Human Support Robot as Research Platform of Domestic Mobile Manipulator

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Abstract. The Human Support Robot (HSR) has been used in Domestic Standard Platform League (DSPL) of RoboCup@Home since RoboCup Nagoya in 2017. Currently, the number of HSR users is expanding to 44 sites in 12 countries worldwide (as of 30th March, 2019). In this paper, we explain the design concept of HSR, and examples of recent activities of the developers community. We hope that it would contribute to RoboCup and researchers.

Keywords: Mobile Manipulation · Domestic Robots

1 Introduction

Domestic mobile manipulators are expected to perform physical work in living spaces worldwide in order to contribute to an aging population with declining birth rates with the expectation of improving quality of life (QoL). In order to achieve such robots, it requires tremendous research of algorithms in addition to the hardware which may coexist with people in their living space. We assume that the research will accelerate by using a common robot platform among researchers since that enables them to share their research results. Therefore we have developed a compact and safe research platform, Human Support Robot (HSR), which can be operated in an actual home environment and we have provided it to various research institutes to establish HSR Developers Community (Fig. 1) [7]. Regarding user experiences, HSR aims to support people having greater needs for daily life (Fig. 2).

2 Design of HSR

Here we explain the overview of HSR design, referring to [15, 16]. Through several trial user tests with prototypes in [15], we concluded that the robot's motion appears to be complicated and unexpected because the arm starts moving after the wheels completely stop, resulting that it gives users uneasy feeling and impression of slow motion. Taking it into account, we started designing a new simple mechanical structure based on coordinated movements of the wheels and

Fig. 1. HSR Developers Community [15].

(a) Independent Living Support

(b) Remote Care Support

(c) Housework Support

Fig. 2. Utilization of HSR [15].

the arm. Regarding the targets of the design, we set the maximum payload weight in arbitrary posture to 1.2 kg in order to grasp 43 classes of objects [9] from floor to desk (0 - 725 mm) in three directions (top, side, front) of the hand [16]. The target height is set to 1.35 m considering the reachability to furniture of shoulder height (1331 mm, referred from [14]), which could be normally accessed by general people standing. The maximum velocity is set to 0.8 km/h based on sensory evaluations using the previous prototype, considering real field tests to elderly people or people with disabilities, while giving them a sense of security. The width of the electric wheelchair is set to 700 mm or less and the width required for a wheelchair and a person facing the sideways to pass each other is set to 120 cm or more. Based on these conditions, the target width is set to less than 50 cm with a cylindrical telescoping body, taking into account the parallel running and passing with the wheelchair. In addition, we set targets with a step difference of 5 mm and a slope of 5 degrees from the barrier free standard in Japan [3]. Moreover the height of the robot's standard posture is set to less than the eye level of the wheelchair user (110 cm [8]), because we do not want to give the sense of intimidation to wheelchair users. Considering experiments under development in actual fields with people, we set the maximum kinetic energy 10 J or less.

Next, we describe actual results of the design. Fig. 3 shows the joint configuration of HSR. Here, the shoulder extends twice the length of the head by the movement of joint #6.

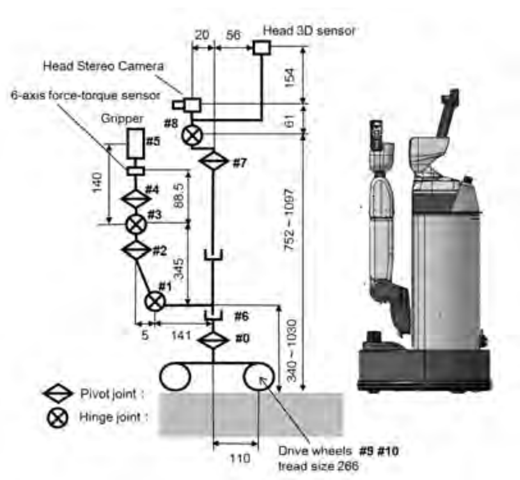
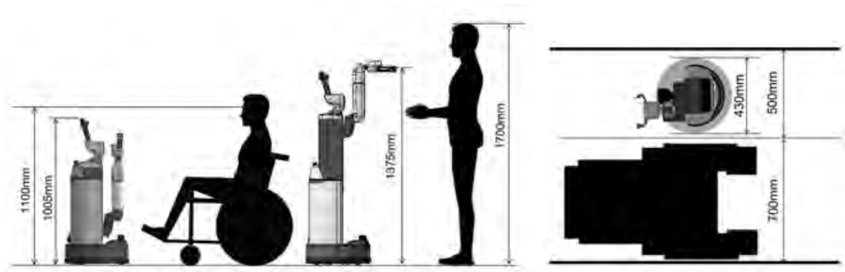


Fig. 3. Joint Configuration of HSR [16].

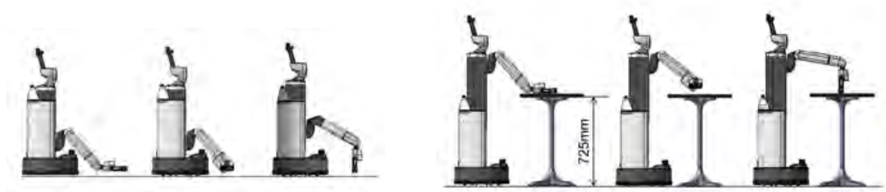
As shown in Fig. 4, it is designed to meet the requirements of the size. In addition, it is designed to be able to handle from a floor to a desk by gripping postures in three directions as shown in Fig. 5. The basic specifications of HSR are shown in Table 1. With regard to the maximum kinetic energy, considering the worst case, we calculate the kinetic energy with the maximum speed of 0.36 m/s from the no-load rotation speed of the wheel motor, and the weight of 50 kg assuming to add 13 kg of additional devices. It is 3.24 J, which is lower than the target value 10 J. These results has clarified the features of HSR.

Fig. 6 shows the sensors installed in the HSR. Various sensors are installed for the ease of use as a research platform. Safety measures include reduction of pinch points by simplification of the arm, reduction of fall hazard through gravity compensation of the arm and self-lock mechanism of the hand, reduction of contact danger by driving thrust reduction and magnetic tape stop function to reduce the risk of fall from stairs and steps. It implements force control with a 6-axis force-torque sensor on the wrist, and compliance control using joint modules based on series elastic actuators [11]. Regarding computational resources, CPU board (Intel©Core™i7-4700EQ CPU 2.4GHz) and GPU board (NVIDIA©



(a) Side View (b) Top View

Fig. 4. Side and Top View of HSR [16].



(a) Picking From Floor (b) Picking From Desk

Fig. 5. Picking From Floor and Desk in Three Directions [16].

Fig. 6. Sensors and Equipements of HSR [15].

Jetson$^{\mathrm{TM}}$) are mounted inside HSR. When a large-scale calculation is required, it is possible to use an external server via wireless or wired LAN.

HSR's software architecture is built on ROS (Robot Operating System) [12]. The overview of the system architecture on ROS (Kinetic) is shown in Fig. 7.

The robot as a whole has 8 DoF for manipulation, comprised of the 3 DoF of the mobile base, 4 DoF of the arm, and 1 DoF of the torso lift. Thus, it is possible to generate flexible movement by moving the mobile base and the arm

Table 1. HSR basic specifications [15].

height	ϕ430×1,005(∼1,350)mm
weight	37kg
arm length	600mm
shoulder height	340∼1,030mm
grasped object	∼1.2kg weight @ full arm reach ∼130mm width
maximum velocity	0.8km/h
mobility performance	∼5mm difference in level ∼5deg slope

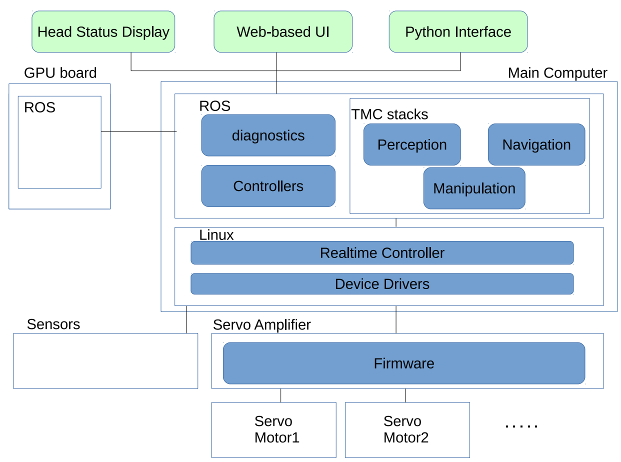


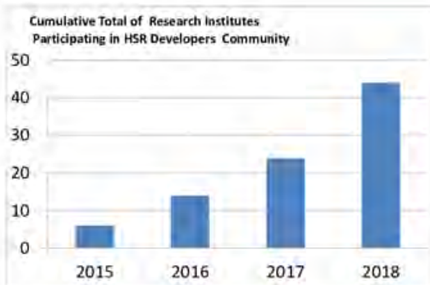
Fig. 7. Software Architecture of HSR [15].

together. We developed a novel whole-body motion control method making better use of the configuration of this robot for coordination between transportation movement and the grasping operation [15].

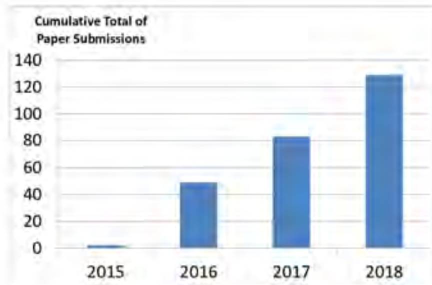
3 Activities of HSR Developers Community

3.1 Status of Community

HSR is provided mainly through public offerings, and research activities are proceeding on each projects. All the users are the members of HSR Developers Community, where they are able to share the research results and receive information of HSR on the community server. As the policy of the community, submitting papers are highly recommended in order to activate mobile manipulation research. As shown in Fig. 8, the community is steadily expanding every year. Currently, the number of research institutes of the community is 44 sites in 12 countries worldwide (as of 30th March, 2019). Along with that, the number of accepted paper submissions has also increased.



(a) Participants in Community



(b) Paper Submissions

Fig. 8. Statistics of HSR Developers Community.

3.2 Competition

In recent years, international robot competitions have attracted attention as an effective approach to accelerate research and development of robots [5, 2, 6]. HSR has been used at the Domestic Standard Platform League (DSPL) for home service robots since RoboCup 2017 Nagoya (Fig. 9(a)). As described in [15, 16], the results suggest that HSR has potential performance as a home mobile manipulator.

Moreover, it has been adopted as a standard platform for the service robot competition of the World Robot Summit (WRS) [6] which is scheduled to be held in 2020 in Japan after the Tokyo Olympic Games. The preliminary WRS was held in 2018 (Fig. 9(b)). The rules were much simpler than RoboCup DSPL. The skill challenge had 2 tasks, which were Bring Me and Tidy Up Here [6]. However, there were a lot of teams for which these tasks were challenging enough. In fact, 14 teams joined the competitions and 6 teams did not get any points. It is clarified that one of the reasons was the short preparation time. Therefore we believe that WRS2020 should start the process of the public offering much earlier than WRS2018. Also it might be very hard for teams to do all the tasks perfectly at the competition place which they have never seen before the competition. Actually, it seemed not to be enough time to prepare all the settings for unknown test environment. Therefore it might be useful to use a simpler and smaller pre-announced competition space with furniture teams can get, which they can set on each sites. We think that it could be a standard regulation to share the same test conditions and compare each results clearly.

Currently, the WRS committee is preparing modified regulations for WRS2020, considering the results of WRS2018. The public offering is going to be held for WRS2020 and it is planned that the selected teams which have no HSR will receive it.

(a) RoboCup2017 Nagoya (b) WRS2018 Tokyo

Fig. 9. International Robot Competitions using HSR.

3.3 Research Activity

In the community, studies and field tests are being conducted in parallel. Fig. 10 shows examples of these activities.

Regarding Fig. 10(a), we believe Tidy Up Here task is one of the most important tasks because it includes general solutions of autonomous technologies and it could be used to a lot of applications. Therefore we have been researching it since we started in-house development of HSR [10, 15].

Next we introduce a example of government-funded projects (CREST) [1]. The project of Fig. 10(b) is using HSRs in each research institutes in order to establish the framework of "symbol emergence in robotics"[1]. The main target of the project is Tidy Up Here task. In the near future, the project is going to show the demonstration with their research results.

Fig. 10(c) shows one of the best demonstrations of Tidy Up Here task, which was held by Preferred Networks. Throughout the event days of CEATEC JAPAN 2018, HSRs were continuously tidying up the messy demonstration space with the excellent deep learning technology. It has led to CEATEC AWARD and increased public's interest in domestic mobile manipulators [4].

Fig. 10(d) shows field tests for elderly people with a medical university. Here, we have experimented various applications of Bring Me task, with different user interfaces such as direct voice command through the microphone on HSR and tablet PCs or smart speakers set in each rooms for elder people. So far, it is too early to conclude it based on statistical methods. However we feel the existence of the robot might be able to give a enjoyable and positive life to elderly people as a kind of partnership, although the possible tasks are still limited. We beleive that field tests could give hints of the research and evaluate the feasibility of the tasks, which are represented in Fig. 1.

4 CONCLUSION

In this paper, we described HSR design concepts and activities of HSR developers community. The design of HSR is still under active development and we will improve it by continually reflecting user and researcher requests. We are sure that the strong connection among researchers is very important to realize domestic mobile manipulators. Through these activities, we really hope to contribute to RoboCup and robotics researches.

(a) In-house Research of Autonomous Tidy-up Task [15]

(b) CREST Project, Symbol Emergence in Robotics for Future Human-Machine Collaboration [1]

(c) Autonomous Tidying-up Robot System, CEATEC JAPAN 2018 [4]
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(d) Test in Robotic Smart Home jointly with Fujita Health University [13]

Fig. 10. Research Activities using HSR.

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