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A CONTEXT-AWARE MOBILE APPLICATION FOR DISASTER PREPAREDNESS OF PEOPLE IN DISASTER-PRONE AREAS

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Abstract. *Disaster preparedness activities for people in disaster-prone areas can be done through community education and empowerment on disaster risks and mitigation. Although various activities have been done, people's disaster preparedness is still considerably low. An appropriate intervention strategy is hence needed to motivate people to behave according to disaster risks and mitigation. This paper presents a context-aware mobile application for the disaster preparedness of people in disaster-prone areas. When a user enters, leaves, or stays in such areas, the application sends a notification that provides relevant disaster information. The application uses context information of his current locations, user profiles, and situations that may affect the areas' status to decide whether to generate and send notifications to him. The application uses the semantic web to integrate heterogeneous context data from multiple sources on the Internet.*
Keywords: Disaster preparedness, Context-aware, Semantic web, Geofence, Mobile application

1. **Introduction.** The phases of disaster management include disaster risk analysis, disaster preparedness, early warning systems, emergency relief, and reconstruction [1]. Disaster preparedness activities should involve people living in disaster-prone areas. The activities can be done through community education and empowerment on disaster risks and mitigation. These include the provision of evacuation plans, logistics during disasters, and disaster alerts [2]. Although various activities have been done, people's disaster preparedness is still considerably low. Hence, an appropriate intervention strategy that can motivate people to behave according to disaster risks and mitigation is needed [3].

Disaster preparedness activities provide people with relevant information about disasters in which the people live. Thus, Information Technology (IT) applications for disaster preparedness should be context-aware in providing information to their users. Contexts represent situational characteristics that are relevant to the interaction between users and the applications, e.g., users' locations and potential disasters in those locations. Such an application can define a geofence, i.e., a virtual perimeter on a geographical area representing a disaster-prone area. Information provided to a user depends on whether the user is inside or outside that perimeter. Also, the application should intelligently collect and interpret users' contexts without user intervention [4].

Nowadays, most context-aware applications run on smartphones as smartphones have several sensors, e.g., GPS (Global Positioning System), accelerometer, and camera, to identify users' contexts and sufficient processing resources to interpret the contexts. When connected to the Internet, smartphones can extend their physical sensors with virtual and logical sensors [4]. They can also search for updated and relevant data to be composed into comprehensive information.

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Information from multiple sources on the Internet generally comes in heterogeneous data. An application can use the semantic web to facilitate the integration of such information [5]. The semantic web uses ontologies, i.e., graphs of vocabularies and their relationships, to represent knowledge in the information.

This paper presents an architecture of a context-aware mobile application for disaster preparedness. Two main contributions are (i) a layered architecture that implements the concepts of context awareness and semantic web for disaster preparedness and (ii) an algorithm of context-aware notification of disaster information. The resulted application uses geofencing to determine whether the information is relevant to its users and semantic web to integrate heterogeneous information from the Internet.

The paper is structured as follows. Section 2 presents related work on context-awareness and semantic web in disaster management applications. Section 3 identifies three main requirements for the application. Section 4 describes the architecture of the application. Section 5 discusses the application by comparing it with similar applications. Finally, Section 6 concludes this paper and identifies future work.

2. **Related Work.** Several studies have been conducted on the use of mobile applications for disaster management. Such an application should offer interactivity, quality of information, capability to increase users' awareness of disasters, and integration with other technologies [6]. Mobile applications allow disaster alert and warning messages to be pushed out targeted to users in disaster-prone areas [7]. Sharing disaster information, i.e., risks and their mitigation, would improve users' ability to respond to disasters [8]. Context awareness and semantic web can be used to improve the quality of information.

Context awareness has been used in many disaster management applications. Those applications are mostly used in emergency relief [9]. The number of applications for disaster preparedness is very limited. An application uses context awareness in disaster training and response using context information from users' cameras and IoT sensors [10]. Another application uses context awareness in estimating the probability of stampede occurrences in a crowded area. This application uses various context information: heat, thermal rise, noise level, video, and location [11].

In disaster management applications, context information is used for different purposes, i.e., (i) prediction, (ii) decision support, (iii) decision making, and (iv) instruction [6]. For prediction, context information, e.g., crowd density, temperature, and noise level, is used in an application that monitors and provides alerts on crowd situations [11]. For decision support, information on air pressure, wind speed, and humidity is analyzed to provide alternatives for an aircraft to fly or be canceled when a hurricane situation happens [12]. For decision making, information on surrounding objects is used to plan a robot's movement that assists a patient [13]. For instruction, information about location, images, degree of disaster, state of victims, and other data from IoT sensors is combined to provide augmented- and virtual-reality as instructions for responders in an area of disaster [10].

Contexts can be categorized into several types, namely (i) user, (ii) physical, (iii) time, and (iv) computing contexts [14]. Different types of context information can be used in an application. For example, an application for delivering instructions for first responders uses user context information (i.e., location, movement, and preferences), physical context information (i.e., lighting, noise, photos, and videos of the area of disaster), and computing context information (i.e., network latency) [15].

Semantic web for information integration has been used in different phases of disaster management, but mostly emergency relief [16]. Applications for disaster preparedness are dynamic disaster process monitoring [17], earthquake disaster mitigation [18], and visualization of earthquake drill scripts [19]. However, none of these applications are for people living in disaster-prone areas.

Geospatial information is essential in disaster management applications. This piece of information is represented in terms of ontologies and rules [18,20-22]. Although geospatial ontologies have been proposed [23], applications prefer to use their ontologies to accommodate information integration. A common approach is by providing a layer of semantic processing that handles information integration from multiple (internal and external) sources. Information integration is thus transparent from the application logic [16].

3. **Requirements.** Three main requirements for our context-aware mobile application for disaster preparedness of people in disaster-prone areas are as follows.

3.1. **Requirement R1.** Figure 1 illustrates the basic idea of our application. Assume that a user has the application installed on his smartphone that continuously monitors his current location. He makes a trip through a disaster-prone area D_1. When he enters at point a, the application sends him an entry notification informing that he is now inside D_1 and providing disaster information of D_1. Hopefully, he will be aware of his situation and have sufficient knowledge to help himself if a disaster happens. When he leaves D_1 at point b, the application sends an exit notification informing that he is now outside D_1.

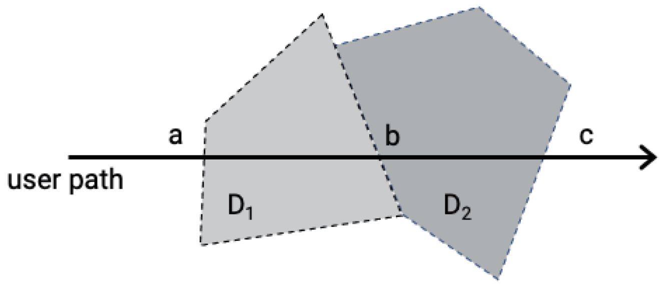

Figure 1. A user makes a trip through disaster-prone areas D_1 and D_2.

A disaster-prone area may consist of several adjacent sub-areas. Figure 1 also illustrates a disaster-prone area that consists of two sub-areas D_1 and D_2. When a user makes a trip through those sub-areas, the application sends him notifications at points a (entry to D_1), b (exit from D_1 and entry to D_2), and c (exit from D_2).

3.2. **Requirement R2.** The status of a disaster-prone area may change depending on certain factors. Hence, the application must decide whether to send notifications based on that status. The notification content should also be customized accordingly. For example, when a user enters a flood-prone area in a dry season, the application should not send any notification. When he enters the area in a rainy season, the application sends a notification to inform the possibility of flooding based on relevant weather conditions. It should be noted that factors affecting an area's status can be outside of the area. For example, heavy rain in the upstream area of a river may cause flooding in the downstream area.

3.3. **Requirement R3.** There are three types of users, i.e., (i) *type-1*: users who pass through a disaster-prone area occasionally, (ii) *type-2*: users who pass through the area frequently, and (iii) *type-3*: users who live in the area. Figure 2 depicts the typical movements of each type of user. The frequency at which the application sends notifications to a user must consider the user's type. Too many notifications would annoy the user so that he might opt to turn off the application. Too few notifications would make them ineffective for establishing disaster awareness of the users.

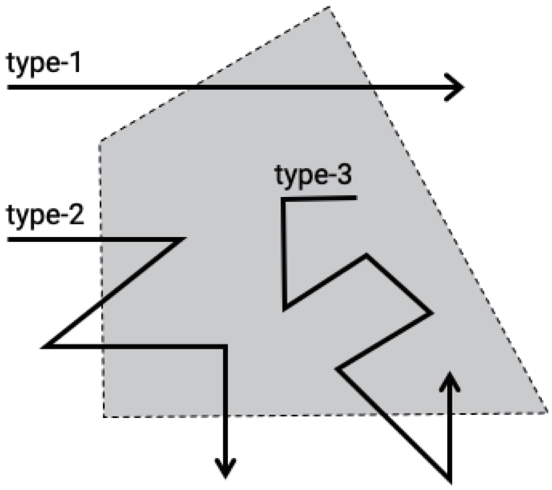

FIGURE 2. Typical movement of each type of users

4. **Architectural Design.** This paper takes a mobile application for context-aware notification of a volcanic disaster developed in [24] as a basis. Disaster-prone areas are defined as geofences. This basis application satisfies requirement R1 only. This paper extends the basis application to satisfy other requirements by using the semantic web. Figure 3 depicts the layered architecture of our application system.

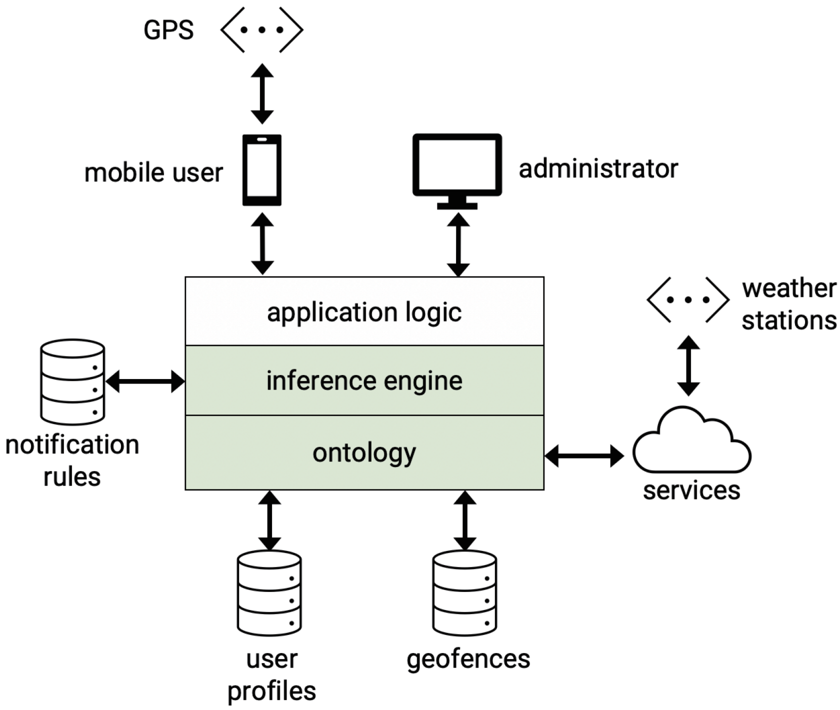

FIGURE 3. The architecture of our application

Components that are involved are (i) user roles, (ii) sensors, and (iii) datastores. The user roles are mobile users who use the application to receive notifications and administrator who manages notification rules and the geofences of disaster-prone areas. The sensors are GPS in users' smartphones and sensors in weather stations that can be accessed via services on the Internet, e.g., Open Weather Map and AccuWeather API. Datastores are for storing geofences of disaster-prone areas, user profiles, and notification rules. Alternatively, the geofences can also be stored in an external location service [25]. User profiles categorize users based on their types (requirement R3) for each disaster-prone area. The type of a user is inferred by the application from the users' movement history. Notification rules define the conditions to generate notifications when users enter or leave disaster-prone areas.

The layers in the architecture are (i) ontology, (ii) inference engine, and (iii) application logic. The ontology layer consists of an ontology for interpreting data from weather services that may come in different vocabularies. This layer makes the weather data conform with the semantics used by the application to be integrated with other data, i.e., user profiles and geofence areas. The inference engine executes notification rules for a particular disaster-prone area using weather data related to that area. The rules decide whether a notification should be generated. The application logic layer is responsible for determining users' types and for sending notifications to individual users.

This paper uses flood disaster as an example. The application uses context information about the user's current locations, user profiles, and weather situation for deciding whether to generate and send a notification to a user. Figure 4 depicts the algorithm of the decision making.

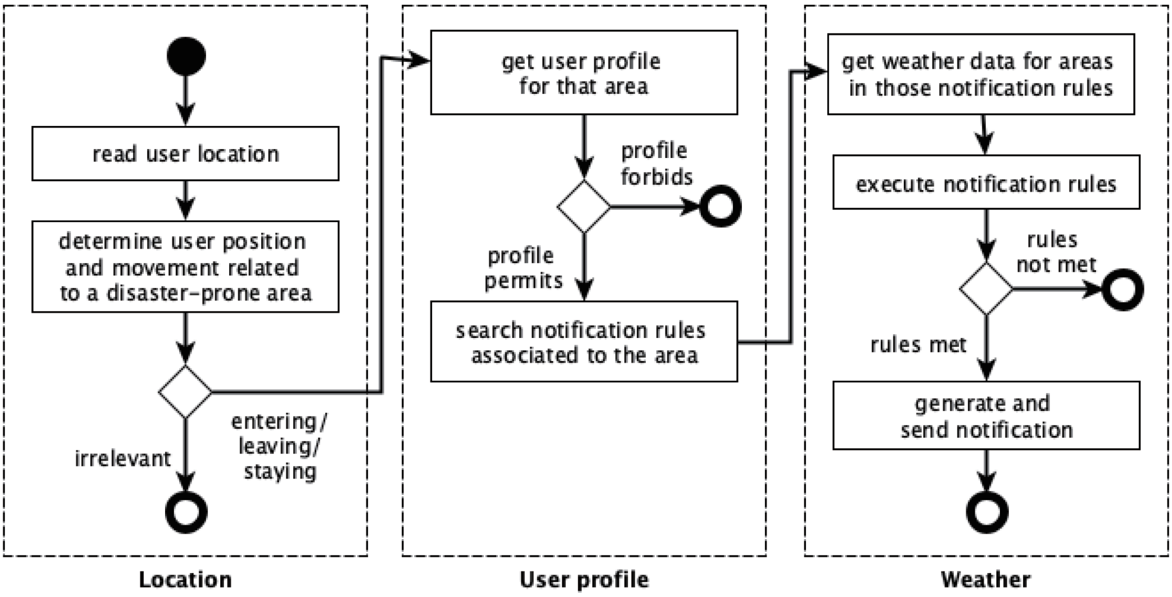

FIGURE 4. Algorithm for generating and sending a notification

Information about users' locations is used to determine the user's position and movement related to disaster-prone areas. The application reads the user's location data from GPS every minute and sends them to the server. Based on information about the current location (x_i, y_i) and previous location (x_{i-1}, y_{i-1}), the server can determine the user's movement according to Table 1. Notifications are relevant only for users that are entering, leaving, or staying in a disaster-prone area.

TABLE 1. User's movement related to a disaster-prone area

Previous location (x_{i-1}, y_{i-1})	Current location (x_i, y_i)	
	outside	inside
outside	irrelevant	entering
inside	leaving	staying

If a user is entering, leaving, or staying in a disaster-prone area, the application searches for his profile for that area. Note that a user can be of a different type for each area. Table 2 lists permission conditions for sending a notification based on user types.

Table 2. Conditions for sending notifications

User type	Sending permission
1	anytime
2	minimum a day after previous notification
3	minimum a month after previous notification

If his profile permits, the application searches for notification rules that are associated with that area. Figure 5 depicts two examples of notification rules for a disaster-prone area named *area1*. A rule is defined as an *if-then* rule. Rule 1 says: If it is a rainy season in the area and heavy rain happens in the area, notify users with a "flood-prone area" message. Rule 2 says: If heavy rain happens in *area2*, notify users with a "flood-prone area" message. The keyword *here* refers to the area for which the rule is defined. *rainySeason* and *heavyRain* are defined as functions. In execution, the application identifies referred areas (i.e., *area1* and *area2*) in the rule condition and sends requests to weather services for getting current weather conditions in those referred areas. A notification is generated when at least one rule is met.

```
1  area1 {
     if (here.rainySeason() &&  here.heavyRain())
     then notify("flood-prone area")
   }

2  area1 {
     if (area2.heavyRain())
     then notify("flood-prone area")
   }
```

Figure 5. Examples of notification rules

5. **Discussion.** Context information has the potential to make the application more effective to improve people's disaster preparedness. However, the number of such applications is still very limited [9]. Table 3 depicts the comparison of our application with similar applications.

Table 3. Comparison of the applications

Application	Activity	Context-aware	Context
iHanda	Disaster preparedness	Yes	Location
AppLERT	Emergency relief	No	Location
SakunAPP	Emergency relief	No	Location, user
Our application	Disaster preparedness	Yes	Location, user, weather

iHanda is a mobile application for disaster preparedness by providing information about the weather forecast, vulnerability map, evacuation plan, and emergency hotlines [26]. It is a context-aware application that uses users' location data to show the nearest hospitals and evacuation centers. The application sends a notification when an announcement is posted on the application. The notification is not determined by context information.

AppLERT is a mobile application that enables users to ask for help during a disaster and send notifications to other users [27]. This application is for emergency relief activities. The application sends users' GPS data so a rescue unit can locate the users. Although the application uses context information, i.e., location data, it cannot be considered a context-aware application as its behavior does not consider the context information.

SakunAPP is a mobile application for information dissemination during disasters [28]. It allows a user to update her status to mark whether she is safe. She can also locate her family members based on their statuses and location data from their GPS. This application is also hardly considered as a context-aware application.

6. **Conclusions.** This paper has described the architectural design of a context aware mobile application for disaster preparedness. Notifications about disaster information are sent when users enter, leave, and stay in disaster-prone areas. Users are profiled into (i) users who pass through a disaster-prone area occasionally, (ii) users who pass through the area frequently, and (iii) users who live in the area. This profile determines the frequency at which notifications are sent to the users. The notifications are generated when their rules are met. Our future work is to refine the architecture to handle a large number of users and disaster-prone areas.

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