Facilitating HRI by Mixed Reality Techniques

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ABSTRACT

Mobile robots start to appear in our everyday life, e.g., in shopping malls, airports, nursing homes or warehouses. Often, these robots are operated by non-technical staff with no prior experience/education in robotics. Additionally, as with all new technology, there is certain reservedness when it comes to accepting robots in our personal space.

In this work, we propose making use of state-of-the-art Mixed Reality (MR) technology to facilitate acceptance and interaction with mobile robots. By integrating a Microsoft HoloLens into the robot's operating space, the MR device can be used to a) visualize the robot's behavior-state and sensor data, b) visually notify the user about planned/future behavior and possible problems/obstacles of the robot, and c) to actively use the device as an additional external sensor source. Moreover, by using the HoloLens, users can operate and interact with the robot without being close to it, as the robot is able to *sense with the users' eyes.*

KEYWORDS

Augmented Reality, Natural Interfaces, Sensor Fusion

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1 INTRODUCTION

Research in robotics has come to a stage where the first robots find their way into our daily life. This process is accompanied by a shift in the targeted user group. Instead of mainly researches, in the near future more and more people without any background in robotics will interact with robots. In contrast to, e.g., robotics developers, they do not have knowledge about a robot's sensors or actuators, its capabilities and its internal state. Our goal is twofold: first, we tackle the knowledge gap by making use of state-of-the-art Augmented Reality (AR) technology enabling users to perceive the world *like the robot does*, and thus also increasing the acceptance of robots in everyday life. Second, we support users (maintenance staff) to visually debug problematic situations for the robot, that might not be obvious without looking at log files or software debug tools for instance.

Augmented and Mixed Reality techniques are already applied in various areas of robotics development and debugging. Stilman et al. [10] created a virtual model of the environment for decoupled and safe testing of algorithms for, e.g., computer vision providing a virtual ground truth for the robot's physical sensors. Sensor data can be directly visualized in the environment as 3D visualizations. Nishiwaki et al. [8] visualize laser and depth data as well as footstep planning on a humanoid robot. Other examples of visualized sensor data are SLAM results [6] or localization accuracy [2].

Already in the early 90s, Milgram et al. [7] proposed applications of AR in telerobotics. They used augmented stereo video of the remote robot location for enhancing the operators visual perception of the environment, facilitating control using virtual pointers and reducing the operators workload by, e.g., showing warnings on critical objects.

Mixed Reality Human-Robot Interactions

Apart from tele-operators and developers, everyday HRI can also be enhanced using AR/MR techniques. Dragone et al. [4] proposed displaying virtual avatars on physical robots. The goal is to make robots appear socially more plausible. AR was also claimed to enhance human-robot collaboration by creating spatial dialogues [5]. In the scenario of an industrial robot arm, a user survey revealed that people see benefits of using AR for a better understanding of the robot they are working with [1]. Coovert et al. [3] visualize arrows to signal a robots intended movement to the user.

In our ongoing work, we pick up these ideas but add a novel approach which we suppose to be even more helpful for a human user. Our aim is to not only use a MR headset for visualizing data, but to also integrate its sensor data, giving the user a more direct interface to the robot. This way, on the one hand the user can always be aware of the current robot status and intent. On the other hand, the robot can integrate the human's location in the environment as well as data of the MR headset from, e.g., RGB-D sensors. Moreover, voice instructions can be given remotely, even when the robot is located in another room.

In the following, we will describe our ideas in more detail in an exemplary MR-augmented HRI scenario that we implemented.

2 EXAMPLE: WHAT YOU SEE IS WHAT I CAN

Humans are good at using their own body schema to infer the capabilities of others. They make use of projecting their body schema on others in cooperative tasks in which it is relevant to estimate e.g. the reaching space. The body schema of a robot, even if anthropomorphic, typically is different from that of a human and naive humans with little experience with a certain robot may have

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difficulties in estimating if a path to navigate through is sufficiently free, or where the extents of a reaching space are. The idea is now that the AR glasses are used to visualize relevant aspects, such as the optimal area in which objects should be held during handover, or the reaching area of a robot to communicate the body schema of the robot to the user. The goal is to help the user with creating a better representation of the capabilities of the robot.

For implementing such a scenario, we integrated the Microsoft HoloLens into our robotic framework based on ROS [9]. We worked with a Pepper robot by SoftBank Robotics. The Unity3D game engine was used for implementation on the HoloLens. Communication between the MR device and ROS was realized using MQTT. Making use of the room-scale tracking capabilities of the HoloLens, we only initially had to calibrate the coordinate system of the robot and the MR device. This was done by displaying a marker on the tablet attached to Pepper. After this marker is detected once, the robot is correctly represented in the coordinate system of the HoloLens and vice versa. Pose updates of the robot are used to also update the representation in the HoloLens.

Having the registration done, we use AR in two different ways to facilitate interactions with the robot: Like done in previous work, sensor data are visualized to a get a better grasp of the robot's capabilities. Here, we show the map and the robot's localization on it, the costmap and laser scans for giving sensory information. The planned path is shown for making the user aware of the next movements. Thus, the user is able to understand the reason for e.g. the robot not being able to reach its current navigation goal. This will also help the human to take the correct path, not interfering with the path of the robot. For grasping, the robot can visualize its grasp space when it is not able to reach to an object. This way, the robot can actively ask the user for help, committing information which otherwise would not be obvious. Secondly, since the HoloLens is integrated with the robot's coordinate system, it can be used as an additional sensory and input device. In our example case, by this means the robot gains knowledge about the user's position and orientation in the environment. Wherever the user goes, she can instruct the robot to come and fulfill a task by a voice command interpreted by the AR device. The users view using the Microsoft HoloLens can be seen in Figure 1.

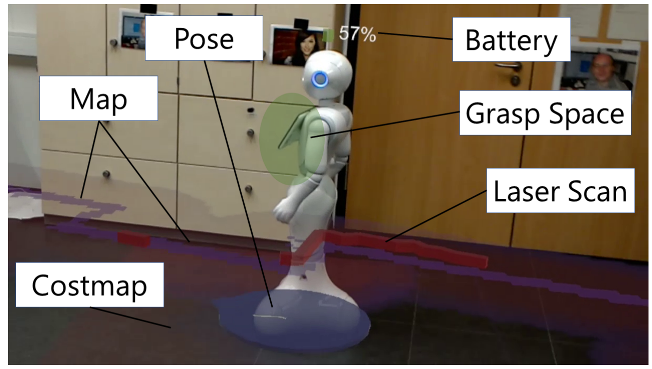

Figure 1: The sensory data which are visualized in the HoloLens: Map, costmap and laser scans, the robot's pose and battery status. Additionally, the space where the robot can grasp objects is shown.

3 CONCLUSION

The presented example scenario already reveals multiple advantages for everyday HRI: The visualization of sensory information as well as planned behavior in the environment lets users easily assess the robot's capabilities and constraints. The robot can use the AR channel to actively prompt for specific help and reduce communication problems, in particular allowing them to communicate without being in the same room.

More application scenarios of our technique are:

Shared Perception: Depth and RGB images from the AR device can be registered with the robot's coordinate frame. By pointing at objects on a table, the human can teach different objects to the robot without it being present. Vice versa the robot may remotely swiftly ask for the confirmation of certain actions in case of uncertainty.

Collaborative Task Management: In collaborative tasks, such as order picking, the robot may use AR to visualize objects which it can easily reach. The human could thus focus on those tasks which are too difficult for the robot to handle.

Training: For training a robot, AR can be used to systematically prompt multiple users to initiate different tasks with the robot, e.g. providing specific poses for handovers. This way large databases of HRI can be collected. The precision with which the placements are depicted may vary, to elicit enough real "noise" which could be beneficial for training.

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