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Comparison study on AIS data of ship traffic behavior

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ABSTRACT

AIS (Automatic Identification System) data provides valuable input parameters in ship traffic simulation models for maritime risk analysis and the prevention of shipping accidents. This article reports on the detailed comparisons of AIS data analysis between a Dutch case and a Chinese case. This analysis focuses on restricted waterways to support inland waterway simulations, comparing the differences between a narrow waterway in the Netherlands (the Port of Rotterdam) and a wide one in China (wide waterway of Yangtze River close to the Su-Tong Bridge). It is shown that straightforward statistical distributions can be used to characterize lateral position, speed, heading and interval times for different types and sizes of ships. However, the distributions for different characteristics of ship behaviors differ significantly.

1. Introduction

This work was instigated by the increasing number of collisions between ships and bridges in busy waterways of China. When ship traffic intensifies, like in the Yangtze River, bridges and other objects are at increased threat from the collisions from ships. For maritime risk analysis, the probability of the accidents can be estimated with probabilistic risk simulation model based on multi-agent simulation and artificial force field theory as developed in this research project (Xiao et al., 2012). AIS (Automatic Identification System) data is collected and analyzed to obtain statistical data on the ship behavior and better understanding of the ship traffic in the waterway. The AIS data is field data that adequately describes “reality”, which provides information for model development. Both the Dutch case and Chinese case are analyzed, because the proposed simulation model should be applicable in different locations worldwide. The similarities and differences of traffic behavior will be a guide for the development of the proposed model.

The characteristics of the ship traffic from the AIS data analysis will be used to generate input parameters at the boundaries of the simulation model. Ship to ship interactions can be based on multi-agent simulation and artificial force field. The multi-agent concept is adopted from Artificial Intelligence (AI) field (Xiao et al., 2013), in which every agent (simulated ship) will be treated as an intelligent individual who can make decisions and avoid collision based on its own local circumstances. The maneuvering behavior of an agent (in this case, a ship) will be simulated separately from other agents. The flow of agents in a given space (in this case a confined waterway) simulates shipping traffic in the waterway. The ship avoidance maneuvers in encountering situations are based on the artificial force field theory, which is the second one of the three obstacle avoidance behaviors introduced by (Ribeiro, 2005).

2. AIS data analysis: theory and method

The model for maritime risk analysis has evolved considerably from analytical methods to simulation methods. Originally, analytical methods were used to calculate the probability of collisions, such as AASHTO model Aashto (1998). (Li et al., 2012; Xiao et al., 2010) compared analytical models and pointed out that these models lacked in the detailed description of the ship movements. Following the first simulation approach by (Davis et al., 1980), in recent years, simulation models have been developed to describe the dynamic movement of ships in all kinds of situations (Goerlandt and Kujala, 2011; Montewka et al., 2011; Statheros et al., 2008). Alternatively, dynamic ship movements can be simulated with manned ship-handling simulators (e.g. the Mermaid 500 at Dutch Maritime Research Institute), but it requires experts to operate it and the equipment is expensive (Webster, 1992). The cheaper alternative is to simulate ship movements based on Fuzzy Logic approach (Priadi et al., 2012), Bayesian Networks (Merrick and van Dorp, 2006; Szwed et al., 2006), and Neural Networks (Łącki et al.,

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2012). However, these methods are still dependent on expert opinions or other human interventions.

As opposed to expert opinions, this work is based on actual behavior of ships and their crews from historical data of the AIS database. In order to make that possible, the first step is studying AIS data to unveil the characteristics of real-life ship movement. The statistics of those characteristics can be further treated either as input of simulation or as a way of model calibration and model verification. Different waterways are studied to compare the similarities and differences in a Dutch waterway and a Chinese waterway, to understand the unique characteristics that are important to reflect realistic ship traffic simulation.

AIS data contains a lot of important information, which is considered to be a precious resource for research. The AIS data analysis provides insight in ship traffic and forms the basis of the simulation model. This section presents the results of statistical AIS data analysis. The ultimate goal of the analysis is developing a realistic simulation model for confined waterways (such as port areas and inland waterways), which can be used for safety assessment of the ship traffic in concerned waterways, or improving safety and efficiency.

2.1. Introduction of AIS system

The AIS system transmits information of the sailing status of ships. The AIS equipment automatically broadcasts information from the vessel to an AIS ship receiver or an on-shore receiver through VHF (Very High Frequency) in a limited geographical space. That information includes ship positions (from GPS), ship course, ship heading, ship rotation angle, ship speed, loading status, location and altitude of AIS antenna, ship type, navigation status, destination, time stamp, together with an unique Identification number MMSI (Maritime Mobile Service Identity) (Harati-Mokhtari et al., 2007). This information can be displayed on the monitor of other ships or VTS (Vessel Traffic Service) center. The received AIS data can be used for additional lookout and collision avoidance onboard, and it also can be used in a VTS center for traffic safety and efficiency by assisted target tracking. Moreover, nautical safety authorities also save the data for further research like accident investigation or analyzing the traffic status. In addition, researchers use historical AIS data to study the characteristics of vessel traffic to further improve safety and efficiency. Historical data analysis is used to lay the basis for a realistic simulation of ship traffic in the confined waterway.

The quality of the AIS data analysis depends on the AIS equipment. There are two types of ship borne mobile AIS equipment, Class A and Class B. The major difference is that Class A system is compulsory installed on the vessels larger than 300 gross tonnages engaging in international voyages, cargo ships larger than 500 gross tonnages not engaging in international voyages, and passenger ships. AIS equipment is not compulsory for some small ships, for which Class B system is simpler and lower cost equipment. Small ships without AIS equipment are not in the AIS data. However they can affect the behavior of large ships in encounters. The time interval for reporting depends on the type of equipment and the ship's dynamic conditions. The accuracy of observed behavior change of ships depends on the time intervals.

Harati-Mokhtari et al. (2007) mentioned errors concerning static information and dynamic information from AIS: for MMSI number, 2% of the information was found erroneous; For vessel type, different studies (VTS-based AIS study and Data-mining AIS study) showed 74% and 56% of discrepancy respectively between AIS data and reality; for navigational status, 30% of ships was displayed incorrect; for dimensions, there was about 18% incorrect information; the reliability of other dynamic information such as position, course, and speed would need to be further investigated.

However, based on experiences on AIS data analysis of the study area in the Port of Rotterdam, the information of positions, course and speed are more reliable there. Only a very small proportion of signals shows ambiguous positions, for example, navigating outside of the channel. This is not a problem since the ambiguous positions can be eliminated in the statistical analysis. Missing several signals for a single ship track is another kind of problem for data analysis. However, there are always single ship tracks without missing signals that can be chosen for analysis. Finally, information of small ships which are not equipped with AIS cannot be included in the AIS data analysis. This proportion of ships needs to be further analyzed and compensated for in a simulation model.

The AIS data in the Chinese case is not as good as the Dutch case. Most information of ship types and LOA (Length overall) in the data is missing. Positions of the GPS antenna were deleted in the data collected. There are a lot of ships that did not carry the AIS system and they were not included in the AIS data. According to the observations from the China MSA (Maritime Safety Administration of the People's Republic of China),[1] the number of ship passages (Table 1) is very different from the number of passages observed in the AIS (e.g. 208 passages per day on average for incoming ships). The China MSA (Maritime Safety Administration of the People's Republic of China) provided three months of AIS data for the case study and was kind enough to provide other related information such as records of wind and visibility.

2.2. Recent study on AIS data analysis

Similar works on AIS data analysis to study the ship traffic were conducted for two different areas, the North Sea and the Gulf of Finland. Mou et al. (2010) analyzed AIS data in the North Sea off the Port of Rotterdam. That study focused on the correlation between Closest Point of Approach (CPA) and other ship characteristics such as ship's size, speed, and course. (De Boer, 2010) presents the results of a case study around Maasvlakte I of the Port of Rotterdam, showing the averaged vessel behavior and the influence of wind, current, and visibility on the ship traffic. (Shen, 2012) further examined the patterns of the vessel traffic by comparing the ship traffic behavior in different locations.

A number of works were conducted in Finland to study AIS data and further utilize the data into ship traffic simulation. Statistical analyses with figures and histograms were presented to represent the characteristics of the ship traffic in Gulf of Finland. Those studies were evolved from Pedersen's model, which was further adapted to the local geographical conditions (Goerlandt and Kujala, 2011; Kujala et al., 2009; Montewka et al., 2010).

2.3. AIS data analysis in this study

A realistic simulation of ship behavior should be internationally applicable, because the ships are conducting international transportation and conforming to international regulations. In this sense, the model evolved from a specific area should be applicable in other places of the world. Possible similarities and differences of ship behavior resulting from many influences should be identified, which include local regulation, behavior of officers on watch, and characteristics of the waterway. After interpretation of ship tracks provided by AIS data, we derive information of ship traffic behavior that is characterized by the mean values and statistical distribution of lateral position, speed, heading, and time interval for different types and sizes of ships.

[1] Number of ship passages of the Nan-Tong Cross-section, provided by the China MSA, http://www.ntmsa.gov.cn