USING AUGMENTED-REALITY AND MOBILE THREE-DIMENSIONAL GRAPHICS TECHNIQUES IN RELIEF WORK ON RADIOLOGICAL DISASTER SITES

by

Ming-Kuan TSAI* * *and Nie-Jia YAU

Research Center for Hazard Mitigation and Prevention, National Central University, Taoyuan, Taiwan

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Many countries tightly manage and monitor various radiological sources and facilities, yet some serious radiological disasters still occurred in recent decades. In order to reach effective relief work on radiological disaster sites, numerous information techniques have become popular, *i. e.* global positioning system, geographical information system, computer simulation, and three-dimensional graphics. However, this study recognizes insufficient information service in global positioning system and geographical information system and inconvenient information operation in computer simulation and three-dimensional graphics. Therefore, this study adopts augmented-reality and mobile three-dimensional graphics techniques to construct a mobile relief work system. This system helps relief workers to comprehend the spatial relationship among their localities, the targeted constructions, and the anticipated shelters. Based on the testing results regarding escaping victims, through the mobile relief work system in contrast to a Google maps-based system, relief workers more easily arrive at the targeted constructions, and more rapidly seek the anticipated shelters. In sum, this study is useful for similar applications in disaster management.

Key words: augmented-reality, disaster management, geographical information system, global positioning system, radiological disaster, three-dimensional graphic

INTRODUCTION

In the past, protecting radiological sources and facilities was an important priority worldwide. Yet, several radiological accidents still happened, and became unfortunate disasters. For example, an explosion caused the Chernobyl nuclear power plant accident in Ukraine in 1986 and an earthquake triggered the Fukushima Daiichi nuclear power plant accident in Japan in 2011. The International Nuclear and Radiological Event Scale [1] shows that these two radiological disasters reached the worst condition and that many countries and civilians were exposed to the widespread radiological materials. The ecological environment was contaminated and there were economic losses of tens of billions of dollars.

In order to decrease the impact of radiological disasters, disaster management has become important. Many researchers [2-4] point out that the use of information technology is a good solution to lessen the likelihood of radiological disasters, provide emergency assistance during radiological disasters, and return radiological disaster sites to their original status. Therefore, numerous information systems have been constructed to effectively manage and monitor radiological activities, such as RODOS in the European Community, SPEEDI in Japan, and AtomCARE in Korea [5]. If radiological disasters occur, these information systems quickly offer disaster information to government agencies and disaster managers [2, 6].

Moreover, regardless of whether radiological disasters are caused by natural or human-made events, a speedy disaster response is necessary. For such response, several information techniques have become popular, *i. e.* global positioning system (GPS), geographical information system (GIS), computer simulation, and three-dimensional (3-D) graphics [2]. Owing to the information techniques, disaster managers although in response centers, accurately comprehend the progress of disaster response in real time. However, relief workers have difficulty applying the same information techniques on disaster sites. Such a situation influences the cooperation between disaster managers and relief workers. Therefore, this study focuses on the recognized problems that hinder relief workers from relief work, especially for escaping victims and inspecting radiological dose.

* Corresponding author; e-mail: twmktsai@ms95.url.com.tw

In the remaining parts of this article we present literature review of the common information techniques used in radiological disasters, we study problems that affect relief work on disaster sites and propose an approach, implementation and testing. After that we present a number of discussions and summarize the findings. Overall, this study is a helpful reference for similar applications in disaster management.

LITERATURE REVIEW

Many information techniques help relief work associated with radiological disasters, as GPS, GIS, computer simulation, and 3-D graphics.

GPS and GIS

For many disasters, relief work is most effective in the first 48 hours [3, 7, 8]. When disaster managers completely understand the correlated information regarding radiological disaster sites and the affected areas (*e. g*., population, shelters, hospitals, spatial locations), they are able to rapidly draft response strategies (*e. g*., allocating first-aid resources and establishing temporary medical centers). In contrast to either textual or numerical information descriptions, displaying the anticipated information through a clear method enhances relief work [6, 9]. The integration of GPS and GIS meets such a requirement, since GPS identifies the accurate localities of radiological disasters and GIS provides a wide range of information acquisition [4].

A number of studies reported the effectiveness when using GPS and GIS in radiological disasters. For example, Battista [10] showed a GIS-based model that was useful to assess the health and environmental risks resulting from the Chernobyl accident. In order to assist disaster managers against radiological disasters, Han *et al*. [11] established a near range model to evaluate radiological dose and presented the results on GIS. Mabit and Bernard [12] highlighted the potential when integrating geostatistics and variography to establish and map the pattern of ^{137}Cs redistribution. The Institute for Information Design Japan [13] constructed a Web- and GIS-based information system (*i. e*., Japan Radiation Map) to provide consistent and comprehensive information representation regarding radiological measurements.

Computer simulation and 3-D graphics

Depending on distance and time, the distributions of radiological dose on disaster sites are different. For example, tripling the distance from the radiological source reduces the dose rate to one ninth [14]. Disaster managers could assess the on-site radiological situation via monitoring data, and make emergency health protection decisions. When the monitoring data is sparse or the measured quantity is inappropriate, using computer simulation (*e. g*., model predictions and statistical analysis) is an alternative to improve the understanding of the limited monitoring results [15-17]. Moreover, in order to assist disaster managers to comprehend the obtained disaster information, visualizing analysis results through 3-D graphics have frequently been used, such as hue and saturation of color, alterations in focus and resolution, broken lines, sharpness of pattern, and overlaying geometries [18].

Some examples are as follows: In the early phase of an accidental release of radioactivity to atmosphere, Haywood [4] proposed an approach to assess the imprecision associated with radiological dose and emergency countermeasure predictions. Na *et al*. [19] adopted artificial neural network-based algorithms to analyze the major severe nuclear power plant accidents, and concluded there were two main causes (*i. e*., inappropriate power plant operators and inactive power plant safety). Based on a radioecological software package, Velasco *et al*., [20] explored the behavior of radionuclides in semi-natural environments and assessed the consequences of exposure for the population. De Almeida Silva *et al*., [21] used agent-based systems to simulate radiological accidents, and to evaluate the consequences of accident contaminations.

STUDY PROBLEMS

Based on the literature review, fig. 1 illustrates the co-operation between disaster managers and relief workers during radiological disasters. While aiming at disaster sites via GPS, disaster managers use GIS to investigate necessary information, execute computer simulation to evaluate radiological dose, and apply 3-D graphics to show the analysis results. In the meantime, relief workers prepare relief work and move to disaster sites. Since relief workers deploy to various affected areas and relay the collected disaster information, disaster managers comprehend the status regarding relief work.

However, this study recognizes two main problems.

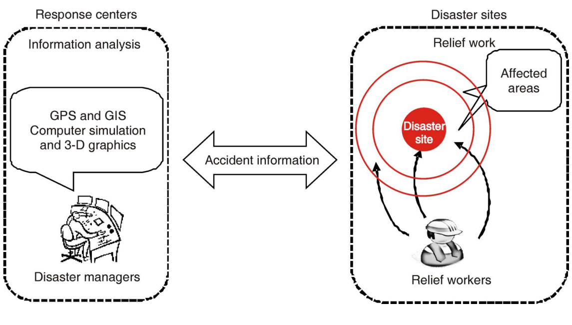


Figure 1. Co-operation between disaster managers and relief workers

Insufficient information service in GPS and GIS

In order to successfully arrive at disaster sites, relief workers benefit from the integration of geographical information, electronic maps, and mobile devices [2]. For example, when relief workers attempt to understand the pathways from their locations to disaster sites, they could immediately obtain assistance through route planning in Google maps. However, because of some causes (*e. g*., bad visibility at night, ambiguous geographical information in developing countries), relief workers still spend much time looking for the correct pathways [3]. For instance, if radiological disasters associate with nature disasters (*e. g*., earthquakes and tsunamis), the appearance in the real world may differ from the obtained geographical information.

Moreover, some GIS-based applications merely show 2-D/3-D objects instead of the details (*e. g*., floor-plan and structural designing drawings); and some GPS-based applications work well only in outdoor environments [22]. Therefore, when relief workers evacuate victims from some constructions (*e. g*., multistory buildings and large-area constructions), they have difficulty in identifying the indoor shelters. In other words, although relief workers successfully arrive at a targeted construction on a disaster site, they still waste time seeking the shelters and victims. For example, if a school has three underground shelters, relief workers cannot easily understand the correct locations of the shelters through Google maps and GPS. Obviously, insufficient information service for relief workers needs improvement.

Inconvenient information operation in computer simulation and 3-D graphics

Radiological materials would be adsorbed onto construction components (*e. g*., roofs, windows, walls). The semi-collapsed construction components also provide crevices for the permeation of radionuclides [23]. Disaster managers may ask relief workers to validate the assessment of radiological dose, particularly in densely-populated cities. Recently, various monitoring sensors (*e. g*., seismometers and surveillance facilities) were installed in many constructions. Through the integration of the monitoring sensors and computer-aided-design (CAD)-based applications, disaster managers can comprehend the extent of damage for constructions, since the detected damage is displayed on structural design drawings.

However, relief workers cannot move rapidly to the specified spots to inspect the radiological dose. Since many CAD-based applications are designed for computers and laptops [24], relief workers either have no devices to access structural design drawings, or may be unfamiliar with the CAD-based applications. As a result, relief workers need to wait for inspection guidance from disaster managers. For example, if radiological sources are exposed to an open environment that is similar to the radiological disaster in Goiania, Brazil, in 1987, the radiological dose injures numerous people. For decontamination, disaster managers have to inform relief workers of the inspection spots by delivering the structural designing drawings that are captured from the CAD-based applications. In other words, relief workers meet inconvenient information operation on disaster sites.

In sum, offering sufficient information service and convenient information operation would smoothen on-site relief work and enhance the cooperation between disaster managers and relief workers.

APPROACH

For the recognized problems, this study proposes an approach and constructs a mobile relief work system that consists of two information techniques. This system would work on mobile phones, since power supply has always been a constraint on disaster sites [25]. In contrast to computers and laptops, mobile phones are convenient, slim, handy, and have low-power consumption, since relief workers may have brought numerous facilities for relief work. Relief workers could easily capture, manipulate, analyze, and access data on disaster sites. The two adopted information techniques include, augmented-reality and mobile 3-D graphics.

Augmented-reality

Collecting information on the characteristics of buildings and lifelines through full ground surveys can be very costly and time-consuming [2]. In order to offer clear information descriptions based on the locations of relief workers, augmented-reality (AR) is a useful solution [26]. For an AR-based application in this study, eq. 1 shows the algorithm and operational philosophy

$$\text{Result of } AR \quad [D(P_i, P_j), O_j(l, m, n\dots)] \qquad (1)$$

where P_i is the current global position of the user (*e. g*., longitude and latitude), P_j – the correct global position of a targeted construction, $D(P_i, P_j)$ – the distance from P_i to P_j, and $O_j(l, m, n\dots)$ – the details of the construction (*e. g*., name, description, photo).

In fig. 2, if relief workers want to comprehend nearby constructions (*e. g*., $D(P_i, P_j)$ is 1 kilometer), they use the GPS embedded in their mobile phones to determinate their locations (*i. e*., P_i). After receiving the positioning information, the AR-based application

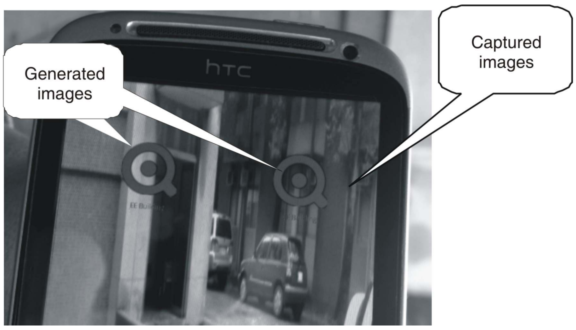


Figure 2. Operational philosophy of AR

identifies the targeted constructions (*i. e.*, P_j), acquires the correlated information from databases *i. e.*, $O_j(l, m, n…)$, and generates various visual images. The AR-based application then captures the peripheral images through the cameras embedded in the mobile phones. When the AR-based application overlaps the generated images and the captured images, the relief workers understand the spatial relationship between their locations and the nearby constructions, even at night or in poor weather. Insufficient information service would obtain supplements.

Mobile 3-D graphics

In order to offer a realistic way of visualizing the real world, along with the potential for direct user interaction and engagement, the application of mobile 3-D graphics is appropriate [27-29]. Due to the rapid development of hardware and software for mobile phones, various constraints on mobile 3-D graphics (*e. g.*, data processing units and programming standards) are improved [30]. Unlike numerous fields (*e. g.*, urban management and product manufacturing), a few mobile 3-D-graphics-based applications are used in radiological disasters. When the mobile relief work system supports the mobile 3-D graphics, relief workers would have many opportunities to execute computer simulation and 3-D graphics during relief work on disaster sites.

If relief workers enter constructions, eq. 2 shows that the mobile relief work system can transfer CAD-based structural design drawings into 3-D graphics objects.

$$\text{Result of a 3-D graphics object} = \\ = [O_i(\text{vertex, element, render})] \quad (2)$$

where O_i is a 3-D graphics object for a targeted construction, vertex, element, and render are the parameters for O_i, vertex involves geometry, texture, rotation, and degree data, element includes point, line, curve, and surface data, and render indicates bevel, color, material, and shadow data. More importantly, in order to avoid that GPS may not work well at indoor environments, based on accelerometer sensors embedded in mobile phones, the mobile relief work system can automatically rotate 3-D graphics objects (eq. 3) while relief workers are moving. Such integration can appropriately display the indoor layouts of various constructions.

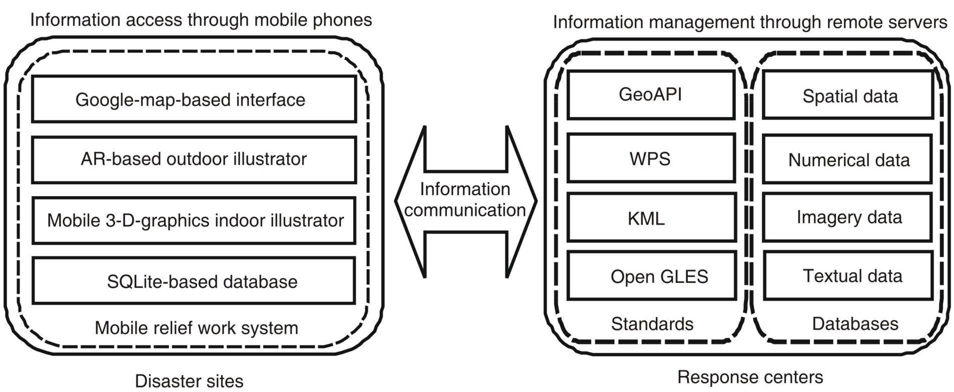
$$\text{Rotation of a 3-D graphics object} = [O'_i\,(angle)] \quad (3)$$

where O'_j is a rotated 3-D graphics object, and *angle* – the orientation difference between the north in the Earth and the targeted construction. Therefore, relief workers effectively access and operate 3-D graphics objects through the gesture and the touch-enabled screens embedded in mobile phones [31]. Inconvenient information operation would be improved.

IMPLEMENTATION

When relief workers use the mobile relief work system, the system framework (fig. 3) shows that the information flowchart between disaster sites and response centers includes two information activities (*i. e.*, information access and information management). In the meantime, information communication connects the two information activities. Since the mobile relief work system works on the Google Android-based platform and the remote servers are the

Figure 3. Framework of the proposed approach



Microsoft Windows Server and SQL Server, with the necessary system components, this study uses the Google Android development toolkits (*e. g.*, designing user interfaces, coding global positioning modules, and configuring information representation via Java programming language) [32] and Microsoft ASP.NET toolkits (*e. g.*, compiling communication protocols, analyzing data attributes, and synchronizing multiple databases via Visual C#.NET programming language) [33].

For information access, fig. 3 indicates that the mobile relief work system presents the specified geographical information on a Google maps-based user interface, and offers two system functions (*i. e.*, AR-based outdoor illustrator and mobile 3-D-graphics indoor illustrator). During relief work on disaster sites, fig. 4 shows that the AR-based outdoor illustrator assists relief workers to arrive at the targeted constructions. For instance, relief workers would move to a 10-floor building. After identifying the current global position, the AR-based outdoor illustrator displays the distance, pathway and direction from the location to the targeted construction (fig. 4). Based on the guidance, relief workers could arrive at the 10-floor building. Since the information representation is combined with the periphery images, the relief workers may not be confused by the nearby environment.

Moreover, when relief workers arrive at the targeted constructions, fig. 5 shows that the mobile 3-D-graphics indoor illustrator helps to find the shelters where victims exist or the inspection spots where radiological dose reaches the state of alert. For example, in a hospital (fig. 5), the mobile 3-D-graphics indoor illustrator presents the structural design drawings and introduces various floors. If relief workers

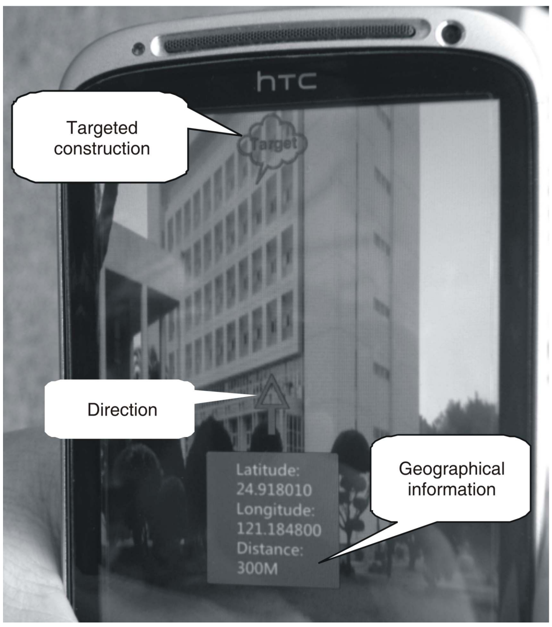


Figure 4. Screenshot for AR-based outdoor illustrator

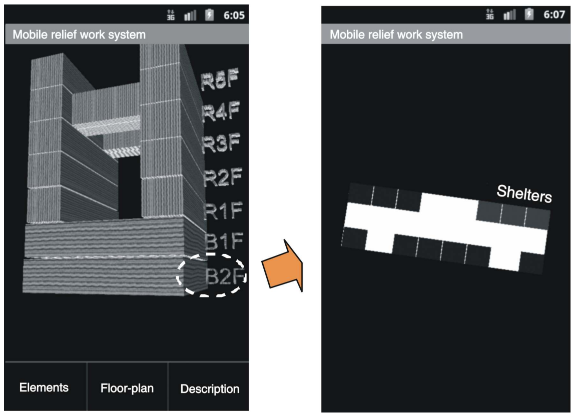


Figure 5. Screenshot for mobile 3-D-graphics indoor illustrator

select a floor, they could zoom-in/out the floor-plan drawing to confirm the pathway from their locations to the anticipated places. By considering that frequent information communication may overload with the mobile relief work system, this study embeds a mobile database (*i. e.*, SQLite-based database) to store temporary data.

Because of the rapid changes on disaster sites, the remote servers transfer various data to the mobile relief work system, including spatial, numerical, imagery, and textual data. Therefore, information management would rely on the remote servers. For example, in the remote databases, this study saves spatial data that identifies the global position of numerous constructions, 3-D graphics objects that display the structural design and floor-plan drawings of the constructions, and textual information descriptions that explain the pathways from the constructions to the shelters. Relief workers could correctly evacuate victims when utilizing the spatial data, imagery data, and textual data from the remote servers.

In order to ensure that the required data could be exchanged among a number of information systems and monitoring sensors, the remote servers support some information standards. These standards involve the GeoAPI for manipulating geographical information based on the international standards, the web processing service (WPS) for standardizing geospatial processing services, the keyhole markup language (KML) for expressing geographical annotations and visualization, and the OpenGL ES for displaying 3-D graphics on mobile phones [34, 35].

TESTING

Six relief workers, who were classified into two groups, participated in this study. For the two groups, the identical mobile phones (*i. e*., HTC Sensation XE) were used in the tests. The operation system of HTC Sensation XE was Google Android Version 4.0. Also, because of the embedded graphic processing unit, and global positioning and accelerometer sensors, the mobile relief work system worked well on this mobile phone. During a simulated scenario, the radiological disaster was defined as a serious accident – namely, radiological materials were widely spread in the atmosphere and some civilians were dead. The relief workers needed to evacuate victims from three constructions, including a hospital, a school, and a 10-floor building. The shelters were in different locations of the three constructions. The shelter of the hospital existed on the south side of the second underground floor; that of the school was in the north-side of the first underground floor; and that of the 10-floor building was located on the east side of the sixth floor.

The operational information systems for relief work were Google maps-based system (fig. 6) and mobile relief work system. Rather than the mobile relief work system, the relief workers performed the tests through route planning in Google maps. In order to understand the difference when relief work was processed during different periods, this study performed the tests in daytime and at night, and measured the using time based on two stages. In one stage (Outdoor), the relief workers moved from a specified location to the targeted constructions; the other (Indoor) was from when the relief workers arrived at the constructions until they successfully found the shelters.

Table 1 shows that the two groups completed the tests. According to the testing results, for the Google Maps-based system in daytime, relief workers spent 25, 31, and 29 minutes in arriving at each of the three constructions. When entering the constructions, the relief workers needed 12, 18, and 17 minutes, respectively, to find the shelters. In the same tests at night, although the relief workers spent more time (31, 38, and 33 minutes) to arrive at the constructions, the time needed to seek the shelters was less 9, 14, and 17 minutes, respectively. Regarding the mobile relief work system in daytime, the relief workers used 19, 24, and

Figure 6. Screenshot for Google maps-based system

21 minutes when arriving at the constructions, and required 7, 16, and 14 minutes, respectively, when seeking the shelters. At night, the relief workers also needed more time (24, 28, and 23 minutes) to move to the constructions, and spent less time (6, 12, and 14 minutes) looking for the shelters.

By comparing the two systems, this study recognized that three variables affected the testing results – testing environment, testing period, and experience. For the testing environment, the relief workers spent more time in the outdoor environment regardless whether daytime or night, since the distances from the outdoor locations to the constructions were longer than those from the constructions to the shelters. Also, when the relief workers sought the shelters, the floor areas of the constructions affected the using time. For

Table 1. Testing results

	Google maps-based system				Mobile relief work system			
Mobile phone	HTC sensation XE				HTC sensation XE			
Period	Daytime		Night		Daytime		Night	
Completing tests	Yes		Yes		Yes		Yes	
	Using time [min]				Using time [min]			
Constructions (shelters)	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor
A hospital (2nd underground floor)	25	12	31	9	19	7	24	6
A school (1st underground floor)	31	18	38	14	24	16	28	12
A 10-floor building (6th floor)	29	17	33	17	21	14	23	14
Average	28.3	15.7	34	13.3	21.3	12.3	25	10.7

example, the area of the school was wider than that of the hospital and the 10-floor building, so the relief workers spent more time completing the test.

When the testing period was considered, the relief workers needed more time at night than in daytime. However, the testing period merely influenced the outdoor testing environment. In other words, the relief workers used more time during the outdoor tests at night because they had bad visibility. Furthermore, the experience decreased the using time for relief work in the indoor environment. Since the tests at night were the second testing, the relief workers might finish the tests based on their previous memories. Therefore, frequent training of relief workers is important for relief work. In average, the efficiency of the mobile relief work system was better than that of the Google maps-based system.

DISCUSSION

After the testing, this study discussed the advantages and limitations of the mobile relief work system, including the on-site information requirements and the mobility for relief work.

Fulfilling the on-site information requirements

This study integrates various information techniques and standards in the proposed approach. Relief workers could use the mobile relief work system to access the necessary on-site information in real time. When relief workers more clearly understand disaster information, they may more easily resolve numerous unexpected conditions on disaster sites. For example, relief workers could comprehend the spatial relationship among their locations, the targeted constructions, and the anticipated shelters. Therefore, relief workers can focus on evacuating victims and assessing radiological dose instead of information operation.

Although the databases involved in the proposed approach have stored a great quantity of data for relief work, it is difficult to predict when and where a radiological disaster may occur. Continuously maintaining the databases, particularly the data regarding radiological facilities and the nearby areas, helps to provide accurate information if a radiological disaster occurs. Moreover, because of some causes (*e. g*., on-site status, government policies), the mobile 3-D-graphics indoor illustrator offered limited information regarding various constructions. For example, the mobile relief work system did not support any radioactivity detectors. If radiological dose distributes unevenly at a disaster site, it may be unsafe that relief workers rashly rescue victims, who have no protection facilities, through any pathway unauthorized by government agencies. Overcoming the aforementioned limitation (*e. g*., connecting to radioactivity detectors, optimizing routes) is necessary to increase the effectiveness of the mobile relief work system.

Ensuring the mobility for relief work

In contrast to disaster managers who are in response centers, the mobility is more important for relief workers who are on disaster sites. Since disaster managers need relief workers to report the latest disaster information on the go, this study enables relief workers to perform information access and communication through mobile phones. Accompanying the mobile relief work system, the co-operation between disaster managers and relief workers is seamless. For example, when relief workers move to specified constructions, they may collect disaster information and relay the collected information synchronously. Based on the received information from various relief workers, disaster managers could make appropriate decisions for relief work.

However, during radiological disasters, mobile phones may fail or be out of service in extreme situations. For example, in order to disrupt the channels for information communication, terrorists may attack numerous base stations. Moreover, since the adopted AR technique requires the cameras embedded in mobile phones, power consumption would increase. The two known limitations may reduce the mobility of the mobile relief work system. Since this study tended to explore the potential when applying AR and mobile 3-D graphics techniques for radiological disasters, the usability of the mobile relief work system still needs various experiments. Proposing the correlated approaches for the two limitations is an important issue for this study.

CONCLUSIONS

Respecting the fact that several radiological disasters have occurred, many countries spend various resources on managing radiological sources and facilities, such as establishing monitoring equipment and developing radiological information management systems. Accidents caused by natural and human-made events cannot be completely prevented, and radiological disasters may still occur suddenly. During radiological disasters, effective relief work abridges the losses. However, although numerous information techniques are available in relief work, this study recognizes insufficient information service in GPS and GIS and inconvenient information operation in computer simulation and 3-D graphics.

For the two problems, this study applies AR and mobile 3-D graphics techniques to construct a mobile relief work system. Based on the testing results, the mobile relief work system offers information representation more clearly, in contrast to a Google maps-based system. Through the proposed approach, relief workers easily arrive at the targeted constructions, and rapidly seek for the shelters. This study not only enhances the efficiency of relief work on disaster sites, but also presents a useful reference for disaster management. For future research, in addition to improving the limitations described in the discussion, introducing the mobile relief work system in various disaster training courses would assist relief workers to enrich their experiences regarding relief work.

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AUTHOR CONTRIBUTIONS

Introduction, literature review, study problems, implementation, and testing were carried out by M. K. Tsai, while N. J. Yau concluded the findings. The manuscript was written by M. K. Tsai and N. J. Yau. The figures and tables were prepared by M. K. Tsai.

REFERENCES

[1] ***, The international Nuclear and Radiological Event Scale, International Atomic Energy Agency, 2008, http://www.iaea.org/Publications/Factsheets/English/ines.pdf

[2] Montoya, L., Geo-Data Acquisition through Mobile GIS and Digital Video: An Urban Disaster Management Perspective, *Environmental Modelling & Software, 18* (2003), 10, pp. 869-876

[3] Farthing, D. W., Ware, M., When it Comes to Mapping Developing Countries, Disaster Preparedness is Better than Disaster Response, AGI GeoCommunity "10: Opportunities in a Changing World 'Innovate – Connect – Succeed", 2010

[4] Haywood, S. H., A Method for Displaying Imprecision in Early Radiological Emergency Assessments, *Journal of Radiological Protection, 30* (2010), 4, pp. 673-685

[5] Han, M. H., *et al*., Development of Radiological Dose Assessment Systems to Support a Radiological Emergency Preparedness in Korea, *Annals of Nuclear Energy, 43* (2012), pp. 187-191

[6] Bonniface, J., Coppins, G. J., Particle Data Management – Turning Data into Accessible Information, *Journal of Radiological Protection, 27* (2007), 3A, pp. A77-A87

[7] Musolino, S. V., Harper, F. T., Emergency Response Guidance for the First 48 hours after the Outdoor Detonation of an Explosive Radiological Dispersal Device, *Health Physics, 90* (2006), 4, pp. 377-385

[8] Tsai, M. K., *et al*., Integrating Four-Dimensional Geographical Information and Mobile Techniques into Radiological Accident Emergency Response Training, *Nucl Technol Radiat, 27* (2012), 1, pp. 84-92

[9] Solaimani, K., *et al*., Flood Occurrence Hazard Forecasting Based on Geographical Information System, *International Journal of Environmental Science and Technology, 2* (2005), 3, pp. 253-258

[10] Battista, C, Chernobyl: GIS Model Aids Nuclear Disaster Relief, *GIS World, 7* (1994), 3, pp. 32-35

[11] Han, M. H., *et al*., Development of a Real-Time Radiological Dose Assessment System, Korea Atomic Energy Research Institute, 1997

[12] Mabit, L., Bernard, C., Assessment of Spatial Distribution of Fallout Radionuclides through Geostatistics Concept, *Journal of Environmental Radioactivity, 97* (2007), 2, pp. 206-219

[13] ***, Institute for Information Design Japan, Japan Radiation Map, 2012, http:// jciv.iidj.net/map/

[14] Mettler, Jr. F. A, Voelz, G. L., Major Radiation Exposure – what to Expect and How to Respond, *New England Journal of Medicine, 346* (2002), 20, pp. 1554-1561

[15] Gering, F., *et al*., Assessment and Evaluation of the Radiological Situation in the Late Phase of a Nuclear Accident, *Radiation Protection Dosimetry, 109* (2004), 1-2, pp. 25-29

[16] Huang, G. H., *et al*., Policy Planning under Uncertainty: Efficient Starting Populations for Simulation-Optimization Methods Applied to Municipal Solid Waste Management, *Journal of Environmental Management, 77* (2005), 1, pp. 22-34

[17] El Harbawi, M., *et al*., Rapid Analysis of Risk Assessment Using Developed Simulation of Chemical Industrial Accidents Software Package, *International Journal of Environmental Science and Technology, 5* (2008), 1, pp. 53-64

[18] Bero, M. A, Gilboy, W. B., Glover, P. M., An Optical Method for Three-Dimensional Dosimetry, *Journal of Radiological Protection, 20* (2000), 3, pp. 287-294

[19] Na, M. G., *et al*., Prediction of Major Transient Scenarios for Severe Accidents of Nuclear Power Plants, *IEEE Transactions on Nuclear Science, 51* (2004), 2, pp. 313-321

[20] Velasco, H., *et al*., Radioecological Software Package: an Interactive Computational System to Simulate the Behaviour of Radionuclides in Semi-Natural Environments, *Journal of Environmental Radioactivity, 73* (2004), 2, pp. 223-230

[21] de Almeida Silva, T. A., de Farias, O. L. M., dos Santos, N., Simulating Radiological Accidents through Software Agents, International Conference on Computational Intelligence for Modelling, Control and Automation, and International Conference on Intelligent Agents, Web Technologies and Internet Commerce, 2006

[22] Bill, R., *et al*., Indoor and Outdoor Positioning in Mobile Environments – a Review and Some Investigations on WLAN-Positioning, *Annals of GIS, 10* (2004), 2, pp. 91-98

[23] Hong, K. J., Lazaro, M. A., Radiological Assessments for the National Ignition Facility, *Fusion Technology, 30* (1996), pp. 1511-1515

[24] Tsai, M. K., Yau, N. J., Improving Information Access for Emergency Response in Disasters, *Natural Hazards, 66* (2012), 2, pp. 343-354

[25] Davies, M., McCulloch, G., Adsley, I., Experience of Monitoring Beaches for Radioactive Particles, *Jour-*

nal of Radiological Protection, 27 (2007), 3A, pp. A51-A59

[26] Tsai, M. K., *et al*., Integrating Geographical Information and Augmented Reality Techniques for Mobile Escape Guidelines on Nuclear Accident Sites, *Journal of Environmental Radioactivity, 109* (2012), pp. 36-44

[27] Zlatanova, S., Holweg, D., 3-D Geo-Information in Emergency Response: a Framework, *Proceedings*, the Fourth International Symposium on Mobile Mapping Technology, Singapore, 2004

[28] Rindahl, G., Mark, N. K. F., Meyer, G., Virtual Reality in Decommissioning Projects: Experiences, Lessons Learned and Future Plans, Halden VR Centre, Norway, 2006, http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/38/009/38009285.pdf

[29] Coors, V., Synthetic Textures for 3-D Urban Models in Pededstrian Navigation, *Proceedings*, 2008 Conference on Techniques and Applications for Mobile Commerce, UK, 2008, pp. 46-53

[30] Chehimi, F., Coulton, P., Edwards, R., Advances in 3-D Graphics for Smartphones, *Proceedings*, Information and Communication Technologies, Switzerland, 2006, pp. 99-104

[31] Burigat, S., Chittaro, L., Location-Aware Visualization of VRML Models in GPS-Based Mobile Guides, *Proceedings*, Tenth International Conference on 3-D Web Technology, UK, 2005, pp.57-64

[32] ***, Get the Android SDK, Google, Inc., 2013, http://developer.android.com/sdk/index.html

[33] ***, Microsoft ASP.NET Using Visual C#.NET, Microsoft, Inc., 2013, http://www.microsoft.com/en-us/download/details.aspx?id=16870

[34] ***, OpenGL ES – The Standard for Embedded Accelerated 3-D Graphics, Khronos, 2012, http://www.khronos.org/opengles

[35] ***, OGC Standards List, Open Geospatial Consortium, 2012, http://www.opengeospatial.org/standards/is

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Минг-Куан ЦАИ, Ние-Ђиа ЈАУ

КОРИШЋЕЊЕ ВИРТУЕЛНЕ СТВАРНОСТИ И МОБИЛНИХ 3-D ГРАФИЧКИХ ТЕХНИКА У РАДУ НА ОБНАВЉАЊУ ЛОКАЦИЈА РАДИОЛОШКИХ КАТАСТРОФА

Многе државе баве се строгим управљањем и надгледањем различитих радиолошких извора и постројења, па ипак, у последњим деценијама и даље су се дешавале озбиљне радиолошке катастрофе. Како би се постигло делотворније обнављање на местима акцидената, бројне информационе технике увелико се користе: систем глобалног позиционирања (ГПС), географски информациони систем (ГИС), компјутерска симулација и 3-D графика. У овом раду указано је на недовољности ГПС и ГИС информационих сервиса и непогодности у рачунарским симулацијама и 3-D графици. Стога су у овом проучавању усвојене технике виртуелне реалности и мобилне 3-D графике за изградњу мобилног система обнављања. Систем помаже радницима на испомоћи да савладају просторне односе између локација, циљаних објеката и жељених склоништа. На основу резултата тестова који се тичу умицања жртава, помоћу овог мобилног система, насупрот систему заснованом на мапирању преко Гугла, радници који се баве санацијом могу лакше стићи до циљаних објеката и брже наћи жељена склоништа. Најзад, ово проучавање је корисно и у сличним применама у управљању акцидентима.

Кључне речи: виртуелна реалност, управљање акцидентима, географски информациони систем, систем глобалног позиционирања, радиолошка катастрофа, 3-D графика