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.

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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.

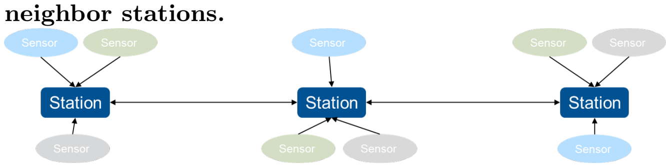
Additionally there are environmental factors like wind or waves, that brings the ship into motion and therefore complicate the disembarkation.

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.

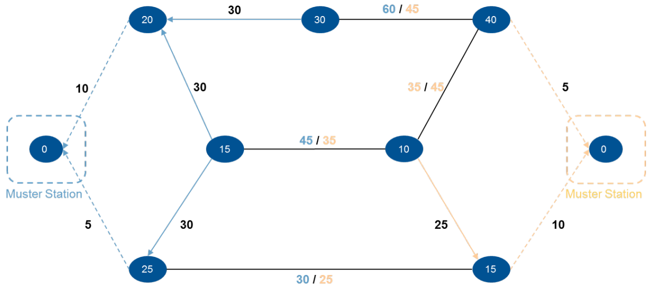
3.3.1 Dijkstra Algorithm

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 shorest 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.

$$w = \sum_{i=1}^{n} \lambda_i * p_i ; \sum_{i=1}^{n} \lambda_i = 1 \tag{1}$$

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.

$$w = \max_{\forall p \in P} p \tag{2}$$

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.

$$w = \sqrt{\sum_{\forall p \in P} p^2} \tag{3}$$

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.

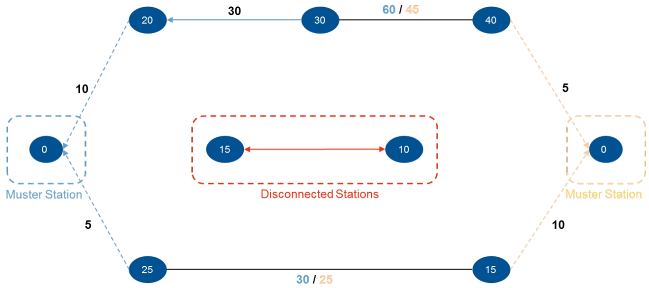
3.5.2 Visualisation on Smartphone

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. Noway 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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