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Mobile Teleoperation Interfaces with Adjustable Autonomy for Personal Service Robots

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ABSTRACT

Personal service robots require a comprehensive set of perception, control, and planning skills to perform everyday tasks autonomously. While achieving full autonomy is an ongoing research topic, first real-world applications of personal robots may come into reach, if state-of-the-art autonomous capabilities are combined with the intelligence of the users in a complementary way. We report on handheld user interfaces for personal robots that allow for teleoperating the robot on three levels of autonomy: body, skill, and task control. On the higher levels, autonomous behavior of the robot relieves the user from significant workload. If autonomous execution fails, or autonomous functionality is not provided by the robot system, the user can select a lower level of autonomy to solve a task. The benefits of providing adjustable autonomy in teleoperation have been successfully demonstrated at RoboCup@Home competitions.

1. INTRODUCTION

Personal robots that shall assist persons in their activities of daily living (ADL) not only require versatile autonomous skills but also intuitive user interfaces. Many high-level tasks that are difficult to achieve autonomously can already be tackled when the intelligence of the user is combined with robot skills by means of teleoperation. In this way, both sides contribute their strengths and complement each other. Nevertheless, users want personal robots as convenient tools that act as autonomously as possible, since steady low-level control of the robot would be tedious and time-consuming. Only in difficult situations, in which no autonomous solution exists yet, the user should need to take over control of the robot on the most convenient, i.e. most autonomous, level.

We propose handheld user interfaces that allow persons to teleoperate a complex anthropomorphic service robot on various levels of autonomy. The user adjusts the autonomy level according to the complexity of the task and available robot capabilities. The notion of adjustable autonomy has been coined by Goodrich et al. [1]. Leeper et al. [2] evaluate body-level teleoperation GUIs for mobile manipulation. We identified *body*, *skill*, and *task* level autonomy [3]. We develop our teleoperation interfaces for our domestic service robots Dynamaid and Coseros [4]. These robots have mobile manipulation and human-robot interaction capabilities to perform tasks autonomously in everyday environments. This involves the manipulation of objects such as grasping and placing of objects. The robots are also required to navigate safely through the environment. They naturally interact with users through speech and gestures.

2. HANDHELD USER INTERFACES

Modern handheld computers such as smart phones, tablets and slates provide complementary user interfaces that add a variety of novel interaction modes. They improve common ground, since the GUI can be designed to mediate what the robot actually can do. For instance, the user may only be given the choice between possible actions and involved objects and locations. They enable teleoperation without direct auditory or visual connection to the robot. The user gains situational awareness through the visualization of the robot's view. We investigate teleoperation with a handheld computer on three levels of autonomy. On the body level, the operator directly controls body parts such as the end-effectors, the gaze direction, or the omnidirectional drive. On the skill level, the operator controls robot skills, e.g. by setting navigation goals or commanding objects to be grasped. Finally, the operator configures autonomous high-level behaviors that sequence skills on the task level.

2.1 Body-Level Teleoperation

The body-level controls allow the user to execute actions with the robot that are not covered by autonomous skills and therefore are not supported on higher levels of the teleoperation interface. The user gains situational awareness through the visualization of live camera images, external robot views, and 2D laser scans (see Fig. 1). To prevent the robot from being damaged by executing dangerous user commands, these modes include obstacle avoidance.

2.2 Skill-Level Teleoperation

The skill-level user interfaces configure robot skills that require the execution of a sequence of body motions. The robot controls these body motions autonomously. By that, the workload on the user is reduced. While the robot executes the skill, the user can supervise its progress. Compared to body-level control, the skill-level UI does require less communication bandwidth, since images and control commands

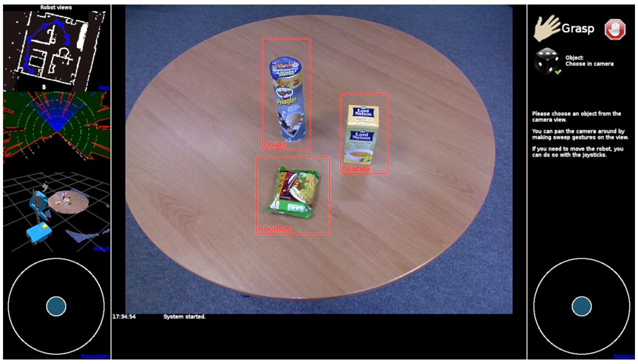

Figure 1: Skill and body-level GUI with a view selection column on the left, a main view in the center, a configuration column on the right, and a log message window on the bottom center. Motion is controlled directly with two joystick control UIs.

Figure 2: Illustration of our task-level teleoperation interface. Top left: A user composes a task. Bottom/top middle: The robot grasps an object. Top right: The robot delivers the object.

have to be transmitted with less frequency. Hence, this mode is less affected by high latency or low bandwidth communication. The user has access to several autonomous robot skills such as navigation to goal poses in a map, grasping objects in the view of the robot, and handing objects over to a user.

2.3 Task-Level Teleoperation

The task-level teleoperation UI is intended to provide the high-level behavior capabilities of the robot (see Fig. 2). The user can compose actions, objects, and locations similar to our implementation for the parsing of complex speech commands. Our user interfaces allow for composing a sequence of skills in two stages. On the top level UI, the user adds and removes skills from the sequence. Once a skill is selected, the user specifies location and object for the skill on a second layer UI. A monitoring UI lets the user keep track of the robot's execution status. One can also watch progress on the body- and skill-level UIs.

3. RESULTS

At RoboCup 2012 and German Open 2013 we demonstrated concepts of mobile teleoperation with Cosero. Note that at that time we used slightly simplified versions of our UIs where the tasks could be selected individually. In the Demo Challenge at RoboCup 2012, we showed an elderly-care scenario in which a user commanded the robot to fetch a drink from another room. At first, the person let the robot fetch a specific beverage. The robot drove to the assumed location of the drink, but since it was not available, the user had to take a different choice. The user switched to the skill-level control UI and selected one of the other beverages that were perceived by the robot on the table and displayed in live images on the UI. Finally, the robot grasped the selected drink, brought it to the user and handed it over. The demonstration was well received by the jury consisting of the league's technical and executive committee members. Overall, our team NimbRo@Home became world champion in the 2012 RoboCup@Home competition. At German Open 2013, we extended the Demo Challenge with receiving objects from users and putting the object in a waste bin. Our team received best score in this test and also won the competition. At RoboCup 2013 in Eindhoven, Netherlands, we presented the teleoperation UI with task specification to the jury in the DemoChallenge. Our team could also win the RoboCup@Home 2013 competition.

4. CONCLUSIONS

We propose mobile teleoperation interfaces with adjustable autonomy for personal service robots. We identified three levels of autonomy and designed various user interfaces on these levels for handheld computers. On the body level, the user can control body motions such as omnidirectional driving and gaze direction. The next higher level allows the execution of robot skills. These skills require a sequence of body motions and perception capabilities which are executed autonomously by the robot. The task-level UI is designed to configure high-level behavior similar to complex speech commands. Failures are detected on the skill- and task-level automatically and reported to the user. The user then decides for the appropriate low level UIs to resolve the situation. We demonstrated our mobile teleoperation interfaces successfully at RoboCup@Home competitions in 2012 and 2013. We will continue to integrate functionality into our user interface and investigate the use of speech as a complementary input modality for the handheld.

5. REFERENCES

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