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Enhancing Coal Mining Efficiency: A Unified Platform for Intelligent Management and Control

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ABSTRACT

Coal is a prominent energy resource for several countries. Of late, exploring the automatic management and control of coal mining has been a significant task. This article presents a framework for a mine-wide integrated automation management and control platform with the goal of advancing coal mining through unified data, models, platforms, and plans. Utilizing cutting-edge technologies, the platform offers resource management, real-time monitoring, remote control, statistical analysis, and intelligent alarm systems. Data access design ensures standardized data collection and exchange, fostering interoperability. A big data storage center manages heterogeneous data sources. The platform interface design emphasizes flexibility and scalability through containerized applications and microservices frameworks, streamlining deployment. The functional design encompasses subsystem configuration access, real-time monitoring, remote access, etc. A detailed evaluation is presented to demonstrate the significance of the proposed platform in terms of functionality, performance, and scalability.

KEYWORDS

Automatic Management and Control, Big Data, Coal Mining, Collaborative Control, Integrated Automation, Intelligent Mining, Real-Time Monitoring, Security, Unified Data

Coal mining sites have limited space and are often harsh environments because of challenges such as gas explosions, roof falls, floods, and fires. These factors significantly impede the efficient development of the coal industry. However, with the continuous improvement of machinery and equipment reliability and stability in the coal industry in recent years, the implementation of environmental monitoring systems, production process automation control systems, and safety production information systems have further enhanced the level of mine mechanization, informatization, and digital management (Nepsha et al., 2021; Wu & Zhou, 2021).

However, the level of automation and informatization in mines is still relatively low, and the foundation for intelligent construction is weak. Currently, the subsystems within the information management system of coal mining enterprises remain separate entities with a single system and a single business model (Li et al., 2020). This results in serious information isolation, insufficient business interconnectivity, limited data value extraction and utilization, and a notable gap in achieving

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intelligent, distance, and unmanned objectives. Therefore, through scientific and technological innovation, it is imperative to drive the overall enhancement of coal mine intelligence. This entails devising and designing comprehensive objectives and a general technical framework for coal mines, defining the construction technology path, establishing a scientifically grounded design and construction paradigm, and realizing various disaster prevention and control scenarios. Such efforts hold theoretical and practical significance as they ensure and enhance the effectiveness of coal mine intelligent construction.

The mine-wide integrated automatic management and control platform applies new-generation information technologies such as the Internet of Things, big data, and intelligent control to the mining field. This platform is supported by the coal industry's big data center, which integrates and manages coal mine safety, production, and operational data. Model training establishes a digital foundation for coal mines, creating centralized and unified production scheduling, collaborative management and control, comprehensive risk prevention and control management, decision analysis, and other intelligent management and control business application centers based on the intelligent mine's fundamental information platform. This leads to comprehensive perception, real-time interconnection, and intelligent management of the mine. Decision-making and collaborative control ensure the safe, efficient, green, and intelligent production and operation of coal mines (Wang et al., 2022; Ding, 2020).

The major contributions of this article are as follows:

- proposing a novel framework for a mine-wide integrated automation management and control platform;
- presenting an effective functional design for the mine-wide integrated automatic management and control platform;
- demonstrating the proposed platform through evaluations using various parameters; and
- exploring the Practical Managerial Significance (PMS) and its applications.

Compared to previous works, the proposed work focuses on the construction of a mine-wide integrated automation management and control platform to accomplish four unifications from the top-level planning, namely "unified data, a unified model, unified platform, and a unified plan." This enhances the level of automation and informatization in mines. The unification of the proposed model eradicates the existing single system and a single business model in coal mining enterprises.

The article is structured as follows: the second section discusses state-of-the-art works related to the automatic management and control platform in an entire mine. The third section provides a brief overview of the research goals for the mine-wide integrated automation management and control platform. The fourth section presents the overall framework of the mine-wide integrated automation management and control platform. The fifth section covers the functional design of the mine-wide integrated automatic management and control platform. The sixth section evaluates the proposed platform by considering various parameters. The seventh section introduces the Practical Managerial Significance (PMS) and its applications. The eight section discusses scenario-based and practical applications. The ninth section elucidates the significance of the proposed platform, its implications, and future research. Finally, the 10th section concludes the research work and outlines future directions.

RELATED WORK

Intelligent mining combines informatization and industrialization and is rooted in mechanized and automated mining methods. It has revolutionized the coal industry (Wang et al., 2016). This new technology enables automatic mining through intelligent environmental perception at the work