Ship Maneuvering Using a Ship Simulator in Search and Rescue Operation

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Abstract. In order to successfully steer a ship, a man, ship's watch officer, or commander of the ship must be physically ready and must know the maneuvering characteristics of the ship he steers, as well as the forces acting on him. For that, it is necessary for him to know the specifics of the ship because each ship has its own ˋˋmood', its specific properties that depend on the type, and size of the ship. Therefore, maneuvering properties differ even in ships of the same type and therefore it is important to know the specifics of a particular ship. Also, the same ship will behave differently in different situations. When the ship finds itself in situations that require urgent reaction during the voyage, then the experience and skills of the ship's captain come to the fore. Then it is important that the captain, based on his experience, chooses the right maneuver, but also that he always has at least one reserve maneuver in his head. That decision in certain situations must be made in a very short period of time, and the future of the ship and human lives often depends on it, as well as the resources on board. Every skill is acquired through practice, and it is logical that the commander will react faster and more correctly in every new situation. Precisely because of this, the most intensive training is necessary for the formation of quality ship commanders. For that reason, the training of future ship commanders on ship simulators gives excellent results. On ship simulators, they can gain a lot of experience and go through countless scenarios. In this paper, the use-value of ship simulators from the aspect of the training was verified through the Search and Rescue (SAR) exercise realized on the ship simulator Wärtsilä Navigation Simulator NTPRO 5000. It has been shown that the simulator can successfully check and recognize the optimal SAR pattern, maneuvering characteristics of the ship, as well as practice, maneuvering the ship and resolving specific situations that ship commanders may encounter in real situations. Training on ship simulators cannot completely replace training in real situations, but it can be used to get acquainted with the maneuvering characteristics of the ship, train in working with navigation devices, and be a good starting point in preparing people who are trained to perform tasks in real situations. The use of hydrological data of relationships between different types of data using an autoregressive model (AR model) can contribute to the creation of more realistic scenarios on ship simulators. It is also possible to apply data in the modeling of the environment and connect them with the current hydrological situation of the waterway. In the exercise evaluation process, we can see if the ship's captain used the hydrological data in the right way.

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1 Introduction

The main objectives of this research are to define training scenarios on a ship simulator in a river environment using hydrometeorological data and the autoregressive model (AR model) of the river level to verify the performance of the SAR operation itself and to check the maneuvering characteristics of a given ship. If we look at the European Maritime Safety Agency (EMSA 2020) data on the total number of reported Marines victims and incidents during the period 2014–2020 we see that despite the new modern technology, a large number of accidents occur. The total number is 22532, and the annual average of the number of maritime casualties or incidents is 3218. In addition to the stated objectives, the training of the ship's captain (participant) in performing the SAR operation is checked, as well as his ability to use the available data.

The data at its disposal are defined in the task through the input parameters on the ship simulator (wind direction and speed, current direction and speed) while the water level is defined through the AR model of the river level for 6 (six) years. We have introduced this way of presenting the water level trend due to the possibility of reacting quickly to unforeseen situations and the ability of the participant to cope with the lack of current data on water levels. We also used a specific empirical formula to calculate wind pressure as a function of its speed.

Of course, all important parameters of wind direction and speed as well as the intensity and direction of the river current are entered into the simulator and assigned to each casualty (man in the water). From the moment of receiving the signal for the beginning of the exercise to the moment of the end of the exercise, the work of the participants is monitored and recorded if necessary for later analysis and making the most optimal decision possible.

In addition to monitoring the work of the participants in the SAR maneuver, the maneuvering characteristics of the ship are controlled. Specifically, we were based on monitoring the maneuvering characteristics of the ship's turning circle, given the fact that this maneuver is used to rescue a man in the water.

The maneuvering characteristics of the ship are shown on the basic ship information display, and we were using that defined data as controlled parameters. Basic data on the ship as well as data on the control maneuvering characteristics of the ship (turning circle) are shown in Fig. 1.

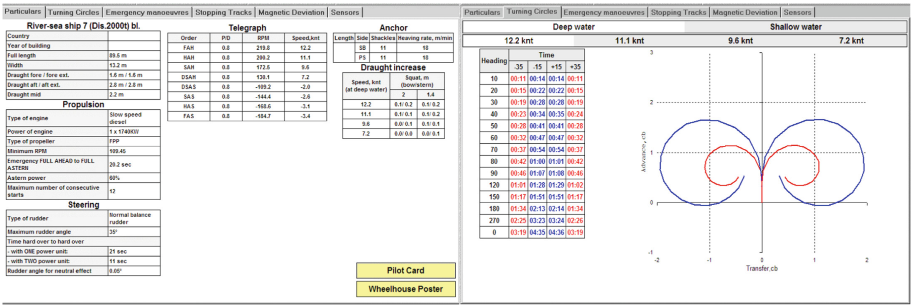

Fig. 1. Basic data of River-Sea ship, simulator Wärtsilä NT PRO 5000

Data on the ship's turning circle were checked during the SAR maneuver and the rescue operation in the water.

2 Simulated Scenario

Input environmental data for SAR operation were calculated and synchronized with real data based on SAR experience and a real incident in Budapest, Hungary, which occurred on 29th May 2019 (Némedi 2021).

We developed a scenario for SAR exercise and simulation environment (Table 1). The Hableany, a small sightseeing cruise collided from behind with a twenty-five-times bigger longship, MV Viking Sigyn capsized and sunk in seven seconds.

Table 1. SAR exercise simulation environment

Input parameters	Hableany disaster	Simulation parameters
Ship	Small sightseeing cruise	Small passenger cruise
Type of incident	Collision with a bigger ship	Collision with a sea-river ship
Wind	No data	N – 4,1 m/s
Temperature	Unusually cold	10 ºC
Water temperature	No data	6,3 ºC
Precipitation	Heavy rain	Heavy rain
Fog	No	No
Visibility	Low	Low (under 100 m)
Drift	Very strong	Very strong (
River current	Strong	Strong 110,5 º, 1,4 kn
Waves	Low	0,5–1 m
Flooding	Yes	Yes
Watercolor	No data	Moody
Number of persons onboard/rescued	37/7	30/7,41

Using this parameter the participant should predict the SAR area (Burciu, 2010). The initial position of the participant is close to the place of the accident, the distance is about 2 Nautical Mile (NM). We did not want the participant to waste a lot of time arriving at the scene of the accident.

The way these hydrometeorological parameters should be used by the Participants is by simply matching the wind pressure vector, which has its own direction and intensity, as well as the river current vector (Berawi, et al. 2019). The resultant of these two vectors in the interval of time should enable the participants to determine the optimized SAR region. The direction, and strength of the current we set in Table 1 Simulated parameters since we did not have accurate on-scene data values are assumed. What is important for the realization of the exercise is that the participant uses the data that he can see on the simulator or get in the task. It is very important that the participant knows how to determine the direction of the current, ie that he knows that the current flows in the direction defined in the table, unlike wind. It is assumed that the defined current represents the real value of the current, ie that for a defined time interval the starting point of the SAR region is moved by that value. In order to more accurately predict the impact of the wind itself, it is necessary to calculate its thrust using speed. The empirical formula by (Tesic 1971) we have used is:

$$P = 0.12 * V^2 \tag{1}$$

P – Wind pressure, v – the wind speed.

More accurate prediction of the search area is crucial for speed of response and saving lives (Xu et al 2011). Although we do not have current data on water level, participants need to take the assumed value on the basis of data obtained by the autoregressive model (AR model) done specifically for this exercise.

3 Search and Rescue Decision Making

Making a decision on the SAR operation itself is a complex activity based on the data, experience, and knowledge of the participants engaged in the operation (Baldauf et al 2015). An algorithm for making the most optimal decision in the operation is proposed in Fig. 2 (revised, Vidan et al 2010).

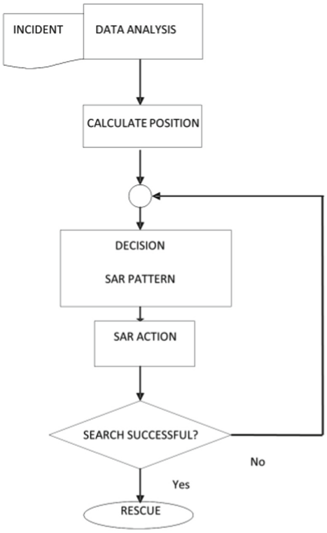

Fig. 2. SAR algorithm in the river environment

If the Search operation is successfully performed on the ship's simulator, participants start with maneuvering and rescuing people who are in the water.

Rescue should be conducted so that the ship reduces external hydrometeorological effects (IMO, 2019). The rescue act itself and the manner of its performance by the participant are monitored and recorded for later evaluation and conclusion on the exercise (Radojević and Kresojević, 2020).

At the end of this phase, the fall of a man into the water from the ship on the starboard side is simulated, the command bridge is alarmed and the work is monitored shown in Fig. 3.

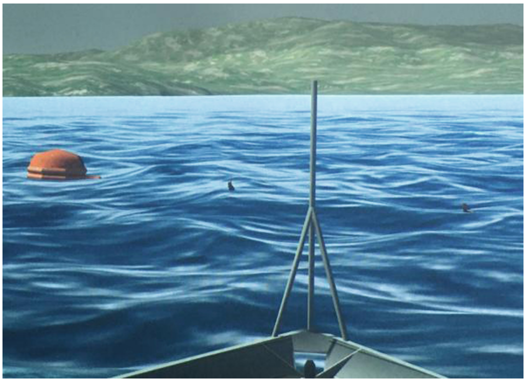

Fig. 3. Saving man overboard, simulator Wärtsilä NT PRO 5000

When performing a full turn maneuver and rescuing a man from the water, the turkey movement of the ship is monitored in order to compare the turning circle with the defined parameters shown in Fig. 1.

4 The Autoregressive Model Applied to the Water Level

The autoregressive model (AR model) can be considered as one of the simplest regression models that can be used to simulate certain qualitative and quantitative parameters of surface flows, then karst spring water and springs and groundwater regime, where the dependent variable is Q_t - the predicted variable at a time t, and the independent variables Q_{t-1}, Q_{t-2},…Q_{t-k} are values 1, 2,… k days before:

$$Q_t = a + b_1 \cdot Q_{t-1} + b_2 \cdot Q_{t-2} + \ldots + b_k \cdot Q_{t-k}$$

where a, b_1, b_2… b_k are model parameters.

In the first place, it is necessary to have a sufficiently long series of random variables (flow, water level, absolute elevations of the water mirror, nitrate concentrations, turbidity,…) to make the equation obtained as reliable as possible (Miladinović et al. 2015, Pešić et al. 2016, Ristić Vakanjac 2015, Ristić Vakanjac et al. 2018). For the purposes of this paper, the data on the absolute water levels of the Sava River observed in the gauging station (g.s.) Obrenovac was used. The average daily values of the water level of the Sava River observed in the Obrenovac profile were available to the authors for the period from the beginning of 1962 to the end of 2019. Due to the fact that there were frequent short-term interruptions in the data at this hydrological station, the longest continuous series was taken for the purpose of forming the simulation model (June 1st, 2014–December 31st, 2019). For different orders, the AR model coefficients were from 0.9917 (for order 1) to 0.9936 (for order 9) (Fig. 4).

Fig. 4. The correlation coefficient for different orders regarding the AR model which was used for water level simulation

We can say that the correlation coefficients obtained for different orders do not differ significantly, so we will present only the results obtained for order 1. In this case, the equation obtained for order 1 is:

$$Z_{calculated,t} = 0.991862 \cdot Z_{measured,t-1} + 0.581253$$

The diagram of the dependence of the calculated and observed values of the water level of the Sava River in the Obrenovac profile is given in Fig. 5.

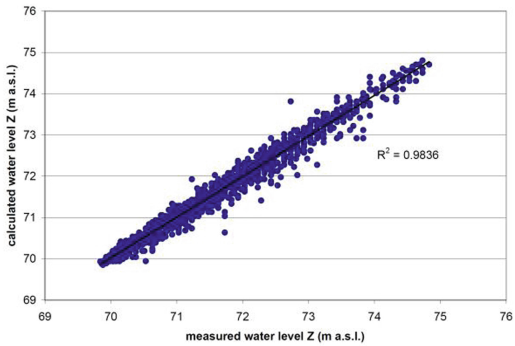

Fig. 5. Diagram of the dependence of the calculated values as a function of the measured values of the water level of the Sava River, g.s. Obrenovac

The comparative level diagram of the absolute levels is given in Fig. 6.

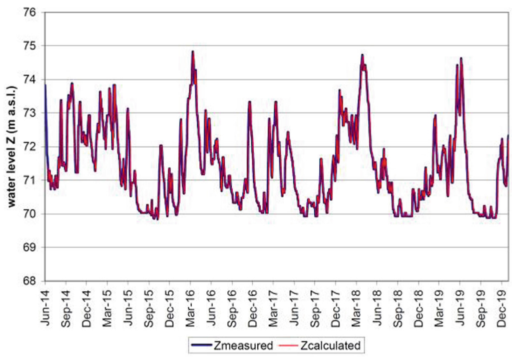

Fig. 6. Parallel water level diagram of observed and computed values, river Sava, g.s. Obrenovac

The AR model showed, as shown in Figs. 4, 5 and 6, that the assumed water level is almost identical to the measured levels. This allows us to assume with great accuracy the water level for the next day (which is most important to us from the point of view of navigation) if we do not have accurate data from the gauging station at the moment.

5 Conclusions

After the realization of the exercise, we noticed that the turning circle differs from the defined turning circle of the ship. However, taking into account the parameters of the environment, the deviation was expected, so we can conclude that the use of a ship simulator for maneuvering is useful in training shipmasters, i.e. the simulator faithfully shows the ship's behavior in defined conditions.

The simulator as a training tool cannot completely replace the sailing experience gained on a real ship, but it certainly represents a good basis and an excellent platform for training shipmasters. The two methods, conventional real ship training, and simulator training need to complement each other for the greatest training effects.

By using data on real accidents that happened on the waterway, their implementation through the simulator and later using a comparative method of exercises performed on the simulator with data on how the actual operation was performed, it is possible to obtain data that would be key to defining future training.

Using the autoregressive model (AR model), i.e. data on the ratio of the river level, for a specific river in which we navigate, can be of great importance to us, especially in situations where we do not have available data on current water levels. Although this is a little assumed scenario, monitoring the water level trend in this way can be useful when planning a voyage or performing specific tasks or specific maneuvers on the river.

In this specific exercise, we saw that the ship's captain successfully used data on the assumed water level, i.e. that he predicted the impact of water on his ship, which we confirmed by successfully positioning the ship in relation to the man in the water.

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