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Research and Application of an Intelligent, Integrated Management and Control Platform for Ore Terminals

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Abstract. With the ever-increasing demands for intelligent and green development in ports, traditional ore terminals are facing numerous challenges in operational efficiency, safety management, and environmental protection. Focusing on the full-scenario operational requirements of ore terminals, this paper develops and applies an intelligent, integrated management and control platform that incorporates intelligent scheduling, remote operation, safety early warning, and coordinated environmental protection. Based on technologies such as big data, cloud computing, 5G communication, and 3D visualization, the platform achieves intelligent, end-to-end management and control of the entire process—from ship unloading, stacking and reclaiming, and truck loading to environmental management. Practical application at the Cangzhou Huanghua Port Ore Terminal demonstrates the platform's significant effectiveness in enhancing operational efficiency, reducing operating costs, and improving environmental management capabilities, highlighting its strong potential for broader promotion.

Keywords: Ore Terminal, Intelligent Management and Control, Integrated Platform, 3D Visualization, Green Port

1. Introduction

Ports worldwide are accelerating their transformation towards intelligence and sustainability [1]. Automation technology for container terminals has reached a mature stage, whereas bulk terminals, which account for approximately 60% of China's port throughput, still commonly grapple with challenges such as low automation levels, significant environmental compliance pressures, and pervasive data silos [2]. 《The Outline for Building China's Strength in Transport》 (2019) explicitly called for "advancing the upgrade of automated terminals, digital pipeline networks, and intelligent handling equipment." Furthermore, 《The Water Transport 14th Five-Year Development Plan》 (2021) mandated the "construction of a new generation of automated terminals" and the development of a "Port Intelligent Brain."

In response to national strategies like "Building China into a Country with Strong Transportation Network" and the "Dual Carbon" goals, and to foster high-quality development in the port sector, there is an urgent need to establish an intelligent management and control system tailored for bulk

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terminals [3]. This system is essential for achieving the coordinated optimization of multiple elements, including production, scheduling, equipment, safety, and environmental protection.

This paper, using the Cangzhou Huanghua Port Ore Terminal as a case study, details the research, development, and implementation of an intelligent, integrated management and control platform for ore terminals. The objective is to pioneer a replicable and scalable smart solution for ore terminal operations.

2. Platform overall architecture and functional design

2.1. System architecture

Based on the context of smart ports, the Integrated Bulk Cargo Management and Control Platform is being further developed with a focus on the bulk cargo control system framework, integrated data platform, and the application of new technologies like big data, cloud computing, and 5G. The foundational platform incorporates a more cohesive integrated management and control system framework. This framework encompasses intelligent production, equipment management, commercial management, safety early warning, mobile applications, and 3D production operation development. Furthermore, it can integrate essential data from sources such as belt weighers, rail weighers, sampling and preparation systems, commercial inspection data, and railway information within the port area.

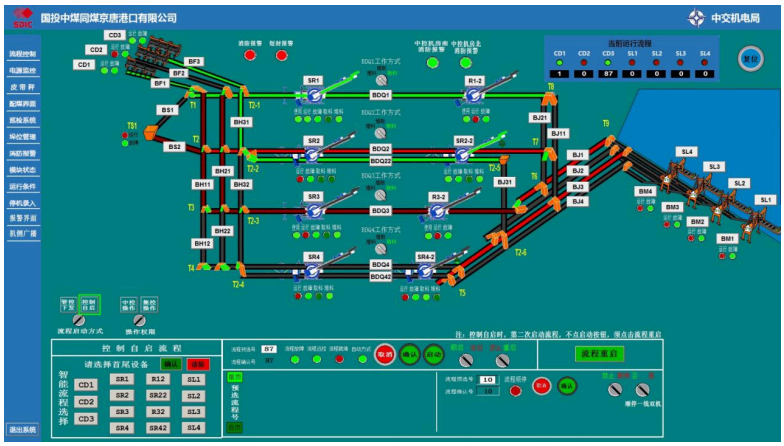
Adopting a Browser/Server (B/S) architecture, the platform realizes an open system framework characterized by a single platform with multiple functional branches. By leveraging these new technological tools, an integrated data processing platform is established. This platform effectively converges production management, equipment management, safety early warnings, and mobile applications, deeply integrating overall port operations with data. This enhances the port's intelligent level by reducing manual operations, increasing the degree of automation and remote control, and providing intelligent recommendations.

Through the construction of a five-layer architecture system—"Perception, Transmission, Analysis, Decision-Making, and Control"—the Intelligent Integrated Management and Control Platform for Ore Terminals achieves a unified data platform, a unified business portal, and unified scheduling and command.



a) Production management system

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b) Control system

Figure 1. Integrated smart port bulk cargo management and control platform

2.2. Core functional modules

(1) Intelligent Scheduling System: Utilizes AI algorithms and big data analysis to achieve intelligent optimization for ship planning, yard arrangement, and equipment dispatch.

(2) 3D Visualization System: Presents 1:1 models of terminal equipment, stockpile configurations, and operational processes, supporting real-time status monitoring and historical playback.

(3) Remote Control System: Enables remote operation and automated functions for equipment such as ship unloaders, stacker-reclaimers, and loading towers via 5G networks.

(4) Safety Early Warning System: Integrates personnel positioning, equipment anti-collision, and environmental monitoring to provide risk early-warning throughout the entire operation process.

(5) Environmental Protection Linkage System: Intelligently controls dust suppression equipment, including water sprinklers, dry fog systems, and bag filters, based on environmental monitoring data to achieve precise dust control.

3. Key technologies

3.1. Multi-source data fusion and real-time processing technology

The platform employs middleware technology to achieve deep integration of data from control systems and management systems. It supports the ingestion of multi-source data, including GPS, LiDAR, RFID, and video surveillance, enabling centimeter-level positioning and sub-second data refresh rates, which ensure system real-time performance and accuracy.

3.2. Big data-based intelligent scheduling algorithm

Leveraging an SOA architecture and ESB technology, the platform integrates resources through a data warehouse and utilizes deep learning to mine historical data, thereby constructing a self-learning "expert-assisted brain." This system enables the automatic generation and full-process simulation of schedules for unloading, berth allocation, and loading operations. To ensure precise execution of the scheduling plans, the platform employs integrated management and control interfaces, utilizing technologies such as OPC, VBA, and Transaction Manager to bridge the

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management and control networks. This establishes a bidirectional real-time data closed loop for command issuance and status feedback, forming a complete technical chain from intelligent decision-making to automated execution.

3.3. 3D digital twin and visual interaction

By establishing a high-fidelity 1:1 3D digital twin [4] model of the physical terminal, the platform deeply integrates real-time data from production control, equipment status, unmanned operations, and yard laser scanning. This enables immersive, interactive dynamic monitoring and granular management of the port's overall operational status.

3.4. Equipment interlocking and anti-collision strategy

The system utilizes individual CMS (Condition Monitoring System) to achieve data acquisition and storage, display operational status of various mechanisms, execute PLC and remote control commands, and manage fault alarm information. It establishes a "one-to-many" control strategy integrating millimeter-wave radar-based active collision avoidance and BeiDou satellite positioning system-based passive collision avoidance, thereby providing safety assurance for unmanned operations in both frontline ship loading/unloading and rear yard handling activities.

3.5. Intelligent environmental management platform

Integrating technologies including environmental monitoring, BIM modeling, and AI analysis, the platform establishes a closed-loop system of "Perception-Analysis-Decision-Control". It enables real-time monitoring and intelligent management of parameters such as dust, noise, and meteorological data, resulting in a significant improvement in environmental protection efficiency.

4. Engineering application and benefit analysis

The successful implementation of this intelligent integrated management and control platform at the Cangzhou Huanghua Port Ore Terminal has led to an increase of over 5% in cargo handling efficiency, generating approximately 18 million RMB in additional annual operational revenue. Concurrently, by adopting a one-operator-multiple-machines" remote control model, the platform has reduced annual labor costs by about 17 million RMB, achieving the dual objectives of cost reduction and efficiency improvement.

The platform's intelligent environmental protection system enables precise monitoring and intelligent suppression of dust pollution, significantly enhancing the port's green operational standards. Furthermore, through end-to-end data integration and real-time visual monitoring, it has substantially improved the refinement of enterprise management and the scientific basis of decision-making [5]. The application of the platform has yielded remarkable comprehensive results.

5. Conclusion and prospects

The intelligent integrated management and control platform for ore terminals, by integrating advanced information technologies and automated equipment, has facilitated the transition of ore terminal operations from "manual handling" to "intelligent operations." Its successful application at Huanghua Port has demonstrated the platform's comprehensive value in enhancing operational

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efficiency, reducing operating costs, and strengthening safety and environmental protection capabilities.

Looking ahead, with the continued advancement of technologies such as 5G, AI, and digital twins, this platform is expected to be promoted and implemented across more bulk terminals, thereby elevating the construction of intelligent ports in China to new heights.

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