Applications and Development Prospects of Intelligent Robots

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***Abstract*—The dissertation starts with an exploration of the historical trajectory of intelligent robots. Specifically, this study dips into their developmental landscape and the possible prospects for contemporary society. In this research, a mixed-methods strategy is used blending a qualitative examination of current literature with quantitative data on recent developments in robotics. Key discoveries reveal a notable increase in the utilization of intelligent robots in diverse sectors such as manufacturing, healthcare, bionics, and military fields, propelled by advancements in artificial intelligence, machine learning, and sensor technology. The ethical and economic consequences of extensive robotic integration are also explored in the essay, addressing possible issues such as job displacement and privacy concerns. The conclusion suggests that although intelligent robots offer unique improvements in efficiency and innovation, thoughtful examination of their societal effects is essential for sustainable development. This dissertation is a thorough reference for grasping the present condition and future direction of intelligent robotic systems.**

***Keywords*—robotics, construction robot, medial robot, bio mimetic robots, military robot**

I. Introduction

After going through the eras of electrical technology and the digital age, robots have now entered the era of artificial intelligence. Intelligent robots, as one of the applications of artificial intelligence technology, have a wide range of applications and a promising future. In terms of technology, robot technology has evolved from traditional industrial technologies such as controllers, servo motors, and reducers to incorporate artificial intelligence technologies like perception, natural language processing, and autonomous decision-making. In terms of application, robots have gradually expanded from industrial manufacturing to fields such as military, medical, bionics, and construction, becoming more deeply integrated into modern society. In human-machine interaction, the relationship between humans and robots has evolved from mutual isolation and non-interference to full human-robot collaboration and integration.

Intelligent robots are a category of robots equipped with artificial intelligence technology, capable of perceiving their environment, understanding information, making decisions, and executing tasks to achieve autonomy and intelligence. It can also engage in natural interactions with humans. In more specific terms, in the fields of construction, healthcare, military, and industry, robots encompass disciplines such as mechanical engineering, electronics, control technology, sensor technology, and computer science. They also touch upon areas like biomedical science, human-computer interaction, rehabilitation medicine, and bionics. Intelligent robots apply technologies such as pattern recognition, automatic control, information fusion and understanding, artificial intelligence, and system integration to traditional platforms.

The development prospects of the intelligent robot industry are extremely broad, with immense market potential. The widespread application of intelligent robots will significantly free up the workforce, allowing for more efficient and convenient completion of arduous repetitive tasks, basic service tasks, and high-risk work. However, accompanying challenges should not be ignored. As robots find applications in more areas, concerns about privacy protection, occupational transitions, ethics, safety hazards in practical applications, and issues related to international law are gradually increasing [1].

Therefore, addressing these issues requires collaborative efforts from governments, academia, industry, businesses, and various sectors of society.

This article provides a brief overview and introduction to the research principles and applications of four different categories of intelligent robots that are widely used internationally. It aims to offer development recommendations and ideas for intelligent robots and their related design principles, providing valuable insights for their advancement.

II. Current Situation in Robot

A. *A Brief History of the Development of Intelligent Robots*

With the deep integration of artificial intelligence with the Internet, Internet of Things (IoT), big data, and cloud platforms, intelligent robots are becoming adaptable to more complex and dynamic application scenarios. The emergence of intelligent robot platforms that combine perception, cognition, and action capabilities into one entity, exhibiting various external functionalities similar to humans, has the potential to drive the Fourth Industrial Revolution [2]. Fig. 1 shows three kinds of common robots.

(a) Welding Robot (b) Manufacturer's Power Supply (c) Household Robot
Fig. 1. Common robots.
(Note: Contemporary three types of robot schematic diagram)

The earliest prototype of artificial intelligence can be traced back to ancient Chinese wooden figurines. Although lacking true intelligence, they symbolize the advanced thought process of the ancient people.

Robots of the first generation emerged in the First

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Industrial Revolution, with the Jenny spinning frame serving as a notable example. Characterized by conventional industrial robots and drones, this era prioritized fundamental operational and movement capabilities. These systems used simple sensing devices like joint encoders for industrial robotic arms and magnetic stripes, exhibiting relatively low levels of intelligence.

The second generation of intelligent robots possesses partial environmental perception, autonomous decision-making, autonomous planning, and autonomous navigation capabilities. They especially excel in pattern recognition, including human-like abilities in vision, speech, text, touch, and force perception. Consequently, they exhibit strong adaptability to different environments and a certain degree of autonomy.

(a) Robot Company (b) Sopia Bionic Robot

Fig. 2. Robot company and its product.

(Note. Robotics company and its product)

The third generation of intelligent robots, in addition to possessing all the capabilities of the second generation, also have stronger environmental perception, cognition, and emotional interaction functions. Furthermore, they have the ability for self-learning, self-reproduction, and even self-evolution. Current AI robot companies are capable of creating robots with a striking resemblance to humans, such as Sophia in Fig. 2.

In summary, as the limitations of deep learning become increasingly apparent, and original artificial intelligence theories experience some stagnation, especially due to the accelerating pace of AI industry implementation, intelligent robots are emerging as a prominent contender, seemingly returning to the forefront of the competitive arena while displacing some of the earlier hype [3].

B. Construction Robot

1) Current research status of construction robots in building construction

This section primarily focuses on representative construction robots in the construction process, discussing the research status of main structural construction, finishing construction, and other emerging construction robots.

2) Bricklaying robots

In construction, bricklaying is a significant part of the workload, and its construction efficiency and quality largely determine the project's schedule and quality. Traditional bricklaying is mostly done manually, resulting in inconsistent construction quality. To improve traditional bricklaying processes, developed countries have pioneered the development of automated bricklaying robots, with their technology being at the forefront. SAM100, Hadrian X, and MULE are three currently widely used representative construction robots, such as in Fig. 3.

(a) SAM100 (b) Hadrian X (c) MULE

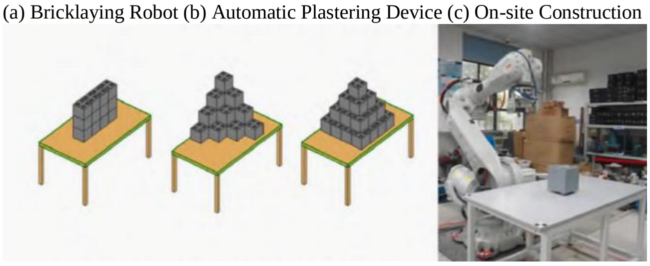
Fig. 3. Commercial brick-Laying robots.

(Note: Three widely used constructive robots)

3) Concrete floor treatment robot

Concrete floor treatment is a crucial construction process during concrete pouring, with traditional methods placing significant physical strain on workers and making it challenging to ensure construction quality [4]. Therefore, a stable and efficient autonomous positioning and navigation system is the key to developing intelligent concrete floor treatment robots (See Fig. 4) [5].

(a) Bricklaying Robot (b) Automatic Plastering Device (c) On-site Construction



(d)Straight Wall, Staircase, and Pyramid Construction Models(e)Masonry Testing

Fig. 4. Research on brick-laying robot technology.

(Note: This figure shows the appearance of concrete floor treatment robot)

C. Medical Robots

In addition to the applications mentioned above in construction robotics, medical robots are also widely promoted in the healthcare industry. Medical robots possess multiple skills, including information gathering, motion execution, image transmission, and assisting in decision-making, all of which play a crucial role in postoperative rehabilitation, surgical treatment, and clinical care for patients [6].

1) Rehabilitation robots and various rehabilitation training modes

The traditional rehabilitation training methods primarily involve manual assistance or the use of simple equipment to facilitate limb movement, often requiring the involvement of multiple healthcare personnel. However, these training methods impose significant physical demands on healthcare providers, making it challenging to maintain the intensity and consistency of rehabilitation training. Additionally, manual rehabilitation methods are susceptible to subjective factors from therapists, which hinder the objectivity, precision, and consistency of training, limiting the optimization of rehabilitation methods and the improvement of rehabilitation outcomes [7]. Particularly in recent years, the rising labor costs have increased the expenses associated with traditional training methods, placing significant financial pressure on patients' families and society.

Rehabilitation robots have emerged and developed to address the shortcomings of traditional rehabilitation training methods. They represent a fusion of advanced robotics technology and clinical rehabilitation medicine, offering automated rehabilitation training equipment. These robots leverage the advantages of robots in performing repetitive and strenuous tasks and can deliver precise, automated, and intelligent rehabilitation training [8]. This advancement elevates the field of rehabilitation medicine, increases access to rehabilitation therapy for patients, enhances their quality of life, and contributes to social harmony [9].

2) Drive mechanism of intelligent rehabilitation robots

The drive mechanism of rehabilitation robots directly influences the establishment of their control model and the selection of control schemes. Typically, while ensuring that rehabilitation robots provide a sufficiently large torque output, it is required that the drive system of these robots possesses characteristics such as a compact structure, small size, high efficiency, lightweight, and fast response [10].

3) Transmission joint

Drive joints are divided into active joints and passive joints. Active joints rely on external power to drive human body movements, while passive joints adapt passively to the body's associated movements [11].

Since the weight of the rehabilitation robot itself is also its load, drive joints should possess characteristics such as lightweight, compact size, high torque output, smooth transmission, and reliable operation. The precision of their operation will directly determine whether the control system can effectively achieve its functionality [12]. Figs 5 and 6 show the type of medical robot in which the transmission joint exists.

Fig. 5. Nu-step limbs linkage rehabilitation training device
(Note: A kind of medical robot used to recover limbs)

Fig. 6. THE A-vital intelligent lower limb training device.
(Note: A kind of medical robot used to recover lower limbs)

D. Bio-mimetic Robots

1) Origin of bio-robotics

The natural world is home to a diverse array of animal species, spread across every corner of the globe, and millions of years of evolution have perfectly adapted their forms to their respective environments [13]. In order to better serve human production and life, scholars have imitated the forms of animals to invent various types of bio-mimetic robots, such as bio-mimetic soft robots, bio-mimetic snake-like robots, and more [14]. Boston Dynamics is a company producing such robots.

Fig. 7. Bio-mimetic Robots from Boston Dynamics Company.

2) Common materials for intelligent bio-mimetic robots

Shape Memory Alloys (SMAs) exhibit the Shape Memory Effect (SME), where after being set at a high temperature, cooled to a low temperature, and deformed with residual deformation, they can return to their original shape when heated to a specific temperature. This process can be repeated cyclically [15].

The primary function of piezoelectric materials is the ability to convert mechanical energy into electrical energy, and vice versa. Currently, major piezoelectric materials can be divided into inorganic and organic (polymer) piezoelectric materials which uses immovable cations principle in Fig. 7. Inorganic piezoelectric materials primarily include single crystals (such as SiO_2) and poly-crystalline materials, while organic piezoelectric materials are mainly polyvinylidene fluoride (PVDF or PVF2) [16].

3) Soft robotics biomimetic robots

Soft robotics is a rapidly advancing field in robotics technology. Its emergence addresses the shortcomings of traditional robots in terms of human-machine interaction and adaptability.

Furthermore, robots have evolved from performing labor-intensive, repetitive, and simple tasks to executing tasks that are more interactive, flexible, and at an advanced level [17].

E. Military Robots

1) Current development status of Autonomous Underwater Vehicles (AUV)

Military robotics research has a history spanning several decades, and many coastal nations are dedicated to the development of underwater military robotics technology and related products. The United States, Canada, the United Kingdom, Japan, Russia, China, and others have established specialized institutions for researching underwater robotics technology. These include the Autonomous Underwater Vehicle Research Center at the U.S. Naval Postgraduate School, the Ocean Systems Engineering Laboratory at Maine State University, the UK Maritime Technology Centre, the Underwater Robotics Application Laboratory at the University of Tokyo.

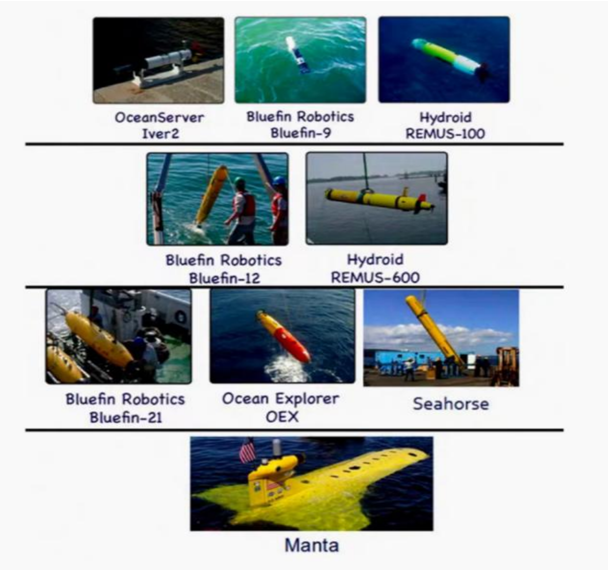


Fig. 8. Examples of typical underwater unmanned systems.

Using two aspects, namely displacement and endurance, Autonomous Underwater Vehicles (AUVs) are categorized into different levels, each with varying operational ranges and main responsibilities, See Fig. 8. The United States, based on displacement, roughly classifies typical underwater unmanned systems into four categories: Portable, Light, Heavy, Large, Portable, Light [18].

2) Underwater military robots

Underwater military robots are indispensable tools for human military activities in rivers, lakes, and oceans. Due to the complex and dynamic underwater environment, conventional propulsion mechanisms like propellers and impellers have limitations such as poor adaptability and high operating noise, significantly restricting their application [19].

Therefore, the development of structurally simple underwater military robots with exceptional underwater mobility has become a focal point of current research [20].

To achieve this, researchers have taken a morphological approach, combining biomimicry and robotics, to design and develop underwater military robots by mimicking the external structures and propulsion mechanisms of aquatic organisms such as fish, reptiles, and soft-bodied creatures known for their exceptional underwater mobility. This approach has yielded a series of research achievements [21].

3) Underwater military robot propulsion principle

When the vehicle lacks propulsion, it undergoes upward or downward motion at different angles of attack, experiencing forward and backward forces [22]. This pressure difference in front and behind the wing generates propulsion for forward or backward sliding. This result can be utilized to control and predict the sliding distance of the vehicle [23]. Experimental analysis reveals that to generate upward lift from the wing, it is necessary to control the vehicle to move forward at a certain depth without producing upward or downward motion. In this case, the angle of attack can be controlled to be around 4 °[24].

The hydrodynamic performance simulation and experimental results of modular small underwater vehicles consistently demonstrate quantitative and qualitative upward trends. [25] Please note that technical terms and context-specific details may require further adjustment depending on the intended audience and purpose of the translation.

4) Current challenges and future trends

Currently, morphological design has achieved significant success in the field of military biomimetic robot design. However, there are still pressing issues to be addressed, particularly in the integration of interdisciplinary knowledge for cross-domain innovative design.

For example, how to leverage the internet to accumulate a vast number of biological examples to support military bio-mimetic robot design, how to achieve thorough military robot bio-mimetic design, and how to facilitate the development of military bio-mimetic robots towards multi-domain and swarm robotics, are all challenges that need to be addressed [26].

III. Challenges and Future Outlook of Intelligent Robot

Today, there is a rising trend in the global economy and society towards the development and demand for robot technology. While developing intelligent robots, it is crucial to consider both their economic and societal benefits [27].

Medical robots are expected to become more prevalent in the future. Rehabilitation robots, as intelligent bio-mimetic rehabilitation devices, represent complex human-machine integrated systems. They have achieved breakthroughs in key technologies and are gradually moving towards commercialization and standardization. These robots provide a safe and effective means of rehabilitation for individuals with physical disabilities. However, the high research and development costs currently make it difficult for patients to afford the usage fees for rehabilitation robots. In the future, efforts can be made to transform rehabilitation robots into shared robots that can be reused by multiple patients during the development process. Optimization can be applied to various parts of the rehabilitation robot, such as the robot’s base, rotating seat, adjustable handles, foot pedals, emergency stop buttons, and display screens, to make them more universally applicable. This approach aims to reduce the economic burden on individual patients by allowing multiple patients to share the same robot.

Similarly, in the construction industry, robots should significantly improve their mechanical efficiency while ensuring safety, thereby saving construction costs and reducing risks. However, this advancement may lead to unemployment issues among construction workers. A similar scenario is occurring in factories, where workers on assembly lines are gradually being replaced by robots, resulting in unemployment and a decline in the living standards of the working-class population.

Bio-mimetic robots have highly flexible and easily deformable bodies that require high-precision sensors for measurement, without affecting the mechanical response of the robot. This necessitates the development of a new type of embedded sensor. These sensors need to be flexible enough to be embedded within a silicone body to measure parameters like bending, stretching, stress, and other information. However, these sensors typically have a relatively high elastic modulus, which can limit the motion of the soft robot itself. Biomimetic robots can apply technologies such as pattern recognition, automatic control, information fusion and understanding, artificial intelligence, and system integration to traditional platforms.

Similarly, robots designed for military purposes should prioritize agility in turning, enhance stability during running, and improve shock-absorption capabilities for jumping. They should increase their load-carrying capacity to ensure robust execution of commands in environments filled with uncertainties. To guarantee the security of mission data, the security factor of their information sensing and receiving devices should be raised, all while ensuring national security.

During the flourishing development of artificial intelligence, the ethical and moral questions it raises deserve careful consideration. At the current stage, AI robots do not possess independent will, and their legal status remains unclear. Existing laws defining the capacity for civil actions of individuals and corporate entities provide valuable insights.

Issues regarding the allocation of responsibility for medical accidents caused by AI design flaws, sudden malfunctions, and related parties such as operating physicians, suppliers, manufacturers, and designers remain unaddressed in current legal frameworks.

Additionally, there is a significant time gap between the upfront research and development costs of intelligent robots and the profitability realized upon product launch. This may lead to financial challenges. Currently, the approach involves initial computer simulations before investing in material-based real-world experiments.

In conclusion, the development of intelligent robots is an inevitable trend as society advances. Only by conserving energy and materials during research and development, and effectively transforming corresponding enterprises upon market entry, can a balance be achieved and progress made in the ongoing development of the international community.

Throughout the process of summarizing this article, I have gained an appreciation for the continuous refinement of physics principles. It has ignited my curiosity for exploration and enthusiasm for learning. This experience has cultivated the habit of planning independent research in advance and fostered a mindset of pursuing excellence in science.

IV. Conclusion

This article provides an overview of the application and current development prospects of intelligent robots. It primarily discusses the history, development, and prospects of intelligent robots, introduces their close connections with contemporary society in fields such as construction, healthcare, biomimicry, and the military. The article elucidates the principles of intelligent robots and provides specific application examples, highlighting the summarized results of how intelligent robots enhance societal and economic benefits. The main conclusions can be summarized as follows:

In the construction industry, the use of building robots is seen as a growing global sector with significant market potential. At the same time, there’s a need to focus on boosting innovation, fundamental research capabilities, improving product performance, and cutting production costs.

In the realm of medical rehabilitation, the integration of artificial intelligence and robotics in medical intelligent robots helps monitor rehabilitation progress and offer real-time feedback, effectively improving rehabilitation results. Moreover, these intelligent robots can aid healthcare professionals in handling physically demanding tasks, showing substantial potential for their use in rehabilitation and support systems.

In the field of bionics, it’s essential not only to optimize existing structural designs but also to conduct broader research to find more efficient propulsion methods. These efforts will provide guidelines for designing future bio-inspired robots, creating a comprehensive framework for evaluating and designing underwater bionic robots.

Within the military domain, military intelligent robots have a wide range of potential applications. They can be utilized for tasks like reconnaissance, search and rescue, and explosive ordnance disposal, enhancing combat effectiveness. Additionally, the autonomy and quick decision-making abilities of intelligent robots are expected to play a crucial role in bolstering national defense and security capabilities on the battlefield.

However, when it comes to pressing concerns related to ethics, privacy, and the job market concerning intelligent robots, it’s crucial for governments, relevant authorities, and research and production teams to ensure the safe and ethical application of these technologies. In the future, studies should focus on reducing costs and improving revenue and the economic viability of factories. As artificial intelligence and robotics technology continues to advance, the sophistication of intelligent robots in sectors like construction, healthcare, military, and bionics will continue to grow. This article provides an overview of intelligent robots and intelligent assistive systems, along with their associated methods and technologies, and can be a valuable reference for researchers in the field of intelligent robots. It is implicated that the study try to ask for researchers in this area to rethink about the application of intelligent robots on ethical level. Furthermore, Intelligent robots play a mutual role in the job market. They can create more high-level positions, such as in robot developer and maintenance technicians, but simultaneously lead to unemployment among low-skilled labor due to automation.

Conflict of Interest

The author declares no conflict of interest.

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