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Research on Rapid Assessment of Earthquake Disaster and Emergency Relief Material Distribution System—Case Study on Earthquake in Yangbi County, Yunnan Province, China

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Earthquakes are one of the most life-threatening natural disasters for human beings. Since earthquakes cannot be accurately predicted, among the most important tasks of the post-earthquake emergency response are to assess the damage in a timely manner, to perform emergency command and rescue, and to prevent secondary disasters. To ensure a smooth start to post-earthquake work, a reliable rapid earthquake disaster assessment system needs to be established, so that effective earthquake assessment results can be quickly obtained after the earthquake, which can help in the rescue and material distribution. Therefore, in this study, we attempt to establish a framework for a rapid earthquake disaster assessment system. The framework includes three modules: the rapid assessment of earthquake intensity, the estimation of economic damage and casualties, and the distribution of rescue materials. We use methods such as regression and entropy methods for the rapid assessment of earthquakes and obtain the results of earthquake intensity analysis, casualty prediction, economic loss prediction, and relief material distribution after an earthquake. These results can help the government in its post-earthquake activities and can also give the public a clearer picture of the impact of the earthquake. The error between the earthquake intensity analysis results and the actual situation is about 21%, which is in line with the Chinese disaster mitigation and emergency response requirements (error < 30%), giving our results a high reference value. In the material distribution, multiple dimensions are introduced for the analysis and a reasonable value is obtained. The system can calculate the results within 2 min after obtaining the input data, demonstrating its timeliness. Moreover, on the basis of the established system, we attempt to design a rapid assessment platform for earthquake disaster, which can help the assessment and rescue in future earthquake disasters. The system can be experienced by visiting https://earthquick.peteralbus.com/.

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1. Introduction

Cities tend to have dense housing and large numbers of people. In such circumstances, an earthquake can often have a huge impact on a city, including but not limited to massive economic damage and loss of life. In the aftermath of an earthquake, a rapid analysis or assessment of the earthquake is necessary. The results of the assessment can be applied to relief efforts and the distribution of supplies, helping cities to overcome the effects of the earthquake more smoothly and quickly.

The assessment of the earthquake can help people create rescue plans and distribute materials, help evacuate people as soon as possible, and reduce casualties and economic losses. The most accurate instrumental intensity maps are obtained in areas with a dense network of seismic observation stations, and the assessment of earthquake damage on this basis is often the most accurate. However, there is a high demand for equipment, and its timeliness is less than that of earthquake assessment based on magnitude, which is also more widely applicable.

Earthquake intensity assessment is the first task of rapid earthquake assessment. There are several different methods to generate an intensity map of an earthquake. The first method is to examine and test the field after the earthquake and produce an accurate intensity map through a survey report. This method yields the most detailed and reliable intensity maps. However, it requires human resources and time; it takes several days for staff to arrive in the field after the earthquake to inspect the damage to buildings.(1) In addition, earthquake intensity assessment can be performed by ground motion parameters measured by local instruments, and more accurate earthquake intensity maps can be obtained by selecting appropriate relational equations for the calculation.(2) This is a more mature method but still has high requirements for input data, and it is difficult to use in regions where the seismic observation network is sparse. Yao *et al.* assessed intensity through the lexical analysis of social platforms such as Weibo. This is a relatively novel method, but its practicality and accuracy still need further improvement.(3) If it is necessary to obtain earthquake intensity maps based on only earthquake location information and earthquake magnitude immediately after an earthquake, this can be achieved using the earthquake attenuation equation, although this method inevitably loses some accuracy. However, we can obtain the results of the seismic intensity analysis extremely quickly.(4)

After obtaining the earthquake intensity data, economic damage and human casualty assessment is required. The use of unmanned aerial vehicles for local photography and disaster assessment through images is a feasible method. However, this method still requires considerable time and cannot provide assistance soon after an earthquake. Jaiswal *et al.* used an empirical equation to assess casualties. Using this method, casualties and economic damage can be quickly analyzed with only a small amount of data such as population density, earthquake time, and earthquake intensity.(5)

After obtaining data such as earthquake intensity and economic loss, the data must be employed as a reference for the initial distribution of rescue forces and materials. There are many distribution methods that consider different indicators. For example, Guan *et al.* used the population as the main factor.(6) However, the situation is fluid after an earthquake and the initially obtained data may be incomplete; there is a high demand for flexibility in methods.

In the rapid assessment of earthquake intensity, there are few methods for calculating the distribution of rescue forces and materials, and there is no complete framework for earthquake assessment. In this study, we have established a complete earthquake disaster assessment system to enable the rapid analysis of each dimension immediately after an earthquake and build a system that displays the results of analysis.

2. Introduction to Framework of Rapid Earthquake Assessment System

As shown in Fig. 1, the framework of the earthquake disaster rapid assessment system proposed in this paper is divided into three main parts: the rapid assessment of earthquake intensity, the estimation of economic damage and human casualties, and the distribution of relief materials. The system requires information on the location (epicenter latitude and longitude) of the earthquake and intensity information as the input, as well as information on the local population density to assist in the analysis.

This assessment framework performs a rapid assessment of the earthquake intensity information upon receiving earthquake information and generates an intensity map of the earthquake. This intensity information is the basis for the next disaster assessment. After that, the system can obtain the intensity for any latitude and longitude in the disaster area at any time, which is invaluable for rapid earthquake assessment.

After the earthquake intensity assessment, the system forecasts the casualties and economic losses due to the earthquake. The analysis is based on existing empirical models, and the results can further help rescuers analyze the impact of the earthquake and the relief materials to be invested.

In the post-earthquake work, the distribution of relief materials is very important. A reasonable distribution of relief materials can maximize the efficiency of post-earthquake relief and reconstruction work. Finally, the system integrates the collected and analyzed information

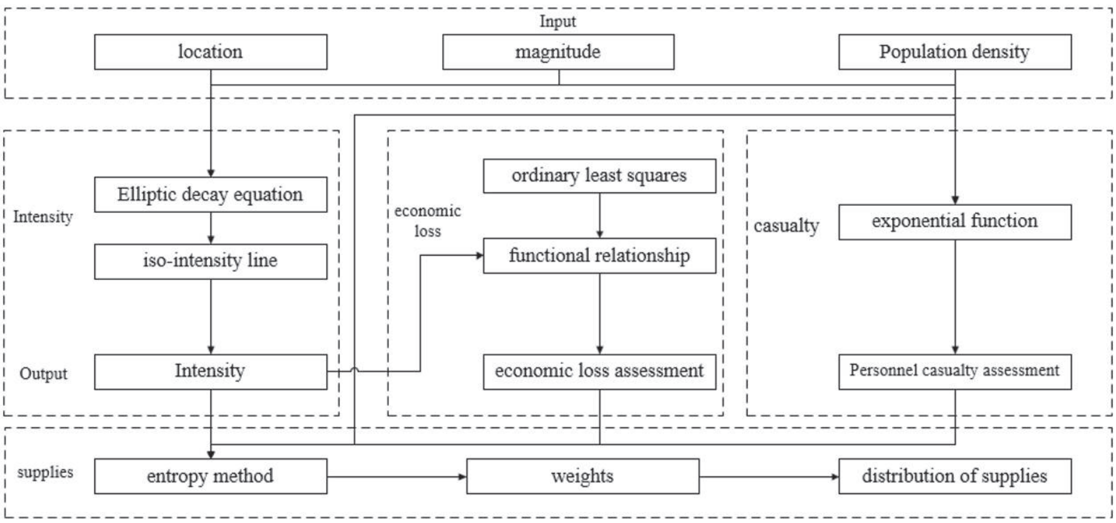

Fig. 1. Framework of the earthquake disaster rapid assessment system.

and gives a relief material distribution, providing a reference for the actual relief material distribution.

2.1 Rapid assessment of earthquake intensity

The analysis of earthquake disasters is usually based on earthquake intensity. Earthquake intensity refers to the strength of the earthquake impact on the ground or on each building in a certain area,(7) which reflects the scale of the earthquake felt by people and the degree of damage to houses and the ground surface. Earthquake intensity basically covers the different dimensions of damage caused by the earthquake, so the assessment of an earthquake disaster is usually based on intensity as the main reference indicator. Intensity maps basically focus on iso-intensity lines of magnitudes 6 to 10, because smaller intensities have less impact, while intensities greater than 10 are basically indefensible. Therefore, the first and primary method of rapid earthquake damage assessment is the rapid generation of an intensity map, which is subsequently used to analyze the impact of the earthquake.

The most common method of earthquake intensity assessment is to obtain the relevant ground motion parameters from earthquake observation instruments and then calculate the earthquake intensity. Although this method is relatively mature, it requires a high number and density of earthquake observation instruments. Zhang *et al.* used a remote sensing technique for seismic intensity analysis, but this technique has unsatisfactory performance for small to medium-sized earthquakes.(8) Because of the need to obtain seismic intensity analysis results quickly, we used regression equations for the intensity analysis.

2.1.1 Elliptic attenuation model

The point circle model is a relatively simple regression analysis model for the rapid assessment of earthquake intensity. It can calculate the intensity at a certain distance from the source by using magnitude data, which is used as the radius of the iso-intensity line. Despite its simplicity, it can represent the attenuation of earthquake intensity in the range of 0–400 km. The point circle model has the following form:

$$I = a + b \times M - c \times \lg\left(R + R_0\right) + \varepsilon, \tag{1}$$

where M denotes the magnitude; R denotes the distance from the epicenter; a, b, c, and R_0 are regression parameters; and ε is a random variable representing uncertainty in the regression analysis, which is generally assumed to be log-normally distributed.(9)

On the basis of this model, a computational analysis has been carried out by a two-step method to derive the following intensity circle attenuation equation for North China:

$$I = 2.751 + 7.549 \times M - 3.409 \times \lg\left(R + 10\right). \tag{2}$$

The variance of I was 0.6149.(9)

Since earthquake intensity maps often have a narrow elliptical shape along the seismic zone, the point circle model produces a rapid assessment of intensity maps that does not reflect this directionality of the earthquake. On this basis, an elliptical attenuation model has been generated, which is currently one of the simplest and widely used models for the rapid generation of earthquake intensity maps. It ignores the effect of the source depth on the earthquake intensity and calculates the intensity through the regression equation of earthquake intensity attenuation as follows:

$$I = b_1 + b_2 M + b_3 \ln\left(R_a + b_4\right) + b_5 \ln\left(R_b + b_6\right) + e. \tag{3}$$

Here, I denotes the intensity, b is the regression constant, M is the magnitude, R_a and R_b denote the long and short semi-axes of the iso-intensity line, respectively, and e is a random variable indicating uncertainty, usually assumed to be log-normally distributed with a mean of 0. Because of the vast size of China and the different geological conditions in different regions, different regression coefficients can be used for earthquakes occurring in different regions, and the intensity can be calculated using the regression equation for the intensity attenuation of the corresponding region. Joint intensity attenuation equations for different regions of mainland China have been calculated for use in calculation and analysis.

2.1.2 Rapid assessment method for earthquake intensity

The point circle and elliptical attenuation models are both regression analysis models, and their regression parameters are basically the same. The elliptical attenuation model is an improvement of the point circle model that also incorporates the effects of the long and short semi-axes of the intensity due to the cross-sectional direction of the seismic zone, such that the rapidly generated intensity maps can include directional information. This further enhances the accuracy of the intensity maps and gives them more accurate reference values.

The rapid assessment of earthquake intensity is currently based on regression analysis, which relies on statistics obtained from a large amount of data. The intensity map generated by the elliptical attenuation model roughly matches the actual intensity map. However, there is generally less agreement for the assessment of the hardest-hit areas (core areas with higher intensities).

The point circle model yields slightly less informative results than the elliptical attenuation model, which yields intensity analysis results with reasonable accuracy that can be used as a reference for subsequent analysis. We selected two elliptical attenuation model equations for eastern and western China (Table 1) for the rapid assessment of earthquake intensity in this study.[10]

2.2 Assessment of human casualties and economic losses

After obtaining the earthquake intensity data, the economic damage and human casualties can be estimated. Traditionally, the assessment of earthquake disaster losses requires waiting for

Table 1
Elliptical attenuation model equations for eastern and western China.

Area	Attenuation equation		Standard deviation
Eastern China (east of 105°E)	$I_a = 5.253 + 1.398M - 4.164\ \lg(R_a + 24)$	(4)	$\sigma = 0.517$
	$I_b = 2.019 + 1.398M - 2.943\ \lg(R_b + 9)$	(5)	
Western China (west of 105°E)	$I_a = 5.253 + 1.398M - 4.164\ \lg(R_a + 24)$	(6)	$\sigma = 0.632$
	$I_b = 2.019 + 1.398M - 2.943\ \lg(R_b + 9)$	(7)	

a certain period of time after the earthquake has occurred, collecting information through satellite remote sensing and aircraft aerial photography, and conducting damage assessment. Although this approach is reliable, the results are produced slowly, delaying subsequent processes such as the distribution of relief materials, and it is not suitable for the construction of a rapid earthquake disaster assessment system.

2.2.1 Economic damage assessment

Because of the limited data available for the rapid assessment of earthquake disasters, the prediction of economic losses is mainly based on two parameters: epicenter intensity and magnitude. By comparing the arithmetic mean and variance of $\lg L$ (L is the direct economic loss of the earthquake) for each magnitude and each epicenter intensity, it can be concluded that the data fluctuates in a larger range at the same magnitude than the data at the same epicenter intensity.[11] Therefore, the epicenter intensity was selected as the main parameter for economic loss assessment. Using the least squares method, the following relationship between $\lg L$ and the epicenter intensity has been obtained:

$$\lg L = 0.84444I - 1.831, \tag{8}$$

where L is the direct economic damage of the earthquake and I is the epicenter intensity.[11]

2.2.2 Casualty assessment

Most previous studies on estimating the number of casualties caused by earthquakes have been based on one or several influencing factors obtained from historical earthquake data, and the number of casualties has been evaluated from the obtained fitting formula. The mainstream earthquake casualty prediction methods currently include the logarithmic function, linear regression, higher-order nonlinear prediction, artificial neural network (ANN),[12] and probability distribution[13,14] methods.

After analyzing the results of various influencing factors, an exponential function can be selected as the basic model for earthquake casualties, with the building damage rate as the main parameter. The measurement results are shown in the following equation:[15]

$$N = 0.461 \cdot e^{12.285 \cdot Bdr}, \tag{9}$$

where N is the number of casualties and Bdr is the building damage rate.

Since the probability or likelihood of casualties occurring in different types of buildings with the same level of damage is not fully considered, the accuracy of the model is reduced and the assessment results may have a large error. To improve the accuracy of the results obtained with the model, corresponding correction factors can be added to the model.(16) In this paper, we include the earthquake magnitude and intensity, population density, earthquake occurrence time, and the death resistance level coefficient of regional buildings as correction coefficients in the model as follows:

$$N = 0.461 \cdot \alpha_m \cdot \alpha_{den} \cdot \alpha_{time} \cdot \alpha_{all} \cdot e^{12.285 \cdot Bdr}, \tag{10}$$

where α_m, α_{den}, α_{time}, and α_{all} are the correction factors for magnitude and intensity, population density, earthquake occurrence time, and overall regional seismic resistance level, respectively.(15)

The correction coefficients for earthquake magnitude and intensity and population density were calculated using the following equations:

$$\alpha_m = \left| \frac{M - 4.17}{0.35I - 0.97} \right|, \tag{11}$$

$$\alpha_{den} = 0.05 \ln(Den) + 0.74 . \tag{12}$$

The time and regional seismic level correction factors are selected according to the actual time and location of the earthquake. For earthquakes occurring from 1 a.m. to 6 a.m., from 6 a.m. to 9 a.m., from 9 a.m. to 8 p.m., and from 8 p.m. to 1 a.m., the time correction factors are 2, 1, 5/9, and 5/3, respectively. The regional seismic level correction factor is divided according to the Heihe–Tengchong line. Figure 2 shows the process of assessing casualties.

2.2.3 Distribution of relief supplies

After obtaining the data of human casualties and economic losses, the distribution of rescue materials can be analyzed and calculated. How to reasonably allocate rescue forces and materials is an important task when facing an earthquake disaster. Accurate and reasonable material distribution results can provide an important reference for earthquake rescue work. This is also one of the main purposes of establishing a rapid earthquake assessment system.

To distribute relief supplies to various areas after an earthquake, it is necessary to first establish evaluation indicators for the distribution of supplies. These indicators are divided into positive and negative indicators. For positive indicators, the higher the value, the higher the demand for supplies in the region. For negative indicators, the higher the value, the lower the demand for supplies.(17)

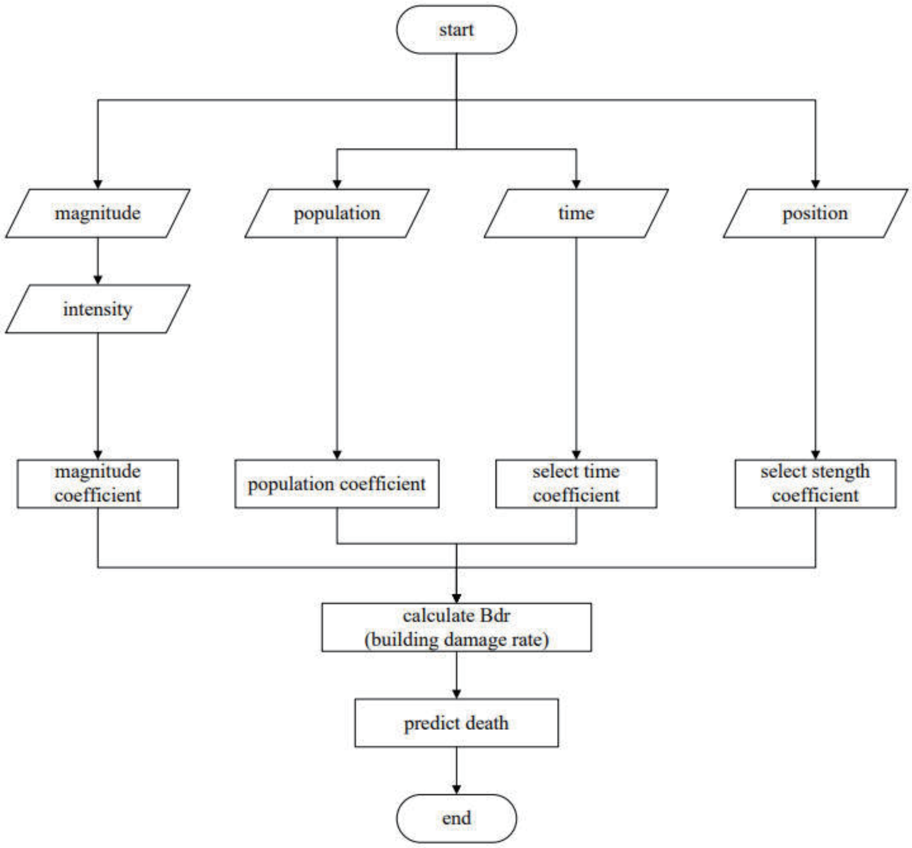

Fig. 2. Flow chart of personnel casualty calculation.

Since the quantity levels of indicators are not uniform, they are standardized. For positive and negative indicators, the treatment is respectively shown in Eqs. (13) and (14), where m is the number of relief points where the distribution of materials is to be carried out, i takes values in the range from 1 to m, and j takes values in the range from 1 to n (n is the number of indicators selected).

$$x_{ij} = \frac{x_{ij} - \min\left\{x_{ij}, \ldots, x_{mj}\right\}}{\max\left\{x_{1j}, \ldots, x_{mj}\right\} - \min\left\{x_{1j}, \ldots, x_{mj}\right\}} \tag{13}$$

$$x_{ij} = \frac{\max\left\{x_{ij}, \ldots, x_{mj}\right\} - x_{ij}}{\max\left\{x_{1j}, \ldots, x_{mj}\right\} - \min\left\{x_{1j}, \ldots, x_{mj}\right\}} \tag{14}$$

The weights of each indicator are then calculated by the entropy method. First, the proportion of each attribute indicator value among all values of that attribute after normalization is calculated as

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \qquad j = 1, 2, \ldots, n \tag{15}$$

After that, the entropy value of each indicator is calculated using Eq. (16), where $k > 0$, by the entropy method. Generally, $k \; \frac{1}{\ln m}$, ln being the natural logarithm, and the entropy value obtained is between 0 and 1.

$$e_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{16}$$

After obtaining the entropy value, the coefficient of variation, g_j, is calculated for each selected indicator. A larger coefficient of variation reflects a greater impact of the indicator on the results. The coefficient is calculated as

$$g_j = 1 - e_j. \tag{17}$$

After obtaining the coefficient of variation, the weights of each indicator can be calculated. Then, the results calculated using Eq. (15) are multiplied by the weights and summed as follows to obtain the weight of each rescue point for the material distribution:

$$a_j = \frac{g_j}{\sum_{j=1}^{n} g_j}, \tag{18}$$

$$w_i = \sum_{j=1}^{n} a_j \times p_{ij}. \tag{19}$$

Figure 3 shows the process of calculating the distribution of materials by the entropy method. After using the entropy method for material allocation, the evaluation indicators can be changed flexibly and the number of indicators can be freely selected according to the amount of data.

In the distribution of relief materials, the selection of indicators should make full use of the results obtained from the rapid earthquake assessment system. Among them, the seismic intensity of the location is a positive indicator. The regional economic level and population density can also be taken into consideration, with the former being a negative indicator and the latter being a positive indicator.

In the actual distribution of supplies, relief points often also initiate requests for supplies. By adding artificial indicators, these needs can be considered. In the actual application, the number of indicators can be flexibly increased and decreased.

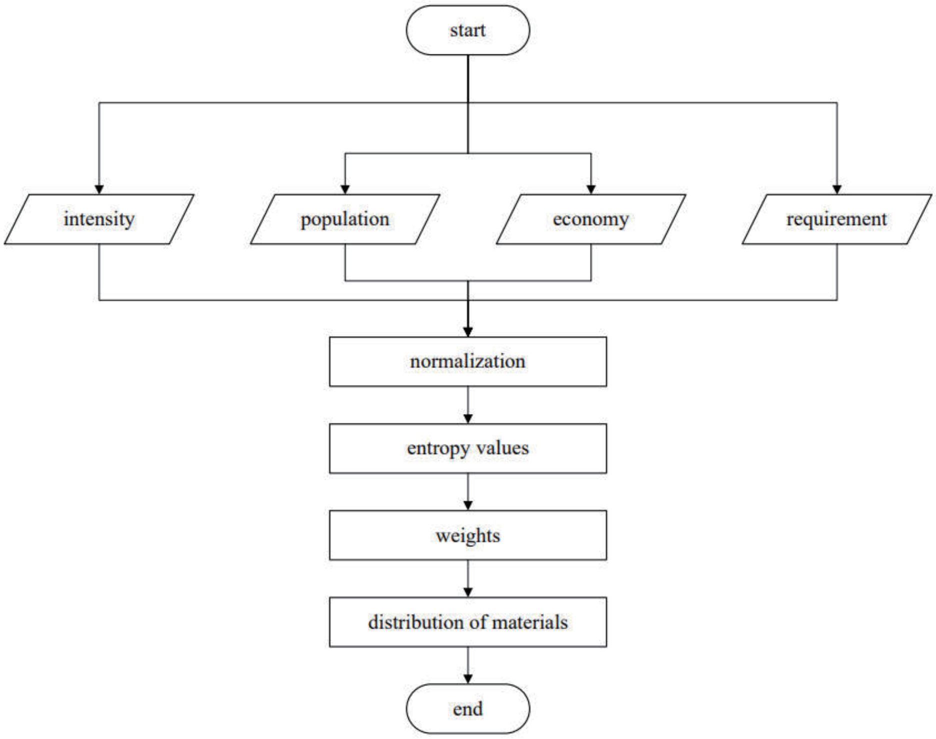

Fig. 3. Flow chart for calculating distribution of materials.

3. Application of Earthquake Rapid Assessment

In this paper, we selected the 6.4 magnitude earthquake that occurred in Yangbi County, Dali, Yunnan Province at 21:48 on May 21, 2021 as the application object. The source location and magnitude data were obtained from the China Earthquake Network (https://news.ceic.ac.cn/), the population density data were obtained from the WorldPop hub (https://hub.worldpop.org/geodata/summary?id=49730), and the economic level data were obtained from the 2021 Yunnan Dali GDP report.

3.1 Intensity rapid assessment

The source of the earthquake was located at 25.67°N and 99.87°E in Yangbi County, Dali, Yunnan. Therefore, the attenuation equation of the joint attenuation model common to western China (west of 105°E) [Eqs. (6) and (7)] was used.

To plot the intensity map using the elliptical joint attenuation model, the maximum intensity at the epicenter was first calculated using the joint attenuation model equation, taking the earthquake in Yangbi County as an example. Because of the magnitude of 6.4, it was calculated with R_a, R_b set to 0: $I_a \approx I_b \approx 8.308$.

Using this method, the maximum intensity, located at the source of this earthquake, can be estimated. Then, the long- and short-axis radii of the intensity map were inversely obtained at integer values using the regression equation of earthquake intensity decay, and the intensity contours were drawn with the source as the center of the circle and the direction matching the earthquake rupture zone.

Figure 4 shows the difference between the generated intensity map and the official intensity map. According to the official earthquake intensity data released after the earthquake, the actual long-axis radius of the intensity 6 region of this earthquake is about 53000 m and the short-axis radius is about 39000 m. The error between the earthquake intensity analysis results and the actual situation is about 21%, which meets the national disaster mitigation and emergency response requirements. The comparison shows that the intensity map quickly generated by the elliptical attenuation model already has some reference values and can be used for emergency relief analysis and rapid casualty assessment after an earthquake. However, it still has some differences from the actual intensity map, and there is room for improvement.

3.2 Economic damage and casualty assessment

After the rapid assessment of earthquake intensity, the rapid assessment of economic damage and human casualties of this earthquake was carried out. According to the above method, the epicenter intensity of this earthquake is about 8.308 and the magnitude is 6.4, giving α_m = 1.1507373909372403 [Eq. (11)]. Also, from the local population density data and Eq. (12), we obtained α_{den} = 0.970756025842063.

Intensity	Long radius (m)	Short radius (m)
8	4831.94	2183.17
7	27598.75	14267.55
6	67176.92	40692.47
5	135980.25	98475.85
4	255589.04	224830.80

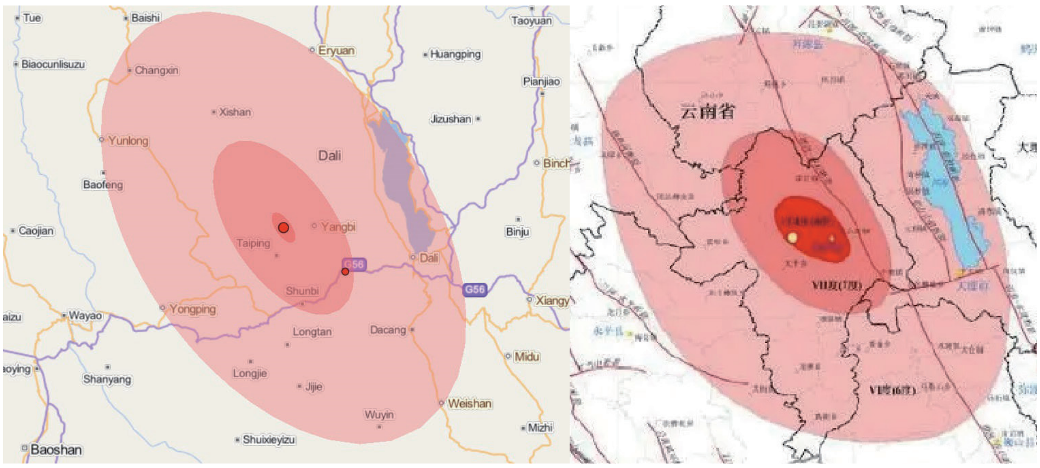

Fig. 4. (Color online) Earthquake intensity map of Yangbi County generated by elliptical attenuation model.

The time correction and local earthquake index correction coefficients were selected according to the occurrence time of 21:48 and the location of the epicenter. The building damage rate was calculated by the method of Yang.[18]

For the earthquake of Yangbi County, Dali, Yunnan, the correction coefficients finally selected are shown in Table 2.

After obtaining the correction coefficients, calculations based on Eqs. (9) and (10) predicted that the number of casualties of the Yunnan earthquake is about 48, with a range of 10–100, and that the economic loss is about 1530.451 (billion) yuan.

According to the notification of Dali Prefecture, the actual number of casualties of this earthquake was 35 and the direct economic loss was 310 million yuan. The number of casualties in this assessment is reasonably close to the actual number. Moreover, because the official data contains only direct economic losses and the post-disaster work of this earthquake was efficient, the economic loss assessment results are higher than the actual situation.

3.3 Supply distribution

To provide an example of rescue material distribution, we randomly selected 10 fire stations in Yangbi County, Dali, Yunnan Province as sample sites for rescue material distribution. The indicators for the areas served by the fire stations are shown in Table 3.

The data for the economic level indicator are from the 2021 Yunnan GDP per capita report and are in yuan/person. Population density is in persons/square kilometer. Requirement data are randomly generated and represent local values corrected for the number of times materials have

Table 2
Correction coefficients.

Key	Value
Magnitude coefficient	1.1507373909372403
Population coefficient	0.970756025842063
Time coefficient	5/3
Strength coefficient	0.3661
Building damage rate	0.4108245809454688

Table 3
Indicators of where supplies need to be distributed.

No.	Longitude	Latitude	Intensity	Economy	Population density	Requirement
1	100.1547634	25.69536921	6.962645	67101	730.3979	1.3
2	100.7342952	25.57363676	5.643831	50732	170.8517	1.7
3	99.95861063	25.67530753	7.775079	39755	89.2054	1
4	100.1926658	25.91212005	6.568763	67101	294.3379	1
5	100.1885425	25.92523295	6.552100	67101	281.1741	1.9
6	99.77684551	25.334288	6.669364	43274	41.5144	1.2
7	99.95864754	25.67529743	7.774892	39755	89.2054	1.4
8	100.3105443	25.67750851	6.511145	67101	518.4596	1.4
9	100.120976	25.79213837	6.966898	67101	382.3772	1.7
10	100.4937289	25.33667493	5.894564	35641	374.3219	1.2

been requested since the last material release. The normalized data are shown in Table 4. The weight of each indicator was obtained by the entropy method and is shown in Table 5. The results of the material distribution are shown in Table 6.

The results show that the material allocation by the entropy method takes each positive and negative indicator into consideration in an integrated manner. For example, the quantity of material allocated is appropriately reduced for areas with higher economic levels, and the artificial demand degree indicator is considered to a certain extent. The results of the material allocation can be used as reference values.

3.4 Design of rapid earthquake disaster assessment system

To apply our proposed earthquake disaster rapid assessment system, we designed and developed a Cesium-based earthquake disaster rapid assessment system. See https://earthquick.peteralbus.com/ for more details.

Table 4
Normalized data of indicators.

No.	Intensity	Economy	Population density	Requirement
1	0.618799	0	1	0.333333
2	0	0.520312	0.187749	0.777778
3	1	0.869231	0.0692294	0
4	0.433986	0	0.367005	0
5	0.426168	0	0.347896	1
6	0.481189	0.757374	0	0.222222
7	0.999912	0.869231	0.0692294	0.444444
8	0.406951	0	0.692345	0.444444
9	0.620794	0	0.494805	0.777778
10	0.117646	1	0.483111	0.222222

Table 5
Weight of each indicator.

Indicator	Intensity	Economy	Population density	Requirement
Weight	0.24714	0.29191	0.290556	0.170394

Table 6
Results of the material distribution.

No.	Result (%)	Intensity	Economy	Population density	Requirement
1	9	6.962645	67101	730.3979	1.3
2	13	5.643831	50732	170.8517	1.7
3	5	7.775079	39755	89.2054	1
4	2	6.568763	67101	294.3379	1
5	19	6.552100	67101	281.1741	1.9
6	6	6.669364	43274	41.5144	1.2
7	12	7.774892	39755	89.2054	1.4
8	9	6.511145	67101	518.4596	1.4
9	16	6.966898	67101	382.3772	1.7
10	4	5.894564	35641	374.3219	1.2

Figure 5 shows the modules included in the system. The system implements and visualizes our proposed system and includes three main functions: the rapid generation of earthquake intensity maps, the approximate estimation of death toll and economic loss, and the reasonable distribution of rescue materials. The system quickly obtains information on earthquake sources through crawler technology, performs rapid earthquake assessment on them, and displays the analysis results visually in the system. On the main page of the website, the system displays the latest earthquake information obtained through the web interface. After obtaining the relevant information, the corresponding earthquake intensity map is calculated and displayed on a 3D Earth based on Cesium technology; at the same time, in the background, the obtained data are substituted into scientific models to obtain preliminary estimates of the number of earthquake casualties and economic losses, which are visually displayed on the web page. The rescue and material distributions are also calculated from the data. As shown by the above results, the proposed system provides rapid and reliable data support for the initial earthquake assessment and rescue work, as well as useful guidance for subsequent work.

Figure 6 shows the main screen of the system. The system is developed as a website and can be accessed easily without downloading a client. The 3D presentation of the system relies on Cesium, which is an open source JavaScript library. It has a range of objects and methods to build the framework for a 3D Earth, relying on existing data classes or customized data types added to the framework and using WebGL-related methods for rendering. By combining Cesium with Vue, the maintainability of the web front end is ensured.

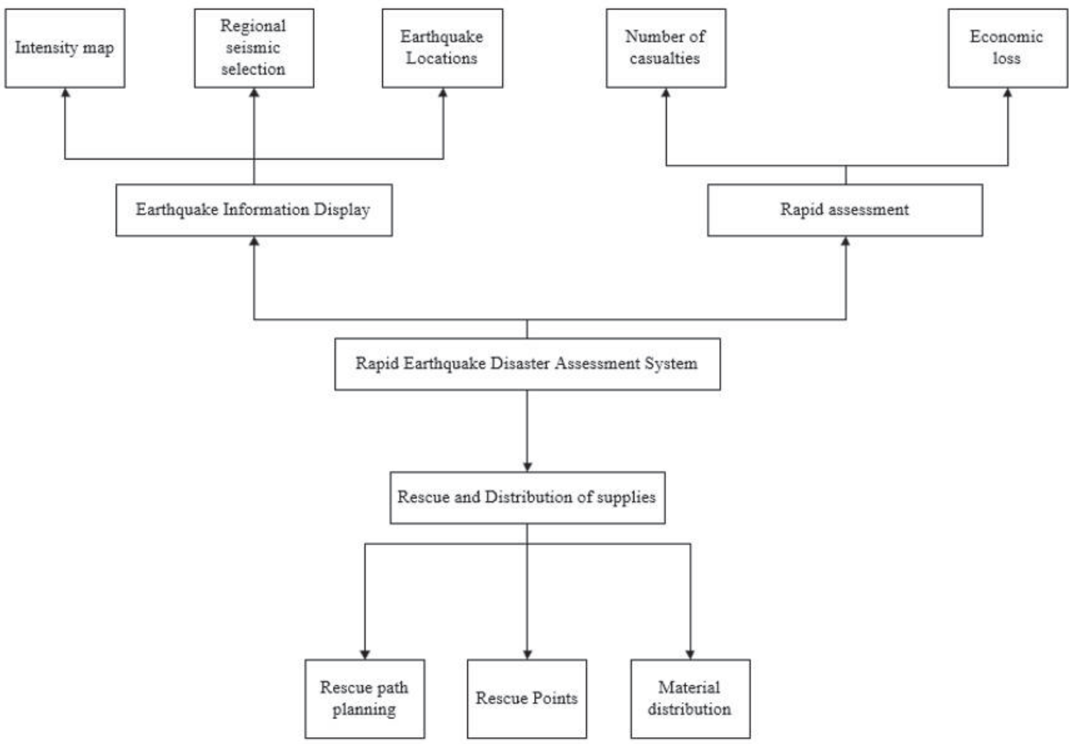

Fig. 5. System function modules.

Fig. 6. (Color online) System interface screenshot.

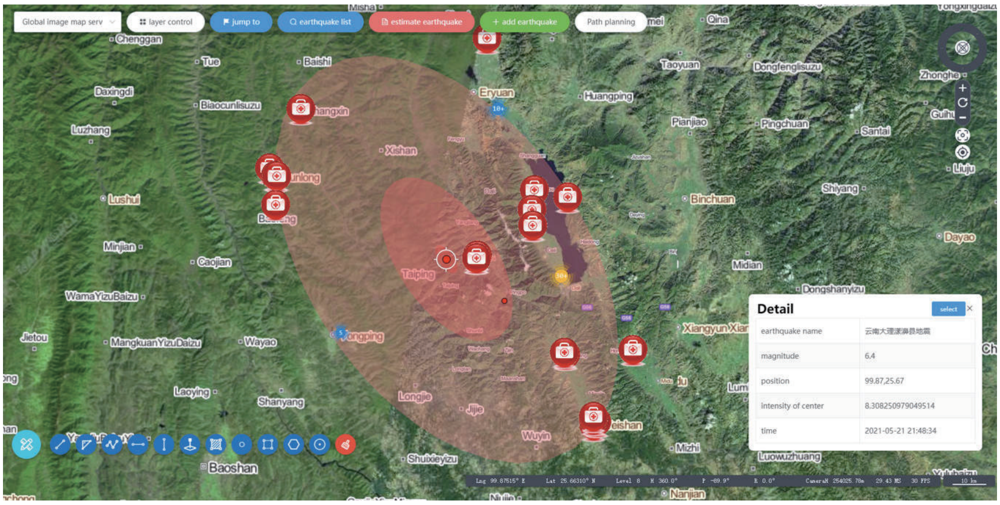

Fig. 7. (Color online) Intensity map and earthquake information display.

The intensity map and medical point information for our example earthquake are shown in Fig. 7. This part of the content is presented using the "Entity" interface in Cesium. The system receives data from the back end and then renders it into different styles of labels and shapes according to the settings through Cesium's interface, presenting the information visually to the user.

The main computational work and web crawling is carried out by the back end. The results of earthquake assessment will be displayed as shown in Fig. 8. The back-end part is developed by Spring Boot, which provides support for the information presentation. The back end calculates and processes the newly acquired seismic data and stores it in a MySQL database. When the front end needs to access the corresponding data, it interacts with the back end via http requests to obtain and display the data.

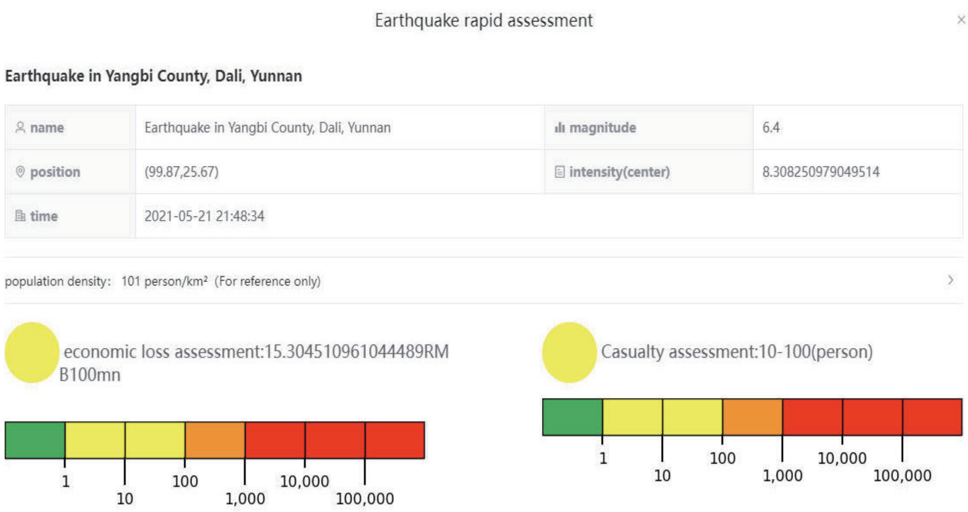

Fig. 8. (Color online) Display of results obtained by rapid earthquake assessment.

4. Conclusions

Faced with an earthquake disaster, it is necessary to arrange rescue operations and plan for material distribution as soon as possible to minimize the damage. We have reported a rapid earthquake assessment system that can obtain rapid and reliable information when the earthquake first occurs to assist in subsequent decisions and provide a reference for rescue and other works. After acquiring earthquake information, the system first calculates the earthquake intensity using the elliptical intensity attenuation model. This is followed by a rapid assessment of earthquake casualties and economic damage through empirical equations. Finally, the entropy method is used to provide a material distribution, and the results are presented to the user for reference.

We tested a system based on the proposed rapid assessment framework using the example of an earthquake in Yangbi County, Dali, Yunnan Province. The results were satisfactory. The error between the earthquake intensity analysis results and the actual situation was less than 30%. The results of the material allocation also successfully took into account a number of influencing factors.

On the basis of our results, we have built a web platform using Vue and Cesium for use as a rapid earthquake assessment system. The system can crawl the latest earthquake information in real time and calculate the evaluation results within 2 min after obtaining the earthquake information, which can provide a reference for rescue and other works.[19]

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