Augmented Reality Ship Handling Training Method

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Contents

Chapter 1

Introduction

Ship handling is the task of precisely controlling a seafaring vessel's movement using its propulsion and navigation systems. Ships move in a variety of marine environments - starting from shallow waters of a harbour, a vessel may navigate vast seas to a port across the ocean. They also navigate inland waterways such as rivers, canals, backwaters and creeks. More recently, developments in offshore wind farming, the oil and gas industry have necessitated regular visits to offshore structures located on continental shelves for construction and maintenance activities (Halvorsen-Weare et al. 2012).

It takes a skilled seafarer to handle a ship with accurate control (Seamanship 2016). In addition to manoeuvring the vessel, natural forces acting on it (current, wind, waves) need to be accounted for. Traditionally, navigational-aid information such as prevailing weather conditions, charts, etc. have been presented using numerous display panels placed around the navigator in the ship bridge (Vasiljević, Borović, and Vukić 2011) with recent developments in instrumentation design featuring relatively minimal, less-cluttered designs (Sauer et al. 2002). This design change is a reflection of increasing automation trickling into maritime industrial processes (Perunovic and Vidic-Perunovic 2011).

As in aviation, modern maritime navigation requires the navigator to assimilate information from various sources. Use of head-up displays, however, is not yet commonplace in the latter (Holder and Pecota 2011). It could be attributable to the maritime industry being a niche sector with a conservative attitude towards innovation (Perunovic and Vidic-Perunovic 2011). Nevertheless, research studies can be found on maritime applications of augmented reality (Hugues, Cieutat, and Guitton 2010, Vasiljević, Borović, and Vukić 2011 Okazaki et al. 2014 and, Lukas, Vahl, and Mesing 2014). Unsurprisingly, there has been a focus on augmenting vision with real-time information of the environment; potentially helping navigators perform the job more efficiently.

Few research studies can be found on the viability of mixed reality technologies to create simulation environments for training purposes. Ship simulations systems are currently the *de facto* method of learning ship navigation. Various schools around the world setup simulation centers where generic principles of sea-faring can be learned and practiced. With increasing automation, the need for human-operation will reduce and so will the need to learn to do them manually. This research studies the feasibility of a training method to learn vessel operations in augmented reality on-board ships.

1.1 Research Questions

Ship simulators are used by ship crew for learning, certification and, upkeep of operational skills. As simulations, they are approximations of the process after all. It can be conjectured that on-board training involving operation of a real vessel in actual conditions is advantageous as it allows for situated learning.

Going by situated learning theory, manoeuvring a ship for example, is better learned by practising on an actual ship in real conditions than on simulators. However, a manoeuvre training programme that requires movement of an actual vessel comes at the cost of ship operation time and operational expenses in the form of fuel and machinery. Nevertheless, it provides hands-on experience of ship's movement behaviour in various weather conditions. Such a training should also result in better acquaintance with vessel-specific instrumentation. But it is difficult to set up training environments on-board since, environments in this context consist of large structures such as ports, natural landscapes, other vessels, offshore constructions etc.

A system of generating visual perception of large objects on-board is then desirable. It can be a solution to the non-trivial problem of setting up training environments. If such a system were capable of producing a convincing feeling of the presence of physical objects in the surrounding, it would enable on-board training in real environments enhanced by visuals of virtual objects.

With the intention of learning feasibility of using augmented reality for on-board training purposes, the following research questions were proposed.

1. **Which are operational scenarios where augmented reality could be used for on-board training?**
2. **How can augmented reality be realized on-board ships?**
3. **What is the experience of navigating ships in augmented reality using state-of-the-art see-through display?**

1.2 Research Approach

A method of research devised by Neerincx and Lindenberg 2008 called situated cognitive engineering (SCE) was employed in this study. SCE method separates a human-computer interaction research into three different phases namely derive, specify and evaluate (see Figure 1.1). Characteristic to each phase is the type of information that is gathered. This section contains a brief description of the phases and work performed in each of them.

In the derive phase, the problem domain is analysed to create abstract definitions of operations that take place in it relevant to the topic of research. Further, human physiological factors that can be influential to the design, technological possibilities for implementation are examined. Interviewing licensed mariners and professionals in the maritime industry was the *modus operandi* to outline operational demands. Additionally, a literature survey on applications of augmented reality in maritime sector provided insight into areas of research yet unexplored in this domain. Further, the literature survey also led to an understanding of trade-offs of various technical options for implementation of augmented reality on-board.

The specification phase is based on information from derive phase. In this phase we chalk out a use case scenario for the design solution, specify functional

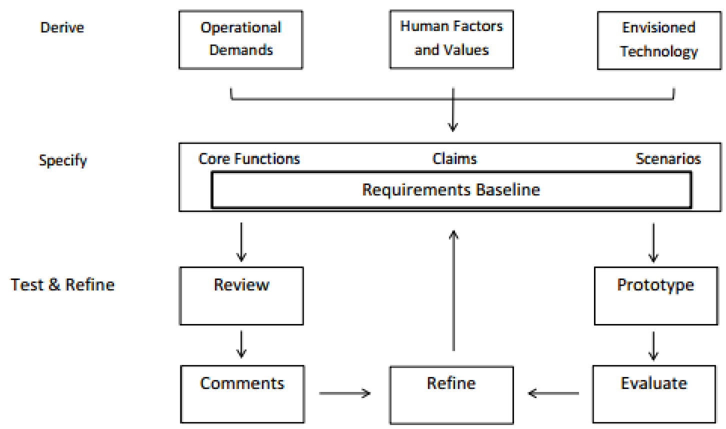


Figure 1.1: Situated Cognitive Engineering Method (Neerincx and Lindenberg 2008)

requirements for the system and make claims on consequences of its use. Previously in the derive phase, a few different on-board training possibilities were considered and grouped into the categories - manoeuvring, navigation and emergency response training. A choice was made between them going into the specification phase. Manoeuvre training was chosen as the scenario for prototyping and evaluation. This decision was driven by a growing market demand for on-board training solutions for manoeuvring and, feasibility of prototyping within the available time-frame. Accordingly, Chapter 3 titled Specification sketches the use-case for a station-keeping (a ship manoeuvre) scenario using augmented reality.

Chapter 4 named Evaluation describes the artefact that was developed, an experiment designed to test the claims and, discusses results and conclusion of the experiment. The final prototype consisted of head-mounted see-through display and outside-in head tracking to generate augmented reality. It accepted input from a maritime simulator which provided for interaction within the augmented reality environment. Even though the prototype is capable accepting position data from a real ship in real-time, its evaluation was made on a maritime simulator developed by VSTEP B.V., Rotterdam. The set-up allowed for precise control

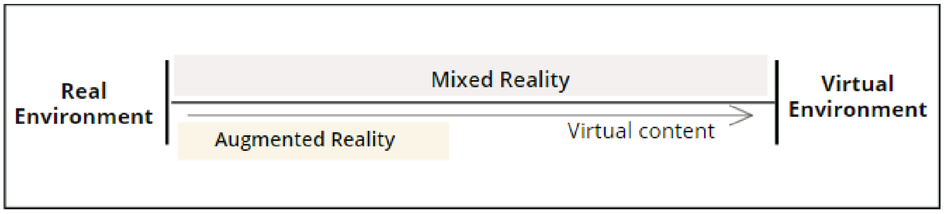


Figure 1.2: Mixed Reality Continuum (Adapted from Milgram et al. 1995)

of weather conditions in the simulation. More importantly it enabled the comparison of quality of depth perception in augmented reality with that in a modern maritime simulator.

1.3 Augmented Reality

This section introduces the concept of augmented reality for a novice reader. It is in good order to have a clear understanding of the primary technology being researched before delving into details of its design and implementation. The information is elementary, readers familiar with the term 'augmented reality' and similar technologies will find the information basic. All the same, an overview of the technological domain can be useful to place the research study in the broader perspective.

Mixed reality is the merging of virtual and real worlds in which physical and digital objects co-exist and interact in real time (Wikipedia 2016). Distinctions have been made between various types of applications in this realm based on the amount of virtual content in the mix. Milgram et al. 1995 drew up a continuum (figure 1.2) characterising different mixed reality environments. Completely real and completely virtual environments bring up far ends of the continuum with different levels of virtuality in between. Virtual reality on the far right of the spectrum refers to the experience in which users' perception of reality is influenced to create the feeling of immersion in a technologically-mediated world (Steuer 1992). This type of mixed reality features digital visuals often composed of entirely fictional environments.

Augmented reality refers to systems that feature predominantly real environments whose perception may be altered to add information not readily available to the user. In a survey paper on augmented reality, Azuma 1997 identified the technology to have the following three characteristics:

- It combines real and virtual
- Is interactive in real time
- Is registered in three dimensions

In general terms, mixed reality is an emerging technology which can be used to display virtual objects merged with real world views. It has been found to be useful in job scenarios that require execution of complex tasks (Henderson and Feiner 2011). A use case that has been explored in the real-world is assembly and maintenance of equipment. 3-D virtual job-support guides overlaid on see-through images of actual equipment obviates the need to look away in order to refer to a manual. It was found that virtual guides help users perform ship building and maintenance tasks in almost half the usual time (Henderson and Feiner 2011).

Chapter 2

Foundation

This chapter covers results of a domain analysis that was conducted to derive requirements for a scenario-based ship crew training method. The contents of this chapter are relevant to answering the research question - what are operational scenarios in which mixed reality training could be useful. A prototype was envisaged to evaluate the feasibility of the training method described here. Prototypes inevitably embody a particular design choice; a choice rife with challenges faced by systems design described below in section 2.0.1. This study deals with the challenge by first outlining a few design choices. Consequently, one is chosen for prototyping and evaluation.

A manoeuvre training scenario was chosen for prototyping and evaluation despite the high level of photorealism thought to be required for the concept to be workable. The reasoning for this choice two-fold. Firstly, an evaluation (user-testing a prototype) in this scenario would bring to light shortcomings, if any, of state-of-the-art consumer grade AR devices for their ability to render high quality 3D graphics necessary to create believable augmented reality training scenarios. Secondly, manoeuvring scenarios in offshore supply context do not require a large number of virtual objects in the scene. Position keeping for example, is an exercise where the vessel is to be kept stationary with reference to a particular offshore construction. Position keeping training scenario then allowed for rapid prototyping with low time-investment on developing the virtual aspect of the augmented reality.

Section 2.3 titled operational demands describe from an operator point-of-view, requirements for safe execution of ship handling operations. In designing a technological solution, the SCE method takes into account human factors that could affect interactions between users and the system being developed. Section 2.4 titled human factors knowledge describes mode errors - a type of error arising from the operation of state-dependent systems out of state. Finally, section 2.5 describes technological options available to implement the augmented reality training method that is envisioned and their pros and cons.

2.0.1 The Design Problem

This section describes the challenge presented by a systems design problem. It is intended for the reader to have an appreciation of inherent trade-offs involved in the endeavour to build a human-computer interaction(HCI) system.

HCI systems are meant to aid human activity. However, system designs are as much constraints on the solution space as they are solutions themselves to the problem at hand (Carroll 2000). In other words, a proposal for a certain way of tackling a problem ties further reflections of it's effectiveness to specifics of the design. Besides, it is often advised that designs must be open-for-change. A popular saying in software design practice is *requirements always change*. How then does a research in HCI deal with this unavoidable conflict?

One way to counter the problem could be to list a few different objectives for the system in question. with the end-goal to outline requirements for a minimum viable product (MVP). An MVP can be defined as an experimental prototype that can be used to empirically evaluate a claim (Münch et al. 2013). A broader look into the problem space allows for insight on requirements of a minimum viable product.

2.1 On-board Training Possibilities

Various scenarios for simulation-based on-board training were devised in collaboration with professionals in the maritime industry (refer Appendix for a listing of experts who were interviewed). Conceived scenarios were grouped in three categories - manoeuvre training, navigation training and, emergency response training, characterised by their different learning objectives. Following is an overview of each of the training options. Table 5.2 (refer Appendix) presents a comparison of the three categories.

	Manoeuvre Training	**Navigation Training**	**Emergency Response**
Photorealism [1]	High	Low	Medium
Market Potential [2]	High	Low	Medium
Downtime Available	Medium [3]	Low	High

2.1.1 Manoeuvre Training

Ship manoeuvring and its growing importance in the maritime industry has been elucidated in section 2.2. Manoeuvring is the skilled task of handling a vessel with precise control in navigationally challenging scenarios, for example in close quarters of large man-made artefacts. The skill involved is noteworthy as the operator faces two-fold demands of timely accurate assessment of evolving weather conditions, their effect on the vessel as well as effecting its movement using ship controls. Currently, experienced seafarers are entrusted with manoeuvring responsibility. It is a reflection the importance of practice-based learning where ship handling skill is concerned.

It is expected that this type of training would require a high degree of photorealism. Manoeuvring typically occurs in physical proximity of large man-made or natural objects. At close range, the human eye sees objects in greater detail than when they're farther away. One implication of this is that the device used for augmented reality display would have to render virtual images at a high resolution. Another implication is that these scenarios will place high demand on registration accuracy since inconsistencies in positioning of virtual objects' will be more noticeable at close range owing to the nature of human vision.

[3]Refer section 2.5.1.4 on page 24 for a description of photorealism
[3]Based on interviews with maritime professionals
[3]As applicable to offshore supply vessels

2.1.2 Navigation Training

Scenarios involving activities aimed to learn the tasks of navigation are described in this section. Navigation here refers to ship handling from the time it is unberthed and, along the journey to the destination. This includes path planning, following the plan to avoid collision in adherence to COLREGS [4], maintaining watch along the path, etc.

There is scope for augmented reality to be used as a training aid in these scenarios. Buoy for instance is a floating device that serves as a navigational aid, and can form part/s of a virtual environment set up for training purposes. More elaborate scenarios maybe envisioned such as visualization of landscape in the vicinity and harbour ports with in and outbound traffic. Simulated scenarios of this nature should also be visualised on ship bridge instruments. In order to be consistent with the augmented reality of sailing by an island for example, the radar should reflect said island in its display system.

2.1.3 Emergency Response Training

Emergency response training in general aims to arm trainees with the knowledge and alertness required to encounter hazardous situations in real life. This type of training has potential for use of augmented reality to create the illusion of dangerous situations. For instance fires in the engine room or water flooding in the ship's deck. Owing to the safety risks in these scenarios, they lend themselves well to simulation-based training. Further, interviews with industry experts revealed that emergency response training on-board could be improved by simulations. During training exercises, visual evidence of a hazard can be a more powerful motivator compared to vocal signals to the same effect. The idiom *seeing is believing* perhaps then applies.

Compared to manoeuvre training, emergency response places looser demands on the augmented reality system. Fires and floods for instance are shapeless and for training purposes their exact form is of less importance than their very existence. Also in such situations, attention of rescue workers is not always entirely

[4] The International Regulations for Preventing Collisions at Sea

on the cause of hazard itself. There is a focus on rescuing crew members and emerging from the situation safely.

2.2 Manoeuvring In Depth

Out of the three categories of on-board training described above, manoeuvre training was chosen for evaluation. Besides being a skilled task, it also involves safety risks by nature of its activities. This section describes challenges of manoeuvring and its relevance in the offshore oil industry. It is followed by a brief description of Dynamic Positioning Systems, the automation technology that assists with ship manoeuvring tasks and its riders that entail the presence of operators with manual handling skills.

Definition Given the varied environments in which ships are handled, a distinction is made between vessel handling in restricted spaces as opposed to in open seas with vast empty space. Manoeuvring typically refers to ship handling in confined spaces, at low speeds; requiring accuracy and precision in movement. Navigation in contrast, takes place in open seas with more room for movement. Handling a vessel during navigation is relatively easy while compared to manoeuvring. A ship usually moves in straight lines while navigating open seas with the objective to reach destination in the most efficient manner. Fewer changes in direction occur over time, there is lesser need to steer. Refer to Inoue 2000 for a method of objective evaluation of ship handling difficulties in restricted manoeuvring area, areas of traffic congestion.

2.2.1 Manoeuvring Challenge

This section describes the challenges of manoeuvring. It is presented to enlighten the reader about difficulties of the task and its relevance to the modern maritime industry. While this chapter answers RQ1 of the study, this section is intended to strengthen the case for manoeuvre training scenario to be a good bet for creation and evaluation of a minimum viable product.

Vessel handling at low speeds has been difficult on marine vessels historically (Ship 2016). From a technical point of view, the working mechanism of past rudder systems made it difficult to turn vessels when stationary. Examples of difficult manoeuvring operations include approaching a harbour, berthing in a port, sailing side-by-side another vessel, approaching and stationing close to an oil platform.

Manoeuvring a large vessel at low speeds is often a challenging operation even from the perspective of a human operator (Inoue 2000). This is because many factors affect the precise handling of a given vessel - it's size, power, thruster configuration, on-board bridge equipment, etc. Further, the vessel's handling characteristics are subject to environmental conditions (the combined effect of current, wind and, waves). Besides, low speed manoeuvring often occurs in close proximity to man-made constructions such as docks, offshore structures and other ships. The potentially destructive consequences of collision risks in such scenarios makes it a stressful operation, further amplifying the challenge of manoeuvring. Mistakes have high associated costs, possibly leading to lost lives and damage to expensive constructions.

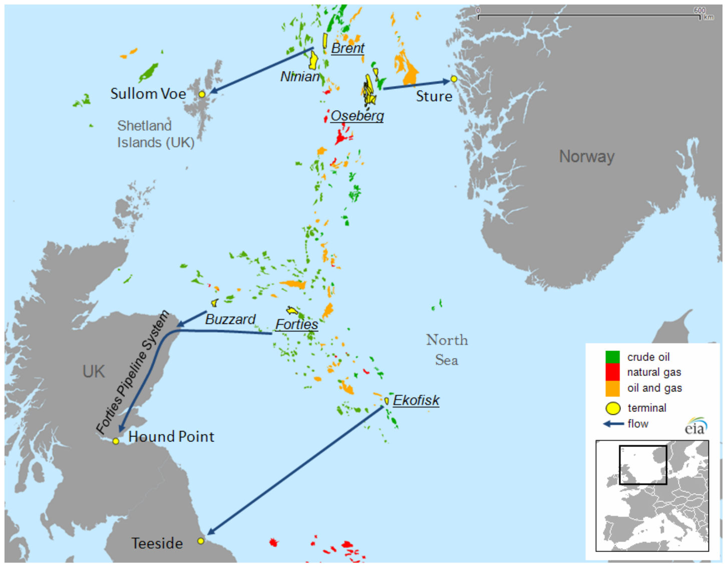
Automation has been seeping into ship bridge operations (Perunovic and Vidic-Perunovic 2011). It assists human operators to accomplish vessel handling tasks with functions such as dynamic positioning for manoeuvring and autopilot for navigation. Nevertheless, manoeuvring continues to be a specialized human job even though automation support exists at many levels.

2.2.2 Offshore Exploration and Supply

A special application of ship handling skills is on offshore supply vessels. These are vessels used to support exploration and production of offshore mineral or energy resources located in continental shelves around the world. For example, figure 2.1 shows prominent oil and gas fields in the North sea.

Manoeuvring plays an important role in platform supply vessels. They transport supplies such as fuel, water and chemicals to the offshore facilities and bring back disposables for proper recycling. Hence, these vessels need to approach and be stationed close to platforms on a regular basis. Loading and unloading operations happen at the stern of a vessel and requires station keeping till the operation is complete. This requirement led to the development of dynamic positioning systems. These are automated systems that help with station keeping and other

Figure 2.1: North sea oil and gas fields



Source: see footnote[5]

manoeuvring operations.

2.2.3 Dynamic Positioning System

This section describes the dynamic positioning system and its working mechanism. It is background information regarding the scenario that was evaluated. In a gist, dynamic positioning systems automate the task of manoeuvring. But as an automated system, it is not completely fail safe and there have been growing concerns in the industry about over-reliance on DP systems. Hence, it is desirable to have trained human operators capable of manual manoeuvring and, a method for human operators to learn manoeuvring in a superlative manner.

Position reference systems are vital to the operation of dynamic positioning systems. Information from sensors that provide the vessel's position and heading along with information from wind sensors, motion sensors and gyrocompasses on the vessel are used to track the vessel and forces acting on it. It is supplied as

[5]U.S. Energy Information Administration, United Kingdom Department of Energy and Climate Change, Norwegian Petroleum Directorate

input to a program that calculates changes in position and heading required to bring the vessel to a pre-set location. The calculation uses a mathematical model of the ship and tries to compensate for unpredictable environmental forces as it decides on power allocations for individual thrusters. While the system takes into account wind forces acting on the vessel measured using wind sensors, a vessel's position is also affected by ocean currents and waves.

DP began to be developed as a system that maintains position and heading of a vessel automatically by using its thrusters. DP systems have been increasingly employed over the years and there are well over 2000 DP vessels in operation today (Sørensen 2011). Although there do not exist rules specifying acceptance criteria for the positioning performance of DP systems, DNVGL [6] guidelines state that "in moderate weather conditions and with a fully operational DP-system the vessel should generally be able to demonstrate position keeping accuracy with a 3 meter radius and $\pm$ 1°of heading." (Veritas 2011)

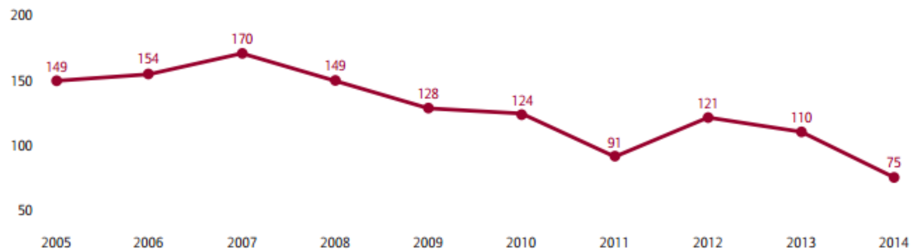
2.2.4 Manual Handling

Going by number of total losses occurring per year (see figure 2.2), the safety of vessels world-wide can be said to have improved over the years, particularly in the last decade, despite the ever increasing number of sea-faring vessels. Nevertheless, there is a growing concern in the industry regarding over-reliance on electronic navigation aids.

Studies have found human error to be the dominant factor in a significant percentage of the accidents (Baker and McCafferty 2005; Hauff 2014). Incidents such as the Norne shuttle tanker's collision with an FPSO in 2000, standby vessel Far Symphony's impact with the mobile installation West Venture in 2004 and, Big Orange XVIII's collision with the water injection facility Ekofisk 2/4-W in 2009 and are mentioned as cases of shipping incidents that showcase the lack of preparedness among crew members to handle with emergency situations. (Vinnem 2013).

[6] Det Norske Veritas (Norway) and Germanischer Lloyd (Germany) - an international certification body

Figure 2.2: Yearly vessel loss since 2005



Source: AGCS Safety and Shipping Review 2015

2.3 Operational Demands

Operational demands are an abstraction of the activities that occur in the operation under investigation, which in this case is manoeuvring. Having described the activity itself in the previous section, this section provides an overview of how human operators perform it. The basic skill involved in manoeuvring and the approach taken by maritime professionals to learn it was uncovered by conducting interviews with them. This section describes results of the investigation which in turn drove the specification of a system that can be used to learn ship manoeuvring

A key outcome of the investigation was that an intuitive understanding of vessel handling is required to manually manoeuvre a vessel. Different vessels exhibit different handling behaviour depending on their propulsion technology, steering controls, and, dynamics of the particular vessel owing to its design. These factors have a combined effect on the handling behaviour of the vessel - unique to that vessel-type. Besides, vessels also differ in their response to various weather conditions.

A clear view of the target object around which the vessel is being manoeuvred provides direct visual feedback of the target's position relative to the vessel. By looking out the bridge windows, the operator can immediately learn about progress of the manoeuvring operation. Using this information, the operator can make adjustments to the vessel's movement as required.

Most commercial vessels in excess of size limits determined by local authorities are handled in confined areas by a marine (or maritime) pilot. Marine pilots are seafarers with extensive seafaring experience and are usually qualified master mariners who have been trained as expert ship-handlers. Gaining a high level of intuitive understanding of the vessel's motion dynamics requires adequate practice. A training system that enables manoeuvring practice on real vessels in real operational conditions is then desirable. It would enable situated learning of ship manoeuvring.

2.3.1 Manoeuvre Training Methods

Manoeuvre training as it currently happens is reviewed here. It takes place on the job. An inexperienced mariner learns to steer the vessel in navigationally challenging situations by doing it in the presence of a master mariner. The experienced mariner keeps a close eye on the situation as the apprentice learns by doing. During the course of operation, the apprentice receives guidance and feedback on performance.

This type of learning can be classified as experiential learning. According to this theory, learning is a ”continuous process grounded in experience” (Kolb and Kolb 2005). When it comes to ship manoeuvring, learning it on the job must have sufficed in past times. However, developments in offshore energy exploration have place a greater emphasis on ship manoeuvring.

A drawback of on-the-job training is that it does not allow for repeated practice in a controlled environment. Also, the learning is not systematic in that it takes place on a need basis with no objective grading of learning outcomes. Simulator-based training may also be used to learn manoeuvring, but ship motion behaviour in simulations is artificial and the learning is not grounded in reality. Augmented reality-based on-board training can provide for training environments where manoeuvring can be learnt methodically. A learning framework may be introduced where specific manoeuvring skills are identified along with best practices for executing them. In such a framework a trainee may build competence incrementally. Table 2.1 presents a comparison of simulator-based training, mixed reality on-board training and practice-based or on-the-job learning.

	Simulator	**AR on-board**	**On-the-job**
Practice on actual vessel in real conditions	✗	✓	✓
Practice in various weather conditions	✗	✓	✓
Perform training repetitions in same conditions	✓	✗	✗
Scope for standardized competency assessment	✓	✓	✗
Scope for gradation of learning outcomes	✓	✓	✗
Close range ship handling training	✓	✓	✗
Scope for introduction of learning framework	✓	✓	✗
Risk of collision with other vessels	✗	✓	✓
Suitable for learning level	All	All	Advanced

Table 2.1: Comparison of training methods

2.3.1.1 Ship Simulators

Among other uses, maritime industry found use for computers as devices that could be used for the simulation of movements of vessels on sea. In a gaming-like use case, computers are used to run ship simulation software for educational purposes. These programs can be used to control virtual ships in virtual marine environments. Some set-ups involve actual bridge equipment to input commands to the program, making the experience more realistic. An array of monitors are used for display. Backed by computer graphics and models of sea, vessel and other objects, the simulation software is supposed to create the perception of being inside a real vessel. It is now standard practice to undergo training using simulators in the maritime industry. Figure 2.3 shows the set-up of a typical dynamic positioning simulator.

Figure 2.3: Dynamic positioning simulator

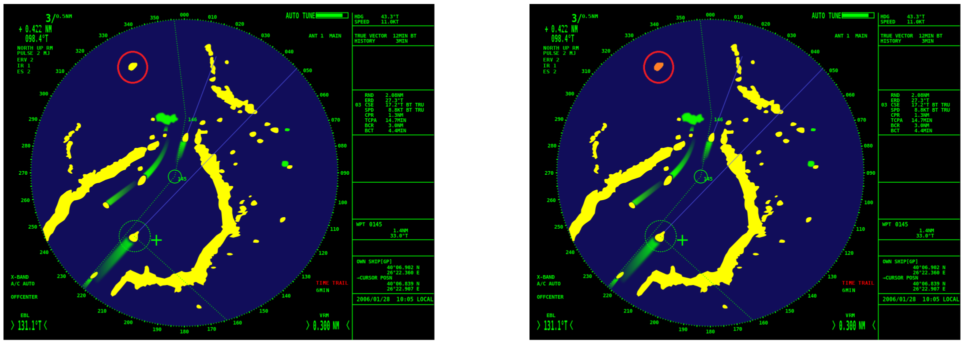
Source: vstepsimulation.com

2.4 Human Factors Knowledge

2.4.1 Mode Errors

Mode errors are the errors that occur when a user operates an interface in a manner that is appropriate to a different state of the system than the one it actually is in. When the user forgets the actual state and performs an action appropriate to a different state, the system response is unexpected and usually undesired. A common example of mode errors is the undesired input of capitalised letters on a computer due to caps lock, or the inability to enter numbers using the number pad due to numlock.

The design of a ship operation training method set in augmented reality needs to take into account the possibility of mode errors resulting from the two realities that are simultaneously at play. A trainee moving a real ship in augmented reality is also moving it in actual reality. Take the example of a training exercise to approach a virtual object out in the open sea. In the course of the exercise, the trainee moves the vessel towards the virtual object in the augmented reality. At the same time, the real vessel is actually moving somewhere out in the open sea. If the bridge equipment is also augmented, the radar would be expected to display an indication of the virtual oil platform. Adding a virtual object to a radar display that already contains information regarding other real objects can be confounding



(a) No colour differentiation

(b) Differentiated virtual object

Figure 2.4: Display of virtual objects on radar

to users (figure 2.4a). A way to distinctly identify virtual objects (for example, figure 2.4b) should help reduce mode errors but it also hampers immersion of the experience.

2.5 Envisioned Technology

An important choice in the design of a new human-computer interface is the technology used to build prototypes, and eventually the end product. This section describes two technical choices made for the implementation of a prototype. They fulfil display and tracking requirements that are part of an augmented reality system. Choices were made based on investigation of literature on the subject and surveying the state-of-the-art consumer devices commercially available at the time of the research.

2.5.1 Augmented Reality Display

This section is about display technology needed to create augmented reality applications. It describes different options for creating the visual perception that is part of augmented reality. Further, the utility of the displays for ship handling training is argued.

Three types of augmented reality displays were first catalogued by Azuma 1997 - namely, optical see-through, video see-through head-mounted displays and, spatial augmented reality. Optical see-through displays allow an unhindered view of the outside world in theory, whereas in video see-through display the user's view is camera-mediated. In comparison, optical see-through HMD appears to be the logical choice for AR and was chosen for prototyping. It is ideologically consistent with AR in that most of the visual reality is left untouched only to add bits of information (real/virtual) as necessary. A more detailed comparison of the utility of optical and video see-through display is presented in section 2.5.1.2. Spatial augmented reality is another option for AR, but the lack of mobility makes it infeasible in this scenario. It is nevertheless described in brief here for posterity. The following sections briefly describes each before comparing optical and video see-through HMDs. For an in-depth coverage of the concepts, readers are referred to Azuma 1997, Azuma et al. 2001 and Zhou, Duh, and Billinghurst 2008.

2.5.1.1 See-through Display

In general, see-through displays allow the user to see the real world through a display system while also being able to seamlessly display digital content on it. These were first developed for military aircraft for applications such as fixing the target of ammunition on locations that could be seen through the aircraft. Such display systems can also be mobile with users wearing them on the head so as to directly influence their view of the outside world. These are called as head-mounted displays (HMDs). The following sections describe optical and video see-through displays in turn. A comparison of the two technologies presented thereafter.

Optical See-Through HMD Optical see-through head-mounted displays (OST) are display systems that exploit the transparency of glass material to provide unobstructed views of the outside world. By definition, they can also digital content on the same surface simultaneously. OST displays use optical combiners to combine light from the real world with digital content. Optical combiners usually reduce the amount of light from the real world. Combiners act like half-silvered mirrors to be able to reflect light from monitors into user's eyes. Theoretically, this display system can provide an undistorted view of the real world (apart from slight obstructions caused by the glasses' frame itself). As a downside, it also affects the display of digital content adversely, making virtual objects appear semi-transparent and 'ghostlike'.

Video See-Through HMD Video see-through HMDs are similar to optical see-through HMDs in that they allow the combining of real world views with digital content. Differences between them stem from their source of real world view. As opposed to OST which provides a direct view of the environment, VST uses video feed from a camera in the HMD system to provide real world views. So, in addition to the head trackers and viewing monitors as in OST, VST HMDs require a camera appendage in the setup. The video camera mounted on the exterior of such an HMD incorporates external view back into the content. This type of HMDs obscures the wearer's external view in favor of better immersion into the stereoscopic view provided by the system.

2.5.1.2 Optical vs Video See-Through Display

This section provides a comparison of optical and video see-through HMDs based on parameters thought to be relevant to this study. For an in-depth review and comparison between these two display types, readers can refer to Rolland, Holloway, and Fuchs 1995. Table 5.3 (see appendix) presents a comparison of the see-through displays on various parameters.

Simplicity In addition to virtual images, there is a need to view the external world in augmented reality applications. Optical see-through systems meet this requirement naturally by employing transparent displays which do not interfere with the outside view. Video see-through systems on the other hand, obscure the outside view and need to use a camera that is looking outwards to compensate. The camera then seeks to perform the role of human vision - one of the most complicated sensory systems in the universe, the various functions of which are either not built into or not yet achievable using consumer grade cameras. For example, the resolution of the entire view (real + virtual) is limited to that of the display device in case of VST. This constraint is also present in optical see-through devices, with a crucial difference that it is only applicable to virtual parts of the scene.

Lag A persistent problem with interactive computer graphics is that of time delay (lag) between expectation of the appearance of a scene and it's actual appearance. In an OST system, there will be near zero lag in viewing real scene as it is viewed directly by the user. Whereas, the display of any virtual objects can be a source of lag. The system first needs to decide whether to display virtual objects based on viewing direction and orientation and, also calculate appropriate projection of the virtual object if and when it is to be displayed indeed. Finally, there will be a small delay in rendering images on the display system.

In VST, additional lag is present in digitizing video stream of the real world. In a display that refreshes at 60Hz, the time that elapses between display of one frame and another is 16.67ms. Hence there will be a minimum of 16.67ms delay in displaying the external view recorded by a camera, discounting the time taken to digitize the camera view. According to (Ellis et al. 1997), for close range tasks, one millisecond of delay causes one millimeter of error. One advantage of VST over OST is that the higher degree of control over display streams (real and virtual) in video see-through makes it possible to avoid the problem of temporal mismatch due to delay in virtual images by delaying real view as well. But then delaying display of real-world view affects proprioception which is intolerable in this scenario as manoeuvring requires timely, fine adjustment of ship controllers.

2.5.1.3 Spatial Augmented Reality

Spatial augmented reality (SAR) refers to the concept of augmenting real-world spaces (with digital media) without the use of special devices such head-mounted display (Bimber and Raskar 2005). A discussion of display options for AR would be incomplete without spatial augmented reality. However, the lack of standardized solutions and the need to set up special hardware tailored to individual ships makes SAR an impractical solution for the creation of AR on-board ships for manoeuvring training purposes. Nevertheless, the concept is described in brief here for completeness. A detailed treatment of the topic of spatial augmented reality can be found in Bimber and Raskar 2005.

Conceptual Overview Alongside HMDs, spatial augmented reality forms another paradigm for the creation of mixed reality content. In SAR, the user experiences augmented reality through one or more monitors placed in front, displaying a combination of virtual and real-world images captured by video camera. This is similar to the CAVE (Cruz-Neira, Sandin, and DeFanti 1993) concept for virtual reality. CAVE (CAVE automatic virtual environment) seeks to immerse the user in a 3D virtual environment created using rear/front facing projectors lighting up projection screens in three dimensions. Although originally designed for virtual reality experience, the concept can be adapted for augmented reality. Advances in projection technology make it possible to have projections on transparent screens (Peterson and Pinska 2006).

Advantages SAR offers unique benefits over HMDs such as obviating the need for users to wear special devices and possibly high resolution, wide field of view displays integrated into natural environments. Large field of view and higher resolution provides a stronger feeling of presence (Lantz 1996), allowing for better immersion and easier eye accommodation[7].

Disadvantages On the downside, it suffers from setbacks such as requiring setting up of expensive custom-made display configurations that need more space and hardware than standardized HMDs. A portable technological solution that enables mobility between vessels is desired. This allows for training to be conducted on various different vessels with minimal time and effort involved in setting up the augmented environment. Using mobile AR devices such as HMDs enables trainees to bring their own AR devices on-board and vessels do not need to be docked for purposes of setting up the AR environment.

In Conclusion As opposed to head-mounted displays, SAR relies on projectors to create the views necessary for the perception of mixed reality. SAR may be just as effective as head-mounted displays in being able to create immersive mixed environments. A study on the use of large projection screen as an alternative to HMDs for virtual environment found no significant difference between the two

[7] refer to section 2.5.1.4 for a discussion on photorealism

for spatial cognition tasks (Patrick et al. 2000). But projector-based display systems are custom solutions that need to be designed for the specific environment in consideration. Ships come in a variety of shapes and sizes, so do their bridge rooms. Setting up AR environments on-board new vessels will need considerable effort to tailor the display system for individual ship. Besides, some modification of the ship's bridge room is involved such as placing of projectors at appropriate locations and turning bridge windows into projection screens onto which virtual objects can be projected. The operation down-time needed to create custom display solutions for individual ships is expensive and undesirable.

2.5.1.4 A Note on Photorealism

Photorealism in this context refers to the quality of visualisation of objects in the simulation. At high levels of photorealism, virtual objects are visible with a high level of detail, blend seamlessly into the surroundings - appropriately occluding objects behind it and, are of proper focus and contrast, with the end result being a realistic visualisation whose virtual aspects are hard to distinguish from the real.

For purposes of this study, photorealism is grouped into three distinct levels. One of the attributes on which the classification has been made is the extent to which accommodation-vergence conflict affects a scenario. Another attribute is occlusion, an essential depth cue that can be important in manoeuvring scenarios for instance. Table 5.2 is a listing of the three categories.

2.5.2 Ship Instrument Augmentation

Augmented reality displays described in the previous section form a part of the enabling technologies for the mixed reality ship manoeuvring training envisioned in this research. HMDs for instance can help create visual perception of an offshore oil platform standing on the open sea. In other training scenarios they may be used to display tracks/lanes for navigational tracking or virtual ships on collision course/sailing side-by-side etc. Different artefacts may be displayed depending on training objectives and the perceptions that need to be created. Ships over the years though have evolved to be technically complex machines. The bridge room of a modern age vessel houses multiple instruments tracking different aspects of its reality. Therefore, the design of a mixed reality environment on-board a modern seafaring vessel should consider how virtual objects interact with various instruments in the bridge room to accurately correspond with the reality that is being visually perceived.

2.5.3 The Tracking Requirement

Tracking is a vital requirement for augmented reality, needed to fulfil the requirement that virtual objects be registered in three dimensions. This section describes the tracking requirement and a design choice made in that regard. Two types of tracking solutions are described along with their implications for the on-board training scenario. For a detailed discussion of tracking methods, readers are referred to Zhou, Duh, and Billinghurst 2008. According to Zhou, Duh, and Billinghurst 2008, tracking, being a core enabling technology for AR, is an unsolved problem with many ”fertile” areas of research.

An AR system needs vision capability in order to track viewer’s position and register objects in his field of view. Specifically, it is of interest to track user’s head position and gaze direction so that virtual objects can be placed in the appropriate location. Tracking systems usually comprise of camera/s that are used to sense real-world space. Cameras produce the raw data necessary for computer vision systems.

Tracking solutions can be one of two categories - outside-in and inside-out tracking, or a hybrid solution of them. The two types differ based on the positioning of camera relative to viewer. Inside-out tracking systems are those in which camera is placed on the viewer and it tracks the environment as he/she moves around in it. Whereas in outside-in tracking, a stationary camera that is placed away from the viewer (but in sight and, without occlusion) tracks the viewer’s movement using markers placed on the viewer themselves. Outside-in tracking was chosen as the method of tracking in this study as it needs significantly lesser modification of the environment in which the tracking takes place compared to inside-out tracking. Moreover, outside-in tracking is considered to be more accurate at tracking position than inside-out tracking systems (Klein 2006).

2.5.3.1 Inside-out Tracking

Inside-out tracking refers to systems in which the camera that tracks positions is located in the same physical location as the device/viewer being tracked (head mounted display for example) so the camera moves along with the tracked object. With the camera mounted on the object that is being tracked, the system tracks the world around it from the vantage point of the tracked object. Changes in location/orientation of the tracked object can be detected from the camera's changing perspective of the outside world.

A straightforward implementation of this idea would process images from video stream captured by the camera to locate objects in the world space and register virtual objects among them. However, interpreting live camera feed is a computationally expensive operation due to the difficult computations involved in processing images on the fly.

Fiducial Markers A popular refinement of this technique is to place so called fiducial markers in the environment being tracked. Figure 4.2 shows a typical marker that can be used for marker-based tracking. Visible markers (to camera) in the tracked space reduce the complexity of image processing computations. The tracking system is then aware of the type of images to look for and make decisions accordingly. Moreover, marker images are usually black-and-white in order to simplify image processing computations by converting raw camera output to black-and-white.

Figure 2.5: A typical fiducial marker

2.5.3.2 Outside-in Tracking

Outside-in tracking systems are those in which a stationary camera placed away from the viewer in the tracking environment tracks the viewer. Changes in viewers position are tracked using markers placed on them. Unlike inside-out tracking systems, tracking range with this method of tracking is not limited by fiducial markers in the environment.

A disadvantage with this system is that since the camera is at a different physical location than the system that generates the virtual images, tracking data is not directly available on the AR system itself. Then data has to be sent to the system from a separate device that does the tracking. Data can be sent by a wireless or wired connection. A wired connection impedes free movement in the environment but it is also the faster and more reliable method of data transfer. Data might also be sent wireless which allows for ease of movement. But it comes at the cost of latency and reliability issues in data transfer.

Besides latency in obtaining tracking information on the AR headset, another disadvantage of this tracking system is that it is susceptible to noise in the form of ambient infra-red light. This is a constraint on the system with the implication that lighting in the tracked space will have to be carefully controlled to prevent the system from being affected by noise.

In Conclusion Outside-in tracking was chosen as the method of tracking for this scenario. This method of tracking allows for the creation of a tracking system with minimal changes to the environment in which the tracking takes place as there is no need to place fiducial markers. It is required to have a clear view from the bridge of the vessel for safety reasons. Markers obscure external view since they will have to be placed on the window of the bridge in order register a virtual object in that region of space.

Chapter 3

Design Specification

This research is a study of the viability of leveraging augmented reality technology for simulation-based training purposes in the maritime sector. A working prototype was envisaged in order to access the user experience of such a system. This chapter contains the devised design solution - specifications that would be used to develop a prototype for evaluation.

Development of the actual prototype was based on a few functional requirements thought to be essential to the system (section 3.2). SCE method prescribes that functional requirements be linked to objectives of the system. The prototype that is developed is then tested for it's ability to meet desired objectives. Evaluation hinges on claims that are made regarding the system (section 3.3). Claims in this context are hypothesis whose truth value is determined during system evaluation. First, section 2.1 makes a comparison of three types of on-board training differing in their expected learning outcomes. Section 3.4 lists a basic use-case flow and alternate steps of system use.

3.1 Design Scenario

"AugMan helps Michiel practice ship maneuvering and, improve depth perception."

Michiel, 25 years old, received the dynamic positioning (DP) certificate a short time ago. He has just taken up his first job as a dynamic positioning operator

(DPO) on-board VOS BASE - a medium-size platform supply vessel. Fitted with Class 1 DP system, the vessel has been rented by Royal Dutch Shell to supply cargo to offshore oil platforms off the Dutch coast. Michiel is joined on the deck by captain Willem and chief mate Steve, both experienced seafarers capable of handling the ship as well as its DP equipment.

He lacks manual vessel manoeuvring skills. Though familiar with bridge equipment, he has little experience using it on an actual vessel. Manoeuvring a large vessel in close range of offshore platforms causes him anxiety. He feels unprepared for an emergency such as failure of one of the DP system's components effectively rendering it unusable. Should this situation arise during a load/unload operation, an operator needs to maintain the vessel's position and heading manually - at least until its safe to stop the operation. Following this, the vessel will be steered away outside the 500m safety zone of the oil rig. With a dysfunctional DP system, either joystick manoeuvring or manual vessel handling will have to be engaged; both of which he is not adequately trained for.

3.2 Functional Requirements

This section lists the functional requirements that were drawn for a prototype application. Requirements were based primarily on specifications of augmented reality put forward by Azuma 1997. They are tailored to suit the operational demands of ship manoeuvring training. Accordingly, functional requirements of the prototype are listed below.

The system shall be able to:

1. **Present 3D images** of objects such as ships, oil platforms, buoys and landscape features to create the augmented environment.
2. **Register virtual objects** in user's physical space.
3. **Generate projections** of virtual object to be consistent with user position.
4. Provide exercises to **accommodate various learning goals**.
5. **Provide manoeuvring instructions** adapted to user's manoeuvring proficiency.

3.3 Claims

1. Presenting user with 3D images helps create a convincing feeling of presence of an object in user's reality.
2. Registering the virtual object in a fixed space creates a convincing feeling of presence.
3. Generating view-specific projections of virtual object based on user position is essential to leverage parallax effect which provides depth cues.
4. Manoeuvring instructions, help automate the task of coaching.
5. Different types of manoeuvring exercises makes the system useful to a wide range of users of varying levels of manoeuvring skills.

3.4 Use Case

3.4.1 Manoeuvre Training

Actors:	DP Operator, AugMan, Captain/Instructor.
Circumstance:	DP operator is idle on an offshore supply vessel.
Precondition:	Vessel is not undertaking any operation.
Post condition:	DP operator has improved manoeuvring skills.
Method:	Practice manoeuvring in augmented reality.

3.4.2 Basic Flow

1. Operator wears AR device and starts the application.
2. AugMan presents a list manoeuvring exercises and asks user to choose.
3. Operator chooses an exercise and orients himself (including head position) in the direction in which the virtual object/augmented environment should appear.

4. Operator indicates he is ready to start the exercise.
5. AugMan brings up the augmented reality environment and asks the operator to set vessel controls to neutral position before starting the exercise.
6. After making sure that the vessel controls are in neutral position, operator starts the exercise.
7. AugMan receives position changes from the vessel and renders visuals of the virtual environment accordingly.
8. Operator practices manoeuvring the vessel in the virtual environment using visuals from the AR device as reference.
9. AugMan provides a review and feedback of the manoeuvring performance at the end of the exercise.

3.4.2.1 Alternative steps (Beginner Level)

Application provides direction and manoeuvring hints throughout the exercise.

1. Operator wears Ar device and starts the application.
2. AugMan presents a list of **low-difficulty manoeuvring exercises** available and asks user to choose.
3. Operator chooses an exercise and orients himself (including head position) in the direction in which the virtual object/augmented environment should appear.
4. Operator indicates he is ready to start the exercise.
5. AugMan brings up the augmented reality environment and asks the operator to set vessel controls to neutral position before starting the exercise.
6. After ensuring that the vessel controls are in neutral position, operator starts the exercise.
7. AugMan receives position changes from the vessel and renders visuals of the virtual environment accordingly.
8. Operator practices manoeuvring the vessel in the virtual environment using visuals from the AR device as reference.
9. Application provides **helpful hints** for manoeuvring such as the directional pointers and controls to be engaged **throughout the exercise**.

10. AugMan provides a review and feedback of the manoeuvring performance at the end of the exercise.

3.4.2.2 Alternative steps (Intermediate Level)

Application provides maneuvering hints during the exercise on request by user.

1. Operator wears AR device and starts the application.
2. AugMan presents a list of **medium-difficulty maneuvering exercises** available and asks user to choose.
3. Operator chooses an exercise and orients himself (including head position) in the direction in which the virtual object/augmented environment should appear.
4. Operator indicates he is ready to start the exercise.
5. AugMan brings up the augmented reality environment and asks the operator to set vessel controls to neutral position before starting the exercise.
6. Having ensured that the vessel controls are in neutral position, operator starts the exercise.
7. AugMan receives position changes from the vessel and renders visuals of the virtual environment accordingly.
8. Operator practices maneuvering the vessel in the virtual environment using visuals from the AR device as reference.
9. Application provides **helpful hints** for maneuvering such as the controls to be engaged during the exercise **on need basis**.
10. AugMan provides a review and feedback of the maneuvering performance at the end of the exercise.

3.4.2.3 Alternative steps (Expert Level)

Application does not provide maneuvering hints during the exercise.

1. Operator wears AR device and starts the application.
2. AugMan presents a list of **high-difficulty maneuvering exercises** available and asks user to choose.

3. Operator chooses an exercise and orients himself (including head position) in the direction in which the virtual object/augmented environment should appear.
4. Operator indicates he is ready to start the exercise.
5. AugMan brings up the augmented reality environment and asks the operator to set vessel controls to neutral position before starting the exercise.
6. Having ensured that the vessel controls are in neutral position, operator starts the exercise.
7. AugMan receives position changes from the vessel and renders visuals of the virtual environment accordingly.
8. Operator practices maneuvering the vessel in the virtual environment using visuals from the AR device as reference.
9. Application provides **no maneuvering hints** during the exercise.
10. AugMan provides a review and feedback of the maneuvering performance at the end of the exercise.

3.4.3 Ontology

Augman - augmented reality prototype consisting of see-through glasses and a head tracking system capable of registering objects a predetermined location in space

See-through glasses - Wearable see-through glasses that are capable of rendering 3D graphics making it possible to create augmented reality environments which leaves the wearer's view of the outside world intact while rendering virtual objects in the same visual field.

DP Operation trainee - Dynamic positioning operator with limited manual vessel handling experience.

DP Vessel - A vessel with dynamic positioning system installed on it that can also be operated in manual mode wherein the automatic vessel position control systems can be disabled for training purposes.

Training supervisor - A qualified and experienced officer-of-the-watch who is capable of manual vessel control that instructs trainees on learning goals, provides feedback on performance and can take control of the vessel if necessary.

Chapter 4

Evaluation

4.1 Artefact

A prototype was developed to evaluate the feasibility of learning ship maneuvering in augmented reality. It was composed of a few devices which work together to meet each one of the three defining aspects of augmented reality.

Device	Purpose
Epson Moverio BT-200	AR Head Mounted Display
TrackIR 5	Tracking Head Position
WiFi-enabled PC	Stream Tracking Data
Ship Controllers	Interaction with AR System

Table 4.1: Components of final prototype

4.1.1 Evaluation Method

It is assumed that the skill of depth perception and judging relative motion of one object with respect to another can be trained for and, improved. Such a training then requires visual targets whose distance/depth can be perceived accurately by the human eye. This experiment is set in the marine environment. In the absence of working motion reference units, manoeuvring a vessel manually requires ac-

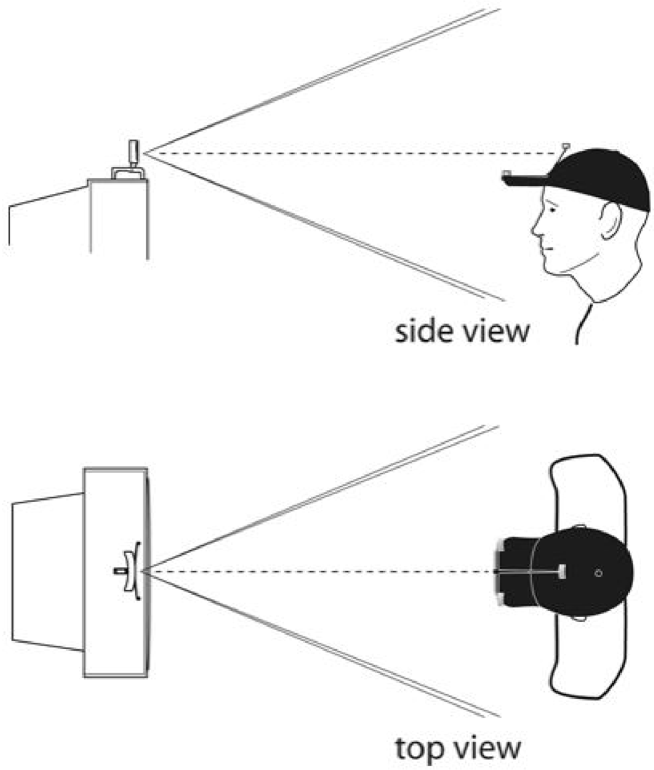


Figure 4.1

curate perception of distance in order to effect necessary adjustments to position over time.

Position keeping is chosen as the exercise against which manoeuvring performance is measured in this experiment. The task of the subject in this manoeuvre is to keep a vessel stationary for a certain period of time. It is to be performed in the absence of aid from motion reference units, so that no automated computer assistance is available in performing the exercise. This will ensure that subject has to rely on their depth perception skills and ability to finely control vessel movements to keep in stationary in the face of wind and current that continuously affect the position of the vessel.

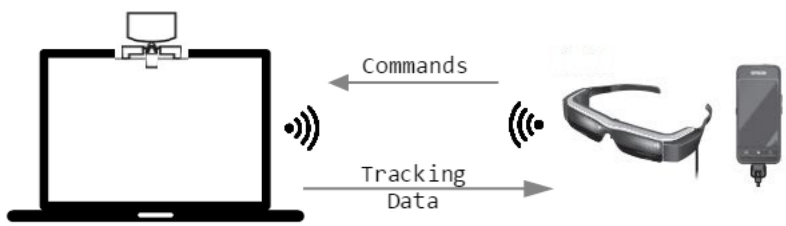


Figure 4.2

Chapter 5

Appendix

5.1 Photorealism

Level	Attributes
High	▪ Occlusion is necessary to induce sense of depth in scene. ▪ Wide field of view is required to create illusion of large object in the vicinity. ▪ Virtual object is the main object of focus in scene.
Medium	▪ Occlusion is beneficial to the scene, transparency is tolerable to an extent. ▪ Wide field of view is not essential to the scene. ▪ Virtual object is not the main object of focus in scene.
Low	▪ Depth cues are not essential to the scene. ▪ Wide field of view is not essential to the scene. ▪ Virtual object is not the main object of focus in scene.

Table 5.1: Levels of Photorealism

5.2 On-board Training Possibilities

	Manoeuvre Training	**Navigation Training**	**Emergency Response**
Learning Objectives	Vessel handling in navigationally challenging situations	Long-distance maritime navigation	Emergency response procedures and teamwork skills
Scenarios	Position keeping, In-place turning, Berthing	Path planning, Navigating port entrances	Fire in engine room, Water flooding in lower deck, Man over-board
Competences Gained	▪ Bridge equipment operation ▪ Vessel movement intuition ▪ Depth estimation	▪ Route planning ▪ Identify, use maritime navigation aids	▪ Emergency severity assessment ▪ Teamwork, communication
Equipments Required	Radar, ARPA, ECDIS, Fiducial markers in bridge	Radar, ECDIS, ARPA, AIS, Markers in bridge	Fiducial markers in engine room, deck, etc.
Crew Requirement	▪ Trainee ▪ Instructor ▪ Officer of the watch	▪ Trainee ▪ Instructor ▪ Officer of the watch	▪ Full crew / part of crew located at emergency site

Table 5.2: Comparison of on-board training options

5.3 Optical vs. Video See-Through Display

	Optical	Video
Peripheral FOV (horizontal)	180 degrees	110 degrees
Time lag - real world view	0ms	>16ms
Digital display FOV (horizontal)	20-40 degrees	>90 degrees
Real world view	Largely undistorted	Camera and display dependent
Simplicity	Process one stream (virtual images)	Process two streams (camera feed & virtual)
Resolution	Partially display dependent	Fully Camera and display dependent
Focus and contrast	Hard to blend virtual object into real scene	Lesser contrast issues (limited by camera's dynamic response)
Occlusion	Challenging to achieve full occlusion	Occlusion is possible due to full control over displayed content

Table 5.3: Comparison of see-through head-mounted displays

5.4 Expert Interview Questions

1. How effective is simulator based training to learn vessel maneuvering?
   (a) Is a trainee capable of maneuvering immediately after simulator based training?
   (b) If not, what is missing?
   (c) How is manoeuver training conducted onboard?
   (d) Why is there no certification system for tug masters?

2. What is your opinion of SMSC's onboard training system?
   (a) Pros and Cons?
   (b) Is it necessary to simulate the bridge equipment?
   (c) Which bridge equipment is important to create the virtual platform illusion?
3. Tugs, Offshore Supply Vessels - PSV, AHTS, ERRV, Construction vessel, Diving support vessel
   (a) Which of the above has the most idle time on average?
   (b) How much idle time do they have every day on average?
   (c) What do they do during idle time?
   (d) Which of them is suitable for onboard training (based on idle time, safety, other criteria)?
   (e) Where can they do onboard training?
   (f) Is there an officer on the lookout onboard OSVs? Is he always on watch?
4. Are there DPOs with little manual vessel maneuvering experience?
   (a) Would they like to learn vessel maneuvering?
   (b) Is over-reliance on DP systems a matter of concern in the maritime industry?
5. Is there a familiarization procedure in place for captains taking over new vessels?
   (a) How do captains familiarize themselves to new vessels?
   (b) How can the level of familiarization be measured?
6. Are there differences in skill between a pilot and a captain?
   (a) Can this be measured? How?
   (b) What are the technical skills of a skilled maritime navigator? (e.g. certain maneuvers like maintain position, turning in place, etc.?)

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