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Development of a Targeted Recommendation Model for Earthquake Risk Prevention in the Whole Disaster Chain

Xiaohui Su*,**, Keyu Ming*,**, Xiaodong Zhang***, Junming Liu***, and Da Lei*,**

Abstract

Strong earthquakes have caused substantial losses in recent years, and earthquake risk prevention has aroused a significant amount of attention. Earthquake risk prevention products can help improve the self and mutual-rescue abilities of people, and can create convenient conditions for earthquake relief and reconstruction work. At present, it is difficult for earthquake risk prevention information systems to meet the information requirements of multiple scenarios, as they are highly specialized. Aiming at mitigating this shortcoming, this study investigates and analyzes four user roles (government users, public users, social force users, insurance market users), and summarizes their requirements for earthquake risk prevention products in the whole disaster chain, which comprises three scenarios (pre-quake preparedness, in-quake warning, and post-quake relief). A targeted recommendation rule base is then constructed based on the case analysis method. Considering the user's location, the earthquake magnitude, and the time that has passed since the earthquake occurred, a targeted recommendation model is built. Finally, an Android APP is implemented to realize the developed model. The APP can recommend multi-form earthquake risk prevention products to users according to their requirements under the three scenarios. Taking the 2019 Lushan earthquake as an example, the APP exhibits that the model can transfer real-time information to everyone to reduce the damage caused by an earthquake.

Keywords

Android Application, Earthquake, Risk Prevention Products, Rule Base, Targeted Recommendation Model

1. Introduction

Earthquakes have occurred frequently in recent years, and the losses resulting from earthquakes have increased greatly. Thus, earthquake prevention and mitigation have become concerns of both the state and society. Disaster management is generally divided into four stages, namely, mitigation, preparedness, response, and recovery [1]. Among them, mitigation and preparedness both occur before disasters; thus, they can be merged into a single pre-disaster stage, the most important task of which is disaster risk assessment. Disaster risk components usually include hazards, exposure, and vulnerability [2]. Response stage is often referred to as the earthquake emergency, the most important work of which is to minimize casualties. Scholars have found that effective measures can reduce both disaster losses and casualties [3], and effective response work depends on timely access to information about the affected areas.

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Corresponding Author: Xiaodong Zhang (zhangxd@cau.edu.cn)

* School of Information Science and Technology, Beijing Forestry University, Beijing, China (suxhui2008@163.com, El_Ming@hotmail.com, bjfuleida@126.com)

** Engineering Research Center for Forestry-Oriented Intelligent Information Processing, National Forestry and Grassland Administration, Beijing, China

*** College of Land Science and Technology, China Agricultural University, Beijing, China (zhangxd@cau.edu.cn, liujunming2000@cau.edu.cn)

During the response phase, the main rescue resource was always assigned to the hardest hit areas. For each person, self-rescue and mutual rescue must be carried out simultaneously to improve the emergency response efficiency. However, the reliance on an individual to determine the best evacuation route and realize self-rescue is difficult when they lack appropriate information. Therefore, a primary task is to recommend to the public users who in the disaster site with the best evacuation route to shelters [4]. After an earthquake, the recovery stage is implemented to reconstruct hit areas. The pre-disaster, response, and recovery stages interact with each other and compose an organic whole. The phases should therefore be considered as a whole chain of disaster prevention and reduction. Different users play different roles in the whole chain. In historical disasters, the role of NGOs (non-government organizations) was not only reflected in recovery, but also in early-warning and disaster response. Moreover, earthquake knowledge popularization and insurance knowledge must be carried out by local government departments [5].

As mobile technology has developed and with the convenience of touch-screen technology [6], mobile phones have become essential items. In fact, they can be treated not only as sensors [3], but also as dissemination tools. When an earthquake occurs, the disaster site usually lacks or has delayed communication [7]. Mobile-end systems based on information technology are important media for the effective dissemination of products. Sending information to systems in disaster sites via mobile phones can promote necessary disaster information and help to reduce losses. According to related literatures, most earthquake risk prevention information systems are primarily used for earthquake early warning, and the existing multifunctional information systems are insufficient. The Global Disaster Alert and Coordination System (GDACS; http://www.gdacs.org/) is a well-known system that was constructed to provide disaster early warning and disaster evaluation information to emergency management personnel and the public. The Japan Meteorological Agency provides early warning products, such as maps and information about the affected population, to the public via the Internet. The National Disaster Reduction Center of China (NDRCC) website (http://www.ndrcc.org.cn/) and official WeChat account also provide disaster products, disaster assessment products, disaster remote sensing products, and popular scientific information about disasters. The typical system for releasing earthquake information was developed by the United States Geological Survey (USGS; https://earthexplorer.usgs.gov/), which provides earthquake felt distribution and the prediction distance decay graphs based on maps, for the acquisition of earthquake influence and damage information. Disasters are changing rapidly, and it is necessary for disaster information recommendation systems to adapt to the users' requirements throughout the entire disaster chain.

Therefore, both multiple user roles and multiple earthquake scenarios are taken into consideration in this study. A rule base formulated through the analysis of the needs of different users in different disaster phases, and a targeted recommendation model is constructed. Finally, an Android system is developed based on the targeted recommendation information system for earthquake risk prevention products, which aims at providing a practical tool for disaster prevention and mitigation.

The remainder of this paper is organized as follows: Section 2 presents the term definitions and methods of this research. Section 3 reports the construction of the targeted recommendation model based on the rule base. Section 4 describes the development of an Android APP, and provides an example of model implementation. Finally, Section 5 concludes this paper.

2. Term Definitions and Methods

2.1 Definitions of Earthquake Risk Prevention and Targeted Recommendation

In this study, disaster risk prevention refers to the government, the community, and the public making efforts to reduce the risk of earthquake disaster-causing factors in three scenarios, namely pre-disaster preparedness, in-disaster warning, and post-disaster relief. Disaster risk prevention is aimed at improving the disaster-resisting ability of disaster-bearing bodies to rapidly respond to disasters and achieve effective recovery.

Moreover, the earthquake risk prevention products in this paper referred to information products related to earthquake disaster risk prevention. The products are aimed at providing practical use in the three scenarios. Disaster-causing factors, disaster condition factors, and disaster relief factors are combined to achieve earthquake risk prevention objectives, such as enhancing disaster risk prevention awareness, improving the disaster response rate, and reducing disaster losses.

The term “targeted” in this study refers to selectivity and pertinence, and “targeted recommendation” refer to the recommendation of earthquake risk prevention products for different users under different earthquake scenarios.

Finally, the rule base refers to the set of rules for targeted recommendation.

2.2 Case Study Methods and Survey Methods

Surveys/interviews are the most popular data collection method [8]. In this study, the case analysis and survey methods were combined to research the corresponding relationships between products, users, and disaster situations. Via the case analysis method, information on historical earthquake disasters was sorted. The information was classified in terms of relating to the periods before, during, and after the occurrence of earthquake disasters to meet the users’ requirements at different stages. Then, the users’ different demands for products were determined via the stratified sampling and survey methods. According to their concerns and roles in emergency work, users were divided into four categories, namely government users, public users, social force users, and insurance market users. Government users are members of governmental departments, such as the NDRCC and other official organizations, and are responsible for the scheduling and command of human resources and other resources. Public users are ordinary people who are spontaneously concerned about disaster information and conditions. Social force users are members of NGOs, such as the Red Cross, non-profit organizations, etc. Insurance market users are workers in the insurance industry.

3. Targeted Recommendation Model

3.1 Product-User Matching

Twenty-two types of risk prevention information were extracted based on historical earthquake disasters via the case study method. The information includes disaster-causing factors, disaster condition factors, and disaster relief factors. Table 1 presents the risk prevention information, targeted information corresponding to user requirements, and recommendation reasons. A table cell with content indicates that the relevant users require this risk prevention information, and provides the reasons. A null cell indicates that the risk prevention information has no corresponding relationship with the type of users.

Table 1. Corresponding relationships between users and risk prevention information

ID	Risk prevention information	Government	Social force	Public	Insurance market
1	Information on high earthquake risk areas	Enables users to know the focus areas and rationally deploy resources	Enables users to know the focus areas and rationally deploy resources	Helps users to have a preliminary understanding of the earthquake risk in their area	Enables users to know the focus areas, and provides references for insurance plans
2	Earthquake history information	Provides references for rationally deploying resources	Facilitates users to rationally deploy resources	Facilitates users to improve risk consciousness	Provides references for insurance plans
3	Supply repositories' distribution and reserve situations	Enables users to know the situation, in order to make timely supplements	-	-	-
4	Social donation resource reserves and reserve status	Helps users to adjust governmental reserve materials	Helps users to reasonably carry out preparatory and deployment work	-	-
5	Rescue stations and rescue force reserve status	Helps users to reasonably deploy manpower	-	-	-
6	Settlements' distribution and basic information	Enables users to know and check the settlements' usage, manpower, and materials statuses to conduct effective placement	Helps users to reasonably deploy manpower and materials	Helps user know where to escape to	Enables users to know the settlements' distribution to facilitate contact with victims making insurance claims
7	Basic knowledge of earthquakes and risk prevention efforts	Enables users to understand the requirements for material reserves, setting conditions for settlements, etc.	Facilitates the collection of promotional materials	Facilitates users to conduct self-examination and preventive work before a disaster	Facilitates users to conduct self-examination and preventive work before a disaster
8	Knowledge of earthquake self and mutual-rescue methods	Helps protect the users' own safety during rescue	Facilitates the collection of promotional materials	Helps protect the users' safety during rescue	Helps protect the users' own safety when in the rescue
9	Knowledge of earthquake insurance	-	-	-	Provides related insurance knowledge
10	Real-time information (location, magnitude, etc.)	Helps the users to conduct emergency response in a timely manner	Facilitates users to locate the areas to be supported	Enables users to escape in a timely manner during an emergency	Enables users to escape in a timely manner during an emergency
11	Detailed disaster condition information of earthquake zones	Provides a reference for post-disaster work	-	-	-

Table 1. Continued

ID	Risk prevention information	Government	Social force	Public	Insurance market
12	Basic disaster condition information of earthquake zones	-	Helps users to organize targeted social assistance work	Improves risk prevention awareness	Provides references for insurance plans
13	Monitoring data of public opinion on social media	Enables users to monitor and control rumors after disasters	-	-	-
14	Social media discussion	Facilitates rescue work	Facilitates the rescue work	Helps users understand the local conditions	Helps users to understand the local conditions
15	Navigation routes and real-time storage data of supply repositories	Helps users to reasonably deploy materials	-	-	-
16	Navigation routes and real-time storage data of social donation station	Helps users to adjust material deployment plans	Facilitates users to deploy social donations	-	-
17	Real-time manpower deployment data of rescue stations	Helps users to deploy manpower in time	-	-	-
18	Real-time status and capacity of settlements	Help users to arrange personnel	-	-	-
19	Weather information of disaster area	Helps users better prepare for relief work	Helps users better prepare for relief work	Provides information in disaster areas	Provides information in disaster areas
20	Reporting data of insurance claims	-	-	-	Helps users make compensation plans and estimations
21	Knowledge of professional earthquake rescue skills	Improves rescue efficiency	Improves rescue efficiency	-	-
22	Knowledge of post-disaster psychological rescue	Helps users to comfort and give psychological assistance to victims	Helps users to comfort and give psychological assistance to the victims	Helps users to adjust their own emotions when necessary	Helps users to adjust their own emotions when necessary

The occurrence of an earthquake is instantaneous. Transmitting information timely is of great significance for disaster relief. Thus, the corresponding relation between users and disaster factors should consider the disaster stages. By analyzing users' requirements for earthquake prevention product which summarized above with scenarios, the corresponding relationship between the requirements and the scenarios is shown in Table 2.

Table 2. Targeted recommendation rule base

User	Scenario	Product recommendation (ID)
Government users	Pre-quake	1,2,3,4,5,6,7,8,10,21
	In-quake	1,2,3,4,5,6,7,8,10,13,14,15,16,17,18,19,21
	Post-quake	1,2,3,4,5,6,7,8,10,11,13,14,15,16,17,18,19,21,22
Public users	Pre-quake	1,2,6,7,8,10
	In-quake	1,2,6,7,8,10,14,19
	Post-quake	1,2,6,7,8,10,12,14,19,22
Social force users	Pre-quake	1,2,4,6,7,8,10
	In-quake	1,2,4,6,7,8,10,14,16,19,21
	Post-quake	1,2,4,6,7,8,10,12,14,16,19,21,22
Insurance market users	Pre-quake	1,2,4,6,7,8,10
	In-quake	1,2,6,7,8,9,10,14,19
	Post-quake	1,2,6,7,8,9,10,12,14,19,20,22

3.2 Recommendation Principles and Model Construction

Two principles were primarily considered when designing targeted recommendation scheme. First, the information should have practical meaning, so the recommendations should be made according to the previous requirements based on the relevant elements of earthquake disasters. Second, not only the roles of users and the corresponding relationships, but also the disaster scenarios, should be considered for recommendations. Thus, the information recommended to each user is highly efficient.

These principles were met by constructing a recommendation rule base library, as shown in Table 2. In the rule base, the ID of each product is consistent with that listed in Table 1.

Earthquake destructiveness is related to many factors, such as the magnitude, focal depth, and distance from the source. The targeted recommendation rules are applied to the system, and are automatically realized in the mobile phone system. The recommendation factors include the user's role, the magnitude of the earthquake, the user's location, and the time that has passed since the earthquake occurred, which are quantified to automatically determine which information needs to be presented. A model was therefore constructed to accurately present the information in consideration of these factors. Earthquakes below a magnitude of 4 are generally less destructive, so the cut-off point was set as whether the earthquake reaches a magnitude of 4. The magnitude is denoted as *M*, and its value is calculated by Eq. (1).

$$M = \begin{cases} 0, < 4 \\ 1, \geq 4 \end{cases} \tag{1}$$

Disaster products must be provided to users in different regions [9]. The distance between the user's current location and earthquake epicenter is compared with the distance of 100km. The distance is denoted as *D*, and its value is calculated by Eq. (2).

$$D = \begin{cases} 0, > 100km \\ 1, \leq 100km \end{cases} \tag{2}$$

The "golden 72 hours" of earthquake disaster relief refers to 72 hours after the occurrence of an earthquake. In this study, the earthquake occurrence time was used as the switching time point of pre-quake preparedness scenario and in-quake warning scenario. The 12th hour after the occurrence of the earthquake was set as the switching time point between the in-quake warning scenario and post-quake relief scenario. Finally, the 72nd hour after the occurrence of the earthquake was set as the switching time point between the post-quake relief scenario and pre-quake preparedness scenario. Therefore, the entire chain of earthquake disasters is a circle, from the pre-quake to in-quake scenario, then to the post-quake scenario, and finally back to the pre-quake scenario. The time after the occurrence of the earthquake is denoted as *T*, and its value is calculated by Eq. (3).

$$T = \begin{cases} 2, time\ within\ 12\ hours \\ 3, time\ between\ 12\ hours\ and\ 72\ hours \\ 1, time\ after\ 72\ hours \end{cases} \tag{3}$$

The targeted recommendation model was constructed in consideration of the magnitude *M*, the user's location *D*, and the time *T*. Via the use of this model, mobile phone APP can automatically detect a user's current disaster scenario to make a targeted recommendation.

$$S = (M \cap D) \times T \tag{4}$$

The value of *S* is 0 or 1 indicated that it was 72 hours after the disaster. Thus, the pre-quake stage is coming right after the post-quake stage, *S* is 2 indicated the in-quake stage, and *S* is 3 indicated the post-quake stage. A product can be recommended according to the combination of the user's role and *S* according to Table 2. The calculation process of the model is presented in Fig. 1. When the magnitude of the earthquake is less than 4, the factors *D* and *T* are no longer judged, and *S* is 0. When the magnitude is greater than or equal to 4, the factor *D* must be judged, when *D* is 0, the factor *T* does not need to be considered, and the result can be given as 0.

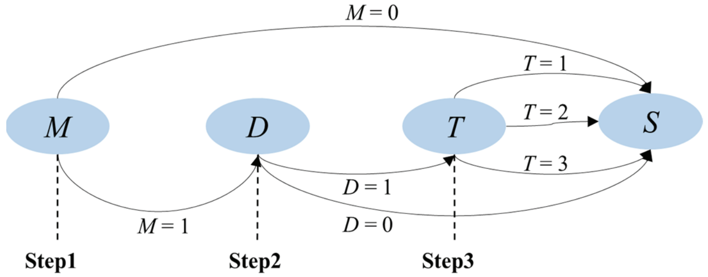

Fig. 1. The calculation steps of the model.

Taking a government user as an example, when the magnitude of the earthquake is greater than or equal to 4, and when the user is located 100 km away from the epicenter, the value of *S* is 0, which indicates that the user is in the pre-quake stage. Product #1(information of high earthquake risk areas), Product #2 (earthquake history information), and Product #3–#8, #10, #21 will be recommended to the government user based on the rule base (Table 2). When the magnitude of the earthquake is greater than 4 and the location is within 100 km, the result of the model is determined by the time that has passed since the earthquake occurred. The time T is 2 indicated that the user is in the in-quake stage, so Products #1–#8, #10, #13–#19, #21 will be recommended to the government user. The time T is 3 indicated that the user is in the post-quake stage, so Products #1–#8, #10–#11, #13–#19, and #21–#22 will be recommended to the government user. The products that will be recommended to different users in the appropriate stage are suitable and accurate. Thus, the model is denoted as the targeted recommendation model.

4. Implementation of the Model on an Android Phone

4.1 Implementation of the Targeted Recommendation Algorithm

For algorithm implementation, two parts require consideration. The first is to automatically switch the scenario according to Eq. (4), and the second is to recommend information products based on the user's role and scenario according to Table 2.

The automatic switching of the scenario includes two steps, namely, real-time earthquake data synchronization and user earthquake record synchronization. In the former step, the system fetches the latest real-time earthquake data from the real-time earthquake list at 5-second intervals. It selects records whose published times are within 72 hours from the current time, finds the latest record that includes an earthquake magnitude at least 4.0 and a distance between the user and source within 100 km, and updates the user's earthquake record table in the database. In the latter step, the system requests the user's earthquake records from the server at intervals of 5 seconds. If there is a record, it checks whether the user is in the earthquake zone, and then automatically switches the scenario of the system according to the length of the interval between the earthquake occurrence time and the current time. The flowchart of the synchronization of the user's earthquake record exhibited in Fig. 2. The proposed algorithm maintains the timeliness of the user's earthquake record by screening out the most recent earthquake in the earthquake data list that may affect the user. In addition, the earthquake record is stored with a one-to-one correspondence with the user information. This can effectively realize the accurate judgment of each user's current scenario. To recommend corresponding information products to different users under different disaster scenarios, it is first necessary to obtain the user's identity. Then, an "if-else" statement and the "switch-case" statement are used to implement the display control of the functional modules and product recommendations. The steps reference the values of the targeted recommendation model and the rule base.

4.2 System Design and Implementation

With the development of mobile technology, the activities of many users are concentrated in mobile APPs [10]. For the implementation of the proposed model, the system's client side is the Android client. Additionally, Tomcat is used as the server, and the MySQL database is used for data management. By sorting out the data flow between the system and external entities, the context diagram of the system was created, and is shown in Fig. 3.

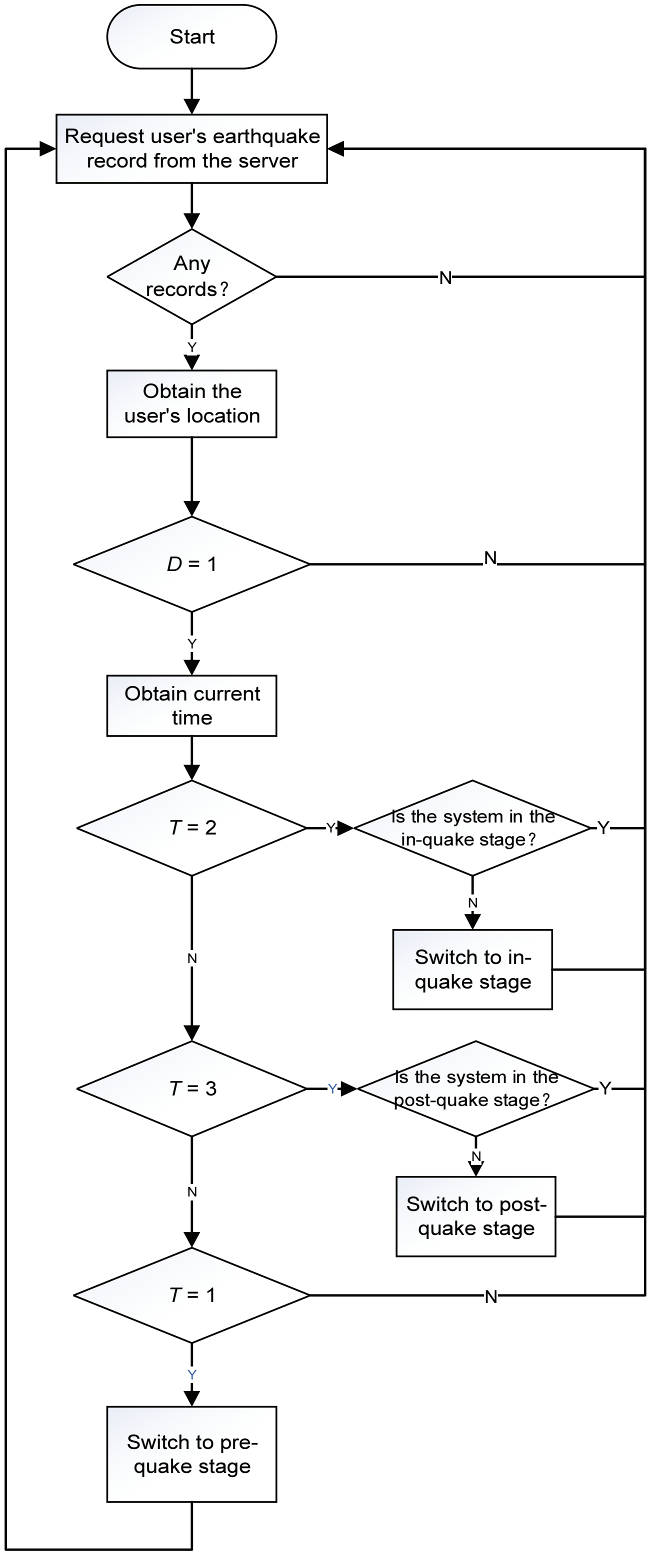

Fig. 2. Flowchart of the synchronization of a user's earthquake record.

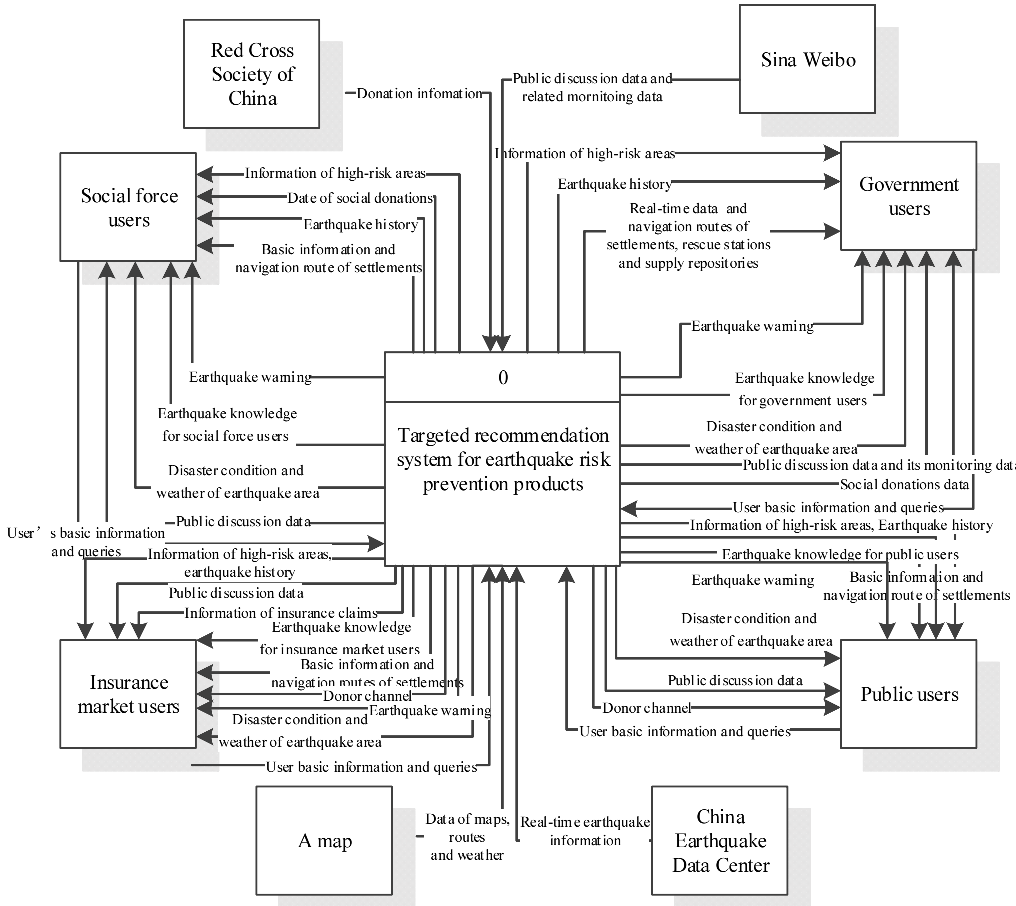

Fig. 3. Context diagram of the Android system.

4.3 Case Study—The 2019 Lushan Earthquake

On May 2, 2019, the Lushan earthquake, registering 4.5 on the Richter scale, hit Ya'an, Sichuan Province, China. The location of epicenter was 30.43°N, 103.01°E, and the focal depth was 14km. The earthquake was taken as an example in this study to apply the proposed mobile phone APP. To illustrate the function of the system, the system time was flexibly set to the three time points corresponding to the delineation of the disaster scenarios. The system interface and switch function are shown in Fig. 4. The pre-quake, in-quake, and post-quake phases form a circle in which the phase is determined by the value of *S*.

4.3.1 Pre-quake preparedness

In the Pre-quake preparedness scenario, the value of *S* is 1 or 0. In the "Information" module, users can view the recent earthquakes in the "Earthquake Express" section, and can obtain related information by browsing the "Concept Popularization", "Disaster Preparedness Guide", and "Help Guide" sections. In addition to the knowledge available to the other two user roles, government users and social force users can also obtain more professional information from the "Rescue Skills" section. Moreover, the "Insurance Knowledge" section is available to insurance market users.

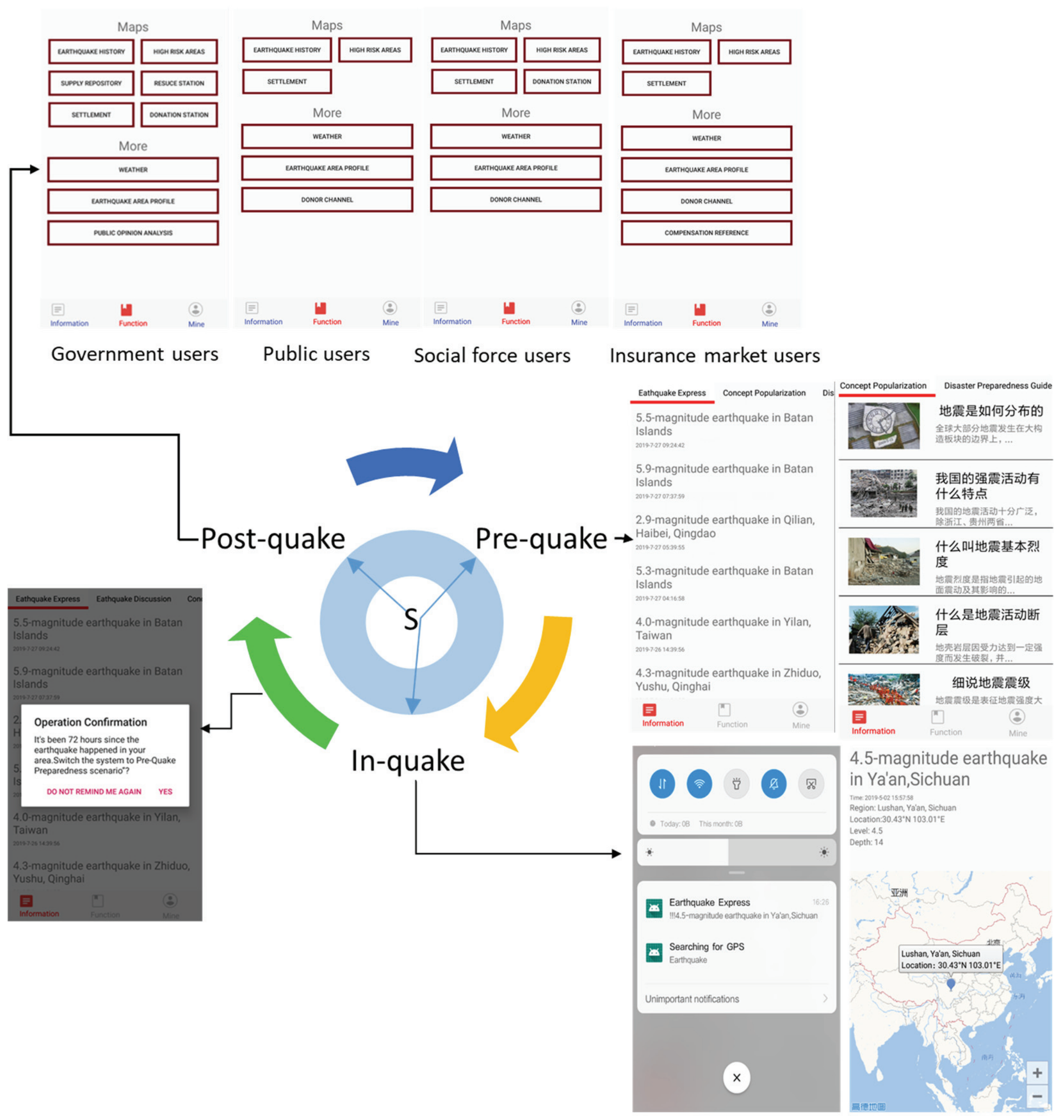

Fig. 4. System implementation of switching between the three scenarios.

At this stage, the differences are shown in the "Function" module. Public users and insurance market users can read information about the earthquake history, high-risk areas, and settlements. Government users can acquire data on supply repositories, rescue stations and settlements related to the disaster management field. They can also browse the donation station information available to social force users.

4.3.2 In-quake warning

When an earthquake occurs, the system will pop-up a notice in the notification bar to alert the user. By clicking this notification, the user can view the earthquake details page (for more details, see the in-quake interfaces in Fig. 4). If the value of S is 2 and the system scenario is not the in-quake warning scenario, the system will pop up a reminder to inform the user of the situation and the distance between the user's location and the source. This function enables the user to obtain the information products required for the in-quake warning scenario in a timely manner. After switching the system scenario, the risk prevention products recommended to the user are changed. At this stage, in the function page of settlements, rescue stations, supply repositories and donation stations, users can view real-time data of each spot and obtain navigation routes to support rescue work in the disaster area.

4.3.3 Post-quake relief

Twelve hours after the earthquake, the system will remind the user to switch to the post-quake relief scenario. In this stage, in addition to providing the earthquake relief related functions in the in-quake warning scenario, the system will also recommend information products related to psychological rescue knowledges. In this stage, "Psychological Guide" section added to the "Information" module. Additionally, in the "Function" module, "Earthquake Area Profile" and "Public Opinion Analysis" added to the list of functions for government users, for to acknowledge the earthquake disaster condition and control public rumors. Moreover, the "Earthquake Area Profile" and "Donor Channel" functions added for the public, social force, and insurance market users. Particularly, in the "Earthquake Area Profile" function, government users can view the detailed disaster data of the disaster area, while other users can only view the earthquake related news reports. What's more, insurance market users have an additional function called "Compensation Reference," in which they can view data on insurance claims.

Seventy-two hours after the earthquake, the "golden period" of disaster relief has passed, and the system will remind the user to switch back to the pre-quake preparedness scenario.

5. Conclusion

In this paper, a model for providing targeted recommendation products in three earthquake scenarios was constructed. The model is based on a rule base that considers different users, disaster information, and stages. The rule base is the basis for targeted recommendations. The construction process of rule base can provide the theoretical basis for information and products pushing in disaster evolution process. It aims at solving the accurate and directional transmission. Thus, the loss caused by disasters can be minimized.

In addition, to realize the model and give it practical meaning, a multi-role and multi-scenario Android APP for the targeted recommendation of earthquake prevention products was designed and developed. The system can realize product recommendation to government users, social force users, public users, and insurance market users according to their requirements in the three major earthquake scenarios, namely pre-quake preparedness, in-quake warning, and post-quake relief.

However, earthquake risk prevention products are not merely simple combinations of images, texts, maps, etc., further research can be carried out from the perspective of earthquake related information elements and their combination when designing products. This research can be used as a reference for other disaster prevention measures and improving disaster awareness in the future.

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Xiaohui Su **https://orcid.org/0000-0001-7608-0797**

She received Ph.D. and M.S. degrees in College of Information and Electrical Engineering from China Agricultural University in 2013 and 2007, respectively. Since July 2013, she is a lecturer in the School of Information Science & Technology, Beijing Forestry University, China. Her current research interests include spatial information technology and disaster risk assessment.

Keyu Ming **https://orcid.org/0000-0002-7471-620X**

She received B.S. degree in Information Management & Information System from Beijing Forestry University in 2019. She is currently a postgraduate student in School of Software and Microelectronics, Peking University, Beijing, China. Her research interests include information technology and computer technology.

Xiaodong Zhang **https://orcid.org/0000-0001-6347-4973**

She received Ph.D. degree in cartography and geographic information system from Institute of Geographic Sciences and Natural Resources Research, CAS, in 2000. She is currently a professor in College of Land Science and Technology, China Agricultural University, Beijing, China. Her research interests include spatial information technology and disaster monitoring technology.

Junming Liu **https://orcid.org/0000-0001-7238-7441**

He received M.S. and Ph.D. degrees in College of Agricultural Resources and Environmental Sciences from China Agricultural University in 1996 and 2003, respectively. He is currently an associate professor in College of Land Science and Technology, China Agricultural University, Beijing, China. His research interests include information system and disaster monitoring technology.

Da Lei **https://orcid.org/0000-0001-6201-924X**

He received B.S. degree in Information Management & Information System from Beijing Forestry University in 2019. He is currently pursuing the M.S. degree in Computer Technology at the State Key Laboratory of Network Technology, Beijing University of Posts and Telecommunications, Beijing, China. His current research interest includes internet of things and data mining.