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Research Article

Designing an Android-Based Application for Geohazard Reduction Using Citizen-Based Crowdsourcing Data

Chaoyang He,[1] **Nengpan Ju**,[1] **Qiang Xu**,[1] **Yanrong Li**,[2] **and Jianjun Zhao**[1]

[1]*State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, No. 1 Dongsanlu, Erxianqiao, Chengdu, Sichuan 610059, China*
[2]*College of Mining Engineering, Taiyuan University of Technology, Taiyuan, Shanxi 030024, China*

Correspondence should be addressed to Nengpan Ju; jnp@cdut.edu.cn

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Application development based on mobile platform is regarded as one of the major trends in information communication technology. However, only a few cases of mobile application are available for geohazard reduction using citizen-based crowdsourcing data. With the development of geohazard informatization and the rapid progress of mobile technology, the design and implementation of phone-based applications that could be used to monitor and prevent geohazards have been received increasing attention. Aiming at minimizing the threat of geohazards to people's lives and assets, this paper presents an android-based application named Geohazards Group Measurement and Guards against System (GGMGAS). Local villagers use the GGMGAS to collect field data, including photos and videos, and transmit them to a database server. Therefore, the efficiency and stability of the data exchange between the mobile phone and the database server is very important. A design method and system solution of a data-exchange scheme was designed based on the WebService technology. Through trial operation, it has been found out that this data-exchange scheme could greatly improve the communication efficiency and the stability of collected field data. Practice has proved that this method based on citizens' crowdsourcing data can effectively reduce the losses caused by geohazards.

1. Introduction

Geohazard, including landslide, collapse, debris flow, ground subsidence, and so forth, has been seriously threaten people's life and properties. Data from multiple studies suggest that geological background is complex in China, especially in the south of Anhui Province [1–3]. Studies also confirm that the geological environment of Anhui Province is fragile, creating favorable conditions for the formation and development of sudden geological disasters [4, 5]. In addition to geological environment, there has also been a debate among scholars concerning whether the frequent occurrence of disasters is associated with human activities [6–12]. Bozzano et al. [10] have found out that human activities, especially the construction of numerous engineering sites, may cause serious geological disasters. Therefore, the development of geohazard guards against systems has gradually started to become the focus of the government and researchers [13, 14]. Disaster monitoring computerized software system has been attached great attention, since the data transmission of mobile equipment has already been achieved today [15, 16].

Most researchers recently have shown an increased interest in developing mobile disaster monitoring and alerting systems [17–19]. It has been proven by field-testing results that crowdsourcing-based system could increase the speed and efficiency of data collection [20]. In geological disaster field, Frommberger and Schmid [21, 22] presents a disaster alert system that are developed based on the concept of crowdsourcing. By gathering information from the disaster-affected citizens, the Mobile4D is proven to be helpful to build a bilateral contact between the local government and residents. It has also been pointed out by other studies that crowdsourcing-based applications are able to deliver "real-time" warnings to local residents, since the bilateral contact has already been established [21–23]. In addition, Coz et al. [24]

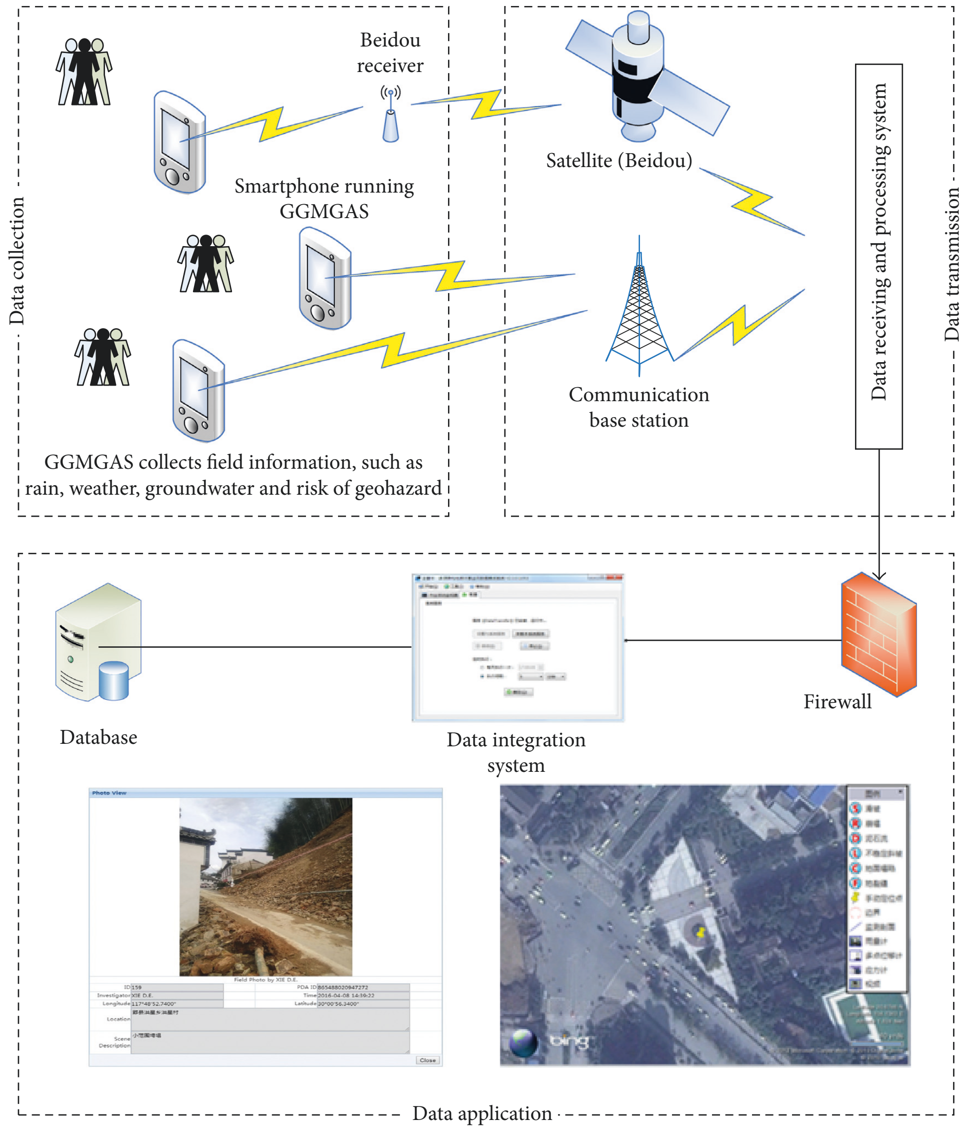

Figure 1: Architecture diagram of GGMGAS, including data collection, data transmission, and data application.

have also noted that the crowdsourced data collection process could help to improve local people's understanding of geological disasters. People's increasing understanding of geohazards could in turn improve the efficiency and stability of crowdsourced information that has been collected by local citizens [23].

Although the crowdsourcing-based system could improve the efficiency of data collection and information transmission, Tsai et al. [23] have also discovered that it is difficult to ensure the data quality, since the crowdsourcing-based data are collected by local people, who do not receive any professional training or learn any knowledge related to geological disasters. Coz et al. [24] also emphasized that the successful application of crowdsourcing-based system requires a simple and easy operation process, suitable data processing system, as well as people's good understanding of geological disasters.

Based on the researches which had been done by other scholars, this study aimed at exploring a geohazards against system that could be operated by citizens, especially those who have little or no professional knowledge. To reduce the time of information transferring, this study proposes an android-based application, which could be used to collect field data, support field investigation, and report potential geohazards. To improve the quality of collected data and data exchange, a data-exchange scheme was designed based on the WebService technology. The application was designed to be a versatile operating system, the main interface of which is intuitive and user-friendly. This paper introduces the architecture design, the function design, and the development process of the application and discusses how to improve the data communication efficiency and stability. Analyze and evaluate the performance of the GGMGAS through the field testing in Huangshan City.

2. Android-Based Application Design

2.1. Architecture Design. As shown in Figure 1, the overall architecture of the GGMGAS could be divided into three

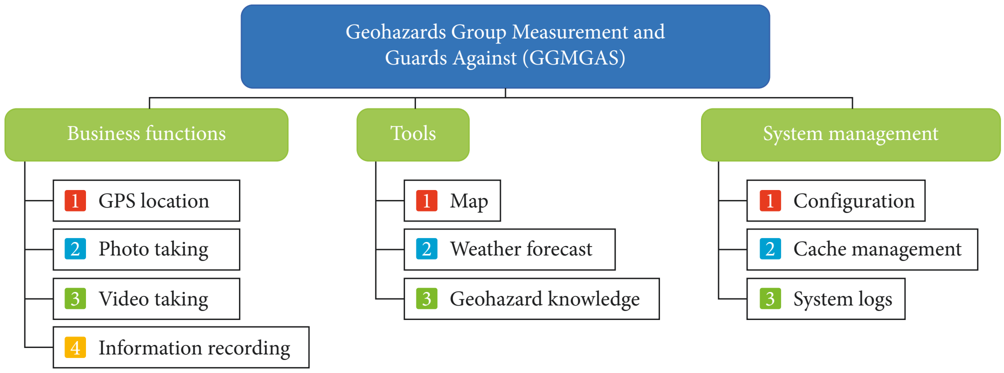

Figure 2: Functions of the GGMGAS could be divided into business functions, tools, and system management.

parts, which are data collection, data transmission, and data application. Data collection part is primarily designed for local citizens to collect the field data, while data transmission is set up for them to send the collected data to data server via wireless communications or Beidou satellite. As long as the mobile terminal supports Beidou communication, the collected data could be successfully transmitted to the data server. After receiving the data from the data server, duty officers are required to use the collected data to analyze the geohazard risk, and to decide whether it is necessary to issue an early warning to residents.

2.1.1. Data Collection. The field data, such as rainfall, groundwater level, and weather photos or videos, could be collected by local people. Given the fact that field investigations are often conducted in areas outside the range of cellular networks [25], it is vital to ensure that the necessary data could be gathered and stored in offline mode.

To address this issue, a database has been designed based on SQLite, which is a small but powerful relational database management system that is popularly used and could be compatible with multiple mobile operating systems [26, 27]. The establishment of this database has ensured all field data could be captured and saved with or without the Internet.

2.1.2. Data Transmission. The collected data could be automatically synchronized to the data server if the networks are available. However, if network connectivity is lost, the data will be temporarily stored in the database, which is designed based on SQLite. After reconnecting to the Internet, the data could be synchronized to the data server by data collectors manually, and the data that were stored in the smartphone would be deleted automatically once the data transmission is completed. The design of the database has guaranteed the safety and integrity of the collected data during data transmission and has also assured the feasibility and efficiency of data collection.

2.1.3. Data Application. The data will be integrated into the data center by the Geohazard Multi-Source Monitoring Data Integration System [28] immediately once received. The collected data, including the data of weather, photos, and videos, will be analyzed by the duty officer, who is responsible for making qualitative risk assessments of geological hazards and determining whether to issue an early warning of geological disasters.

2.2. Function Design. The function design of GGMGAS is as essential as the architecture design. Most local villagers, who are the primary users of GGMGAS, generally have low education background. It is therefore vital for GGMGAS to provide simple, intuitive, and user-friendly functions.

As shown in Figure 2, multiple functions have been added to the GGMGAS, and they could also be divided into three parts, including business functions, tools, and system management.

2.2.1. Business Functions. Business functions have been developed as the core function of the GGMGAS, which is mainly designed to achieve the comprehensive collection of field information. As illustrated in Figure 2, the business functions of the GGMGAS includes GPS location, photo taking, video taking, and information recording. The implementation of these functions not only ensures that the collected data could be more diversified, but also raises the convenience of data collection.

(1) GPS Location Function. It mainly provides location information such as longitude, latitude, and altitude. Since the smartphone that is used to collect field data already has the Global Positioning System (GPS) module installed, the location information could be automatically tagged to each photo, video, and other data that has been taken in that location. The coordinate system is set as WGS84, and the coordinate accuracy depends on the GPS module in the smartphone.

(2) Photo-Taking Function. It is designed for data collectors to take photos by using the camera of the smartphone and to save the images to the disk in the jpeg format. Before saving the images to the disk, data collectors could review the photos by zooming in and rotating the images so as to decide whether it is necessary to do a retake or not.

(3) Video-Taking Function. It is considered as a critical function of the GGMGAS, because video information is

more convincing than other information. In order to ensure all recordings could be replayed and analyzed after data collection, videos (as well as photos) will be automatically saved in the disk of the smartphone, the directory path of which is "/sdcard/GGMGAS/media/." All videos are designed to be automatically saved as MPEG-4 format so that the video quality could be ensured.

(4) Information-Recording Function. It is mainly used for reminding the duty officer to check the data that has been just received. The primary role of this function is to ensure that the duty officer, who has responsibility for analyzing all collected data, would check and analyze the field data in time.

2.2.2. Tools. The tools of GGMGAS consist of map, weather forecast, and geohazard knowledge modules.

To obtain positional information during the field investigation, the Baidu Map has been embedded into the *map* module of GGMGAS. This tool guarantees that users of GGMGAS could have access to online maps, as well as local high-definition (HD) remote-sensing image maps. With the help of this tool, data collectors could get a preliminary understanding of the investigation area, obtain basic geographic information, and measure the length and area of the investigation area.

The *weather forecast* module provides weather data such as temperature, rainfall probability, PM 2.5, and so forth. All weather data come from the China Meteorological Administration. The GGMGAS is also designed to automatically read the weather data. If the investigation area faces heavy rain in the coming days, the GGMGAS will automatically notify data collectors to pay significant attention to geohazards and hidden dangers.

The *geohazard knowledge* module is developed for data collectors, who are also local villagers. Considering that most local villagers do not have any professional knowledge of geohazards, this module collects a few frequently asked questions, such as what is a landslide, and provides correspondence answers. By transferring geohazard knowledge in this way, this module is intended to increase data collectors' theoretical knowledge of geohazards.

2.2.3. System Management. In this section, data collectors can manage the system configuration, caches, and logs and reset their passwords. They can also browse the collected data and transfer them through cellular networks, Wi-Fi, or even Beidou satellite.

3. Data Communication

3.1. Data Exchange. A successful data exchange between the smartphone and the database server generally involves network data communication technology. To ensure a stable and reliable data exchange, WebService, a kind of protocol standard of remote procedure call, has been applied in the GGMGAS [29]. WebService is based on the Simple Object Access Protocol (SOAP), and it is well known as a platform-independent, loosely coupled, and web-based application

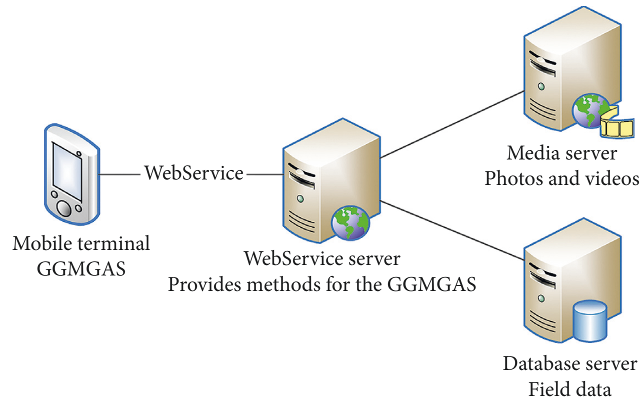

Figure 3: Deployment of the GGMGAS.

described by Extensible Markup Language (XML), which is also mainly used to develop distributed heterogeneous applications.

The reason for choosing WebService to provide data services is that WebService could improve the security and reliability of the GGMGAS. WebService provides an encapsulated environment in which users could only access the interface provided by the WebService, but the specific internal functional logic is not visible to users. Practice has proven that the system's security has been guaranteed by these features. Therefore, WebService has been selected to provide data services for the mobile terminal. The system deployment chart is demonstrated in Figure 3.

3.1.1. Mobile Terminal. It is the android-based smartphone in which the GGMGAS has already been installed.

3.1.2. WebService Server. It is the main bridge between the database and the mobile terminal. The WebService provides GGMGAS methods. Mobile termination could carry out operations by the WebService, such as access authentication, data uploading, and data downloading.

3.1.3. Media Server. It stores the photos and videos that are taken by the mobile terminal.

3.1.4. Database Server. It stores the data of the entire system, including basic geohazard information, monitoring data, GGMGAS-collected data, and system configuration. Oracle database (version: Oracle 11g R2) has been applied in this study.

3.2. WebService Methods. The data exchange of WebService uses XML by default. However, given that mobile termination is normally working on a cellular data network, it cannot store and parse massive amounts data, such as XML data. To accelerate the loading speed of the data and save data traffic, data compression should be the first consideration.

Compared with XML, the JavaScript Object Notation (JSON) data have a simpler structure. Most JavaScript programmers find it simpler and more intuitive to reference

Table 1: The data size in XML format and JSON format.

#	Data (rows)	XML (Kbytes)	JSON (Kbytes)	JSON/XML (%)
1	1	1.74	0.27	15.28
2	10	5.17	1.74	33.72
3	20	9.00	3.39	37.67
4	30	12.84	5.04	39.26
5	40	16.68	6.69	40.12
6	50	20.51	8.34	40.65
7	60	24.35	9.99	41.02
8	70	28.19	11.64	41.29
9	80	32.03	13.29	41.49
10	90	35.86	14.94	41.65
11	100	39.70	16.59	41.78

JSON data structures than to access an equivalent XML Document Object Model structure. Thus, the JSON format is applied in this study to compress data, and the overload method is used to convert data into JSON format, combined with data characteristics.

To test the performance of JSON data, 10 rows of geohazards data, which are obtained from the WebService named GetGeohazardList, have been collected and further analyzed. It could be clearly seen from Table 1 that the size of XML data is 5.17 Kbytes, while the size of JSON data is 1.74 Kbytes, taking only 33.72% of the XML data. With the increase of the data, the proportion that the amount of JSON data accounted for XML data size has maintained around 41%, as shown in Table 1. It could be detected from the above example that the amount of data could be greatly reduced when using JSON data for data exchange, even though the data size depends on the size of the field data.

Considering the function design and architecture requirements of the GGMGAS, a WebService is compiled based on the Microsoft Visual Studio 2010 and C#, as shown in Figure 4. The interactive data between mobile termination and media/database server are formatted by JSON. Eleven methods, including permission validation, are involved in the WebService, and the details of all eleven methods are listed in Table 2.

Figure 4: WebService provided for the GGMGAS.

4. Android Application Development

Android platform is an open architecture that includes the operating system, middleware, and several key platform applications [16, 30]. To develop the GGMGAS, the android software developer kit has been applied in this project. The android software developer kit that has been selected to develop the GGMGAS is provided by Google [15]. Since developers are more familiar with Java programming language, the Eclipse, an integrated development environment, is selected to develop the GGMGAS.

The main interface of the GGMGAS has a clean layout with functions ordered logically on the main screen, as shown in Figure 5. Textual labels such as weather forecast, group measurement and guards against, and danger report are displayed in the center of the main screen. Image-based labels at the bottom of the screen perform actions, such as the globe icon that opens a high-resolution map screen of the current position, as shown in Figure 6.

The user operation interface of the group measurement and guards against (GM&GA) module and the danger report modules is shown in Figures 7 and 8, respectively. As illustrated in Figure 7, a list of various data fields has already been provided on the operational interface of the GM&GA. With the help of the list, data collectors could collect sufficient field data simply by filling in the blanks. It has also guaranteed the availability and quality of the collected data. Field information such as location information, rainfall amount, groundwater level, and risk level could be clearly documented, by using the GM&GA.

The danger report modules also allow data collectors to upload photos and videos, as shown in Figure 8. This module could be tremendously helpful. Given that primary users of GGMGAS, who are usually local villagers, are not professionals, the duty officer may obtain more useful information from pictures or videos.

5. Field Testing

5.1. Study Area. To verify the capability of the GGMGAS, a field testing was conducted in Huangshan City, which is in the southern mountainous area of Anhui Province, China.

Table 2: WebService methods provided for the GGMGAS.

ID	Method name	Parameters	Main function
1	GetPermission	uid: PDA Id	Get user permission
2	GetPreventList	uid: PDA Id	Get a prevention list
3	GetGeohazardList	uid: PDA Id	Get a geohazard list
4	GetMonitorList	uid: PDA Id pid: Geohazard Id	Get a monitoring point list
5	GetMonitorData	uid: PDA Id pid: monitor Id stime: start time etime: end time	Get monitoring data
6	GetWarningMessage	uid: PDA Id	Get a warning message
7	GetWeather	uid: PDA Id	Get weather forecast
8	SendReportMsg	uid: PDA Id msg: encoding string of report message	Send a report message
9	SendPhoto	uid: PDA Id p: encoding string of photo	Send a photo
10	SendVideo	uid: PDA Id v: encoding string of video	Send a video
11	SaveConfig	uid: PDA Id cfg: encoding string of configuration of the system	Save the system configuration

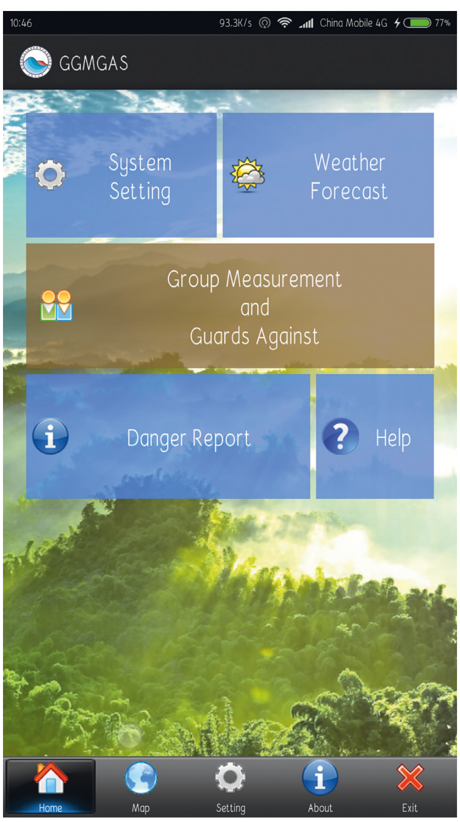

Figure 5: Main interface.

Figure 6: Electronic map module (based on Baidu Map).

As illustrated in Figure 9, the geographic coordinates of Huangshan City are 29°24′N to 30°31′N and 117°12′E to 118°53′E, and it covers an area of 9,807 km^2 and consists of three districts (Huangshan, Tunxi, and Huizhou) and four counties (Xiuning, Yixian, Qimen, and Shexian). The Huangshan City is a geohazard-prone area in Anhui Province. The geohazards in the Huangshan City are characterized by their high frequency, wide distribution, and threat to the population. Therefore, the government attaches great importance to the control and prevention of geohazards. Considerable work has been conducted on geohazard prevention, monitoring, and early warning. Emergency response and engineering management have also been strongly promoted by local government. In addition,

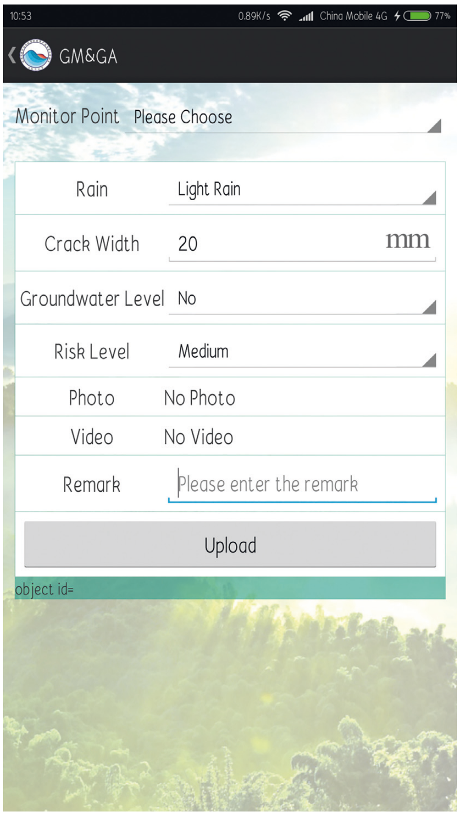

Figure 7: Group measurement and guards against module.

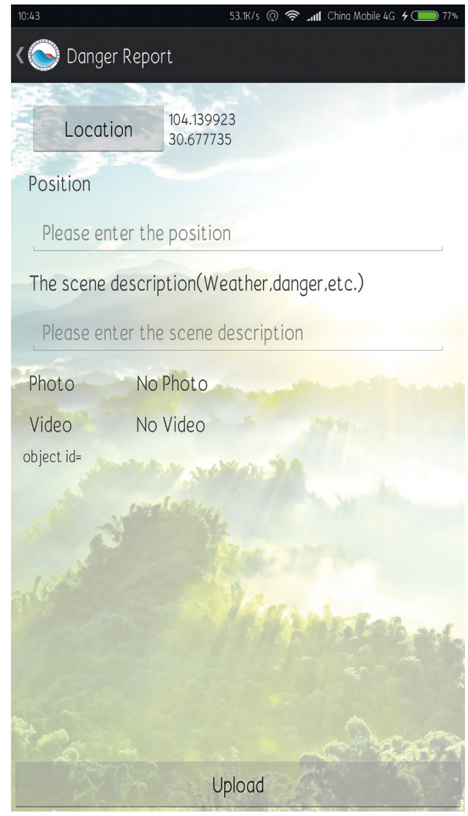

Figure 8: Danger report module.

the establishment of disaster warning systems in various districts and counties has also been taken into great consideration.

5.2. Data Collection. During the data collection process, it has been found out that local people could quickly pick up the basics of how to use the GGMGAS. According to an interview with a member of local community, GGMGAS is a user-friendly system. Most local people hold the opinion that the android-based smartphone with GGMGAS is simple and easy to use, even though they are not acquainted with electronic equipment.

The testing results also suggest that the implementation of GGMGAS could significantly reduce government spending. As shown in Figure 10, intuitive photos and videos of the geohazard scene could be collected by residents themselves. The government only needs to pay monthly mobile data traffic charges, which in Huangshan City is usually 10 to 15 yuan per user.

5.3. Data Application. In the process of data analysis, the Geohazard Monitoring and Early Warning Platform that is independently developed [28] was used. With the help of this platform, the field data that are collected by local people could be easily viewed and managed.

Figure 11 shows the data lists of collected data. Detailed information such as PDA ID, longitude, latitude, time, and location is provided in the list. During the data analysis, each data could be marked as "Untreated" or "Treated." To make unread information more obvious, "Untreated" data are set up to be displayed on the top of the platform, and the text color of "Untreated" information is red.

All final three icons are clickable and direct duty officers to more details on disaster areas. For example, a new page named "Photo View" will open after right-clicking the first globe icon, as shown in Figure 12. The new webpage contains detailed information, including investigator, time, location, and scene description.

After nearly a year of trial operation, more than 170 rows (Figure 11) of valid data were collected by local residents. In the process of data analysis, it has been discovered the GGMGAS was significantly useful in helping the duty officer to grasp the situation at the scene, with the aid of Geohazard Monitoring and Early Warning Platform. It has also been found out that the GGMGAS could greatly improve the prevention of the geohazards.

6. Discussion and Conclusion

The purpose of this paper is to present a simple and low-cost method to reduce the losses caused by geohazards. An android-based application named GGMGAS was developed for residents to collect field data. The architecture of GGMGAS includes data collection, data transmission, and data application. In addition to the architecture design, business functions such as GPS location function, photo-taking function, and video-taking function are also developed to increase the usability of the GGMGAS. Tools, including map and weather forecast, are designed to make the process of data collection more simple and accessible.

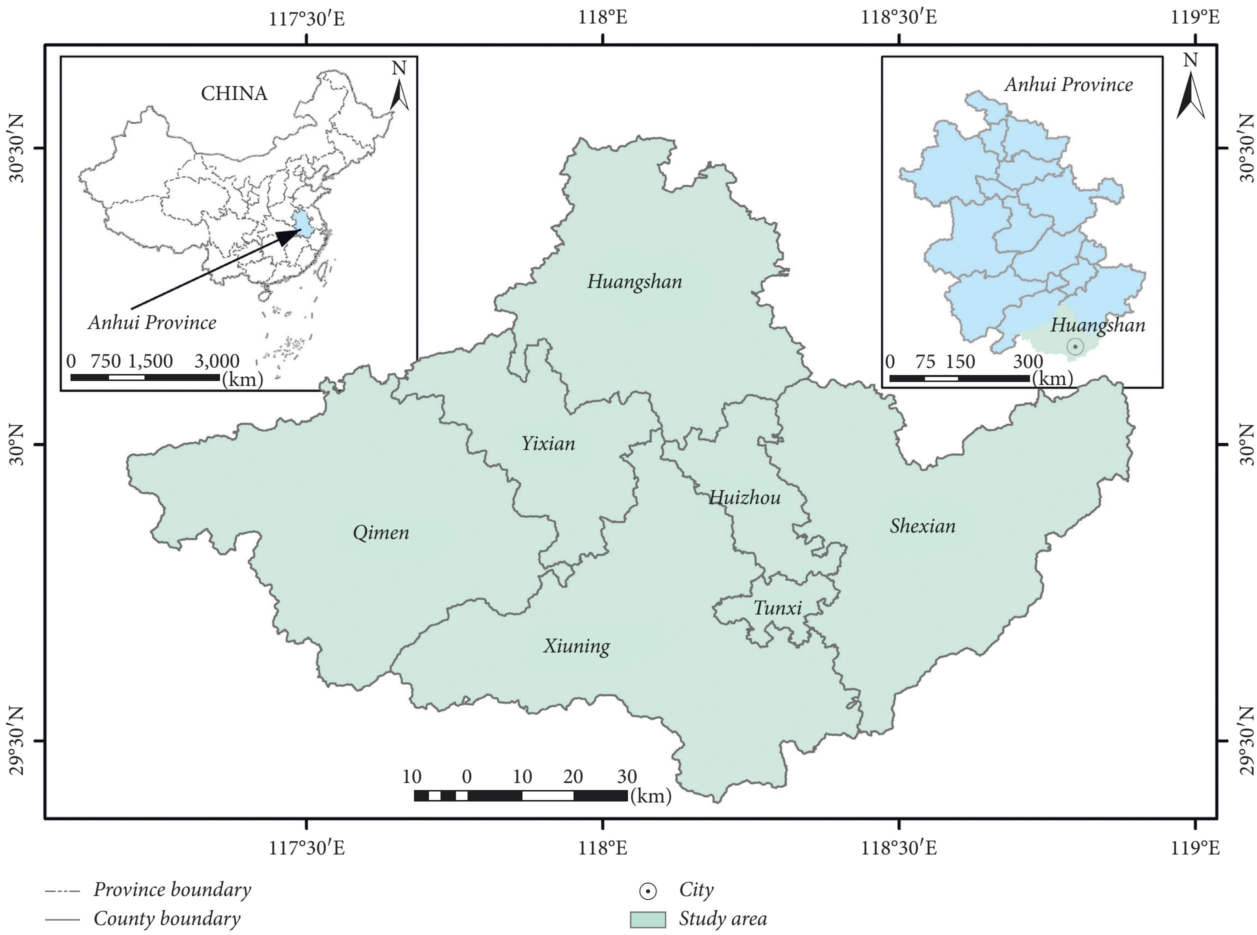

Figure 9: Map of the location of the study area and its surroundings.

(a) (b)

Figure 10: Photos taken with GGMGAS by safety-responsible individual. (a) Location: 29°46′37.4520″N, 118°34′51.8160″E. Description: the cracks in Xiaochuan landslide are covered with plastic film by the villager. (b) Location: 29°52′41.1240″N, 118°41′18.4200″E. Description: damage of the house caused by Gaoshan landslide deformation.

One of the main objectives of the GGMGAS is to provide sufficient field data for decision-making of local government. To achieve this goal, the GGMGAS is designed based on the concept of crowdsourcing. Enough field data could be collected by local people, and a stable and reliable data exchange is guaranteed since the WebService technology has been applied in the GGMGAS. Another objective of the GGMGAS is to ensure the quality and integrity of field data. For this objective, several business functions such as map and geological knowledge modules have been developed to advance local villagers' understanding of geological disasters. In addition, the design of A group measurement and

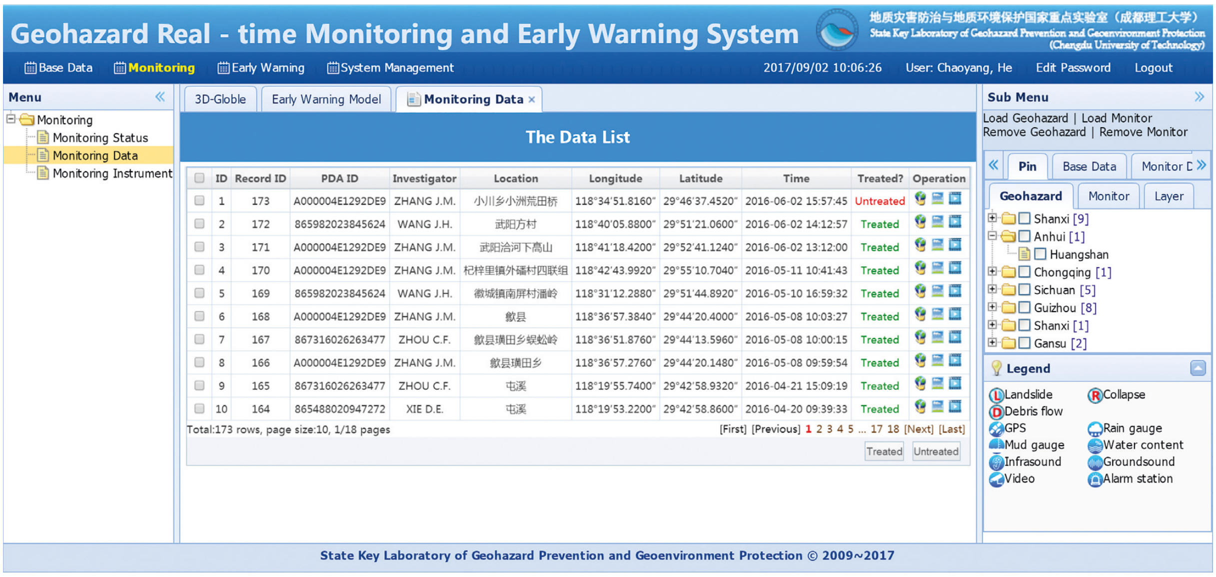

Figure 11: The data collected by the GGMGAS.

Figure 12: Photo view page in the geohazard real-time monitoring and early warning system.

guards against (GM&GA) module not only could improve the convince of data collection, but also could assure the quality of collected data.

To detect the performance of the application, the GGMGAS has been tested in Huangshan City, which is typically characterized by geological hazards. Based on test results, it could be found out that the realization of the GGMGAS could greatly improve the reliability and authenticity of the data and satisfy the function requirement of practical work. Test results also prove that the GGMGAS could gather sufficient valid information from local citizens, and it could also help to reduce the government spending on the prevention of geological hazards. However, further studies and testes are needed. Future works will mainly focus on developing the iOS version of the GGMGAS. A more effective utilization of the crowdsourced data will also be discussed in a future article.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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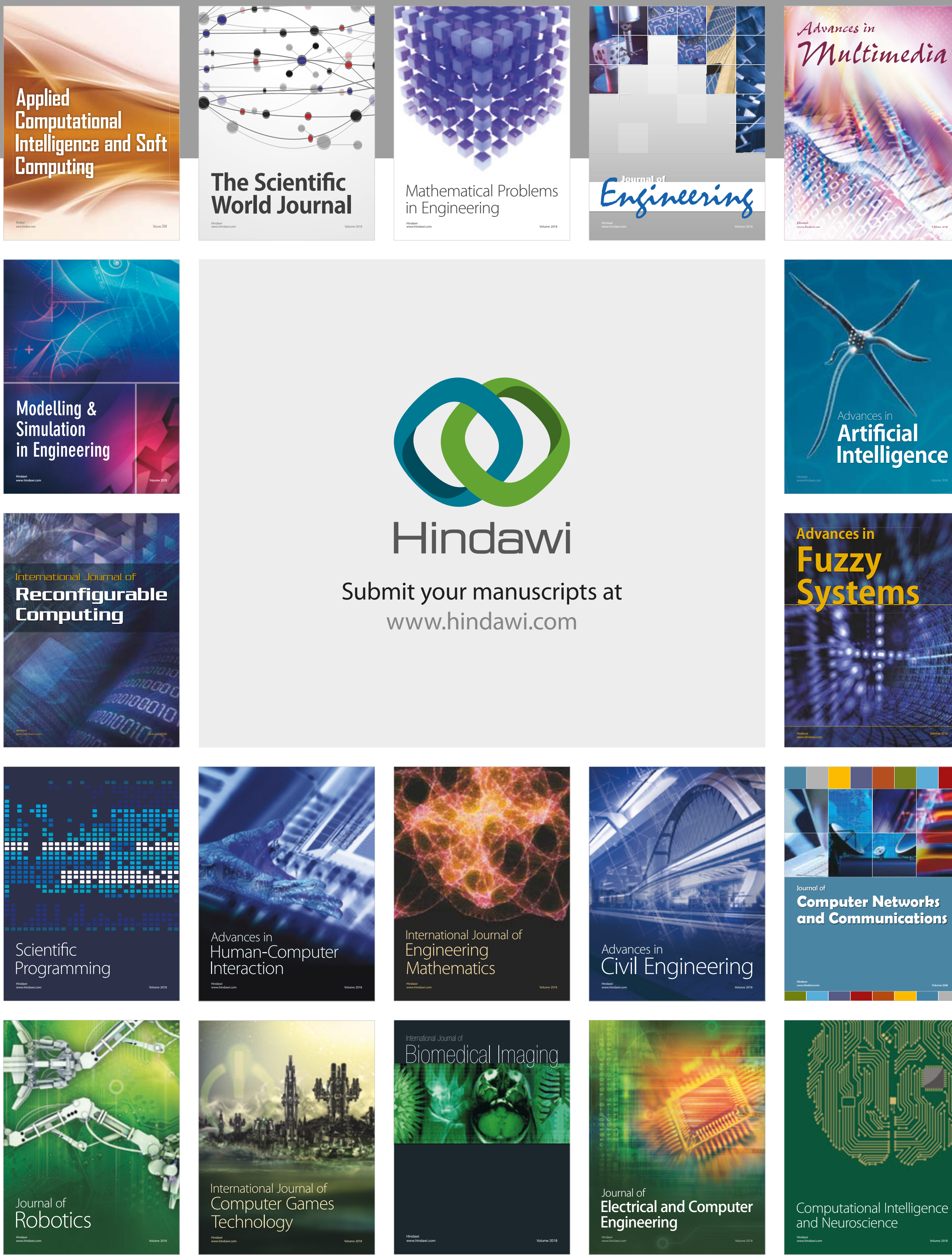
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