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Team UNIST at the $10M ANA Avatar XPRIZE: Core Technologies, Integration, and Evaluation*

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***Abstract*— The Bio-Robotics and Control (BiRC) laboratory in the Department of Mechanical Engineering at UNIST has been researching wearable human-robot interaction systems for about last 10 years. Our research focuses on developing sensors that accurately measure human movements, machine learning algorithms that can estimate and interpret the intention and meaning behind human movements, and actuators and heaters that can deliver various sensations to humans. These results have been applied for interface systems for tele-operated robots and metaverses. From 2018, we participated in the $10M ANA Avatar XPRIZE competition under the name Team UNIST, where we ranked 6th out of about 100 registered teams from all over the world. This paper discusses the core technologies, system integration, and evaluation through the competition of Team UNIST's avatar system.**

I. INTRODUCTION

Robot intelligence and automation technologies continue to advance, but they remain unable to match the intelligence and adaptability of humans in responding to and making decisions in unforeseen circumstances. As a result, teleoperation technologies that incorporate human expertise and judgment are extensively used in disaster relief efforts, including natural disasters and industrial accidents, as well as space and marine exploration.

In this paper, we present an advanced version of the interactive and intuitive control interface for a teleoperated robot (abbreviated AVATAR) [1], which includes the implementation of a haptic interface platform for whole-body integrated telepresence, as well as the use of force/torque and ultrasonic sensors to measure various environmental information. Specifically, we have upgraded the user interface to a haptic platform that provides force feedback to the user's arm and hand, and a foot haptic controller for controlling the robot's mobile platform. These improvements greatly enhance the teleoperation experience by providing the user with intuitive and immersive haptic feedback, thereby enabling them to interact more seamlessly with the teleoperated robot.

With the name of Team UNIST, we took part in the $10 million ANA Avatar XPRIZE competition, which aims to promote the research about the non-autonomous robotic systems that allow remote operators to feel human presence in real-time while completing a variety of challenging tasks specified by the competition [2]. Throughout the semifinal and championship rounds of the competition, the AVATAR system was put to the test and judged, and its performance was evaluated based on its ability to complete the assigned tasks

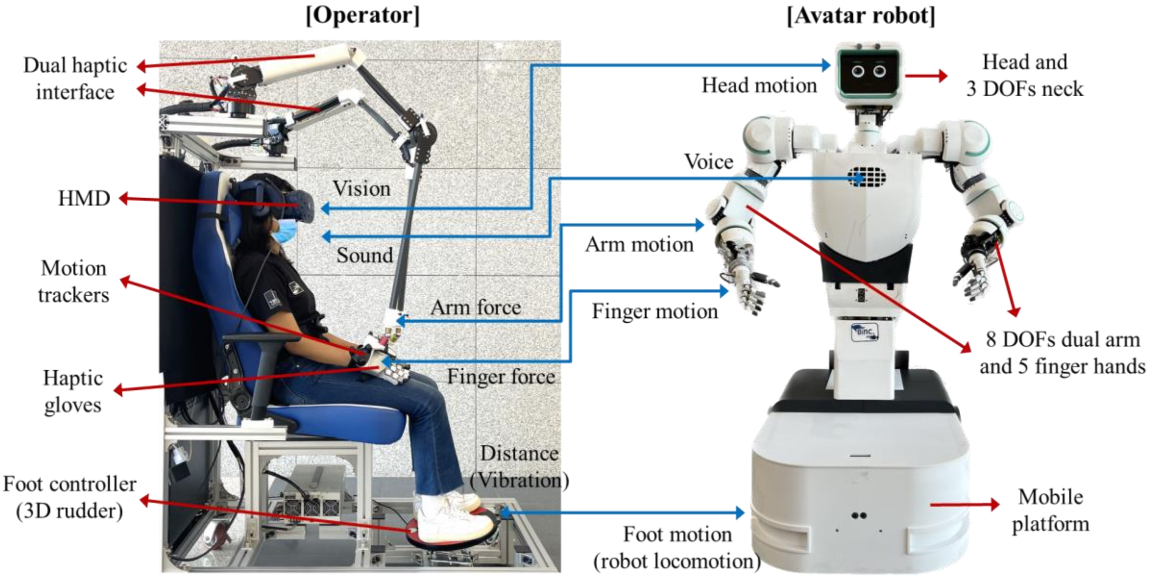

Figure 1. AVATAR system of Team UNIST.

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quickly and effectively. As a result, Team UNIST achieved a rank of 6th among approximately 100 registered teams.

II. AVATAR SYSTEM OF TEAM UNIST

A. *Tele-operated Robot*

The AVATAR system's teleoperated robot is specifically designed to perform tasks with human-like structure and appearance, as depicted in Fig. 1. The upper body's joint structure is designed to mimic the skeletal structure of the human body, allowing it to perform tasks that require dexterity and precision. The omnidirectional mobile platform comprises four mecanum wheels, which enable the robot to move in any direction required to explore the environment and complete tasks. The robot is equipped with various sensors that provide the user with tactile feedback. The entire system is untethered, including the power source and a wireless router. Additionally, for safety purposes, an emergency stop button has been incorporated into the design.

B. *Haptic Control Interface*

The AVATAR system's haptic control platform, shown in Fig. 1, is responsible for tracking the user's movements and providing haptic feedback throughout their entire body. The platform is composed of multiple components, including a wearable haptic interface that measures the user's arm and finger movements and provides corresponding haptic feedback. Additionally, a head-mounted display (HMD) provides users with three-dimensional visual and audio feedback, tracking their head movements in real-time. Finally, a foot haptic controller allows for intuitive control of the robot's mobile platform while simultaneously providing haptic feedback to the user's feet. These components all work together to provide users with a comfortable and intuitive experience that enables whole-body haptic control.

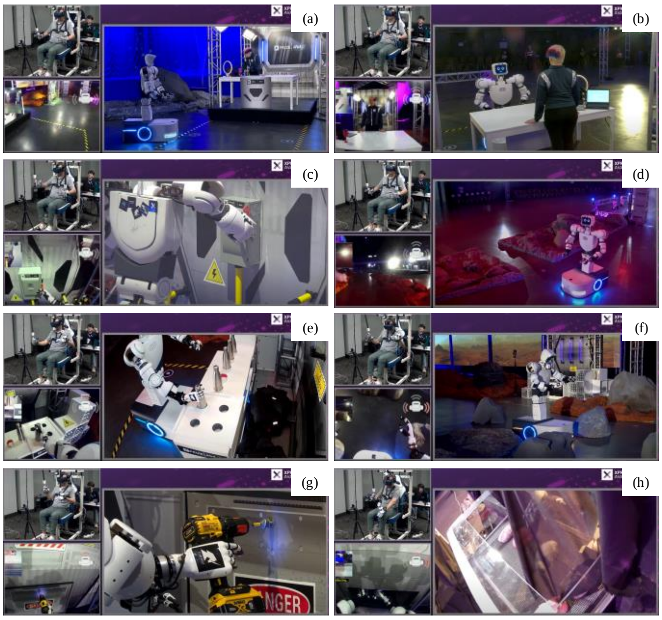

Figure 2. Team UNIST performing tasks in the final testing. (a) Task 1: Navigating designated area. (b) Task 2 and 3: Communicating with the mission commander. (c) Task 4: Activating a switch. (d) Task 5: Moving long distance. (e) Task 6 and 7: Identifying the heavy canister and manipulating the heavy canister into the designated slot. (f) Task 8: Navigating through a narrow pathway. (g) Task 9: Utilizing a drill within the domain area. (h) Task 10: Feeling the texture of the object without seeing it and retrieving the requested one.

III. FINAL TESTING IN $10M ANA AVATAR XPRIZE

The final tasks of the competition proved to be significantly more intricate and demanding than those of the semifinals. The finals consisted of a single scenario set on an unknown planet, divided into three domains that each contained 10 tasks. The first domain, Connection, prioritized enabling immersive interactions between individuals who were geographically separated. The second domain, Exploration, emphasized navigating through hazardous and unpredictable environments. Finally, the third domain, Skill Transfer, involved the delivery of critical skills and expertise to remote locations in real-time. The specific tasks that Team UNIST performed during the finals are shown in Fig. 2.

Communication with the mission commander (Tasks 2 and 3) was facilitated through the robot's facial expressions and our system's visual and auditory feedback. To complete the navigating or moving tasks, we used an omnidirectional mobile platform and foot haptic controller. Specifically, during Task 8, the system's visual and foot haptic feedback based on the mobile platform's distance sensing was helpful when passing through a narrow pathway. The system's intuitive control and haptic feedback were particularly useful in Tasks 4, 6, 7, and 9. In Task 9, the five-fingered robot hand allowed the user to operate the drill in the same way as the operator. Task 10 involved a texture sensing system and back-of-the-hand haptic feedback based on classification results. Additionally, to ensure the robot stopped in the correct position for manipulation, we activated the automatic stop algorithm in tasks involving walls or desks (Tasks 4, 6, 7, 9, and 10).

IV. CONCLUSION

The AVATAR system evaluated in the semi-finals and finals of the $10M ANA Avatar XPRIZE by judges who had no prior experience with the system. During the semi-finals, the system received a score of 86 out of 100 points, ranking 11th out of 38 semi-finalists. In the finals, the system scored 13.5 out of 15 points, achieving 6th place out of 17 finalists. Although we identified some critical issues that need to be addressed based on our experience in the competition, the results suggest that the AVATAR system has the potential to be an effective and innovative solution for teleoperated robots.

REFERENCES

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[2] XPRIZE, “Anywhere is possible.” Accessed on: March, 2023. [Online]. Available: https://avatar.xprize.org/.