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Embedded Interactive Systems Laboratory

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Novel Interaction Techniques for Oceangoings

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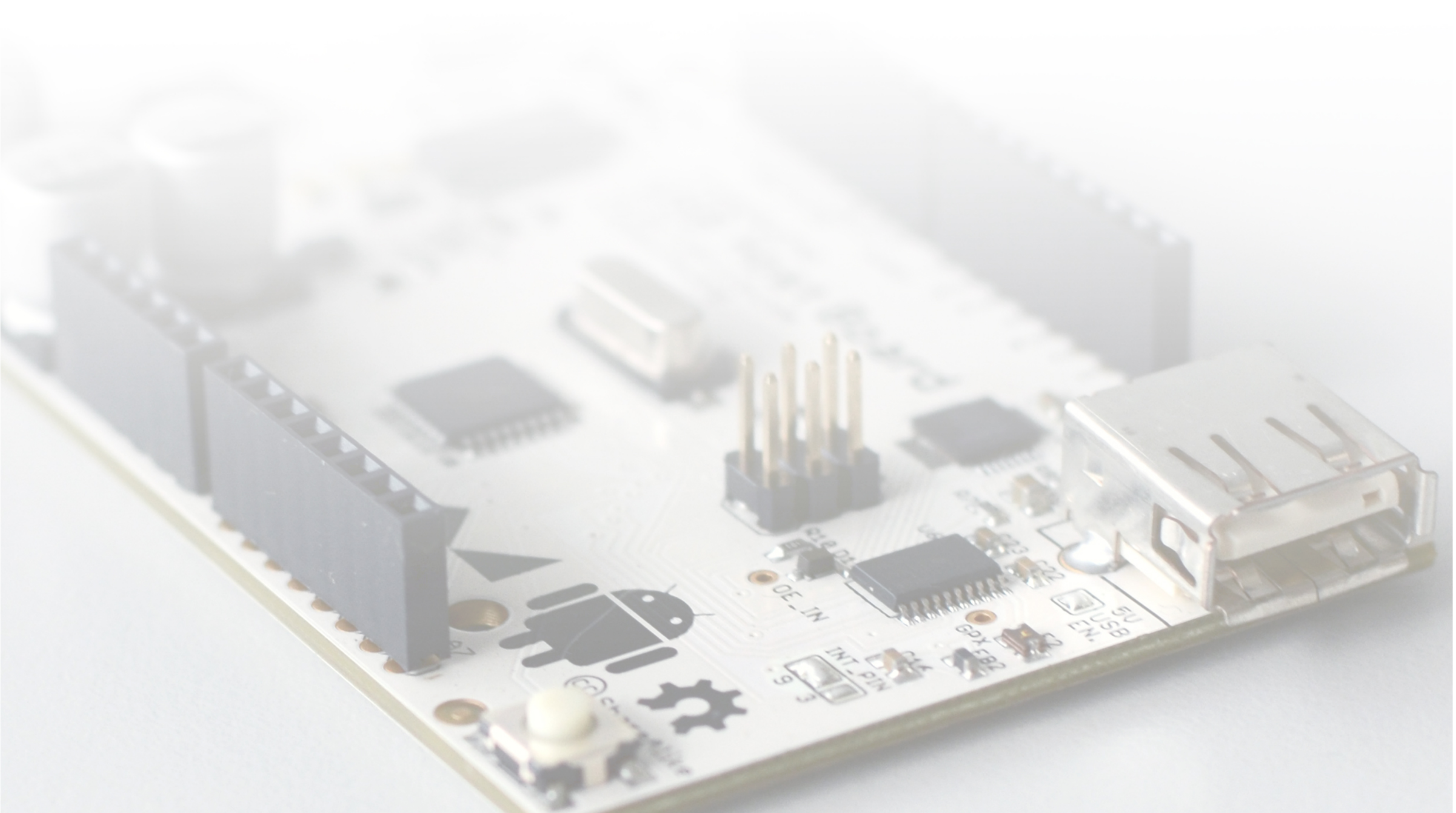

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Preface

Novel Interaction Techniques for Oceangoings are upcoming challenge in representing adding more and more smart technology to ships and boats that represent information in an easy to understand manner to the user. This report investigates into multiple facets and technologies that can be used to provide novel interaction metaphors for future application scenarios.

This technical report gives an overview of recent developments and results in the area of Interaction Techniques for Oceangoings. The topics comprise a number of areas, communication, object modelling and forming, technologies to get ideas and visions about novel interaction techniques of various kind.

During the summer term in 2017, the Embedded Interactive Systems Laboratory at the University of Passau encouraged students to conduct research on the general topic of "Novel Interaction Techniques for Oceangoings". Each student analyzed a number of scientific publications, built a prototype and summarized the findings in a paper.

Thus, each chapter within this technical report depicts a survey of specific aspects of a topic in the area of Novel Interaction Techniques for Oceangoings. The students' backgrounds lie in Computer Science, Interactive Technologies, Mobile and Embedded Systems, and Internet Computing. This mixture of disciplines results in a highly post-disciplinary set of viewpoints. Therefore, this technical report is aimed at providing insights into various aspects of current topics in Human-Computer Interaction.

Passau, July 2017

The Editors

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Advances in Embedded Interactive Systems

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ABSTRACT

Although seafaring with cruise ships is relatively safe nowadays due to modern technology, evacuation scenarios are still an important topic which lead in some casualties to deads and injuries. This paper introduces an approach of a system that supports the evacuation of the passengers of a cruise ship with dynamic information gathered by observing the situation. To achieve this stations are positioned consecutively which observe a corresponding segment of the ship. Based on the measurements a weight is calculated which states the difficulty of passing through the segment. The stations are connected between each other. The connected net of stations can be visualised in a graph which shows the availabilty of routes. Based on the weights determined by the stations an optimal route to the resue zone is computed. The calculation of the best route is based on the Dijkstra algorithm. In addition the system provides information that supports decission making for overcoming emergency situations. The visualistion is realised through dynamic signage that is installed in the ship. A wireless interface to the passenger's smartphones allows the system to display the direction information in a 3D model. Also augmented reality can be used to direct the passengers. The interface allows the users to prioritise between some parameters of the route calculation to adapt the evacuation route on personal needs. The smartphone also supplies tools for selfhelp if no connection to the routing system is available.

Keywords

Oceangoing, Emergency Scenarios, Emergency Situation, Routing, Evacuation, Cruise ship

1. INTRODUCTION

The evacuation of a cruise ship is a very importent step for preserving the safty of the passengers. Although in many cases the evacuation of the passengers isn't necessary, it is still a life-threatening situation which even caused multiple deads in modern history. Arrangements are made how to behave in such situations to minimize the risk of acting uncoordinated and therefore lose time to clear the ship. This works quite fine in some situations, but accidents, like the Costa Concordia incident, show that the arrengements are not sufficient constantly changing situations and therefore a more dynamic coordination of the evacuation is needed. Because of late decission of the staff the evacuation started delayed. After the ship started to incline, about 500 passengers were trapped because they could not walk at the evacuation paths any more and needed to be rescued by external helpers.[10] Of course other factors worsen the situation as well, for example high waves. This factors play only a role if the evacuation plans fail and therefore the passengers need to be rescued by external helpers like the coast guards.

So the importent factor for the evacuation is the time the passengers need to get of the ship. Unfortunatly the hallways on a ship are very long. So by choosing a route that leads into a dead end can double the amount of time that is needed to get to the rescue zone. This is very problematic for older people.

A system that supports the decission of the passengers to choose the write route can improves the situation. Therefore sensors are installed that recognize emergency situations and path blocking obstacles. These sensors are arranged in stations which are connected between each other. This allows the system to interchange information, to weight up different paths and decide which is the fastest one to get to the recue zone.

2. RELATED WORK

Since the system consists of different parts, there are also different branches where related work was done.

2.0.1 Evacuation route calculation systems

The systems concerning dynamic evacuation routing were mostly built for larg complex buildings, which are in some kind similar to evacuation process of cruise ships. A Paper presented at the Conference on Pedestrian and Evacuation Dynamics 2014 presented a system that reacts dynamically to the emergency situation and the behavior of the people affected by it. In order to achieve this sensors are installed which recognise hazards. The amount of people passing an area of the building is tracked by system counting the amount of people in different rooms. The evacuation paths are visualised by signs that point in the direction of the emergency exit. A graph is used to find possible evacuation paths. The system stores all information in one central system. The movement data are also stored in a database.

A simulation determines an improved strategy for evacuation based on the movement data.[22] This concept addresses some points that are also very important for the evacuation of an cruise ship.
Another paper form Delft University of Technology from the year 2005 addresses the same topic, but with some different aspects. Same as in the previous article they considered an indoor positioning technology and a proper working wireless connection as given. For the determination of available paths they also used a graph. Differently to the last paper was that it also considered the structure of the building such as stairs or floors and induvidual criteria like the mobility of persons from different age or physically handicapped people. This criteria were used to computing the shortest path with a search tree algorithm. For presentation of the the results a mobile device was chosen.[42] The concept shows some important factors that play a role for individual persons.
Another article from 2014 used a wireless sensor networtk based on ZigBee wireless sensor network to recognise fire in larger buildings. The locations of persons were captured by a RFID based location system. The information was sent to a central control system which contained a database for storing information. The direction to the available emergency exits were displayed by signage modules consisting out of a LCD monitor and a development board controlling the monitor.[36]
Another related work from Lassonde School of Engineering focused on the modeling and visualisation of the information gained by multi criteria decission making to represent the situation not also to the affected people but to the rescue team. They built a system that allowed the users to input data about the hazardious situation and their current position in order to determine evacuation paths in real time. For this Multicriteria Decision Making and Analytic Hierarchy Process were used. The visualistaion and the input are based on Geographic Information System. The virtual system was tested in different scenarios by setting the position of the evacuees and the hazard position differently.[1]
The systems from the mentioned articles make some important steps to realise dynamic evacuation route planing. This steps are also relevant for the evacuation scenario at cruise ships, since the routing is similar to that of a building. Unfortunatly emergency situations are far more complex. Systems using a sensor infrastructure are mostly dependent on a reliable connection, especially when a centralised approach is used to store data and execute computations. If connection breaks down, the system cannot be used any more. If the hazard situation has to be input by the user, he needs a good knowledge of the situation. This is often not the case, since people might be under shock due to the emergency situation. Additionally it should be the systems task to warn the users from life threatening situations.

2.0.2 *Decission Support system*

There are also some paper which are not directly related to systems which compute evacuation routes, but support decission making. This systems could be included in the path calculation of evacuation route determination. A paper form Centre for Marine Technology and Engineering supports decission making in flooding scenarios. In order to do this, an algorithm was developed to estimates the progressive flooding ahead in time. Therefore the damage of the ship is considered. Additionally counter compartments are determined which should be flooded to improve the situation. The computation is executed by a central control unit. The simulation determines also the inclination of the ship.[47] Such an estimation would be profitable for the determination of evacuation paths since the progress of the flooding makes it more difficult to use certain parts of the ship and water height is a critical factor. The simulation of these parameters could also reduce the number of sensors used for a routing system. A disadvantage of the simulation is that it has to be precise, so huge computing power is necessary to obtain good accuracy. So this technology can only be used with a system that uses a central control unit. The damage of the ship also has to be input manual. In order to use this approach effectivly the damage have to be recognised automatically and more precise then by observation.
Another article from the same department focused on the effect of movements induced by waves on rescue operations. The simulation is executed in a virtual environment in which the states of the sea are set. [46] As well as the previous mentioned article, this approach could improve the routing process since it allows the system to make assumptions about the future and therefore prevent passengers from future hazards. This simulation also needs a lot of computional power and the inputs have to be automated.
Another article from the ITMO University presented a simulation for passenger evacuation by stormy weather. A crowd model which describes social forces and a model that simulated the physical forces on the body were used. The ship's movements were computed through a seperate wave propagetion model. The Simulation was displayed on a 2D map of a fictive ship. The model was evaluated by different scenario inputs. They came to the conclusion that the speed of the movements are very critical for the evacuation time, but for more accurate calculation more criterions have to be included.[17]

2.0.3 *Activity Recognition*

A topic that is important for the smartphone application which allows the user to interact with the routing system is the recognition of abilities of the user. For this approach it is very important to estimate walking speed or the level of mobility of the user. A paper from Eindhoven University of Technology presented an approach which used the height, acceleration, gyroscope and barometer data and the GPS speed to estimate walking speed or walking activities like managing stairs. The GPS data which was recorded on a short self-paced walk is mainly used to reduce the estimation error by subtracting an offset value. The model was validated on a dataset with 20 participants which contained data of activities recorded in the lab as well in free living. The algorithmn was able to reduce estimation error. Due to computional complexity of the algorithm the system was not executed at a smartphone yet.[13] The limitations of the system lie not only in the use of GPS and complexity but also in the position of the smartphone. So this method needs more development to be applied properly in the route determination.

3. EVACUATION ROUTING SYSTEM

3.1 Current Situation and Evacuation Standard

3.1.1 Statistics

According to the Bureau Veritas about 50 percent of all accidents lead to evacuation at sea, the other half to disembarkation at port. Over 50 percent of all incidents are caused by fire or grounding. The casualties related to fire lead in 50 percent to evacuation at sea, the ones related to grounding in 70 percent. Other incidents like collisions mostly lead to evacuation at berth.[41] So the life threatening situations are mainly related to fire and grounding. This are also casualties where time plays an important role.

3.1.2 Evacuation process

The evacuation process is seperated in six different steps. three of them are performed at the vessel and the other ones at sea. So after the emergency situation is detected and the alarm rang, the passengers assemble to muster stations. To assemble the passengers, crew members search for them and pool them into smaller groups. The crew counts the passengers and reports the number to the control station. The groups are transfered to the muster station where the passengers are counted once again. After this happend the passengers are distributed on embarkation stations and moved to the evacuation zones. Finally they are disembarked in Life Saving Appliances and launchend in the sea. After the Life Saving Appliances are untied from the ship, the passengers have to wait for rescue. Finally the Life Saving Appliances are rescued by the coast guards or other helpers.[41]

3.1.3 Human and environmental factors

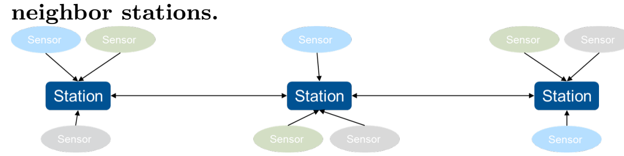
The evacuation routine is practised once every travel, so that each passenger should knows the process. But as reality shows, people react differently to emergency situation and it does not work as planed. Passengers may be unfamiliar with the environment. This can lead to confusions and hence lead to a mass panic which endangers the evacuation process. Also group dynamic effects leads passengers to follow other voyagers into a wrong direction. This causes not only a crowding of people which makes it harder to distribute the passengers on the Life Saving Appliances but complicates the restoration if the group reaches a dead end. Other factors are the abilities of passengers from different ages or with different physical abilities. A evacuation path may be optimal for people with good mobility but not for overweighted, older or physical handicapped people. So choosing the wrong path worsens the situation not only for the individual person but also for others, since hallways or stairs on ships are blocked easily.
Additionally there are environmental factors like wind or waves, that brings the ship into motion and therefore complicate the disembarkation.

3.1.4 Requirements concerning the system

As previously mentioned emergency situation like the evacuation scenario need a system that can adapt and provide the affected people with dynamic information about the situation. So a supportive system should not only display the shortest route to the rescue zone but also update the recommendation if an easier path is available. Additionally it should consider different paths for passenger with different needs.

3.2 Concept of the System

Figure 1: The figure shows the setup of the stations. Each station is connected to sensors and to their neighbor stations.



3.2.1 Basic Concept

In order to improve the evacuation process sensor stations are installed in the ship as shown in 3.2.1. The stations are powered over the ship's power supply. They also possess a small battery in case of a blackout. Each of them observes a segment of the ship and records environmental data which help to direct the passengers on the best suited way to the rescue zone. Sensors are used to detect emergency situations which hinder passengers to use the specific route and others to quantify the difficulty of the evacuation route. The stations are wired with their direct neighbor stations to exchange data. Till now it isn't possible to detect all emergency situations since there isn't a general procedure. So the system should recognize the most common situations. As mentioned in 3.1.1 the majority of all accidents are caused by fire and grounding and therefore resulting in flooding of segments of the ship. The result of an accident may be obstacles that block the route to the muster station. This also should be recognised to obtain accuracy. Additionally the utilization of the paths is recorded to prevent congestions of voyageurs which makes it also easier to distribute them to Life Saving Appliances. Each station possesses a gyroscope to determine the rotation of the ship. In most cases the ship will sink in one direction, either to the left or to the right, so the ability to walk in some areas is impaired by the cross slope. A model of the ship which contains information about the structure helps to determine whether the area is walkable. The sensor setup of the stations cannot be generalised on a fixed amount of sensors since it depends on the situation how many detectors are needed. Usually it depends on the size of the segment which is observed by the station. So multiple sensors of one type can be used in one station (i.e. smoke detectors) but from other types of sensors only one exemplar is sufficient (i.e. gyroscope). The interface between the system and the user's smartphone is realised by beacons which send and receive small data packages over Bluetooth Low Energie. Of course any other wireless communication allowing bidirectional communication between smartphone and system can be used.
The rescue route is displayed to the passengers by symbolic boards which are installed on the ceiling. The system also provides individual route calculation for passengers with different needs due to physical handicappes. In order to achieve this the user priorities between different parameters by editing the setting. The values chosen in the setting are used for the calculation of weights which are sent to the stations in the route for evaluating the measured parameters to find the optimal route. If more than one person is recognised by the station the weights of all are averaged and a evacuation path from the averaged weights is calculated and provided to all users in the segment. If no connection to a station is available or if stations are disconnected from the base sta-

tions further information is provided to the passengers how to behave in this situation. Tools are also made available in the smartphone application to collect usefull information that helps to find a way to the rescue zone or to signal the need of help.
The system is easily enlarged for other emergency situations. Therefore additional sensors must be installed at each station which help to detect additional situations. It is also possible to apply machine learning or sensor fusion to detect other emergency scenarios.

3.2.2 Fire / Smoke Detection

The fire detection is performed by the smoke detectors which have to be installed in every ship or public building. The smoke detectors are not connected to each other but they are coupled with the sensor stations. The detectors provide the station with information and the station distributes the information through the system. The detectors are used for detecting fire but not for quantification of the difficulty of the path.
The smoke detectors have to be installed comprehensively to obtain a good accuracy. Normally there are rules how to install the sensors. E.g. for hallways in the European Union every 60 m^2 a new smoke detector is needed. The distance between two smoke detectors should not be greater then 15 meters.[9] So the amount of detectors depends on the size of the segment and they are usually installed at the ceiling.
Additionally temerature sensors are positioned at the ceiling to quantify the intensity of the fire. There have to be multiple sensors to gather information about the affected area of the segment. The heat measurement is used for the determination of the danger factor of the route.

3.2.3 Water Detection

The water detection is performed by water sensors which measure the conductivity. Since the sensors only can recognize the presence of water multiple sensors per segment are added to measure the water level. Low water level doesn't interfere the passengers from walking through the segment. The sensors are mainly installed on decks which are closer to the water since the upper decks aren't threatened to be flooded. The water measurement is treated as an obstacle and is therefore not included in the difficulty calculation of the path.
The water detectors are installed at the ground. The sensors are installed in the middle of the segment. If there are points where the water is supposed to collect and which interfers the voyageurs from crossing additional sensors can be placed. For measuring the water level sensors are added in the same position at the wall one above the other. The water level is also needed to calculate the danger factor.

3.2.4 Obstacle Detection

To recognize obstables in narrow passages like hallways or steps, structure sensors are installed at both walls of the segments. To cover larger areas the sensors are arranged consecutively. The distance between the sensors is determined by their range. They record the area of the segment. If an obstacle occures the sensors use a picture from the unblocked path and the depth information to compare and estimate the object's size. Due to the estimation the path is declaired as blocked or unblocked. The size of the obstacle is used to quantify the danger caused by the object. Since voyageurs are crossing the sensor's range, measurements have to be taken over a period of time to determine whether there is a static object with blocks the path.
The sensors are installed in the middle of the room height to obtain the most coverage of the three dimensional space. To improve the accuracy of obstacle detection additional sensors may be installed at the ceiling.

3.2.5 Air Polution

Gas detetion is also a very importent factor in order to determine a safe evacuation route. Gases like carbon dioxid might be covered by the smoke detection, but others like carbon monoxid might arise through fire and cannot be recognised by the passengers itself. Therefore a gas detection should be included to notify the voyageurs or lead them in a different direction.
In order to achieve this a carbon monoxid detector is installed close to the bottom. The detection is used as obstacle sign and the measurment of the concentration as danger factor.

3.2.6 Flow Detection

The flow detecten is realised through the beacons. They recognize the amount of smartphones in a segment and estimate the amount of people. The beacons are installed at the middle of the segment. Additionally light barriers are installed at the ends of the segments which count the amount of people entering or leaving the area to obtain a more accurate estimation.

3.2.7 Determination of walkable Areas

Each station contains a model of the corresponding observed segment. This model contains information about the segmnet like length, minimum width and information to the structure of the walking path. The structure information tells the system which percentage of the walkable area is flat, ramps or stairs containing slopes. In that way the system is able to dertermine the difficulty of the path or whether it can be used by wheelchair users or physically handicapped people. Additionally the gyroscope provides a value of the current inclination of the ship. This value is used to compute the difficulty of the evacuation route due to cross and longitudinal slope by updating the slope values of the structures.
Each structural model also contains the direction to it's neighbor stations and to emergency kits in close range in vector form representing the x, y and z axes. This is important for displaying the direction of the evacuation route on the smartphone screen. This is further explained in 3.5.2.

3.2.8 Tool Availability

If no obstacle free evacuation route is available, it is important to know where to find tools which help to escape from this situation. At a cruise ship this concerns mostly tools for fire fighting like fire extinguishers, water hose and hydrants. The position of the tool is forwarded to the affected people if it is still available.

3.2.9 Smartphone Interface

The interface to the smartphone is realized by beacons. They broadcast small packages of 27 octets through Bluetooth Low Energy which can be received by the smartphones. For this system bidirectional communication is needed for individual path computation therefore the smartphone also is able to send small packages to the station. This is enough data to send basic information like the direction to the rescue zone for different classes of passengers, alarm information, distance to the next sensor station and equipment available at the station.

3.2.10 Station Placement

The stations are placed consecutively in strategic points in the ship. E.g. a station is placed to observe the segment of a stair which connects two decks. For parts of the ship with less changing structures a broader range of the station may be chosen. The stations are placed consecutively. Sensors covering a whole area should have an overlapping range with the neighbor stations, since it is more secure to cover the whole path. Additionally a station is positioned per resue zone.
At intersection points a control unit is needed which receives information from all possible neighbors of the intersection. This is necessary since this control unit has to decide which way is the fastest to get to the rescue zone based on the information of all neighbor stations. This is necessary for the algorithm to work properly. The algorithm is described in 3.3.2.

3.3 Algorithm

After wiring the stations with its direct neighbors, the system can be seen as logic net if we consider the system as whole. So the net results in a graph where the stations are the nodes and the the segments are the vertices. To describe the difficulty of passing through a segment the vertices are weighted according to the parameter of the segment and the measurements taken by the sensors. So if a station falls out the connection to it's neighbors is removed. In this situation the segment can be considered as not walkable.
The algorithm is based of the Dijkstra shortest path algorithm, since it is better suited to the decentralised approach of the system.

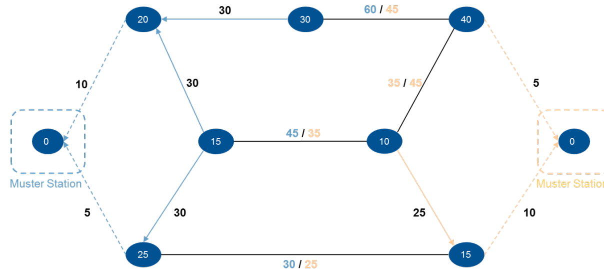
3.3.1 Dijkstra Algorithm

The Dijkstra algorithm starts with one node in the graph which is marked with the path length of zero. All other nodes are initialised with infinite. The starting node is added to the set of visited nodes with the path length of zero. After that the algorithm checks the nodes that can be reached from the visited nodes (contained in the visited set). For this the reachable nodes are updated with the shortest path length that results from the path length to a visited node plus the weight of the path that has to be gone for reaching this specific node. The unvisited node with the shortest path is added to the visited set. The algorithm keeps checking for reachable nodes and adding the shortest one till the target node is reached.

3.3.2 Algorithm used by the System

The system proceeds very similar to the Dijkstra algorithm. The algorithm starts with the stations located in the rescue zones. This stations initialise the communication to their neighbors. The path difficulty count is initialised to zero.As shown in 3.3.2 the neighbor stations select the shortest path by the incomming signal, add their segment difficulty to the count and send it to all neighbor stations ex-

Figure 2: The figure shows the routing algorithm which is applied to the logic net. The nodes select the smallest weight as best path. The weight of the nodes is considered the difficulty of the station. The graph contains two starting points. The colored arrows show in the direction of the route. The black edges are not chosen as route because of their weight.



cept that node which was selected as the least difficult path. A set where the visited nodes are stored is not needed, since each station decides which path is best. This is a difference to the Dijkstra algorithm.
Another difference is that there are multiple starting nodes, since there may be several rescue zones contained in a ship. So each station receives signals from various directions. Therefore it is importent not to send back the output signal of a station to the station which was selected as least difficult path but to all the others. Otherwise it could happen that circulations arise because two neighbor stations select each other as best path. Also the Dijkstra algorithm can not handle paths from multiple directions, this is done by the decission making of all stations. The decission splits the graph in multiple subnets with start node at the corresponding muster station. The Dijkstra algorithm also has given an end node which tells when the algorithm has to stop. In the system's implementation there is no end node since the all stations have to be updated.
It is also necessary to update the calculation according to difficulty changes of segments of the ship. The orginal Dijkstra algorithm doesn't provide a recalculation of the shortest path, but it can be easily included in the system's algorithm by implementing an update message that induces the effected nodes to recalculate the path weight. This doesn't necessary mean that the whole graph has to be recalculated. The updating process ends at the station which choses, even by considering the new weight, a different path as optimal.

3.3.3 Communication

There are two types of communication in the system. The first is communication between the stations and the second one is communication through the interface to the smartphone.
Information used in the first type of communication is the ID of the corresponding station. This is necessary to match the message with the right station. Then the status of danger detection is needed. This is only a simple flag that tells whether the route obtains an dangerous segment. The alarm information is also transmitted. Additionally to the flag, the danger factor is transmitted. Then the different parameters are transmitted. At last the availability status of the emer-

gency tools is communicated. The communication between two stations is narrowed to a few bytes and is sent on a regular basis or thenever parameters change.
The communication to the smartphone is realised through Bluetooth Low Energy. Therefore it is restricted to 27 octets. The smartphone needs to know the ID of the station. Then the danger flag and alarm information is transmitted and the direction containing the emergency. After that the direction to the next station is coded in vector form. So there is enough octets left for coding the direction to available emergency tools in vector form. The smartphone sends only an ID and the weights chosen by the user.

3.4 Multicriteria Decission Making

The edge weights are very important for the algorithm to dertermine the best suited path. As in the previous chapter mentioned each vertice possesses one weight associated with the difficulty of crossing the segment. Since there is only one value used for calculating the least difficult route, multiple values from different parameters have to be combined. There are multiple ways to achieve this.

3.4.1 Weighted Sum

To apply the weighted sum a weight for each parameter out of a set with size n has to be chosen. The sum of all weights gives one. After that the value of each parameter is multiplied with it's corresponding weight. The result is summed up to a positiv number.

$$w = \sum_{i=1}^{n} \lambda_i * p_i; \sum_{i=1}^{n} \lambda_i = 1 \qquad (1)$$

This would be an adeqate calculation of the value since all parameters are considered and can be prioritized by choosing the weight. A disadvantage of this solution is that is the linearity doesn't observes the height of the parameter values. E.g. low water level isn't life-threatening. If the water level rises to a certain point it slows the passengers down or endangers the passengers to drown. Therefore the water level should be prioritized higher. This can't be done with the linear solution.

3.4.2 Maximum Value

The max value chooses the maximum of all parameters of the set P.

$$w = \max_{\forall p \in P} p \qquad (2)$$

This is as good as simple, since the all values are considered as well as their heights. Another advantage of this procedure is that the amount of parameter doesn't matter. This is very handy as some of the stations do not possess all sensor types and therefore measure less paramters then others. The disadvantage of the maximum value calculation is that the values have to be comparable, since some values are higher by default.

3.4.3 Root Mean Square

The Root Mean Square is calculated by summing up the squared values of each parameter and extract the root of the result of the sum.

$$w = \sqrt{\sum_{\forall p \in P} p^2} \qquad (3)$$

The RMS allows higher values to be prioritized.

Table 1: The table shows the classification and description in two different classes.

Classification	Parameter	Description
Danger	Fire detection	The fire is detected by smoke detectors. The intensity is quantified by temperature measurement
	Water detection	The parameter is quantified by the measured water level
	Obstacle detection	The parameter is quantified by the estimated size of the object
	Gas	The parameter is quantified by the measured concentration of the gas
Weighted	Route length	The length is calculated from the sum over all segment lengths contained in the route
	Stair length	The parameter is calculated from the sum over all lengths of stairs contained in the route
	longitudinal Slopes	The parameter is the maximum value of longitudial slope contained in the route
	Cross Slopes	The parameter is the maximum value of cross slope contained in the route
	Passenger Flow	Determined trough the amount of passengers utilising the route divided through the size of the segment

3.4.4 Normalisation

If a criterion is used that sums up all parameters, the values has also to be normalised by the amount of parameters used for the calculation. This has to be done since some station do not possess all of the sensors and therefore the value are less by default.

3.4.5 Parameter and Weights

There are various parameters which can be included to calculate the the weight of a segment. The obvious ones are the length of the path, the flow, structural information like stairs or cross and longitudinal slopes, path width and the danger factor of the segment. This includes also most of the parameter which are needed for wheelchair accessable routes.[11] The left out parameters are important for outdoor wheelchair routing, but not for routing on a cruise ship since most of the ship's part are made accessible for wheelchair users. There are two types of parameters. The first one is related to dangerous situations. This are factors which don't need weights because they affect any passenger in a different way. The second type are the weighted parameter which are adapted on the preferences of the user. As weighting algorithm a weighted sum is used as explained in 3.4.1. The parameters and allocation to types is listed in 1.

The length is easily determined by the strutural information of the segments. The flow parameter is determined by

the amount of people in the segment and dividing through the size of the segment. The overall danger factor of a route is computed by summing up all individual danger factors. The other parameter are treated similarly. The lengths and the flow factor are summed up. The slope parameters are determined by the maximum over all slopes contained in the route. This allows each station to calculate the parameters with individual weights.
The weights of the parameter are determined by the input of the user. The user is questioned about his mobility or ability to walk, ability to manage stairs and the usage of wheelchairs or other walking frames. The smartphone sensors also can give an estimation about the mobility and walking stability which also could be used to adjust weights as proposed in 2.0.3. The app provides two default settings, one for pedestrians and the other one for wheelchair users. The user is also allowed to customise the weights as needed.

3.5 Route and Data Visualisation

There are multiple options to display the direction which leads to the rescue zone to the passengers. Of course there should be installed a dynamic signage which leads the passengers into the right direction, since not every passenger possesses a smartphone.

3.5.1 Path Signage installed in the Ship

The signage is very important because it allows every passanger to find the route without using a smartphone. The difficult part in this situation is that the system should provide individual routes for every passenger. If multiple passengers are in the same segment of the ship, there is a conflict in displaying the paths. So there are two solutions to this problem. First the system dispalys a route which was calculated on fixed weights and the individual calculation is only executed on the smartphone.
The better solution is that the stations receive weights form all passengers currently using the segment and calculate average weights. Since there are more then one voyagers it is more likely that they stay together and seak a common evacuation route then separating in different groups. A group allows also physically handicapped people to use more difficult since they receive help from other people. So this is a compromise between individuality and common path routing which goes aline with the evacuation strategy.

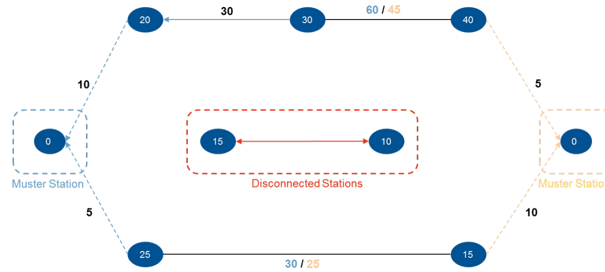
3.5.2 Visualisation on Smartphone

The routing information is presented in two different ways. First in the aerial perspective a 3D model of the ship is used. The model contains all locations of the different stations. Then the current stations sends it's own ID and that of the next station in the evacuation path and the ID of stations containing dangerous situation. So arrows are drawn that point in the routing direction. The routes which leads to an emergency is also displayed with a read cross or stop symbol. Additionally information like the availability of emergency tool can be also displayed easily. This gives the user a good overview at a glance since everything is in a model.
The second possiblilty is to use augmented reality. This is more difficult then the first approach because the orientation of the ship and the location of the stations are unknown. To aline the arrows showing the routing direction, the smartphone receives the direction information from the station which is next in the path. Since the direction to the next

Figure 3: The figure shows the screen of a smartphone using the augmented reality approach of route visualisation. The red cross signs that this direction will lead to an emergency. The extinguisher sign in the navigation bar states that this tool can be found in the other direction.

Figure 4: The figure shows the screen of a smartphone using the augmented reality approach of route visualisation. The green arrow shows that this direction leads to the rescue zone. The extinguisher sign shows that the tool is found in this position.

Figure 5: The figure shows the graph with disconnected stations. The disconnected stations start communication to gather more information.



station doesn't stay the same it has to be refreshed regularly. At the top of the screen a bar is displayed which resembles a compass displaying all cardinal points while turning. Different symbols are added to the bar which present the direction to a emergency tool, so the user knows which direction he has to go to reach the tool. This is a very sparse presentation of the information, but it gives the user a short notion where to find the tools. Routes that leads to dangerous situations are also represented with a red cross or stop symbol as shown in 3.

3.6 Disconnected Stations

As the signal is propagated from the muster station through the system, it can happen that some stations aren't reached by any signal if the wiring is damaged. This is shown in 3.6. Normally if the wiring is damaged this means that the path is also not secure enough to consider it as safe to walk. So for the connected system this isn't a problem at all, since the disconnected stations arn't considered for the path determination. A more serious problem is that people might be traped in this islands and don't receive usefull information to escape the situation. So the system have to provide some tools to overcome this problem. Some of the tools can also be used while the system is intact, but they are especially important if no path to a rescue zone is found and the passengers are forced to make decissions on their own.

3.6.1 Island Building

If a station recognizes that it doesn't receives signals from any muster station for a longer period of time it starts to initialise a network by sending signals to the neighboring stations if they are available. If other stations are found, the user is offered a broader range of information about the situation.

3.6.2 Emergency Equipment

Since the passengers can't reach a muster station they also can't be supplied by external helpers. So it is very important to know where to find tools such as fire extinguishers or medical kits to improve the self helping abiltiy of the affected people. Each station possessing these tools is able to recognise whether they are in place and unused. This can be done in various methods, e.g. by induction , RFID technology or simpler approaches like a button which is pressed when the tool is mounted and released otherwise. The information is displayed at the smartphone.

3.6.3 Alarm Notifications

As previously mentioned the sensor ranges of different stations overlap so that the alarm is recognised even without wireing. This information is used to notify the trapped people and advice them how to overcome this situation.

3.6.4 Information Transport

The accurance of two seperated nets isn't optimal. So in order to merge the nets the smartphone of passengers are used as receiving as well as sending device. If the sending range of the staions are overlapping it occures that the smartphone is able to temporarly fill the gap between to separated stations. This could be enough to transfer the information collected by one net to the other without intact wiring. If the gap is to big the information is stored at the smartphone and is transmitted as soon as the connection to a different net is available.

3.6.5 Local tools

Of course it occures that there isn't a connection to any station. So the system must deal with this situation as well. The situation allows the system only to operate localy on the smartphone. This isn't optimal, because life threatening situations only can be recognised at short distance. It is often the case that information that can be recognised with the smartphone's built in sensors can be realised by the passenger itself. So it is not beneficial to take local measurements.
It can be very usefull to utilize the built in actuators of the smartphone, such as flash light or the loudspeaker in addition of the microphone. So the application should provide an easy interface for the user to activate a flash light that signals SOS, a predefined sound that simplifies localisation or to amplify the users voice to call for help. This isn't a novel technology since it is used in multiple apps available in app stores, but it still is usefull in such an scenario.
Other factors that can play an important role in this situation are conditions that can't be recognised by humans. While smoke can be seen there are gases like carbon monoxide which are tasteless. In order to warn the passengers extending sensors for the smartphone are placed with the stations. This sensors can be connected to the smartphone. So the amount of oxygen in the air can be measured and the passengers can be advised to avoid these areas if possible.

3.7 Discussion

As stated in the previous chapters most parts of the system are realisable with nowadays technology. The communication is bound to a few bytes, so there should not be much overhead. Except from the obstacle detection the system doesn't need much computing power. This is beneficial because a smaller contol unit is sufficient. Although the concept shows improvements for evacuation scenarios of cruise ships there are reasons why the system might needs time to be realised in future or isn't realised at all. Since the system uses sensors that cannot cover a larger area but gives only a measurement at a specific point, it happens that emergency situations might be overlocked. So in order to improve the system, experts has to be questioned and tests have to be made to validate the sensor placement. This will give an accurate measure how many sensors are needed in order to maintain accuracy. Also the obstacle detection is an issue that has to be solved. Nowaday there is no efficient way to determine random obstacles in hallways or public places which occure in such emergency situation. To make the system more accurate, the obstacle detection is needed since the other sensors cannot measure all states of the existing situation. So a more efficient way to determine path blocking objects has to be invented in order to maintain accuracy. This could also reduce the amount of sensors needed, since the functionally is profided by a working area covering obstable detection.
Another factor that might makes the system uninteresting for ship owners is the price. Purchasing a cruise ships is allready very expensice. The system needs a lot of different sensors to be placed to cover the whole area. Although the system can be realised with low cost sensors and the smoke detectors are already installed, there are still many sensors needed which makes the system very pricy. Also the costs for installation and maintainance have to be added. In the cruise trip industry it is very common to neglect emergency support system since they are not necessary needed and the task of the system can be done by the crew. For example Man-Overboard system aren't installed although such emergencies occure regularly.[2] Since the evacuation support system can be replaced by organised behavior of the crew it is imagineable that a system like this is never installed.

4. CONCLUSIONS

This paper suggested a routing system for evacuation scenarios at large cruise ships considering environmental factors as well as the personal preferences or abilities of the user. It improves the situation of passengers, since they are early informed about the changing circumstances. Most parts of the system are realisable with nowadays technology. But especially the obstacle detection which is needed to obtain accuracy needs further development to obtain a more efficient and more favorable approach. Although improvements are achieved with the routing system it will take time till such a system is installed since the development is very expensive.

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Advances in Embedded Interactive Systems

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ABSTRACT

In this paper we present an augmented reality interface with interaction possibilities for maritime applications. This interface is utilized using a head up display, which should be projected onto the bridge window or a glass screen in front of the steering officer. We analysed which data has to be displayed on this screen and how to order it. We use the dynamic projection of data to support the situation awareness. We want to supply a collision avoidance system, by presenting alternative routes to the steering officer. An interaction with the augmented reality should be able using a touch input or gesture control enabling an augmented interaction on the bridge. We created a video prototype to evaluate the situation awareness and satisfaction with the functionality. We conducted a field study with participants with maritime experience to view the prototype and give commentaries about the usage.

Keywords

Maritime, Navigation, Augmented reality, Interaction

1. INTRODUCTION

Computer support systems for navigation and work tasks are used in a broad spectrum. The goal for those systems should always be to provide the information necessary for the user, without the user having to explicitly pay attention to the information source. Head up displays are used to project information directly into the field without drawing the attention away from the object of interest. Those interfaces are already used for cars and planes.

Those interfaces are a combination of data, provided through sensing systems, like speed or amount of fuel left and navigation data, which is provided through GPS data and saved maps. A wide variety of data is gathered and provided to the controller of boats. There are multiple sensing systems and support communication systems, which provide a wide array of data. This big amount of data has to be processed by the user, meanwhile always keeping an overview of the situation on the outside. To adjust parameters like speed or rudder the steering officer has to put his attention away from the screen, down to a console. An intuitive system should be desired due to the low standardisation for existing ship instrumentation, in contrast to for example cars or planes with a high level of standardisation [23].

In this project we aim to create a prototype of a system for augmented interaction in the navigation of ships. The augmentation is done through a head up display, where all necessary information is projected to dynamically focus the user's attention on the most immediately changing information. This provides a good situation awareness and through this data fusion to one central point it allows a single person navigation, by reducing the workload [34]. It should be possible for the user, to directly interact with the projected data and thereby adjust live settings and navigation planning. The legal boundaries of naval shipping are put into consideration for this method of interaction.

2. RELATED WORKS

In the car and plane industry head up displays for augmented reality are already in use. There are different attempts to maximise the clarity of the projected data, deciding between the amount of data projected and the ability of the user to process the shown information correctly and intuitively. Those systems also try to offer error prevention instruments, such as collision warnings or support under bad outdoor conditions.

In the car industry there have been multiple attempts, for creating the correct strategy and layout for head up displays. Park et al. (2013) used an augmented head up display to supply the driver with additional safety information [29]. The system offers the driver also augmented information when the weather conditions are bad. This aspect can be very useful for a ship's steering officer, due to bad conditions on sea. They also detect objects, that are not given information through GPS system or similar. A decision module helps to decide which objects are important and how to deal with them. Their system uses a camera to detect the objects in the field of view. For the implementation on a ship, these kind of systems can also rely on the information of i.e. a radar system to project dangerous obstacles below the surface.

There have been attempts before to create a use for augmented reality on the bridge. Mostly those attempts used a head up display or some kind of smart glasses to project the information into the field of view. For those projection systems it is necessary to be aware of the ships horizontal

alignment and a tracking of the infinite horizon is needed.
Hugues et al. (2014) proposed a system which is able to track the horizon in real time for operations in a maritime context [16]. For their approach they use a combination of sensor and video data. The inertial measurement unit is used to define a smaller area, which the image processing algorithm uses to detect the horizon. Using this method they are able to diminish false positives for their set-up and use the detected horizon to project the route to follow in the correct position of the display.
A mobile approach was made by Morgere et al. (2014), highlighting important aspects in the field of view through arrows pointing on the objects [25]. They approach the necessity of not overlaying every object in the field of view, because it would be too difficult for a user to process all the information at once. They separate the field of into two categories, near and far. Both of these groups have a maximum number of objects to fit in. The system is limited by it having to be able to work under extreme luminosity variations and needs to be fitted for every user.
A research about the situation awareness on ships using augmented reality was conducted by Hong et al. (2015), where they projected the AIS data into the field of view [15]. They evaluated the situation awareness through multiple metrics, such as the situation awareness rating technique (SART) or the situation awareness global assessment technique (SAGAT). They conducted a study of people with knowledge of maritime scenarios. The results for both metrics showed significant advantages of the augmented reality system. All participants preferred the setting with augmented reality, but asked for more detailed information and a map view from above also projected somewhere in the field of view.
A survey about the belongings of the interface was conducted by Oh et al. (2016) to organize the information given to the user [17]. Their focus lies on the support of fast and clear decisions, in difference of the complicated overloaded design of the usual setting on the bridge of a ship. They categorized the data into three parts, the ownship information, traffic ship information and Electronic Chart Display and Information System (ECDIS). We will split the data similarly for the prototyping. For their set-up the ownship information which is projected in a display above the window on a conventional setting is projected in the top of the augmented display and the AIS information is directly overlain, to the object it corresponds to. The feedback to the system was positive in a survey about the satisfaction with the provided functions.
We also want to give the user the possibility of interaction with the augmented reality. We considered the approach of Spies et al. (2009), creating an augmented interaction system for the automotive domain [35]. For the part of the data presentation they also used a head up display. For their approach of interacting with the augmented reality a touch display was used, which mirrored the display. The touch pad can either give completely hap-tic feedback through vibration to the user or can include few movable elements. This way the user does not have to look down from the screen and is able to input commands intuitively. They proposed to use the system to be able to get information about points of interest in the field of view and to be able to interact with the adaptive cruise control.
The information presented must be chosen carefully. Even in with today's systems it is not easily possible to use the right system in the right situation. Madden (2016) compares in his article the ARPA and AIS systems and notes the importance of the steering officers understanding, what system to use in which situation and warns about overly relying on single systems [22]. Similar is stated by the Japan Ship Owners Mutual Protection and Indemnity Association (2015) also state on this over reliance on the system, to a degree, that marine officers fail to look out of the window and thereby do not notice objects that are not projected by the system [1]. They emphasize strongly on the fact that ARPA and AIS are not able to tell that there is absolutely no risk of collision and thereby the surrounds have to be watched by the steering officer.
The head up display also should show how to change course to prevent collisions. Therefore the ship needs to know how to evade a critical situation. Kuwata et al. (2011) proposed a system that automatically follows the rules of the International Regulations of Preventing Collisions at Sea (COLREG) for unmanned shipping devices [19]. This system also takes uncertain movements of swimming hazard into account and does a pre-collision check. Instead of automatically changing the course, in an augmented environment these kind of systems can be used to project the course change, for the captain to decide if he wants to follow through.
On top of this structure we aim to support the user by pulling his attention to important places in the field of view. In the paper of Mueller et al. (1989) research the influence of different methods of steering the attention of the user [26]. They compare a symbol in the middle, which shows as an arrow in the direction, where the information is shown. They compared this method to a peripheral flash in the direction of the attention focus. Their first experiment conducted that the attention gets drawn faster to the location using a peripheral flash. In their second experiment, it was conducted, that the attention of a central cue can be more easily disturbed by sudden peripheral changes.
We want to fuse the ideas of the previous work, by using the information known about the interface composition of ship interfaces. Situation awareness and user preferences are taken into account, as well as information from similar fields with more experience in this object, as the car industry. We want to extend the presented augmented reality with input devices to interact with the information presented and thereby allow the augmented interaction on the bridge of a ship.

3. METHODS

3.1 Information data

The data that is needed for the steering officer to control the ship is gathered by multiple systems. On one hand the data has be provided by the ships instruments, as the alignment of the ship, which is especially important for the head up display to be able to project information correctly. For all other purposes the ship gathers information by using the Automatic Identification System (AIS).

3.1.1 Automatic Identification System (AIS)

The AIS system is designed for collision prevention between ships and is used for vessel traffic services to control the shipping navigation on a big scale. Every ship is legally forced to have an AIS on board, with the only exception of military ships, which often have the system with the op-

Figure 1: The name of the ship, speed over ground, heading and destination are projected above for easy readability.

Figure 2: After using the input device to click onto the information, the IMO number, MMSI number, rotational rate and exact ship position are added.

tion of turning of the transmitter. Using this system the ship is able to receive data of other vessels on the sea. The data received can contain static information of the individual ship, like name, ship type or identification number. Also changing data, like gps position, rotational rate, speed over ground and destination.

3.1.2 Ownship Information

The own instruments provide further information to the ships. On top of the information, that is transmitted using the AIS, we can use the information of the heading, speed through water, echo sounder, radar and wind direction and speed.

3.1.3 ARPA

The ship's automatic radar plotting aid (ARPA) also provides additional information, which are commonly used for collision avoidance through the calculation of the closest point of approach (CPA) for other ships and landmass. The system provides information about the course and speed of surrounding objects. Also the effect of own manoeuvers can be predicted by the system and therefore can support the successful avoidance of a collision [4].

3.2 Interface

For the decision, whether or not to use the data available on the head up display, we used the survey of Jayong et al [17], which conducted a questionnaire over what information was needed and how it should be represented effectively.

3.2.1 AIS Interface

Of the AIS data we project the ship name with the addition of the country on top of the representation. In addition we display the speed over ground in knots and the ship heading in degree. On the bottom we aim to display the destination. This information are exchanged by the information in harbour or not manoeuvrable. We want to use these settings as a standard set up for our system to keep the information limited. It is also possible for the captain to select the projection of additional information by interacting with the projecting object and selecting it. This way it is possible to get more detailed information in form of the IMO number, the MMSI number, rotational rate and exact ship position. As an option these displayed information can also be configurable for personal preferences. The data is placed above the object, as can be seen in figure 1. Of small yachts or sailing boats which just shortly cross the field of view only the name gets displayed, when not in harbour, to not fill the interface.

3.2.2 Navigation Interface

For the navigation the route is projected directly in front of the vessel. It shows the pathway for the course in sight. In different articles it was discussed, whether or not to project a top down view of the boat into the interface. These range from the near surroundings of the bot to the map that is projected by the electronic chart display and information system (ECDIS). We also experimented with using or not using this option in figure 3. We thought about positioning the data on the top left or top right, since the position is the most times inside the sky, and does not overlap any other information. The third option was to project the map onto the part of the screen, from where only the own ship was

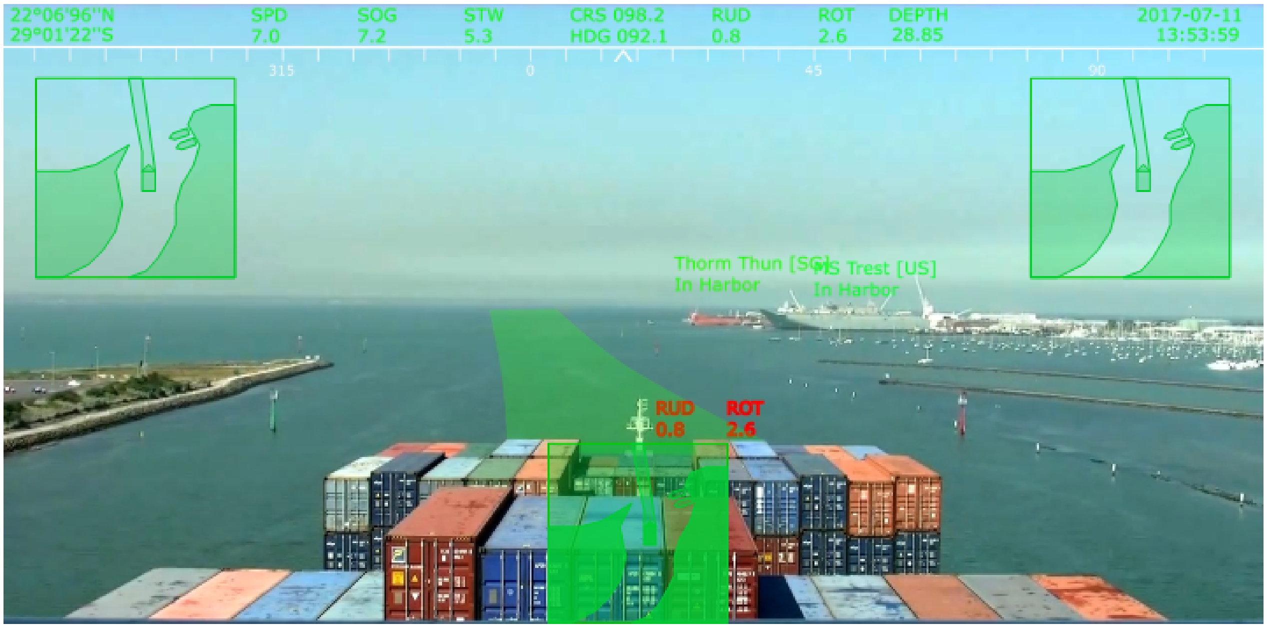

Figure 3: The data of the ecdis display is added to the display on the top left corner or the top right corner. In addition to these options we also tried to project the information over the visible part of the ship. The RUD and ROT settings were recently changed and are displayed in the center until they fade away when the steering process is done.

visible, and thereby also not overlapping any navigational information. Instead of the ECDIS or in addition on another position, i.e. top left and top right we suggest the ARPA system, which is presented by a 4:3 raster scan in modern systems.

3.2.3 *Own ship interface*

We project the data of the own ship on top of the screen, as can be seen in figure 4. There are no units displayed in this top screen, because this way it is easier to focus on the projected number and the fixed data together with the description makes it clear for people that have experienced the necessary training to be allowed to steer a ship, which values are presented. We used to order the information from left to right, as follows.

On the top left we project the global position of the ship. This information are far from the centre of attention due to their slow change. These kind of information are not controlled in short intervals, but whenever the attention can be spared.

To the right, we project the wind speed and direction relative to the vessel, for the captain to be able to react properly to critical conditions. These information are followed by the values of speed over ground (SOG) and speed through water (STW). Those are the different values to describe the ship's speed. The speed over ground value is used to be able to predict the time used to get from one point to another, since it displays the speed a ship is moving on a global scale and can be measured using the gps system. The speed through water measurement is meanwhile needed for collision avoidance. The speed over water is needed to determine the correct viewing position of another ship and then correctly apply the collision avoidance rules [2].

Next data presented are the course and heading. Those values can often be the same when navigating on the seas. The course is the angle of the planned route to the compass north. These values gets influenced on every turn of the ship. The heading is described by the angle, where the ship's nose is pointing [8]. This explains, why under neutral conditions the course and heading are the same. They differ for example under strong wind conditions or in a drift. These conditions need to be compensated by crossing and therefore heading the boat in a different direction as the course would suggest.

The rudder indicator informs about the angle of the rudder from the straightforward position. The rate of turn (ROT) indicates the rate the ship is turning in degrees per minute in relation to its starboard. The Depth is also represented for the steering officer to deny grounding, when getting into too low water. On the top right we display the date and time, which are also information that do not need a big amount of attention.

3.2.4 *Dynamic Information*

On top of the static interface of the own ship information, we want to flash the information changed in an instant on screen. When speeding up or steering, the captain does not have to look up to the own ship bar, but can directly view the information in his centre of attention, where the data is overlaid projected in figure 3. For this screen the data protected are the wind speed, SOG, STW, CRS, HDG, RUD, ROT. The GPS position, date and time and depth are not displayed through this, since their constantly changing values. For the rest of the data, the information is projected in the centre, as long as changes are applied i.e speeding up or turning the boat, or external changes happen, i.e. wind

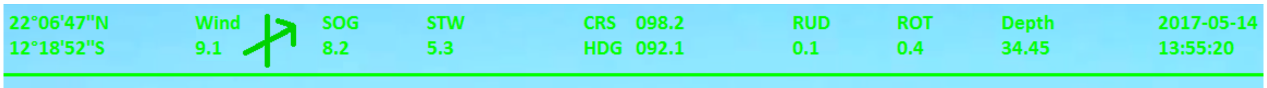

Figure 4: The data presented on top of the augmented screen. All data belongs to information obtained by the ships instruments.

is getting stronger. Until the changes are done, the data is represented for an additional 10 seconds to check the information in the centre of attention. On top of flashing data like this critical objects, that could cause collisions are highlighted through them blinking, until the situation is resolved.

3.3 Controls

For the interaction with the interface we suggest the usage of either a touch panel with tactile feedback to feel the interface without looking down or gesture recognition to directly interact with the projection screen.

3.3.1 Tactile touch

An option to control the presented interface could be tactile touch panel. It needs to have a similar shape of the screen, of the head up display which is mirrored by this panel. For an easy ability to reach over the display with one hand we suggest the size of smaller tablet devices, from 7 to 8 inches. For the feedback we need a 3 dimensional representation of the projected data, which can be achieved with lateral friction forces [18]. In figure 5 it is shown which parts of the display would need to be touchable by the user. To reduce the possibility of marking wrong objects we suggest the need for a double click. On the first click on an object it is highlighted on the screen. If the object on the screen matches the object the steering officer desired to click on it can be confirmed by a second click, which results in the projection of additional data, for the AIS information or starts the navigation reroute process which is explained in the next chapter 3.4.

3.3.2 Gesture recognition

Another option for the input we want to suggest is gesture recognition. For this we could either utilize a camera based system or a wristband for the recognition [31][28]. For the system to be easily understandable the gestures used should be reduced to a minimal amount. Therefore we only want to use a pointing gesture for the user to hover over the interactive items. When the preferred item is hovered over the additional information can be showed by an outwards pinching gesture, similar to maximising a screen on a touch interface. By a repeated pinching gesture, the additional information can be closed. The route selection menu can also be dragged, by grabbing the projected route and pulling it to the left or right.

3.4 Navigation

For navigational purposes the course will be selected in the beginning of the cruise using a map, similar to application of google maps or usual navigation systems. The system provides the option to change the course life by adjusting the route in sight. By this option, especially i.e. cruise ships have the ability to decide to change the course to stay near landscapes worth seeing, depending on weather and conditions of visibility. The course is adjusted, by dragging the projected route to the preferred position. During the process the navigation system recalculates the course and gives a feedback, whether or not this route is possible. After finishing the process the steering officer can lock the route to the new course. The ship then adjusts the rudder settings to get onto the newly adjusted course.

3.5 Technical requirements

3.5.1 Display

We need to cover the windshield of the bridge with the information, for them to be perceived on the correct position. For this to achieve we need to project two separate images for each eye as can be seen in figure 6. Therefore we need two optical systems, which project the information from the micro displays onto the wind shield [27]. The advantage of this technique would be that all instruments are inside the bridge and there is no need for them to have parts outside where there are exposed to the weather conditions.
One of the disadvantages of these kind of systems are the low brightness. On the maritime context the display needs to be able to work under various conditions. Ranging from night scenarios where it should not blind the steering officer for things that happen outside the window to bright daylight, where the display still needs to be visible and give reliable information. For a higher brightness we could use the system proposed by Sato et al. (2006) which uses a projector to directly converge the light at the user's eye position and which has showed to achieve a high luminance on the display [33], shown in figure 7. We also chose the green colour of the display because of their results in comparing the projection of different colours. A drawback to this system could be the exposure of some elements to the weather due to them being placed outside the window. This problem can be fixed by planting a second glass in front of the actual window and projecting the information there.

3.5.2 Touch panel

The optical objects that are mapped to the input panel are for the most simply shaped, as they only need to stand out from the flat display and do not need to have for example cubic or complex shapes. For the ability to feel the objects we suggest system using the electrovibration principle [3].It uses an electrode sheet with an insulator layer on a glass plate. It uses electrically induced force to create friction when moving over with the finger. These feeling of friction can be controlled by changing the amplitude and frequency of the signal. This friction can be used to find the objects when not looking down and selecting the data or pulling over the navigational route.

3.5.3 Data collection

On top of the usual array of sensors the ships and its instruments provide combined with the AIS system we need the option to detect objects in the field of view. For this we

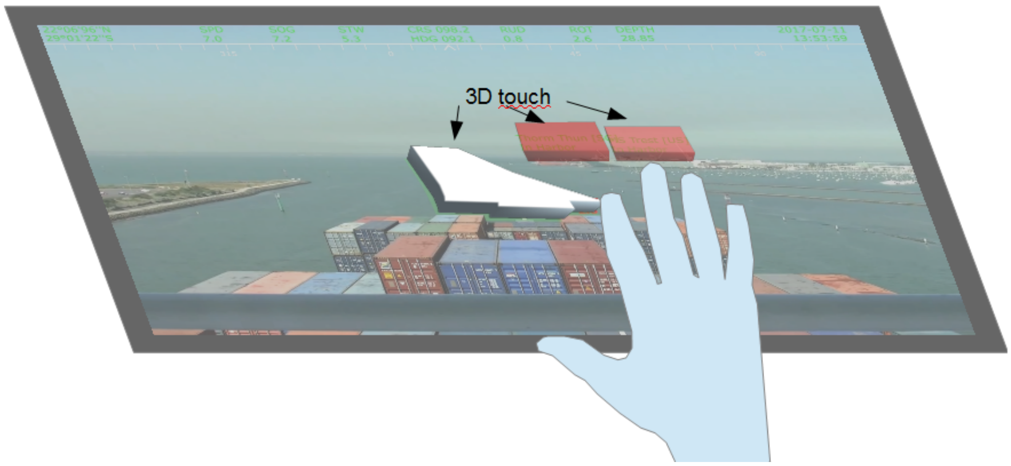

Figure 5: The data on the panel can be felt without looking down from the screen. Every interactive object has its representation. The white navigation plane can be moved, by dragging i to the left or right and the in this example red marked information boxes can be clicked. Depending on the panel used the screen can be mirrored from the camera image from outside or not having a screen if a simple touch panel without interface is used.

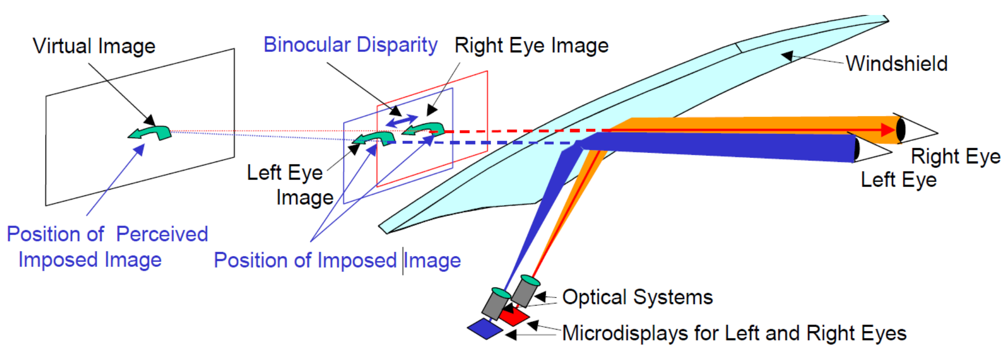

Figure 6: An image for every eye is projected into the field of view of the user, to perceive the image as far away inside the outside reality (Nakamura et al. 2004). Even if the system does not always provide the items range to the full accuracy, this effect can be overlooked, since especially on high sea objects that are seen are not physically close to each other.

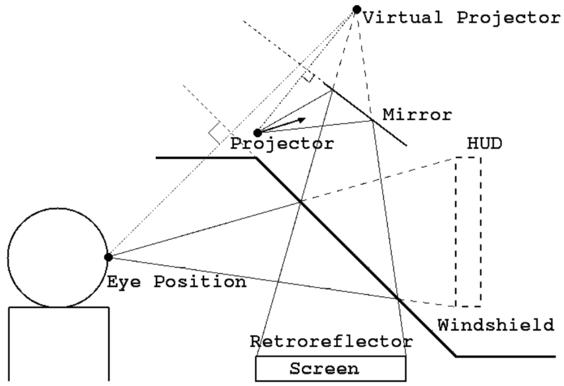

Figure 7: For this system an outside mirror and projector are used to directly project the light to the users eye position (Sato et al. 2006), thus creating brighter images. These images are easier to see in bright daylight than conventional head up displays.

want to use those existing data stream and combine it with a camera system for object detection. The object detection can be able to classify different objects [6] and then match it to the closest fitting object of the sensor system. This way it should be possible to project the ship information or similar above the actual object without overlapping information. Also through the radar detected objects under the water should be displayed, if they are close enough to the surface to pose a threat for the ship. This way we could also limit the capacity needed for the classification process if we aim only for the regions, in which we expect something to be through the data. This approach would be similarly to the detection algorithm of the infinite horizon [16].

4. PROTOTYPE

For our constructed interface we first tried to apply it to an image of a bridge view to fit all objects we want to use. Afterwards we decided to use a video prototype. We used a video of a ship leaving the port of Melbourne [36] for this. We used this video because of the constant front view and the ability to show different aspects of our system in a relatively short time to the potential user. We adapted our interface to this video, by watching the video and adding plausible data, which is displayed. We created a video with and without the dynamic aspects of our interface, as for example in figure 3 the red marked data was only projected in one video. The prototype we use does not provide the option for inputs and therefore can only be used for the interface testing and not the interaction.

Using the video we conducted a field study to evaluate the user's situation awareness [5]. This was done by asking the participant questions after the video, since the time of the video is short and we decided not to ask online questions or freeze frame questions. Beforehand the user was told to just observe the situation and stay on watch and a short explanation of the scenario. After each video was watched the user was asked about which tasks were carried out and how they influenced the ship during its harbour exit. We asked eight questions. Four about information of the ship data and four about the ais data which was projected. We asked if there were critical moments, where actions needed to be taken. On top of these the user was asked about his satisfaction of the function and satisfaction of the augmented reality system [17]. On a likert scale from one two five, very satisfied to very dissatisfied, the participant had to evaluate the satisfaction with the ownship, traffic ship and route plan as well as the clarity, efficiency, legibility and effectiveness of the system and commentaries to the system.

We needed to test between subjects because of the learning effect of the scenario projected. Due to the short amount of time, which was needed to watch the video and fill out the questionnaire twice, we used a crossover design, to get additional data.

5. RESULTS

We conducted an initial study to evaluate our set-up and get an initial guess of the performance of the proposed system. Our study group consisted of two people with experience in navigating a ship. The participants had experience using systems without any augmented technology. The participants remarked, that in the scenario observed there was no reason to interact as the officer on the watch, because no critical situations are displayed. For the satisfaction with the interface the they valued the ownship information with a score of 4.0, the traffic ship info with 3.5, and the route plan with 3.5. They rated the clarity 4.5, efficiency 4.0, legibility 3.5 and effectiveness with 1.5. In our evaluation of the situation awareness for the system with dynamic information the answers were correct in 6 out of 8 times in difference to the setup without dynamic data which were answered correctly in 5 out of 8 times. For their own usage of the system they remarked the will to use it given an error free functionality. They also commented, that the information about small ships and sailing boats was not really useful, by just showing the name, and the information should be extended or removed.

6. DISCUSSION

The biggest problem of the participants showed to be the inability to interact with the system, and that there was no necessity to do so, which led to a bad rating of the systems effectiveness. They provided feedback about the interface of the system and supported our aim to a clear and efficient interface, which brings together all information sources the ship and navigation aids can provide. The likeness of the interface was similar to the results of Jeayong et al. [17], which was positive. In our case this also might be due to the fact, that the participants are used to navigate smaller high sea boats with simple equipment and were positively surprised by the idea of having one system only to work with and in the same time beeing able to observe the outside. The results of the situation awareness test have shown to be supported by the dynamic display in this test group but the amount of data is not enough as a proof for significance [15]. The effectiveness of the system was doubted by the participants, even if they liked the purposed system, but just believed it would not work optimally under real conditions. The criticism about the legibility can also be explained by the video which was used, in which the data was sometimes too hard to read due to low brightness and small letters. These are changes, that can be applied easily for future tests.

7. CONCLUSION AND FURTHER WORK

We created a system to combine all information sources on a ship into one augmented reality interface, which is projected on to the bridge window. We created an augmented interaction method, by giving the user the possibility to directly interact with the augmented reality and their changes their being applied to the ships controls. We conducted a small field study to evaluate our system proposal, which results were positive but many suggestions on how to change the system for a better functionality were given.

For the system to work we need a high amount computing capacity due to the data fusion between the camera system, the ship's instruments and navigation data. It needs to be evaluated if the whole system is possible given the various conditions on sea to work smoothly. The system has to deal with connection losses to the different systems and bad sight conditions for the camera. For this the system must be robust without the possibility of failure. For further and more informative studies a virtual reality setup using a training simulator should be conducted. In these setups the information projected are more accurate to the video usage and different interaction methods can also be tested. In these specialised scenarios it would also be possible to observe critical scenarios in which actions by the participant are required to prevent collisions or grounding.

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Novel Interaction Techniques for Oceangoings: Technologies used for Navigation

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ABSTRACT

Global navigation satellite systems support the process of performing navigational tasks today, so an accurate position determination is mainly possible. Assistance devices like Electronic Navigational Charts and the Automatic Identification System are used besides radar and GPS to provide ship navigation related information. Often the visual representation of the data is fixed, meaning it does not depend on the vessel's course and speed how things are displayed. This increases the sailor's cognitive workload and may lead to wrong decisions in emergency cases due to additional stress.

In this paper we present the concept and prototypic sketch of a new maritime navigation tool. It combines widely used assistance devices with the aim to reduce the seafarer's cognitive workload and to improve maritime safety and situational awareness, independent of the type of the ship. Therefore the system is able to execute ordinary navigational tasks, detect dangerous situations based on the boat's environment and to inform the user visually and acoustically about such. We propose a touch-based approach using a tablet, a smartwatch and a monitor to simplify interaction and information provision. To handle the system while driving without explicitly focusing on the mobile device, enlarged touch areas are used.

Keywords

Oceangoings, mobile devices, navigation system, touch-based interaction, emergency detection

1. INTRODUCTION

Throughout history inventions like magnetic compass, sextant and more recently radar and GPS helped to solve the problem of an accurate current position determination [4]. Especially in the navigational context a small position error is important when travelling from A to B [4]. For a long time, inertial navigation systems (INS) have been used to calculate the position, speed and orientation of a vehicle in a 3D space [4]. To obtain the coordinates double integration was performed on accelerometer and gyroscope data, resulting in small errors accumulating over time and hence an increasing position error [4]. Later, the Global Positioning System (GPS), that covers any part of the world, was used [4]. To identify a vehicle's position the distance from ground to at least four GPS satellites is measured [4]. Today, global navigation satellite systems (GNSS) are usually applied in the process of performing navigational tasks [2]. One drawback of the increased use in daily life is that the satellite signals become more prone to jamming, so other positioning systems and methods, which are equivalent to the existing ones, have to be searched for [2].

In general there are two kinds of information in marine navigation, some are related to sea or landmarks, others to assistance devices [14]. Seamarks are visible from the user's view and indicate either some danger or the way to follow [14]. Assistance devices like GPS, radar, the Automatic Identification System (AIS) or Electronic Navigational Charts (ENC) provide additional navigation related information, normally with the course of the boat on top of the display [14]. This poses a problem, since charts are often printed with the North on top [14]. Hence when changing the boat's course and speed the sailor has to keep in mind that the orientations are different [14]. Especially in emergency cases the probability of making wrong decisions increases due to the additional stress [14]. So despite the effort of developing new navigational equipment for safe navigation, the amount of maritime accidents because of human errors has not reduced to the degree expected [16]. Reasons for that are the provision of excessive and unnecessary information, as well as unintuitive methods of supplying data [16].

This paper presents the concept of a new navigation technology that could be used for any type of oceangoing, from pleasure crafts to cargo ships. The goal is to create a prototypic sketch that illustrates the design and use of the proposed system. The latter should be intuitive to work with and combine widely used assistance devices in a single one. This means the system does not only deal with common navigational tasks, but also with the detection of dangerous situations related to them. To get some insight into the latest research, section 2 shows existing approaches and methods to improve maritime navigation. Section 3 talks about basic requirements of an innovative maritime navigation tool, while section 4 presents the design and use of the developed prototype. Section 5 discusses the pros and cons of this system. Finally, conclusions are drawn in section 6, along with a short prospect of what could be done in further research.

2. RELATED WORK

As previously stated the number of maritime accidents caused by human errors could not be reduced to the degree expected by developing navigation systems with advanced information technology (IT) [16]. The complexity of the equipment along with excessive information provision interfered with a safe vessel operation [16]. Therefore current research mainly focuses on the improvement of maritime situational awareness by investigating two aspects: anomaly detection using machine learning approaches, and effective information provision by means of augmented (AR) or virtual reality (VR) [16].

Maritime situational awareness could be described as the aim to create a maximum awareness of activities in the maritime environment using data sources relevant to maritime security, like the AIS [1]. As information about ship type, size and movement becomes more and more available, automatic processing should be applied to support human operators filtering out the information of interest [17]. To handle the big amount of data, recent experiments use machine learning techniques like Neural Networks [17], genetic algorithms [1], or unsupervised and supervised learning methods [18]. Despite the different approaches, anomaly detection is driven by expert knowledge and data in most cases. The objective is to teach those self-learning systems what usual events are, such that they are able to adapt continuously without the need of frequent expert input later on [18]. However, this definition differs between contexts, like vessel type, tidal status or current weather conditions [18]. Thus expert knowledge is important to define rules and characteristics of normal and anomalous behaviour [1, 18]. Fusing ship and voyage data available from radar and AIS along with expert-based rules facilitates the development of sustainable self-learning anomaly detection systems, like shown in [1], [17] and [18].

So far most ship and route related information is displayed on multiple screens and devices [3]. As a result the operator has to turn his attention to a specific device and away from the view outside the bridge [3]. In order to provide the amount of data in a more effective way, for instance directly in the person's field of view, AR and VR implementations similar to airplane and military applications were developed and tested recently [3, 13, 14, 16]. Jaeyong et al. [16] use a head-mounted display that shows the view outside the bridge, but with an overlay of maritime services, like GPS, heading, speed through water, wind and others. To determine which of the available services are necessary for navigation and how they should be represented they did a survey with 20 experienced ship officers. After evaluating the prototype Jaeyong et al. concluded that most participants gave positive feedback about the system, but some of them had problems in distinguishing the still big amount of data displayed. Therefore those persons had concerns related to the workload from the new technology. Hugues et al. [13] present the integration of a vision system with thermal and classical cameras into maritime navigation software. Here the user can switch between a virtual representation of the navigation route and an augmented view of the current environment. The navigation tool combines the data from embedded hardware, like radar or GPS, with nautical charts. It displays details about the route, as well as additional information from the AIS or other assistance devices. Furthermore they propose a video monitor system, where the virtual world is augmented by the video flow from the cameras. This means that for instance sea and landmarks and other route related pointers could be projected onto the view of the real world. However, the use of cameras has some drawbacks especially in case of bad weather conditions. Also the problem of aligning virtual and real world properly is not trivial. Morgère et al. [14] implemented a system on chip (SoC) that is connected to see-through glasses. The SoC acquires necessary data from the boat network and combines them with meaningful information computed and extracted from a chart generator, according to the current coordinates. Depending on the user's head orientation the glasses then display specific route related pointers. De Vlaming et al. [3] conclude that the use of AR could help to improve safety and situational awareness. The main argument is that the operator would not have to look at multiple screens, but instead could concentrate on the events outside while having all the important information in front of him. Furthermore such systems could show on-screen alarms and warnings in dangerous situations. In the end de Vlaming et al. also state the main drawback of AR systems in the maritime context: they are only reliable if the AR view aligns with the real view outside. If this is not the case, for instance because of incorrect input data, then AR cannot provide much improvement to the current navigation process.

3. REQUIREMENTS

The previous section shows there are lots of ideas and approaches how maritime navigation could be improved. However, a common problem to all of those methods is that there is no defined and agreed upon standard yet. So it is important to first find out what would be requirements of an innovative navigation tool before thinking about a meaningful design of it.

3.1 Technical Difficulties

When implementing visual computing technology in the maritime domain there are some aspects to be kept in mind. First of all there are different requirements for each vessel type, depending on characteristics like speed, size, draught or operational area [14]. Second, the environment in which ships and corresponding applications operate is typically harsh (water, pressure, splash water, extreme temperatures and heavy movements) [19]. This may cause further problems, for instance when developing camera-based approaches. Apart from aligning the camera's field of view to the real world scene, disturbances like direct or reflected sunlight on the lens, as well as bad weather conditions like fog and rain, require quite some image processing effort in order to reduce noise, circles and other glitches in the picture [14]. Furthermore cameras need to have a high resolution to be able to also acquire small elements in far distances, causing additional computation effort later on [14]. Third, the connectivity to navigation satellite systems or wireless data networks is sometimes limited or unavailable on the open sea [19]. Not directly related to the maritime context, but a rather general requirement is the correct data generation and provision. Otherwise it may be difficult to create reliable services.

3.2 User Interface

According to the International Maritime Organisation ship handling consists of three tasks: track-keeping, manoeuvring and collision avoidance [5]. Thus the seafarer has to process environmental data and data presented on the vessel bridge [3, 5]. However, keeping track of all the information and furthermore interact with numerous assistance devices is not easy, especially in situations where bad weather or stress may quickly cause decision errors [15, 14]. Though groundings or accidents can also happen because of ignoring or forgetting navigational rules [14]. So in order to lower the chance of getting into dangerous situations one of the main aspects of an innovative maritime navigation tool is the reduction of cognitive workloads [15, 14]. This could be achieved by providing navigational information in the user's field of view and displaying the data from assistance devices on charts dependent on the ship's course or heading [14]. Additionally the application should be configurable, meaning the user is able to select the information to be shown or hidden [14].

By default the amount of displayed data should be reasonable. The seafarer cannot process too much information in very short time, whereas with too less he might not be able to adequately survey the current situation. Concerning the way of presenting data it is evident that every used symbol or illustration should be easy to understand, related to the real world, and be distinguishable from others. The same applies to the colouration of such items. Moreover, elements like buoys, beacons and other sea and landmarks should be compliant with the standard representation of the International Association of Lighthouse Authorities (IALA) [15].

As described by Morgère et al. [14] the data can be organised in three categories. The first category contains state data like speed, course, position and time. Alert data from AIS, radar or sonar form the second category. Here, flashing elements could be applied to indicate a hazardous situation. However, it is important that alarms are raised carefully. A small rapid passenger vessel in the vicinity of a cargo ship does probably not lead to a collision, whereas exactly the opposite might be the case when two cargo ships cross routes. The third and last category covers the data important for the navigation task.

3.3 Hardware

Regardless of boating on a small river or on a big sea, the surrounding area influences the usability of the application. First, the system must provide information under various light and weather conditions, from a shining sea to a dark night or a heavy rainstorm [14]. Second, the system has to stay usable even when getting wet due to rain or sparkling water. This also holds for the ship's on-board sensor technology and cabling. The sensor data are then used by software to execute the navigation related computations. By this, graphical objects can be positioned and removed on the electronic chart based on the boat's current position and heading [15]. Furthermore the data from radar and AIS also have to be processed in order to detect potential dangerous situations [15]. Since all this requires quite some computational effort, powerful computational units should carry out the calculation and emergency detection tasks. This includes that the navigation also works properly in case of no satellite connection, meaning it uses the data from on-board sensors like speed and compass to maintain this process, similar to car navigation systems. Ideally, redundant components are used to increase the reliability of the system and to lower the impact of hardware errors.

4. PROTOTYPE

Reading through literature and talking with sailors showed that ship handling in general requires a lot of knowledge, experience and training. In addition to that the number of displays and buttons increases with the size of the vessel. So the idea was to create a system that combines as many assistance and information devices as possible and to display their data in a single and centralised place. In this way it might be possible to create a standard technology that could be implemented on any kind of ship such that every bridge looks and works similar. To run the route calculating and emergency detecting tasks, on-board computational units would be preferable, since they can directly receive and handle the sensor data. After being processed a single screen in the user's field of view will provide the information. This rather classical approach of data visualisation was chosen for various reasons. First, it has been applied in practice for many years, so the user does not need to get used to an unknown or new technology, unlike with AR or VR (at least at the moment). Second, today's displays mainly are adaptive to different kinds of daylight, so information is always visible, even in extreme sunlight. Third, showing data on a screen means that it can also be shown somewhere else. Hence distributing multiple screens on the ship allows for having a look at the current situation outside the bridge too.

4.1 Touch-based Interaction

To control the system an off-the-shelf mobile device is applied. Smartphones could be used, but tablets would be preferred in general as they usually have larger screens and thus a bigger interaction surface. These devices offer various advantages. First, they provide by default numerous modalities that can be used to enhance interaction possibilities, like for instance buttons, haptic and audio feedback [7]. Second, they can store data [7]. This allows planning the route already in advance, saving it on the device and sharing it with the boat's on-board computer later. Third, smartphones and tablets are daily companions and literally used for everything. So most people know how to work with them and therefore do not have to learn something new.

The idea is to enable all ship navigation related tasks on a single device, from entering the route through to selecting a specific map section during the voyage. However, these actions have to be distinguished in terms of focus and interaction. For instance when entering the route, the user has to explicitly look at the smartphone or tablet screen, whereas switching between radar and map view should be possible without a closer look. So ideally selecting a view could be done without looking at the device. For this reason it should be placed in the user's area of control. Figure 1 shows an example scenario where the tablet is on the right-hand side of the steering wheel and the information display in the lower part of the sailor's field of view, similar to the automotive context.

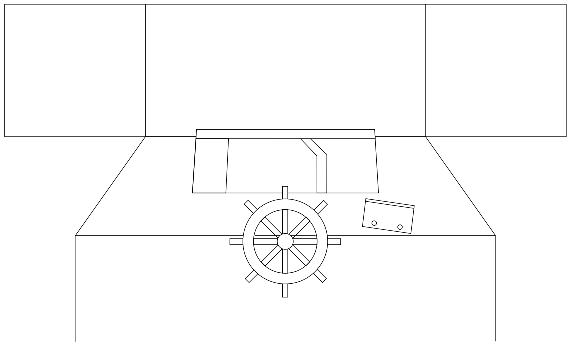

Figure 1: Example scenario of a ship bridge. The tablet is on the right-hand side of the steering wheel, placed in the user's interaction area and rotated towards him. The information display is behind the wheel and at the bottom of his field of view, which is known from car dashboards.

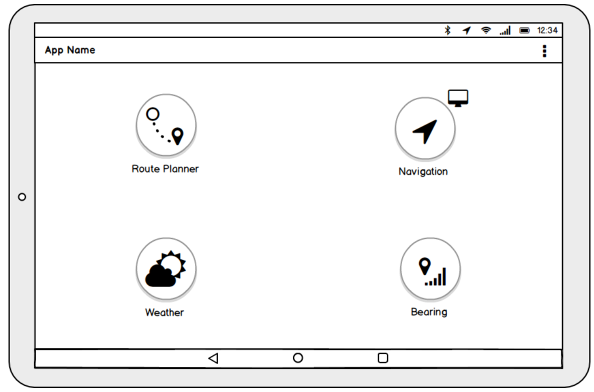

Figure 2: Core functions of the application: route planner, navigation view, weather forecast and location accuracy visualisation. By opening the 3-dots menu in the upper right corner the application can be configured, closed or synchronised with the onboard IT. A small monitor icon indicates that this specific function requires an extra screen.

4.2 Application

The user should concentrate on the ship handling tasks instead of being distracted by the smartphone or tablet itself, meaning that it should not be allowed to use the device for other things while driving. Thus for the UI design an approach similar to the first version of Google's Car Home is chosen, where only those functions are available that are useful for maritime navigation. As a result, the application's main screen consists of four elements: route planner, navigation view, weather forecast and bearing, like shown in figure 2. An additional small monitor icon on the upper right side symbolises that an external screen is required to display the function related information. Via the 3-dots menu in the action bar the application can be configured, synchronised with the ship's on-board IT and closed.

4.2.1 Settings

The user should be able to adapt the application according to his needs. This includes common settings like language and units (for instance temperature, pressure and distance), as well as more specific ones like alert signals and elements to be displayed or hidden in navigation view. It is possible to do the configuration in advance, but also while driving. If the device is connected to the on-board IT, the latter is favourable for configuring navigation related settings, as changes are immediately visible on the external screen.

4.2.2 Weather Forecast, Position Accuracy

The weather forecast contains common data like temperature, humidity, sunset/sunrise, moonrise/moonset, rain, wind force and direction. If no navigation has been started, the forecast only refers to the user's current location. Otherwise it is related to the recent and estimated location, depending on the ship's speed. In this case also data about the swell is shown. Four time intervals can be selected: 1, 3, 6 and 12 hours. More than 12 hours might be too inaccurate.

Applying the bearing screen a virtual representation of the momentary location accuracy is shown.

4.2.3 Route Planner

Entering a route works almost the same like with any other common route planner. The only difference is that before selecting a start and end point, the user has to provide a few details about his ship. Environmental conditions like weather and sea state, but also boat characteristics have an impact on the route. A big cargo ship cannot pass a small river, as well as a sailing boat might get into trouble on the sea because of high waves and heavy wind. For this reason the first step is to enter ship type, draught, maximum speed and average fuel consumption. Afterwards start, end and waypoints can be selected and the route will be calculated, considering the ship data. When the calculation process is done, the user can decide between multiple routes: fastest, economic, or the one the most preferred by the seafarer community. However, the latter presumes that such a route is available and that there are active communities, which share their experiences. Otherwise only two routes will be shown. For each course distance, travel time and estimated fuel consumption are indicated. After the user has selected the route an overview will be displayed, as shown in figure 3. Here it is possible to edit the route again, save it on the device such that it can be reused later on, or start with the navigation directly if the device is connected with the vessel's system. By default the sidebar on the left presents the three main parts of the journey, which are most of the time leaving the port, being on the sea and entering the port. To get more information about a specific part the user just needs to click on it.

4.2.4 Navigation View

So far the mobile device has been actively used to configure the application, check the weather or enter the route. In this mode it plays a more passive role, as its only purpose is to switch between different views and handle the navigation map. The main idea is to simplify the interaction with the system while driving as much as possible. For this the number of elements to be available on each application menu was limited to five, such that the interaction area can be divided into more or less equal parts, like exemplarily shown by the red dashed rectangles in figure 4. As a result there are larger

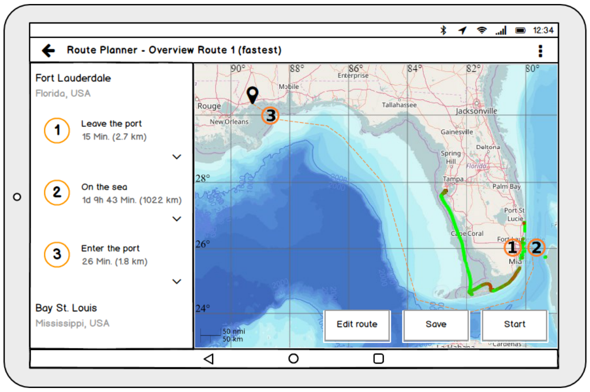

Figure 3: Route overview after selecting one of the suggested routes. On this screen the user has the options to edit the route once again, save it on the device or start the navigation. The sidebar on the left provides further route information on click, similar to Google Maps.

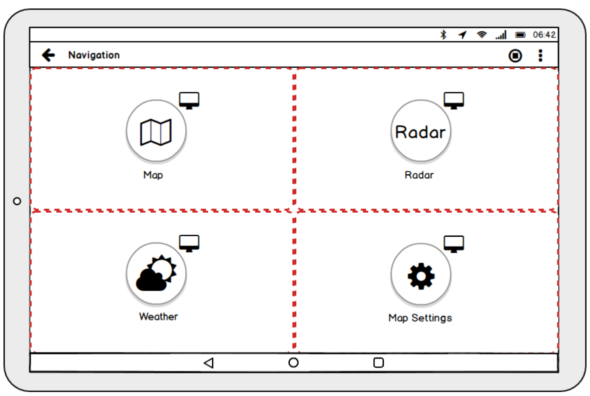

Figure 4: Navigation main screen with hinted touch areas. Four functions are available: a map view to display current navigation related information, ship radar to check the traffic in the ship's environment, weather forecast along with a live radar view, and settings to adapt the data visualisation according to the user's needs. All these functions require the connection to an external screen, indicated by the small monitor icon on the upper right side of each function. The interaction area is split into four equal parts. Due to the enlarged target size it is more likely that the user can trigger a specific function even when not actively looking at the screen.

target sizes for each element than in common applications. In theory the user then just needs to know roughly on which side or corner of the screen a desired function is and will not have to take a closer look at the screen to be able to trigger it.

Like on the application's main screen there are four functions: map view, ship radar, weather forecast and settings, as depicted in figure 4. Again, the small monitor icon indicates this part requires an external screen, since all information will now be shown on that one and no longer on the mobile device.

1) Settings. This is almost the only situation in navigation view where the user explicitly has to look at the mobile device. Basically the settings here are the same as in 4.2.1, but since the focus is on the visual and acoustic information provision, they are rearranged. By this the user may for instance enable or disable data elements on the screen and observe the changes immediately.

2) Weather forecast. To get a quick overview of the upcoming weather situation, the function known from 4.2.2 is also available here. The forecast is related to the estimated location and depends on the chosen time interval. In addition to that there is a live radar view to present the latest weather data.

3) Ship radar. Another important tool is the ship radar. In recent years the number of ships that use the AIS has grown. However there are still many of them that either do not have it or where it is available, but not activated. Ships in a certain vicinity of the own position are shown in the navigation map. If the user wants to have more information about what else is around him, the live radar view can be applied.

4) Map view. Apart from the route planner this is the main feature of the application. Here the user can switch between two different views and manipulate the map using the mobile device. As this should be again possible without explicitly looking at it, the touchscreen is split into three sections, a larger and two smaller ones. The latter have the same size and are placed at the bottom part of the screen, whereas the bigger section covers the rest of the available screen space. Common map manipulations as panning, zooming in and out can be applied in this area by swipe and pinch gestures. Normally these are performed directly on the map. Yet in this case there is a difference concerning the pinch gesture, since the map handling happens on one device and perceiving the changes on another one. Hence the user does not know which part of the map will be actually changed when pinching. In order to avoid that a cursor will be shown on the external monitor by the time the user touches the screen with a finger. The cursor can be positioned by moving the finger on the touchscreen. Afterwards the pinch gesture can be applied as usual. For swiping this intermediate step is not necessary. The other two sections at the bottom part are used to switch between the map's views and to restore its original zoom level and position.

By default an aerial view like in car navigation is displayed. The screen is sectioned into three parts, as shown in figure 5. The top part covers general data: current speed and distance to the ground, fuel consumption and tank capacity, compass, distance left to go and estimated time of arrival, bearing accuracy and time of day. The left-hand side of the screen indicates weather data for the upcoming three hours, as well as the current and next ship steering actions

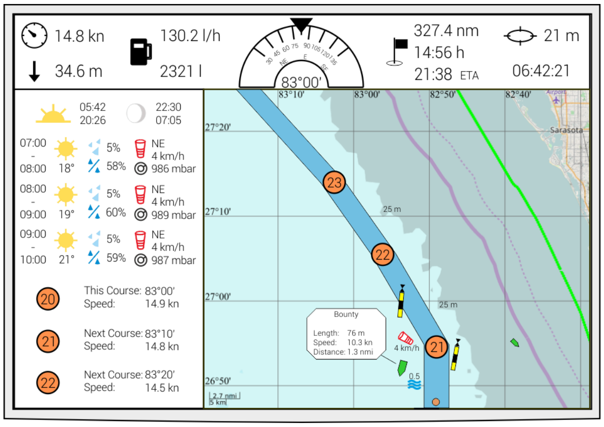

Figure 5: Default navigation view. The top and left-hand part of the screen are used to provide ship, weather and steering hints, while the rest shows the nautical chart and navigational information. The number of displayed elements in the chart depends on the user's settings.

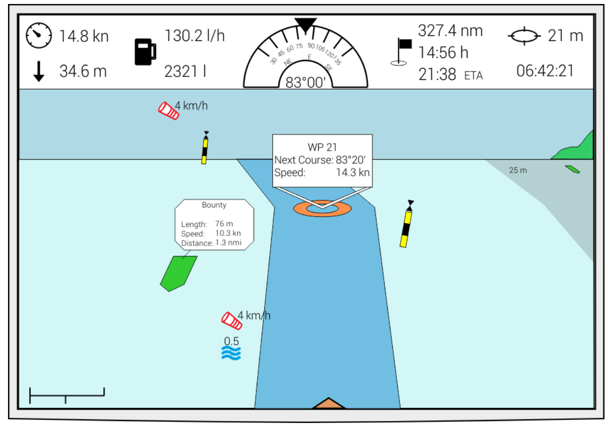

Figure 6: First person view. The area in front of the ship is simulated to enable safe ship handling, especially in tough weather situations. Steering instructions are now indicated right on the route, thus the sidebar on the left could be omitted. As a result only information important for the current situation is displayed.

to be made (adjusting speed and course). The remaining part displays the nautical chart and navigation related information. These are the following: latest ship position and colour-coded route, seamarks along the route, ships in the vicinity (including AIS data like name, length, speed, distance and course if available), coordinates, wind force and direction, swell, sea profile and depth contours. Depending on the user's settings, more or less data will be shown in the chart. To reduce the cognitive workload the visualisation of route and chart always refers to the current course. Radar and AIS are used to indicate ships that are in one's environment. However, only those that are relatively close to the own ship are displayed. This might avoid an overfilled screen. For the nautical chart, OpenSeaMap[1] is used. Apart from offering many possibilities to configure the map, it also can be used ashore. This may be convenient especially in case of planning a trip with waypoints or when looking for specific points of interest.

The other one is a kind of first person view that simulates what can be seen when looking straight outside the window of the bridge. The main purpose of this view is to provide a virtual representation of the area in front of the ship in case of poor sight, for instance because of a dark night or heavy rainstorm. So ideally it should be possible with it to still manoeuvre the ship safely, even under tough weather conditions. Hence an accurate location determination is required. Otherwise if the bearing is too vague, the view is not reliable anymore. The top part and data provision is the same as in aerial view, but the sidebar on the left with information about upcoming weather and steering actions was removed to have more space available for the first person view. Hence the steering instructions are now shown directly on the colour-coded route, as depicted in figure 6. Swipe and pinch gestures for manipulating the map can also be applied like in the default view.

[1]http://map.openseamap.org/?lang=de, last visited on 6 July 2017

4.3 Emergency Detection

Another aspect of the application is to detect and prevent dangerous situations early on. In general there is a wide range of what could be potentially harmful, from invisible rocks under water, to heavy storms and vessels that move towards each other. By means of the various technologies that are available, like radar, AIS, sonar and so on, all those situations should be detected at an early stage and ideally be avoided from the beginning. The type of the ship is important for that. Compared to a big cargo ship a pleasure craft can be handled easier, as it reacts faster to changes due to the smaller size and weight. Furthermore it is often no problem to drive in shallow waters with it. So the information about the own ship provided when planning a route, along with the mainly static data like seamarks, depth profiles and obstacle positions will be used for the route calculations.

The second part is to detect anomalies while driving. This requires permanent monitoring of the ship's environment under and over water. The difficulty is to identify potentially risky situations, but not instantly raising an alarm on every one of them. For instance a pleasure craft crossing a cruise ship's route a few hundred meters away may probably be nothing dangerous, whereas the contrary would be the case if it were not a pleasure craft that is crossing but another cruise ship. From a psychological point of view an alarm may increase a person's stress level. Since the goal of this application is to improve maritime safety while decreasing the stress in harmful situations, an alarm should only be triggered if the attention and focus of the user is really required. Depending on what the system has detected, more or less information is shown on the mobile device and on the screen. For instance if the ship has been set to maintain its current position, but is no longer able to do so, a short info text about this will be displayed. If it is probable to collide with another ship, then there will be an additional suggestion how this situation could be avoided, such as by decreasing the speed or changing the course. This is also

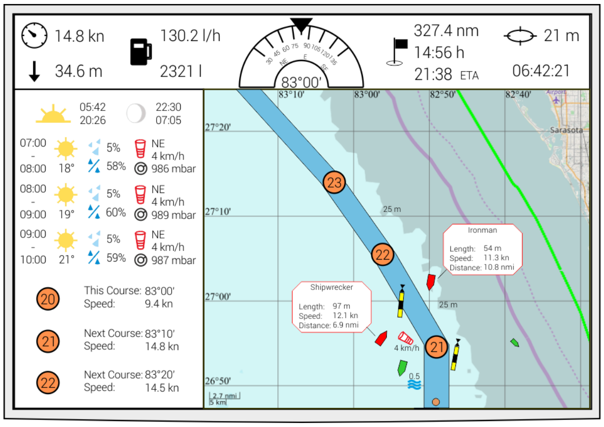

Figure 7: Default navigation view indicating two ships that are crossing the route. For better visibility they are coloured red as long as the situation is considered to be potentially harmful. Comparing this image with figure 5 it can be seen that the proposed current speed was reduced by the system in order to avoid a collision.

visualised in the map. If a vehicle is coloured green this means there will likely be no danger. Otherwise, if there could be a collision or something else, it is indicated by red colour and flashing at regular time intervals such that the user pays more attention to it, as depicted in figure 7.

To turn off the alarm the user needs to confirm it by pressing a button on the screen of the mobile device for two seconds. By this it should be made harder for the user to deliberately ignore the warning, as he is forced to look at it. Hence the probability might be higher that he would read the info text, at least subconsciously.

4.4 Smartwatch

A mobile device like a tablet or smartphone is the main input device of the system. Furthermore it would be possible to integrate a smartwatch into the on-board IT for basic actions like switching between screens and confirming alarms. This would be advantageous especially on larger ships for two reasons. First, numerous monitors can be distributed on the ship to provide information at different locations. If it is necessary to switch between the map views, ship or weather radar while being somewhere else than on the bridge, this could be done by means of the watch. If the user wants to change for instance some map settings, he has to do it using the tablet or smartphone on the bridge, since this device is not intended to be carried around on the ship. Furthermore the screen size of the smartwatch is a limiting factor for this task. Second, the smartwatch could also provide haptic, acoustic and visual feedback in case of an alarm. So even if the user is not on the bridge or near a display he still could be notified. Turning off the alarm works the same as on the mobile device. However, depending on the situation, the confirmation via smartwatch may not possible. This would be the case when ship handling actions are involved. By confirming the alarm on the bridge, the user can simply look at the system's suggestion instead of remembering the message.

5. EVALUATION

Up to now the suggested system has been realised in form of a clickable prototype. Based on the current state it is difficult to get qualitative feedback from the users, since the functionality of the prototype is rather limited. So the evaluation in the following is more of an objective comparison with other, already existing approaches.

In this system all information is basically shown on one screen. Unless the amount of data is not reduced, it probably might lead to an increasing cognitive workload. However, this is exactly what should be avoided in the first place. So the next step, after developing a more functional version of the prototype, would be to find out if it would be better to either split the single screen into two separate ones, such that there is for instance one for navigation and another one for weather radar data, or to reduce the number of available information to be shown. On the other hand, separating the data on two screens may also increase the workload, as the user then has to filter again what is the important information on each screen.

The prototype idea and design is based on existing approaches, like those described in previous sections, as well as on applications like the Navionics Boating App[2], and discussions with friends (with different seafarer experiences) about the pros and cons of new maritime technologies and assistance devices. Even for the small amount of people it can be concluded that there are two types of seafarer: some are open-minded to try out and use new technologies, others are not very convinced of all the technical gadgets. So the system tries to be a solution suitable for any kind of ship and person. With the acquired knowledge a general survey could be done to investigate what would really be helpful to improve maritime safety and situational awareness, in relation to seafarer experience and boat type. This also includes testing the performance of the proposed touch zones in general and with various screen sizes. Furthermore it has to be found out if the applied colours for everything not standardised, like the visualisation of ships in green and red, are intuitive, and if the colours are generally suitable for different lighting conditions. Finally it is important in this context to determine whether the suggested position of tablet and monitor, as described in section 4.1, is meaningful. Afterwards the results could be used to improve the prototype.

The proposed virtual first person view of the ship and its current environment also needs further investigation. In general the idea of the AR approaches to show navigational and safety related information right in the user's field of view is beneficial, especially when bad weather limits the sight. Due to the drawbacks of AR, this virtual version of the current surroundings was created. However, it may also be possible that this kind of representation increases cognitive workloads or the stress level in dangerous situations, since it is not the real world like outside the bridge. In addition to that it has to be figured out whether the user would rely on the system in such cases.

Taking classical, non-reflective screens instead of AR or VR the readability problem in different light conditions may be avoided. Furthermore this approach allows distributing the current state to every part of the ship, and not only on

[2]https://play.google.com/store/apps/details?id=it.navionics.singleAppMarineLakes, last visited on 5 July 2017

the bridge itself. Using a smartwatch the user can easily switch between different screens and also get instantly notified about dangerous situations, independent from where he actually is on the ship. Though this additional feature is presumably not necessary for every type of ship or trip.

Planning a tour is also straightforward, since it works basically the same as in Google Maps. It can be done everywhere and thus also in advance. Furthermore, the combination of a tablet device with the computational units on-board has multiple advantages. Since the computational units handle all sensors and assistance devices, their number, as well as corresponding displays and controls on the bridge could be reduced. As a result it would also be possible to create a common standard concerning the on-board IT infrastructure and the representation of information. Using a mobile device as a kind of input and control device does not require long training and learning time, as today the majority of people knows at least how to interact with a smartphone, whereas this might not be the case for AR and VR technologies. Finally it is also a lightweight solution, as a tablet and smartwatch, including their charging units, are not very heavy and big and therefore can be stored in any bag.

6. CONCLUSION AND FUTURE WORK

In this paper we presented a new type of maritime navigation tool. For this basically existing technologies were combined. The proposed system uses a touch-based approach instead of AR or VR, consisting of a tablet, a monitor and optionally a smartwatch. The tablet is used as an input and interaction device for mainly three tasks: planning routes in advance, switching between different views (map, weather, radar) and 'manipulating' the navigation map while driving. The monitor provides navigational information dependent on the selected view and settings. It is possible to distribute various screens on the ship and to control them with a smartwatch, such that the current situation may also be checked from somewhere else outside the bridge. Furthermore the watch can display alert notifications when the system detects a dangerous situation.

To improve this prototype further research has to be done. This includes for instance surveys and expert interviews to find out which colour schemes are applicable and whether the suggested range of functions and information provision is meaningful. In order to exchange data between the system on the ship and the input devices it is necessary to think about an interface such that tablets, smartphones and smartwatches could be integrated into the on-board IT and malicious software on these devices would not be able to jam the whole system. The probably most difficult part is to create the algorithms that merge the information of weather, sea state and other environmental influences for navigation route calculations and emergency detection. Nevertheless all essential technologies and techniques for that are available. So this step rather requires combining the potential of things that already exist instead of inventing something completely new.

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