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High-Fidelity Telepresence and Teleaction

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The collaborative research center SFB453 (www.sfb453.de) aims to realize high-fidelity telepresence and teleaction systems.

Telepresence and teleaction systems, see [1]–[3] for an overview, extend the human workspace to remote locations in order to overcome barriers like distance, scaling, danger or the human skin. Using a human-system interface the human operator controls a remotely located teleoperator. Multi-modal feedback in form of visual, auditory, and haptic data is used to increase the feeling of telepresence [4].

Different application areas including minimally invasive surgery, on-orbit servicing, microassembly as well as tele-manufacturing and tele-maintenance are targeted.

For minimally invasive surgery the DLR developed the MiroSurge Robotic System. The master console is equipped with an autostereoskopic monitor along with a bimanual haptic input devices (omega.7 by Force Dimension, Inc.). The slave consists of several inhouse developed light weight, torque controlled, and redundant robotic arms (MIROs) guiding an endoscopic stereo camera and two endoscopic instruments [5], [6]. For dexterous telesurgery the surgical instruments add 2 DOF and functional actuation, e.g. a gripper, along with 7 DOF force measurement.

In another project a highly advanced surgical assistance system was developed, see [7], which aims at helping the surgeon with time-consuming and exhausting situations. A surgical knot, e.g., does not have to be performed any more by the surgeon himself using direct teleoperation, but can be executed by the robotic assistant in a semi-autonomous mode [8].

Operation in space [9] is another field of application. On-orbit servicing has been selected as a typical demonstration scenario which requires first docking to the satellite and then executing the maintenance task [10], [11]. The real satellite communication channel introduces quite large time delays and packet loss. To achieve stable interaction with the remote environment several projects of the SFB453 aim at developing new bilateral control algorithms [12]–[15]. Efficient data transmission is hereby achieved by adopting perception-oriented compression algorithms [16], [17].

Teleoperation promises tremendous potential for micro assembly. Owing to its scaling capability, teleoperation in micro-assembly [18] provides a number of advantages including increased gripping percision and improved ergonomics. Due to the seperation between workplace and operator, decreased contamination through the removal of direct human contact is also achieved. Furthermore, in [19] vacuum gripping for pick and place tasks allow micro-chips and micro-structures to be easily manipulated.

Selected results achieved in the collaborative research centre are also transferred to industry by means of special transfer projects. Subject of one of the transfer projects is e.g. the transfer of in-depth knowledge in the control of macro-telemanipulation systems [20].

Tele-manufacturing and tele-maintenance is furthermore studied in first multi-user scenarios, which are enhanced by highly sophisticated systems for locomotion and manipulation [21]. Rate-controlled locomotion interfaces are compared to a mobile human-system interface that allows walking around freely and thus experiencing a natural feeling of locomotion [22]. A combination of admittance-type haptic interfaces providing arm force feedback [23] and hand exoskeletons for finger force-feedback enables realistic interaction with the remote environment. Parameters of bilateral control algorithms are selected to guarantee stable interaction even in the case of closed kinematic chains over objects.

By using special augmentations of the visual, auditory, and haptic feedback channel the feeling of telepresence can be significantly improved.

One of the projects, e.g., implements location unbound views and predicted video information to assist the human operator in performing certain tasks, see [24], [25]. For this purpose 3D scene information is captured by using a PMD sensor mounted on top of the telerobot. Combining these images, a 3D representation of an arbitrary scene can be

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produced. Combining these images, a 3D representation of the teleoperator's immediate surrounding can be produced. Combining color information retrieved by two video cameras with the created 3D model a quite immersive representation is obtained. To enable the teleoperator to react on sudden changes, the system projects live video data onto the 3D model in real-time while recent depth data from the PMD Sensor is integrated perpetually.

3D audio information significantly enhances the feeling of telepresence. The teleoperator used in the experiments is a humanoid robot equipped with an artificial head and two silicon ears. Microphones are accurately inserted inside the ear canals. Using this hardware setup a sound localizer has been developed which is able to detect randomly moving sound sources in space. Using real-time binaural sound synthesis over headphones these sound sources are displayed to the human operator in a spatially correct manner, see [26], [27] for more information.

Finally, also haptic augmentation is used to improve the sensation of physically interacting with the remote environment [28]. An actuated data glove has been built to display object properties like surface roughness and weight. As the technical system is restricted in its rendering capabilities, human perception processes are studied with special focus on intra-modal dependencies. Appropriately modified visual and auditory stimuli are adopted to increase immersion when haptically interacting with a virtual environment. Performed studies finally lead to new design guidelines for future teleoperation systems [29].

In the collaborative research center institutes of the Technische Universität München, the German Aerospace Center, the University of Armed Forces, as well as the Ludwig-Maximilians Universität München collaborate in creating High-Fidelity Telepresence and Teleaction systems.

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