Research Prospects of Ship Traffic Flow Simulation Technology

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Abstract. At present, the traditional ship traffic flow simulation technology has not been able to meet the requirements of researchers for model fidelity and simulation timeliness. Considering that AIS (Automatic Identification System) data has the characteristics of authenticity and real-time, ship traffic flow simulation based on these data can make the results more practical. For huge amounts of AIS data, it is difficult to solve problems by using the previous simulation methods. According to the achievements of machine learning method under the background of big data, the possibility of ship traffic flow simulation technology based on AIS data is analyzed.

1. Introduction
Ship traffic flow refers to the movement state which is similar to water flow characteristics formed by ships under certain rules. Simulation, also known as ‘Emulation’, refers to constructing the model corresponding to the actual system to carry out experimental research, which is based on that similarity principle. Ship traffic flow simulation is a kind of simulation test carried out on ship traffic flow model by using computer technology. It is a technical method to study ship traffic by placing the development, operation and implementation of the traffic system all in the laboratory. Compared with conventional methods, it has good controllability, economy and reproducibility, etc. This technology can provide optimization and improvement programs for ship traffic management systems in practical applications, and provide scientific basis and data support for traffic planning and related navigation system design.

With the increase of traffic volume and vessel types, the quantity and quality of the ship on the voyage have changed a lot. Ship traffic flow simulation technology is required in order to assess and predict the traffic flow condition in advance when the navigation channels are widened, the new navigation routes are set up, the navigation channels are exploited and traffic control changes, or the safety of the newly-built harbor and anchorage needs to be understood. In this way, traffic flow can be reproduced and compared with various scheme so as to evaluate that risk degree of navigation, to optimize and improve the route system and management mode, to make the benefit cost to the best, and to make the vessel traffic simulation system to be the most economical and reasonable. The researchers found that the degree and detail of simulation varies greatly depending on the simulation area. How to improve the fidelity and efficiency of simulation has become the focus of future research on technological development.

2. Main classification
According to the reproduction degree of ship's navigation collision avoidance behavior, vessel traffic flow simulation can be divided into micro simulation and macro simulation.

2.1. Micro simulation
The micro simulation focuses on the performance of each ship's navigation, and it's a simulation of the
ship's individual, and it usually contains the following models:

2.1.1. Ship model. Since ships are the basic elements that constitute the traffic flow of ships, and each ship has its own characteristics, it can conduct regression analysis by making statistics on relevant data of ships, such as length, speed and tonnage, and build a ship model accordingly.

2.1.2. The field model. The field model is built according to the segments with different shapes and types. All the fields can be composed of straight segments, cross segments, y-shaped segments and inverse y-shaped segments.

2.1.3. Ship motion model. Ship motion model is a model in which speed is the basic variable of vessel traffic flow simulation.

2.2. Macro simulation
The macro model is to regard the vessel traffic flow as a whole, and it is used to study the impact of the network system of the big channel network and the whole vessel traffic flow. The method is to evaluate relevant traffic control or route network conditions by counting the waiting time and waiting quantity of the ship in the bifurcation point of the channel or channel. According to the evaluation, it's an optimized plan to reduce the time and quantity of the ship, and to run the simulation again, until it's optimal.

‘Network Simulation’ is the representative of macroscopic simulation. The basic model of the simulation is the route system made up of nodes and lines. ‘Node’ indicates the intersection, end points, and branch points of the route selected. ‘Line’ indicates the routes of the ships chosen to sail. The basic principle of the model is that the network composed of these nodes and lines represents the whole route system.

3. Development review
Since the 1960s and 1970s, the study of ship traffic simulation has never stopped, and in terms of time division, it has been through the most important evolutionary stages of the 1970s, 1980s, 1990s and early 21st century.

3.1. 1970s
In this period, the ship traffic flow simulation model was built mainly to describe the model, which was mainly due to the extensive use of computers. Compared with the past, the model had had qualitative changes in precision and function. At this time, software can be used to simulate the typical ship traffic phenomenon and traffic management measures, and reproduce such situations as the situation of meeting (crossing, facing, chasing), avoiding and controlling, traffic capacity simulation and traffic diversion. Owing to the beginning of the study, most of the traffic flow simulation systems at this time were mainly the research on inland river navigation. In most cases, the encounter model was adopted, accompanied by the theoretical system related to accident science.

3.2. 1980s
During this period, the main research subjects of ship traffic flow simulation gradually developed from micro-simulation model to the combination of micro-simulation model and macro-simulation model. The most typical one was the study of three typical micro-simulation models represented by Sugisaki Akio of Japan and the study of the network simulation model of ship arrival and departure conditions represented by Aoshan Yuying of Japan. In the meantime, the dynamic and static characteristics of most common port ships were abstracted into discrete models by skilled use of physical and mathematical models. Typical models included ship track distribution model, navigation density model, closed area and loop traffic model, ship motion model, ship domain model, OD traffic flow model, ship traffic volume combination system prediction model, etc.

3.3. 1990s
At this stage, the research on maritime traffic flow tended to be diversified. The research on VTS (Vessel Traffic System) was emerging in various countries around the world, and many simulation softwares
simulating the situation of ships entering and leaving ports were developed. In this time, the evaluation method of ship traffic flow was gradually systematic and specific, and the main conventional evaluation indexes were also established, such as risk degree, queue length, CJ (Collision Judgment) value, SJ (Subject Judgment) value, waiting time and utilization rate, etc. So far, the uncertainty analysis model based on probability risk assessment has been still the most widely used model in the ocean traffic risk assessment model. Wu Zhaolin [5] and Fang Xianglin [6] of Dalian Maritime University deeply studied the principles and methods of safety assessment of ship traffic system, and the team made contributions to the complete construction of safety assessment methods for marine traffic environment.

3.4. Early 21st Century
With the rapid development of science and technology, the world has launched a search for intelligent ships, which has led to a new level of intelligent research on ships. The classical research achievements included intelligent navigation management system, intelligent collision avoidance and navigation system, smart airway planning system and intelligent sea state monitoring system. Two of the most iconic models of the period were people, boats, environmental and management interactions and a model of a multi-intelligent ship. Yang Shenhua [7] etc developed the intelligent port traffic flow simulation System by using the MAS (Multi-Agent System) technology, which greatly improved the simulation timeliness by adopting automatic navigation theory and discrete event algorithm. The paper [8] uses the fuzzy theory and the neural network to study the ship's intelligent evasive approach, and it analyzes the solution to the problem.

4. Core technology

4.1. Modeling method
Monte Carlo is the basis of a model of the ship traffic flow modeling, and it has been upgraded to a number of artificial intelligence methods, such as Cellular Automaton and Agent.

4.1.1. Monte Carlo method. The method of Monte Carlo modeling to generate ship traffic flow is to use various probability statistical tools, such as histogram, hypothesis test or curve fitting, to conduct detailed analysis of the data history of various ship random variables. So as to obtain the probability distribution of relevant variables, such as ship speed, captain and arrival time interval, and to summarize the rules, and then construct the generation algorithm of random data. The paper [9] has a statistical analysis of the type, size, arrival time, and the route of a few ships in the Finland Gulf, and the probability model is constructed, then the traffic flow is generated by the Monte Carlo method. The paper [10] uses the Monte Carlo method to simulate the ocean traffic flow and assess the traffic conditions at sea.

4.1.2. Cellular Automaton method. The Cellular Automaton method is to divide the study space into cells in an orderly manner according to the actual needs and observe the changes of these cells with the advance of discrete time. In vessel traffic flow study, researchers will route into the corresponding grid is referring to meta cells, and the ship motion related time, space and speed divided into integer can be intuitive. When the grid contains vessels, cellular state is called a "1"; On the contrary, it is "0". On this basis, the movement of the number of cells per unit time (that is, the process from t to t+1) according to traffic rules is observed. The Feng H [11] sets up a model of a Cellular Automaton, considering the impact of the ship's interaction and the simulator channel being partially closed by the ship's traffic flow. The paper [12] is a model of the ship's movement by describing the movement of the ship to simulate a simple cross and a loop channel.

4.1.3. Intelligent Body method. Agents have a certain degree of autonomy, sociality and reactivity. That is to say, the behavior state of agents can be completely controlled, interact with people or other agents, perceive the environment, and change their behavior state according to environmental changes. The obvious advantage of using the Agent to simulate the ship traffic flow is to add the human mind to the simulation, which is more ideal, and often used for the ship traffic simulation. The paper [13] has developed a real-time Marine simulation system based on the presence of an Agent, capable of simulating the movement of more than 200 ships at the same time, which can be applied to the ship's safety
navigation assessment. Xiao F etc [14] created a multi-agent simulation model of ship traffic flow based on the Yangtze River environment, which can simulate the interaction between ships and also help traffic management and route design.

4.2. Modeling tools

4.2.1. The formed traffic flow simulation software. Because of the high randomness and discreteness of water traffic, the construction of water traffic simulation software is difficult. For the characteristics of the water traffic dispersive features, the researchers have done their research, and they've developed some of the more intact simulation software, such as Any Logic, Arena, et al. Köse E etc [15] by using Slam II software under different conditions is studied in Istanbul strait traffic flow; The paper [16] uses Arena software to study the ability of ships in the inland and channel areas. The same defect of these software is that the research direction of simulation is carried out from the macro-level, so the interaction and micro-behavior between ships cannot be directly reflected.

4.2.2. Independent programming based on programming language. In order to simulate the behavior of ships from the microscopic level more accurately, people began to carry out independent programming. Software such as Access, SQL and Oracle can be used to collate ship data, and program in computer languages such as Visual C++ or Java, then use electronic chart as the visual display background. For example, the paper [17] is a Visual representation of the ship traffic flow through Visual C++ programming; The paper [18] uses Java programming to implement a mock-up of the ocean traffic flow based on the Agent. Both C++ and Java can describe and program ship behavior as an object, so as to realize the programming of ship traffic flow simulation model. However, compared with C++ language, it is more mainstream.

5. In background of big data

5.1. Deficiencies of traditional methods
Each of the three modeling methods mentioned above has its own advantages, but there are corresponding disadvantages. Its roots can be summed up in the simulation of fidelity or modeling efficiency that doesn't satisfy the need of the system simulation in a big data age.

(1) The Monte Carlo method is actually a stochastic simulation method, which adopts the technology of random sampling to solve the related calculation problems with random numbers. Finally, the approximate solution is also obtained by computer simulation. Due to the large amount of data, the modeling efficiency cannot be satisfied, so the method of random sampling can only be adopted. Nevertheless, the simulation effect generated in this way can only be a few randomly generated free moving ships. The course, speed and navigation state are all random and the motion trajectory is chaotic, which cannot meet the requirements of intelligent collision avoidance. However, Monte Carlo method is considered to be the basis of ship traffic flow simulation research, because it has essential characteristics for the generation of ship navigation path. However, this method generally needs to be combined with other artificial intelligence methods to conduct more accurate decision-making research on ship collision avoidance.

(2) The characteristic of Cellular Automaton is that time and space are discrete, and each variable has only a finite number of states, and the rules of change are localized in time and space. These characteristics limit the acquisition quantity and range of the elements of position, speed and heading, which is basically the simplification of complex system, establishing a simplified model, observing the changing law and moving situation between "0" and "1", so that the result precision is not very high, but the intellectualization is also to be improved. According to the feature that Cellular Automation can use simple and intuitive evolutionary method to simulate the complex traffic flow state, researchers often use this method to simulate the ship traffic flow in a large area of the sea, at which time the error is relatively small.

(3) One of the pioneers of Intelligent Body research, Macs in the United States believes that "Autonomous or autonomous intelligence refers to those computing systems that host complex dynamic environments, autonomously perceive environmental information, take action independently, and achieve a series of preset goals or tasks." The Agent method can be said to be the closest to realizing the automatic
collision avoidance of the ship model. By this method, the ship model can be added with people's subjective collision avoidance consciousness, so that the ship model movement has certain regularity of the actual situation. Nevertheless, the Agent modeling is only applicable to the simple water area with a small amount of ship data. In the process of simulating complex traffic flow, the workload is greatly increased, which requires not only editing multiple agents, but also accurate calculation of each Agent operating framework. That will lead to lower operating efficiency, increased costs and slower generation results.

5.2. Forecast of ship traffic flow simulation based on AIS data

5.2.1. Brief introduction to AIS. AIS is a kind of automatic identification system for ships. It is used in the autonomous exchange of navigation information during the voyage of ships. It can display the position, speed, course of the surrounding ships, ship running status and other information. The data will be sent and updated in real time at the frequency of less than 10s. According to SOLAS Convention, ‘AIS shall be provided to all vessels with a gross tonnage of 300 tons or more engaged in international navigation, cargo vessels with a gross tonnage of 500 tons or more not engaged in international navigation, and passenger ships of any size.’ Ships loaded with AIS equipment will record large amounts of data when they are sailing, and these are available [19]. Considering that AIS data can be used as a data source for modeling, the simulation results will be closer to the real ship traffic behavior [20]. However, it is unrealistic to use traditional methods for processing and analysis, and new technologies need to be introduced.

5.2.2. Machine learning. The concept of ‘Deep Learning’ originates from the research of artificial neural network. As a popular branch in the current field of machine learning, its rapid development not only makes machine learning get many practical applications, but also expands the scope of the whole artificial intelligence, which has a good performance in some representative fields, such as driverless cars, face recognition, stock prediction and bio-medicine. In view of that limit of learning depth and the lack of feedback mechanism, it is mainly applicable to the processing of image, text, and speech, and ‘Reinforcement Learning’ can truly realize the self-learning and self-reflection of the machine, which has the characteristic of learning through interaction with the environment according to the relevant feedback, need not supervise the signal and can improve the own action plan according to the evaluation feedback information in the environment so as to adapt to the environment. In sum, it’s very suitable for the processing of on-line, real-time forecasting and decision making problems. Deep learning can not only bring the convenience of end-to-end optimization for intensive learning, but also make intensive learning no longer limited to low-dimensional space and greatly expand the application scope of reinforcement learning. The combined ‘Deep Reinforcement Learning’ method [21-23] is more widely used.

In the era of big data, Hadoop, Spark and other well-established distributed computer platforms have been able to provide technical support for large-scale data analysis and modeling problems. The calculation speed of traffic flow depends largely on the distributed strategy. The more reasonable the strategy is, the faster the speed is. Another example is Map-Reduce [24] batch processing distributed computing framework, which can process huge amount of trajectory data in parallel and efficiently, and can use cluster computing power to significantly improve the efficiency of trajectory processing. The comprehensive application of emerging cloud computing is diverse, providing solutions, speed and efficiency for massive data processing. Literature [25] takes road traffic as the research direction, and comprehensively examines the method of modeling by car data as the data source through big data technology, then elaborates the current mainstream road network matching algorithm based on Hidden Markov Model.

5.2.3. Prospects of future technologies. Through the successful performance of the above machine learning in certain fields and the corresponding mature big data technology, it can be expected that the ship traffic flow simulation based on AIS data is feasible. The specific reasons are as follows: for the large number of ships in the sea, the level of AIS data generated by ships equipped with AIS equipment. Both horizontal data and vertical data can meet the data volume requirements of machine learning, which will make the results more accurate. The AIS data contains ship’s speed, ship’s position, and so on. Making use of the time and space of the data, it can be associated with a lot more of the heterogeneous data [26]. Then by the convolution of neural net technology, it reduces the number of parameters in the relative relation of space
to increase the ability to train, to save time and to get more real results. The ultimate effect of ship traffic flow simulation is to realize automatic collision avoidance of ship model. The key lies in identifying collision risk, taking collision avoidance action and predicting navigation trajectory [27]. The identification function of deep learning and the feedback mechanism of reinforcement learning can solve these problems well.

6. Conclusions
The big data research direction has been in the mainstream of science, and it's not efficient to deal with the vast amount of data and the technical architecture and the route, but the machine learning method is able to optimize the analysis and process, and make the problem simpler. Considering that a large amount of AIS data can be obtained in the sea area with complex traffic environment, Hadoop, Spark and other machine learning tools are used to preprocess and model the data, then C++ and Java language are used to program the final simulation. It is speculated that the simulation effect can be similar to the vehicle traffic simulation based on GPS data. In the future, it is highly possible to implement ship traffic flow simulation technology based on AIS data, which needs further study.

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