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# *Application and Challenge of Automation Technology in Ocean Engineering*

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***Abstract:*** As the world becomes increasingly dependent on marine resources, applying automation technology in ocean engineering is becoming increasingly important. This paper discusses the latest progress and problems of automation technology in ocean engineering. Research shows that underwater vehicle (ROV) technology and Digital Twin technology are gradually changing the way ocean exploration, construction and maintenance are done. Accurate data acquisition and real-time monitoring significantly improve operational efficiency and safety. In sustainable ocean development, automation technology not only optimizes resource utilization, but also finds solutions for environmental monitoring, such as intelligent monitoring systems created by remote sensing technology and sensor networks, which can effectively deal with the problems of Marine ecological protection. The study identifies bottlenecks including technical complexities, environmental and safety risks, and regulatory hurdles. These challenges must align with technological innovation and policy development. Future research should enhance system intelligence and autonomy while fostering technical collaboration to effectively address the complexities of the marine environment.

***Keywords:*** Marine engineering automation, Sustainable Marine development, Digital twins, Intelligent underwater robot

## 1. Introduction

Automation technology in ocean engineering has advanced significantly since the mid-20th century, particularly in deep-sea exploration, resource extraction, and environmental monitoring, underscoring its growing importance.

With the rapid development of information Technology, especially the breakthroughs in emerging fields such as "Robotics", "Sensor Technology" and "Data Analytics", the automation technology in Marine engineering has achieved unprecedented improvement [1].

With regard to technological development, the need for safety, efficiency and sustainable growth in the market is always increasing. This has prompted companies to develop various 'remotely operated vehicles (ROVs)' and 'automated unmanned surface vessels (AUVs)' to facilitate safe and efficient ocean operations. (2) Research purpose and significance

The integration of automation technology in marine engineering is increasingly vital for navigating complex marine environments and ensuring project safety. This study aims to examine the influence of automation on innovation and development within marine engineering, as well as its potential effects on sustainable marine resource management, economic growth, and environmental

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preservation. Automated systems, including unmanned underwater vehicles (UUVs) and autonomous surface vessels (ASVs), are extensively utilized in ocean exploration, data collection, and environmental monitoring, significantly enhancing operational efficiency and data precision.

This paper uses a series of systematic frameworks to ensure the proposed arguments' reliability and applicability. Review the literature in related fields, identify the key research trends and evolution, and ensure that the subsequent research can be further in-depth based on the existing results. Practically, this study provides actionable frameworks for optimizing automation deployment in ocean engineering, offering direct guidance to enhance operational safety and resource utilization efficiency. Theoretically, it bridges gaps in interdisciplinary knowledge integration and proposes a trend analysis model that advances methodological foundations for future research in marine technology innovation.

## 2. Automation technology in ocean engineering

### 2.1. Overview of automation technology

Automation technology is a critical component of modern marine engineering, significantly influencing research and application in related fields. Automation technology uses mechanization and information technology to reduce human intervention and achieve the process of autonomous operation and self-regulation of the system. Its main characteristics are high efficiency, reliability and repeatability, which promotes the development of Marine engineering in many aspects towards intelligent and networked direction.

### 2.2. Typical applications in the field of ocean engineering

#### 2.2.1. Underwater robot

As a major ocean engineering automation technology, underwater robots play an extremely important role in ocean exploration and oceanic resource exploitation [2]. Underwater robots can operate in harsh environments and withstand extreme conditions such as deep-sea high pressure and low temperatures, making them indispensable for human deep-ocean exploration. The AUV model operates at depths of 6,000 meters, enabling high-resolution exploration of seabed landforms, marine ecosystems, and mineral resources.

#### 2.2.2. Digital twin technology

The concept of Digital Twin Technology is derived from the fusion of a physical entity with its virtual mapping in the digital world to build a continuously updated, two-way interactive model. This technology can integrate highly complex data and monitor, simulate, and analyze the actual system and optimize it in real time. It has tremendous potential for application in the field of ocean engineering. For example, in Marine resource extraction and environmental monitoring, digital twin technology can remotely operate and control critical infrastructure such as subsea oil and gas platforms to achieve condition monitoring and fault diagnosis.

# 3. Sustainable ocean development and automation technology

## 3.1. The concept and importance of sustainable development

Table 1: Examples of the application of automation technology in ocean engineering

| Application field | Automation technology | Effect | Challenge |
|---|---|---|---|
| Ocean engineering | Underwater robot | Efficiently complete deep-sea exploration and facility maintenance | Reliability and adaptability need to be verified |
| | Digital twin technology | Monitor and predict security risks in real time | |
| | Intelligent management and information mean | Optimize resource allocation and reduce environmental burden | Environmental and safety issues need attention |
| Sustainable development | Support Marine ecosystem protection | | A sound system of regulations and policies is needed |
| | A new round of Sustainable Development Goal solutions | Enhance adaptability and response efficiency | Technology and policy two-wheel drive |

In the field of Marine engineering, the rapid development of automation technology has provided unprecedented efficiency and safety guarantees for various operations [3]. In various contexts, including deep-sea exploration, resource extraction, and environmental monitoring, these technologies are pivotal for enhancing operational efficiency and data precision. Notably, advancements in Marine Automation Technology have transformed human interaction with and utilization of the marine environment.

The automation of Underwater robots (underwater robots) is quite cutting-edge, and its ability to perform complex tasks in complex Marine environments has been shown. The integration of advanced sensors and data processing enables these robots to autonomously perform tasks like deep-sea exploration and facility maintenance. This makes Marine engineering work towards a higher level of autonomy and intelligence, and has obvious economic benefits in the development and utilization of Marine resources.

The implementation of Digital Twin Technology has significantly enhanced the efficiency and safety of offshore engineering projects. By establishing a dynamic link between physical marine facilities and their digital counterparts, engineers can monitor equipment operations in real time and foresee potential safety hazards. This technology not only minimizes manual monitoring errors but also improves adaptability to marine environmental changes, facilitating predictive maintenance. This has far-reaching implications for ensuring Sustainable Operations and reducing Environmental Risks in Marine operations [4].

Automation technology is pivotal in advancing Sustainable Ocean Development and offers solutions for the latest sustainable development goals [5]. Intelligent management and information technology facilitate optimal allocation of marine resources, minimizing waste and environmental impact. Additionally, automation technology enhances agility and efficiency in tackling global oceanic environmental challenges, thereby supporting marine ecosystem protection [6].

Despite the significant potential of automation technology, numerous challenges persist in its development. Technical reliability and adaptability of emerging equipment require thorough validation, particularly under extreme environmental conditions, which affects its widespread application. Environmental and safety concerns are critical, as the proliferation of automation equipment has led to frequent instances of marine pollution and ecological damage. Consequently,

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the establishment of comprehensive regulatory and policy frameworks is essential to govern the advancement of this sector [7].

The application potential and prospect of automation technology in ocean engineering are great. However, the challenges and risks it poses will be driven by technological innovation and policy development to enable ocean engineering to achieve the Sustainable Development Goals. Through systematic case analysis and data support, the understanding and application of automation technology will be deepened in the future, and a more solid theoretical foundation and empirical support will be provided for the progress and development of ocean engineering [8].

### 3.2. The role of automation technology in sustainable development

In the global trend towards resource depletion and environmental degradation, Sustainable Marine Development (SMD) is gaining increasing significance [9]. Automated Technology (AT) is crucial for improving efficiency and safety in offshore engineering, highlighting its role in sustainable development. It optimizes resource exploration and exploitation, reduces labor costs, and minimizes environmental impact.

Specifically, Unmanned Underwater vehicles (UUV) and Remotely Operated vehicles (remotely operated vehicles), ROV and other advanced equipment have become an indispensable technical tool in the exploration and exploitation of Marine resources (such as oil, gas and mineral resources) [10]. Statista (2022) indicates that UUV-based marine projects enhance efficiency by 42% and decrease environmental impact by 35% relative to traditional methods. This data underscores the potential of automation technology to optimize resource exploitation while minimizing ecological disruption, thereby offering a technical framework for the sustainable integration of marine ecology and economy.

The integration of automation technology in sustainable ocean development presents significant challenges. Small and medium-sized enterprises encounter high costs associated with technology, equipment maintenance, and operator training. Additionally, the reliability and failure risks of automation systems are critical considerations. For example, technical failures in UUV systems have resulted in project suspensions and substantial financial losses in previous offshore operations. This underscores the necessity of ensuring technological stability and security while striving for efficiency.

Automation technology also has unique advantages in environmental monitoring. Through Big Data Analytics, combined with Machine Learning (ML) and Artificial Intelligence (AI), Marine engineers can monitor changes in the Marine environment in real time. And promptly took countermeasures [11]. For example, the use of automated sensors to collect data on water quality, temperature, salinity and other relevant data to accurately assess the health of Marine ecosystems, in order to promptly warn and intervene in possible environmental risks, such as diffuse pollution.

In the area of sustainable ocean development, automation technology is both an opportunity and a challenge. Automation technology enhances resource extraction and environmental monitoring, significantly advancing sustainable development. However, companies must address cost and technical reliability challenges to realize genuine sustainable marine development. Therefore, future research should focus on how to find the optimal balance between technological innovation, economic accessibility and environmental protection, to promote the sustainable development of the Marine engineering field.

### 3.3. Case analysis

In Norway, for example, subsea automation technology in offshore oil and gas extraction has reached a high degree of automation, and the environmental impact has been significantly reduced. Equinor

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uses Subsea Production Systems (SPS) to conduct oil and gas exploration and facility maintenance through Unmanned Underwater Vehicles (UUVs). Thus, operational risks and environmental disturbances are reduced [12]. Quantitative data shows that when automation is applied, productivity increases by 30% and carbon emissions drop by 15%.

## 4. Challenges of automation technology in ocean engineering

### 4.1. Technical challenges: software reliability and system safety

At present, the application of automation technology in ocean engineering is rapidly expanding globally [13]. Despite the evident advantages, numerous technical challenges require thorough investigation and resolution. Software reliability significantly impacts the safety and efficiency of automation systems. The growing complexity of marine engineering projects depends on automated decision-making systems capable of timely and accurate responses in varied marine environments. Research indicates that real-time processing of complex data sets by software systems may expose vulnerabilities and uncertainties in algorithms, potentially leading to critical failures.

### 4.2. Environmental and safety issues

In the current Marine engineering, the promotion and development of automation technology, although it has brought a lot of benefits to improve operational efficiency and save labor costs, but at the same time, it has also brought a number of environmental and safety problems. TThe heightened contamination risk necessitates specific precautions. Advanced technologies, including deep-diving AUVs and automated mining equipment, are commonly employed. Nonetheless, these innovations may introduce environmental hazards, such as oil spills, solid waste discharge, and noise pollution. The 2010 Deepwater Horizon spill, for instance, highlighted the environmental hazards associated with the automation of marine engineering equipment. The view that inadequate environmental monitoring during automation can have serious ecological impacts is widely confirmed in the relevant literature.

## 5. Future development direction

### 5.1. Emerging technologies and trends

The future of automation in marine engineering is shaped by emerging technologies, particularly the potential of intelligence and networking. As artificial intelligence (AI) advances, automated systems increasingly depend on intelligent algorithms like Deep Learning and Machine Learning for enhanced environmental monitoring and data analysis [14]. These intelligent systems can greatly improve the accuracy of structural health monitoring and provide a scientific basis for the maintenance and management of Marine facilities.

### 5.2. Improve the prospects of automation technology

In the future of marine engineering, advancements in automation technology will present unprecedented opportunities for the industry. Strengthening interdisciplinary cooperation will undoubtedly be a key driving force behind the development of automation technology. More comprehensive and sophisticated solutions can be achieved by combining expertise from fields such as engineering, computer science, and environmental science. For instance, the use of “deep learning (DL)”and “machine vision (MV)” technology for intelligent navigation and autonomous control in marine environments can enhance work efficiency and reduce the risk of human error. Therefore, the

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integration of multidisciplinary technologies has the potential to significantly advance automation in marine engineering.

## 6. Conclusion

Automation technology has become pivotal in ocean engineering, significantly enhancing operational efficiency, safety, and sustainability. Innovations like AUVs/ROVs and digital twin systems facilitate accurate deep-sea exploration, real-time monitoring, and predictive maintenance, minimizing environmental impacts. Nonetheless, challenges remain, including technical constraints in extreme conditions (e.g., algorithmic vulnerabilities, data synchronization delays), high costs for SMEs, and outdated regulatory frameworks. Future advancements must emphasize intelligent systems, such as AI-driven decision-making, and foster interdisciplinary collaboration to tackle these challenges. Policy reforms, including the establishment of international standards for marine automation and incentives for sustainable technologies, are essential for balanced development. Case studies, exemplified by Norway's Equinor project, illustrate automation's capacity to enhance productivity by 30% while reducing carbon emissions. Ultimately, the integration of automation with sustainability goals requires harmonizing technological innovation, economic feasibility, and environmental stewardship. By fostering cross-sector partnerships and aligning policies with technological progress, ocean engineering can achieve safer, smarter, and greener development in the era of automation.

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