Command Robots from Orbit with Supervised Autonomy: An Introduction to the Meteron Supvis-Justin Experiment

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ABSTRACT

The on-going work at German Aerospace Center (DLR) and European Space Agency (ESA) on the Meteron Supvis-Justin space telerobotic experiment utilizing supervised autonomy is presented. The Supvis-Justin experiment will employ a tablet UI for an astronaut on the International Space Station (ISS) to communicate task level commands to a service robot. The goal is to explore the viability of supervised autonomy for space telerobotics. For its validation, survey, navigation, inspection, and maintenance tasks will be commanded to DLR's service robot, Rollin' Justin, to be performed in a simulated extraterrestrial environment constructed at DLR. The experiment is currently slated for late 2015-2016.

Keywords

Teleoperation; Space Robotics; Supervised Autonomy; Knowledge-Driven HRI; Intuitive UI Concept

1. INTRODUCTION

Meteron (Multi-purpose End-To-End Robotic Operations Network) [5], initiated by ESA, with partners NASA, Russian Federation Space Agency (Roscosmos), and DLR, aims to study different space telerobotic scenarios, with different communication latencies and bandwidth specifications. A robot (e.g. rovers or service robots) on a simulated planetary surface (e.g. Mars) is commanded from a space station such as the ISS using different human-robot interface (HRI) options, from laptop and tablet PCs, to force reflection joysticks, and exoskeletons.

The Supvis-Justin experiment, shown in fig. 1 is lead by a team from DLR and ESA. It aims to study the user

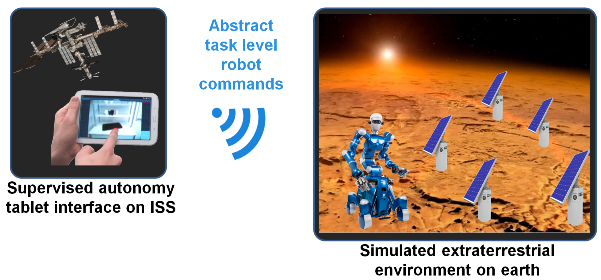

Figure 1: Meteron Supvis-Justin Concept. An astronaut teleoperates a dexterous humanoid robot (e.g. DLR Rollin' Justin) on the planetary surface using a tablet PC with task level commands from the orbiting space station or spacecraft.

interface (UI) design for a tablet PC on the ISS to operate a mobile humanoid robot on earth at the task level. The robot shall carry out these commands on a simulated planetary surface constructed on earth at DLR. Task level command has shown its viability in teleoperation tasks which require high levels of dexterity [4]. Supervised autonomy differ from telepresence in that the commanded robot utilizes a blend of local intelligence and prior object knowledge to reason the appropriate action to complete each commanded task [3] . This also enables coping with time-delays of multiple-second in the communication link, which is not possible for full haptic feedback telepresence.

Supvis-Justin employs knowledge-driven HRI design on the tablet PC [1], which mirrors the prior object knowledge on robot side. The shared knowledge base on both the robot and HRI sides is the final component to enable the abstract task level command for realizing the supervised autonomy utilized in this experiment.

2. EXPERIMENTAL DESIGN AND SETUP

An off-the-shelf Dell Latitude 10 tablet PC has been upmassed to the ISS with ESA's ATV5 flight in July 2014 for the Meteron Haptics-1 experiment [6], and installed in the Columbus module. The tablet UI software can be uploaded from the ground via a data up-link. DLR's mobile humanoid robot, Rollin' Justin [2], as shown in fig. 1, would serve as

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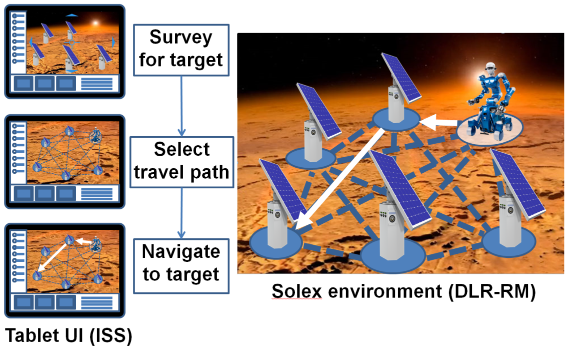

Figure 2: Protocol 1 and 3: Survey and navigation tasks of Supvis-Justin. The astronaut commands Justin to perform environment survey, travel path selection, and navigation to target in the Solex environment located on earth at DLR. Snap shots of objects and surroundings of interest can be taken with Justin's head-mounted camera for further analysis.

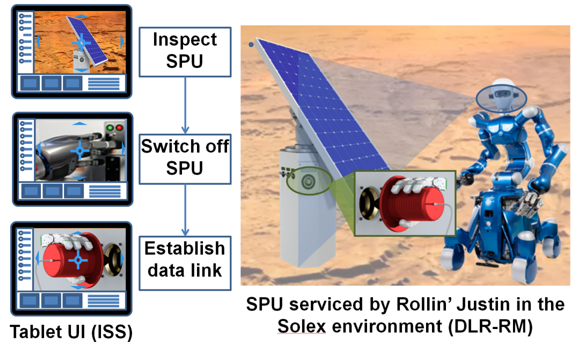

Figure 3: Protocol 2: SPU inspection and maintenance tasks. Once the robot reaches a target destination such as a defective SPU, the tablet UI guides the astronaut to command the robot, by visualizing the current state of the robot and the progress of the protocol. Different tasks such as shut down, reboot, and SPU data collection, can be performed.

the planetary service robot to be commanded by the astronaut in supervised autonomy fashion. The Solex (*SOL*ar array *EX*periment) environment, shown in fig. 2, located on earth at DLR Oberpfaffenhofen, simulates a solar array farm on the Mars surface. The Solex environment consists of a small fleet of functioning solar panel units (SPU) equipped with mechanical switches, displays, and data interface. A data link is available between the Columbus Control Center (Col-CC) located on-site at DLR, and the ISS. It is expected to provide sufficient bandwidth of 2 Mbit/s, but high latency of 2-10 seconds round-trip time.

3. EXPERIMENT PROTOCOLS

To demonstrate a robot's ability to carry out a sufficient range of tasks in space, Supvis-Justin includes three experimental protocols. The protocol description is visualized on demand as part of the UI to intuitively guide the astronaut.

The first and last protocols, as shown in fig. 2, utilizes the robot's vision to survey the surrounding environment it works in, and mobility to navigate around the terrain to reach a pre-defined target selected by the astronaut. These two protocols function similarly, with the only difference being the navigation target. Protocol 1's destination would be identified defective SPU, whereas protocol 3 returns the robot to the base station.

Once Rollin' Justin reaches a defective SPU, protocol 2, as shown in fig. 3, would be carried out. As an extraterrestrial solar farm would likely be remotely operated during normal conditions, a robot would be deployed to service a SPU only for unforeseen defects or major maintenance. Justin would be able to inspect the SPU, manipulate appropriate switches, and establish a data link. A data interface probe (DIP) has been designed to be used by Rollin' Justin to connect to the SPU, as illustrated in fig. 3, for data collection, diagnostics, and possible software updates.

4. EXPECTED RESULTS AND CURRENT PROGRESS

We have performed preliminary supervised autonomy tasks at DLR, using a tablet PC to teleoperate Justin for environment survey and object manipulation tasks [1]. These will be applied to the Supvis-Justin experiment, which is currently slated for 2015. Our team is currently developing the tablet software, together with our partner team at ESA, for space mission qualification. The Solex environment is scheduled to be completed in the first half of 2015.

With the data collected from Supvis-Justin, we hope to help further our understanding of intuitive UI design, particularly for space applications, and supervised autonomy. We also aim to extract design cues from the astronaut's performance and perception of the entire Supvis-Justin HRI experience. We will analyze the experiment through the tablet usage data collected during the experiment. Questionnaires will be conducted with the astronaut(s) after the experiment to gain more insight into the effectiveness of our supervised autonomy concept.

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