www.cafetinnova.org

ISSN 0974-5904, Volume 10, No. 02

DOI:10.21276/ijee.2017.10.0227

International Journal of Earth Sciences and Engineering

April 2017, P.P. 334-340

Research on Key Technology of Life Detection and Rescue Based on Augmented Reality Technology

YONG CHANG AND SHUFANG JIANG

School of Geography and Environment, Shandong Normal University, 88 Wenhuadonglu Road, Jinan 250014, China

Email: *chy.163@163.com, jshfsdnu@163.com*

Abstract: *In this paper, 3D positioning model was presented based on particular life detector in rescue. In this model, GPS receiver and 3D electric compass must be used in order to measure the position and direction information. It is necessary to get more than two sets of position and direction data to ensure the accuracy. The demonstration was done to verify the reliability of this model. The results showed that horizontal accuracy is less than 10 cm and vertical accuracy is less than 20 cm. Finally, this paper presented an assumption of Life Detection and Rescue System (LDRS) based on augmented reality (AR) technology and its preliminary implementation. The hardware of the LDRS may include life detector, GPS receiver, 3D electric compass and Head Mounted Display (HMD).The software of the system is based on improved ARToolKit. ARToolKit is one of the main AR development tools and is open source software, but it is based on computer vision techniques and is not able to receive the sensors data. So this paper proposed a new software framework which is able to receive the data from sensors such as GPS receiver and electric compass. With this system, the rescuer can "see" the survivor in the ruins with HMD and will improve the rescue efficiency greatly. The future work of this study will include two aspects. One is to improve ARToolKit to receive the sensor data, and so it can be used as a tool to construct outdoor AR system. The other is to accomplish the LDRS using the implementation this paper puts forth.*

Keywords: *earthquake rescue, life detection, augmented reality, ARToolKit.*

1. Introduction

"Recent disasters have drawn attention to the vulnerability of human populations and infrastructure, and the extremely high cost of recovering from the damage they have caused"[1]. Some examples include the Wenchuan earthquake in May 2009, Haiti earthquake in January 2010 and the Great East Japan Earthquake in March 2011. In the disaster after an earthquake, it is very important for the rescuer to obtain various types of information as soon as possible. "Quick acquisition of information on the locations of the damaged area, nature of the damage, and locations of debris under which victims are possibly trapped is necessary for rescue strategy planning." [2]. It is necessary to quickly locate and rescue after the earthquake. "The US Federal Government Emergency Response Plan" indicates that the mortality rate will be in a sharp rise after 72 hours for the trapped people after the earthquake [3]. One main problem in the earthquake rescue is the lack of real-time information such as location information and physiological information of the trapped victims [4]. So, how to determine the accurate positioning of survivor and visualized rescue is very necessary and is also a challenge of geographic information science. At present, there are three main search methods which include manual technique, rescue dogs and other search technologies such as acoustic/vibration life detector instrument, optics life detector instrument, infrared life detector instrument, low frequency electromagnetic life detector instrument, and radar life detector instrument, etc. When an earthquake occurs, about 35% of those who are trapped will be rescued by the local community [5]. This is relatively easy because most of the survivors are often shallowly buried, and can be found quickly. But the other victims will be difficult to rescue, because they are trapped under the ruins and must be found by rescue dogs or detector instruments [6]. Though the rescue dogs and life detector instruments are able to find the survivor, they are difficult to determine the accurate three-dimensional position of the survivor. In the rescue of Wenchuan and Yushu earthquakes, accurate positioning to survivor is a great difficulty for rescue workers, which delays the rescue time [7].

Augmented reality (AR) is a relatively new technology which developed with the computer software and hardware. Recent advances of computer and positioning technology make possible AR systems to go beyond indoor applications to support complex analysis, decision-making and governing processes [8]. As a useful visualization technique, AR has been used on terrain simulation [9], city navigation [10], computer assisted surgery [11], education [12], tourism [13], and military [14], etc. As a useful visualization technique, it is possible that AR technology can be used in visualized rescue especially after the earthquake. So if rescuers can "see" the

Received: December 03, 2016; Accepted: February 08, 2017; Published: April 26, 2017
International Journal of Earth Sciences and Engineering, 10(02), 334-340, 2017, DOI:10.21276/ijee.2017.10.0227

buried people directly through augmented reality technology, it is undoubtedly of great help for rescuers.

2. Main Technologies of Search and Rescue after the Disasters

Searching for survivors after a disaster is always a race against time. Life detector can help to search and rescue the trapped people who can still indicate that they are alive. Life detector is capable of detecting these signs of survivor by using special sensors designed to pick up the extremely small vibrations transmitted in solid or gaseous media. The most commonly used life detector appliances may be divided into two categories. One is passive life detection technique such as acoustic life detection system, optical life detection system and infrared life detection system, the other is active life detection technique such as radar life detection system [15]. Each requires special technology and needs trained expert to operate. The details of each technology are as follows.

2.1 Electromagnetic Life Detector Technology

Electromagnetic life detector technology can detect the life information outside walls or under the non-metallic covering when the radar electromagnetic waves pass through the walls and other blocking media. In fact, life detection radar can detect a variety of micro-activities of human life caused by moving, body movement, breathing, heartbeat signs and identify the life signal from these obstacles. The advantage of the electromagnetic life detector technology is the ability to penetrate the shield and to detect the life digital signal after filtering out the environmental signal noise. Electromagnetic reflection waves will be generated during the propagation when they pass through two different media surfaces. The life signal can be detected based on difference between the life and other obstructions.

2.2 Acoustic/Vibration Life Detector Technology

Acoustic/vibration life detector system is constituted by a highly sensitive sensor, a dedicated data acquisition system and multi-functional computer processing system. The basic principle is that small vibration, percussion and calling can be detected and analyzed by special sensor to determine the trapped people location. When they are fully buried under several layers of concrete in the disaster, life detector will provide a very powerful tool to detect and locate victims for research team. By positioning up to six of the sturdy and highly responsive seismic/acoustic sensors of the life detector, it is possible to pick up the minute structural vibrations caused by any victim moving, tapping, scratching or calling out. Since the listening devices require peace while the listening/detection is in progress, so any interruption will be hinder the rescue.

2.3 Optical Life Detector Technology

Optical life detector can observe and look for survivors by optical imaging principle. It consists of the probe, variable-length metal rods and monitor. The probe can pass through the inter-space of ruins and drilling and detect the trapped people's position and life state. But this kind of equipment cannot be used in seamless place, smoke conditions and high temperature place.

2.4 Gas Detector Technology

Gas detector is a device which detects the presence of various gases within an area, often as part of a safety system. Gas detector is mainly composed of three parts: sensing portion, a signal transmission part and a data processing unit. This type of equipment is used to detect a trapped people in the ruins. A gas detector can also sound an alarm to operators in the area where presence of trapped people is occurring, giving them the opportunity to find the trapped people.

In summary, various search technologies have their own advantages and disadvantages. Generally, all of these technologies are able to find the survivor in the ruins, but they are not able to determine the accurate three-dimensional position of the survivor. This may increase the difficulty of digging and delay the rescue. In fact, in the process of search and rescue, the exact location of survivor is very important to rescue workers, because they must determine the environment around the survivor and choose the appropriate way to rescue.

3. Methodology

3.1 Establishment of 3D Positioning Model

According to the theory of space analytic geometry, the linear equation will be identified according to one known point and the direction of this line. We can acquire the coordinates data from GPS and the direction data from electronic compass, then the straight line equation will be established. In theory, if two linear equations are established, the coordinates of the linear intersection (location of trapped people) will be computed (as shown in figure1). The process of establishing linear equation is as follows:

Assume the coordinates of one point in straight line and the direction of it are obtained by sensors, and then the equations of each straight line are established as follows:

$$\frac{x-x_1}{\cos\alpha_1}=\frac{y-y_1}{\sin\alpha_1}=\frac{z-z_1}{\tan\beta_1} \qquad \frac{x-x_2}{\cos\alpha_2}=\frac{y-y_2}{\sin\alpha_2}=\frac{z-z_2}{\tan\beta_2}$$
$$\frac{x-x_n}{\cos\alpha_n}=\frac{y-y_n}{\sin\alpha_n}=\frac{z-z_n}{\tan\beta_n} \tag{1}$$

In the formula, α is the angle between the straight line projection on XOY and x-axis. β is a angle between the straight line projection on XOY and the straight line itself. The direction vector of the straight line can be expressed as $\vec{V}$ ={cosα, sinα, tanβ}.

Theoretically, the intersection of these straight lines is the 3D position of the survivor. Due to the influence of various factors, errors in measurement will not be unavoidable. So it is possible that the straight lines will not intersect. That means two straight lines are not at the same surface. The next section will discuss the different solutions in detail.

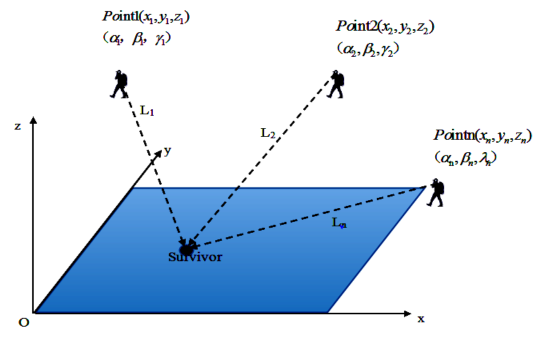

Figure 1: *Schematic Diagram of 3D Positioning Model*

3.1.1 Extracting the Solution of Two Coplanar Equations

If two straight lines L1 and L2 are coplanar (shown as figure1), they will have intersection and meet the following conditions,

Δ =0 and cosα1 : sinα1 : tanβ1 ≠cosα2 : sinα2 : tanβ2 (2)

Then, the two linear equations are,

$$\begin{cases} \dfrac{x-x_1}{\cos\alpha_1}=\dfrac{y-y_1}{\sin\alpha_1}=\dfrac{z-z_1}{\tan\beta_1} \\ \dfrac{x-x_2}{\cos\alpha_2}=\dfrac{y-y_2}{\sin\alpha_2}=\dfrac{z-z_2}{\tan\beta_2} \end{cases} \quad (3)$$

Assuming the point P0 (x0, y0, z0) is the intersection of two straight lines, then,

P0 (x0, y0, z0) =

$$\left(\frac{\sin\alpha_1\cdot\cos\alpha_2\cdot x_1-\cos\alpha_1\cdot\cos\alpha_2\cdot y_1-\sin\alpha_2\cdot\cos\alpha_1\cdot x_2+\cos\alpha_1\cdot\cos\alpha_2\cdot y_2}{\sin\alpha_1\cdot\cos\alpha_2-\sin\alpha_2\cdot\cos\alpha_1},\ \frac{\sin\alpha_1\cdot\sin\alpha_2\cdot x_1-\sin\alpha_2\cdot\cos\alpha_1\cdot y_1-\sin\alpha_1\cdot\sin\alpha_2\cdot x_2+\sin\alpha_1\cdot\cos\alpha_2\cdot y_2}{\sin\alpha_1\cdot\cos\alpha_2-\sin\alpha_2\cdot\cos\alpha_1},\ z_2+\frac{\tan\beta_2\cdot(\sin\alpha_1\cdot x_1-\cos\alpha_1\cdot y_1-\sin\alpha_1\cdot x_2+\cos\alpha_1\cdot y_2)}{\sin\alpha_1\cdot\cos\alpha_2-\sin\alpha_2\cdot\cos\alpha_1}\right) \quad (4)$$

3.1.2 Extracting the Solution of Two Non-coplanar Equations

If two straight lines L1 and L2 are non-coplanar, they will not intersect. We assume that PQ is the common perpendicular of L1 and L2, point P is the intersection between L1 and the common perpendicular, point Q is the intersection between L2 and the common perpendicular(shown as figure2), Then the survivor location P0 can be replaced by the midpoint of PQ. L1 and L2 will meet the following conditions,

$$\Delta=\begin{vmatrix} x_2-x_1 & y_2-y_1 & z_2-z_1 \\ \cos\alpha_1 & \sin\alpha_1 & \tan\beta_1 \\ \cos\alpha_2 & \sin\alpha_2 & \tan\beta_2 \end{vmatrix}\neq 0 \quad (5)$$

Then,

$$\Delta=(\sin\alpha_1\cdot\tan\beta_2-\sin\alpha_2\cdot\tan\beta_1)\times(x_2-x_1)+(\cos\alpha_2\cdot\tan\beta_1-\cos\alpha_1\cdot\tan\beta_2)\times(y_2-y_1)+(\cos\alpha_1\cdot\sin\alpha_2-\cos\alpha_2\cdot\sin\alpha_1)\times(z_2-z_1)\neq 0$$

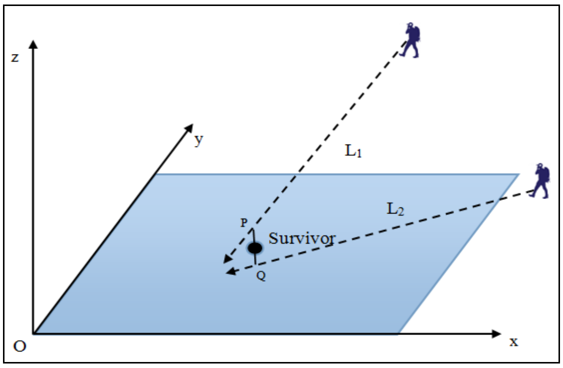

Figure 2: *Two Non-coplanar Equations*

If there are more than two linear equations, the midpoints of common perpendicular line need to be computed respectively. P0 can be obtained by calculating the average of each midpoints.

In fiugre1, the coordinates of point1(x_1,y_1,z_1) and point2(x_2,y_2,z_2) are known. So the equation of common perpendicular line between L1 and L2 is shown in equation 6.

$$\begin{cases} \begin{vmatrix} x-x_1 & y-y_1 & z-z_1 \\ \cos\alpha_1 & \sin\alpha_1 & \tan\beta_1 \\ A & B & C \end{vmatrix}=0 \\ \begin{vmatrix} x-x_2 & y-y_2 & z-z_2 \\ \cos\alpha_2 & \sin\alpha_2 & \tan\beta_2 \\ A & B & C \end{vmatrix}=0 \end{cases} \quad (6)$$

In above formula,

$$A=\begin{vmatrix} \sin\alpha_1 & \tan\beta_1 \\ \sin\alpha_2 & \tan\beta_2 \end{vmatrix},\quad B=\begin{vmatrix} \tan\beta_1 & \cos\alpha_1 \\ \tan\beta_2 & \cos\alpha_2 \end{vmatrix},\quad C=\begin{vmatrix} \cos\alpha_1 & \sin\alpha_1 \\ \cos\alpha_2 & \sin\alpha_2 \end{vmatrix}$$

After the simplification of equation 6, the common perpendicular line equation can be transformed into:

$$\frac{x-a_0}{\begin{vmatrix} k_2 & k_3 \\ m_2 & m_3 \end{vmatrix}}=\frac{y-b_0}{\begin{vmatrix} k_3 & k_1 \\ m_3 & m_1 \end{vmatrix}}=\frac{z-c_0}{\begin{vmatrix} k_1 & k_2 \\ m_1 & m_2 \end{vmatrix}} \quad (7)$$

In the above formula,

$k_1=C\cdot\sin\alpha_1-B\cdot\tan\beta_1$

$k_2=A\cdot\tan\beta_1-C\cdot\cos\alpha_1$

$k_3=B\cdot\cos\alpha_1-A\cdot\sin\alpha_1$

$k=k_1\cdot x_1+k_2\cdot y_1+k_3\cdot z_1$

$m_1=C\cdot\sin\alpha_2-B\cdot\tan\beta_2$

$m_2=A\cdot\tan\beta_2-C\cdot\cos\alpha_2$

$m_3=B\cdot\cos\alpha_2-A\cdot\sin\alpha_2$

$m = m_1 \cdot x_2 + m_2 \cdot y_2 + m_3 \cdot z_2$

$a_0 = \dfrac{m_2 \cdot k - k_2 \cdot m}{k_1 \cdot m_2 - k_2 \cdot m_1}$

$b_0 = \dfrac{m_1 \cdot k - k_1 \cdot m}{k_2 \cdot m_1 - k_1 \cdot m_2}$

$c_0 = 0.$

We assume the coordinates of point P and Q are (x_p, y_p, z_p) , (x_Q, y_Q, z_Q) then,

$$\begin{cases} \dfrac{x_p - x_1}{\cos\alpha_1} = \dfrac{y_p - y_1}{\sin\alpha_1} = \dfrac{z_p - z_1}{\tan\beta_1} \\ \dfrac{x_p - a_0}{\begin{vmatrix} k_2 & k_3 \\ m_2 & m_3 \end{vmatrix}} = \dfrac{y_p - b_0}{\begin{vmatrix} k_3 & k_1 \\ m_3 & m_1 \end{vmatrix}} = \dfrac{z_p - c_0}{\begin{vmatrix} k_1 & k_2 \\ m_1 & m_2 \end{vmatrix}} \end{cases} \quad (8)$$

$$\begin{cases} \dfrac{x_Q - x_2}{\cos\alpha_2} = \dfrac{y_Q - y_2}{\sin\alpha_2} = \dfrac{z_Q - z_2}{\tan\beta_2} \\ \dfrac{x_Q - a_0}{\begin{vmatrix} k_2 & k_3 \\ m_2 & m_3 \end{vmatrix}} = \dfrac{y_Q - b_0}{\begin{vmatrix} k_3 & k_1 \\ m_3 & m_1 \end{vmatrix}} = \dfrac{z_Q - c_0}{\begin{vmatrix} k_1 & k_2 \\ m_1 & m_2 \end{vmatrix}} \end{cases} \quad (9)$$

The solution is,

$$P(x_P, y_P, z_P) = \left(\dfrac{E\cdot\sin\alpha_1\cdot x_1 - E\cdot\cos\alpha_1\cdot y_1 - F\cdot\cos\alpha_1\cdot a_0 + E\cdot\cos\alpha_1\cdot b_0}{E\cdot\sin\alpha_1 - F\cdot\cos\alpha_1}, \dfrac{F\cdot\sin\alpha_1\cdot x_1 - F\cdot\cos\alpha_1\cdot y_1 - F\cdot\sin\alpha_1\cdot a_0 + E\cdot\sin\alpha_1\cdot b_0}{E\cdot\sin\alpha_1 - F\cdot\cos\alpha_1}, c_0 + \dfrac{G\cdot(\sin\alpha_1\cdot x_1 - \cos\alpha_1\cdot y_1 - \sin\alpha_1\cdot a_0 + \cos\alpha_1\cdot b_0)}{E\cdot\sin\alpha_1 - F\cdot\cos\alpha_1} \right) \quad (10)$$

$$Q(x_Q, y_Q, z_Q) = \left(\dfrac{E\cdot\sin\alpha_2\cdot x_2 - E\cdot\cos\alpha_2\cdot y_2 - F\cdot\cos\alpha_2\cdot a_0 + E\cdot\cos\alpha_2\cdot b_0}{E\cdot\sin\alpha_2 - F\cdot\cos\alpha_2}, \dfrac{F\cdot\sin\alpha_2\cdot x_2 - F\cdot\cos\alpha_2\cdot y_2 - F\cdot\sin\alpha_2\cdot a_0 + E\cdot\sin\alpha_2\cdot b_0}{E\cdot\sin\alpha_2 - F\cdot\cos\alpha_2}, c_0 + \dfrac{G\cdot(\sin\alpha_2\cdot x_2 - \cos\alpha_2\cdot y_2 - \sin\alpha_2\cdot a_0 + \cos\alpha_2\cdot b_0)}{E\cdot\sin\alpha_2 - F\cdot\cos\alpha_2} \right) \quad (11)$$

So, the coordinates of survivor P_0 (x_0, y_0, z_0) is the midpoint of the line PQ,

$$x_0 = \frac{x_P + x_Q}{2}, y_0 = \frac{y_P + y_Q}{2}, z_0 = \frac{z_P + z_Q}{2} \quad (12)$$

3.2 Design of Life Detection and Rescue System Based on Augmented Reality

3.2.1 Design of System Framework

This paper puts forth the system framework based on improved ARToolKit. ARToolKit is a C and C++ language software library and uses computer vision techniques to calculate the real camera position and orientation relative to marked cards. ARToolKit includes the tracking libraries and complete source code for these libraries enabling programming to port the code to a variety of platforms or customize it for their own applications. ARToolKit can overlay the video stream with 3D model and output the image with HMD. But it cannot obtain the data from GPS and electric compass. So this paper proposes a new solution based on improved ARToolKit[16].The system framework is shown in figure 3.The whole system mainly consists of two parts: the first is to acquire the positioning data by GPS and direction data by electric compass, and then to compute the 3D coordinates of survivor with 3D positioning model put forth by this paper. The second is to overlay the virtual graphics of survivor over the video stream and generate the augmented reality effect on HMD.

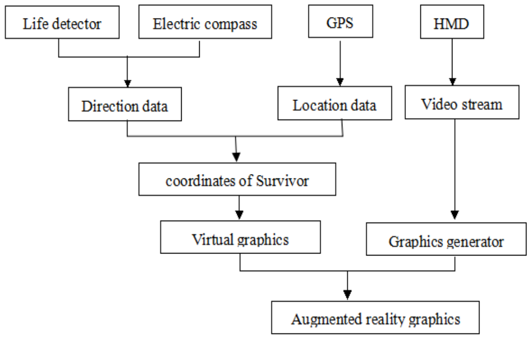

Figure 3: *Design of system framework*

3.2.2 Design of System Software

Each function module of the system is integrated in Visual Studio platform (as shown in figure 4). The 3D virtual modeling and visualization will be established by OpenGL. In this paper, 3D red sphere which is programmed in OpenGL represents virtual graphic of trapped people in augmented reality. The interface of GPS and electronic compass will be developed in VC++ and integrated into ARToolKit.

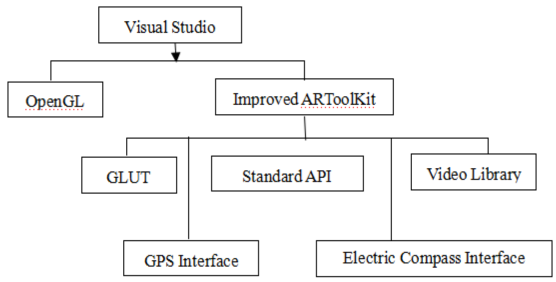

Figure 4: *Design of system software*

3.2.3 Design of System Data Flow and System Function

The system data flow is shown in figure 5.

①The system searches through specified serial ports on the computer for GPS and electric compass data.

②If data is found; the system will extract the coordinates and direction information from received string and calculate the transformation matrix.

③The 3D virtual graphic model of survivor will be set up according to the 3D coordinates computed by the system.

④The virtual model will be overlaid on the real world video by HMD, then it looks like a 3D real position forms.

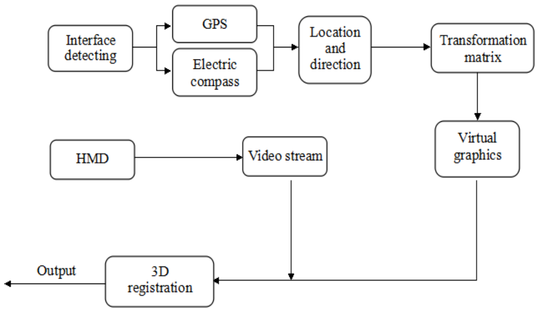

Figure 5: *Design of system data flow*

System function is divided into five parts (shown as figure 6).Positioning and computation module is to detect the survivor with life detector and to compute the 3D coordinates of survivor. Data receiving and processing module is to receive the sensor data from the serial ports of GPS receiver and 3D electric compass, and then extract the direction and location information from the string. Virtual graphics generation module is to generate the 3D virtual graphics of survivor with OpenGL. Tracking and registration module is to track the head position by GPS and sight direction of the user by 3D electric compass. Visualization module is to overlay the 3D virtual graphics of survivor on the video stream by HMD.

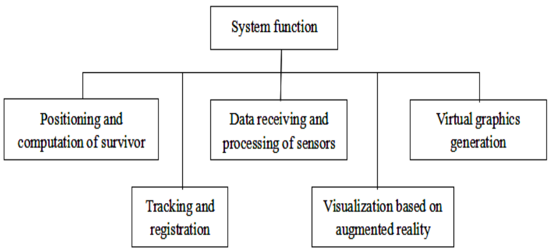

Figure 6: *Design of system function*

4. Results

In order to verify the 3D positioning model derived above, the following scenario is assumed to occur. After a heavy earthquake, the rescue workers find a survivor in the ruins with life detector. But they are unable to accurately locate the survivor because the life detector can only provide the direction and distance. So they must use 3D positioning technology which put forth by this paper to compute the 3D coordinates of survivor. The first step is to find a suitable place for observation and at least two places are necessary (shown as figure 7).Then at each place they will acquire the 3D coordinates by GPS receiver and the direction data by 3D electric compass. The third step is the computation of 3D coordinates of survivor. At last, the rescue works can "see" the survivor with HMD based on augmented reality technology. The rescue efficiency is greatly improved, and the survivor is saved successfully.

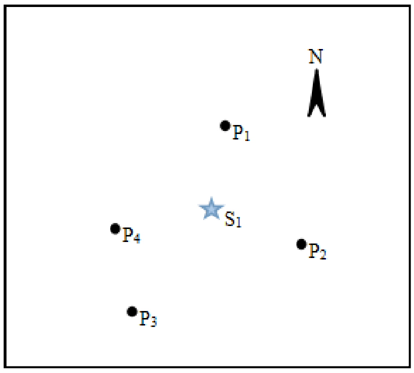

Figure 7(a): *First experiment map of observation points*

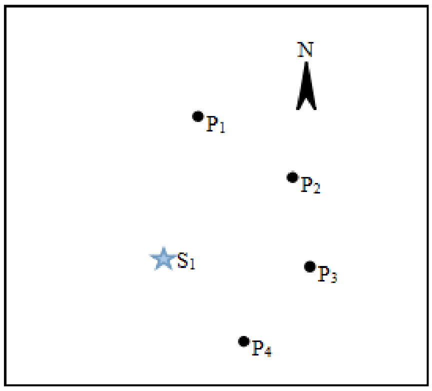

Figure 7(b): *Second experiment map of observation points*

The data of two experiments are shown in table 1. *X,Y* and *Z* are 3D coordinates of observation place. Horizontal and pitch are angle of antenna in life detector. There are four observation points in each experiment.

Table 1: *Measurement data of experiments*

Item	Point 1 (m)	Point 2 (m)	Point 3 (m)	Point 4 (degree)
X	48170.590	48157.881	48149.337	48158.070
Y	52555.509	52565.367	52540.462	52539.529
Z	65.998	65.955	66.052	65.998
Horizontal	198.565	300.648	51.526	74.650
Pitch	-5.543	-3.523	-1.713	-3.021
X	48164.687	48161.030	48154.539	48149.812
Y	52557.612	52564.408	52565.077	52560.899
Z	66.03	65.981	65.94	65.997
Horizontal	328.500	282.365	233.235	190.014
Pitch	-7.201	-9.521	-8.068	-11.548

The results of calculation value are shown in table 2. The true values of survivor location are acquired by GPS RTK. The coordinates will have centimeter-level accuracy. From the table 2, we can see the plane coordinates error between true value and calculation is less than 10 cm, the elevation error is less than 20cm.

***Table 2:** Results of calculation and error*

Item	Calculation value(m)	True value (m)	Error (m)
X1	48163.097	48163.044	0.053
Y1	52553.873	52553.957	-0.084
Z1	66.255	66.107	0.148
X2	48162.972	48163.044	-0.072
Y2	52554.023	52553.957	0.066
Z2	66.287	66.107	0.180

The above demonstration is a simple example of locating only one trapped people. When the strong earthquake occurs, thousands of people may be trapped in the ruins at a particular site. It is difficult to locate so many people with one set of equipment because of low efficiency. So it is necessary to use many sets of equipments in the serious hazard at the same time.

5. Conclusions and Future Work

This paper has presented 3D positioning model of trapped people based on augmented reality. With the positioning data acquired by GPS and direction data acquired by 3D electric compass, the 3D coordinates of survivor will be computed. The demonstration of this 3D positioning model showed that horizontal accuracy is less than 10 cm and vertical accuracy is less than 20 cm. The result of demonstration of this model proves to meet the rescue requirements. Then this paper presented an exploratory system design of life detection and rescue system based on augmented reality technology and the preliminary implementations of system. The hardware of the system includes life detector, GPS receiver, 3D electric compass and HMD. The software of the system is based on improved ARToolKit. As ARToolKit is one of the main AR development tools and is open source, so this paper puts forth a new software framework which is able to receive the data from sensors such as GPS receiver and electric compass. With this system, the rescuer can "see" the survivor from the ruins from HMD and is helpful to improve the efficiency of the rescue.

The future work of our study includes two aspects. The first part is to improve ARToolKit to receive the sensor data [16], and then ARToolKit can be used as a tool to construct outdoor augmented reality system. The second is to build the life detection and rescue system using the technological route this paper puts forth.

Acknowledgements

This study is partly supported by Shandong Provincial Science and Technology Key Projects "Research on Key Technologies of IE&E and Its Application in Regional Energy-saving and Emission-reduction "(Grant No. 2012GGB01115). The authors thank Professor Bai Chengjie (Shandong Normal University, China) very much for his important advice to this paper.

References

[1] Michael F. Goodchild,J. Alan Glennon, "Crowd sourcing geographic information for disaster response: a research frontier". International Journal of Digital Earth, 3(3), pp.231–241, 2010, DOI: 10.1080/17538941003759255

[2] Asama H, Hada Y, Kawabata K, Noda I, Takizawa O, and Meguro J., "Rescue infrastructure for global information collection." Proceedings of the SICE-ICASE International Joint Conference, Bexco, Busan, Korea, 18-21 October, 2006, pp. 3443-3448, DOI: 10.1109/SICE.2006.315161

[3] Miao Chonggang, "The US federal government emergency response plan." Recent Developments in World Seismology. (9), pp.27-31, 2000, DOI:10.3969/j.issn.0253-4975.2000.09.008

[4] LU Changjiang, LI Xuemei, "Design of an earthquake rescue portable mobile terminal". Earthquake Research in Sichuan, 138(1), 2011, DOI:10.3969/j.issn.1001-8115.2011.01.007

[5] Jianfa Huang, Ming Lu,Hong Chen, "Manual and methods of international search and rescue." Earthquake Press, 2007

[6] China Earthquake Administration, "Earthquake emergency." Earthquake Press, 2004

[7] Li Jingyu, "Discussion on the firefighting army handling quake relief work." Value Engineering, 33, pp.98, 2010, DOI:10.3969/j.issn.1006-4311.2010.33.092

[8] Zlatanova S, "Augmented reality technology." GIS Report NO.17, 2002

[9] Tomohiro Fukuda, Tian Zhang, Nobuyoshi Yabuki. "Availability of mobile augmented reality system for urban landscape simulation." Cooperative Design, Visualization, and Engineering - 9th International Conference, CDVE 2012, DOI: 10.1007/978-3-642-32609-7_33

[10] Michele Ruta, Floriano Scioscia, Danilo De Filippis, Saverio Ieva, Mario Binetti, Eugenio Di Sciascio, "A semantic-enhanced augmented reality tool for Open Street Map POI discovery. " IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT), 2015, DOI: 10.1109/WI-IAT.2015.243

[11] Giovanni Badiali, Vincenzo Ferrari, Fabrizio Cutolo, Cinzia Freschi, Davide Caramella, Alberto Bianchi, Claudio Marchetti,"Augmented reality as an aid in maxillofacial surgery: validation of a wearable system allowing maxillary repositioning. " Journal of Cranio-Maxillofacial Surgery, 42(8), pp. 1970-1976, 2014

[12] Danakorn Nincarean, Mohamad Bilal Alia, Noor Dayana Abdul Halim, Mohd Hishamuddin Abdul

Rahman, “Mobile augmented reality: the potential for education,” Procedia - Social and Behavioral Sciences, 103(26), pp. 657-664, 2013
[13] Eulalia Rodríguez Fino, Jorge Martín-Gutiérrez, M. Dolores Meneses Fernández, Enrique Armas Davara, “Interactive tourist guide: connecting Web 2.0, augmented reality and QR codes.” Procedia Computer Science, 25, pp. 338-344, 2013, doi: 10.1016/j.procs.2013.11.040
[14] Gregory Kipper, “The value of augmented reality: public safety, the military, and the law.” Augmented Reality, pp. 97-109, 2013
[15] He Ye, “Life detection technique in earthquake search and rescue.” 2012 Second International Conference on Instrumentation & Measurement, Computer, Communication and Control, 2012, DOI:10.1109/IMCCC.2012.161
[16] Chang Yong, Xue Liming, “Research on constructing outdoor augmented reality system based on improved ARToolKit.” Journal of System Simulation, 21(8), pp. 2273-2276, 2009