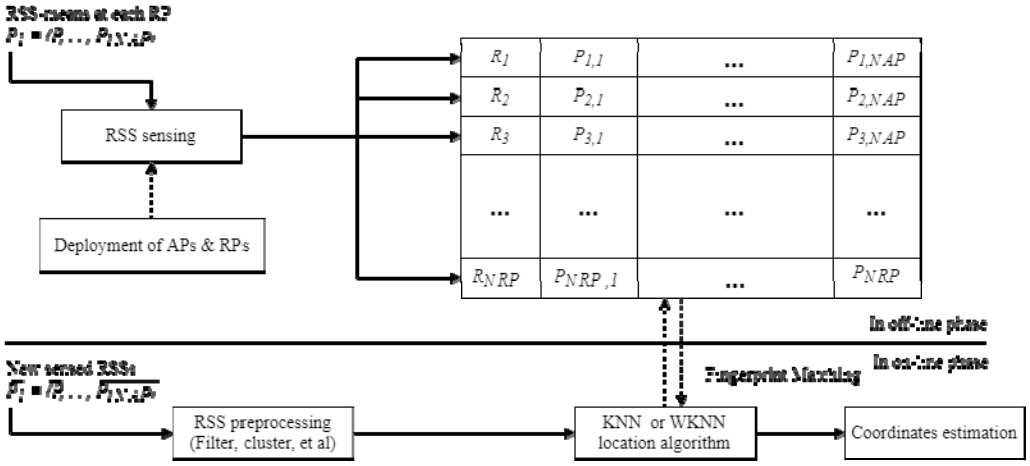

Fig. 2. Location Fingerprint Positioning Algorithm

3.2. System Design

In developing the Portable Construction Maps system, the following system design was obtained illustrated in Fig.3.

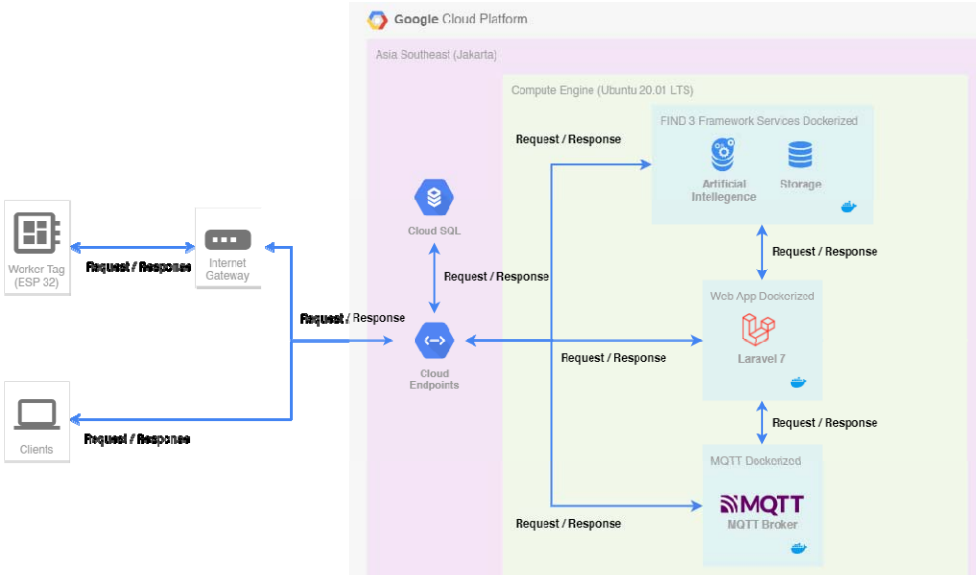

Fig. 3. System Architecture Design

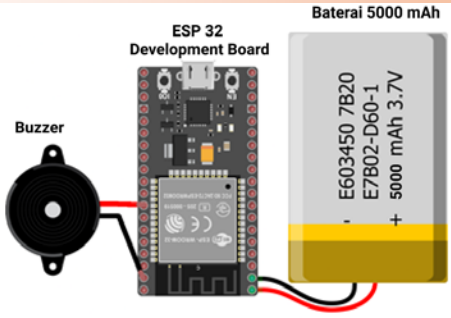

Fig. 4. Worker Tag Prototype Block Diagram

In the Worker Tag device, the main component used as a data processor is ESP32. ESP32 was chosen because it can communicate securely via Secure MQTT via WiFi as a liaison between the Worker Tag device and the server. In addition, the ESP32 has many pin interfaces to connect with many LED lights and is a Low Power Consumption microcontroller that has high performance compared to other microcontrollers, thereby reducing the possibility of lagging during data processing. ESP32 can process HTTPS protocol, which is a data transmission protocol over the internet that has high-security features. In each Worker Tag, there is a buzzer that functions as an alert to workers. The Worker Tag prototype uses a 3.7 V battery with a capacity of 5000 mAh as shown in Fig.4.

3.3. Worker Tag Prototype Design

The prototype design was created using the Blender application. Designs made such as ID cards or identification cards are intended to be easy for workers to carry and do not interfere with mobility. On the front of the Worker Tag, there is a QR code of worker id, and the worker identity is shown in Fig.5. The back is used as a housing for the ESP32, buzzer, LED, and battery that has been put together in such a way.

Fig. 5. Worker Tag Prototype Design

In the Portable Construction Maps device, the main component used as a data processor is ESP32. ESP32 was chosen because it can communicate securely via WiFi as a liaison between Portable Construction Maps devices and the internet.

3.4. Portable Construction Maps Application System

PCM Web applications are created using PWA or Progressive Web Apps technology as shown in Fig.6. The programming language used in the development of this application is PHP. This language was chosen because there is complete documentation and a large community. Therefore, this application can get updates faster than other applications that do not use the PHP language.

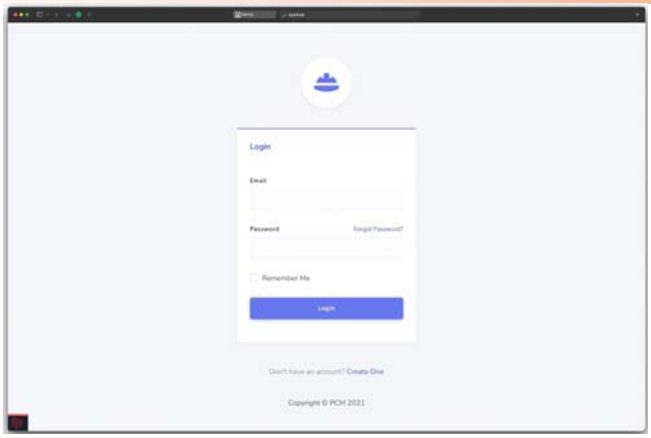

Fig. 6. Application Login Page

The web framework used by the "PCM" application is Laravel 8. Laravel was chosen. It can accelerate the development of PWA applications because it supports hot reloading and also in-play debugging so that the application development process becomes more productive. For backend services, a microservice architecture is used where there are three main services, namely: ML Service, MQTT Service, and Frontend Service. The three services are deployed by Environment Dockeenulisr as independent containers. For ML Service, the GoLang programming language is used, Location Fingerprinting Algorithm is used as the main algorithm in this service.

Broadly speaking, data from users will be processed using a location fingerprint algorithm which is then classified using the K-Nearest Night Algorithm to predict the location of the user. MQTT service is used for communication between Worker Tag and the server. MQTT was chosen because of its lightweight so that it will save data transfer which has an impact on battery savings in Worker Tag. For the Frontend service, Nginx is used as PHP runtime. Nginx was chosen because it is more stable and scalable than Apache, so it can accommodate periodic updates and can manage multiple users. In addition to using Docker to deploy services, Google Cloud Platform features are also used, and Cloud SQL is used to deploy Storage Services. Google's Cloud SQL was chosen because of its scalability and fast response time.

Fig. 7. PCM Location Scanner Application

The process of inputting Received Signal Strength Indication (RSSI) data from WiFi and Bluetooth to the server using an android-based application. This application was created using the Flutter Software Development Kit (SDK) and the Dart programming language. Flutter performs well and is included in the official SDK developed by Google. The application works by scanning the nearby WiFi and Bluetooth RSSI. After obtaining the RSSI data, the data will be sent to the ML Service on the server using HTTP POST. Where the data sent is in the form of JavaScript Object Notation (JSON) which contains information about RSSI, location, and timestamp. This application can run in the background so it can save the smartphone battery. How to use the PCM application can be seen in Fig.8.

Fig. 8. Application Usage Diagram

4. Conclusion

Portable Construction Maps (PCM) Using Location Fingerprint Positioning Algorithm for Construction Workers Safety has been successfully developed using Golang programming language for Location Fingerprint Services, PHP for Web Services, Dart for Mobile Applications, and C++ for Worker Tag firmware development. In addition, the Location Fingerprint Service uses the Find 3 library that already implements some algorithms to support the location Fingerprint algorithm like K-Nearest Neighbors (KKN) and Artificial Neural Network (ANN). From Web Apps, the location of workers can be known in real-time. Certain areas of the construction site may be designated as hazardous areas or safe areas. Worker Tag can alert workers automatically when entering hazardous areas. Worker Tag with 5000 mAh battery and use of deep sleep mode every 10 seconds can maintain its life for about 30 hours.

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