PortML and Smart Port Framework Solutions

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The technologies and research related to smart ports can be classified into the following four categories: (1) Device communication, (2) Info visualization, (3) Digital model, and (4) Analytics algorithms. Let's talk about our views on these four aspects.

1. **Device communication**: To solve the issue of automation and remote control directly. The most technical aspects of equipment, such as AGVs and unmanned cards, automated/remote control of shore bridges and field bridges, including autonomous ships or automatic customs clearance. Along with it, IoT sensors and network communication technologies, such as WIFI, Near Field Communication (NFC) and LTE / 5G, solve the problem of state detection and command transmission between automation equipment and control system. This type of technology developments is mainly aimed at the autonomous port and reducing labor costs. Equipment and communication technology are prerequisites and necessary conditions to establish an intelligent port. However, its working principle is based on the established protocol in strict accordance with the instructions passed in, and therefore does not have a "wisdom" factor.
2. **Info visualization**: To provide intuitive graphical and digital information for operations management and decision makers at the port. Presentation formats include data charts, two-dimensional flat displays, three-dimensional displays, virtual reality, augmented reality, and mixed reality technologies. Similarly as previous, the presentation technology itself does not involve the “wisdom” factor, as it only shortens the distance between people and equipment, and reduces the time and space cost of observation decisions.
3. **Digital model**: To digitally describe the configuration design and operational status of the port. The model includes two types, first is the **data model**, which is used to structure the data collected by the communication into an entity relationship/ stored as a temporary spatial sequence for later query and analysis. The second is the **interaction model**, which is used to simulate the evolution rules of physical systems (such as discrete event simulation), which can be used to predict future scenarios and data and make timely response decisions. The digital model is the key foundation of "smart decision-making", which is equivalent to "memory" and "logic" in the brain.
4. **Analytics algorithms**: To make sense of the information in the model and optimize the decision. For example: how to assign berths, allocate yards, dispatch vehicles, etc. Like the thinking process of the human brain, the analytics algorithm is the core of the port's "wisdom." From shallow to deep, from easy to difficult, the level of analytics algorithms includes: performance measurement, heuristic construction, sorting selection, search optimization, and reinforcement learning.

According to our preliminary understanding, the European ports have made considerable progress in all four aspects, and their shortcomings may exist in:

(1) The latest automation equipment and communication technology

(2) The latest virtual, enhanced and mixed reality interactive technology

(3) High-precision data and interaction model (high-precision simulation model)

(4) Sorting selection, search optimization, and enhanced learning algorithms

In comparison, the shortcomings of ports in other developing regions may be:

(1) Basic or advanced automation equipment and communication facilities

(2) Real-time chart analysis and 3D rendering capabilities

(3) Basic data and interaction models

(4) Basic performance measurement and heuristic construction algorithm

Compared with ports in developed regions of Europe, ports in developing regions have high throughput and large numbers, and key technical difficulties are different. In order to increase the “wisdom” of these ports, it is advisable to design a sustainable and expandable smart port ecosystem and technology framework, as compared to adoption of a capital & technology intensive development approach for a single port. It is hoped that with this system framework, we can effectively learn from the experience of developed ports in Europe, create a healthy "smart" co-operative model. This could potentially stimulate the enthusiasm of researchers, protect intellectual property rights, and improve the intelligence of regional port groups in general.

From the time dimension, we can also draw similar conclusions. Referring to the road map for the development of human intelligence, we can conclude that "intelligence" is not a one-step process, but a step-by-step process. At the beginning of system design, the most important issue to consider is not to seek the best analysis or optimization algorithm, but to build an adaptive system that can be continuously updated, transplanted, hybridized, and evolved. In this way, we can provide a test improvement environment for excellent algorithms, find the best matching solution for the unique problems of various ports, and can continuously upgrade the system's intelligence by learning from convergence.

The key to building this "smart" system is "Standardization". Only when the interactive interface is defined, the algorithm researcher can deeply explore the actual problem, compare and improve the solution; only when the interactive interface forms a certain standard, the algorithm research work can achieve large-scale benefits, and form an ecosystem, let various intelligent algorithms in the system interacts and achieve improvements in individual performance. Through standard interfaces, physical and digital components can be seamlessly connected in a variety of combinations, forming digital twins that can be parallel to the real physical world, greatly accelerating the evolution and improvement of smart algorithms.

For the "standardized smart port system" architecture, C4NGP fits the roadmap developed by MPA, proposes using PortML (Port Markup Language), combines O2DES modeling paradigm, and describes the static attributes and running of each component of the port in a hierarchical structure. Under this concept system, the port is divided into five levels of hierarchical structure, including more than twenty functional modules that follow the information interaction protocol each correspond to different devices, work units, or functional groups, and their associated operational control issues. With this conceptual structure, the specific needs of the “smart system” can be clearly defined, including time nodes, input information, and decisions output.

In terms of implementation, for each component that PortML describes, "smart system" can use "Microservices" software architecture and containerization to write it as a small functional block with single responsibility and function and combine complex port systems in a modular way. In this way, hardware devices, intelligent scheduling algorithms, and global operating systems (such as TOS) or local control systems (such as ECS) can be quickly tested and deployed by virtual and real replacement of a single block. Due to the continuous delivery software development process, the device can be hot swapped and the algorithm updated during the deployment process. Moreover, each intelligent module can be used as a stand-alone software from different algorithm engineers or software developers, eliminating the monopoly of a single vendor; in conjunction with it, digital twins provide a seamless test environment for systems of different software vendors. Integration testing provides an effective platform.