Beam: A Collaborative Autonomous Mobile Service Robot

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Abstract

We introduce the Beam, a collaborative autonomous mobile service robot, based on SuitableTech's Beam telepresence system. We present a set of enhancements to the telepresence system, including autonomy, human awareness, increased computation and sensing capabilities, and integration with the popular Robot Operating System (ROS) framework. Together, our improvements transform the Beam into a low-cost platform for research on service robots. We examine the Beam on target search and object delivery tasks and demonstrate that the robot achieves a 100% success rate.

Introduction

In the past decade, there has been a significant growth of research and development on service robots (Quigley et al., 2007; Veloso et al., 2015; Chen et al., 2010; Khandelwal et al., 2017; Hawes et al., 2016; Srinivasa et al., 2012) due to their wide range of applications in real life. Although the current working environment of service robots is mostly industrial, these robots are gradually moving from factories and labs to homes, offices, schools, and healthcare facilities. In order for service robots to become an intrinsic part of human environments, they need to be able to perform tasks autonomously and interact with people efficiently.

Autonomy can be challenging to implement on service robots. Unlike many industrial settings, where robots perform repetitive preprogrammed tasks, service robots must act autonomously in dynamic, uncertain, and multi-goal environments. In addition, to be convenient for human users, service robots need to be able to interact with humans in a natural way, by understanding speech and language and reacting to human instructions appropriately.

The lack of affordable and commercially available open platforms is a major obstacle in advancing the research on service robotics. The Beam is a mobile telepresence system developed by SuitableTech and offers an impressive hardware array for its price. In this paper, we present our modifications to the Beam, which make it possible to use the system as a low-cost platform for research on all aspects of service robotics, including autonomy, human-robot interaction, and multi-robot collaboration and coordination. Our modifications include:

Figure 1: Hardware setup of the Beam

- **Hardware Enhancement:** We add more hardware resources for increased computational and sensing capabilities. These include a laptop to handle expensive computations and multiple depth cameras for increased sensing of the environment. The hardware setup of the Beam is shown in Figure 1.
- **Integration with Robot Operating System (ROS):** We integrate the ROS middleware framework into the Beam to transform it into a programmable research platform. The source code of the ROS package can be found on our GitHub repository[1].
- **Autonomy:** Using ROS, we make the Beam capable of navigating in indoor environments and charging its battery autonomously. We created a circuit to make the Beam's battery charge the laptop as well, allowing the Beam to autonomously perform time-extended tasks.
- **Human Awareness and Interaction:** We add human detection, recognition, and tracking capabilities to the Beam, incorporate a speech recognition system to allow the robot to work with spoken input, and use the laptop's touchscreen to facilitate touch input. We also implement a

[1] https://github.com/people-robots/rosbeam

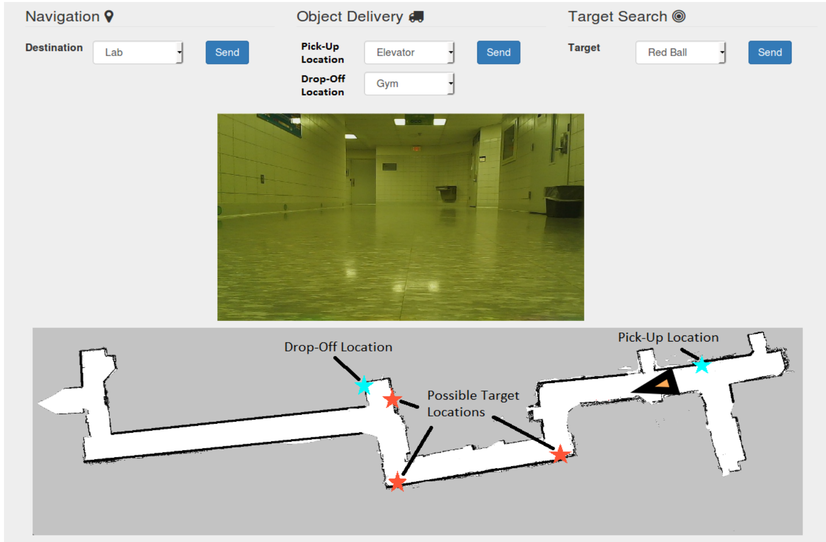

Figure 2: The Beam's web interface. The laser map in the GUI shows the third floor of Fenn Hall building at Cleveland State University.

web interface, shown in Figure 2, and an emailing system to enable remote human users to schedule tasks, monitor, or interact with the robot.

We investigate our improvements to the Beam in target search and object delivery tasks to verify their effectiveness.

Experiments and Results

We extensively examined the Beam's ability to navigate and charge autonomously. In total, the Beam has traversed over 12 km across four buildings connected by bridges at Cleveland State University.

We additionally performed proof-of-concept experiments investigating the Beam's performance in two service tasks: target search and object delivery. All experiments took place on the third floor of Fenn Hall Building at Cleveland State University, a map of which is shown in Figure 2.

Target Search

In the target search task, the Beam had to search the building for an object and report its location. To ensure that this would be a test of Beam's abilities and not of the object recognition library implementation, we simplified the object recognition component of this task by attaching AR markers to each object.

For each trial of this task, we hide an AR marker in a random location on the map and instruct the Beam to search for it. The search algorithm consists of the Beam randomly visiting a sequence of predefined possible item locations, illustrated by red stars in the map in Figure 2. Upon reaching a potential location, it rotates for 30 seconds to scan for AR markers. If it sees a marker, it says "I found the object" using its text-to-speech capability.

We conducted 10 trials of this experiment and found that the Beam successfully found the object in all 10.

Object Delivery

In the object delivery task, the Beam had to move objects from one location to another. For each object, we gave the Beam a pick-up location and a delivery location, each of which were selected randomly from the map. One of the pick-up and drop-off locations are illustrated by cyan stars in the map in Figure 2. We then started the Beam from a random location. The task was for the Beam to travel to the pick-up location, get the object, and then travel to the delivery location.

To facilitate the carrying of objects, we attach a small basket to the Beam, and a human is present at the pick-up and delivery locations to load and unload the object. When the Beam arrives at the pick-up location, it must say "please load the object", after which the human loads the object and presses a button on the laptop touchscreen to indicate that the Beam can move on. Similarly, at the drop-off location the Beam says "please unload the object" and the human uses the touchscreen to indicate when the object had been unloaded.

We tested 10 trials of the object delivery task and recorded the number of times the Beam was able to successfully complete the delivery. We found that the Beam was able to pick up and deliver the object in all 10 trials.

Conclusion

We presented a set of modifications to SuitableTech's Beam telepresence system to transform it into a collaborative autonomous service robot, and made it usable as a low-cost platform for research on different aspects of service robotics, including long-term autonomy and lifelong learning, physical/cognitive/social human-robot interaction, multi-robot collaboration and coordination, and human multi-robot interaction.

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