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Contents

"The use of Augmented Reality technology to enhance maritime Safety of Navigation" case study Training ship Aida 4

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المستخلص
نظرا لطبيعة عمل السفينة عايدة/٤ من حيث إمداد الفنارات المعزولة بالبحر الأحمر وخليج السويس، ولضمان كفاءة عمل المساعدات الملاحية فى هذه المناطق ونتيجة للعدد الكبير لسفن الصيد ومنصات وحفارات البترول وكذلك حركة المرور الكثيفة للسفن فى خليج السويس والتى تؤثر على سلامة الإبحار للسفينة عايدة/٤ وكذلك نتيجة الكم الهائل من المعلومات المرئية المتوفرة من الأجهزة الملاحية بالسفينة عايدة/٤ والتى تؤدى إلى تشتيت انتباه ضباط السفينة. ونتيجة لذلك تبحث هذه الدراسة استخدام تقنية الواقع المعزز (AR) على السفينة عايدة/٤ من خلال مراجعة النظام واختباره مع استخدام استبيان لضمان كفاءة عمل المنظومة لزيادة مستوى سلامة الملاحة البحرية وكذلك تدريب الطلبة البحريين.

Abstract
Due to the nature of work of M/V Aida 4 in terms of supplying isolated lighthouses in Red Sea and the Gulf of Suez, as well as ensuring the efficiency of navigational aids in such areas, these tasks necessitate sailing in areas that may affect the safety of the ship due to the complexity of the surroundings in terms of large number of fishing vessels, oil platforms, rigs and heavy traffic in Gulf of Suez. Also, as a result of large amount of visualized information available from different devices, this leads to the distraction of the officers of the watch of Aida 4. According to our findings, This study examines the application of Augmented Reality (AR) technology onboard Aida 4, by reviewing and testing the system and using a questionnaire to ensure the efficiency of the cadets training system, as well as increasing the maritime safety of navigation.

1. Introduction

Augmented Reality is a type of technology that allows digital images and information to be displayed onto the physical environment and direct superimposition of digital content over a user's actual view (TSB, 2020). In modern bridge systems, there are unlimited number of navigational information such as Global Navigational Satellite System (GNSS), echo sounder, speed log, radars, gyro, and magnetic compass. Among the challenges of AR is to determine the most beneficial information to display and what types of visual representations are best for conveying that information. (Bandara, Woodward, Chin and Jiang, 2020).

A multitude of digital technologies have emerged on ship bridges over the past decades. Many are meant to help with navigation and avoid collisions when visibility is low, but because they are shown on different screens and in different ways, operators may get too much information.

Running into a ‘big data’ problem, the ever-increasing volume of information that is also not well organized may result in information overload for the operator. The information is displayed on a variety of different screens and monitors and to read it, the officers of the watch must turn their attention away from the surrounding physical environment. This becomes even more difficult when a ship enters or leaves a harbor or restricted / congested waters.

In 2020, the most common forms of maritime accidents were collision (43%), grounding (21%), and fire/explosion (16%) (TSB, 2020); making it important to try to mitigate factors that may cause these accidents. Furthermore, accident analyses have shown that human error is a dominant factor (Bandara, Woodward, Chin and Jiang, 2020). It is important for the navigator to sort out the information for planning a safe navigation path and that is difficult when attention is divided between digital displays and the outside world. Although much effort is taken to minimize the risk of collision, accidents still happen. Accident investigations show that fatigue and human error play an important role in the cause of accidents.

This research paper aims to survey the latest advances in AR technology to be applied onboard Aida 4 to increase the level of safety of navigation and preserve the marine environment, as well as improve the training of cadets.

2. Required Navigational Aids

The International Maritime Organization (IMO) has been concerned with the safety of navigation. Despite the tremendous development witnessed by the technology of navigational devices, as well as the training methods for officers and captains of ships, it was noted that many maritime accidents have been caused by human-error including mistakes in ship handling and inadequate watch keeping. The most significant issue with existing navigational technology is the supply of excessive and superfluous information or incorrect data delivery techniques. Specifically, the alert functionality for emergency situations that is now supplied by radar and Electronic Chart and Display Information System (ECDIS) (Procee, Borst, Paassen, and Mulder, 2017), (Jahn, 2021), (Hareideand, and Porathe, 2018).

Captains and Officer of the Watch (OOW) on the bridge must deal with the increasing amount of visualized information accessible through several devices, including:

- The Electronic Position Fixing System (EPFS), utilizing GNSS, provides the ship's absolute position.
- The Heading Control System (HCS), which controls the ship's heading.
- The Speed and Distance Measuring Equipment (SDME), which tells how fast the ship is going and, by extension, how far away it is.
- The ship's echo sounding system (ESS), which provides the ship's depth data.
- Navigational assistance sensors
    - Wind sensors that measure the speed and direction of the wind.
    - The Automatic Identification System (AIS), a ship-based automatic tracking

- Use of Communication channels such as Global Maritime Distress Safety System (GMDSS), which uses for example the NAVTEX to receive navigational messages, or other communication channels for distributing data such as satellite communication (SATCOM) or mobile broadband.
- ECDIS is utilized for displaying charts and pertinent information to the OOW.
- System utilizing radar for terrestrial navigation.
- The Conning application provides engine and maneuvering status information.

This information is not well organized, especially during critical situation, which need quick decisions to maintain the safety of navigation of the ship, as well as the multitude of tasks that OOW has to deal with, as listed below:

- Avoid collision (overhead objects, ships, floating and fixed objects).
- Avoid grounding (checked planned track, contingency plane, Under Keel Clearance (UKC) control, safety contour line).
- Comply with ETA.
- Safeguard own ship (react to alarms, generate alarm).
- Communicate and report (other ship, company, authorities, and manufacturers).
- Check integrity (GPS, gyro, log, radar, ARPA, communication equipment, visibility, ECDIS safety settings and mode of operation).
- Preplan cargo operation.
- Avoid damage to own ship and cargo.

Finally, as the output of information becomes too much and more detailed, it is important to provide the OOWs with a way to minimize the amount of data or a way to visualize important data.

3. AR Projects Features

Several AR projects took place in different organizations and institutions such as; European e-Navigation project (ACCSEAS), UNH/NOAA Joint Hydrographic Center AR project, Porathe 3D chart application, VISIPORT Project. In addition, AR was practically used in accident avoidance.

A. European e-Navigation project (ACCSEAS)

Between 2012 and 2015, Accessibility for Shipping, Efficiency Advantages and Sustainability (ACCSEAS) EU-funded project, demonstrated the potential for e-Navigation in the North Sea Region (IALA, 2022). Among the fourteen ACCSEAS candidate solutions, Augmented Reality / Head-Up-Displays (HUDs). AR was used in two ways; pointing directly visually in the direction of the dangerous target, thus induce an immediate focus of the OOW on the dangerous, displaying operational information such as intended or suggested tactical routes or Marine Safety Information MSI or No-Go-Area.

Figure (1) illustrates the first approach, showing dangerous target, and Figure (2), illustrates the second approach, showing operational information (Accseas, 2013), (Williams, Shaw and Ward, 2015)

Figure 1, Highlighted target, using red box, is projected into the bridge window.
Source: (Accseas, 2015)

Figure (2) Projected suggested route, and a No-Go-Area on into the bridge window.
Source: (Accseas, 2015)

B. UNH/NOAA Joint Hydrographic Center AR project

Dynamic and flexible bridge simulation for experimenting with a range of possible AR devices and information overlays across different times-of-day, visibility, and sea-state/weather. This simulation allows for safe evaluation in a more diverse set of conditions. The project's goals include identifying which technical specifications are required for future AR devices to be useful for navigation, what information is most beneficial to display, and what types of visual representations are best for conveying that information.

Figure (3) shows the simulated projected nautical chart information (UNH/NOAA Joint Hydrographic Center, 2019)

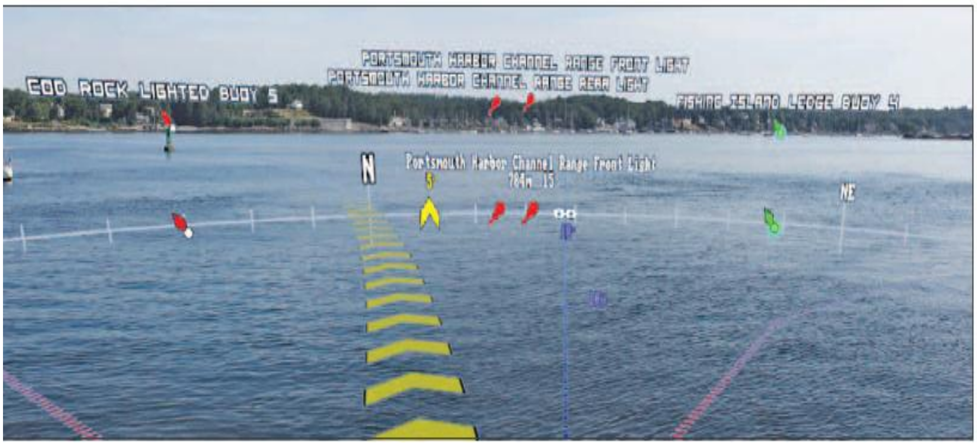

Figure (3) Simulated augmented reality overlay of nautical chart information
Source: (UNH/NOAA Joint Hydrographic Center, 2019)

C. Porathe 3D chart application

Porathe offers an application that draws 3D charts (Porathe, 2006) with the land, No-Go-Area, indicates boats from AIS data and other objects from radar in order to help users to make the right decision in a very short time. All data are displayed in the bridge view, with the help of the course from a GPS, on LCD screen. A representation of the prototype application is visible in Figure (4) (Morgère, 2015).

Figure (4) Prototype and photo of the Gothenburg approach
Source: (Morgère, J., 2015)

D. VISIPORT Project

Visual Information system for Protection (VISIPROT) is a project introduces a specialized AR collaboration approach based on a "visual situation" shared by multiple users. This visual situation correlates to the tactical and nautical situations depicted on the 360-degree on-board surveillance sensor's video. It facilitates coordination between local, remote, and distant users. It makes it possible to share information about the situation, follow engagement standards, and put decisions into action. (Moulis and Larminat, 2015)

4. AR application in accident avoidance

On the morning of 16 August 2012, the container ship VEGA SAGITTARIUS departed from the port of Nuuk, Greenland, heading for Aasiaat in the north-western part of Greenland. The navigators lost awareness of their surroundings, as a result the ship ran aground on an underwater rock. A practical experiment was carried out using AR through a bridge similar to a container ship VEGA SAGITTARIUS bridge. Through the AR panel the navigator can see the most important information, as a result the navigator doesn't have to shift their attention between environment outside and AR screens inside. When the ship approach icebergs, AR system identifies the objects outside and provides relevant status information, finally, the system informs that the ship approaching an underwater rock. The result indicate that these features could help prevent such accidents. (Danish Maritime Accident Investigation Board, 2013)

5. Proposed AR on board M/V Aida 4

The navigational aids onboard M/V Aida 4 consists of a set of devices that determine the ship's position, speed, course, and ensure safety during navigation in shallow waters or when meeting other vessels. All bridge equipment onboard M/V Aida 4 checked and tested regularly. The list of shipborne navigational equipment depends on the tonnage of the vessel, its destination and date of construction. It is defined by SOLAS Chapter V, Regulation19. So, an overview of the navigational aids used on M/V Aida 4 (MIHO SHIPYARD CO., LTD, 2010),

Captain and officers of M/V Aida 4 monitor the data of the electronic navigational devices through a set of screens in the bridge so that these data can be used to maintain the safety of the ship's navigation as well as to preserve marine environment in the sailing areas. As a result of the multiplicity of sources of navigational devices data, as well as alarms and warnings, this leads to the distraction of the OOWs and captain of M/V Aida 4. (MIHO SHIPYARD CO., LTD, 2010)

5.1 Aids to Navigation on board Aida 4

M/V Aida 4 has all the required aids to navigation for both safe navigation and support cadet training. All Aids to Navigation are according to IMO SOLAS convention. The purpose is to integrate all appropriate equipment in the AR project. Table 1 lists aids to navigation equipment on board M/V Aida 4.

Table (1) M/V Aida 4 ship Aids to Navigation

Type	Equipment
ECDIS	Transas Navi-Sailor 4000 ECDIS MFD
Heading Data Interface	Navitron System
Automatic Identification System	FURUNO FA-150
GPS	FURUNO GP-37 Receiver
Echo Sounder	FURUNO FE-700
Speed Log	FURUNO Doppler Speed Log DS-70
Wind speed and direction	FURUNO FI-50
Radar	FURUNO FAR-28x7

5.2 Proposed presentation

The proposed AR Navigation Furuno System to be installed onboard M/V Aida 4 superimpose digital information over the physical world and aims to contribute to the safety and security of the voyage by offering visual support to maneuvering and navigation during any operation, especially during supplying the isolated lighthouses in the Gulf of Suez and the Red Sea. AR navigation standard system equipment consists of Processor, IP camera, Adapter, ENC dongle and Trackball mouse.

The AR system overlays relevant information on stabilized video images from a forward-facing camera such as (azimuth, AIS, heading, radar target tracking, route, waypoint, user chart and ENC symbols) as shown on Figure (5). Just as navigators can choose which information layers to display on an ECDIS, AR navigation users can choose to display AIS, radar, ECDIS, gyrocompass and route information on their AR system. AIS and radar targets change colour according to their threat level, and users can increase or decrease range and take bearings, just as with a radar or ECDIS.

The systems alert the Master and/or OOW of the M/V Aida 4 to buoys, ships, and other targets of interest; display shallow water, no-go zones, and the planned track; and even include information from other navigational instruments. Additionally, the Master and/or OOW can check vital voyage information such as the speed of other ships, the Closest Point of Approach (CPA), and the Time of Closest Point of Approach (TCPA) of targets. Figure (6) shows that when visibility is low or when there is a lot of coastal traffic at night, AR navigation systems greatly improve situational awareness by making it clear which lights are likely to be ships and which are likely to be shore lights, as well as where to look for targets in fog.

AR navigation systems allow easy access to all relevant electronic information on a single screen. This improves situational awareness, improve decision making support to the officers, decreases cognitive load, and makes validating and cross-checking navigational information easier than ever. Improved situational awareness leads to preserve the safety of navigation and the marine environment in the sailing areas. (Furuno Product Solutions, 2022)

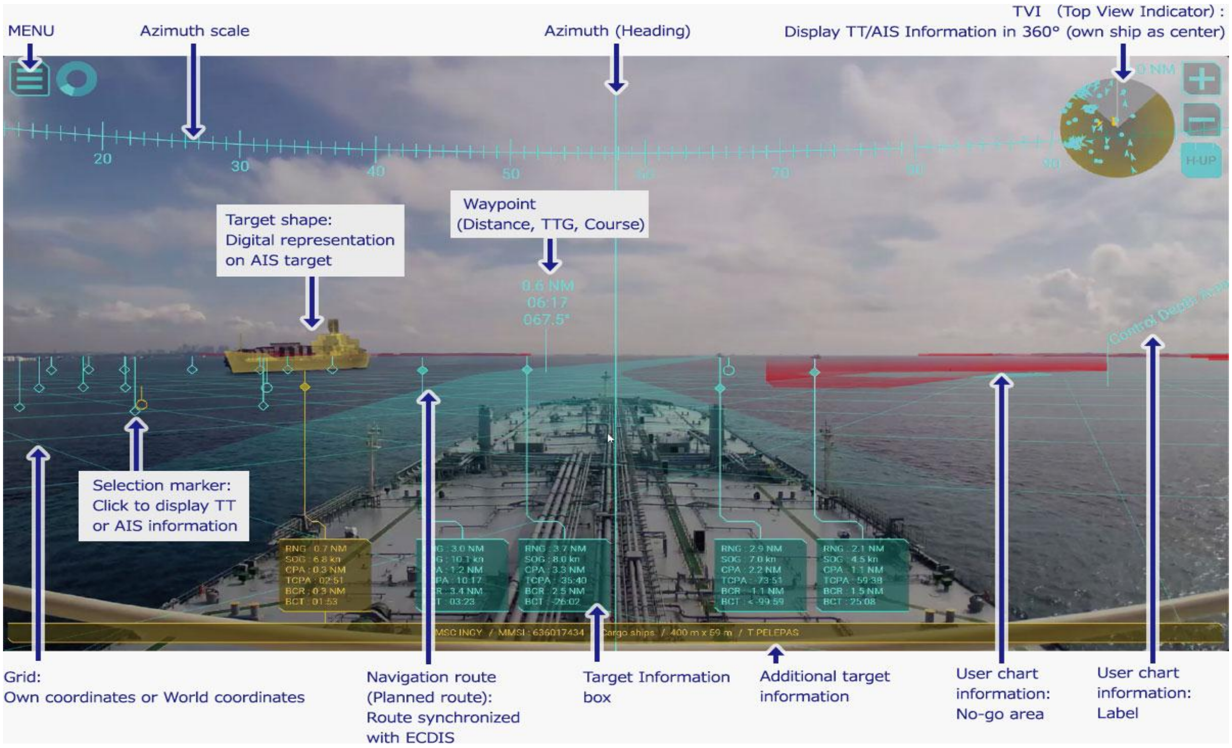

Figure (5) AR Navigation System overlay
Source: (Furuno Product Solutions, 2022)

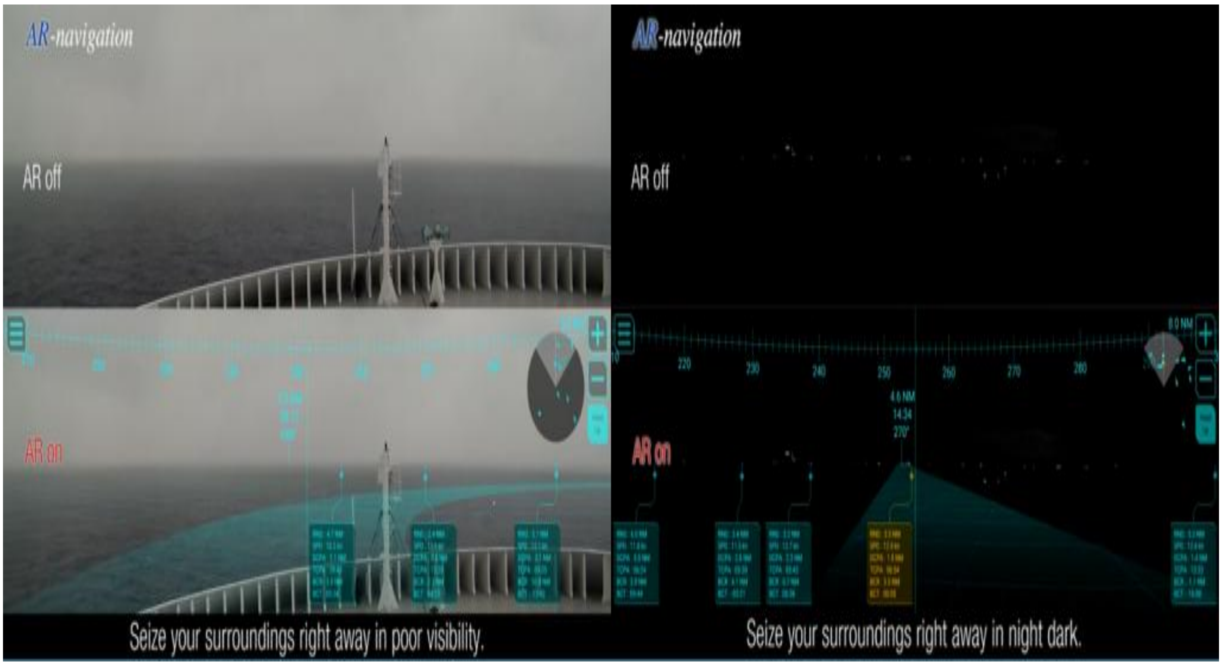

Figure (6) AR Navigation System in poor visibility and night dark
Source: (Furuno Product Solutions, 2022)

5.3 Improve cadets' skills

M/V Aida 4 is used to train AASTMT cadets to provide them with practical and hands-on training while sailing in the Mediterranean, Red Sea and Gulf of Suez by using coastal, celestial navigation and electronic navigational devices to maintain the safety of navigation of the ship. The proposed AR Navigation System onboard M/V Aida 4 will enhance the training of cadets, as a new technological tool which displays information on other vessels sailing on a vessel's planned route and surrounding sea areas and other ocean conditions, such as shallow waters as shown on Figure (7), (Furuno Product Solutions ,2022). AR system aiming to increase their safety and operational effectiveness and can provide them by a direct view of the ship's movement and a path with the current rudder position and speed orders and provides visual support during their watch-keeping by integrating information from AIS and radar target tracking (TT) with real-time video images from the bridge camera . (Frossinis, Anaxagora and Chatzopoulou, 2021), (Correia and Goncalves, 2019), (Maritime Conference in Dubai, 2019)

AR system is capable of teaching cadets onboard M/V Aida 4 how the system notify warnings to navigation, dangers in the area and meteorological warnings, in order to guarantee the safety and facilitate the crossing of the ship, especially in hazardous situations such as approaching Al-Ashrafi Islands and the Strait of Jubal in the Gulf of Suez, as well as the Gulf of Aqaba While sailing M/V Aida 4 to supply the isolated lighthouses in the Red Sea.

Figure (7) AR Navigation System onboard Aida4 ship.
Source: (Furuno Product Solutions, 2022)

5.4 Trial of Augmented Reality (AR) System

As a form of trial which will be carried out onboard M/V Aida 4, AR System is reviewed and tested by 20 respondents, which are 13 lecturers from AASTMT (Sea Training Institute) and 7 officers onboard M/V Aida 4. After testing the AR system, each respondent will fill in a questionnaire as a form of input to evaluate the AR system. The respondent assessment questionnaire consists of 6 questions listed in Table (2). By using Likert scale questions which is provides more granular information on respondent's attitudes towards a subject than a simple yes/no question type, each respondent gives a value for each question from one to five with the value of one is the lowest value and the value of five (5) is the highest value. With the result explained in Table (2), the questions are

Table (2): AR questionnaire

1	Is the AR display easy to understand?
2	Is the AR system capable of displaying navigation warnings, targets and support track control in sailing?
3	Is sailing using AR System more interesting, more helpful and easier to understand by cadet's onboard M/V Aida 4 Ship?
4	Is this AR application very helpful for learning purposes about bridge Navigation devices?
5	Can sailing using AR onboard M/V Aida 4 ship provide better experiences than sailing through bridge simulator?
6	Can learning using augmented reality increase the Cadet's ability to react by making quick decisions in critical situations?

Figure (8) explains the overall score of AR System onboard M/V Aida 4 based on the questionnaires. The highest score is 89 out of 100 in question number 2, which means AR system is capable of display navigation warnings, targets and support track control in sailing. The lowest score is 78 out of 100 in question number 6, which means AR needs further study and evaluation in order to ensure that the AR system is able to learn Cadets and How to increase their ability to react by making quick decisions in critical situations.
However, the total score of user assessment questionnaire is 498 out of 600 with average Score 83%.
To evaluate the overall results of the questionnaire, there are several values that need to be determined first. Those value are:
1. The maximum value =largest answer value ×total questions× total respondents

$$5 \times 6 \times 20 = 1200$$

2. The minimum value = smallest answer value× total questions× total respondents

$$1 \times 6 \times 20 = 120$$

3. The median (Q2) = (maximum value + minimum value) ÷2

$$(600+120) / 2 = 360$$

4. The first quartile (Q1) = (minimum + median value) ÷ 2

$$(120 + 360) / 2 = 240$$

5. The third quartile (Q3) = (maximum value + median value) ÷ 2

$$(600+360) / 2 = 480$$

By using a box plot which is a method to summarize a set of data that is measured and also used in explanatory data analysis, the AR System onboard M/V Aida 4 ship will be categorized based on the minimum value, Q1, Q2, Q3, and the maximum value. Score between Q3 and the maximum value will be excellent (480-600), score between Q2 and Q3 will be very good (360-480), score between Q1 and Q2 will be good (240-360), and score between minimum value and Q1 will be fair (120-240). Based on the results of the questionnaire, consisting of 6 questions with 20 respondents, AR system is excellent because the total score is 498 which is between the Q3 and the maximum value (480-600).

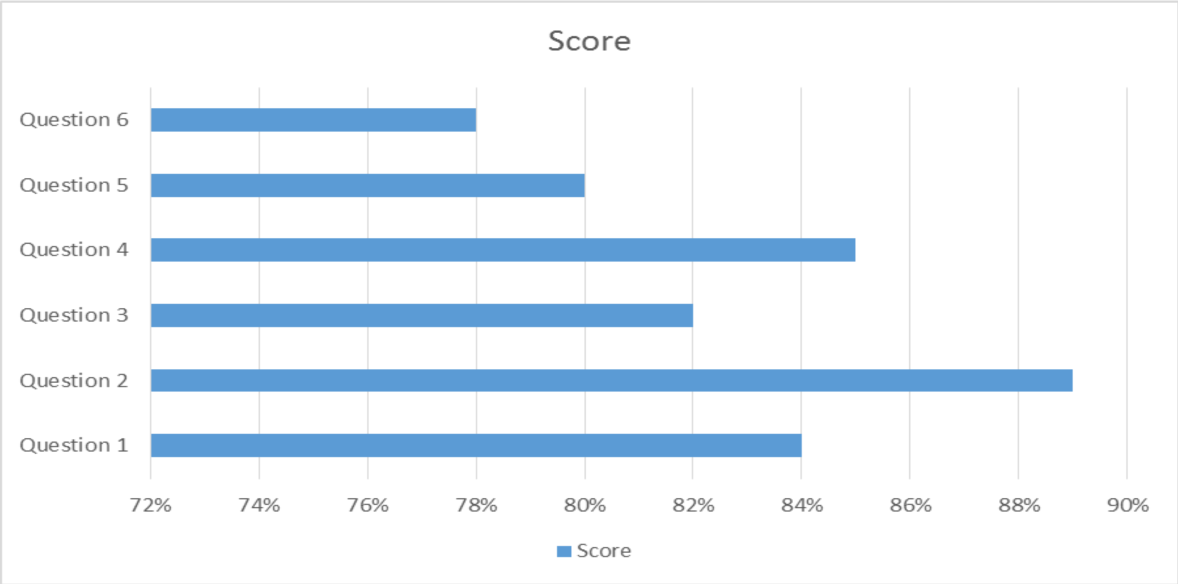

Figure (8) Questionnaire Results

6. CONCLUSION

The objective of the research paper can be concluded that AR onboard M/V Aida 4 can be especially useful for the OOW on the bridge where the risk of information overflow is very high and the loss of situational awareness can lead to extremely dangerous situations. AR System is able to be used as a supporting device to increase the level of safety of navigation and the marine environment as well as in practical training for cadets onboard M/V Aida 4 while sailing.

The paper presents a study on the use of AR System onboard M/V Aida 4 to enhance maritime safety by strengthening officers' situational awareness and improve decision making support to the officers as well as add value to education and training Cadets.

Based on the results of an assessment questionnaire that was carried out by 20 participants By asking 6 questions, the Augmented Reality (AR) System is in the excellent category because it has total value of ٤٩٨, which is between ٤٨٠ and ٦٠٠ (maximum),. However, A R System needs further study and evaluation in order to ensure that AR system is able to learn Cadets to increase their ability to react by making quick decisions in critical situations.

7. References

- Accseas (2013), Accseas Baseline and Priorities Report, (Online), Available: https://www.iala-aism.org/content/uploads/2016/08/accseas_baseline_and_priorities_ report_v3.0.pdf (24 May 2022).

- Bandara, D., Woodward, M., Chin, C. and Jiang, D. (2020), Augmented Reality Lights for Compromised Visibility Navigation, Journal of Marine Science and Engineering, 8(12):1014.

- Correia, A. and Goncalves, A. (2019), Using Augmented Reality for Learning Naval Operations,(Online), Available: https://www.researchgate.net/publication/332104890. (10 June 2022).

- Danish Maritime Accident Investigation Board (2013), marine accident report (Vega Sagittarius Ship grounding report),(Online), Available: https://dmaib.com/reports/2012/ vega-sagittarius-grounding-on-16-august-2012. (14 May 2022).

- Etienne, G., Kjetil, N., Olav, E. and Odd Sveinung, H. (2020), A review of augmented reality applications for ship bridges, Necesse, Vol. 5.

- Frossinis, D.–Anaxagora, N.and Chatzopoulou,E.(2021), Augmented Reality Technology As a Training Tool,(Online),Available: https://www.qjoest.com/index. Php/qjoest/article/view/22/19 (30 Mar. 2022).

- Furuno Product Solutions (2022) furuno envision, (Online), Available: https://www. https://www.furuno.com/special/en/envision(11 May 2022).

- Gillis, A.(2022), augmented reality,(Online), Available: https://www.techtarget.com /whatis/definition/augmented-reality-AR/,2022. (19 Apr. 2022).

- Hareideand, O. and Porathe, T. (2018), Maritime Augmented Reality, International Navigation Conference, Bristol, U.K.

- IALA (2022), E-Navigation Testbeds, (Online), Available: https://www.iala-aism.org/technical/e-nav-testbeds/accseas (28 May 2022).

- Jahn, C. (2021) White Paper: Increasing Maritime Situational Awareness by Augmented Reality Solutions, Hamburg: Fraunhofer Center for Maritime Logistics and Services CML.

- Maritime Conference in Dubai (2019), MOL Introduces AR Navigation System, (Online), and Available: https: //www.mol.co.jp/en/pr/2019/19069.html. (22 Mar. 2022).

- Morgère, J. (2015), Mobile augmented reality system for maritime navigation, France: Southern Brittany University.

- MIHO SHIPYARD CO., LTD, (2010), Navigation Equipment's Instruction Manual, Japan: S, NO.1399.

- Moulis, G.and Larminat, V. (2015), How Augmented Reality can be fitted to satisfy maritime domain needs, Virtual Reality International Conference April 2015 Article No.: 27 Pages 1–7, (Online), Available: https://doi.org/10.1145/2806173.2806200 (18 Jun.2022).

- Porathe, T. (2006), 3-D Nautical Charts and Safe Navigation, Sweden, Malardalen University Press dissertations. Mälardalen University.

- Procee, S., Borst, C., Paassen, M. and Mulder,M. (2017), Toward Functional Augmented Reality in Marine Navigation: A Cognitive Work Analysis,UK, Conference.

- The Transportation Safety Board of Canada (TSB). (2020), Marine transportation occurrences in 2020, (Online), Available: https://www.bst-tsb.gc.ca/eng/stats/marine/2020/ssem-ssmo-2020.html (22 Aug 2022).

- UNH/NOAA Joint Hydrographic Center (2019), Performance and Progress Report, Durham, UK.

- Williams, A., Shaw, G. and Ward, N. (2015), Accseas: The Innovative North Sea E-Navigation Demonstration, (Online), Available: https://mycoordinates.org/vol-xi-issue-7-july-2015 (15 Jun 2022).