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# Research on obstacle-surmounting mechanism of transformable robot

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**Abstract.** With the innovation and advancement of technology, the research in the field of transformable robots have shown explosive growth and are moving towards intelligence and diversification. Transformable robots can transform their mobile mechanisms according to different terrains for obstacle surmounting, with high flexibility, strong adaptability, and scalability. Thus, transformable robots are widely used in fields such as reconnaissance, rescue, and military. In this article, the characteristics of different obstacle surmounting mechanisms of transformable robots are analysed. Based on three traditional obstacle surmounting mechanisms: wheeled, tracked, and legged, this article introduces the concepts and advantages of combined obstacle surmounting mechanisms and emerging soft and biomimetic robot obstacle surmounting mechanisms. After elaborating on the current research status and partial applications of composite transformable obstacle surmounting robots, the key technologies and difficulties in the research of obstacle surmounting mechanisms for transformable robots are summarized. In addition, this article provides prospects for the application of transformable obstacle surmounting robots in medical and agricultural fields.

**Keywords:** transformable robot, obstacle surmounting, composite robot.

## 1. Introduction

The transformable robot has become an important research direction of robotics in recent years due to its potential applications in various fields such as search and rescue, manufacturing, medicine and entertainment. Transformable robots can maintain their moving ability in different working environments, so more and more attention has been paid to the research on the ability of transformable robots to navigate under complex terrains and overcome obstacles in their paths. Transformable robots have the following advantages:

1. High flexibility in operation and the ability to use various drive strategies to achieve autonomous movement according to the required environment [1].

2. Scalability to fuse feedback from various sensors to meet different task requirements [2].

3. Flexible configuration allows for a wide range of operations in conjunction with many types of robotic arms and actuators [3].

Obstacle surmounting is a crucial capability that transformable robots need to possess to operate effectively in real-world environments. The ability to navigate through different terrains and overcome obstacles is critical to ensure the completion of tasks efficiently. With the progress of technology, robots are now being developed to adapt to the environment by changing their shape and size. These transformable robots have become increasingly popular due to their flexibility and versatility, especially for tasks that require traversing challenging terrain. For instance, a robot that can transform from a quadrupedal form to a bipedal form would have an advantage in traversing rocky terrain. It could switch to a more stable quadrupedal form to maintain balance while navigating difficult terrain, and then revert to a bipedal form when required for specific tasks. Similarly, a robot that can modify its shape and size to fit through narrow gaps or crawl spaces would have an advantage in search and rescue missions. Transformable robots can also adapt to changing environmental conditions. Such as, aquatic robots can change their shape to move more efficiently through water [4].

In this article, the state-of-the-art in transformable robots is examined, with a focus on their design principles and control strategies. The different types of transformable robots, along with their advantages and limitations, as well as the challenges and opportunities in their development, are discussed. Furthermore, the applications of transformable robots in various fields are reviewed, highlighting their potential to address real-world problems and improve human well-being.

## 2. Classification of transformable surmounting robot

The traditional obstacle-surmounting mechanism of transformable robot mainly includes three types of structures: wheeled type, tracked type and legged type. In addition, emerging soft and bionic robots are more suitable for climbing because of their variable form of obstacle-surmounting mechanism. As the most common mobile mechanism, wheeled mechanism has simple structure, high mechanical efficiency, but poor obstacle-surmounting ability. Compared with the wheeled mechanism, the tracked mobile mechanism has better obstacle surmounting performance, but has low efficiency, high energy consumption and slow speed. The legged type of mobile mechanism can adapt to complex terrain and are more flexible, but they have poor mobility, light loads. Obstacle surmounting mechanisms of soft and bionic transformable robot can break the constraints of rigid bodies and reach narrow spaces that traditional robots cannot reach.

Wheeled, legged, and tracked obstacle surmounting mechanisms of transformable robot have specific advantages on suitable terrain, and their comprehensive performance is poor. The driving technology of obstacle surmounting mechanism for soft robot is also not mature. Composite obstacle surmounting mechanisms have the characteristics of multiple obstacle-surmounting mechanisms, and can be converted according to work needs, improving both mobility and trafficability.

### *2.1. Wheel-track composite robot*

The wheel-track composite obstacle-surmounting mechanism combines the structure of wheel and track to improve the obstacle surmounting ability. The directly connected wheel-track composite robot has combination of a wheel mechanism and a track mechanism and switches a motion mechanism according to the terrain. The integrated wheel-track composite robot has only one motion mechanism, and the switch between wheel and track is realized through the reconfigurable track and internal extension mechanism[5]. Figure 1 shows a wheel-track composite transformable robot with reconfigurable track wheels. The chassis of the wheel-track composite obstacle surmounting mechanism is more stable and is not prone to tipping and rollover. Therefore, the technology of wheel-track composite robot in assisting disabled people in walking, medical rehabilitation, explosive ordnance disposal, search and rescue has become a current research hotspot.

**Figure 1.** VGTV robot [5].

### 2.2. Wheel-legged robot

Wheel-legged robots combine the high mobility of wheeled robots with the flexible obstacle surmounting performance of legged robots, improving the motion performance. According to the different types of robot wheel leg combinations, wheel-legged robots are divided into three types: wheel-legged series type, wheel-legged separation type, and wheel- legged integration type. Wheel-legged series robot with real-time path planning and external environment awareness functions has significant obstacle surmounting effects, and the relevant research theories are mature [6]. Figure 2 shows a wheel-legged composite transformable robot. The wheel-legged separation robot has a large volume, fewer wheel-leg fusion structures, and good stability.

**Figure 2.** NOROS-II [6].

### 2.3. Bionic robot

Bionic robots involve many different subjects, such as bioinformatics, mechanical electronics, system cognitive science, mathematics and mechanics [7]. The bionic robot combines the principles of bionics and electromechanical control and is designed according to the characteristics of the bionic organism. According to the obstacle surmounting mechanism of bionic robot, bionic robots can be divided into multi legged bionic robots and jumping bionic robots [8]. Besides, the obstacle surmounting mechanism of the bionic robot can also be combined with wheel, track, leg and other structures.

### 2.4. Soft robot

With the development of material science and mechanics, materials with a Young's modulus between $10^4$-$10^9$Pa have been used to manufacture soft robots. Compared to rigid robot with heavy loads and high-accuracy, soft robot made of flexible materials have infinite Degrees of Freedom. The movement speed of obstacle surmounting mechanisms of soft robots is very slow, and there is less research on obstacle surmounting mechanisms of soft robots suitable for multiple terrain. According to different driving methods, soft robots can be divided into pneumatically driven soft robots, cable driven soft robots, and chemically driven soft robots [8]. Currently, as a new branch of robotics, soft robots have good application prospects in medical surgery, deep-sea exploration, and other fields [9].

## 3. Current research status

Up to now, robots have developed various composite transformable structures and integrated bionics and other disciplines for design. The combined obstacle surmounting mechanism of transformable robots has the intelligent function of autonomous avoidance of obstacle paths that are difficult to cross.

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The emerging transformable obstacle surmounting mechanism has developed more obstacle surmounting methods, such as climbing and jumping.

Rui proposed a wheel-track composite transformable wheel obstacle-surmounting mechanism based on modified gears, which can be directly applied without modifying the vehicle structure [10]. Genetic algorithm is applied to optimize the mechanism parameters. The mechanism has good obstacle surmounting performance. However, due to the influence of the internal pressure of the hydraulic cylinder, it is necessary to switch the motion mechanism at low speed. The Warrior 710 wheel-track composite robot has an average speed of 8 km/h in all terrain and a maximum control distance of 800 meters [11]. Warrior 710 can cross obstacles with a height of 50 cm through track deformation. Figure 3 provides a visualization of Warrior 710.

**Figure 3.** Warrior 710 [12].

Xu designed a circularly symmetric bionic insect 6 wheel-legged robot: NOROS, and proposed several different periodic gait plans [13]. The movement mechanism switching, and obstacle surmounting abilities of the robot were tested through a simulated prototype. The NOROS has a very small turning radius and does not wear the wheeled tires during leg travel. ANYMAL, a wheel legged composite robot developed by the Swiss federal Institute of Technology, completed a vertical obstacle climbing of 120 meters in 31 minutes [14]. The four-legged structure of ANYMAL robot has a wheel structure at the end, which is flexible in overcoming obstacles, but the tires at the end are easy to wear in the legged motion mode. The BHR-7 humanoid robot has achieved core technological breakthroughs in complex environmental adaptability and overall balance and coordination, which is currently the highest level in China [15]. The BHR-7 humanoid robot currently does not have the function of hand and foot cooperation to surmount obstacles. The four-legged bionic robot dog Spot Min launched by Boston Dynamics has 17 Degree of freedom, weighs about 30 kilograms, and can carry 14 kilograms to run freely [16]. The Spot Min has a compact appearance and a robotic arm with a camera on its head, which can help it better detect and avoid obstacles. Figure 4 provides a visualization of Spot Min.


**Figure 4.** Spot Min[16].

Meng have designed a self-growing soft robot for urban environments [17]. The soft robot mimics the tip structure of plant tissue and the ligament muscle tissue of Mollusca, with an asymmetric fold structure. The soft robot can effectively complete tasks such as traversing narrow gaps, making autonomous turns at large angles, and crossing obstacles vertically and horizontally. The self-powered soft bionic robot developed by Tie feng Li has broken through 10000m deep diving for the first time in the Mariana Trench [18]. The soft robot imitates the biological characteristics of lionfish, integrating electronic hardware into soft tissue to adapt to high hydrostatic pressure. It controls its course and surmounts obstacles by rhythmically flapping its bionic wings in the water. Michael Wehner team has

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developed the world's first octopus like autonomous soft robot: Octobot, driven by chemical reactions [19]. The robot uses a microfluidic circuit and flexible devices and moves through the platinum catalyzed $H_2O_2$ release in the body of the soft robot to generate pressure.

## 4. Difficulties of transformable robot research

### *4.1. Wheel-track composite robot and Wheel-legged robot*

Wheel-track composite and wheel-legged composite robots are more outstanding than single wheeled, legged or tracked robots in terms of operating speed, flexibility, and obstacle-surmounting capabilities. There are still problems in the research of the transformable robot in the following aspects.

(1) The design of the switching mechanism is difficult. As wheeled, legged and tracked robots have different adaptability to the ground, in order to achieve fast switching and perfect adaptation to the terrain, it is necessary to fully consider the mechanical structure, motion planning and control system and other aspects to improve the ability to overcome obstacles.

(2) The motion control algorithm is complex. The robot needs different control algorithms for motion control on different road surfaces or in different environments, meaning that when the robot is surmounting obstacles, it needs to judge different terrains, coordinate and switch between wheeled and tracked or wheeled and legged. Therefore, the design and optimization of the motion algorithm of the compound robot is more complicated.

### *4.2. Bionic robot*

With the gradual deepening of scientists' research on bionic robots, the bionic categories, disciplines and application scenarios involved in bionic robots have gradually expanded, so the requirements for bionic robots in terms of structure and function are getting higher and higher. Bionic robots are gradually showing new development trends including intelligence, miniaturization and sustainability to better adapt to complex and changeable environments. For example, in the process of surmounting obstacles, it is necessary to make decisions about path planning and obstacle avoidance.

(1) Intelligence.The obstacle-surmounting ability of the robot is also subject to its own physical constraints, such as weight, volume and mechanical structure. The intelligence of bionic robots is mainly reflected in the precise imitation of the physiological functions of living things, and is developing towards higher autonomous decision-making capabilities and the ability to cope with complex and changeable environments.

(2) Miniaturization.The robot consumes a lot of energy in the process of overcoming obstacles. In order to achieve more flexible movement and operation in some situations that require precision and narrow environments, it is necessary to highly integrate components such as drives, sensors, and controllers to realize the miniaturization of bionic robots [8].

(3) Sustainability.In order to save resources, reduce pollution and prolong service life, and achieve more environmentally friendly and economic development, bionic robots must develop towards sustainability.

### *4.3. Soft robot*

Soft robots are still in their infancy and belong to an emerging robotics research direction. Therefore, there are still many problems to be solved urgently in the research of soft robots.

(1) Soft materials have defects in terms of stress and service life. As soft robots are still in their infancy, research on soft materials is very limited, resulting in the immaturity of existing soft materials in terms of stress and strain [20]. And soft materials are not as stable in shape and rigidity as rigid materials, it may be deformed and damaged during the obstacle surmounting process [21]. Therefore, it is necessary to develop new Smart Materials that can ensure the softness of soft robots while improving their stability so as to enhance their ability to overcome obstacles.

(2) The modeling is not precise enough and the control precision is not high enough. The theoretically infinite degrees of freedom of soft robots cannot be established by the traditional D-H method. The

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continuous and flexible deformation and movement of soft robots in the process of overcoming obstacles increases the difficulty of modeling, so more efficient and accurate control algorithms are required to achieve the task of overcoming obstacles.

## 5. Conclusion

Transformable robots with obstacle-surmounting functions have good perception, deformation, navigation, obstacle-surmounting, autonomous decision-making and other functions, so they are widely used in medical, search and rescue, manufacturing and other industries. In order to analysis the current research progress of transformable robots with obstacle-surmounting capabilities, typical transformable robots with obstacle-surmounting functions are classified into wheel-track composite robots, wheel-legged composite robots, bionic robots and soft robots in this paper. At present, the research on these four types of transformable robots with obstacle-surmounting functions is gradually moving from the experimental research to the stage of practical application and has achieved significant results in some areas. However, due to limitations of technology and other reasons, there are still some research difficulties in transformable robots with obstacle-surmounting functions that need to be solved one by one in the future. For the motion control algorithm of composite robots and the switching of transformation mechanisms, the intelligence, miniaturization and sustainability of bionic robots as well as the materialization and modeling aspects of soft robots should be further studied in depth.

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