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Research on Seismic Site Emergency Rescue Traffic Path Analysis System Based on Public Image Information

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Abstract. *The last kilometer problem that occurs when emergency vehicles respond to a highly destructive earthquake is a continuing problem that needs an immediate solution. To solve the problem of optimizing the traffic path for emergency vehicles, this study integrated an existing public image information system, active floating car technology, and an improved bidirectional Dijkstra algorithm. The proposed traffic path analysis system uses public image information for real time traffic path optimization so that emergency vehicles and personnel can expedite their response to an earthquake site.*
Keywords: VSN, Public image information, Earthquake Site, Emergency Rescue, Path Analysis.

1. **Introduction.** In recent years, earthquakes and secondary disasters have increased in frequency and severity. Rapid mobilization of emergency response vehicles and communication command vehicles requires real-time solutions to emergency traffic path optimization problems. Specifically, the problem is how to determine the safest and most feasible traffic path that emergency vehicles can use to enter the core disaster area as soon as possible after a devastating earthquake. Solving this problem requires a system for evaluating and selecting traffic paths. In order to ensure that the staff and vehicles of the field team can reach the disaster area safely, effectively and quickly. In urban and rural areas of China, the density and distribution of public image in-formation systems are rapidly increasing. We hypothesized that systems for monitoring these information systems could be extremely useful for solving traffic routing problems during emergencies. Therefore, this study developed a system for extracting useful information about roads and traffic from public image information systems after a severe earthquake. The objective was to obtain the best solution considering road infrastructure damage and geographic characteristics [1].

2. **Acquisition of Public Image Information.** Real-time image information currently available to emergency personnel and communications vehicles includes "Global Eye" information, satellite images, real time images obtained from the network real-time image information obtained by staff and emergency communications vehicles. The "Global Eye" system is a basic service platform for video surveillance service providers. The platform uses broadband IP for remotely controlled monitoring throughout its coverage area. The

system is currently mainly used by the public sec-tor (e.g., judicial system, public security, customs, metrology, fire protection, civil affairs, and administrative law enforcement) and by many business sectors and industries (e.g, electric utilities, petrochemicals, finance and banking, transportation, real estate, and food retail). The functions of Global Eye include digital storage, net-work monitoring, on-site voice control transmission, remote monitoring of real-time images, scheduled image acquisition, and on-site alarm linkage control. Therefore, this study evaluated the use of Global Eye for optimizing the traffic paths used by emergency vehicles in response to an earthquake disaster. The information system software and hardware currently used by the Fujian Seismological Bureau and by Global Eye were used to set up the developmental and experimental environments for the proposed system. Global Eye data were processed and analyze to identify its blind spots in areas of severe earthquake damage and to identify areas where imaging function was normal. Images in the affected areas are collected from the global eye which were still normal working.The artificial intelligence system (Expert System) used in the proposed traffic path analysis system predicts current road and traffic conditions by comparing images obtained by Global Eye before and after disasters. The traffic path analysis system detects the edge of the Global Eye blind area at regular intervals after a disaster occurs. The system uses this information to determine the flow of emergency vehicles and personnel and to determine what traffic paths are currently feasible. It helps we analysis the passage possibility of the following path. Combined with the damage and repair of possible paths given by the expert information base, the optimal path selection scheme is given. So as to realize the content of the operation scheduling layer and the service layer in Figure 1 [2]. Figure 1 shows the 4-layer service architecture, which communicates information about the optimal traffic path to the field communication and command vehicle, field work team and command center dispatch personnel via the query and live video access service.

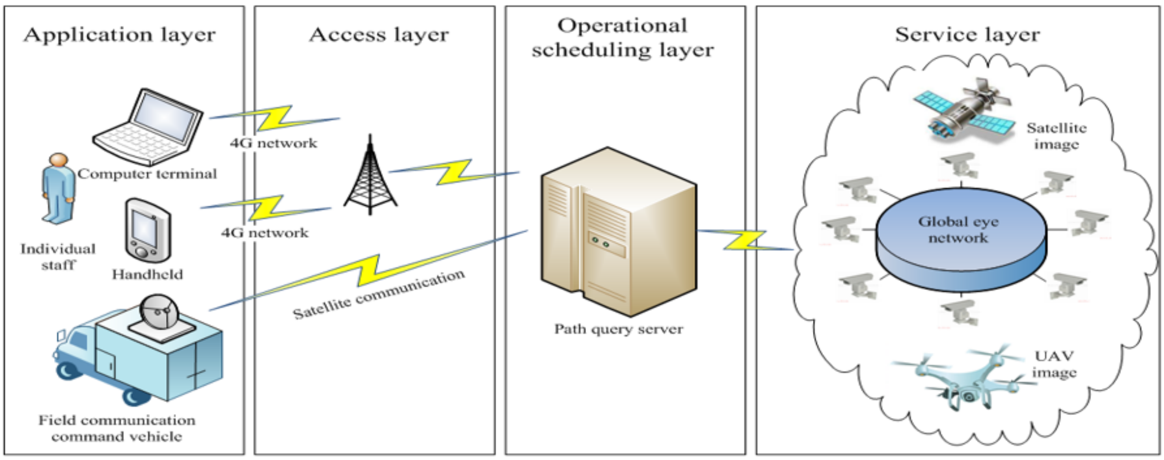

FIGURE 1. Architecture of deep-learning-based target recognition using high performance computing platform and embedded computing platform

The application layer provides WEB- and WAP-based browser platforms or mobile APP servers for operators, on-site workers, and command center dispatchers. The staff can use interactive devices such as portable computers, smart phones or vehicle computers to initiate interactive query requests to the system through WEB- or WAP-based browsers or through the APP client. For reference, the application layer displays an electronic map of the traffic path on the corresponding platform. The interface also provides clickable links to Global Eye. The links can be used as needed to access relevant live video images.

The access layer provides access to network services used by the application layer. The system can access VPN links through various networks, including personal 4G networks, vehicular 4G networks, maritime satellite telephone networks, and mobile VSAT networks. Command center dispatch personnel can search query servers by using local LAN access paths [3]. The operation scheduling layer query server is the main server for path queries and Global Eye video invoking. Based on the query requests sent by the client the status of Global Eye, and related image information, the server calculates and annotates the best reference path on the electronic map and sends it to the client. The system uses continuously updated traffic information to make real-time recommendations [4]. The service layer is a platform for various public image information services. It includes the Global Eye service platform provided by the operator system, satellite image information, and image information provided by field equipment and personnel. Rescue workers can use the image information obtained from the Global Eye platform and for accurate, real-time assessment of traffic conditions, including traffic conditions in the blind area.

3. **Traffic Path Inquiry after Earthquake.** Earthquake damage sustained by buildings and Global Eye equipment depends on the intensity of the earthquake. If the earthquake damage is not strong, the global eye equipment and related communication equipment work normally. The problem of emergency path routing can be solved by combining the real time road traffic condition observed by the global eye with the mature technology of floating car. If there is an earthquake with strong intensity and strong destructive type, the area of the global eye blind area can be circled immediately. Floating car technology can then be used for path planning outside the blind area. In the blind area, the algorithm determines all possible traffic paths in the road network under varying earthquake intensities. At the same time, the traffic condition monitored by the working global eye of the blind edge can also be used as the traffic indicator of its precursor path. [The developmental environment and experimental environment for the system proposed in this research project were based on an existing system currently used by the Fujian Seismological Bureau. The starting point of the system was set as the earthquake emergency command center in Fujian. Databases were set up for five destinations: Yongding of Nanping, Pucheng of Zhangzhou, Zhangpu of Longyan, Xiapu of Ningde and Lianjiang of Fuzhou. The system analyzes all possible traffic paths from the Starting point to the destination. For each path, the system assigns an index for the predicted need for repair of earthquake damage and an index for the predicted time needed to perform the repairs. These data are stored in four matrices. Matrix L stores the traffic index for the pre-cursor path. The traffic index is obtained by real-time image information analysis of the forward road section. If the number of vehicles passing through the road section within the specified time increases, the traffic index increases, and the value increases. Matrix T stores the traffic velocity index for the corresponding section of road. Highways, which have the fastest traffic, have a traffic velocity index of 1. For other road types, the index depends on the condition of the specific section of road. Matrix G stores the hazard index of the corresponding link. The hazard index for a road section is calculated according its geographic features (e.g., roadside cliffs), its infrastructure (e.g., tunnels and bridges), and its current status (e.g., blocked by landslide). Based on this matrix and data obtained from relevant industry experts, a passability coefficient is generated for the assigned for different seismic levels. Matrix Q is the difficulty coefficient of repair after serious damage to the corresponding section (Such as bridge fracture, tunnel collapse, landslide and so on.). This matrix will combine the relevant industry experts to give the coefficient of the corresponding repair time. The longer the time it takes to repair it, the smaller the coefficient. Since the number and frequency of urban and rural planning and construction

projects in China are rapidly increasing, the above data must be updated in real time to maintain reliable traffic path information. The c is based on the weighted value of each section and is calculated as $c = L \cdot T \cdot G \cdot Q$. Depending on the traffic path requirements, the "best path" can be defined as the shortest path or as the fastest path by adjusting the weight for T. The best path can be obtained by adjusting the weights of G and Q.

4. **An Improved Bidirectional Dijkstra Optimal Path Selection Algorithm.** In this study, an improved bidirectional Dijkstra algorithm was used as the dynamic path solving algorithm for the Global Eye blind area. The traditional Dijkstra algorithm is itself an algorithm generated by the order of increasing path lengths. This algorithm has proven to be among the most efficient algorithms for calculating the optimal path from one point to all other points [6]. Since the Dijkstra algorithm itself has no directionality, the entire search process is subject to blind spots. Performing such a search increases overhead and increases the complexity of the algorithm. Another drawback is that the real-time performance of the system decreases. Therefore, the bidirectional Dijkstra algorithm was selected. The optimal path is obtained by simultaneously running the two sub processes at the starting point (S) and at the destination point (D). When the two sub processes meet, the best path between S and D is obtained, and the search ends. If two sub processes do not meet. When the two reverse search processes end, the better of the two sub paths is defined as the optimal path. The steps of the improved bidirectional Dijkstra algorithm are briefly described below.

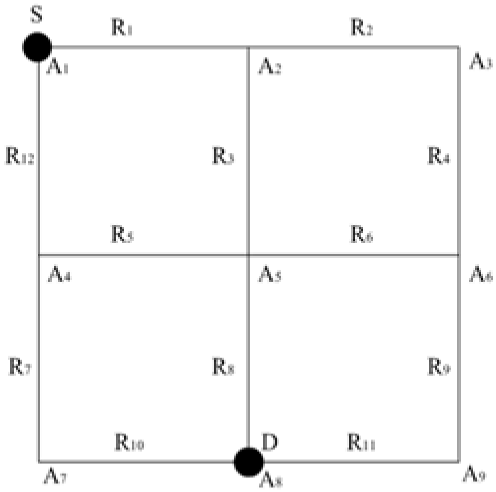

FIGURE 2. Network Links

For a network $G = (A, R)$, let A be the node set, let R be the edge set, let S be the starting point, and let D be the end point. The T_{ab} is the edge weight between the nodes. The d_{ab} is the optimal path length for node a and node b. For any node a, set the node properties to $(d_{Sa}, p_{Sa}, d_{Da}, p_{Da}, m, n)$. The values d_{Sa} and d_{Da} indicate the length of the optimal path from S and D to node a, respectively.

In the classic Dijkstra algorithm, p_{Sa} designates the front node of node a in the optimal path from S to the end of node a. The p_{Da} is the front node of node a in the optimal path from D to the end of node a. Markup bit m and markup bit n are set for each node. These markup bits indicate whether or not an optimal path has been found from S and D to node a. For example, $m = 1$ indicates that the optimal path from S to node a has been found. If $m = 0$, then the optimal path from S to node a has not been found. If $n = 1$, then the optimal path from D to node a has been found. If $n = 0$, the

TABLE 1. Links of S-D

Num	S-D Links
1	*R1—R2—R4—R9—R11*
2	*R1—R2—R4—R6—R8*
3	*R1—R2—R4—R6—R5—R7—* Chart Area
4	*R1—R3—R6—R9—R11*
5	*R1—R3—R8*
6	*R1—R3—R5—R7—R10*
7	*R12—R5—R3—R2—R4—R6—R8*
8	*R12—R5—R6—R9—R11*
9	*R12—R5—R8*
10	*R12—R7—R10*

optimal path from D to node a has not been found. The set of linked lists v and w are used for storage nodes, which are adjacent to a marked node. The detailed steps of the bidirectional Dijkstra algorithm are as follows:

(l) Initialize the network, and set $d_{SS} = 0, d_{DD} = 0$ and $p_{SS} = p_{DD} = \Phi$. The flag bits for Sare $S(m = 0, n = 0)$, and the flag bits for D are $D(m = 0, n = 1)$. For $a \in VSD, d_{Sa} = \inf, d_{Da} = \inf$, the flag bits for a are $a(m = 0, n = 0)$. Linked list v and linked list w are emptied, and nodes adjacent to S and D are added to linked list v and linked list w, respectively.

(2) Find nodes k and l for marked bit m and flag bit n. The optimal path length for node a is adjacent to node k, but flag bit m for node a is unmarked (i.e., since these nodes are already stored in linked list v). The optimal path length for node l is adjacent to tag node b but is not marked in node n (i.e., since these nodes are already stored in linked list w). Set $d_{Sa} = min(cd_{Sa}, c[d_{ka} + v_{ka}]), d_{Da} = min(cd_{Db}, c[d_{lb} + w_{lb}])$.

(3) In linked list v and linked list w, choose the minimum node f in d_{Sa} and the minimum node h in d_{Da}. Node f, which is one node of S, then searches for the optimal path forward. Node$h$, which is one node of D, searches for the optimal path backward. When precursor nodes f^* and h^* of nodes f^* and h, respectively, are found, $p_{Sf} = f^*, p_{Df} = h^*$ flag bit f for flag node $m = 1$, and flag bit n is constant. Flag bit h for flag node $n = 1$, and flag bit m is constant.

(4) Identify the flag bits of the new tag nodes f and h: If $f(m = 1, n = 0)$ and $h(m = 0, n = 1)$, go to step (5); If $f(m = 1, n = 1)$ or $h(m = 1, n = 1)$, determine whether the two processes has one starting node and one destination node. If neither node is a starting node or a destination node, go to step (6);

If either node is a starting node or a destination node, the two subprocesses of the forward and reverse seek do not meet. Proceed to step (7).

(5) If node f and node h are connected but the tagged unlabeled node is added to linked list v and linked list w, delete node $f$and node h in list v and list w. Return to step (2).

(6) If node$f(m = 1, n = 1)$, find its predecessor node f^*, and set $d_{SD} = d_{Sf^*} + d_{f^*f} + d_{Df}$. If node $h(m = 1, n = 1)$, find its predecessor node h^*, and set $d_{SD} = d_{Sh} + d_{h*h} + d_{Dh^*}$. The d_{SD} is then the optimal path length from S to D.

(7) If the positive search and reverse optimization of the two sub-processes do not meet, obtain the optimal forward paths d^1_{SD} and d^2_{SD}, respectively. The min (d^1_{SD}, d^2_{SD}) is the

TABLE 2. Statistical table of S-D

Path name	The number of times it is used	The frequency it is used/%
R1	5	50
R2	4	40
R3	4	40
R4	4	40
R5	5	50
R6	4	40
R7	3	30
R8	2	20
R9	3	30
R10	3	30
R11	4	40
R12	5	50

shortest distance, and the corresponding subroutine optimal path is the optimal path between the final points.

Note: When there are more than one minimum node h or f the points of the calculate the minimum points of leading points h^* and f^*. Set the minimum value of the point as the precursor point. Further calculations are analogous to this method.

5. **Real-time Available Path Corrections.** When the optimal path obtained by the system is used by emergency communications rescue workers, the system continues to use real-time image information to calculate and revise the emergency path to the disaster site. The site of a severe dis-aster area is expected to have a visual blind area, which causes uncertainty. The system must use real-time information about actual traffic conditions to predict whether the emergency path can go through each section of the blind area. Real-time information collected by various communications vehicles, unmanned aerial vehicles, communications personnel and rescue teams is used for vehicle routing. Table 1 shows the statistical results obtained by applying formula (1), and Table 2 shows the probabilities.

$$P_{R(i)} = \frac{N_{R(i)}}{N_w} \times 100 \tag{1}$$

In formula (1), $P_{R(i)}$ is the probability that the $i - th$ link is used ($i = 1, 2, 3, ..n$); $N_{R(i)}$ is the times that the $i - th$ link is used; and N_W is the total number of replaceable links. According to the probability calculations shown in Table 2, the paths that have the highest use counts and the highest use frequencies are R1, R2, and R3. Therefore, the status of the traffic path is known, and this information is used to calculate the passability of the traffic path.

6. **Case Analysis.** The effectiveness of the earthquake emergency path selection method was veri-fied by performing simulations under varying earthquake intensities in the daily emergency rehearsal of emergency communication vehicles in Fujian earthquake bureau. Because of the complex topography and geomorphology in Fujian province, many factors affect road conditions under disaster conditions. The landforms in-volved in this experiment were selected according to common geomorphic conditions of roads in Fujian province (including bridges, tunnels, roadside landslides, rivers, etc.) and according to the practical value of the historical situation (three earthquakes of magnitude 4 or higher

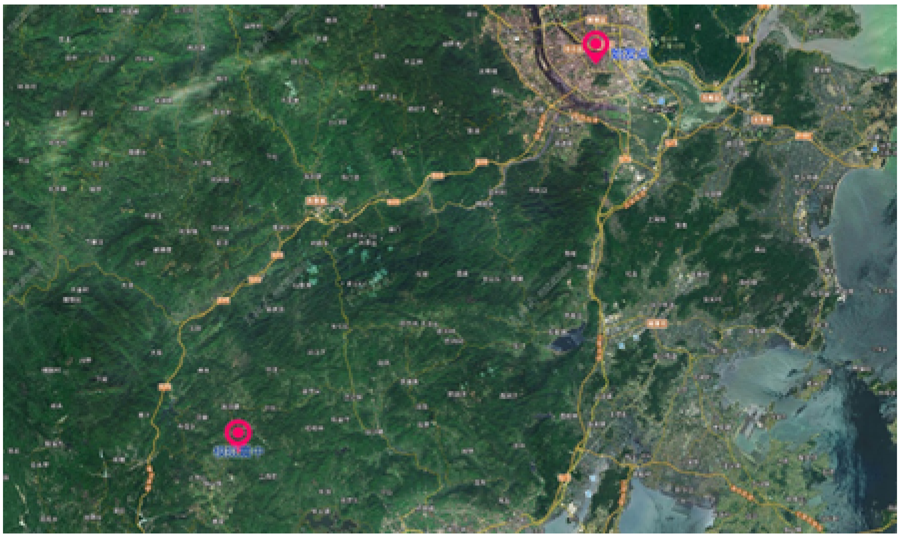

FIGURE 3. Satellite image of test area

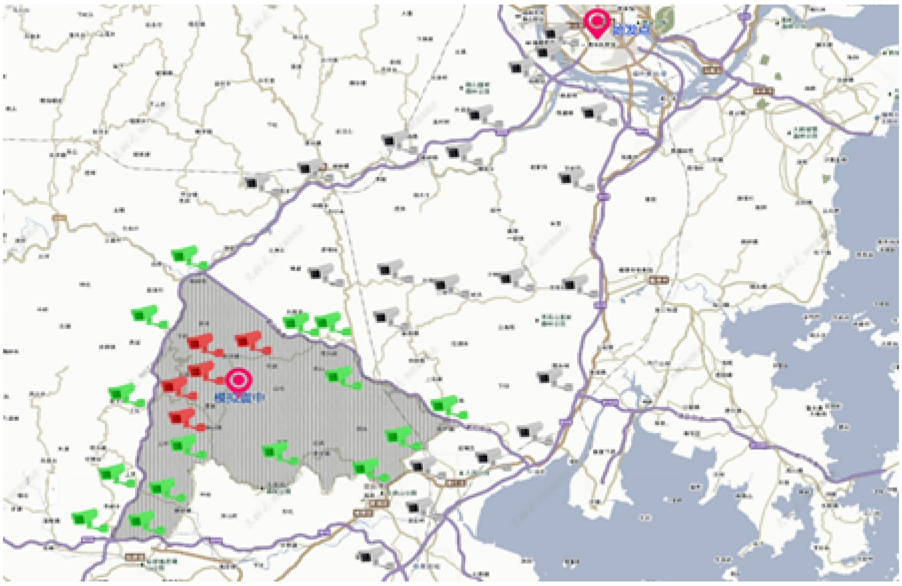

FIGURE 4. Map of the Global Eye blind area

occurred in 2013). The counties of Putian Xianyou Shi Cang were the selected sites for simulation of an earthquake disaster. The path selection procedure used in the experiment was performed as follows. Figure 3 shows a satellite image of the test area selected for the experiment Figure 4 shows the Global Eye blind area simulated by the test system in the case of a severe earthquake disaster. Figure 5 shows a reconstruction of the network structure in the blind area. The numbers in parentheses are the number of passes of unit time of the paths used by the test system. Figure 6 shows the optimal path given by the system after calculation. To compare the effectiveness of the proposed traffic path analysis system, a simulation was performed to compare three simultaneously departing vehicles: one emergency communication vehicle and two privately owned vehicles. The optimal route recommended by the system for emergency communications vehicles. The two privately owned vehicles had similar performance, but one was equipped with a general vehicle navigation and one was not. After the simulated disasters, the three vehicles started from the emergency command building of the Fujian Seismological Bureau.

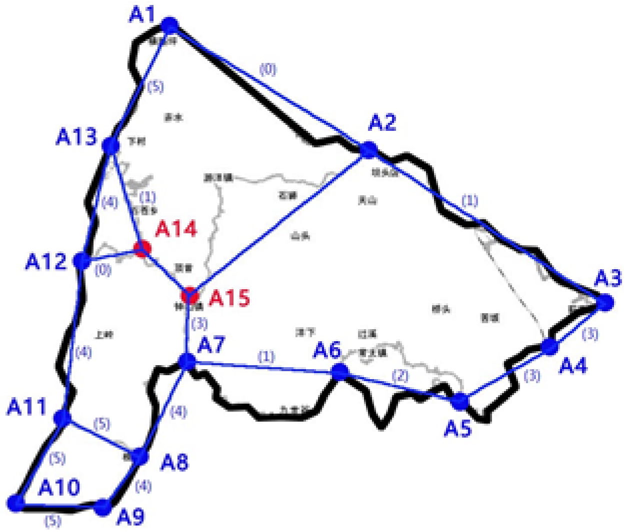

FIGURE 5. Structural model showing road network in the blind area

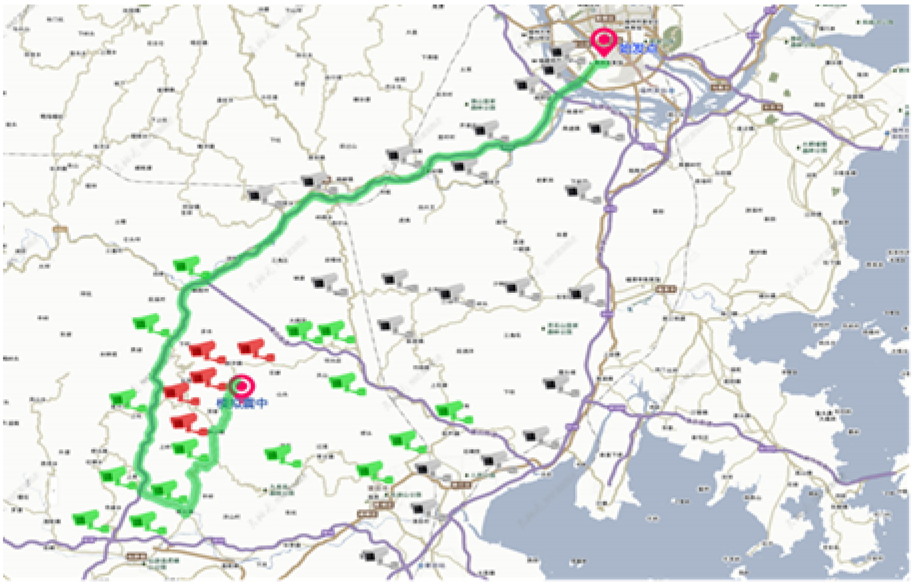

FIGURE 6. Optimal path

Table 3 compares the driving times from the starting point to the destination point (Fujian Province, Xianyou County, Putian ShiCang County).

The experimental data in the table reveal that, for all four simulated disaster conditions, the emergency communication vehicle had a shorter driving time com-pared to the other two vehicles. Additionally, the difference in driving time increased as the severity of the earthquake increased.

7. **Conclusion.** The key factor in the success of an emergency rescue after a severe earthquake is the response time of emergency rescue vehicles. For an effective earthquake emergency response, the priority tasks are getting to the disaster site as quickly as possible and establishing communication channels between the emergency rescue vehicle and the command center. To solve this problem, this study developed and applied an emergency traffic path analysis system based on public image information. The broad range of image information used by the system includes not only Global Eye satellite images, but also

Table 3. Comparison of driving times (min)

Simulated disaster situation	Emergency communication vehicle	Car 1 (off-line navigation)	Car 2 (online navigation)
Low intensity without blind spot	228	245	233
Concentration in the small range of blind spots	238	292	250
High intensity with narrowly distributed blind spots	245	310	295
High intensity with widely distributed blind spots	264	351	343

real-time images acquired by personal and vehicular 4G networks, from maritime and vehicular satellite telephone networks, and from unmanned aerial vehicles. The traffic path optimization performed by the system considers existing road characteristics and road repairability. An improved bidirectional Dijkstra path optimization algorithm and a real-time dominant path correction method are used to obtain the optimal path solution after an earthquake. After further refinement, application of the proposed system will greatly improve efficiency in optimizing emergency traffic paths to earthquake disaster sites. Implementation of the system would improve efficiency and cooperation in the use of field rescue equipment and manpower. The system would also improve the [safety scheduling technology level not clear] of emergency vehicles and personnel. Finally, the pro-posed system for using public image information technology to improve the efficiency of emergency response to earthquakes has potential applications in other disasters that require a rapid response by emergency vehicles.

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