

Robots at the Beijing 2022 Winter Olympics

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The 2022 Winter Olympics has shown that robots can serve, protect, and help people excel in many aspects of their lives.

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With new Olympic and world records and incredible memories (1), the Beijing 2022 Winter Olympics saw athletes defy the odds, persevere to perform, and excel at the highest level on the world's grandest stage. Robots were ubiquitous during the Games, appearing in the torch relay and assisting broadcasting, logistics, and security inspection. Unlike their debut at the PyeongChang 2018 Winter Games (2), the robots were there not only to demonstrate their technological capabilities but also to reduce infection risks and to help keep COVID-19 at bay.

Service robotics is a burgeoning area of development in China, and its market demand has seen explosive growth in recent years, accelerated further by the recent COVID-19 pandemic and the shortage of skilled labor. It was therefore unsurprising to see service robots for automated disinfection and smart catering (robot chefs and baristas) present at this year's event. The government and the organizers of the Winter Olympics, however, had a much bigger plan. Since 2019, in addition to evaluation contests on service robots for tasks such as security, translation, delivery, and catering, they wanted to demonstrate how robots could be involved in actual Games—opening further technological opportunities and challenges to robotics and stimulating greater participation of the general public in winter sports.

Eight types of robots were specially designed for the torch relay (Fig. 1), involving ground, air, and underwater transfers. These included an amphibious robot, an underwater robot, an aerial robot, and an uncrewed ground vehicle. The amphibious robot was designed to resemble a curler, with multimodal motion control to achieve high adaptability and dexterity to switch from gliding on ice to maneuver underwater. It

used omnidirectional wheel movement and gliding motion control to ensure flexible gliding movement on ice and dynamic positioning to achieve fixed-point hovering underwater. The underwater robot, on the other hand, adopted a deformable, variable structure design and motion control with disturbance prediction to overcome movement errors of the manipulator and ice water flow disturbances. The sensory system ensured accurate torch docking, flame point-of-contact detection, and spatial positioning such that the robot could navigate under ice and emerge from a designated exiting ice hole. For the torch relay in the air, the aerial robot performed fully autonomous docking with target positioning and attitude determination (3). The robot was capable of autonomous operation based on visual guidance and flight control to counteract the disturbance of hovering ground effect on rotor lift and to balance the movement of the manipulator and the robot body. The aerial robot was designed to carry out the torch relay with both the amphibious robot and an uncrewed ground vehicle. For the latter, it had the capability of coordinated operation using a pair of manipulators mimicking the actions of human hands to turn on the torch switch. Multimodal sensor fusion based on lidar, inertial measurement, and other sensory data enabled autonomous navigation with high terrain traversability and precision (4). Not all robots were deployed for the actual torch relay itself; on 2 February 2022, the amphibious robot and the underwater robot with variable structures successfully completed an underwater torch relay in the Beijing Winter Olympic Park, realizing the first underwater torch relay between robots in the history of the Olympic Games.

In addition to robots for the torch relay, multilegged robots (5, 6) also made their appearance this year. The first was a six-legged skiing robot as shown in Fig. 1B (top). With this robot, the front and hind legs were fixed on the skis, and each of the two middle legs was holding a ski stick. Each ski had five degrees of freedom, through which the height, body pitch-roll angles, center of gravity in relation to the four fixing legs, the edge angle of each ski, and the relative position/orientation of the skis could be adjusted, allowing full speed and steering control of the robot. The robot could be controlled either by a joystick or operate autonomously, and it was tested on both beginner and intermediate slopes to assess its performance and obstacle avoidance capabilities.

The second multilegged robot was a curling robot as shown in Fig. 1B (bottom). Unlike previously reported wheeled robot for curling (7), it had six legs, and the front two were used as “hands” to control the delivering direction and rotational speed of a curling stone. The two middle legs and the bottom of the body were combined to use as the sliding foot of the robot player, whereas the two rear legs were used as the “hack foot” to push against the hack when starting the delivery of the curling stone. No sweeping was implemented, so the game was similar to that of wheelchair curling in Paralympics. The robot was integrated with both visual and force perception, allowing accurate directional control and delivery of each shot as determined by game plans and team tactics. The robot was demonstrated at the Ice Cube for the Beijing Winter Olympic and Paralympic Games. One exciting prospect of this new curling robot is that it can also be controlled remotely. With high-level decision support, real-time dynamic modeling, and shot planning, one can orchestrate defensive or offensive strategies, making this game of “chess on ice” truly exciting. It is expected that the robot can also become a trainer for curling athletes or enthusiasts, making the sport more accessible to the general public.

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Fig. 1. Torch relay, skiing, and curling robots showcased during the Beijing 2022 Winter Olympic Games. (A) Robots developed for the torch relay involved ground, air, and underwater transfers. The amphibious robot and the underwater robot with variable structures were employed for the actual relay in the Beijing Winter Olympic Park, realizing the first underwater torch relay between robots in the history of the Olympic Games. (B) Top: Six-legged skiing robot. Bottom: Hexapod curling robot developed for Beijing 2022 Winter Olympics.

The robots at the Beijing 2022 Winter Olympic Games opened fresh potential for robotics and promoted sustainable development of robots for broader applications in response to the grand challenges of robotics (8). This time, we have witnessed the maturity of some of these technologies, particularly field robotics, and can anticipate their rapid uptake in our daily lives in future years. Some of the robots showcased at the Games may also find applications in coastal ecological monitoring, disaster protection, uncrewed inspection, and polar scientific explorations. The Beijing 2022 Winter Olympics not only left a legacy for a bright future in winter

sports but also expanded the scope for the capability of robotics to serve, protect, and help people excel in many aspects of their lives.

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