# Disaster Management Mitigation Using Geofencing Concepts in West Bandung Regency, Indonesia

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## Abstract

Floods and landslides often hit disaster-prone areas in districts of Indonesia, causing casualties, damage to housing units, and damage to fields and plantations. National Disaster Management Agency calls for increased preparedness. One of them by doing technology-based disaster mitigation. Geofencing plays a vital role in implementing several disaster management mitigation strategies. Previous studies have used geofencing in administration, finance, and security. We conducted this research to apply the haversine formula in disaster management mitigation using geofencing in a district in Indonesia. By utilizing GPS technology, the signal of a cellular device can be tracked or monitored. If an object with a cellular device approaches or enters the geofence area, it will automatically receive a notification that it is approaching or in a disaster-prone area. We carried out this research in several stages. These stages collect data from a list of disaster-prone regions in the West Bandung Regency, analyze software requirements, and conduct software development, including testing. We recorded the latitude and longitude of each area to provide a virtual fence to establish that the area is a disaster-prone area. All of this will result in a system that can monitor people who approach or enter the geofence area, calculate the distance between the object and the center point of the geofence area and send notifications about it with high accuracy. However, this system only can use with the Android operating system. We suggest developing this system, so Android and iOS operating systems can use it.

## Keywords
Geofencing, Disaster Mitigation, Location Based Service, Haversine Formula

## 1. Introduction
Natural disasters, physical losses, and social losses are inseparable. When a disaster occurs, physical and social failures are inevitable, especially for areas that fall into the category of disaster-prone regions with a very high level of risk, such as several areas in West Bandung Regency (Passarella et al. 2018). Currently, some stages aim to reduce the impact of disasters by implementing disaster management, namely disaster mitigation (Agustina et al. 2020). Disaster mitigation has several strategies in its implementation, ranging from mapping, monitoring, information dissemination, and education to early warning. Understanding disaster mitigation can reduce casualties (Ramadhan, Sukma, and Indriyani 2019). Based on this, we propose to use geofencing technology for disaster management mitigation in West Bandung Regency.

Geofencing research appeared in Munson and Gupta's research literature in 2002 (Munson and Gupta 2002). Several studies on geofencing have also been carried out in the security field (Insani 2020)(Priono and Setiawan 2017) and in the field of disaster prevention or management (Suyama and Inoue 2016)(Suwal et al. 2015).

Previous studies build disaster management mitigation using the concept of geofencing using smartphone ad hoc networks (SPANs). They use SPAN as a framework to implement MANET, so they can still communicate if there is no internet connection. They also use the Global Positioning System (GPS) to track objects' location (Passarella et al. 2018). Besides that, previous studies have used geofencing in administration, finance, and security. We conducted this research to apply the haversine formula in disaster management mitigation using geofencing in a district in Indonesia. By utilizing GPS technology, the signal of a cellular device can be tracked or monitored. The haversine formula is believed to be able to make calculations more accessible and accurate and has a low error rate (Esenbuga 2016).

In this study, we developed disaster management mitigation software using the geofencing concept in West Bandung Regency to optimize disaster mitigation. We built the software as a mobile app with an android operating system that requires GPS Technology. Geofencing is implemented in this software to monitor moving objects and provide information to these objects. The information provided includes weather information, flood and landslide disaster information, and information on disaster mitigation containing information on disaster mitigation actions that must do by visitors or the villagers and the efforts that must do when floods or landslides occur. Besides that, this software provides features for monitoring the existence of objects and areas prone to flooding and landslides in the West Bandung Regency. This software also can calculate the distance of object location and flood/landslide-prone in the West Bandung Regency.

## 2. Methods

The stages carried out in this research are shown in Figure 1. These stages are (1) Data collection, (2) Software requirements analysis, (3) Software development, and (4) Software Testing.

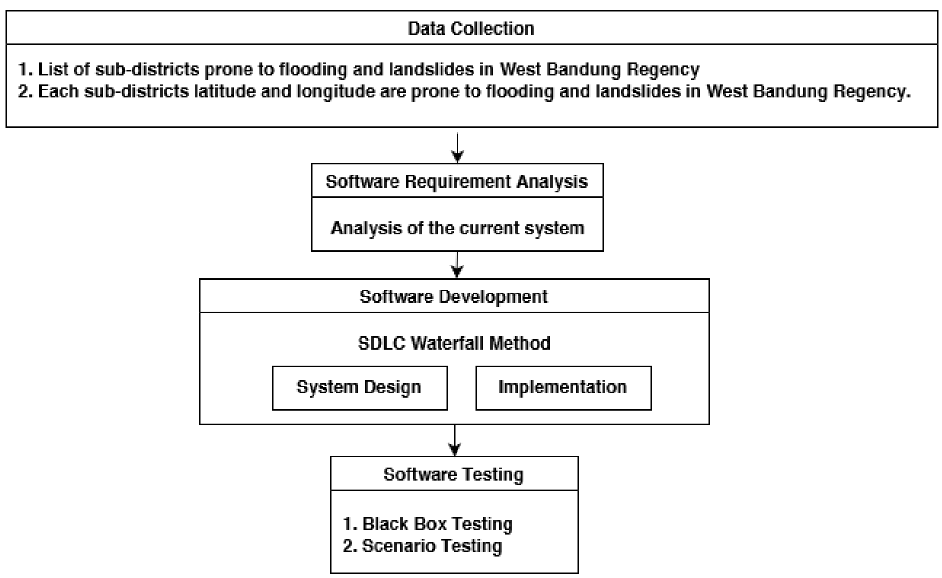



Figure 1. Research methods

### 2.1 Data Collection

The first stage is data collection, weather information data, and sub-districts prone to flooding and landslides in West Bandung Regency. We get weather information data from Open Weather Map, where the platform provides hyperlocal minute forecasts, historical data, current conditions, and short-term to annual weather data. These data are available through industry-standard APIs. Previous studies have used Open Weather Map to get real-time weather data (Dewi and Chen 2019; Yuan et al. 2018)(Maulana, Solichin, and Luhur 2018). In addition to weather information, we collect data on areas prone to flooding and landslides in West Bandung Regency, where there are 11 regions recorded. We get data on areas prone to flooding and landslides from the West Bandung Regency Legal Information and Documentation Network, while the latitude and longitude of each location we get from the free online map from Google, Google Map. Table 1 shows the data of flood/slide-prone areas in West Bandung Regency.

Table 1. Data of flood and landslide-prone areas in West Bandung Regency

| Location | Latitude, Longitude |
|---|---|
| Location 1 (Cililin) | -6.979033, 107.461317 |
| Location 2 (Cipatat) | -6.830247, 107.353326 |
| Location 3 (Cipongkor) | -6.943735, 107.347732 |
| Location 4 (Cisarua) | -6.805852, 107.446866 |
| Location 5 (Gununghalu) | -7.043495, 107.302580 |
| Location 6 (Lembang) | -6.815542, 107.514213 |
| Location 7 (Ngamprah) | -6.860202, 107.639731 |
| Location 8 (Parongpong) | -6.805586, 107.584082 |
| Location 9 (Rongga) | -6.977206, 107.251879 |
| Location 10 (Saguling) | -6.897515, 107.372591 |
| Location 11 (Sindangkerta) | -7.031335, 107.400613 |

## 2.2 Software Requirement Analysis

Before we build the software, it is necessary to analyze the software requirements first to determine the system's design according to the problems found in the old running system. The National Disaster Management Agency conveys disaster information to local governments and villagers in the ongoing disaster mitigation system. They give information to local governments and the public through the bnpb.go.id website, their social media, and TV Poll Live Streaming which can use on electronic media. The information conveyed started from an appeal to local stakeholders and the villagers to increase awareness and preparedness when it rains with high intensity and by paying attention to the information submitted by the Meteorology, Climatology, and Geophysics Agency regarding weather and disaster forecasts. They also conveyed that the villagers must understand the potential for disasters in their respective areas and have mitigation measures with media that can give this information to reduce the impact that will arise due to disasters.

Based on the current disaster management mitigation system, we propose to optimize the disaster mitigation strategy in West Bandung Regency by building a mobile-based software using the concept of geofencing and calculating distances using the haversine formula. The software we made needs to be connected to the internet and involves cellular technology with the android operating system, GPS technology, geofencing, and information sources. This information source includes an open weather map and an Indonesian Weather Forecast from BMKG. We built this software to inform the public that they have entered a flood/landslide-prone area. Besides that, we create the feature that can calculate the distance between object location and flood/landslide-prone areas in West Bandung Regency. This software only has one actor who interacts with the software, namely users who visit or occupy areas prone to floods and landslides in West Bandung Regency.

## 2.3 Software Development

We develop software using the Software Development Life Cycle (SDLC) waterfall methods at this stage. Based on the software requirements analysis, we do the system design of the software that we build and implement geofencing and haversine formulas into mobile applications. We implemented geofencing as a mobile app because mobile devices are becoming ubiquitous. The kids carry it, and so do the adults (Jayanthi and Niguel 2014).

### 2.3.1 System Design

In this study, we build a mobile app to convey weather information and information about disaster mitigation efforts that visitors or villagers in flood/landslide-prone areas in West Bandung Regency can do. Apart from being a medium for delivering information, the mobile app was created as a tool to monitor the presence of objects in areas prone to flooding and landslides and calculate the distance between objects and locations prone to flooding and landslides in West Bandung Regency. Figure 2 shows the workflow of our proposed system.

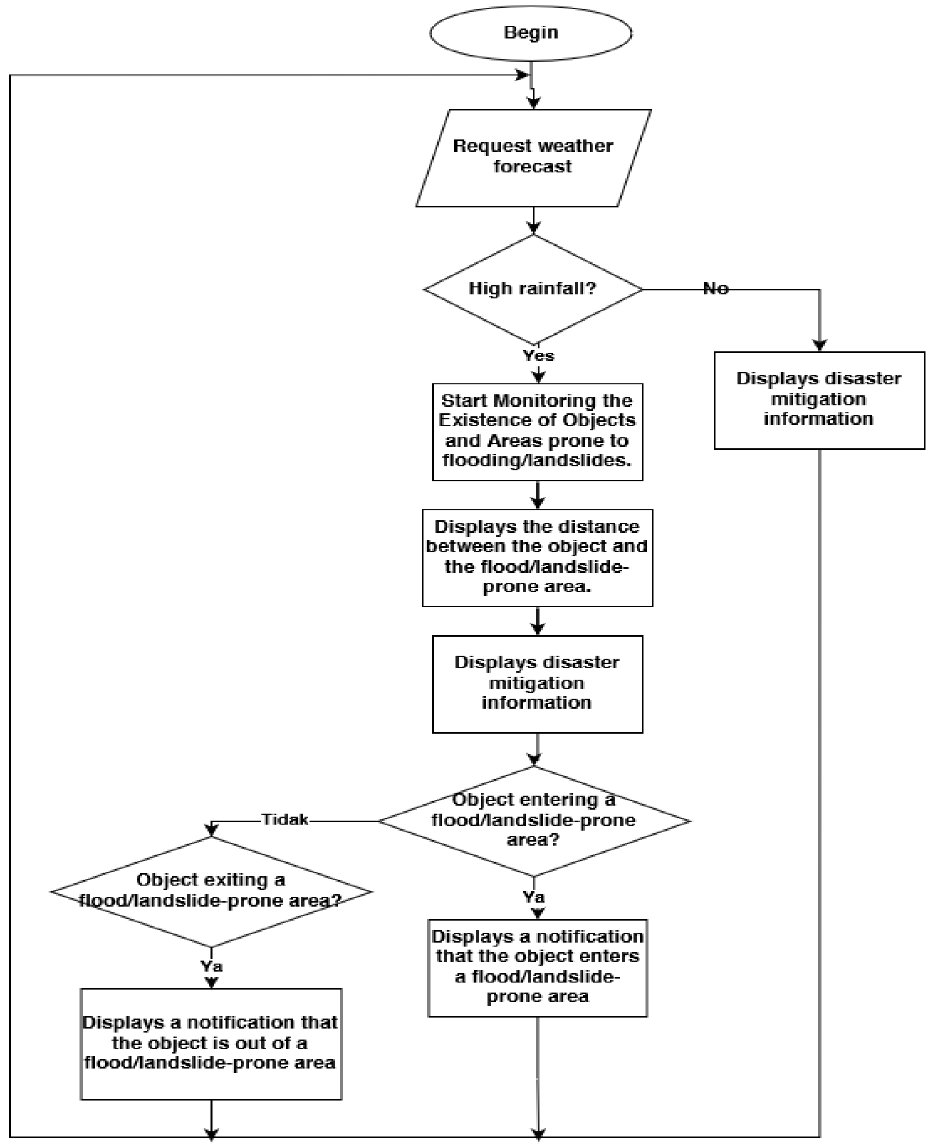



Figure 2. System work flow

### 2.3.2 Implementation

#### 2.3.2.2 Geofencing Implementation

Geofencing is implemented in a mobile app so that users can use it to monitor the presence of users and the existence of flood and disaster-prone areas in the West Bandung Regency. We made eleven areas prone to flooding and landslides as geofence areas. We create the geofence area based on the data shown in Table 1. The geofence area is depicted in red circles with different regions, according to the area of each flood and landslide-prone area. We made this geofence area permanently, so the user cannot delete it. There are three conditions when monitoring: when the object (user) enters the geofence area, when the user remains in the geofence area and when the user leaves the geofence area. The system can know the user's location and the disaster-prone regions through GPS technology on the user's mobile device. This software has a push service, a situation where the user requests or does not request information from the system, the system will continue to send it (Junglas and Watson 2008). An illustration showing the implementation of geofencing in the software we built is in Figure 3.

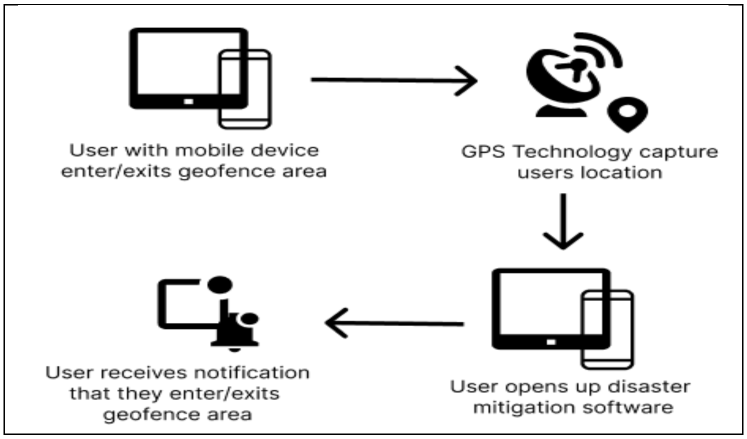



Figure 3 Geofencing Implementation

### 2.3.2.3 Haversine Formula Implementation

In this study, we also implement the haversine formula on the system to calculate the distance between the object (user) and areas prone to flooding and landslides. In addition to calculating the distance, the haversine formula can also calculate the shortest distance between one point and another( (Pratama et al. 2020)(Gintoro et al. 2010). The following is the haversine formula used (1)-(3):

$$a = \sin^2(\Delta lat/2) + \cos(lat2).\sin^2(\Delta long/2) \quad (1)$$
$$c = 2atan2(\sqrt{a}, \sqrt{1-a}) \quad (2)$$
$$d = R.c \quad (3)$$

Where:
R = Radius of earth 6371(km)
$\Delta$lat = Magnitude change in latitude (lat2-lat1)
$\Delta$long = Magnitude change in longitude (long2-long1)
c = Axis intersection calculations
d = Distance (m)
1 degree = 0.0174532925 radian

There are eleven areas prone to flooding and landslides. We calculate the closest distance between objects and locations prone to flooding and landslides using the haversine formula eleven times. We convert location data into radian by multiplying by 1 degree or 0.0174532925 before performing calculations using the haversine formula. Table 2 shows the conversion data for object (users) locations and eleven flood and landslide-prone areas.

Table 2. Conversion with haversine equation

| Location | Latitude, Longitude | Converted Latitude | Converted Longitude |
|---|---|---|---|
| Object location | -6.918415, 107.499578 | -0.12074912 | 1.876221578 |
| Location 1 (Cililin) | -6.979033, 107.461317 | -0.121807104 | 1.875553798 |
| Location 2 (Cipatat) | -6.830247, 107.353326 | -0.119210298 | 1.873668999 |
| Location 3 (Cipongkor) | -6.943735, 107.347732 | -0.121191037 | 1.873571365 |
| Location 4 (Cisarua) | -6.805852, 107.446866 | -0.118784525 | 1.873571365 |
| Location 5 (Gununghalu) | -7.043495, 107.302580 | -0.122932178 | 1.872783314 |
| Location 6 (Lembang) | -6.815542, 107.514213 | -0.118953648 | 1.876477007 |
| Location 7 (Ngamprah) | -6.860202, 107.639731 | -0.119733112 | 1.876477007 |
| Location 8 (Parongpong) | -6.805586, 107.584082 | -0.118779883 | 1.878667709 |
| Location 9 (Rongga) | -6.977206, 107.251879 | -0.121775217 | 1.871898415 |
| Location 10 (Saguling) | -6.897515, 107.372591 | -0.120384346 | 1.874005237 |
| Location 11 (Sindangkerta) | -7.031335, 107.400613 | -0.122719946 | 1.874494313 |

We calculate one by one the distance between the object location and each flood/landslide-prone area in West Bandung Regency with the converted data location. The calculation results are in Table 3.

Table 3. Calculation of the distance between objects and flood/landslide-prone areas using the haversine formula

| **Location** | **Distance** |
|---|---|
| Location 1 (Cililin) | 7,97 km |
| Location 2 (Cipatat) | 18,98 km |
| Location 3 (Cipongkor) | 17,02 km |
| Location 4 (Cisarua) | 13,91 km |
| Location 5 (Gununghalu) | 25,79 km |
| Location 6 (Lembang) | 11,64 km |
| Location 7 (Ngamprah) | 6,75 km |
| Location 8 (Parongpong) | 15,68 km |
| Location 9 (Rongga) | 28,13 km |
| Location 10 (Saguling) | 14,27 km |
| Location 11 (Sindangkerta) | 16,59 km |

The calculations in Table 3 show that the closest distance between the object locations and the eleven locations prone to flooding and landslides is 6.75 km.

## 2.4 Software Testing

At this stage, we conduct scenario testing of one of the features in the software to ensure that the system we build can run according to requirements and function properly. In this study, we tested scenarios for the feature to calculate the distance between the user's location and the location of disaster-prone areas in the West Bandung Regency. The following is a test scenario of the distance calculation feature in our software. (Table 4)

Table 4. Scenario test of calculating the closest distance

| Module | Features | Test Steps | Expected Result |
|---|---|---|---|
| Monitoring object location and flood/landslide-prone areas | Calculate the closest distance | user press "Hitung Jarak Terdekat" button | User receives the closest distance between eleven flood/landslide areas |

In this study, testing the closest distance calculation feature was performed five times with five different user locations. Table 5 shows latitude and longitude data from five user locations and locations prone to flooding/landslides in West Bandung Regency for testing.

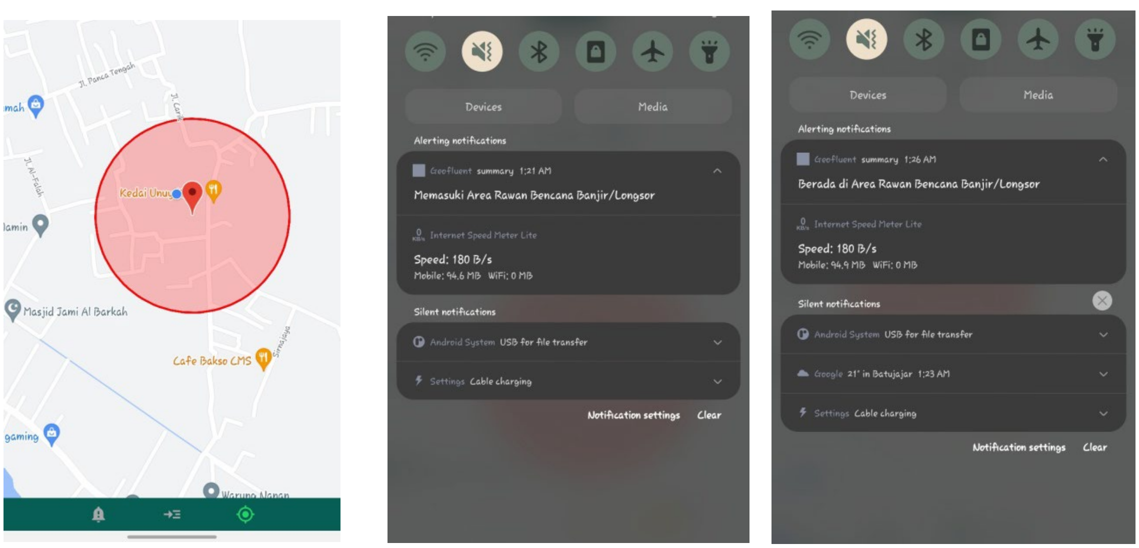
Table 5. Data object location and flood/landslide-prone areas for scenario testing

| | Experiment-1 | Experiment-2 | Experiment-3 | Experiment-4 | Experiment-5 |
|---|---|---|---|---|---|
| Object Location | | | | | |
| Latitude | -6.918415 | -6.832532 | -6.9421279 | -6.805852 | -7.045462 |
| Longitude | 107.499578 | 107.361837 | 107.360905 | 107.446866 | 107.313297 |
| Location 1 | | | | | |
| Latitude | -6.979033 | -6.979033 | -6.979033 | -6.979033 | -6.979033 |
| Longitude | 107.461317 | 107.461317 | 107.461317 | 107.461317 | 107.461317 |
| Location 2 | | | | | |
| Latitude | -6.830247 | -6.830247 | -6.830247 | -6.830247 | -6.830247 |
| Longitude | 107.353326 | 107.353326 | 107.353326 | 107.353326 | 107.353326 |
| Location 3 | | | | | |
| Latitude | -6.943735 | -6.943735 | -6.943735 | -6.943735 | -6.943735 |
| Longitude | 107.347732 | 107.347732 | 107.347732 | 107.347732 | 107.347732 |
| Location 4 | | | | | |
| Latitude | -6.805852 | -6.805852 | -6.805852 | -6.805852 | -6.805852 |

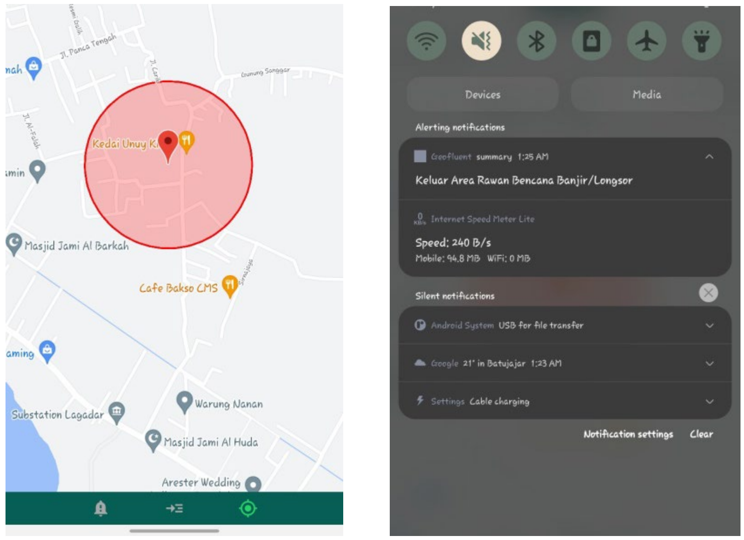
| | Experiment-1 | Experiment-2 | Experiment-3 | Experiment-4 | Experiment-5 |
|---|---|---|---|---|---|
| Longitude | 107.446866 | 107.446866 | 107.446866 | 107.446866 | 107.446866 |
| Location 5 | | | | | |
| Latitude | -7.043495 | -7.043495 | -7.043495 | -7.043495 | -7.043495 |
| Longitude | 107.302580 | 107.302580 | 107.302580 | 107.302580 | 107.302580 |
| Location 6 | | | | | |
| Latitude | -6.815542 | -6.815542 | -6.815542 | -6.815542 | -6.815542 |
| Longitude | 107.514213 | 107.514213 | 107.514213 | 107.514213 | 107.514213 |
| Location 7 | | | | | |
| Latitude | -6.860202 | -6.860202 | -6.860202 | -6.860202 | -6.860202 |
| Longitude | 107.639731 | 107.639731 | 107.639731 | 107.639731 | 107.639731 |
| Location 8 | | | | | |
| Latitude | -6.805586 | -6.805586 | -6.805586 | -6.805586 | -6.805586 |
| Longitude | 107.584082 | 107.584082 | 107.584082 | 107.584082 | 107.584082 |
| Location 9 | | | | | |
| Latitude | -6.977206 | -6.977206 | -6.977206 | -6.977206 | -6.977206 |
| Longitude | 107.251879 | 107.251879 | 107.251879 | 107.251879 | 107.251879 |
| Location 10 | | | | | |
| Latitude | -6.897515 | -6.897515 | -6.897515 | -6.897515 | -6.897515 |
| Longitude | 107.372591 | 107.372591 | 107.372591 | 107.372591 | 107.372591 |
| Location 11 | | | | | |
| Latitude | -7.031335 | -7.031335 | -7.031335 | -7.031335 | -7.031335 |
| Longitude | 107.400613 | 107.400613 | 107.400613 | 107.400613 | 107.400613 |

## 3. Results and Discussion

We implement geofencing technology, GPS, and haversine formulas for monitoring the location of objects (users) and flood/landslide-prone areas in the West Bandung Regency using the Java programming language. Geofencing is used to create a region that indicates that the area is prone to flooding and landslides to increase public awareness of floods and landslides. We use GPS as a tool to track the user's location and the location of disaster-prone areas. User movements will be seen in real-time when monitoring. If the GPS detects an object is entering or exiting the geofence area, the system will send a notification to the user.




(a) (b) (c)

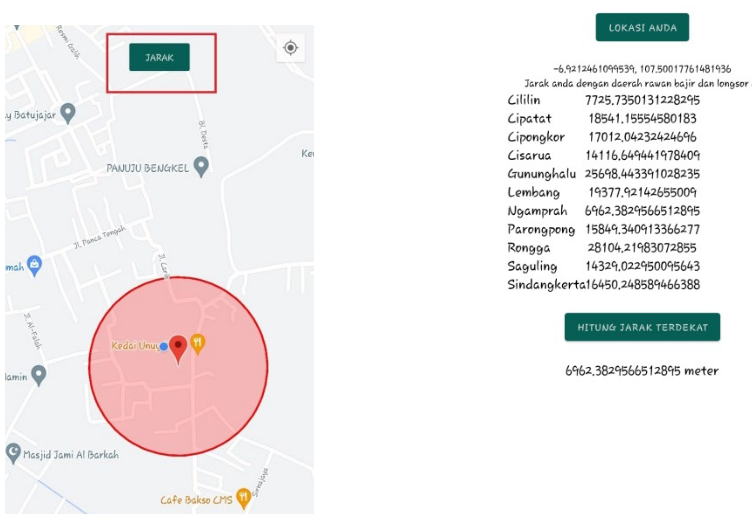



(c) (d)

Figure 4. System Implementation

In Figure 4, four pictures show the condition of (a) the user's location is in a geofence area or flood/landslide-prone area. The user's location is marked by a blue dot, while the red mark is the geofence area. When the GPS detects the user's location is entering or being in the geofence area, the system sends a notification as in conditions (b) and (c). When the GPS detects the user's location has left the geofence area as in condition (c), the system sends a notification as in condition (d).

The software we created can also calculate the distance between the user's location and areas prone to flooding/landslides and display the results of calculating the closest distance between the user's location and areas prone to flooding/landslides. The haversine formula is doing this calculation. To calculate the distance, the user can press the button marked with a red line in the image (e) so that the calculation results will appear in condition (f).




(e) (f)

Figure 5. Calculating the distance between objects and flood/landslide-prone areas

Condition (f) shows the distance between the object's location and the location of the flood/landslide-prone area and the closest distance between the object's location and eleven flood/landslide-prone areas. (Figure 5) The results of the calculation of the closest distance show 6.96 km, while the results of the distance calculation are in Table 6.

Table 6. The results of the calculation of the distance between objects and prone to flooding/landslides

| Location | Distance |
|---|---|
| Location 1 (Cililin) | 7,97 km |
| Location 2 (Cipatat) | 18,98 km |
| Location 3 (Cipongkor) | 17,02 km |
| Location 4 (Cisarua) | 13,91 km |
| Location 5 (Gununghalu) | 25,79 km |
| Location 6 (Lembang) | 11,64 km |
| Location 7 (Ngamprah) | 6,75 km |
| Location 8 (Parongpong) | 15,68 km |
| Location 9 (Rongga) | 28,13 km |
| Location 10 (Saguling) | 14,27 km |
| Location 11 (Sindangkerta) | 16,59 km |

We tested the closest distance calculation with different user location data five times using the data contained in Table 5. The following are the results of the tests we carried out.

Table 7. Output of system testing

| | Experiment-1 (km) | Experiment-2 (km) | Experiment-3 (km) | Experiment-4 (km) | Experiment-5 (km) |
|---|---|---|---|---|---|
| User – Location 1 | 7,97 | 19,82 | 11,80 | 19,36 | 17,93 |
| User – Location 2 | 18,98 | 1,33 | 11,35 | 11,04 | 23,28 |
| User – Location 3 | 17,02 | 12,6 | 1,46 | 18,87 | 11,98 |
| User – Location 4 | 13,91 | 9,8 | 17,88 | 0,34 | 30,49 |
| User – Location 5 | 25,79 | 24,4 | 13,00 | 30,87 | 1,23 |
| User – Location 6 | 11,64 | 30,8 | 33,40 | 21,31 | 44,19 |
| User – Location 7 | 6,75 | 16,85 | 19,30 | 9,59 | 30,29 |
| User – Location 8 | 15,68 | 24,5 | 29,00 | 15,14 | 40,08 |
| User – Location 9 | 28,13 | 20,20 | 12,65 | 28,77 | 10,23 |
| User – Location 10 | 14,27 | 7,17 | 5,13 | 13,11 | 17,76 |
| User – Location 11 | 16,59 | 22,3 | 10,84 | 25,62 | 9,75 |
| System Result | 6,75 | 1,33 | 1,46 | 0,34 | 1,23 |
| Status | Pass | Pass | Pass | Pass | Pass |

In the experiments we did, there was a system result that showed the results of the calculation of the closest distance calculated by the system. The pass or file status is given based on the system result. If the system result shows the closest distance correctly, then the status is "pass". If the system result does not show the closest distance correctly, then the status is "fail". Based on the experimental results in Table 7, the system can calculate the closest distance between the object location and the location of the flood/landslide-prone area correctly because from experiment 1 to experiment 5, the system result has a “pass” status.

## 4. Conclusion

In this study, we create disaster management mitigation software using the concept of geofencing in the West Bandung Regency to convey information on flood/landslide-prone areas to visitors or the local community. The software we build can send notifications to users when users enter or out of flood/landslide-prone areas in West Bandung Regency. In addition, the software we have built can calculate the shortest distance between users and locations prone to flooding/landslides so that users can be prepared when approaching the area.

There are weaknesses in this study, where mobile devices can only use this software with the Android operating system. We suggest developing this software, so Android and iOS operating systems can use it. Also, in the closest distance calculation feature, users must press a button to find the calculation results. We suggest being able to display the distance calculation results without going to other features of the software or pressing the button first.

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## Biographies

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