Railway Sciences

Design and research on seismic intensity monitoring system for railway based on Kriging interpolation method

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Abstract

Purpose – This research aims to monitor seismic intensity along railway lines, study methods for calculating the extent of earthquake impact on railways and address practical challenges in estimating intensity distribution along railway routes, thereby achieving graded post-earthquake response measures.

Design/methodology/approach – The seismic intensity monitoring system for railways adopts a two-level architecture, namely the seismic intensity monitoring equipment and the seismic intensity rapid reporting information center processing platform. The platform obtains measured instrumental intensity through the seismic intensity monitoring equipment deployed along railways and combines it with the National Seismic Network Earthquake Catalog to generate real-time railway seismic intensity distribution maps using the Kriging interpolation algorithm. A calculation method for railway seismic impact intervals is designed to calculate the mileage intervals where the intensity area corresponding to each contour line in the seismic intensity distribution map intersects with the railway line.

Findings – The system was deployed for practical earthquake monitoring demonstration applications on the Nanjiang Railway Line in Xinjiang. During the operational period, the seismic intensity monitoring equipment calculated and uploaded instrumental intensity values to the seismic intensity rapid reporting information center processing platform a total of nine times. Among these, earthquakes triggering the Kriging interpolation algorithm occurred twice. The system operated stably throughout the application period and successfully visualized relevant seismic impact data, such as earthquake intensity distribution maps and affected railway mileage sections. These results validate the system’s practicality and effectiveness.

Originality/value – The seismic intensity monitoring for the railway system designed in this study can integrate the measured instrumental intensity data along railways and the earthquake catalog of the National Seismic Network. It uses the Kriging interpolation method to calculate the intensity distribution and determine the seismic impact scope, thereby addressing the issue that the seismic intensity distribution calculated by traditional attenuation formulas deviates from reality. The system can provide clear graded interval recommendations for post-earthquake disposal, effectively improve the efficiency of post-earthquake recovery and inspection and offer a decision-making basis for restoring railway operations quickly.

Keywords Seismic intensity monitoring, Railway, Kriging interpolation, Impact scope

Paper type Research article

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1. Introduction

Earthquakes pose a major natural disaster threat to railway safety. By the end of 2024, China's total railway operation mileage had reached 162,100 kilometers. Since 2012, the former Ministry of Railways and the China Earthquake Administration jointly initiated research efforts to develop an early warning system for high-speed railways (Sun, Xuan, Jiang, Wang, & Song, 2023; Zhang, 2014). By the end of 2015, the development of this system was largely completed, and it has been progressively promoted nationwide (Jiang, Ma, Ye, Zhang Shi, & Xuan, 2019; China Railway Corporation, 2018). In addition to high-speed railways, China still has over 100,000 kilometers of conventional-speed railways. According to current handling regulations, after an earthquake occurs, conventional-speed railways near the epicenter must suspend operation and undergo track inspections before services can resume. Compared with high-speed railways (Pan, Xie, & Ma, 2022), conventional-speed railways have greater line density and larger network scale. Even a minor earthquake may trigger the suspension and inspection of multiple conventional-speed lines simultaneously. Therefore, the current focus should be on post-earthquake emergency response and rapid recovery. To achieve this goal, after an earthquake occurs, the affected railway sections must accurately determine damaged segments and carry out graded and layered post-earthquake inspections based on real-time seismic intensity data collected along the lines. Thus, real-time monitoring of seismic intensity along railways and precise assessment of the earthquake-affected range have become key technical supports for efficient post-earthquake handling and rapid recovery of conventional-speed railways.

Over the past decade, the continuous expansion of seismic station networks and the maturation and advancement of modern information technology have facilitated the development and application of various techniques, including ultra-rapid earthquake reporting, real-time intelligent seismic processing, seismic intensity quick reporting, automated earthquake cataloging, and earthquake early warning (Li, Su, Mi, & Chen, 2010; Zhang & Wang, 2016; Ouyang *et al.*, 2024). Based on the Nationwide Earthquake Instant Messenger System for rapid earthquake information sharing, experts and scholars have developed numerous earthquake information dissemination and emergency response software systems. However, none of these systems have been capable of rapidly calculating the distribution of seismic impact fields for conventional-speed railways (Xi, Gao, Xin, & Li, 2022; Zhang, Liu, Liu, Yu, & Tan, 2023).

At present, the rapid assessment of seismic impacts in China primarily relies on results calculated from seismic intensity attenuation formulas. However, due to the extensive east-west and north-south span of conventional-speed railways and the complex and regionally varied geological conditions along the routes, the use of a unified attenuation model often leads to discrepancies between the calculated seismic intensity distribution and actual monitored values. Furthermore, existing methods for analyzing earthquake impacts on railways generally depend on manual operations: verifying the three key earthquake parameters, performing manual positioning and calculations, and then delineating affected radii using offline maps or railway distribution maps to estimate impacted railway mileage. This process is not only labor-intensive and cumbersome but also difficult to automate, resulting in delayed post-earthquake responses and inefficient support for emergency decision-making and recovery operations (Sun, Wang, & Zhou, 2022; Zeng, 2012).

Therefore, it is essential to deploy seismic intensity monitoring facilities along railway lines. By acquiring measured intensity data from areas around the epicenter, the system can calibrate the attenuation formula-based seismic impact field in real time, enabling more accurate prediction of actual affected railway sections. To address this need, this paper designs a railway seismic monitoring system. Following an earthquake, the system instantly integrates earthquake catalogs from the National Seismic Network and measured intensity data from monitoring instruments along the railway lines. By incorporating source fault characteristics and measured intensity information from surrounding stations, it rapidly generates a distribution map of seismic intensity along railways, determines the extent of earthquake impact on railway operations, and automatically delivers visualized analysis results to management personnel. The system achieves full automation throughout the entire process—from seismic information monitoring and collection, intensity estimation, and impact scope assessment to result visualization and dissemination— improving the efficiency of railway seismic impact analysis and providing a scientific basis for rapid post-earthquake restoration of railway operations.

2. System architecture and functions

2.1 Overall architecture

The Railway Seismic Intensity Monitoring System adopts a two-level architecture: seismic intensity monitoring equipment and seismic intensity quick-report information center processing platform. The seismic intensity monitoring equipment accesses the seismic intensity quick-report information center processing platform via public 4G communication. The composition diagram of the Railway Seismic Intensity Monitoring System is shown in Figure 1.

The Railway Seismic Intensity Quick-Report Information Center Processing Platform is composed of central processing servers and seismic intensity quick-report display terminals. The central processing servers include front-end interface servers, information processing servers, database servers, geographic information servers, equipment management servers,

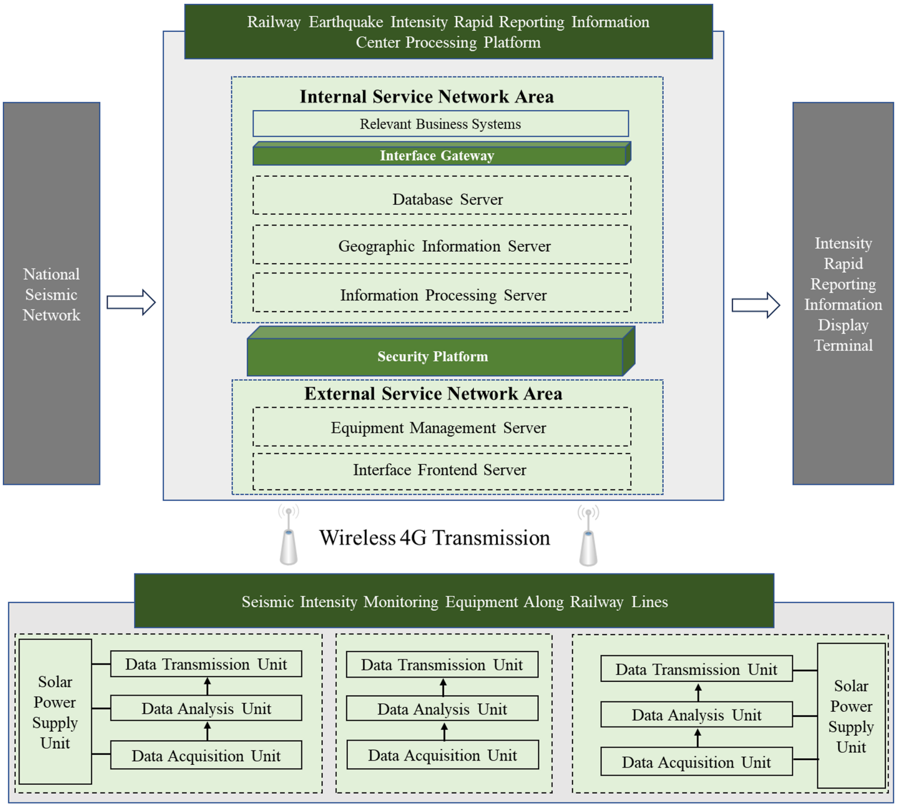


Figure 1. Schematic diagram of the composition of the railway seismic intensity monitoring system. Source: Authors' own work

and gateways. The front-end interface servers receive intensity information pushed by seismic intensity monitoring equipment along railways and retrieve seismic catalog information from the National Seismic Network, transmit it to the internal network information processing servers via the network security platform, and provide external internet services; the information processing servers are used for real-time calculation of seismic intensity along railways and determination of earthquake-affected railway sections; the equipment management servers implement functions such as equipment status monitoring and equipment management; the database servers provide data storage services, including intensity information, status information, and waveform information reported by seismic intensity monitoring equipment; the geographic information servers provide geospatial data along railways and earthquake location information. The seismic intensity quick-report display terminal is a computer installed with seismic intensity quick-report terminal software, which can display earthquake-affected areas and manage seismic intensity monitoring equipment.

The seismic intensity monitoring equipment along railways includes data acquisition units, data analysis units, data transmission units, and power supply units. The data acquisition units are used for real-time monitoring and data collection of seismic ground motion along railways; the data analysis units generate earthquake trigger information (including intensity data), waveform information, and status information based on the monitored seismic ground motion data, and upload such information to the front-end interface server of the Railway Seismic Intensity Quick-Report Information Center Processing Platform via the data transmission units. The seismic intensity monitoring equipment along railways is deployed at regular intervals in earthquake-prone areas along railways. Preferably, the equipment is installed in existing buildings such as railway communication base station rooms and powered by the room’s power supply; if conditions are not met, it can be installed in open areas and powered by solar energy. Due to the long length of railway lines and the wide distribution of seismic intensity monitoring equipment, the data transmission units use 4G wireless routers to build communication links, transmitting the earthquake trigger information, status information, and event waveforms processed by the data analysis units to the front-end interface server with a public IP address. Meanwhile, the data transmission units support VPDN technology, which enables the establishment of virtual communication links with the equipment management server of the Railway Seismic Intensity Quick-Report Information Center Processing Platform, allowing the server to remotely access and control the seismic intensity monitoring equipment.

2.2 System functions

(1) Seismic Intensity Quick-Report Information Center Processing Platform

The Seismic Intensity Quick-Report Information Center Processing Platform is equipped with functions including monitoring station information reception, seismic data processing, information display, information storage, station status monitoring, system management, remote system monitoring and maintenance, and system log recording. The software adopts a B/S (Browser/Server) architecture, with specific functions as follows:

- Seismic Information Reception Function: The central server of the processing platform receives seismic information transmitted by stations along railways and stations of the National Seismic Network. Information along railways includes intensity, PGA (Peak Ground Acceleration), alarm records, and waveform information; network information includes station location, PGA, and intensity.
- Seismic Data Processing Function: After an earthquake occurs, the central server of the processing platform can automatically calculate the intensity and PGA of stations along the line based on the acquired station waveform data. In different stages after the

earthquake, it conducts comprehensive intensity analysis and estimation using different algorithm models according to the amount of acquired information. Through the web-end map, it calculates and displays in real-time information such as earthquake location, surrounding railway line distribution, seismic intensity distribution map, mileage at intersections along railways, and intensity of corresponding sections.

- Information Display Function: The client software of the processing platform's monitoring and maintenance terminal can display station distribution information, seismic network information (including magnitude, origin time, epicenter longitude, epicenter latitude, and focal depth), station trigger information (including station ID, intensity, earthquake initial motion time, and earthquake end time), earthquake event trigger waveforms, equipment working status information, and communication network status.
- Information Storage Function: The information stored by the processing platform includes station distribution information, seismic waveform data, earthquake event information, and equipment working status information.
- Status Monitoring Function: Equipment status monitoring covers the power supply status (charging status and power level) of power sources (including external power supply and solar energy) and the working status of seismic intensity meters.
- System Management Function: Remote operations such as user information modification and user login can be performed through the client. The system has parameter configuration, authority, and security management functions.
- Remote System Monitoring and Maintenance Function: A remote terminal is set up to realize remote monitoring and maintenance of the processing platform and seismic intensity monitoring equipment along the line through network connection. Remote monitoring and maintenance functions include remote deployment, remote monitoring, and remote modification.
- System Log Recording Function: Seismic monitoring data, equipment working status, software upgrade information, and data backup information can be viewed by retrieving the log records of the processing platform.

(2) Seismic Intensity Monitoring Equipment

The seismic intensity monitoring equipment is an on-site device for real-time monitoring of seismic acceleration and intensity, with functions including seismic event detection, seismic data calculation, data transmission, operation log and data recording, and management. The specific functions are as follows:

- Seismic Event Detection Function: Built-in threshold triggering method and STA/LTA ratio triggering method to detect seismic events.
- Seismic Data Calculation: Calculate instantaneous acceleration, velocity, and the final PGA, PGV, and instrumental intensity value of seismic events based on three-component acquisition data.
- Data Transmission Function: Transmit seismic waveform data and event trigger information to the processing platform, including trigger time, trigger parameters, PGA, PGV, intensity value, trigger end time, etc.
- Operation Log and Data Recording Function: Record clock synchronization status, configuration parameters, seismic event monitoring and disposal status, data

transmission status, etc., in the operation log; record real-time waveform data of the E-W, N-S, and U-D components.

- Management Function: Write and modify installation information; set operating parameters; provide FTP remote download service.

3. Calculation method for the seismic impact on railways

3.1 Calculation method for seismic intensity distribution

The steps and process of the calculation method for seismic intensity distribution along railways are shown in Figure 2, and the details are as follows:

(1) The system acquires earthquake information from the National Seismic Network in real time

The system regularly retrieves the National Seismic Network Catalog at set time intervals to obtain earthquake source parameters, including origin time, epicentral region, epicenter longitude and latitude, magnitude, and focal depth.

(2) Calculation of instrumental intensity at stations

As shown in the Figure 3, in accordance with the instrumental intensity calculation method defined in China Seismic Intensity Scale (National Committee for Standardization of Seismology, 2020), the seismic intensity monitoring equipment processes the waveform data, calculates the intensity values, and uploads the results to the server of the processing platform.

(3) Waiting for data from the seismic network

From this point onward, the system waits to receive seismic intensity data from stations around the earthquake source transmitted by the seismic network.

(4) Associating station data with the origin time

The system starts calculation based on the origin time of the earthquake information from the National Seismic Network, and acquires the station intensity data triggered within a set time period. The time interval for associating station data with the origin time can be manually set, with a tentative setting of 30 seconds.

(5) Judgment and selection of instrumental intensity at stations

The intensity scattered points are corrected in the following two ways:

Based on the distance calculated between the epicenter longitude and latitude coordinates (provided by the National Seismic Network) and the actual coordinates of the stations, only the station measured values whose deviation from the theoretical attenuation values falls within the range of ±1 are used for the calculation of the seismic intensity map.

With the epicenter as the center, in the same direction, the instrumental intensity values that are recorded at farther stations but with larger intensity values are retained, while those recorded at closer stations but with smaller intensity values are discarded.

(6) Insertion of virtual stations

If there are no valid stations in a certain fan-shaped area, virtual stations are inserted to supplement the data (Hu, 2017).

(7) Selection of seismic intensity distribution map

If the seismic intensity value at the epicenter is greater than 3°, and the number of valid intensity values from stations within the area is more than 3 (including the epicenter), the

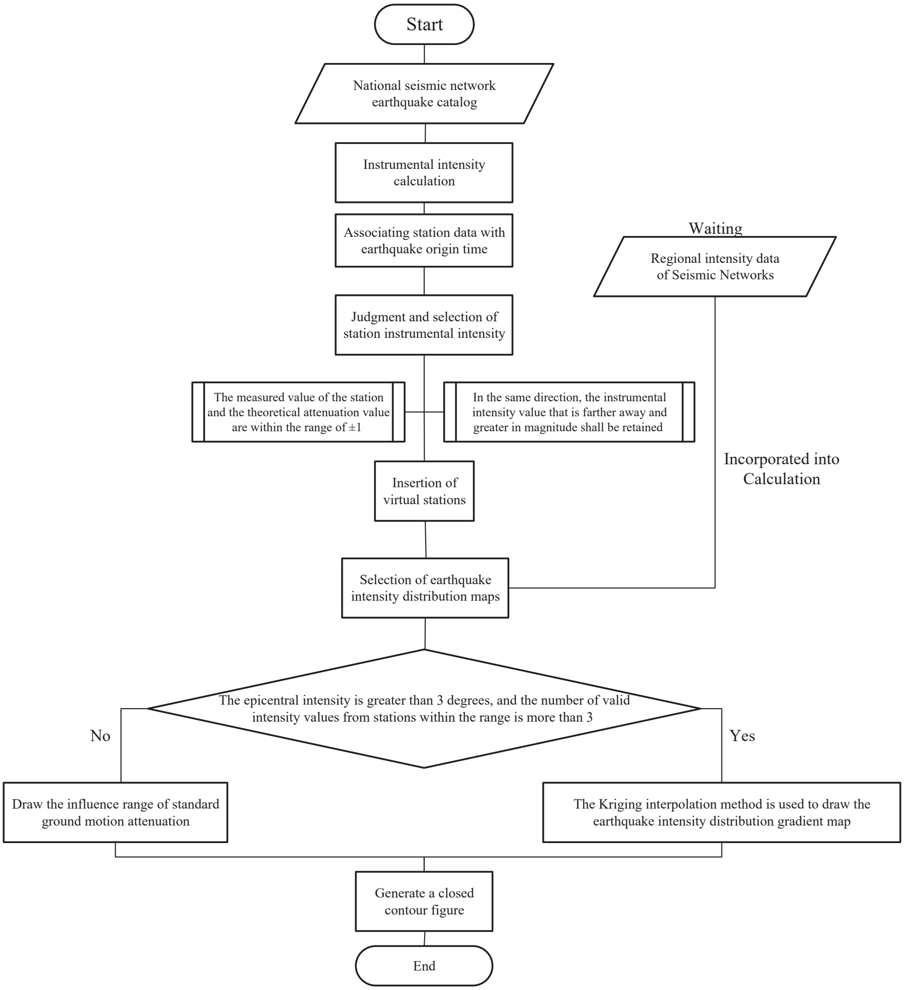


Figure 2. Flow chart of the calculation method for seismic intensity distribution along railways. Source: Authors' own work

Kriging interpolation method is used to draw the seismic intensity distribution gradient map. If the above conditions are not met, the influence range of standard ground motion attenuation is drawn. The formula for calculating standard ground motion attenuation is as follows.

$$I = A + BM + Clg(R + R_0) \tag{1}$$

Wherein, A, B, C and R_0 are regression coefficients; M is the surface wave magnitude; I is the seismic intensity; R is the epicentral distance. The values of the seismic intensity attenuation relationship coefficients A, B, C and R_0 for each sub-region are shown in Table 1 (Yu, Li, & Xiao, 2013). These values are derived from the seismic intensity attenuation relationships defined in the fifth-generation seismic zoning map.

Among them, the steps for drawing the intensity distribution gradient map using the Kriging interpolation method are as follows:

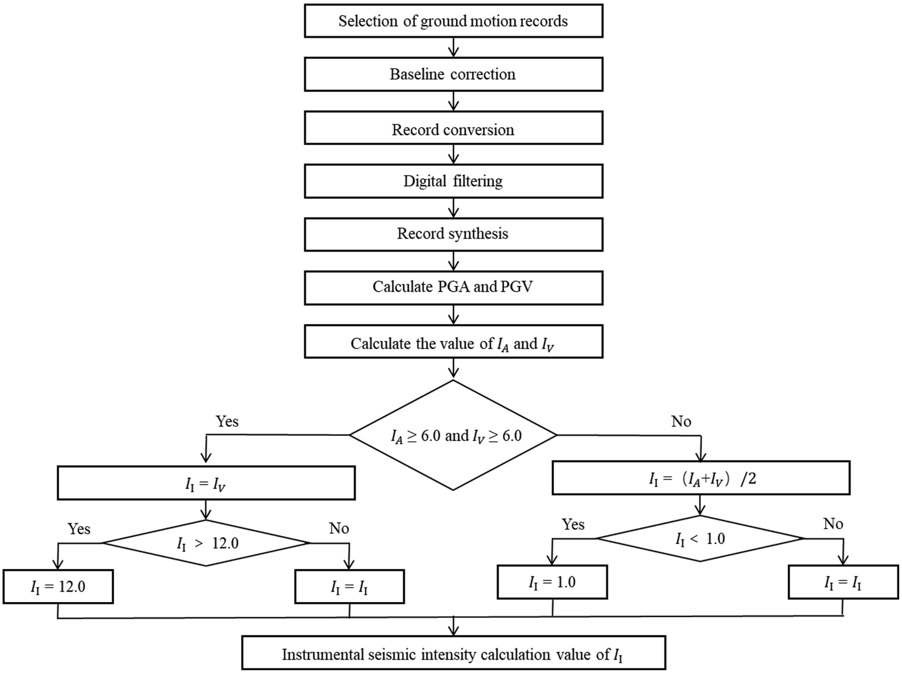


Figure 3. Flowchart for instrumental measurement of seismic intensity. Source: China seismic intensity scale (2020)

Table 1. Seismic intensity attenuation relation coefficients for each sub-region

	Eastern strong earthquake-prone area		Moderate-to-strong earthquake-prone area		Xinjiang region		Qinghai-Tibet region	
Zoning Coefficient	Major axis	Minor axis	Major axis	Minor axis	Major axis	Minor axis	Major axis	Minor axis
A	5.7123	3.6588	5.8410	3.9440	5.6018	3.6113	6.4580	3.3682
B	1.3626	1.3626	1.0710	1.0710	1.4347	1.4347	1.2746	1.2746
C	−4.2903	−3.5406	−3.6570	−2.8450	−4.4899	−3.8477	−4.4709	−3.3119
R_0	25	13	15	7	25	13	25	9
Standard deviation σ	0.5826		0.5200		0.5924		0.6636	

Source(s): Development of ground motion attenuation relations for the new seismic hazard map of China (2013)

(1) Substitute the epicenter's longitude, latitude and intensity $I = 0$ into Formula (1) to obtain the theoretical radius value R of the earthquake impact coverage. With the epicenter as the center, select four points $(R, R), (-R, R), (-R, -R), (R, -R)$ and connect them to form a rectangle as the Kriging spatial geographic scope.

(2) Let the rectangular area in (1) be Area A, and the points with known intensity values in A be denoted as (x, y), where x and y represent longitude and latitude respectively. Let $z_i = z(x_i, y_i)$ be the intensity value at point i $(i = 1, 2, 3, \ldots, n)$, and n be the number of points with known intensity values in Area A.

The semi-variance between any two different points is calculated as:

$$\gamma_{ij} = \frac{\left(z_i - z_j\right)^2}{2} \tag{2}$$

(3) Calculate the distance between each pair of points:

$$d_{ij} = r_0 * \arccos\left(*\cos\left(y_i - y_j\right)\right) \tag{3}$$

(4) Select the exponential function model to fit the relationship between the distance $d_{ij}$and the semi – varianceγ_{ij}:

$$\gamma(d) = C_0 + C_1\left(1 - e^{-d/a}\right) \tag{4}$$

Wherein, C_0 and C_1 are parameters to be determined, and a is a constant.

(5) Divide the Kriging spatial geographic scope into grids to obtain grid points at equal intervals. For each grid point $\left(x_0, y_0\right)$ among them, calculate the distance d_{i0} to the known intensity point i according to Formula (3), then calculate the semi-variance d_{i0} between this grid point and point i according to Formula (4).

(6) Calculate the weight coefficient of each grid point according to Formula (5):

$$\begin{bmatrix} w_1 \\ \vdots \\ w_n \\ \varepsilon \end{bmatrix} = \begin{bmatrix} \gamma_{11} & \cdots & \gamma_{1n} & 1 \\ \vdots & \ddots & \vdots & \vdots \\ \gamma_{n1} & \cdots & \gamma_{nn} & 1 \\ 1 & \cdots & 1 & 0 \end{bmatrix}^{-1} \begin{bmatrix} \gamma_{10} \\ \vdots \\ \gamma_{n0} \\ 1 \end{bmatrix} \tag{5}$$

Wherein, $w_1, \ldots, w_n$ are the weight coefficients of each grid point relative to the known intensity points, and ε is a constant.

(7) Calculate the intensity value of each grid point according to Formula (6):

$$z_0 = \sum_{i=1}^{n} w_i z_i \tag{6}$$

(8) Generation of closed contour graphics

From the previous Step (7), the intensity values of each grid point in the area are obtained. Grid points with an integer intensity value of 5° or higher and identical intensity values are connected using smooth curves to form closed boundaries, thereby generating the seismic intensity contour map for different intensity levels.

3.2 Calculation method for railway impact sections

(1) Calculation method

If the contour lines of the intensity distribution map intersect with railway lines, it is necessary to calculate the K mileage sections where the intensity area corresponding to each contour line intersects with the railway lines. A calculation method of “point envelope + straight-line distance judgment” is designed, with steps as follows:

First, data preparation is conducted: the railway line is divided into discrete points at intervals of 500 m along the curve length, which are sequentially marked as K0, K0+500, K1, K1+500, and so on. The curve-length interval of the discrete points divided in this step is related to calculation accuracy—the smaller the interval, the higher the accuracy, but the larger the computational load simultaneously. After comprehensively considering calculation accuracy and computational load, 500 m is selected as the curve division interval.

- For each discrete point, use the ray casting algorithm to judge whether the point is within the range of the corresponding closed contour line: draw a horizontal ray from the point, if the number of intersection points with the polygon corresponding to the contour line is odd, the point is within the range of the contour line; if even, the point is outside the range of the contour line.
- Obtain the set of discrete points within the contour line range according to step (1), as shown by the red dots in Figure 4. Let the total number of calculated discrete points be n.
- Take the intersection points of the railway line and the seismic intensity contour lines as marker points, as shown by the blue plus signs in Figure 4.
- According to the result in step (2), calculate the straight-line distance from one outermost discrete point to the marker point in step (3), as shown by “x” in the figure. Similarly, obtain the distance “x’” at the other end of the contour line.
- Since the discrete points are marker points with K mileage, assuming there are 18 discrete points within a certain intensity contour line, which are (K1, K1+500…K9+500), then the railway K mileage section surrounded by this intensity contour line is [K(1-x’)—K(9 + 500+x)]. The curve length X of the railway line surrounded by this intensity contour line can be approximately equal to the total length of the railway line within the discrete points plus the straight-line lengths on both sides, that is, X = (n-1)*100 + x + x’ = 8.5 + x + x’ (km).
- Similarly, the railway K mileage sections surrounded by contour lines of other intensities can be obtained.

(2) Error analysis

During the data preparation, the railway line is divided into discrete points at intervals of 500 m curve length. In step 4), the straight-line distance from the outermost marker point on

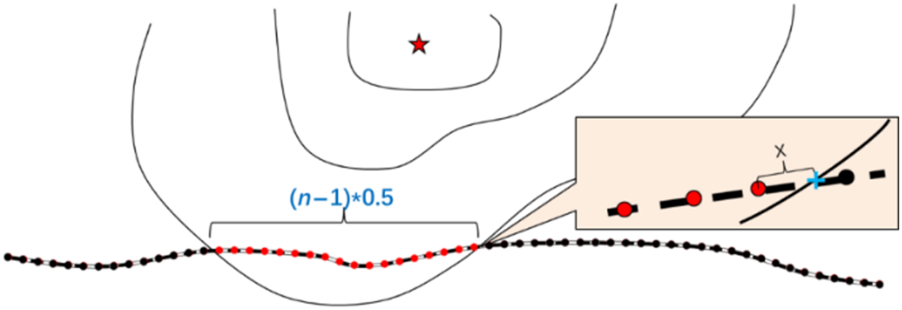


Figure 4. Schematic diagram of principle judgment for railway mileage sections. Source: Authors’ own work

both sides to the intersection point of the intensity contour line and the railway line is calculated, and this straight-line distance is used as an approximation of the railway curve length. Since this section of the railway is not a perfect straight line, errors will occur here. Assume the worst-case scenario where the intersection points at both ends are very close to the marker points but not completely coincident, and conduct an error analysis as follows.

According to Regulations on Railway Technical Management (Part of Ordinary-Speed Railways) (China Railway Corporation, 2014), assume this section of the railway has the minimum curve radius of 500m. As shown in Figure 5, the ratio of the calculated chord length of this section to the actual arc length of the railway is 479.4:500. Therefore, in the worst-case scenario, the total error between the calculated chord lengths of the two sections and the actual railway length is approximately 20m. Thus, the overall error in a single mileage section judgment is about 20m. This error is not of the same order of magnitude as the length affected by seismic intensity distribution and the length involved in post-earthquake railway disposal, so it can be neglected.

4. Application status

This system has been deployed in the demonstration section from Baqiang to Wudaoban on the Nanjiang Railway Line. A total of 12 intensity monitoring devices have been installed along this section, with an approximate spacing of 15 kilometers between adjacent devices. 4G wireless network is adopted for data transmission. During the trial period, there were no operational failures such as execution errors, system crashes, memory overflow, or communication interruptions.

Among the earthquakes that occurred during the trial period, the instrumental intensity values calculated by the station equipment and uploaded to the intensity rapid reporting information processing platform totaled 9 times, as shown in Table 2. Among them, a total of 2 earthquakes triggered the Kriging interpolation algorithm, which are the earthquake events marked by Serial No. 8 and Serial No. 9 in Table 2 respectively. The following is an analysis of these two earthquakes.

(1) M3.6 Earthquake in Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang

According to the determination by the Seismic Network Center, a magnitude 3.6 earthquake occurred in Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang (77.44° E, 39.95° N), with a focal depth of 23 km. The system calculated that the closest point to the nearby railway line is Xikelkule Town, Jiashi County, Kashgar Prefecture, Xinjiang Uygur Autonomous Region on the Nanjiang Railway Line, with a minimum distance of

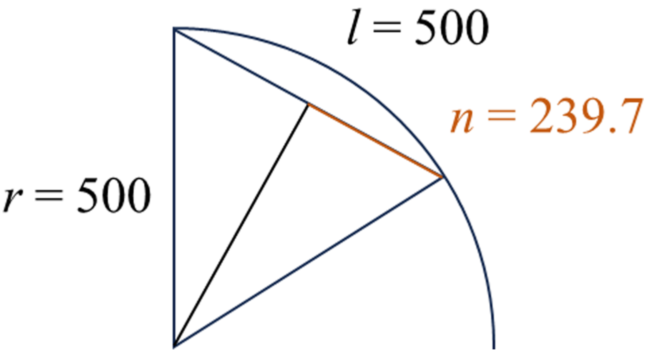


Figure 5. Schematic diagram for calculating the required chord length and the actual arc length of the railway.
Source: Authors' own work

Table 2. The earthquake in which the station equipment generates instrumental intensity values and uploads them to the intensity rapid reporting information processing platform

Serial number	Earthquake event ID	Magnitude (M)	Longitude (°)	Latitude (°)	Depth (KM)	Reference location
1	20230531141432	3.4	77.16	40.46	16	Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang
2	20230531151247	4	77.2	40.27	16	Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang
3	20230615215809	3.7	77.46	40.14	23	Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang
4	20230619132449	3.7	77.59	40.49	25	Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang
5	20230706032504	3.4	77.12	40.13	10	Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang
6	20230707221311	3	77.21	40.09	15	Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang
7	20230805082345	3.1	77.28	39.47	15	Jiashi County, Kashgar Prefecture, Xinjiang
8	20230809203534	3.6	77.44	39.95	23	Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang
9	20230820232823	4.3	77.77	39.91	18	Jiashi County, Kashgar Prefecture, Xinjiang

Source(s): Authors' own work

approximately 15.48 km and an estimated PGA of 4.66 gal. The earthquake location and railway distribution are shown in Figure 6, and the seismic intensity distribution map automatically calculated by the system is shown in Figure 7. Among the results, it is determined that the intensity Grade 4 area affects the section of the Nanjiang Railway Line from K1287 + 472 to K1315 + 923.

There is a total of 1 station with intensity greater than IV. The data waveform of Station NJ.K1291 is shown in Figure 8. The maximum PGA of the three-component synthesis is 28.1 gal at 20:35:44.

(2) M4.3 Earthquake in Jiashi County, Kashgar Prefecture, Xinjiang

According to the determination by the Seismic Network Center, a magnitude 4.3 earthquake occurred in Jiashi County, Kashgar Prefecture, Xinjiang (77.77°E, 39.91°N) with a focal depth of 18 km. The system calculated that the closest point from the epicenter to the nearby railway line is Yudaikelike Township, Jiashi County, Kashgar Prefecture, Xinjiang Uygur Autonomous Region on the Nanjiang Railway Line, with a minimum distance of approximately 5.31 km. The earthquake location and railway distribution are shown in Figure 9, and the intensity distribution map automatically calculated by the system is shown in Figure 10. Among them, it is determined that intensity IV affects the section from K1204 + 580~K1306 + 977 on the Nanjiang Railway Line, intensity V affects the section from K1239 + 607~K1294 + 057 on the Nanjiang Railway Line, and intensity VI affects the section from K1252 + 583~K1287 + 658 on the Nanjiang Railway Line.

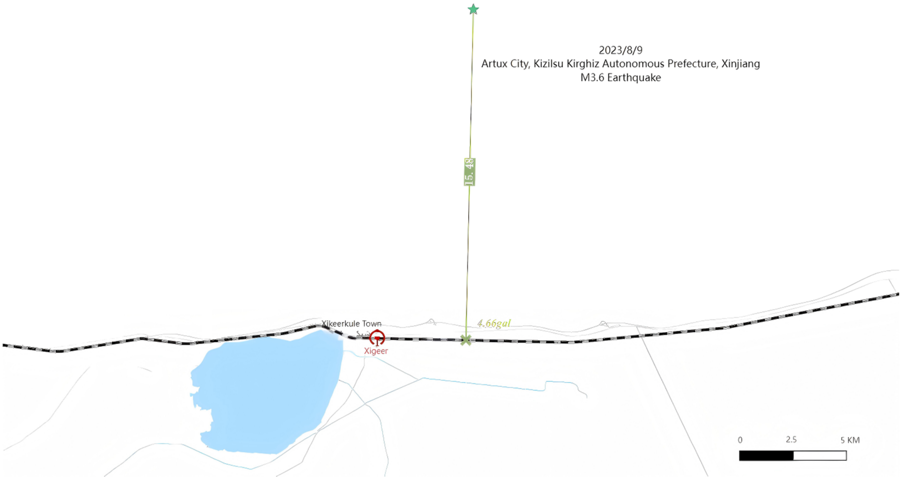
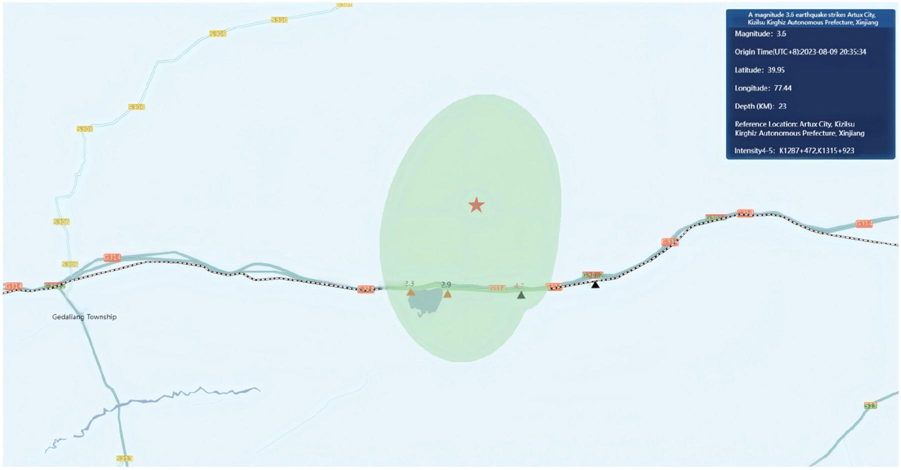


Figure 6. Relationship between the M3.6 earthquake in Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang and railway location. Source: Authors' own work


A magnitude 3.6 earthquake strikes Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang

Magnitude: 3.6

Origin Time(UTC+8):2023-08-09 20:35:34

Latitude: 39.95

Longitude: 77.44

Depth (KM): 23

Reference Location: Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang

Intensity4-5: K1287+472,K1315+923

Figure 7. System-generated intensity distribution map of the M3.6 earthquake in Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang. Source: Authors' own work

There are a total of 3 stations with intensity greater than IV, which are NJ.K1278, NJ.K1291 and NJ.K1304 respectively. The data waveform of NJ.K1278 station is shown in Figure 11. The maximum PGA of the three-component synthesis is 168.3 gal at 23:28:28.

5. Conclusion

Based on the practical needs of railway seismic safety monitoring, this paper designs a railway seismic intensity monitoring system. Following an earthquake, the system integrates earthquake catalog information released by the National Seismic Network with measured intensity data from instruments deployed along the railway lines to generate a real-time spatial

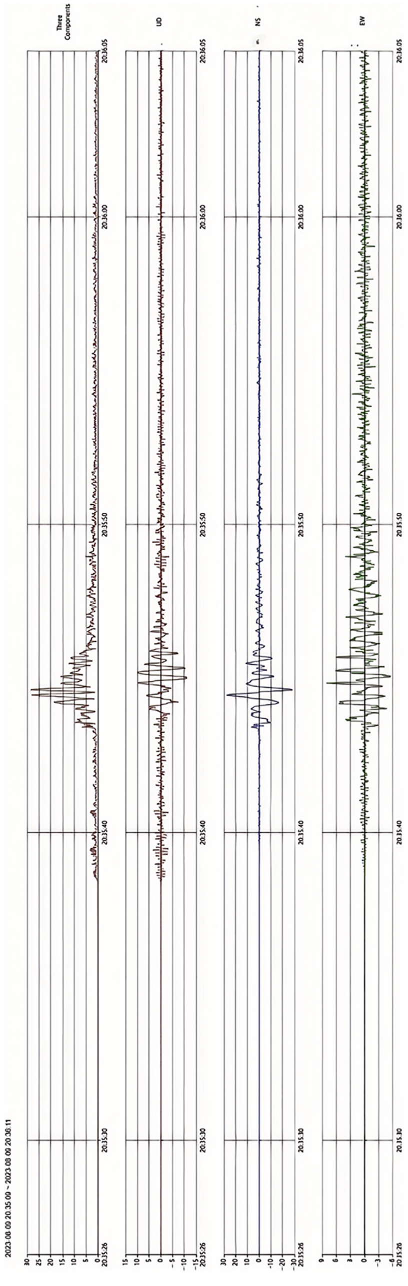


Figure 8. Data waveform diagram of station NJ.K1291 for the M3.6 earthquake in Artux City, Kizilsu Kirghiz Autonomous Prefecture, Xinjiang. Source: Authors' own work

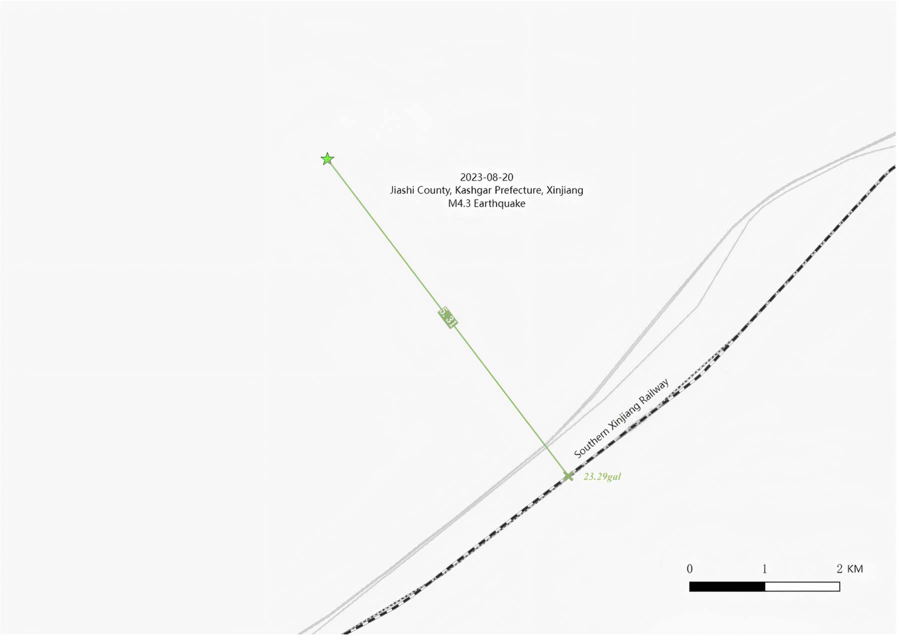
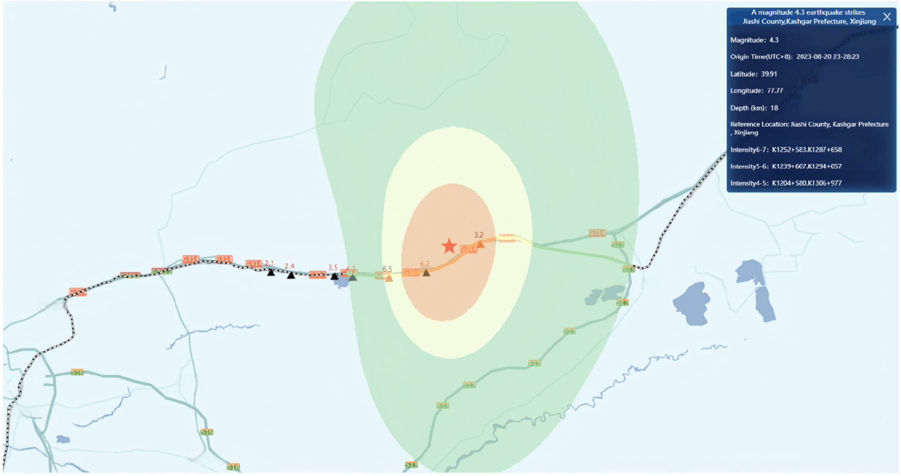


Figure 9. Relationship between the M4.3 earthquake in Jiashi County, Kashgar Prefecture, Xinjiang and railway location. Source: Authors' own work


A magnitude 4.3 earthquake strikes
Jiashi County,Kashgar Prefecture, Xinjiang

Magnitude: 4.3
Origin Time(UTC+8): 2023-08-20 23-28:23
Latitude: 39.91
Longitude: 77.77
Depth (km): 18
Reference Location: Jiashi County, Kashgar Prefecture , Xinjiang
Intensity6-7: K1252+583.K1287+658
Intensity5-6: K1239+607.K1294+057
Intensity4-5: K1204+580.K1306+977

Figure 10. System-generated intensity distribution map of the M4.3 earthquake in Jiashi County, Kashgar Prefecture, Xinjiang. Source: Authors' own work

distribution map of seismic intensity along the railway. Based on railway infrastructure data, it automatically and rapidly determines affected railway mileage sections under different seismic intensity levels.

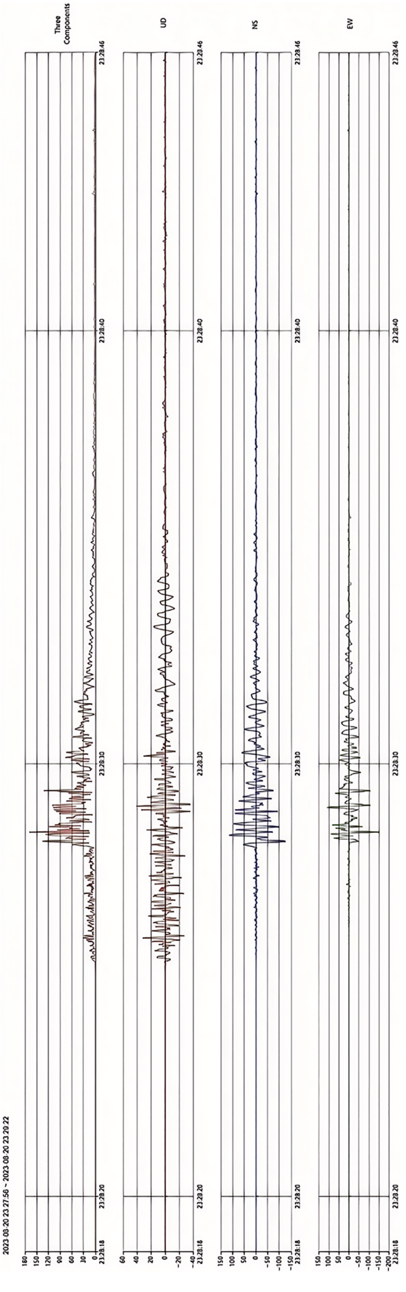


Figure 11. Data waveform diagram of station NJ.K1278 for the M4.3 earthquake in Jiashi County, Kashgar Prefecture, Xinjiang. Source: Authors' own work

Through its demonstration application on the Nanjiang Railway Line, the system's effectiveness in railway seismic intensity monitoring has been validated. It holds potential for widespread deployment across various railway lines, where it can deliver scientific and accurate grading recommendations for railway sections to support post-earthquake emergency response. This capability thereby enhances the efficiency of post-disaster line restoration and equipment inspection.

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