Computer-aided visualization aids for indoor rescue operation

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COMPUTER-AIDED VISUALIZATION AIDS FOR INDOOR RESCUE OPERATION

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SUMMARY

Finding a way out effectively and rapidly in emergency is always a problem for occupants who get trapped in an indoor environment. In such situation, rescuers often rely on emergency signs or verbal communication to direct the trapped people to the exits. However, many problems could arise during evacuation such as mobile signal interruption, low visible scene caused by dense smoke, etc. These problems might prevent the rescuers from communicating with Command Centre as well as to see the emergency signs and passageway clearly. Moreover, a complex spatial layout with obstructed spaces will add more difficult in deciding the correct way to take.

To address the above problem, this thesis introduces an approach for effective rescue task in the context of way-finding in an indoor environment, namely inside vessels or buildings. The proposed approach takes into account how rescuers who are less familiar with the rescue area could immediately make sense of the spatial space while performing way-finding task regardless visibility of the environment. Based on principles and criteria of visual communication in emergency and human way-finding studies, this approach is investigated with the use of computer-aided visualization technologies and indoor trackers. To implement the approach, a visualization system is developed and integrated. Outcomes of the visualization system which are directional messages and aided information for way-finding performance are presented in terms of visual representations. It is real-time generated corresponding to the rescuer's information (e.g. current position and viewing orientation) and environment visibilities (e.g. clear, smoky). The visual representation is made up by combining a dynamic 2D You-Are-Here map integrated with directional signs superimposing on either 3D virtual environment or recording video of the real one. The visualization using virtual environment is called *Virtual Reality (VR) display* which can be used in case of low visual access or smoky scene. VR display enables the rescuer to recognize their ways easily since virtual scene is a 3D replication of the real one. The visualization using real scene is called *Augmented Reality (AR) display* which is applicable for way-finding in clear scene. This display enables the rescuer to concurrently view the real

scene while still keep track of supporting information (computer-generated graphics) since both of them are simultaneously displayed on the HMD's screen. Dynamic YAH map is also introduced by real-time aligning with the real layout based on the rescuer's viewing direction. The escape path and other items appeared on the map are also updated according to the change of rescuer's information.

To demonstrate the visualization system, an application is developed for way-finding on level B4 of block N1 in Nanyang Technological University. By using the visualization system, the way out could be recognized in a short time regardless the environment visibility since the provided visual effect could reduce mental interpretation and manipulation in reading the supporting information. This approach is not only appropriate for practical cases but also applicable for any training purposes.

CHAPTER 1

INTRODUCTION

This research focuses on the practical problem of finding the best way-finding technique support for rescue during emergency in indoor environment, namely in buildings and vessels.

Technical support for way-finding can take many different forms, but it also involves the technique of using graphical instructions which uses signs to inform occupants the way to a certain place or how to find a way out in emergency situations. In this research, computer-aided visualization is studied to provide an effective graphical instruction to rescuers by providing a digital visual support in order to navigate and direct passengers to the nearest exits in minimum. Virtual Reality (VR) and Augmented Reality (AR) are the two main techniques focused to develop computer-aided visualization system.

This chapter begins by giving the motivation of the research and an introduction to the research focus. It is followed by research problems including general problems and technical ones that need to be solved in the context of how to find a way out in an emergency inside buildings and vessels. Research objectives are then highlighted in order to introduce what the research is going to achieve. The following part is research methodology. The last part introduces how the chapters are organized.

1.1 Motivation

Effective and efficient rescue after a disaster is always a demanding, difficult task and a matter of life and death for both outdoor and indoor environments. In such a case, rescuers need to take the immediate and accurate responses based on disaster situations to direct trapped people to the safe and nearest exits. Technical supports are manifold, however this matter is still a practical problem needed to address, especially the problem of how to find a way out in a short time during emergency situation.

To address this need, various researches are studied to help rescuers to achieve their tasks effectively. Technical supports for rescuing are generally take many different forms such as using robot to search and rescue [1], using web-based GIS to locate and search [2] or simply using 2D or 3D digital maps to support of emergency teams during rescue operations [3] and so on. Those researches contribute considerably to mitigate the loss of men and damage of properties to the minimum. However, they predominantly focus on rescue problems on land [1][2][4][5] but a little deal with rescue in maritime domain such as in ships and vessels. In fact, safety in maritime domain is important to passengers as there are a lot of severe tragedies happening every year in ships and vessels.

According to Wikipedia [6], there are a magnitude of deaths due to ship and ferry disasters. Vessel and ship disasters were caused by many reasons such as grounding, flooding, collisions, fires and other problems. From 1800s to the late 1900s, losses and damages in disasters were unable to be controlled because of lack equipment and communications for search and rescue. Terrible tragedies still happen to passenger ferries and vessels in the recent years, although such vessels are equipped with modern technology. The most deadly tragedies include the capsizing of MV Joola ferry (see Figure 1-1) on September 26, 2002 with 1863 deaths, the sinking of M/V al-salam Boccaccio 98 passenger ferry (see Figure 1-2) on February 2, 2006 with 1018 deaths. The huge number of deaths proved that search and rescue as well as techniques for rescue are still not given special attention in passenger ships, ferries and vessels.

Figure 1-1: MV Joola ferry sank on Thursday 26th September 2002 off the Coast of Gambia with 1863 deaths

Figure 1-2: M/V al-salam Boccaccio 98 ferry sank with 1018 deaths.

Also in Wikipedia [7], there are a number of deaths owing to getting trapped inside building fires.

Search and rescue tasks in indoor environment have to cope with various difficulties with limited resources. Once disaster happens, panic could arise because passengers get trapped in enclosed areas and are unable to find the way out. So the first priority is to evacuate passengers inside buildings or vessels to the outside but sometimes the complexity of spatial layouts prevent so.

Normally, rescuer performance almost relies on verbal communication (Figure 1-3) and emergency signs to operate rescue task. These means are very effective to support rapid decision and help occupants to navigate in unfamiliar environments.

Verbal communication refers to the exchange information between rescuers and Command Centre through hand-held communication devices such as walkie-talkies or cell phones [8]. By using verbal communication, Command Centre is able to know the actual disaster situation and conversely rescuer operations are conducted directly and comprehensively. Therefore, rescuers could response and act promptly. Besides many advantages, verbal communication has some limitations and could not be applied to every rescue case. Verbal communication is not able to communicate in indoor environments where mobile signal cannot reach. The communication could also be interrupted or disconnected. In ships and vessels, due to most of walls and doors being made of steel or thick metal, the signal is quite difficult to penetrate and thus unable to reach the areas at the lower decks. In this case, rescuers and trapped people are unable to find the way out if they are unfamiliar or only slightly familiar with spatial arrangement.

Figure 1-3: Today, rescuers are using walkie-talkies and cell-phones

Graphical instructions could be useful alternative to verbal communication. Inside buildings and vessels, graphical instructions for way-finding are often found as symbols, maps and a network of graphical arrows. Viewer could rely on those signs to find where they currently are in a complex and unfamiliar environments. Also, they could navigate to their chosen destinations. For way-finding, symbols could help to pinpoint locations; maps could help to identify relative locations and the network of arrows could help to indicate the direction to the nearest exit (Figure 1-4 (a) (b)).

(a)

(b)

Figure 1-4: Emergency signs; (a) You-Are-Here map; (b) Exit signs

However, those signs are easy to see in a clear scene only. In case of fire, dense smoke and other visual obstructions will cover the whole scene and block escape view.

So, instruction signs and passageways cannot be seen clearly. Additionally, people could take time to look for the proper signs, so they are uncertain to decide which way to take.

According to [9], in the Scandinavian Star tragedy in 1990, many passengers were found dead very close to emergency exits. They had died from asphyxia in the heavy smoke. The Norwegian Fire Research Laboratory SINTEF carried out a series of experiments after the fire disaster concluded that better emergency lighting and graphical signs will not be enough. “The tests showed that the standard signs that point to the emergency exits are difficult to see and interpret. Visibility was poor because of the thick smoke. Just under 40% made different types of mistakes and could not find the emergency exit. They either passed it, or tried to get out through the wrong door, and some turned round on the way out... Traditional signs give us little support when we are in motion”. Channel for verbal communication is disrupted by smoke (because of choking) [10] as well as the channel for graphics-visual communication.

With the aid of technology, computer-aided visualization could take the advantage of graphical instructions to facilitate viewers by digitalizing graphical instructions in terms of image and motion images. These images could be displayed on display devices such as Head Mounted Displays (HMDs) or goggles through which viewers are able to see instruction signs in any environment conditions.

In this research, rescue in buildings and vessels is studied under computer-aided visualization approach. A visualization system is developed to generate the real-time visualization support to rescuers in emergency. By using such kind of system, users could rely on system features which are highly accurate and updated in real-time according to current situation.

This research focuses on the two following aspects:

- To determine an effective and efficient visualization that could be understood in short time without using any elaborate menus or mouse clicks.
- To develop a visualization system that generates the determined visualization in real-time.

1.2 Problems

Various problems occur to rescue operation in buildings and vessels that need to be overcome. Some problems could be handled beforehand but a number of them are unforeseeable. In this research, those problems are classified into two main groups which are often coped with by rescuers. They are (1) general problems with regard to the difficulties and occurrences during rescue operation in buildings and vessels and (2) technical problems with regard to difficulties and limits of using technology to deal with general problems. To investigate and anticipate problems which encounter rescuers, proposed solution for rescue in buildings and vessels could be applicable in real disaster situations and handle maximum disaster damages.

1.2.1 General Problems

The first problems have to deal with is how to find a way out in buildings and vessels with less time. In small buildings and ships, the spatial arrangement is relatively simple and the rescuers can easily direct passengers to the nearest exits and in this case way-finding is not an issue [10]. However, large buildings and huge passenger ships pose problem in way-finding because of the complex spatial arrangement and with restricted space for rescue operation (Figure 1-5, Figure 1-6). Spatial layout varies from level to level, so the arrangement of all levels is not uniform. Hence rescuers are unable to rely on their visual experience of one level to other level as they often do so in simple built environment. The complex spatial layout will not be

a problem if the rescuers are familiar with or know the layout in advance. Otherwise, occupants get trapped in closed areas and rescuers have limited time to rescue will be a big problem need to be considered.

Figure 1-5 : A building with complex structure

Figure 1-6 : Spatial layout of vessels varies from deck to deck and arrangements are not in the same way

Suppose rescuers know spatial arrangement of buildings and vessels in advance, however many unforeseen situations still occur and put rescuers in uncertain decision. For instance, escape scene might change with time due to dense smoke, collapses occur or a part of vessel is submerged under water. In this case, rescuers will not be certain of the way to direct passengers to escape in short time and with less risk. Figure 1-7 is an example of unforeseen situation during rescue operation with escape scene changing from clear scene to smoke scene. In this case, rescuers' view is masked with thick smoke and exit ways are hard to recognize or to find out.

Figure 1-7: Escape scene is changed from clear scene to poor visibility

1.2.2 Technical Problems

Technical supports for way-finding in indoor environment are limited. Global positioning and local positioning are deficient [11], so it is difficult to track the position of rescuers and seek out the disastrous places to find a safe way out from the current position of rescuers. Rescuers normally rely on verbal communication through walkie-talkie or using their mental manipulation to find the way out based on printed maps or a network of graphical symbols.

As mentioned, verbal communication using mobile signal has problem in indoor environment due to weak signal. In case of fire, channel for verbal communication is disrupted by smoke (because of choking) as well as the channel for graphic-visual communication [10].

To locate and orient oneself in a printed map of a complex spatial model is a common problem in an indoor environment. Rescuers often rely on “You-are-here” maps placed on their way to figure out their positions and use compass to know the orientation. In an emergency, the need for location and orientation support is especially critical for rescuers because of time constraint and uncertainty of disaster environment.

Rapid decision from provided support is needed in every emergency. Verbal communication could achieve this demand to provide immediate understanding from direction commands. However, verbal communication is sometimes useless at the lower decks because of choking and not effective in complex layout because of confusion and ambiguity. Printed maps and graphical symbols are not effective tools in way-finding in emergency due to rescuers taking time to find and infer from mental manipulation. Rescuers demand a technical support which provides an imperative instruction in an easy way to facilitate interpretation in short time.

1.3 Research Objectives

The overall goal is to develop an effective computer-aided visualization to support rescue operation in the context of way-finding in an emergency with which user could read off support information easily and quickly. This thesis has the following objectives:

1. To study and design an effective visualization based on some crucial principles and criteria of visual graphic design. This visualization could facilitate rescuers perception in an emergency situation, so they can understand the spatial information and grasp the way-finding instructions in less time.
2. To find a proper format computer-aided visualization. To scrutinize to technical support of Virtual Reality (VR) and Augmented Reality (AR) techniques to facilitate rescuers in either visible or less visible (dense smoke) environment condition.
3. To develop a robust, accurate and reliable way-finding support system in terms of computer-aided visualization system by integrating AR, VR and other supported tools and devices such as networking technology, high performance laptop, HMDs, positioning and orientation trackers, etc ...
4. To implement, operate and verify such kind of system in a simple indoor environment, namely at level B4 of building N1 in Nanyang Technological University (NTU), Singapore. This implementation could be a case study that could be applied to develop the visualization system for vessels or other indoor environments.

1.4 Research Methodology

Methods used in this thesis are as follows:

- Identify research problems
- Determine research objectives
- Create a framework to present the comprehensive scenario of the system
- Visualization System development (software integration and hardware hook-up)
- Test and verify the application

The overall research working flow chart is depicted in Figure 1-8 and explained in the following Sections.

1.4.1 Flow of Research Work

Figure 1-8: Research working flow chart

As shown Figure 1-8, the research work is divided into three stages: construction stage, development stage and final stage. Each stage is introduced in details as follows.

1.4.2 Construction Stage

Firstly, research problems are identified within the research scope. Then, literatures which are relevant to the research topic are investigated. In the end of this stage, research objectives are specified with the overall goal is to develop an effective computer-aided visualization system for support of rescue operation to find the way out in an emergency. In order to develop the system, two other objectives should be carried out in prior: (1) determine the proper content and format of the visual representation and (2) integrate the visualization with the use of AR and VR technologies (hardware and software) into the visualization system. Figure 1-9 depicts the working flow of construction stage.

Figure 1-9: Construction stage

1.4.3 Development Stage

First of all, a framework is created to present the research approach and outline the comprehensive picture of the system including sufficient components (input, output, functions and hardware) and scenarios.

Afterwards, the visualization system is developed based on the proposed framework with the use of selected hardware and software which are determined in the literature review step. The software are some CAD tools and programming language which are used to develop the visualization (2D graphics and 3D environment), to implement approach's functions, to retrieve data from system's hardware and to integrate all components of research's framework. The system's hardware are some specialized devices such as orientation trackers, positioning tracker, HMDs, etc that used to perform AR and VR's features of the visualization system.

The final step of this stage is system hook-up in which all hardware come in pieces are put together to perform the specific task. The development stage is introduced in Figure 1-10.

Figure 1-10: Development Stage

1.4.4 Test and Evaluation

Test and evaluation is the crucial and vital part of development process to ensure the robustness and correctness of the system operation. In this research, the visualization system is demonstrated in the simple indoor environment in a number of times first. Modification and calibration of system features are carried out in this stage. If the system is able to work properly, then its achievement will be made use to other complex environment.

Final report and papers are achievements of the research which introduce the research in details with sufficient information and illustrated figures. Figure 1-11 represents the final stage of the research working flow.

Figure 1-11: Final stage

1.5 Organization of the Thesis

This thesis is organized into 5 chapters. They are as follows:

- **Chapter 1** introduces focus of the research and features that relevant to research topic including motivation, research problems, research objectives and research methodology.
- **Chapter 2** reviews the literature related to research topic and discusses previous works.

- *Chapter 3* introduces the research work to determine the effective visualization and good ways for way-finding in emergency situations based on the practical problems of traditional signs and the knowledge of visualization design in emergencies through the principles and criteria benefited from other researches. This visualization is then utilized in the research to develop the content and format of the visualization which is generated by the visualization system.
- *Chapter 4* presents the development procedure of the visualization system including framework determination and application of VR and VR in rescue mission.
- *Chapter 5* draws the final remarks and gives some directions about future work.

CHAPTER 2

LITERATURE REVIEW

This chapter presents the relevant knowledge on the research focus and its related works. Section 2.1 points out the definition of visualization and Section 2.2 takes a close look at the main technologies of computer-aided visualization used to develop the visualization system for rescuers, namely AR and VR. Section 2.3 introduces the current visualization for way-finding in vessel. Finally, Section 2.4 briefly represents related works which use visualization techniques to assist the decision making support for emergency situations.

2.1 Visualization

2.1.1 Definition

There are various definitions of visualization. In brief, the definition of visualization could be understood as follows.

Outside the scope of computer graphics, visualization has two standard definitions:

- Making a mental visual image of things not visible to the eyes [12].
- Forming a mental visual impression of things not present to the sight, an abstraction, etc. [13]

Within the scope of computer graphics, the terms visualization is understood as scientific visualization. It is defined more specifically, e.g. as follows:

- The use of computer imaging technology as a tool for comprehending data obtained by simulation or physical measurement [14].
- Techniques that allow scientists and engineers to extract knowledge from the results of simulations and computations [15].

As computers are an important feature in most of visualization product hence the basic of visualization definition could be depicted as Figure 2-1.

Figure 2-1 Basics of Visualization [16]

In general, visualization is essentially a process of mapping *information* (*computer representation of reality*) into *visual form* (perceptual representations) enabling the *viewers* to observe, make sense and deeply understand the information as well as the realistic phenomena. Normally, visualization employs computers to process the information and display devices to view it in terms of interactive graphics, images and visual design.

2.2 Computer-Aided Visualization Techniques

2.2.1 Introduction

Historically visualization techniques have been used for a long times. The early forms of visualization included map, data plots/graphs and science drawings. With the development of computers, computer graphics were used to study scientific problems. Scientific visualization employs computers to understand insight data of realistic phenomena or mathematical methods. The tools and techniques of scientific visualization allow scientists to derive knowledge and meaning from huge sets of data and grasp the result of simulations and computations in a meaningful format. Therefore, people are able to access, process, view and understand the computer-generated images instead of a mass of characters and numbers.

Scientific visualization via computer-generated images can be portrayed as pictures, graphs, 3D images presented in 2D form, models/simulations, animations, movie loops. A suitable visualization will be determined for a certain and specific application depending on the effect and contribution of such visualization to this area.

To enhance human perception and cognition as well as to add more exciting to the visual world, the technique of Virtual Reality (VR) and Augmented Reality (AR) enable people to see “real time” information associated with various actions such as zoom in/out of a location, navigate to explore the world and “interact” with objects. Practical use of VR was the flight simulation system for training and AR examples were in surgery and interventional therapies. With the development of technology, the possibilities are endless for practical applications for these types of visualization.

Visualization technique is used to create and manipulate a graphic representation from a set of data. Some techniques will be appropriate only for specific application while others are more generic and can be used in various applications. In this thesis,

the generic techniques of VR and AR are suitable to deal with the problem of way-finding in rescue in indoor environment hence VR and AR are focused and investigated in details.

2.2.2 Virtual Reality (VR)

According to <http://whatis.techtarget.com> which comprises more than 1000 IT terms, VR is described as follows:

“...simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may additionally provide an interactive experience visually in full real-time motion with sound and possibly with tactile and other forms of feedback.

The simplest form of virtual reality is a 3D image that can be explored interactively at a personal computer, usually by manipulating keys or the mouse so that the content of the image moves in some direction or zooms in or out.”

2.2.2.1 What is VR?

VR is a special technology that models an artificial 3D world which has properties like a real world. In this virtual world, users are able to perform the following aspects [17]:

- Move in real-time
- Self-moving items within the model
- User-moveable items within the model
- Deformable items within the model

- Changeable items within the model
- Spatially-correct sound
- Interaction with other users
- Cooperation with other users

VR is very attractive to users as VR provides the real feeling to most of human senses such as haptic, aural and visual. Specifically, they can use their hands to interact, use their ears to hear and use their eyes to see the virtual world as they often do so in reality. Of course, VR devices are crucial parts that enable realistic sensations and feeling to users.

With the advent of VR, users are able to better understand, interpret and discover various physical phenomena in which human have never been or involved such as in a molecular, on other planet or in a hazardous situation likes fire, collapse, etc.

VR provides users three possibilities: immersion, interaction and real-time. These possibilities also characterized VR system. Immersion enables users to experience the virtual universe as if they are really in it. The possibility of moving, deforming, translating of virtual objects while discovering the virtual world is called interaction. Real-time is the possibility which responds to events or signals as fast as possible. Therefore, each time the users interact with the virtual world, they would have the immediately feedback response from VR system.

2.2.2.2 VR applications

Nowadays, VR application could be widely seen in our daily life as well as in scientific researches. AR is a particular branch of computer graphics, hence its products is used for simulation, visualization or demonstration. The use of VR

applications increases productivity, improve team communication and reduce cost [18]. In brief, the typical VR applications are as follows:

- Entertainment: virtual rides, game, 3D cinema
- Training: phenomenon modeling, virtual cars, flight or ship
- Vehicle design: ergonomics, styling, engineering
- Architectural design and spatial arrangement; sub-marines, deep-sea oil platforms, process plants
- Medicine and medical surgery : treatment and operation
- Probe microscopy

The first application of VR is vehicle simulation [18]. This is a VR system in which a virtual model of vehicle such as a car, a ship or a plane is simulated as the real one. Sufficient components, around scene as well as real situations are also provided. Once users engage in this system, they could experience it as in reality. Such system could be used as an entertainment or for training purpose. The profit-production applications of VR lie in the entertainment area. At present, high-fidelity virtual world is difficult to obtain as the constraint in processing power, technical limitations, image resolution and communication bandwidth [19]. With further development of the technology, those limitations are expected to be overcome in the near future.

Figure 2-2: A vehicle simulation for training

2.2.2.3 VR Technologies

There are three crucial technologies in VR [18] which are used to characterize VR system possibilities:

- The visual (and aural and haptic) displays that enable the users to immerse in the virtual world.
- The tracking system that continuously provides the position and orientation of the user's head and limbs.
- The graphics system for building and rendering detailed and realistic models of the virtual world.

2.2.2.4 VR displays

VR displays are the devices that present the 3D virtual world to users. They are categorized into two main types. The first type is semi-immersive display that enables the users to see both real world and virtual world, for instance desktop display, surround-screen display. The second type is fully immersive display that completely blocked out the real world from the users such as HUD (Head-Up Display) / HMD (Head-Mounted Display) and arm-mounted display (BOOM). Each display device is appropriate for a specific application according to application purpose and requirement.

Desktop display or desktop VR just uses the ordinary computer screen to display the virtual world. By viewing through the shutter glasses, this is the easiest way to set up a virtual environment (Figure 2-3). Besides, users are able to use of keyboard and mouse. However, they cannot move around and only sit in front of the monitor.

Figure 2-3: User wears special glasses to see the stereo display on desktop

VR CAVE (Cave Automatic Virtual Environment) or “*Immersion VR*” is a surround-screen display where projectors project directly to four, five or six walls of a room- sided cube (Figure 2-4). Real and virtual objects can be mixed in this environment. Then users could be put in this space for visual immersion. Wearing only a pair of light weight shuttle glasses, they could view the stereo display. On one CAVE, people are able to inhabit and explore this space simultaneously.

Figure 2-4: Four projectors in VR CAVE project to four walls

One of the most common display devices is the *head-mounted display* (HMD). This device has either two CRT or LCD screens plus special optics in front of user's eyes (Figure 2-5). With an attached tracking device, it produces a stereoscopic view that moves relative to user's head position and orientation. By wearing HMDs, user's eyes will be blocked hence he or she cannot naturally see the real world. Cameras are sometimes mounted on the HMDs which enable viewers to see both real world and the computer-generated graphic objects. This kind of HMD is called see-through HMD. It is used in augmented reality technology [20].

Figure 2-5: Head-Mounted Displays

Head-Up Display (HUD) also uses a helmet and tracks the head position/orientation or even eye position/orientation (Figure 2-6). HUDs are mostly used in aerospace and defense industry to provide the pilots the combination of virtual and real world in augmented reality. In fact, HUDs can be used for both augmented reality and virtual reality. The difference is whether the outside world is visible.

Figure 2-6: Head-Up Display and Arm-Mounted Display

Arm-mounted display (BOOM) likes a HMD but is mounted on an articulated arm [20] (Figure 2-6). The devices also use mechanical tracking technology to track the user's head position and orientation.

2.2.2.5 Tracking Systems

One of the most important aspects of 3D interaction in virtual world is to provide a correspondence between the physical and virtual environments. Trackers in VR system are used to track the position or orientation of user's head or limbs. So that VR system will generate the feedback response based on the tracked data. As a result, having accurate tracking is extremely important to making the virtual environment usable. Currently, there are a number of different tracking technologies in the market such as magnetic, mechanical, acoustic, inertial, vision/camera, GPS, WLAN and hybrid trackers.

Chapter 2 Literature Review

<p><i>Magnetic Tracker</i></p>	<p><i>Mechanical Tracker</i></p>

<p><i>Acoustic Tracker</i></p>	<p><i>Inertial Tracker</i></p>

<p><i>Vision/Camera Tracker</i></p>	<p><i>Hybrids Tracker</i></p>

Figure 2-7: Some commercially available trackers

The important issue of tracking devices is the lag between the action in physical and virtual world. Although, every tracker has to do the same work, however the

obtained result is not the same because of the different tracking technology. Therefore, users need to get use of tracker's pros and cons in order to get an appropriate tracker for their VR system.

Magnetic tracking uses a transmitting device that emits a low frequency magnetic field. A small sensor or the receiver uses to determine the position and orientation related to the magnetic source (Figure 2-7). Moreover, these trackers could use the extended range transmitters to increase the range of the device from around 3m radius to 10m radius. The smaller emitters and receivers are more accurate than the regular system but the range is limited to about 1.5m radius. Hence, those trackers are primarily used in medical applications in which range of the device is not a factor [20].

Mechanical trackers have the rigid structure with a number of joints (Figure 2-7). One end is fixed in place while the other is attached to the object to be tracked (usually the user's head). The joint angles are used to obtain position and orientation records. BOOM uses this kind of tracking technology [20].

Acoustic tracking devices use frequency sound emitted from a source component which is placed on the hand or the object to be tracked (Figure 2-7). Microphones which are placed in the environment receive ultrasonic pings from the source components to determine the area of tracked space. One of the most interesting problems with this type of tracking is that the certain noises such as jingling key or a ringing phone will interfere with this device.

Inertial tracking systems use a variety of inertial measurement devices such as gyroscopes. These devices are small with no senders or necessary transmitters, hence could be used in long range [20] [21] (Figure 2-7). These devices have limitation in that it only tracks the orientation and tracked data is subject to error accumulation. Nowadays, the InterSense IS300 handles the error accumulation by using a gravitometer and compass measurements to prevent accumulation of gyroscopic drift

and also uses motion prediction algorithms to predict motion up to 50 milliseconds into the future [20].

Camera/vision based tracking takes one or more cameras and places them in the physical environment (Figure 2-7). The cameras then grab video of the users or objects to be tracked. Usually image processing techniques, such as edge detection algorithms, are used to identify the position and/or orientation of various body parts such as the head and hands. Setting up the vision-based tracking system can be difficult since there are many parameters that must be fixed in order to track the user properly [20].

WLAN (Wireless Local Area Network) tracking determines the current position of people, equipments or goods based on maps. The position is measured based on the triangulation of WLAN signal. Ekahau Position Tracking is a commercial software package for this technology (Figure 2-8).

Figure 2-8: Tracking equipment's positions using Ekahau Positioning Tracking

Hybrid trackers attempt to put more than one tracking technology together to help increase the accuracy, reduce the latency and generally provide a better virtual environment experience [20]. An example is the InterSense IS900 (Figure 2-9). This

system is the wireless tracking devices with 6 degrees of freedom motion (6-DOF) based on a hybrid technology of inertial and ultrasonic tracking. An IS900 tracks all tracked objects in a 6-DOF mode, meaning each tracked device outputs an X, Y, Z position information along with a pitch, yaw and roll orientation information. The position and orientation of the tracking stations are determined by the output of the accelerometers and gyros. The result of the full 6-DOF data is very smooth, precise and free. The MiniTrax Head's Tracker (Figure 2-10) is a lightweight, ergonomically designed tracking device for using on stereo glasses. The High Accuracy MiniTrax Head Tracker is the ideal for the applications required higher orientation accuracy such as in augmented reality systems [22].

Figure 2-9: IS900 Wireless Minitrax Head Receiver, Head Tracker and Transmitter components (left to right)

Figure 2-10: MiniTrax Head Tracker on stereo glasses and the High Accuracy Head Tracker

The problems still needing improvement are the latency and the updated rate of the tracker. The update rate determines the interval between measuring a position and its availability to the VR software. If the update rate is too high, say 100ms, it makes interaction and navigation tiresomely [23].

In summary, tracking technology is a crucial and vital feature of any Virtual Reality (VR) systems. By using trackers, the position and orientation of user's head or limbs are tracked properly.

2.2.2.6 VR Software

VR software or graphics system is used for building and rendering detailed and realistic models of the virtual worlds. VR software is the key to any success of VR systems. Such softwares are very complex as they integrate the areas of 3D geometric databases, rendering, interaction, navigation, 3D tracking, graphics peripherals, sound, human factors and interface design. All are required to run in real time. By using these

kinds of software, users could create various virtual environments (VEs) of their own specialized areas. In general, a VR software should have the following features:

- **World simulation** will create the virtual world which simulates the real one by providing some characteristics following the “laws of nature” such as gravity, collision detection and response, object manipulability, etc.
- **Importing models** is a necessary feature used to import models from different system. This feature will facilitate the ability of using 3D models created by many available modeling systems in the market such as AutoCAD, Unigraphics II, CADD5, Pro/Engineer, 3D Studio MAX, MAYA, Lightwave, etc.
- **LOD** (Level Of Detail) is a system feature for optimizing the amount of detailed rendering in a scene. A model should have several levels of geometric detail. The closer the distance of the viewer the more detailed of the model is. For example, a model of a virtual vessel will require a lot of details when it is viewed with close distance. In indoor space, we could see internal walls, doors, stairs and furniture. If the windows or doors are viewed from a far distance of 200m, the details will appear very small and can not be able to discern. Obviously, it would be waste time to render the same model in different distances due to the far distance rendering time is similar to the close distance rendering time of the same model. Therefore, the model will be built to several levels with different levels of detail. LOD is very useful for every VR application whose virtual model sizes are large [23].
- **Input device software interface** is required to communicate with the input hardware. This feature is used to handle different forms of input like continuous input (e.g tracking data) or discrete input (e.g button press). It is also needed to process the incoming data such as filter the tracking data

for calibration, smooth operation or convert the discrete inputs to continuous form and vice versa [21].

- **Multiple processing** is an important feature that must be used in case of multiple users participating in a VE. With course-gain parallel processing, data is read simultaneously from each user. Then, the world is simulated corresponding to the input data. Finally, the outputs are rendered and distributed to each user [21].
- **Networking** is needed to share the worlds to remote users. The shared information could be the voice, avatar position or changes of the world, etc. Networking is implemented by using client/server communication or peer to peer.

To date, some software tools are commercially available in the market such as World ToolKit (WTK), Visualization ToolKit (VTK), OpenSG (OpenSG Forum), OpenGL (OpenGL Consortium), Performer (SGI), and etc...

2.2.2.7 Summary

In brief, VR is used to enhance the user's perception and cognition with rescue scene in case of low visibility environment condition. With VR technology, users could experience the virtual world as they are in the realistic one. For the application of way-finding in rescue, VR technology could be used to portray the real rescue environment to rescuers in case of dense smoke or any collapse reduces environment visibility. The virtual environment is built and rendered in terms of real-time 3D model with sufficient properties as the real world. Tracking devices are provided to track the current position and orientation of rescuer's head. The VR system will alter the virtual scene according to tracking data and therefore the virtual scene will be displayed to

rescuers properly. To view the virtual scene, a rescuer should wear a small HMD or a goggle.

2.2.3 Augmented Reality (AR)

VR technology enables the users to immerse in a virtual world where the surrounding is completely computer-generated graphics. Users are entirely blocked from the real scene as their senses are occupied by VR equipments. To enhance the users' perception and interaction with real world, the concept of mixed reality including Augmented Reality is invented.

Let's take a look at the reality-virtuality continuum which is defined by Milgram [24] (Figure 2-11) to figure out the position of AR in the range of mixed reality.

Figure 2-11: Milgram's continuum of real-to virtual environment

The two ends of continuum are represented by the two kinds of environment: real and virtual. Mixed reality is the range in between the two ends. In this range, Augmented Reality is located near the real environment therefore AR is essentially an

augmentation of real environment which is superimposed by 3D virtual objects on several certain places. The definition of AR is presented in the next part.

2.2.3.1 What is AR?

AR provides a possibility that the interactive virtual world (computer-generated) and the interactive real world could be combined and displayed simultaneously. In this combination, virtual objects are registered and superimposed onto the real world in different proportions. Users are able to see physical objects and virtual objects simultaneously in real time. Once the real world scene changed, the registered objects also respond as if it is part of the real world. Conversely, if the virtual objects are moved, the real world should be constrained with respect to these movements.

In brief, an AR system should have the following features [25]:

- blends real and virtual objects in a real environment
- real-time interactive
- registers (aligns) real and virtual objects with each other.

Registration refers to the association of real and virtual object with proper and accurate alignment. Without accurate registration, the illusion of the virtual objects in the real environment is severely compromised. At present, registration is still a critical problem in AR.

To date, AR has gained a variety of remarkable achievements in many fields such as medical surgery visualization, maintenance and repair of complex equipment, training, entertainment, collaboration, navigation and so on. Some AR applications are depicted in Figure 2-12. An AR application would be a visualization of a new building that is going to build in a certain place would replace the current building or any

objects located in this place at present. Another example is the visualization of sub-surface pipes of a water supply system.

Figure 2-12: Some Augmented Reality examples

In fact, the definition of AR is not restricted to visual sense. It could be able to apply to all senses, including haptic and aural.

2.2.3.2 AR technologies

This Section focuses on AR technologies which are used for developing AR systems in indoor environment. An AR system provides a combination of real and virtual objects in one integrated scene. To obtain an AR view, data of the real objects observed by the user are sent to computer. The virtual objects are then generated from the received data. The real and virtual objects are blended and rendered in such a way to give the user the perception of observing one integrated scene. Depending of what kind of application is developed, different technology approaches could be used to obtain an AR system. Basically, an AR system often involves four components (and corresponding technologies), i.e. displays, tracking systems, devices for interaction and

graphics system (computer). This Section concentrates on displays and tracking systems, since the type of display and tracking system have a great influence on a particular AR system.

The display which is responsible for the level of immersion, field-of-view and image resolution is one of critical component in AR system. The tracking system is the most important component which is used for tracking position and orientation of the objects in the real world. The more accurate the tracking data are, the correct and robust registration of virtual and real objects could be achieved. For generating the virtual objects as well as registering the virtual with the real one, graphics system which normally is a conventional powerful computer, is responsible for this work by generating frames of virtual objects based on the frames of the real ones and then combining two frames together.

2.2.3.3 AR Displays

The combination of real and virtual images in one integrated scene could be relied on the following display technologies:

- Head-mounted displays (HMDs)
 - Optical See-Through
 - Video See-Through
- Virtual Retinal Systems
- Monitor-based AR systems
- Direct Projection Displays

See-through displays

See-through display which is a particular kind of HMDs is mounted on the user's head. See-through displays enable the users to observe the mixture between the virtual objects and real world as well as the surrounding environment. The users could be able to see-through the virtual objects.

There are two approaches of see-through displays which allow the users to see both physical and virtual environment simultaneously at the same time. They are video see-through (video-based) and optical see-through (optical-based)

In video-based see-through HMD, a camera is mounted on the helmet to record the surrounding scene. The camera performs a perspective projection of the 3D world to 2D image plane. The internal (focal length and lens distortion) and external (position and orientation) parameters of the camera determine exactly what are projected onto the image plane. The virtual image is generated by a computer graphics system based on the internal and external parameters. Then the virtual objects are registered with the real world to provide augmented reality view. Figure 2-13 depicts the conceptual diagram of a video see-through HMD.

Figure 2-13: Conceptual diagram of a video see-through HMD

In optical-based, the physical and the virtual world are registered by optical merging. The optical combiners (partial mirrors) enable the user to see the combination through glasses. The position and orientation of the user's head are obtained by using position and orientation tracker. With this optical see-through HMD, the user could see the real world directly and therefore no distortion appears. Figure 2-14 depicts the conceptual diagram of optical see-through HMD.

Figure 2-14: Conceptual diagram of optical see-through HMD

To-date, the development of AR system still meets some limitations in display technology. There are no see-through displays that have sufficient brightness, resolution, field of view, and seamless blend between real and virtual objects has not been achieved. Furthermore, many technologies that begin to approach these goals are not yet sufficiently small, light weight, and low-cost [25]. Several kind of see-thought displays are showed in Figure 2-15.

Figure 2-15: (a) (b) Optical see-through; (c) (d) video see-through

Virtual Retina Displays

Virtual retina displays use a technology that directly projects the computer-generated graphics on the user's retina. This technology is developed by MicroVision which draws on the retina with low-power lasers whose modulated beams are scanned by micro-electromechanical mirror assemblies that sweep the beam horizontally and vertically (Figure 2-16).

Figure 2-16: Virtual Retinal Display – Personal Display System made by MicroVision

Monitor-based AR system

The monitor-based AR system allows the user to observe the AR image which is the integrated scene of real and superimposed virtual objects on a regular PC screen display without the need of wearing special glasses. This approach is widely used in laboratories for testing systems and creating low-cost demonstrations. Figure 2-17 shows the conceptual diagram to set up monitor-based AR system including the basic components to achieve the augmented view.

Figure 2-17: Conceptual diagram of Monitor-based AR system

Projection Displays

An alternative approach to AR is to project the virtual objects directly on physical world that are to be augmented. In the simplest case, the virtual objects are projected coplanar with the surface on which they are projected or mono-scopically projected from a room-mounted projector [25] (Figure 2-19).

Figure 2-18: Virtual images are projected coplanar with the surface on which they are projected

Another approach for projective AR relies on head-worn projectors, whose virtual objects are projected along the viewer's line of sight at objects in the real world. The target objects are coated with a retro-reflective material that reflects light back along the angle of incidence. Multiple viewers can see different images on the same target projected by their own head-worn systems because the projected images cannot be seen except along the line of projection. If using the projector with low resolution output and non-retro-reflective objects, the virtual objects could not be seen clearly as they are obscured by real objects [25].

Figure 2-19: Head-worn projective display

2.2.3.4 Tracking Systems

Similar to VR, tracking is very crucial in AR. Once tracking is not accurate, the registration between the real and virtual world is unable to be implemented. According to Azuma [26], tracking in AR is significantly difficult than in Virtual Environments. As AR is the combination between the real and virtual scene, AR could be developed for both indoor and outdoor environment. In this part, the AR tracking technology for indoor environment will be discussed in accordance with the purpose of the research which requires the assistance of AR for indoor environment.

In general, the commercially available tracking technologies are applicable to both VR and AR such as mechanical, inertial, acoustic, electromagnetic, ultrasonic and optical trackers. In fact, those trackers could be used for both indoor and outdoor environment but still have some limitations and restrictions with respect to each technology.

According to Azuma [26], inertial trackers facilitate user because it could be used without a source (source-less) but the precision will be drifted during operation. The active source trackers such as optical, magnetic and ultrasonic ones should be used in structured and controlled environment where the working range is restricted. Magnetic trackers are vulnerable to distortion. Precision of ultrasonic trackers is subject to variation in ambient temperature. Lastly, optical trackers are highly accurate but expensive. Mechanical trackers are high accurate and no latency however users will feel uncomfortable of being tethered. Typically, AR systems employ hybrid tracking techniques (e.g., magnetic and video sensors) to strengthen and compensate weaknesses of individual tracking technologies hence they should yield the best results [25].

2.2.3.5 Summary

Augmented Reality (AR) enables the user to see the combination of real objects and superimposed virtual ones in an integrated view or augmented view. A basic AR system normally includes display device, tracking system and a graphics-generated system (computer). To be able to integrate the virtual objects to the video-images of the real world, the accurate position of the object with respect to the real world is required. The AR visualization is then obtained by combining the frames of real objects with the frames of virtual objects generated by computer.

In rescue mission, AR could be used to enhance rescuers perception and decision making in way-finding during their operation. AR is used in the case of visible environment condition. By wearing AR display device, a rescuer could be able to view real scene combined with the superimposed computer-generated guidance graphics. Tracking system is used to provide user's viewing position and orientation.

2.3 Visualization for Way-finding in Emergency

Rescuers who are not familiar with the rescue environment often rely on verbal communication or directional signs to find their way.

In indoor environment, visualization support for way-finding is often found as graphical signs informing occupants of the way to certain places. These signs are (1) *maps* locating object relating to each other (Figure 2-20); (2) *symbols* naming objects (Figure 2-21); (3) *a network of graphical arrows* indicating the direction to the nearest exit [10] (Figure 2-22).

Some graphical signs are used to direct passengers and occupants under normal conditions of way-finding and some other specialized signs for way-finding in

emergencies. Graphical symbols, maps and networks are designed to meet three distinct functions to assist way-finding:

- to identify places and routes
- to map the spatial layout of an area
- to direct occupants and passengers to route

The pictographic symbols will typically be used to direct occupants to certain places in case of emergencies and “you-are-here maps” is used to assist passengers to identify places and routes in emergencies as well as in general way-finding tasks.

Figure 2-20 is an example of a “you-are-here” map in which directional signs is embedded to give way-finding information of important places on the ship under normal condition. In an emergency this type of complex sign would not be very useful.

Figure 2-20: A you-are-here map on a ship

Besides the conventional emergency signs which typically required in every built environment, there are a set of graphic symbols that have been approved for

assisting passengers on ships in finding their way in emergencies. These signs are showed in Figure 2-21 and Figure 2-22.

Figure 2-21: Pictographic symbols (in green): assembly sign, lifejackets, emergency exits

Figure 2-22: Pictographic symbols (in green) used in a network of local arrows representing the escape routes through a ship

To enhance human perception in way-finding, some graphic symbols are grouped together into a sequence of signs. The meaning embedded in the sequence of signs is to express a clearly instruction to viewers. Figure 2-23 is an example of a sequence of graphical symbols including an assembly sign with the adjoining arrow which could be interpreted as “*An assembly station is found by going this way*”.

Figure 2-23: An assembly station is found by going this way

However, many semantic problems in interpreting groups of signs and sequence of signs were found out. These problems are as follows:

- Misinterpretation in reading of sign groups and sign sequences.
- Ambiguity of signs
- Confusion of similar signs

Nowadays, the traditional pictographic (static graphic symbolic) signs has been replaced with photo-luminiscent signs as well as dynamic graphic signs for emergencies. An example of dynamic graphic signs is the “animated network” of arrows that light up in the floor of an aircraft in case of evacuation. These signs have also been introduced on cruise ships.

2.3.1 Summary

The graphical signs for emergencies are used to assist occupants and passengers in way-finding when they try to escape or evacuate. It is very useful for human agents who are the primary assistance resource in emergency procedure and evacuate passengers.

In general, these signs are static signs that are placed at appropriate locations where viewers could easily to observe. These signs are very effective and efficient in way-finding in the context of low level emergency. In case of major hazard like fire, panics might arise and smoke causes low visibility. Therefore, some signs could be obscured.

To take advantages of graphical signs to facilitate rescuing task, these signs are studied and integrated into visualization system accordingly. Instead of looking for the static signs in spatial decks, rescues would be directly provided proper symbols in a way that they could be easy to perceive.

2.4 Review of Related Works

The 29th regulation of SOLAR (Safety Of Life At Sea) convention, which is about Decision Support System for Masters of Passenger Ships, stated that *in all passenger ships, a decision support system for emergency management must be provided. It should consist of, at minimum, printed all emergency plans or plans covering all foreseeable emergency situations, including fire, damage to ship, pollution, unlawful act threatening the safety of the ship and security of passengers and crew, personnel accidents and emergency assistances to other ships* [27]. Although the convention is widely accepted, however the effort to ensure that following an accident, survivors could safely abandon ship, survive at sea, be detected and retrieved by rescuers, is still carried out.

This Section introduces the related works which use visualization techniques to assist the decision making support for emergency situations. Although some researches were studied in different areas, however their achievements could be made use in maritime safety.

ViSGrEn (Visualization System for the Grid Environment)

Sura [28] proposed an architecture design for a real-time web-based visualization in the grid environment. Such system is used to predict the future events based on what has happened and notifies the concerned personnel. The goal of this research is to develop such a system by finding an appropriate design that minimizes the limitations imposed by the Web and the grid environments. Numerical simulations and predictions are run on the high-performance computing resources of a grid to generate results in real-time or faster than real-time. Those results are displayed to the clients, who operate in extreme conditions, in an accurate and easy-to-read way. The goal is to convey the information in a short time. This visualization must be highly interactive and should respond to user actions immediately. This visualization runs in a simple interface provided by a Java3D-enable web browser, as shown in Figure 2-24. User can interact with visualization by rotating, translating, and zooming into the scene.

Figure 2-24 also shows snapshots of the scene after various interactions. With all the above features, this system acts as a remote design and training tool for the designers and trainees.

Figure 2-24: The visualization runs as an Applet in a Browser. Scene zoomed and translated.

SHARE

Linde Vande Velde et al [29] did a project named SHARE, an EU funded 6th Framework Program project, addresses the need of emergency teams for multimodal communication and for decision support with a prototype advanced mobile service based on Push-to-Share technology.

The SHARE system provides emergency workers with on-site, online details of operational history and current operational status as well as access to pertinent supporting information, in particular information concerning the environment of the incident.

In the SHARE project, TeleAtlas provides digital maps which include advanced features such as the presence of road furniture such as trees, electric poles, locations of

emergency exits, locations of stairs and elevators, etc. Hence these features are really essential for making tactical decisions. In addition to 2D information, 3D information will also be provided, which makes a crucial contribution to rescue operations.

Emergency workers will access the SHARE system using mobile end devices such as PDAs or tablet PCs. A multimodal interface that combines stylus and speech will make querying or addition of information to the system intuitive and comfortable.

Displaying information relevant to the operation, such as the location of units, vehicles and field hospitals as well as the location and direction of escape routes and tactical movements, in a spatial environment, allows the rescue planners to get an immediate general view on the situation at a certain point in time and allow them to act accordingly.

The management of large emergency incidents is distributed over a command hierarchy composed of different levels (Level A, B, C). Lower levels of command are specialized to particular tasks or areas. Each level of command will get only that static and dynamic spatial and non-spatial information which is relevant at a certain moment to help with fast and intelligent decisions.

Figure 2-25 shows the 2D and 3D maps that are provided by the SHARE system. In this figure, 3D map is enhanced with depiction of trees while the 2D map represents the relevant information to the operation.

Figure 2-25: 2D and 3D maps are provided by SHARE system.

In the SHARE project, the Map interface allows the user to pan, to zoom or to jump to a particular position, specified either by a street name or by geo-coordinates. The user could define sections (regions of responsibility for individual firefighting units) on the digital map using the drawing tools available on the right side. Figure 2-26 shows the Map User Interface on Tablet PC.

Figure 2-26: Map User Interface on Tablet PC

MIND

Morin et al, [30] addressed in 1998 the problem of how to transform operational objectives into goals for the visualization of the operation, and how those goals could direct the modeling of the operation. The end result is a mission history which is an executable, discrete-event model of the rescue operation. A mission history is made up of hierarchical object models, representing the units participating, and a sequence of events that represents the state transitions that take place in those objects. Each event is marked with the time when it occurred during the operation.

Construction and visualization of a mission history are performed by the MIND system. MIND is an integrated presentation system, which includes displays for tactical maps, annotated photographs from the exercise, recorded tactical radio communications, and compiled statistics about unit performance.

MIND includes several views for displaying data and visualizing events from the mission, each of which can be moved, resized or hidden on request from the user. In addition to data views, the system has controls for mission history selection and navigation and replay. Figure 2-27 shows a screen dump from the MIND system during the replay and visualization of a mission history.

Figure 2-27: The user interface of the MIND visualization tool.

RESCUE3D

Rescue3D is proposed by Alexander Kleiner and Moritz Gobelbecker [31] by displaying 2D and 3D visualization and also statistical information at the same time. Therefore, the introduced viewer system is designed to create multiple views of the simulation. Additionally, it will be supported to merge multiple views into one window by the technology of Head-Up Displays (HUDs). At any time and mode of the visualization, the scene currently rendered on the 3D screen will be indicated within the 2D view.

Rescue3D provides a new visualization of the rescue domain, namely enhancing behavior of multiple agents in real-time and providing a solution to the recognition problem in 2D. Figure 2-28 illustrates the proposed interface of Rescue3D.

Figure 2-28: Proposed interface of Rescue3D with simultaneous scene rendering in 2D and 3D, and visualization of statistic

CHAPTER 3

DEVELOPMENT OF CONTENT AND FORMAT FOR DISPLAY ON HMD

Section 2.4 presented the general visual support for emergency which is typically used to assist way-finding in indoor environment. This visualization represents physical signs in terms of maps, symbols and network of arrows (up, down, right, left). They are used to convey the way-finding instructions to viewers through visual communication. Besides plenty of advantages in way-finding assistance, these graphical signs still have some drawbacks that prevent way-finders from comprehensively perceiving and cognizing the provided information.

This chapter introduces the research work for determining the effective visual representation which is generated by the visualization system. This work is based on the practical problems of traditional signs and the knowledge of visualization design in emergencies which are the principles and criteria benefited from other researches (Section 3.1 and 3.2). This visualization is then utilized in this research to develop the content and format of the visualization to be display on rescuer's HMD (Section 3.3).

3.1 Problems of Traditional Signs for Way-Finding

As discussed in chapter 2 and according to [10], the visual instructions in indoor environment are generally provided with maps, symbols and the network of arrows which are designed by official authorities and therefore have been approved for assisting occupants in finding their way in emergencies [32].

Although these graphical signs are very useful in way-finding since their achievements have been considerably gained in practice. However problems still

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occurs with regard to visual, syntactic and semantic aspects, hence these signs become ineffective in case of emergencies that require fast decisions and responses. The visual problems are as follows:

- Visual access to signs
- Visual obstruction to signs
- Visual masking of signs

Visual access to relevant signs can be impeded by the imposed viewing angle. Signs can be obstructed by collapses or passengers in situations of crowding or can be masked by visual noise (smoke, power failure) [10].

The syntactic and semantic problems arise when viewers interpret groups of signs and sequences of signs [10]. These problems are as follows:

- Misinterpretation of sign groups and sign sequences
- Ambiguity of signs
- Confusion of similar signs
- Confusing gestalt effects (proximity of signs etc.)

The “misinterpretation” is referred as a problems in case of several unrelated symbols are formed into a group or a sequence of symbol groups to express an instruction. As the context of each symbol in the group is unrelated hence the viewers could interpret the group syntax wrongly (Figure 3-1).

Figure 3-1: Several unrelated symbols in a group could cause de-contextualized problem

Ambiguity and confusing problem arises from the semantics of free choice of route (Figure 3-2). These problems also arise when interpreting a complex You-Are-Here (YAH) map in which users are unable to extract information to locate and orient themselves. The unworkable YAH map could cause by its components like YAH symbol, escape route, etc. For instance, YAH symbol is too small to be detected or its shape in terms of a filled circle or a filled equilateral triangular cannot be used to indicate the user's view direction in immediate surroundings. Some YAH maps lack escape routes from current location of the user to the nearest exit (Figure 3-3).

Figure 3-2: Ambiguity of choice

Figure 3-3: (left) YAH symbol is too small; (right) Lack information of escape route

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If rescuers are familiar with the spatial arrangement, they could find their ways without relying on the instructions of the visual signs. In the other hand, the syntactic and semantic problems are really an issue for proper understanding the assisting information.

Last but not least, the problem of using you-are-here (YAH) maps, which is a category of emergency scheme, should be taken into account. YAH maps are used to assist the users to locate and orient themselves in a spatial space. They provide the users the knowledge of the current layout such as exit, escape route possibilities.

In fact, YAH maps are omnipresent in indoor environment. However, there is the critical problem in YAH map design and map placement [32] since there is no clear principle for the design of these maps and for their proper placement.

In this research, the visual problems could be overcome by using the different approach of display. Specifically, the traditional method of placing the visual signs on the real environment is replaced by putting directly all the relevant signs which related to the current way-finding situation in front of the viewer's eyes with the use display devices, namely using Head Mounted Display (HMD). As such, rescuers no longer have to look for the proper direction signs placed somewhere around them but follow what appearing on the HMD's screen. The detail of this approach is presented in chapter 4.

The remaining challenge is to confront the syntactic and semantic problems when the viewers interpret a group of signs. To overcome these problems, the next Section (Section 3.2) will introduce the principles and criteria to determine effective visualization for way-finding in an emergency.

3.2 Principles and Criteria to Determine Effective Visualization for Way-finding in Emergency

According to [33], a good visualization should have following features: correct, concise, self-explaining and providing insight. A good visualization will give viewers a clear picture of data, moreover a phenomenon behind data. Therefore, creating and interpreting a good and effective visualization is a difficult task due to there is no generic blueprint available [34].

In cases of emergency, rapid cognition and proper understanding is crucial. This aspect should be an issue in developing the visual representation in emergencies.

In this research, the visualization which represents the assisting information is provided to rescuers through HMD. Contents of the visualization which can include a simultaneous display of several components such as YAH maps, symbols, etc or each component could be individually appeared in accordance with the real situation. No matter what the content is appeared in what way, the visualization should have to meet the overall goal of the visualization support in emergencies.

Literature on visual graphic communication provides a rich knowledge-base for formulating general and effective design criteria. Among them, some criteria are relevant to determination the task-specific visualization for emergency situations. Although, these criteria were used to determine visual representation in reality like physical signs, symbols and maps which are directly placed on the real environment but they serve the same target with this research objective. Besides, effectiveness of the visualization which is created based on these criteria has been experimentally evaluated by several authors [35]. Therefore, they could be applied to identify the effective visual representation in this research as well as to diminish the visual problems (syntactic and semantic problems).

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According to [32], these criteria are as follows:

- **Completeness:** All information that is necessary to fulfill a given task needs to be represented on the visualization.
- **Perceptibility/syntactic clarity/visual clutter:** All the relevant graphic features for a given task – once they are represented in the visualization – need to be easily perceptible and readable. Visual clutter or superfluous objects should be reduced to minimum.
- **Semantic clarity:** All the symbols and map features need to be easily imbued with meaning. In other word, they should be self-explanatory.
- **Convenience:** A good visualization should take into account how, when and where the appropriate information is used.

Since the main function of YAH map is to provide the current position and orientation of a user in an environment as well as to provide the comprehensive view of the layout, hence it should be an indispensable component to assist way-finding processes. Besides using the above criteria, the following principles to design content of the map should be considered:

- **Alignment:** The YAH map and the environment should be aligned in a way that the floor layout in the map should have the same orientation with the real one with respect to the user's perspective. In case of emergency, alignment is the most important criterion for the design of good YAH map in order to obtain congruence with the user visual experience. The alignment would reduce the necessity for mental or head rotation. According to [32], non-aligned YAH maps significantly complicate the way-finding process.
- **YAH symbol:** The YAH symbol has to serve two functions: First, it provides the current location of the user within an environment; second it indicates the user's orientation within immediate surroundings.

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According to [32], the two functions could be achieved by combining the located dot with an arrow or by a triangular shape (contextual use of the acute triangle indicates the orientation) (Figure 3-4).

Figure 3-4: The two functions of YAH symbol could be achieved by combining the located dot with an arrow

- *Alignment of text in the map:* The text in a map should be generally readable without requiring to turn one's head.

3.3 Proper Content and Format for Display on HMD

3.3.1 Content of Display

Section 3.1 and 3.2 pave the way to develop an effective graphic signs which are used to assist occupants in case of emergencies. The content to be displayed on HMD

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would be developed based on the benefit given by the criteria for design a good visualization and the principles of YAH maps in the previous Section.

Completeness: According to [10], the content should be fulfilled the three following functions:

- To identify places and routes
- To map the spatial layout of an area
- To direct occupants and passengers to routes

In this research, the technique of VR and AR provide a visual possibility to easily identify places and routes in any condition of environment visibilities. VR facilitates the users in case of visual noise by enabling them to figure out the places and routes through a 3D model which is the 3D replication of the real one. Alternatively, AR achieves this task by enabling the users to see and interact directly with the real scene in case of high visibility. The details of using AR and VR technique for rescue are worked out in chapter 4. Moreover, rescuers are provided other possibility to identify places and routes through the floor plan on YAH map. Specifically, name of the floor plan and possible escape routes will be explicitly given on the map.

To map the spatial layout of an area, a good design YAH map is introduced to achieve this task. The map components comprise a specific floor layout of an indoor environment, the current location and head orientation of the user and the possible escape routes. In this research, YAH map is introduced as dynamic map in which map's components are changed in real-time in accordance with the user's location and orientation in real-time. With ordinary static graphic maps which are normally placed in real environments, the user has to rotate his head or uses mental rotation to interpret the map properly. With the dynamic map, for instance, rescuer could know where he is within the vessel and how he is moving such as from bow ("front") to stern ("back") or changing sides from starboard ("right") to port ("left"). The dynamic map could also rotate itself in order to obtain congruence with the user visual experience.

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To direct occupants and passengers to routes and to the exits, the exit signs should be marked explicitly on the floor plan to indicate the place of exit doors or exit staircases. Based on the exit signs and the YAH map, the user could be directed quickly to the exits.

Thus, to provide the user sufficient necessary information to achieve way-finding task in emergency, content of the visualization to be displayed on HMD should comprise the combination of YAH map and direction arrows superimposing on either real scene or 3D virtual scene. Depending on the visibility condition, the real scene or 3D virtual scene would be selected (Figure 3-5).

Figure 3-5: Content to be displayed on HMD in case of visible scene

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Figure 3-6: Content to be displayed on HMD in case of low visible scene

Perceptibility/ syntactic clarity/ visual clutter: In general, the whole content is developed with less but sufficient information. Too many provided information will cause confusion to the rescuer. The relevant graphic components of the content are the YAH map, arrows and 3D model (for scene with visual noise). These graphic components are the crucial ones that convey almost information needed for way-finding in rescue task. As all content should be displayed on one screen, hence all components should be arranged in appropriated places and appeared with readable scale that the user could be able to extract needed information in a short time.

- YAH map:** The map depicts a floor plan which is merely the floor arrangement. Superfluous objects like furniture, structure components are not necessary to appear on the map in order to make the map easily readable to the user. The legibility of travel space arrangement is very crucial in way-finding, hence travel space is distinguished with other spaces by using different filled colors (one color for travel space, one color for accommodation space and one for structure of vessel). YAH and possible escape routes are made prominently with red color (the most

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attractive color) and put them superimposing on the floor plan. The location and orientation of the user is indicated through the YAH symbol (Figure 3-7). Due to the fact that, vessel's layouts are formed longitudinally. That means the vessel length is much longer to the width. Once the whole YAH map fits in the HMD screen, the user are unable to extract information as map's components are too small to identify. Therefore, the YAH map scale should be kept in an appropriate proximity that could be readable by the user. The last but not least, the floor plan should be set to semi-transparent, so that the hidden area behind the floor plan could be recognized by the user.

- **3D model:** 3D model is the 3D replication of the real scene. Like the map, unnecessary objects like furniture should be eliminated out of the model to avoid visual clutter. However, scene reality could be enhanced through using lighting, photo realistic materials and texture (Figure 3-8).

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Figure 3-7: Travel space, YAH symbols and possible escape routes are highlighted in YAH map. (Original layout (left); YAH map (right))

Figure 3-8: 3D model of the real scene (unnecessary objects are cut down)

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Semantic clarity: Contextual use of the YAH map's components, AR and VR scene are very straightforward to provide the user sufficient information. The issue at hand is to express and highlight which component is more important with respect to the whole content.

Convenience: All assisting information should be displayed and updated in real time to support rescuers to achieve their task at any time.

YAH map alignment: Dynamically YAH map alignment is very crucial in way-finding as it could ease orientation and reduce mental interpretation and head rotation. As such, the map orientation should rotate in accordance with the map reader perspective. With the aid of orientation tracker, once the user orientation change hence the map also rotates in real-time accordingly. However, tracker operation is pretty sensitive as it could detect the change of the user's head rotation in very small angle. Therefore, any small change should be avoid otherwise it could cause visual disturbance to the user. Another important feature of alignment is text alignment. All important text such as the name of deck, name of important places, etc should be rotated horizontally as it is used to be in general. Therefore, the reader is no longer to turn his/her head to read. Example of YAH map alignment is as in (Figure 3-9).

Figure 3-9: YAH map rotates to adapt the user perspective. Rescuer goes straight (left image) then turns right (right image)

3.3.2 Format of Display

In this research, Java3D and J2SE (Java 2 Platform, Standard Edition) are used to develop the visualization system. The whole content will be generated by the system and then displayed on applet window. In order to display the visualization on HMD screen, the HMD should be plugged into the system properly (the notebook in this case). Therefore, the information which displays on applet could be presented on HMD screen.

3.4 Summary

Chapter 3 has introduced a method to determine the proper content and format to display on HMD. Firstly, the content is investigated based on the visual problems during performing way-finding process. Then it is developed with the use of literature on visual communication in emergency.

Ultimately, content of the information to be displayed to the rescuers is the combination of a YAH map superimposing on a 3D scene. On the map, current position of the rescuer, his viewing orientation and possible escape routes are marked prominently. Name of the floor and exit locations are also explicitly indicated. The 3D scene will be switched from real scene to virtual scene depending on the environment visibility. During navigating in the indoor environment, the YAH map will be rotated in accordance with the user viewing perspective.

This research employs Virtual Reality technique and Augmented Reality technique in representing the visualization for virtual scene and real scene, respectively. Therefore the content will appear in either Virtual Reality display or Augmented Reality display upon the environment visibility. Virtual Reality display is the combination of the YAH map superimposing on the virtual scene. Augmented

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Reality display is the combination of the YAH map superimposing on the real scene which is recorded by a video mounted on the user's head.

After the content has been determined, it is made use in developing the visualization system which is introduced in Chapter 4.

CHAPTER 4

COMPUTER-AIDED VISUALIZATION SYSTEM

This chapter introduces the research work to develop the computer-aided visualization system. First, a framework of the system is created to depict the overall picture of the system including main functions and system's activities. Then, the framework is deployed in details with respect to the two research approaches VR and AR. Finally, the system would be demonstrated in a simple environment to test the robustness and correctness, namely in B4 floor of N1 building in Nanyang Technological University (NTU) campus. The results of the demonstration are introduced in this thesis and would be a case study to enhance and amend the system for vessels and other indoor environments.

4.1 General Framework

4.1.1 Overall Paradigm

This overall paradigm represents for the main idea of the visualization system (Figure 4-1). Specifically, rescuer sends necessary data to the visualization system including rescuer's current position, his head's orientation and the environment visibility status (visible or less visible). Based on the data, the visualization system generates proper graphics to assist the rescuer to find the way out from current location and at present situation accordingly. The graphics are then displayed on rescuer display device. All activities are kept in a loop as in Figure 4-1 and operating in real-time.

Figure 4-1: Overall paradigm

4.1.2 General Framework

The framework is developed based on the main idea in overall paradigm. This framework depicts the comprehensive picture of the visualization system with main features and system activities. In other word, the framework represents what is involved in the system and how the system actually works. Figure 4-2 illustrates the general framework for way-finding in rescue. Since this framework is generic, it could be applied for relevant cases which have the same objectives by modifying the content of some framework's components or adding additional minor features.

Figure 4-2: General framework

4.1.3 Framework Specifications

Framework specifications are as follows:

Input

Input is the data needed by the visualization system in order to generate the proper graphics to achieve the rescue task. There are two types of input data: real-time data and pre-defined data. Real-time data are current position of rescuer, rescuer's head orientation, current environment condition. Pre-defined data are floor plans and

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3D model of the environment. Real-time data are obtained continuously during system operation. The pre-defined data should be prepared in advance.

Rescuer position could be detected in real-time by using positioning tracker. Based on the review in Chapter 2, Ekahau positioning engine is used in this research for position tracking the current position of the rescuer within an indoor environment via wireless signal. Ekahau is chosen among various types of position tracker as it is very convenient to use, easy to develop and omnipresent wireless signal. To make it work, simply installing the Ekahau software packet to the devices which support wireless feature and then performing site calibration. The position retrieved from Ekahau is in terms of x, y and z coordinates.

Rescuer head's orientation is obtained through orientation tracker. The data could be retrieved in real-time in terms of roll, pitch and yaw orientations which are rotations about x, y, z axes, respectively. In this research, Inertial Cube2 is used for orientation tracker which is often mounted on the user's head. Inertial Cube2, a product of Intersense, is chosen since it is small, easy to use as well as to develop. The only limitation of inertial tracker is error accumulation but InterSense has handled this limitation by using a gravitometer and compass measurements to prevent accumulation of gyroscopic drift [20]. Also, this research does not require the tracker to detect orientation in a very small angle hence it is not a problem that needs to pay attention to.

The environment condition is subjected to the visibility of the surroundings. It often exists in either of visible scene or visual noise scene (smoke, collapse ...). The environment condition is manually input to the visualization system by the rescuer in accordance with the actual scene.

Floor plans which represent the layout of the YAH map must be available because each environment has its own spatial arrangement. Besides, floor plans are also used to perform site calibration for position tracking by Ekahau. The site calibration

should be done before start using the visualization system. Detail of position tracking using Ekahau is introduced in Section 4.2.

3D model of the environment which is the 3D virtual replication of the real scene provides rescuers a possibility to navigate in visual noise scene. It is created by using 3D modeling software such as AutoCAD and 3DS Max.

With this framework, any specific cases could be taken form by inputting different pre-defined data. Therefore, this framework could be utilized in either built environment or vessel environment as well as in other indoor environments.

Route determination

This part deals with generating possible escape routes from current position of the rescuer.

YAH map determination

In this part, YAH map and its components are generated based on input data and result of the previous part. Specifically, the possible escape routes and current position are visualized and integrated with floor plan to become YAH map.

Environment selection

Environment selection depends on the condition of environment visibility. According to the condition of either clear scene or visual noise scene, real scene (AR mode) or virtual scene (VR mode) is selected to take part in the visualization, respectively. Each kind of environment employs corresponding technology to implement. Virtual environment uses VR technology and real environment employs AR technology.

Integration

This part contains the procedure to merge all generated graphic elements together. Specifically, YAH map and arrow are placed superimposing on the selected scene.

Rendering

This is the final process of giving appearance to the visualization. Roughly, this process would combine geometry, light, viewpoint, texture, lighting, shading information and other effects to produce a visible graphic output. This visualization system uses real-time rendering to provide the real-time visualization to the rescuer.

Output visualization

This is the final result of the framework which is the visual representation to be displayed on HMD. In order to observe both VR and AR display by using one device, a video see-through HMD should be the most suitable display device to use in real situation. However, high resolution HMD cost is very expensive [36]. Also, output of the system could be verified on laptop screen. Hence in this research, a normal HMD is used instead. To perform real-time video recording function, a webcam is used in addition.

4.1.4 Framework Operation

Input data are retrieved from corresponding devices and sources. The position information is used to determine the possible escape routes. Then these routes are made use of with the orientation information and the specific floor plan to generate the YAH map and direction arrow. The next step is to determine which scene should be used to assist the rescuer to recognize his way easily in accordance with the current environment condition. If the environment is covered with visual noise then the virtual scene would be selected, otherwise the real scene is used in case of high visibility. The following procedure is to integrate YAH map and the determined scene together and

put each element to its appropriate place. Lastly, the visualization is given appearance via rendering process and displayed on rescuer's HMD.

4.2 Application of the Visualization System

Based on the general framework, a practical application of visualization system is developed and demonstrated in a certain building. To make the system workable in such environment, the provided information such as 2D floor plans, sections should be sufficient and precise. In this research, the visualization is demonstrated in B4 floor of N1 building in NTU campus. Details of application development are introduces in the Sections below.

4.2.1 Input Data

As introduced in Section 4.1 General Framework, Ekahau positioning engine is selected for position tracking to provide real-time position of the user based on wireless signal. In constrast other positioning trackers which are hardware devices, Ekahau is a kind of software package that could be installed to tracked devices that support Wi-Fi feature. In this research, Ekahau is installed in a light laptop. In order to make it work properly, site calibration is performed after installation to recording data for the Positioning Model. This work is done by taking the laptop and walk along possible travel paths between rooms, corridors, floors and other locations. Since rooms in N1-B4 are inaccessible due to private reasons, let's assume that the way-finding process almost take place on the way between corridors. Therefore site calibration is carried out on the passageway areas, as depicted in Figure 5-3.

Figure 5-3: Possible travel paths and site calibration areas in N1-B4 floor

For orientation tracking, Inertial Cube2 device (Figure 4-4) provides real-time precise orientation data of the user's head rotation in terms of *yaw*, *pitch* and *roll*. To make it work, device's driver should be installed properly. The device is then plugged in the laptop and mounted on the user's head to carry out tracking task.

Figure 4-4: Inertial Cube2 orientation tracker

The pre-defined input data is 2D layout of the floor and its 3D model with sufficient features like a real one. The 2D layout is created with AutoCAD software application and then stored in terms of image format (JPG). The 3D model is built from 2D blueprint (plans, sections, etc) by 3D modeling software like AutoCAD and 3DS Max and then stored in terms of 3DS format.

4.2.2 Route Determination

The route here presents possible escape routes from the current position of the rescuer to the nearby exits. This information associated with the current position, are then registered and superimposed on floor layout to present YAH map. As the objective of this research is to provide the visual effect to rescuer, hence the route determination is tailored for the applying floor plan of N1-B4 and any simple environment as well.

The route determination process is carried out by following steps:

- First, the 2D layout is scaled in proportion to position tracking coordinate system with respect to unit ratio (Figure 4-5). Top edge and right edge of the layout are placed coincidently on the X and Y axes, respectively. Hence, the top right corner of the layout is placed at the origin (0,0).
- Then, a graph of nodes which includes exit nodes and dummy nodes is constructed (Figure 4-6). Dummy node is the intermediate node for connecting the position of rescuer with an exit node in accordance with geometry of corridor's layout.
- According to [37], corridor's area is divided into a bunch of regions (Figure 4-7). When the x-y position of rescuer falls within a region then its corresponding nodes (exits, dummy) which make up an escape route are determined.
- From the current position coordinate of the rescuer and coordinates of exits, possible escape routes are determined in (Figure 4-8). Each route is made up of current position and a node, or a set of nodes (exits, dummy).

Figure 4-5: 2D layout is scaled in proportion to position tracking coordinate system

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Figure 4-6: A graph of exit nodes and dummy nodes is constructed

Figure 4-7: The whole corridor's area is divided into a bunch of regions.

Region N°	Route should take
1	(P,D1, E1) (P,D1,D2,E2)
2	(P,D6,E1) (P,D6,D5,E2)
3	(P,E1) (P,D1,D2,E2) (P,D6,D5,E2)
4	(P,D1,E1) (P,D2,E2)
5	(P,D5,E1) (P,D6,E2)
6	(P,E2) (P,D2,D1,E1) (P,D5,D6,E1)
7	(P,D2,E2) (P,D1,E1)
8	(P,D3,D2,E2) (P,D3,D1,E1)
9	(P,D4,D3,D2,E2) (P,D4,D3,D1,E1)
10	(P,D5,E2) (P,D6,E1)

Figure 4-8: Possible escape routes with respect to corresponding regions

All possible escape routes from rescuer's position are concerned. Due to the fact that unforeseen situations may occur hence one route could be inaccessible. So that, rescuer could take other routes instead.

4.2.3 YAH Map Generation

After possible escape routes have been determined in accordance with a certain position of the rescuer, these routes and YAH symbol (current position) would be drawn and registered with the floor layout to make up YAH map.

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In the map, YAH symbol is presented in triangular shape. The smallest angle of the triangle indicates the current rescuers head orientation with respect to Z axis (pitch orientation) obtained from orientation tracker.

When the rescuer turns to other way, YAH map is rotated accordingly to provide image alignment with the user's perspective and therefore reduce the necessity of mental and head rotation. With the alignment map on the move, the rescuer could interpret assisting information with ease. Map rotation is based on the data obtained from orientation tracker, namely pitch orientation (Figure 4-9). Due to the fact that, tracker operation is pretty sensitive as it could detect the change of the user's head rotation in very small angle and in real-time, therefore if the map is rotated with corresponding angle and time then it would cause visual disturbance to the user. According to every corridor in floor layout is perpendicular to each other, hence it could be a constraint condition for map rotation. In the visualization system, the map would be rotated 90, 180, 270 and 360 degrees if the pitch orientation is in between [70,160], [160,250], [250,340] and [340, 70] degrees, respectively.

To enable the user to recognize the area which is hidden behind the YAH map, the floor plan is set to semi-transparent. Therefore, the floor plan could be appeared at any place without obscuring the content underneath and the possible escape routes could be presented prominently on such kind of background.

**Figure 4-9: YAH map alignment corresponding to the rescuer's orientation
(VR mode)**

4.2.4 Application of the Visualization System in VR Mode

This Section is pertinent to the approach of Virtual Reality (VR) technology to provide rescuers an assistance to navigate within an environment where the whole scene is covered with visual noise (smoke, collapse, etc). First, a paradigm of VR system is introduced to depict the overall procedure. Then, an application of the visualization system which employs VR technology would be presented including development process, software and hardware involved.

4.2.4.1 Paradigm

VR system paradigm is one specific form of general framework which uses VR technology to assist the rescuers to navigate and find the way out within an environment where the whole scene is covered with visual noise. In this case, the system is developed based on VR approach with the use of VR devices and virtual environment (3D scene). The VR system paradigm is introduced in Figure 4-10.

Figure 4-10: Paradigm of the visualization system in VR mode

Generally, the VR paradigm operation is similar to the framework operation with respect to the sequence of operation. Rescuer's information obtained from trackers is sent to the system. Assistant information in terms of 2D graphic (route determination, YAH map generation) is then generated. Virtual environment which is the 3D representation of the real scene is retrieved and set up perspective view in accordance

with rescuer's information (current position and head's orientation). Next, the 3D view is combined with the assistant information in a way that the 2D graphic superimposes on the 3D view with proper scale adjustment. The visual representation is finally given appearance after rendering process and it could be able to display on VR display, namely on the HMD.

This loop is kept iterating in real-time in accordance with the real-time input data (position and orientation) which is produced by position tracker and orientation tracker.

4.2.4.2 Application of the Visualization System in VR mode

The main point of developing this application in VR mode is to create the virtual environment and make it viewable to the user on VR display in accordance with the visualization system's input parameters and the user's viewing perspective. VR techniques used in this application including VR display (HMD), VR software and tracking systems (position tracker and orientation tracker).

For modeling the virtual environment, AutoCAD software application is used to build the B4 storey model based on some specific information such as floor plan, interior façades, etc. This file is then exported to 3DS format in proper scale and position in accordance with the coordinate system (unit and origin) of the positioning tracker. The final environment is archived and will be retrieved when VR mode is invoked. Figure 4-11 illustrates some views of this virtual environment corresponding with the real ones.

Figure 4-11: Virtual scene is created from the real scene

In this research, Java3D programming language is employed to implement the visualization system. It is also used to manage the virtual environment to display properly to the user. To set up the camera view including viewpoint and view direction in accordance with the user's position and his perspective view (head orientation), the position and orientation data are passed to corresponding Java3D's functions (*setTranslation* and *rotateView*). After that, a perspective view will be generated in appropriate with the passed parameters (Figure 4-12). With real-time data, the users could experience the virtual environment as they often do so in reality.

Figure 4-12: A perspective view will be generated in appropriate with the position and orientation data

The virtual scene will be given realistic appearance by mapping real textures, materials to scene's objects. To enhance reality to the whole scene, lighting is also provided for ambient light and directional lights.

In this virtual scene, collision detection is also enabled to ensure the realistic of model physics so that the user could navigate in passageway without cut through other objects like walls, doors or window.

To complete the content of the visualization, Java3D enable the 2D item (YAH map) overlaying over the 3D canvas at specified place. The YAH would be displayed as a foreground without disturbing the underneath 3D model.

After execution, the whole content will be rendered in real-time and displayed in a canvas3D window. To display on HMD's screen, the HMD should be plugged properly into the laptop and all laptop's screen will be transferred to HMD's screen.

Figure 4-13 depicts the hardware devices to be used for the visualization system in VR mode including a laptop, an orientation tracker and a HMD.

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Figure 4-13: Hardware devices are used for the visualization system in VR mode

To perform the system, all devices are carried along passenger ways of B4 level. The following snapshots in Figure 4-14 to Figure 4-17 are the capture images generated by the system.

Figure 4-14: 3D virtual view and information in YAH map are generated in accordance with the user's position and his head orientation

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Figure 4-15: YAH map is rotated to suit the user's viewing perspective

Figure 4-16: The visualization is generated in real-time

Figure 4-17: The red arrow indicates the user's position and his view orientation.
The red lines show possible escape route.

4.2.5 Application of the Visualization System in AR mode

This Section presents how to apply Augmented Reality (AR) technology in the visualization system. In this research, AR presents a possibility to incorporate YAH map with the real environment. In this case, the user is enable to interact with the real scene while still keep track of supporting information (computer-generated). To depict how AR is involved in the visualization system, a paradigm is presented. Then, a practical application of this paradigm is introduced in details including application development process and the use of hardware and software.

4.2.5.1 Paradigm

Paradigm of the visualization system with AR approach is shown in Figure 4-18. Apart from generic procedures like route determination and YAH map generation, the main feature in the paradigm is the participation of real environment to other

procedures of visualization system. As shown in the paradigm, the real environment is recorded from a camera which is plugged into the laptop and mounted on the user's head. The video data stream is then passed to the system in real-time and associated with the YAH map to generate the visual representation. The content displayed on HMD's screen is the combination of real environment and the YAH map (computer-generated).

Figure 4-18: Paradigm of the visualization system in AR mode

4.2.5.2 Application of the Visualization System in AR mode

In most of AR applications, video of the real scene is obtained by using video see-through HMD as mentioned in Section 2.2.3.3. In this research, video of the real scene is obtained by using a webcam instead. The webcam is plugged into the laptop and then corresponding Java3D functions will be used to get the video stream from the webcam in real-time.

The remaining procedures of integration and rendering are similar to the same procedures in VR mode. Figure 4-19 represents the hardware devices used for the visualization system in AR mode as well as for the whole system. In VR mode, the webcam function will be turn off and the video image in Canvas3D will be replaced by the virtual scene.

Figure 4-19: Hardware devices are used for the visualization system in AR mode

The following snapshots in Figure 4-20 and Figure 4-21 illustrate the visual content generated by the visualization system in AR mode in accordance with the user's viewing perspective. The augmented computer-generated graphics will enhance rescuer's perception in finding escape route in this building.

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Figure 4-20: An AR content displayed on HMD suits user's viewing perspective

Figure 4-21: The augmented computer-generated graphics is changed in real-time according to the user's position and his head orientation

4.3 Summary

Chapter 4 has presented in details how to develop the computer-aided visualization system. Firstly, a general framework of the system is built which represents comprehensively the system's operation and features. Based on the framework, a specific application is then developed and demonstrated to perform way-finding in specific area. Input data of the application are obtained from indoor trackers. In this research, Ekahau positioning engine is made use to real-time tracking current position of the rescuer based on wireless signal. Rescuer viewing orientation is obtained by using Inertial Cube2 which is mounted on the rescuer's head. 2D floor plans are obtained from the authority, then 3D model of the area's interior is built

based on the floor plans. With this input data, possible escape routes from current position of rescuer to surrounding exits are determined providing multiple escape possibilities to the rescuer. Then, these routes and YAH symbol are registered with floor layout to make up YAH map. The map will be automatically rotated to align with the real layout if the rescuer changes his viewing direction. Map rotation is based on data obtained from orientation tracker. Due to the fact that, tracker operation is pretty sensitive and the floor arrangement is perpendicular, hence in this research map is controlled to rotate 90, 180, 270 and 360 degrees. To enable the user to recognize the area which is hidden behind the YAH map, the floor plan is set to semi-transparent. Therefore, the YAH map could be appeared at any place without obscuring the content underneath and the possible escape routes could be presented prominently on such kind of background.

According to the content determined in Chapter 3, the application has been developed in two modes: Virtual Reality mode and Augmented Reality mode. Based on environment visibility, display mode is selected. AR display is made up by superimposing YAH on real scene. In this research, the real scene is obtained by using a webcam for recording the around environment. VR display uses 3D virtual scene instead.

In this research, some following devices are hooked up to make up the visualization system. They are (1) a light laptop; (2) a HMD; (3) an orientation tracker (Inertial Cube2) and a webcam for recording video. Java and Java3D programming language is used to develop the system's functions as well as to work out with tracking devices. Output of the system is displayed on an Applet window.

To perform, the system is carried along the area's corridors. Output of the system is automatically generated and real-time viewed.

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1 Summary and Conclusions

This thesis has introduced an approach of using computer-aided visualization to support rescue task in buildings and vessels. A visualization system is developed to implement the approach with the use of Augmented Reality and Virtual Reality technology. First, a general framework is created to depict the comprehensive picture of the system including main procedures and features. Then, a specific visualization system is implemented based on this framework and the use of specific environment input. Content of the visualization system is generated in accordance with the provided information of rescuer like current position, head orientation and environment visibility status. Position and orientation are obtained from position tracker and orientation tracker, respectively. The visual representation is generated in real-time and appeared to rescuer through HMD.

To demonstrate, a specific visualization system is developed with the input of a simple environment, namely the level B4 of block N1 in Nanyang Technological University campus. This work is used as an effective case study for future work.

To conclude, this research contributes an effective and practical method to support rescuers to achieve their rescue task in the context of way-finding in buildings and vessels. Rescuers are facilitated in finding the way out in short time regardless the visibility of the vessel or building. Among many existing researches related to this area, this research could be the first of its kind. Due to the constraint in time and technology, this research has just completed the demonstration work in a simple environment with the use of some non-specialized devices. However, this research has

provided a base for the future work or other research with regard to using computer-aided visualization in rescue.

5.2 Research Contributions

The approach of using computer-aided visualization for way-finding during emergency contributes to the question of how rescuers could effectively find the way out in building and vessel environments.

By using the visualization system, the rescuers could easily find the way out in a short time regardless the environment visibility of the disaster area by following the visual representation displayed on HMD. This research is not only appropriate for practical cases but also applicable for any training purposes.

The visualization system will automatically generate and provide real-time visualization support to the rescuer through HMD. Hence the rescuer could feel free to use the system with ease. Moreover, the visualization content is investigated based on human-centric factor, which concentrates on easy-to-perceive aspect. Therefore, the rescuers could quickly perceive and grab the provided information on HMD.

By using the general framework, specific visualization system could be developed based on specific environment input. Therefore, the framework could be utilized for every indoor environment.

5.3 Future Work

The approach of using visual communication provides a concise and self-explaining visualization with which the rescuers could easily to perceive the provided information in less time. Virtual Reality, Augmented Reality and indoor tracker

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technologies are very important to solve the problem environment visibility changing during rescue operation. However, way-finding in buildings and vessels still confront with various problems that must take time to address. Some of them could be solved in short time while others might take longer.

The first problem regarding some complex indoor environments, it could take time to build the 3D model. In VR mode, a complex 3D model could cause an unsmooth navigation on the move. In future work, it could be overcome by using Level of Detail (LOD) method to provide different scene's appearances in accordance with different distances.

The main challenging problems in this research relate to device technology and device's cost. These problems could form a barrier in developing the visualization system. Precision of tracking devices are the most challenging. The more precise the tracking devices are, the more robust the system is. Besides, cost of display devices such as video see-through HMD are really high and could not be affordable for a commercial product. In brief, these problems are unable to deal in a short time but could expect for better technology in the near future.

Since the overall goal of this research is to provide an effective and efficient visualization support to rescuers, therefore the whole thesis focus on visualization aspect. However, the research could extend to meet other requirements of emergency situation by adding more useful features such as ubiquitous calculation the shortest path or control the evacuation flow.

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