Research on the path of artificial intelligence to empower intelligent port upgrading and transformation

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ABSTRACT: As the key nodes of the global comprehensive transportation network, ports play a pivotal role in global trade and shipping. With the progress of artificial intelligence technology and the promotion of intelligent port development concept, intelligent port will be the inevitable trend and choice of all countries in the world. This paper analyzes the application status and problems of artificial intelligence in promoting the construction of smart ports, discusses the typical application of artificial intelligence in the intelligent port upgrading, and details the practical application of artificial intelligence in the construction of intelligent port, including container electronic tags, unmanned driving technology, intelligent ship stowage, and intelligent port scheduling. Finally, the corresponding optimization countermeasures of intelligent port are put forward.

1 INSTRUCTIONS

In January 2017, the Ministry of Transport of China issued the Notice on Carrying out Intelligent Port Demonstration Project, vigorously advocating the construction of "intelligent port" and seeking port transformation and upgrading. Ports around the world are being transformed by artificial intelligence. To date, 34 automated or semi-automated container port have been built around the world, according to public data. There are only 13 fully automated terminals, which are mainly distributed in Europe and America with high labor costs [4].

Intelligent port construction is the concept of remote automation of port machinery. It is not that there are no operators, but operators remotely control various mechanical equipment in the background. The global artificial intelligence port is to realize the artificial intelligence cargo handling from gate to landing bridge, the artificial intelligence transformation of port machinery, the horizontal transportation of unmanned containers, and the full coverage of the terminal operation system, to fully realize the human-like intelligence. At present, Artificial intelligence is widely applied in the overall layout of intelligent ports, loading and unloading process, intelligent gate, yard coordination, unmanned driving and "5G" technology application, enabling the upgrade and transformation of intelligent ports [2].

2 DEVELOPMENT STATUS AND PROBLEMS OF INTELLIGENT PORT POWERED BY ARTIFICIAL INTELLIGENCE

In 2021, Chinese ports handled 15.5 billion tons of cargo, a net increase of 1 billion tons over 2020, equivalent to an increase of roughly 1.5 Shanghai seaports a year. In 2021, the port container throughput of China is illustrated in Figure 1 [3]. The port cargo handling capacity is steadily rising, and it is expected that the port throughput of China will continue to grow steadily in 2022. With the increase of port cargo handling capacity, upgrading the efficiency of cargo handling and transportation has become the key to port management.

Taking Chinese ports as an example, although China has accumulated some experience in the construction of smart ports, there are still some gaps and deficiencies compared with developed countries. At present, there are mainly four problems in the upgrading of smart ports:

First of all, one of the biggest problems in the upgrading of intelligent port is the pressure of construction cost. Take a port with an annual container throughput of 2 million TEU as an example. The construction investment of the existing automated wharf is generally more than CNY 1 billion, and there are special building materials for supporting later use, resulting in high

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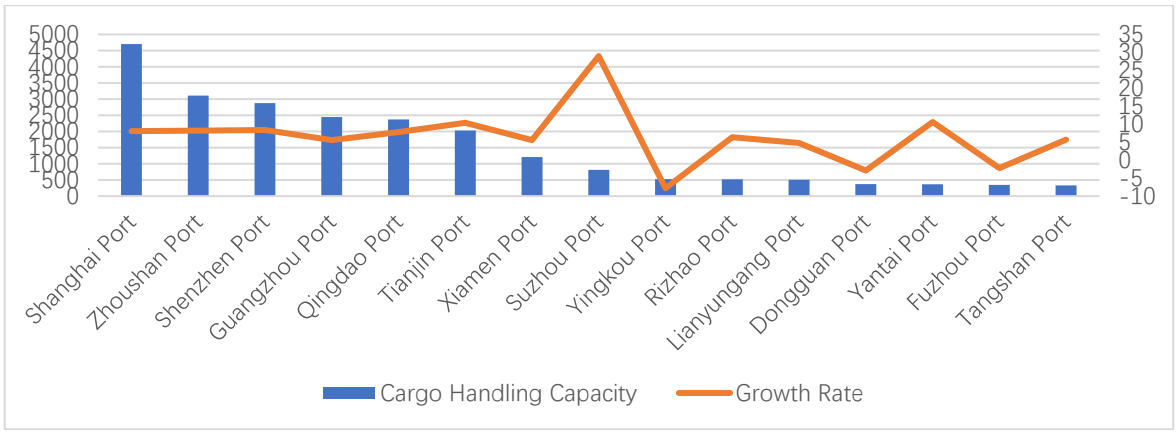

Figure 1. Top 15 Chinese ports in cargo handling capacity in 2021 (Unit: ten thousand TEU)

construction costs [3]. Comparing to high investment, the loading and unloading income is relatively low, resulting in a long investment return cycle, which made investors be cautious about this.

Secondly, due to the limitations of intelligent transformation technology, if the ports currently in operation want to carry out major transformation, they need to completely stop work for upgrading and reconstruction, which is also a tricky problem in actual operation.

Finally, the mechanism of transformation of scientific and technological achievements and application shall be innovated, which improve the industrial chain.

3 TYPICAL APPLICATION OF ARTIFICIAL INTELLIGENCE IN INTELLIGENT PORT

The intelligent port system platform includes intelligent information comprehensive processing system and data collection and comprehensive processing of inland collection and distribution, port wharf, storage, port supervision, waterway transportation and other related nodes. Therefore, the intelligent port platform can be divided into three levels. The bottom layer is the information collection part and the sensing terminal, the middle layer is the comprehensive system for processing the collected information, and the top layer includes the information release and decision support system. Intelligent port system platform structure is shown in figure 2, intelligent port platform shall set in each job site of the port, such as the wharf, warehouse storage area, transportation facilities and so on. Based on intelligent port platform, the following part respectively details on container electronic tags, unmanned driving technology, intelligent ship stowage, and intelligent port scheduling.

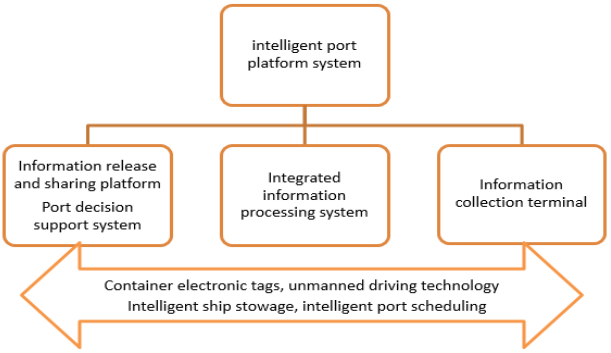

Figure 2. Intelligent port system platform structure

3.1 Container E-tag

Intelligent container generally refers to the addition of multiple active electronic tags to external and internal devices. This type of electronic tag can combine with GPS technology. when the container state changes, it can transfer the time, place and surrounding environment information to the machine of the cargo owner or the management personnel in real time, so as to realize the real-time tracking of the container. The breakthrough of artificial intelligence computer vision and deep learning algorithm can realize the autonomous identification of container number, improve the efficiency and accuracy of container number identification, and further realize the functions of unmanned intelligent gate and unmanned intelligent lifting in the port area on this basis [7].

At present, intelligent container system has not been really widely used. Taking the door-to-door mode of international ocean container transport as an example, existing systems and equipment need to be added and transformed if it is to be promoted. The operation process of intelligent container system is shown in the below figure 3.

Figure 3: The operation process of intelligent container system

Relevant statistical data show that when artificial intelligence is introduced into port container operations, the identification accuracy of container number is close to 100% [7], which is of great help in many links of logistics

chain such as container processing efficiency, inspection damage, and tally data collection and so on.

3.2 Unmanned driving empowers the construction of intelligent port

With the development of artificial intelligence technology, the application of automatic driving and unmanned driving of port gathering and distributing equipment is more and more extensive, such as the application of unmanned intelligent trans-vehicle and unmanned collecting card [6].

In December 2017, the world's first Intelligent Guided Vehicle (IGV) made its debut in Zhuhai Port, China, marking a major breakthrough in smart port construction by relying on artificial intelligence technology. The path planning of IGV can refer to the ant colony algorithm. Place IGV with the quantity of N at the starting point S. For each IGV, the current node is taken as the center, and it goes to the next node according to certain rules, and the path fitness of each truck is evaluated [8].

It is assumed that $M_{ab}(t)$ is the pheromone concentration on the path (a, b) at time t. Initially, the pheromone concentration on each path is equal, so $M_{ab}(0)=C$(C is a constant). Q_{ab} is the heuristic information for path (a, b), which is subject to the questions. In formula $Q_{ab} = \frac{1}{/|d_{ab}|}$, d_{ab} shows the distance of path (a, b) [5]. The probability that truck K, located at intersection point A at time t, chooses intersection point B as the target point can be expressed by the following mathematical expression:

$$\rho_{ab}{}^{k}(k) = \begin{cases} \frac{M_{ab}{}^{x}(t)Q_{ab}{}^{y}(t)}{\sum_{b\in allowed} M_{ab}{}^{x}(t)Q_{ab}{}^{y}(t)}, & b \in allowed \\ 0, & otherwise \end{cases} \quad (1)$$

In the formula, x≥0 and y≥0 represent information heuristic factor and expectation heuristic factor respectively. Allowed Indicates the nodes that truck K allows to select in the next step. Its value is affected by the actions of truck K. After m moments, the truck completes a cycle. Pheromones left on the path will be updated as the cycle progresses. Pheromone concentration on each road section should be updated according to the following formula:

$$M_{ab}(t+m) = \rho Q_{ab}(t) + \Delta M_{ab}(t+m) \quad (2)$$

According to the pheromone concentration renewal strategy [5], there are three different forms: (1) IGV-Cycle System

$$\Delta M_{ab}^{k} = \begin{cases} \frac{W_1}{J_k}, & \text{If IGV k pass the ab in the cycle} \\ 0, & otherwise \end{cases} \quad (3)$$

(2) IGV-Quantity System

$$\Delta M_{ab}^{k} = \begin{cases} \frac{W_2}{d_{ab}}, & \text{If IGV k pass the ab in the cyle} \\ 0, & otherwise \end{cases} \quad (4)$$

(3) IGV-Density System

$$\Delta M_{ab}^{k} = \begin{cases} W_3, & \text{If IGV k pass ab} \\ 0, & otherwise \end{cases} \quad (5)$$

In above formula, W_1, W_2 and W_3 is constant that show pheromone concentration, J_k is the length of the path through the loop.

3.3 The application of artificial intelligence in intelligent ship

Container ship stowage is a complex, comprehensive and high technical work, which requires high comprehensive quality of operators. The stowage quality of container ships directly affects the efficiency of loading and unloading operations and the safety performance of ships [9]. Ship stowage is the area that can be more predictable, where current AI technology can add "great value." The artificial intelligence algorithm is used to simulate the idea and method of container terminal stokers, and automatically stow the containers destined for the exit to the target ship.

According to the regulations of ship transport management, ship transport is limited to the use of special transport ships, currently mainly using international standard cabin 20ft, 40ft for stowage [1].

In order to facilitate the stowing of ship cabin group, ship cabins are numbered, and the number of 20ft cabin is defined as m =1,2... .,m, 40ft tank number is n=1,2..... , n, and N≤M. or less shipping weight calculation formula shown by the following formula:

$$T = \frac{\left[S_0 t_0 + (W_1^{20} + W_2^{20})\frac{t_{20}}{2} + W_n^{40}\left(t_{20} + t_c + \frac{t_{40}}{2}\right)\right]}{S_0 + W_1^{20} + W_2^{20} + W_n^{40}} \quad (6)$$

In the formula, S_0 and t_o respectively represent the dead weight and the height of the center of gravity of the empty cabin. W_m^{20} represents the weight of 20ft cabin M. The t_{20} and t_{40} represent the height of the two cabins respectively, W_n^{40} represents the weight of 40ft cabin N. The tc represents the thickness of the bulkhead between the two cabins. Poor bearing is expressed as the following formula:

$$\begin{cases} S' = f\frac{W_2^{20} - W_1^{20}}{d} \\ W_n^{40} - W_1^{20} - W_2^{20} < 0 \end{cases} \quad (7)$$

d is the center distance of bearing during ship sailing. Based on the stowage parameters selected above, the stowage optimization model of ship cabin group was obtained with the minimum sum of the height of ship's center of gravity as the objective and safety factor as the constraint condition as below formula [10]:

$$\begin{cases} min \sum_{k=1}^{K} T \\ \sum_{m=M}^{M} A_{mi} W_m + \sum_{n=N}^{N} A_{ni} W_n \ll \tilde{S} \\ \sum_{m=M}^{M} A_{mi} W_m - \sum_{n=N}^{N} A_{ni} W_n > 0 \\ \acute{S} \leq \frac{10t}{d} \end{cases} \quad (8)$$

In the above formula (8), A_{mi}, A_{ni} respectively two kinds of weights of tank, W_m and W_n is the total weight of two kinds of tank respectively, S shows the capacity tonnage of the ship. The above process is the construction of the stowage optimization model of the propagation pod group, which provides model support for the artificial intelligence algorithm.

4 CONCLUSIONS

The construction of smart port is a long-term and continuous task. With the development of social needs and technological progress, the connotation of intelligent port is continuously augmented. At the same time, in the process of development, we should also actively promote the establishment of smart port construction standard system and evaluation system. This paper analyzes the application status and problems of artificial intelligence in promoting the construction of smart ports, and discusses the typical applications of artificial intelligence in the construction of smart ports, such as electronic container labels, unmanned driving, smart ship stowage etc.

For enterprises, different ports have different social, economic and natural environments. Therefore, port managers need to make the application of artificial intelligence technology fit the port business objectives according to their own conditions. Port production operation, as a sub-industry scenario of artificial intelligence, has high professional barriers. Those with artificial intelligence technology and a deep understanding of the actual port scenario will be the leaders in the application of technology in the field. At the same time, terminal operators need to build a resourceful, innovative and AI-capable work team. Ports need to integrate superior resources and coordinate the introduction of technical talents for "chain" linkage development, so as to make full use of the power provided by artificial intelligence.

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