MITSUBISHI ELECTRIC RESEARCH LABORATORIES
https://www.merl.com

Avatar Technologies of Team LAST MILE Toward Mobile Smart Device Operation Service

Haruna, Masaki; Ogino, Masaki; Tagashira, Shigeaki; Kashiwa, Munetaka; Morita, Susumu; Koike-Akino, Toshiaki; Imai, Kota; Zuho, Tiancheng; Makita, Masashi; Takahashi, Yasutake

TR2023-047 May 25, 2023

Abstract

The realization of practical teleoperation services can solve the social problem of uneven population distribution, enabling anyone to live/work where and with whom they want to live. We introduce two main strategies of technology development for this purpose: 1) simple and intuitive vision-based operation technology integrated with mobile smart devices, and 2) augmented avatar technology that can be flexibly designed to complete diverse set of tasks.

IEEE International Conference on Robotics and Automation (ICRA) 2023

Mitsubishi Electric Research Laboratories, Inc.
201 Broadway, Cambridge, Massachusetts 02139

Avatar Technologies of Team LAST MILE
Toward Mobile Smart Device Operation Service

Masaki Haruna, Masaki Ogino, Shigeaki Tagashira, Munetaka Kashiwa, Susumu Morita,
Toshiaki Koike-Akino, Kota Imai, Tiancheng Zuho, Masashi Makita and Yasutake Takahashi

***Abstract*— The realization of practical teleoperation services can solve the social problem of uneven population distribution, enabling anyone to live/work where and with whom they want to live. We introduce two main strategies of technology development for this purpose: 1) simple and intuitive vision-based operation technology integrated with mobile smart devices, and 2) augmented avatar technology that can be flexibly designed to complete diverse set of tasks.**

I. Introduction

AVATAR technology is expected to be able to solve the uneven distribution of the working population. Our team "LAST MILE" strives to realize a tele-operation service that enables anyone to live and work where and with whom they want (Fig. 1). In this paper, we introduce two main strategies developed to make this service reality: 1) a simple and intuitive vision-based operation technology using human cognitive characteristics [1]; and 2) an augmented avatar technology, which can be flexibly designed for each task by separating the "mind" and the "body" of the avatar. Our team LAST MILE was ranked 12th place in the XPRIZE/AVATAR competition, in which 820 teams participated over the world, even though we did not rely on any intuitive humanoid robots or head mount displays (HMDs) [2][3].

* Masaki Haruna is with the Advanced Technology R&D Center, Mitsubishi Electric Corporation (MELCO), Amagasaki 661-8661, Japan, and also with the Faculty of Informatics, Kansai University, Takatsuki, Osaka 564-8680, Japan (corresponding author to provide e-mail: haruna.masaki@ab.mitsubishielectric.co.jp).

Masaki Ogino is with the Faculty of Informatics, Kansai University, Takatsuki 564-8680, Japan (e-mail: ogino@res.kutc.kansai-u.ac.jp).

Shigeaki Tagashira is with the Faculty of Informatics, Kansai University, Takatsuki 564-8680, Japan (e-mail: shige@res.kutc.kansai-u.ac.jp).

Muenetaka Kashiwa is with the Advanced Technology R&D Center, Mitsubishi Electric Corporation (MELCO), Amagasaki 661-8661, Japan (e-mail: kashiwa.munetaka@cj.mitsubishielectric.co.jp).

Susumu Morita is with the Advanced Technology R&D Center, Mitsubishi Electric Corporation (MELCO), Amagasaki 661-8661, Japan (e-mail: morita.susumu@dh.mitsubishielectric.co.jp).

Toshiaki Koike-Akino is with the Mitsubishi Electric Research Laboratories (MERL), Cambridge, MA 02139 USA (e-mail: koike@merl.com).

Kota Imai is with the University of Fukui, Fukui, 910-8507, Japan (e-mail: imai.kota@ir.his.u-fukui.ac.jp).

Tiancheng Zuho is with the University of Fukui, Fukui, 910-8507, Japan (e-mail: zhuo.tiancheng@ir.his.u-fukui.ac.jp).

Masashi Makita is with the University of Fukui, Fukui, 910-8507, Japan (e-mail: makita.masashi@ir.his.u-fukui.ac.jp).

Yasutake Takahashi is with the University of Fukui, Fukui, 910-8507, Japan (e-mail: yasutake@ir.his.u-fukui.ac.jp).

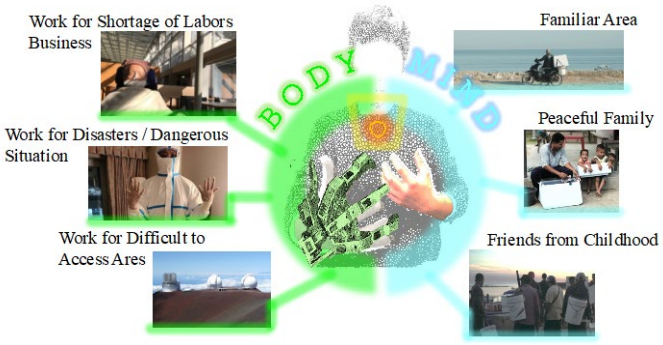

Figure 1. Envisioning future of team LAST MILE.

II. Avatar Technologies of Team LAST MILE

A. Vision-Based Operation

In order to use mobile smart devices as an operating interface, it is of importance to transmit motion information from the operator to AVATAR and sensory information from AVATAR to the operator via the device's monitor as much as possible. For this purpose, we have developed the following four vision-based information transfer techniques and a step-by-step automation technique to reduce the operator's workload (Fig.2).

- **Visual Haptics**

  Focusing on the cross-modal phenomenon between human vision and force haptics, we have developed a visual haptics technology that presents force haptic information from AVATAR with augmented reality (AR) at the point of contact. We have confirmed that this technology has a significant benefit by brainwave analysis [4][5].

- **Human Eye Display**

  This technology creates more natural visions by adjusting the resolution of the central and peripheral fields of view according to the task and condition. The central and peripheral fields of view are important for manipulation tasks and movement, respectively [1].

- **One-Click Operation**

  This technology enables the user to move and approach the arm by tapping on the touch panel monitor. Currently, this technology is evaluated with a mouse click as a preliminary implementation [3].

- **Eye Contact**

  Linking a smartphone camera to an extended monitor enables natural eye contact without being aware of the camera [2][3].

- **Human to Automated Operation**

  Multiple task operations are segmented into sub-tasks. By gradually automating the tasks step by step, starting with the subtasks that can be automated, the operator's load can be reduced and one operator can operate multiple machines concurrently [1].

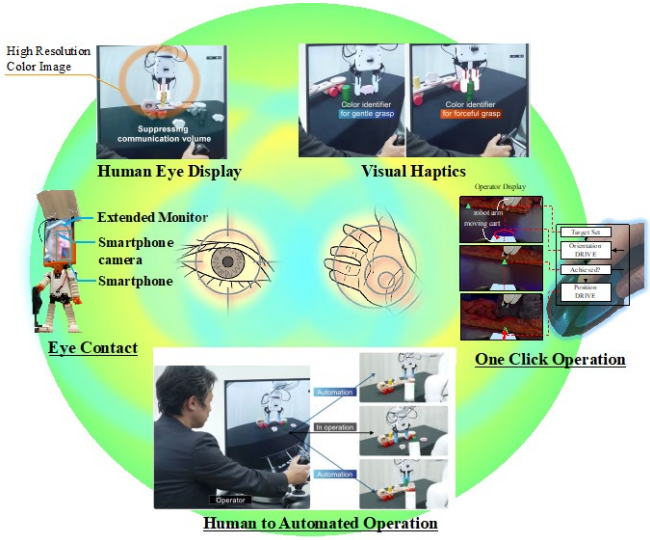

Figure 2. Developed vision-based operation technologies.

B. *Augmented Avatar*

We propose an "Augmented Avatar" as a teleoperation system that reconstructs human functions by combining each Avatar after independently designing two functions, "body" and "mind," of human manipulation and communications [3]. The "Augmented Avatar" can be designed with the minimum set of necessary and simple specifications for each function, enabling a low-cost system. The function-specific Avatar designed for each function can be reused in multiple applications, thus improving design efficiency. In addition, when the system is operated in an environment where people are nearby, it is possible to operate the teleoperation system with the "Communication Avatar" while ensuring safety by turning off the power of the "Manipulation Avatar" with high-power motors. The proposed Augmented Avatar has the following features.

- Flexibility and reusability of each functional avatar because of independent designs as manipulation avatar, that is "body" and communication avatar, that is "mind."
- Safety for people around the Augmented Avatar by inactivating the manipulation avatar while communication avatar is working.
- Relatively low cost against humanoid robots.

Figure 3. Proposed augmented avatar and prototype for XPRIZE/AVATAR.

III. Result of Team LAST MILE in XPRIZE/AVATAR

Our LAST MILE entered XPRIZE/AVATAR by utilizing some of the aforementioned technologies. In the XPRIZE/AVATAR Final, first-time operators were given a 60-minute lecture on the operation of the system, and then tested at a site that was opened to the public two days prior to the event. The test consisted of 10 tasks in series, and if any of the tasks could not be completed, the test ended there. Teams were narrowed down each day for three days, including the final qualification check. Our team managed to stay in the competition until the last day, and finished at 12th out of 820 teams worldwide. Nimbro from Germany won the competition by a landslide [6].

IV. Conclusion

Aiming to realize teleoperation technology that can work beyond space as a solution to alleviate the uneven distribution of population, we introduced a set of technologies that enable vision-based operation to make a mobile smart device an operating interface that anyone can use. We participated in the XPRIZE/AVATAR competition, and at the final held in Los Angeles in November 2022, we were ranked 12th place in the world among the 820 teams participating at the beginning of the competition, and the highest ranked in Japan. We believe our team can keep enhancing the development to launch a service that enables remote employment.

Acknowledgment

We appreciate all the people involved in organizing XPRIZE/AVATAR, the people who operated the system as operators, MELCO and Kansai University for their efforts to participate in the competition, and my family and team members who supported my participation in the competition.

REFERENCES

[1] M. Haruna, N. Kawaguchi, T. Katsumata, M. Ogino, and T. Koike-Akino, “Development of Remote Machine System with Sense of Oneness,” J. Robot. Soc. Japan, vol. 39, no. 3, pp. 283–286, 2021, doi: 10.7210/jrsj.39.283.

[2] M. Haruna, M. Ogino, S. Tagashira, and S. Morita, “Proposal for Augmented Avatar and verification of prototype I - Advance to XPRIZE/AVATAR Finals-,” Inf. Process. Society Japan interaction2023, 2P-66, pp. 755–760, 2023, [Online]. Available (from 8th April 2023): http://www.interaction-ipsj.org/proceedings/2023/data/pdf/2P-66.pdf

[3] M. Haruna, M. Ogino, S. Tagashira, and S. Morita, “Verification of Augmented Avatar Prototype 2 for One-Click Operation - XPRIZE/AVATAR Final, Japan's Highest Ranking -,” Inf. Process. Society Japan interaction2023, , 2P-67, pp. 761–766, 2023, [Online]. Available (from 8th April 2023): http://www.interaction-ipsj.org/proceedings/2023/data/pdf/2P-67.pdf

[4] M. Haruna, M. Ogino, and T. Koike-Akino, “Proposal and evaluation of visual haptics for manipulation of remote machine system,” *Front. Robot. AI*, vol. 7, Oct. 2020, doi: 10.3389/frobt.2020.529040

[5] M. Haruna, N. Kawaguchi, M. Ogino, and T. Koike-Akino, “Comparison of Three Feedback Modalities for Haptics Sensation in Remote Machine Manipulation,” IEEE Robot. Autom. Lett., 2021, doi: 10.1109/LRA.2021.3070301

[6] Max Schwarz, Christian Lenz, Raphael Memmesheimer, Bastian Pätzold, Andre Rochow, Michael Schreiber, and Sven Behnke, “Robust Immersive Telepresence and Mobile Telemanipulation: NimbRo wins ANA Avatar XPRIZE Finals,” *IEEE Int. Conf. on Intelligent Robot and System,* doi: https://arxiv.org/abs/2303.03297 (under submitted)