eR@sers Team Description Paper [DSPL]

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Abstract. Home service robots must be capable of assisting humans to perfrom common daily tasks in shared environments. To achieve this, the robots are required to understand spoken and visual commands in a natural way from humans, navigate in known and unknown environments while avoiding static and dynamic obstacles, recognize and manipulate objects, detect and identify people, among several other tasks. This paper describes our current research topics and main findings as well as the efforts to implement all the developed software into the Toyota Human Support Robot (HSR). We have improved the abilities of robots with various techniques. We briefly introduce them and our latest related research in this description paper.

1 Introduction

Team eR@sers was formed around 2000 to participate in RoboCup 4-legged league. Thereafter, the team joined the @home league where eR@sers achieved first place at RoboCup 2008, 2010, second place in RoboCup 2009, 2012, 2017, and third place in RoboCup 2018, and its social robot HSR obtained the @Home Innovation Award in 2016. Furthermore, Team eR@sers was a finalist in World Robot Summit (WRS) 2018. As a joint team, we have participated in RoboCup 2021, RoboCup 2022, and RoboCup 2023; we ranked 4th place and got the "Smoothest, Safest Navigation" Award twice.

We mainly focus on the adaptability to the environmental changes and human-robot interaction. All developed functions can be packed in ROS modules and the system has been tested in real environments.

2 Innovative technology and scientific contribution

2.1 Multimodal feedback for active perception

We use a multimodal system for active robot-object interaction using laser-based SLAM, RGBD images, and contact sensors. In the object manipulation task, the robot adjusts its initial pose with respect to obstacles and target objects through RGBD data so it can perform object grasping in different configuration spaces while avoiding collisions, and updates the information related to the last steps of the manipulation process using the contact sensors in its hand.

We propose in [1] [2] an active object manipulation system using a 3-DOF RGBD camera (height, pan, and tilt movements) on top of a service robot and a 6-axis force sensor in the hand. Through these sensors, the robot is able to detect the obstacle's position and orientation in robot coordinates while the different states of the manipulation process take place, as shown in Figure 1.

In particular, the robot arrives near the target within an uncertainty given by the localization system based on 2D laser scans, but with a localization error big enough to affect the performance in the grasping step using only the arm's inverse kinematics. Therefore, we propose the use of the upper RGBD camera to update the robot's relative position to the furniture and to locate the target object, and then we use the contact sensor in the robot manipulator to detect when the robot reaches it.

On the other hand, in the recognition task, in [3] we propose a series of strategies for object recognition in human-made environments. We have proven the feasibility of the proposed methods by evaluating the performance in the object recognition task as part of the Storing Groceries and Clean Up tasks in the RoboCup at Home international competition and in the Tidy Up task in en World Robot Summit.

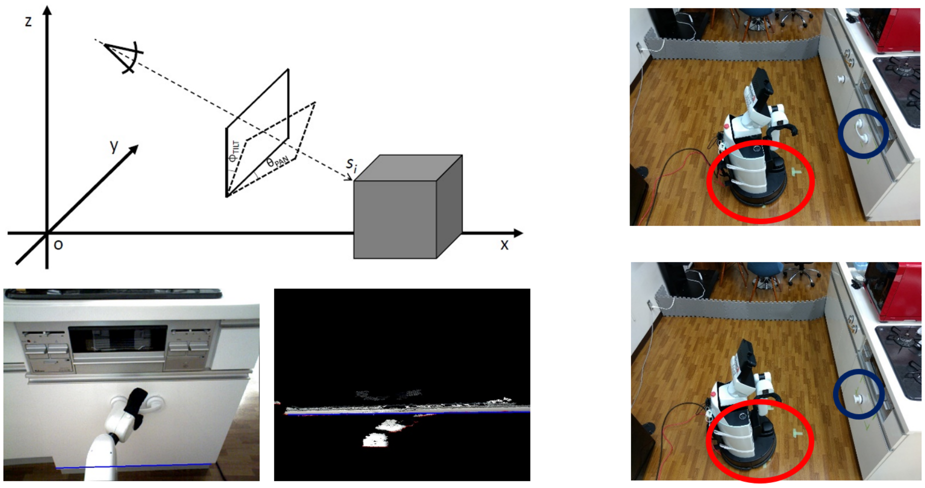

Fig. 1. The robot's distance to the dishwasher should allow manipulation without collisions; the upper RGBD camera is used to detect the dishwasher and door handle positions with respect to the gripper in the context of object manipulation.

2.2 Few-shot object recognition

Our object recognition system incorporates a few-shot object recognition system based on CLIP for rapid deployment on actual robotic platforms [4]. Additionally, we employ powerful segmentation models from the segment-anything toolkit to construct datasets, enabling faster and simpler construction of object recognition models. In contrast to traditional methods that require extensive image datasets and annotation efforts, this object recognition method was deployed on our robot at the Bordeaux competition in which preparation time was limited. In addition, the combination of this object recognition method and the perception method described in the previous section reduced misrecognition.

2.3 RoboCup@Home Simulation for human-robot interaction

Evaluating the quality of human-robot interaction, such as the impressions of an individual user and whether a robot utterance is easy to understand, involves dealing with cognitive events, which are difficult to observe as objective sensor signals. One of the ultimate aims of RoboCup@Home is to realize intelligent personal robots that operate in daily life. While evaluating such social and cognitive functions is important, tasks for real competitions with time and space limitations cannot be designed for such evaluation. For example, using questionnaires is one conventional method for evaluating the social and cognitive functions of robots; however, this is difficult in real competitions because the number of samples that can be obtained is quite small.

Therefore, in [5] we propose a novel platform, shown in Figure 2, for competition design that can be used to evaluate the social and cognitive functions of intelligent robots through VR simulation. First, we have proposed a novel software platform that integrates ROS and Unity middleware to realize a seamless development environment for VR interaction between humans and robots [6,7], shown in Figure 3. Second, we have proposed two tasks as examples of task design for evaluating social and cognitive functions, which are 'Interactive Cleanup' and 'Human Navigation' tasks. They aim for statistical evaluation of human-robot interaction in VR. Especially, the Human Navigation task is proposed to observe and evaluate human behavior in terms of the quality of robot utterances.

2.4 RoboCup@Home Simulation DSPL [8]

Although the skills required to solve isolated robotics problems have reached amazing performances recently, we propose the evaluation of such individual solutions in fully integrated robot systems tested in real daily situations like those presented at international robotics competitions. The simulation Domestic Standard Platform League (sDSPL), shown in Figure 4, which utilizes the HSR simulator developed for the World Robot Summit, surges from the necessity to standardize and spread the research on Domestic Service Robots where a series of solutions can be tested to solve a general-purpose task in a standard domestic

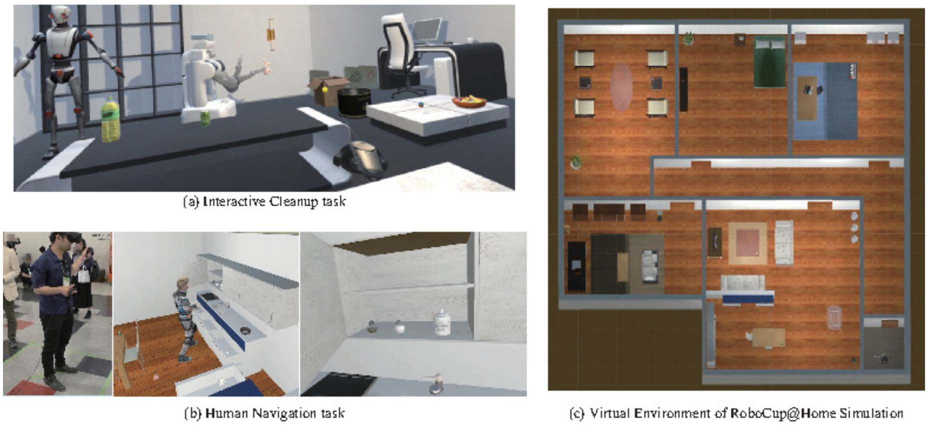

Fig. 2. RoboCup@Home Simulation

environment; this approach has been proven successful at several international competitions, namely, the RoboCup Japan Open, the Mexican Tournament of Robotics, and the RoboCup 2021.

Following the rules presented at the WRS - Partner Robot Challenge (Real Space), we proposed the Tidy-Up task to evaluate the robot's performance. It consists of taking objects from the incorrect locations to a predetermined deposit and then providing a person within a group with some food from a shelf when requested while avoiding obstacles when navigating (`https://worldrobotsummit.org/`). It uses the YCB Object and Model set ([9]) consisting of objects commonly found in home and office environments and they vary on shape, material, size, texture, weight, etc.

Whereas promoting Smart solutions, the key performance indicator is based on a 4S philosophy: Speed, Smooth, Stable, and Safe, using a compact field that can be easily set up anywhere to allow for continuous evaluation for a variety of research activities [10]. While rewarding actions like opening the drawers, depositing objects softly and in free spaces, and, in some cases, placing objects according to a specific orientation, the rulebook discourages actions such as dropping or hitting objects and furniture, false deliveries, and delivering an object in an occupied space that might prevent teams from getting full scores in a specific action.

3 Contribution for RoboCup@Home

Due to the COVID-19 pandemic, many robot competitions have been canceled in the past years. To address this problem, we designed and hosted the RoboCup@Home 2021 WorldWide, as in [12] [13], where the platform is still online and available for interested people to test their service robots' solutions to the proposed challenges.

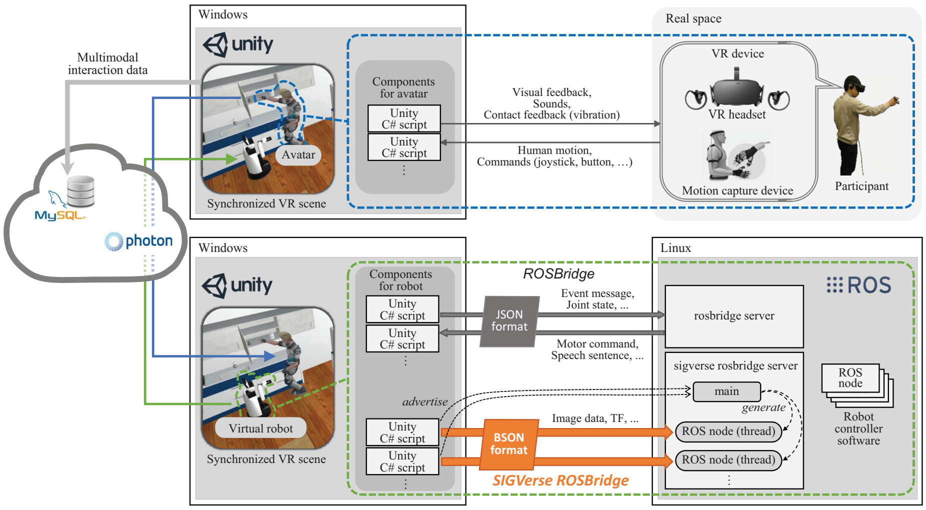

Fig. 3. VR-based competition platform

Especially when the human-robot interaction competition is conducted remotely with real robots, the problem of statistical unreliability is even more difficult to solve. In response to this situation, we have proposed the human-robot interaction simulation system for robot competition since 2013 [7] and offered a cloud-based virtual reality system to conduct online competitions in response to the coronavirus pandemic in 2021[11].

In Navigation tasks such as the Carry My Luggage, our proposed method demonstrated high performance and won the Smoothest, Safest Navigation Award at RoboCup 2022 and 2023.

3.1 RoboCup@Home Education

In addition, starting from 2006, RoboCup@Home has been the largest international annual competition for autonomous service robots as part of the RoboCup initiative. However, it is observed that the development curve of the RoboCup@Home teams has a very steep start. The amount of technical knowledge and resources (both manpower and cost) required to start a new team has made the event exclusive to only established research organizations. For instance, in the domestic RoboCup Japan Open challenge, the participating teams in RoboCup@Home were merely around 10 teams, which are about the same teams for the past few years. There were actually several new team requests however the development gap was huge for them to even complete the construction of the robots.

For this reason, RoboCup@Home Education initiative was started at RoboCup Japan in 2015. RoboCup@Home Education is an educational initiative in RoboCup@Home that promotes educational efforts to boost RoboCup@Home participation and

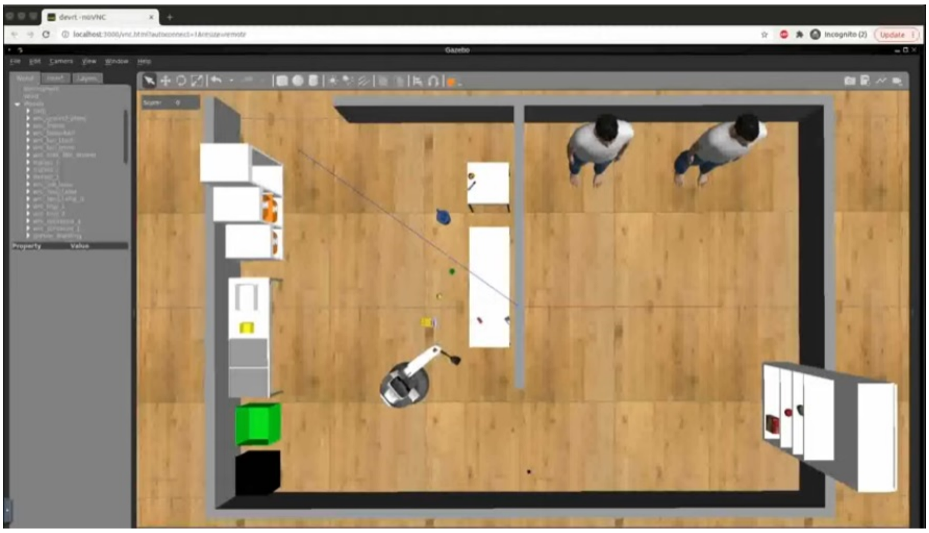

Fig. 4. RoboCup@Home Simulation DSPL

service robot development. Under this initiative, currently, there are 3 projects started in Japan:

1. RoboCup@Home Education Challenge at RoboCup AsiaPacific2017 Bangkok.
2. RoboCup@Home Education Challenge at RoboCup Japan Open since 2014.
3. Development of an educational Open Robot Platform for RoboCup@Home
4. We hosted RoboCup@Home Education Workshop Rome, Italy, March 15–16,2017 `https://sites.google.com/dis.uniroma1.it/athomeedu-rome2017/home`
5. Outreach programs (domestic workshops, international academic exchanges, etc.)

(For more information, visit `http://www.robocupathomeedu.org/`)

4 Link to Team Video, Team Website

Official website:
`https://trcp.gitlab.io/erasers/`

Our team Video:
`https://youtu.be/rzmfsBL0-ck`

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HSR Software and External Devices

We use a standard HSR robot from *TOYOTA*. No modifications have been applied.

Fig. 5. TOYOTA HSR

Robot's Software Description

For our robot we are using the following software:

- Platform: Ubuntu20.04 Operating System
- Face recognition: None. Not designed for human interaction.
- Object detection: YOLO based object detection and recognition.
- Object recognition: Tip-Adapter[4]
- Arms control and two-hand coordination: MoveIt and Toyota HSR API

External Devices

HSR robot relies on the following external hardware:

- 2× MSI katana laptops.
  - CPU: Intel core i7
  - Mermoy: 32GB
  - GPU: Nvidia RTX3070

Cloud Services

HSR connects the following cloud services:

- OpenAI GPT4