Ship Agent model for traffic flow simulation in inland waterway

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Abstract. Water traffic is a nonlinear complex system, which is difficult to be described by a mathematical model. Naturally, simulation has become an important method to study it. In the simulation system, how to establish a ship simulation model is very crucial. In this paper, according to characteristics of ship’s behaviour, the Ship Agent model for simulation in the inland waterway is constructed, and the Multi-Agent simulation system is composed of these Ship Agents. As a case, the simulation system is set up based on the Monte Carlo method. The conclusion can be drawn that this Multi-Agent system can imitate the ship’s behaviour, and achieve the basic operation, such as the ship’s free navigation, overtaking, turning, collision avoidance and so on.

1. Introduction

The shipping through inland rivers is a kind of green transportation which takes advantage of the existing channel, does not occupy the land area, and has the characteristics of large traffic volume, low cost, small energy consumption and less pollution. Governments attach great importance to this mode of transportation and greatly improve the navigation condition. This leads to the increasing of ships in these channels, and the frequency of maritime accident may also be increased. Ship’s behavior need to be researched to reduce this kind of accident, evaluate navigation risk, increase transit capacity of the channels, and effectively organize and manage the inland transportation. However ship’s behavior is affected by many conditions, including human, ship, and environment and so on. It is difficult to describe the ship’s behavior with the precise mathematical model, and it is also very difficult for ship transportation to do experiment with a real ship. So many researchers choose simulations to study ship’s behavior. Among several simulation methods, the modeling and simulation based on Agent presented in the 1990s is suitable for simulating the complex system of ship traffic.

M. Numano et al. [1] develop a real-time marine simulation system based on Agent, which is composed of multiple computers. Each ship is seen as an Agent that moves along its own planned path. The system can simulate behavior of more than 200 ships at the same time. It can be applied to the evaluation of ship’s safety navigation and the arrangement of visual navigation marks. O. Vanek et al. [2] design a data-driven marine traffic flow simulation system based on multi-agent to evaluate the traffic status of ships transiting the area affected by piracies. Three kinds of Agent models are constructed: the mechanical Ship Agent, the pirate Ship Agent and the naval Ship Agent. This system can accurately simulate the global shipping mode and the distribution of pirate attacks. F. Xiao et al. [3] introduces multi-Agent technology to simulate the ship traffic system, and studies the description model, system decision model and learning mechanism of Agents.
To sum up, in essence, the ship’s behavior is the embodiment of human behavior, and their behavior characteristics are similar to those of Agent. It is very appropriate to use Agent to simulate the ship traffic flow. Ship Agents in the above mentioned literature are all applied to maritime traffic, however inland waterway traffic is more complex than maritime traffic, and so simulation based on an Agent is appropriate for inland waterway traffic. In this paper, the ship Agent model in the inland waterway is constructed according to the characteristics of Agent.

2. Feature of Agent

In the field of a computer, Agent can be regarded as the authorized “personal software assistant”. It is a kind of computer entity, also known as Agent, which can play a continuous and independent role in distributed or cooperative systems.

The concept of Agent appears in the artificial intelligence of the 1970s, and it is now applied to the complex system simulation of different industry background, such as financial system, cargo movement system, the transportation system simulation and so on [4]. Because of the large structural differences of different systems, it is difficult to adapt to these systems with Agent definition in general sense. An Agent has the following features:

1. Agent is an entity to handle matter.
2. Agent is in a specific environment, which is used to observe the environment through sensors, and the environment is acted by the effector.
3. Autonomy: this is one of the most essential characteristics of Agent. It shows that the Agent has its own computing resources and its own behavior control mechanism, and can determine and control its own behavior based on its internal state and perceived external environment information without external direct operation.
4. Social: in one system, an Agent must observe the rules of Agents’ society and can talk with other Agents in some suitable way through some kind of Agent interaction language, and cooperate with other Agents.
5. Reactivity: Agent can sense its environment and answer these corresponding events.
6. Initiative: Agent can follow the commitment to take the initiative to show the goal-oriented behavior.

In general, Agent is abstraction of some kind of actual system. It can determine and control own behavior to realize its goal in a certain environment; it can always sense the environment in which it is located; it has a plurality of ability to influence the environment and can adapt to the change of environment.

3. Multi-Agent system

With the continuous development of technology, many systems to be studied are becoming more and more large and complex. Some subsystems tend to be more and more scattered in time and space which have the characteristics of variability, interaction, intelligence and so on. For such complex systems, it is obviously inappropriate to describe them with a single Agent. So, they must be described using multiple Agents. In general, a system made up of multiple Agents is called “Multi-Agent system, or MAS”. The simulation method based on MAS involves the theory of distributed artificial intelligence and artificial life which can solve the problems of large scale and complex structure. The MAS is with the following features:

1. Interaction among multiply Agents

Interaction among multiply Agents is the most important behavior in MAS, which makes the MAS have a highly complex intelligent behavior. The interaction between agents is accomplished by some events including direct and indirect. Both direct and indirect interactions are accompanied by the sending process of messages.

2. Cooperation and coordination among multiply Agents

In MAS, if the ability of an Agent cannot complete the jobs, it needs the cooperation of multiple agents to complete it. When multiple agents are organized to cooperate with each other because of their own needs, how to coordinate with each other becomes the main problem. The easiest way to do this is to break down the jobs and allocate them to each agent.
(3) Communication among Multiply Agents

The interaction and cooperation is completed by communications in the MAS. If there are no communications, the Agent is not able to convey messages and ideas to other agents. A good communication way means that agents can conveniently convey messages. There are many ways to communicate, including direct communication, broadcast or blackboard mode, etc. [5].

Water transport is vital to the country's economic development. Ship traffic is a complex system, ship behavior is highly similar to the Agent, and so it is very suitable to use the MAS to simulate ship traffic. [6].

4. Ship Agent Model

A ship is operated by human, and its behavior is essentially the embodiment of human behavior. Based on behavior characteristics of a ship, a ship Agent’s block diagram is described as Fig.1. Its structure is mainly composed of ship attribute, sensing module, waterway information, communication module, knowledge base, decision-making module, executing module and status updating module. The functions of each module are described as follows.

**Figure 1. Logical structure of a Ship Agent**

(1) Ship attributes

The ship attributes mainly include Maritime Mobile Service Identify (MMSI) of a ship, the ship type, the ship size, the ship speed, the course, the latitude and the longitude of a ship, and so on.

(2) Sensing

The sensing module can sense the navigable environment information. The navigable environment information mainly includes hydrological, meteorological, waterway attributes, navigational facilities, bridge attributes and so on. This information are collected and stored in the database. During simulation, Ship Agents obtain the corresponding information from the database through the sensing module.

(3) Waterway information

The navigation tracks of different ships in the waterway are different and have random characteristics. According to the distribution characteristics of the tracks, the navigation trajectory points of the ships are connected successively to form the route of the ship. These points are generated and stored in the database. After the Ship Agent is generated, the point data are read from the database and are sent to the waterway information module.

(4) Communication
When a Ship Agent encounters other Ship Agents in the course of navigation, it should take avoidance measures to prevent occurrence of collision. The Ship Agent needs coordination with other Ship Agents before it makes collision avoidance decisions. So there is a need for an interaction mechanism among these Ship Agents. According to the characteristics of ship interaction, the communication mode of “Blackboard” as shown Fig.1 is used to realize the interaction among Ship Agents. During communication, the Ship Agent can write information to the Blackboard through communication module, and can also read the required information from the Blackboard. In this way, the interaction among Ship Agents can be realized.

(5) Knowledge base
The information related to navigation of ships is stored in the knowledge base. The information mainly includes the traffic rules for the navigation of ships in inland waterways and other rules: for example, collision avoidance of ships, free navigation, overtaking and following of a ship and so on.

(6) Decision-making
The Ship Agent combines the external environmental conditions, route information and its own status information, through reasoning, to determine the next navigation behavior, such as: straight line navigation, turning, deceleration, acceleration, free navigation, overtaking and following and so on.

(7) Executing
The Ship Agent carries out the navigation plan determined by the decision control module, sails step by step along the route, reaches the end of the route, and end the voyage.

(8) Status updating
After the Ship Agent performs one Time Step during simulation, it will update its own status information: speed, heading, position and so on, and write the information to the Blackboard and the data base.

5. Simulation

5.1. Steps of simulation
Ship traffic is a discrete event system. Characteristics of ship traffic flow obey random distribution. In this paper the Monte Carlo method is used to realize the simulation of ship traffic flow. The simulation process flow chart is shown in Fig. 2. The main steps are as follows [7]:

![Flow chart of simulation for ship traffic flow](image-url)
Step 1: Problem description. The problem researched is analyzed and described in detail in order to
determine the research goal, the modeling method and the simulation software.

Step 2: Collection and processing of historical data. Through the investigation of the actual traffic
flow, relevant parameters of traffic flow, such as ship type, speed and arrival rule, are obtained. The
statistical analysis of these data is carried out to obtain their probability distribution.

Step 3: Establishing simulation model. According to the above probability distribution of traffic
flow, ship generation model, traffic flow generation model and collision avoidance model are
established. In this paper, the Multi-Agent method as section 3 is used for collision avoidance.

Step 4: Programming and verification.
Step 5: Designing simulation experiment and running.
Step 6: Verification and evaluation. The simulation results are analyzed and the reliability of the
model and simulation is evaluated.

5.2. A case of simulation

In this work, the Wuhan section of the Yangtze River is taken as a case for simulating ship traffic.
Wuhan city is located at the middle of the Yangtze River. In the about 30 km section of the Yangtze
River crossing the urban area, six bridges constructed from the 1950s are spanning over the river.

The steps of simulation are as section 5.1 and all ships are look as Agents. The simulator is based
on VS 2012 platform, the programming language is C, the data management is SQL Server 2012, and
the Inland Electronic Navigation Charts (IENCs) is used as the display background.

Output of the simulator is described as Fig. 3. In Fig. 3 the simulation ships are moving on the
bridge area waterway of the First Yangtze River Bridge in Wuhan. The ships move in the inland river
complying with the traffic rules and are able to avoid collisions.

![Figure 3. Output of the simulator](image)

6. Conclusion

In this paper, according to the characteristics of the ship’s behaviour, the Ship Agent model in the
inland waterway is constructed, and the Multi-Agent simulation system is composed of these Ship
Agents. As a case, the simulation system is set up based on the Monte Carlo method, and The
conclusion can be drawn that the above system according to the Multi-Agent can imitate the ship’s
behaviour, and achieve the basic operation, such as the ship’s free navigation, overtaking, turning,
collision avoidance and so on.
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