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Research on VTS system by using the digital twin technology

1 SUMMARY

In response to the growing demand of VTS users and the development of intelligent shipping, China Maritime Safety Administration has actively explored the construction of a new generation of intelligent VTS systems with accurate perception, intelligent early warning, and support for advanced decision-making, and successively deployed a large number of multi-functional sensing devices in important waters, key waterways and other navigable environments. Digital twin models were established for navigation factors such as channel water depth, bridges, navigation obstacles and navigational AIDS, and three-dimensional simulation technology was used to form a three-dimensional virtual simulation VTS system monitoring platform by integrating underwater terrain, flow velocity and landform data of the channel. Through AI technology and traffic flow theory, ship collision avoidance model, flow field simulation in key waters, regional traffic flow situation inference and other early warning and judgment simulation and decision-making auxiliary mechanisms are established to complete the functions of maritime navigation risk early warning and regulatory decision-making assistance. In addition, focusing on the interaction between human (VTS duty personnel), computer (VTS system) and ship (ship and crew), through the use of simulation, AI, 5G and other technologies, and the deep integration of the ship traffic management platform, the human-computer-ship interaction platform of the VTS system is established for simulation evaluation, online judgment and auxiliary decision-making, and is constantly optimized according to actual needs, so as to maximize the functional objectives of navigation support, assistance and advanced decision support services.

1.1 Purpose of the document

The purpose of this document is to introduce the research on vessel traffic service (VTS) system by using the digital twin technology, so as to support and encourage more competent authorities of States parties to participate in exploring more applications of the digital twin technology in the field of VTS, further promote the development of emerging technologies related to “future VTS”, and create a more complete new generation of intelligent VTS systems that match the era of intelligent shipping.

1.2 Related documents

VTS53-6.3.6 New VTS Task Register 2023-2027

2 BACKGROUND

With the development of artificial intelligence, Internet of Things and big data technologies, the shipping industry has ushered in a new era of digital transportation and intelligent shipping, where new shipping

formats such as "digital ports", "smart waterways" and "smart ships" are mushrooming and bringing about revolutionary transformation in the field of maritime supervision and control. As an important functional department of maritime traffic safety supervision, the basic structure, processing model, calculation method, function and equipment performance of the traditional VTS systems are mostly designed based on the technical conditions and user needs of more than ten years ago, which cannot fully cope with the growing needs of VTS users and shipping development in the future. Therefore, based on the above problems and the description of emerging trends of “future VTS”, technologies and practices related to navigation support and assistance, and advanced decision support services, it is urgent for relevant competent authorities to break through the bottleneck restricting the development of VTS and promote the implementation and coordination of VTS with the construction of digital transportation and intelligent shipping. Since 2019, China has actively explored and practiced the application of the digital twin technology in water transportation organization, ferry operation, port management, waterway construction and other related fields.

3 METHODOLOGY

The purpose of VTS in the Guidelines for Vessel Traffic Services (resolution A.1158(32)) is defined as following: “contribute to the safety of life at sea, improve the safety and efficiency of navigation and support the protection of the environment within a VTS area by mitigating the development of unsafe situations through: 1.providing timely and relevant information on factors that may influence ship movements and assist onboard decision-making; 2.monitoring and managing ship traffic to ensure the safety and efficiency of ship movements; 3.responding to developing unsafe situations.” Based on the above statement, a new VTS system relying on the digital twin technology platform has been designed, through making full use of physical models, sensor updates, operation history and other data, integrating multi-disciplinary, multi-physical quantities, multi-scale, multi-probability simulation process, completing mapping in virtual space, establishing water traffic digital twin model based on water traffic information perception, numerical simulation and visual simulation, realizing the simulation, monitoring, diagnosis, prediction and control of water traffic, helping solve the complexity and uncertainty in the closed-loop process of traffic planning, design, construction, management and service, and improving the effective allocation of traffic resources and the safety of operation status.

The new VTS system has a stronger information perception ability and higher degree of functional integration. It has intelligent transportation functions such as automatic all-weather monitoring, real-time information service, navigation situation deduction, traffic organization suggestions, early warning feedback processing, and accident risk decision-making suggestions. In line with the above-mentioned VTS purposes, its functions can be divided into three modules: information perception, early warning management, and interaction between humans, machines, and ships. The new VTS system can greatly reduce the development of unsafe conditions in the area under VTS coverage, promote the safety of life, improve the safety and navigation efficiency of water transportation, and support environment protection, and build an intelligent VTS management model that meets the requirements of safe, green, and intelligent shipping development.

3.1 Information perception

Through the seamless integration of real-time navigation information perception, mathematical model of ship traffic and three-dimensional modeling of waterway environment elements, the new VTS system uses powerful 3D scene rendering ability to realize the visualization of the digital twin model of water traffic, and more intuitively displays ship navigation dynamics and navigation environment, which helps VTS personnel fully obtain the timely and relevant information that may affect ship motion and support ship decision-making.

Taking the Jiangsu section of the Yangtze River as an example (see Figure 1). It can realize the accurate perception and real-time dynamic update of the navigation elements information of land and water such as water depth, bridges, underwater obstructions, aids to navigation on water, hydrology and meteorology, wharf layout, berth level, ships, emergency resources, navigation and berthing rules. Based on the real-time display of the ship's position, speed and heading, the system can display the ship's traffic operation status, regional traffic flow, real-time monitoring of aids to navigation, dynamic tracking of water environment and

other information through simulation and visualization functions, helping VTS personnel on duty to more deeply control and understand the overall situation of water transportation safety and navigation and the support and protection of water environment.

Figure 1: Digital twin visualization model

Taking the waters of Qingdao port as an example (Figure 2 and Figure 3), Through digital simulation, information such as channels, harbor pool waters, berth data, ships, navigational aids, hydrometeorological date, emergency resources, navigation and berthing situation can be animated in 3D Simulation and displayed in real time. in addition, VTS operator can visually grasp dynamic information, such as ship navigation dynamics, meeting situation, berthing and departure plans, etc. Digital twin technology is an effective supplement to radar and AIS, and represents the development direction of multi-function and multi-data fusion display of VTS in future.

Figure 2: Navigation Simulation

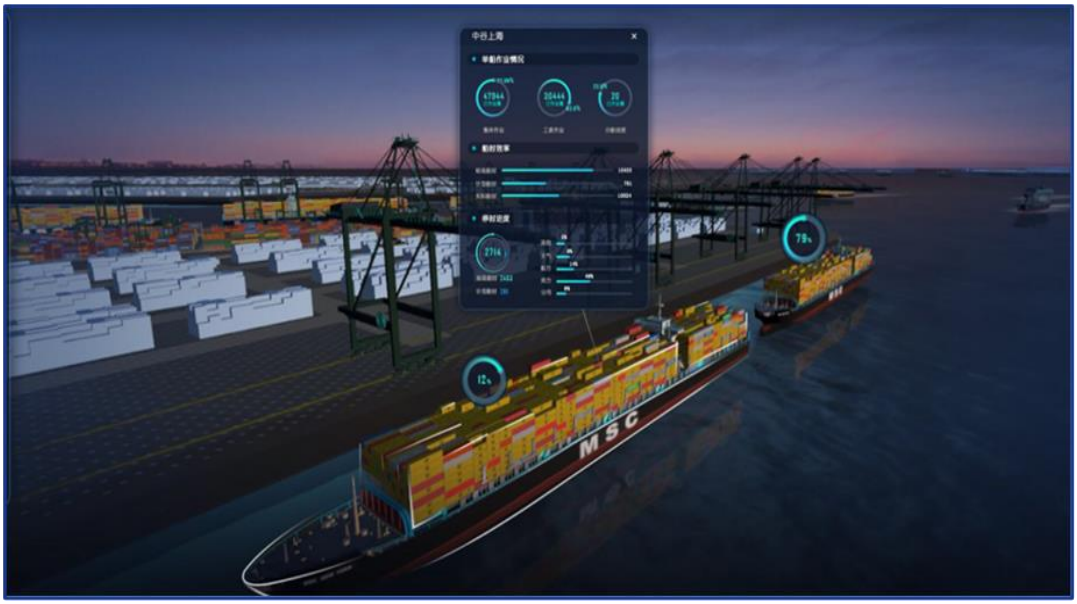

Figure 3: Berthing Simulation

In addition, in view of the low visibility environment at night in the Yangtze River Basin, an intelligent ship visual perception system integrating ship-side radar, AIS equipment, starlight camera, thermal imaging camera and other equipment is established to realize the intelligent identification and tracking of surrounding ships, navigation marks, bridges and other navigable targets, and provide a three-dimensional virtual simulation channel to guide ships to sail safely. In light of the massive and complex source data of the Yangtze River water transportation, the new VTS system incorperates an industry data governance system, establishes a spatial database of multi-source heterogeneous massive data, and completes the collection and processing of water level, terrain, navigation mark, AIS and video data.(see figure 4)

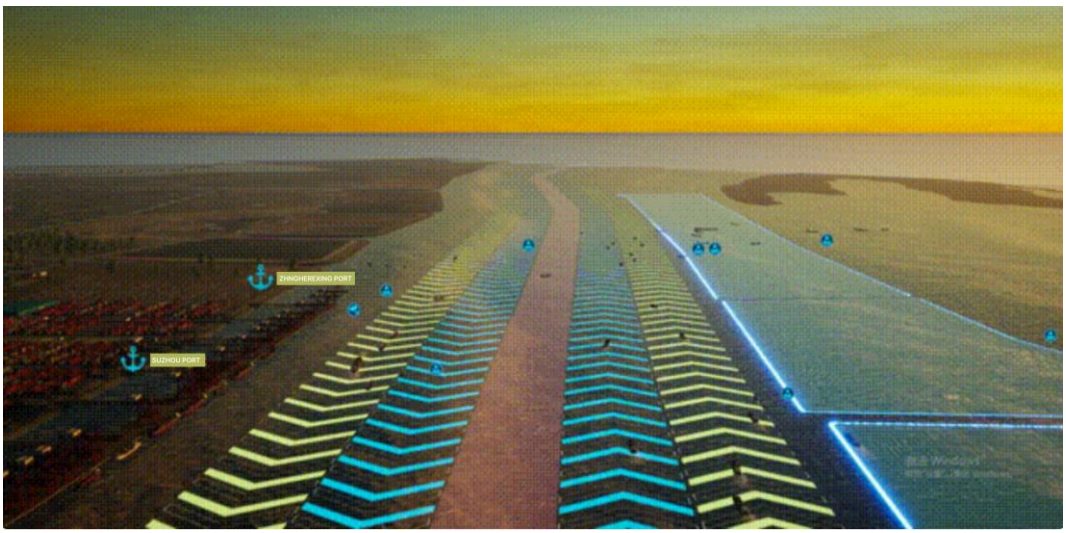

Figure 4: 3D Virtual Simulation Channel

3.2 Early warning management

Based on the realization of information model visualization, the new VTS system utilizes the AI technology and traffic flow theory to identify the operation risk and safety risks of water traffic in real time, and further analyze the cause and mechanism of the problem, so as to realize early warning management, assist in the supervision and management of ship traffic, and ensure the safety and efficiency of ship navigation.

In the traffic flow analysis of the intelligent waterway, the new VTS system can process the perception information, and can quickly obtain the operation situation of the regional navigation environment at the

macro level, and locate the trajectory-level ship behavior data at the micro level. The early warning management mechanism of the system obtains the dangerous prediction judgment result through the mutual verification of the dangerous situation deduction and the setting standards of navigation, berthing and collision avoidance rules, and then timely feeds it back to the ship or relevant departments and users to assist with traffic control, port operation scheduling, safe operation of crossing area, etc. In addition, the system will also collect water level, water depth, velocity and direction data online, taking into account supercomputing resources and big data analysis, study the accurate simulation of the flow field in key waters, and provide users with real-time warning of water navigation risks such as bad flow patterns and high velocities, and assist decision-making for berthing.

For instance, on the basis of the traditional DCPA and TCPA technologies and ship-side application, the new VTS system sets up a ship collision avoidance model that is more applicable for busy waters such as port areas and ferry areas, and provide risk warning for encounter scenarios (chase, encounter and cross encounter), taking into full consideration the requirements in *Regulations for Preventing Collisions at Se*a, ship line size, ship maneuverability and speed and other factors. (see figure 5)

Figure 5 : Collision warning system for ferries in ferry waters

3.3 Interaction between human, machine and ship

Focusing on the interaction between human (VTS duty personnel), machine (VTS system), ship (ship,crew), the VTS system technology system of online judgment, control optimization and simulation evaluation is established to cope with the evolving safety issues, using simulation, AI, 5G and other technologies, and the deep integration of ship traffic management platform, realize the transformation of water traffic digital twin application mode from problem identification to cause analysis, from situation development to scheme pre-evaluation, and from offline decision-making to online optimization.

The interaction between machine and ship is to achieve real-time tracking of ship signals, deduction of navigation trajectory situation, real-time injection of control events, self-learning of traffic flow simulation parameters, self-calibration, decision support for deduction and judgment, etc in the VTS system.

The interaction between human and machine means that the VTS system intuitively and quickly displays the daily operation supervision and decision support information such as the operating status of the system and the navigation environment of the jurisdiction to the personnel on duty via the human-computer interaction interface. When encountering situations beyond the scope of the system's autonomous judgment, such as early warning feedback, dangerous accidents, etc., the personnel on duty will be reminded to intervene in time. At the same time, the system supports the hierarchical processing of events, and processes key alarm

information according to the priority of the event to assist the staff on duty in making quick decisions. (see figure 6)

The interaction between man and ship exists in artificial active intervention and passive intervention, which can be roughly divided into two forms: passive intervention of VTS duty personnel when the interaction between machine and ship cannot form a closed loop and active intervention of duty personnel out of work needs.

Figure 6: Collision risk alarm and decision support function

4 CURRENT DEVELOPMENT AND FUTURE OUTLOOK

China has completed the active exploration and practical application of the digital twin technology in some sections of the Yangtze River waters to date, such as intelligent formation of ships in complex sections, automatic warning of ship collision prevention in bridge areas, channel maintenance and traffic flow monitoring, intelligent operation of ship locks, panoramic display of port and navigation environment, three-dimensional digital map, water ecological monitoring, accident investigation, etc. Furthermore, China is looking forward to strengthening the research and application update of new technical means such as the Beidou Satellite, unmanned vehicle, maritime autonomous surface ship (MASS), passive radar, millimeter wave, phased array, etc. in the future, so as to enrich the means of information perception, expand the scope of supervision, enhance the accuracy of positioning, and shorten the network delay.

Therefore, the future digital twin VTS system pursues richer means of information perception, higher accuracy, more complete single-ship trajectory tracking and traffic flow model construction, stronger situation deduction ability, lower error rate, and more scientific judgment and decision-making mechanism. It is necessary to consider all waters, all objects, and all elements, iteratively optimize AI models, improve the autonomous learning ability of artificial intelligence, realize modeling of various navigation behaviors, perform visualization calculations, and provide advanced decision support services to achieve the best management and control safety goals and efficiency.

5 REFERENCES

VTS53-12.2.7.1 Attachment - Future VTS Discussion Paper

6 ACTION REQUESTED OF THE COMMITTEE

The Committee is requested to note the above information about the VTS system using the digital twin technology.