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Insides into the robotic exploration activities in the research section of the German Aerospace Center (DLR)

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Short Abstract

Mobile robotics will play a key role in future space exploration activities. The main challenges will be the actual development of the robotic systems as well as the different ways of commanding them, using technologies that range from teleoperation with the humans in the loop to shared autonomy approaches and towards highly autonomous systems. This paper describes the robotic activities of the DLR institutions within the Helmholtz projects ROBEX and ARCHES, dealing with robots for autonomous space and ocean exploration applications. Furthermore, it describes some insights of the actual flight mission MASCOT, which demonstrated successful developments of DLRs Research Institutions in the framework of the impressive Hayabusa-2 JAXA Mission. Continuing this track, DLR and CNES together have signed a cooperation agreement to provide a common rover payload for the MMX JAXA mission, which will be presented in its outline and timeline. Finally, an outlook on the internal DLR roadmap for next common missions will be shown.

Keywords: robotics, autonomy, exploration, shared autonomy, teleoperation

1. Long Abstract

This document describes the developments inside the DLR research institutions regarding mobile autonomous exploration robots that finally are able to cooperate and solve tasks of high complexity given via high-level commands.

Common and overarching projects have been established in the field of planetary exploration in order to fuse the competences of different DLR research labs and tracks. This includes mainly the institutes of planetary research, space systems, communication and navigation, mission operations and of course the three robotic institutions.

In general, the idea was to have robots assist human operators in dangerous or inaccessible environments. This application scenario is not only valid for space exploration but also for deep sea robotics, disaster relief, search and rescue, decommissioning and other hazardous areas, where humans are either exposed to high risks or that are hard and costly to access and work in. In these applications, the communication to a robot may be interrupted or delayed, therefore each robot must be able to perceive hazardous situations on its own and deal with them without user intervention. This is the first level of autonomy that is mandatory to exploration systems. Furthermore, when thinking of delayed communication links, robotic teleoperation is either slowed down tremendously or the robot skills need a higher level of autonomy. This scenario leads to the idea of robots performing autonomous tasks with only high-level commands given by their human operator. When several robots are envisioned to collaborate and combine their skills to benefit from parallelization as well as from complementary capabilities, their level of autonomy needs to be increased even further.

Our first rover platform with perception and autonomy skills able to explore an previously unknown Moon-like environment was shown at the SpaceBotCamp [1]. The platform is called LRU (Light Weight Rover Unit). In this scenario, one autonomous rover should explore [3] unknown terrain and search for two objects that were known before. These objects had to be brought back to the start position. Additionally, the objects needed to be assembled at a base station near the start position. All these tasks were executed autonomously without user intervention. Furthermore, any telemetry data from the system had been artificially delayed by two seconds to simulate a Moon to Earth communication link.

In the ROBEX (Robotic Exploration for Extreme Environments) Moon analogue mission, performed on Mt. Etna, Italy in 2017, the goal was to install a seismic network on the volcano [4]. Again, objects needed to be picked up, transported to defined locations and be placed on the soil. To gain a maximum experience from this project, two rovers were used and controlled from a remote control center in Catania at the foot of the volcano. These two rovers were working in parallel but were not collaborating. However, still the grasping and placing of seismometers needed to be performed as an autonomous task as this would be very challenging to be tele-operated.

These findings will be transferred to the project ARCHES (Autonomous Robotic Networks to Help Modern Societies), which started in 2018. Its main focus is on cooperative aspects of heterogeneous robotic teams. In contrast to ROBEX, the robots shall now work together to explore, deploy, and maintain infrastructure and scientific instrumentations on planetary surfaces or in the marine environment. The developed algorithms and methods will be strongly relevant for the robotic support and operation of permanent installations and bases (e.g. the Lunar Village concept, or large scientific observatories, such as interferometers). This paper discusses the different conceptual modes of operating robots in such scenarios, starting from teleoperation and shared autonomy to highly autonomous behaviors that even include collaborating systems. The aim of ARCHES is to develop approaches that allow robots to acquire, analyze, and interpret measurement data autonomously, covering large areas and long periods of time. The project thereby focuses on the key technological challenges required for robot autonomy as well as for high-level human supervision of the robotic teams operating at remote sites. In order to cope with the challenges addressed in the project, the evolution from single robotic systems to cooperating autonomous robotic networks is essential. The focus thereby is not only on the ability to monitor large-scale processes, but also on the autonomous assessment of the recorded situation and the resulting on-site intervention [5]. This is particularly important for exploration and manipulation tasks in extreme, inaccessible and dangerous environments [10].

During the ROBEX Mission and the H2020 Projects of the Peraspera Framework, several field trials and datasets for long term autonomous driving has been acquired and made available for the community [9].

Regarding the operation of such robots, even if they include high degree of autonomy, the operations and the control concepts are challenging and also under research during ROBEX for single autonomous robots and during ARCHES for multiple robots. In the ESA METERON (Multi-Purpose End-To-End Robotic Operation Network) Framework, DLR-RM has investigated the control concept of shared autonomy control to be executed from far distance, in METERON from the ISS to Earth, to trigger complex execution task on multi-degree-of-freedom robots, such as Justin, with a simple tablet computer using a user-friendly graphical interface

[8].

During the Kontur project line, haptic and visual telepresence control has been investigated with the Russian colleges together in several ISS and Earth experiments [6][7]. In the next follow-up project of Kontur, a planetary operational scenario has been planned and investigated regarding tele-operated navigation and probe sampling [2].

Currently, several European activities focus on the development and enhancement of technologies for such missions. The H2020 space activities in the Peraspera framework (Compet-4) seek for the common development of base technologies for orbital space robotics as well as planetary exploration with the common goal of demonstration missions in relevant environments. In the next ESA METERON framework, several sub projects are and will be established as experiments addressing validation of technologies needed to operate robotic assets on the surface of the Moon or Mars from a Lunar/Martian orbital station. The experiments in METERON will also serve as baselines for the HERACLES scenario which has the target to use the Deep Space Gateway (DSG) to deliver samples to scientists on Earth

Meanwhile ESA, DLR and its partner Agencies look for Mission opportunities with e.g. the Japanese space agency JAXA and the Russian ROSKOSMOS for common activities. Within the DLR cooperation with JAXA the flight opportunity during the HAYABUSA-2 mission has enabled the DLR to contribute the small MASCOT lander to this interesting Mission of the Japanese to the Asteroid RU-1999. A possible follow-up cooperation probably combined with the French space Agency CNES will allow DLR and CNES to contribute a small landing element to JAXA's MMX Mission which aims the research on the Mars moon Phobos.

This publication will include the actual status of the MASCOT/Hayabusa-2 project, some insides of the current ongoing MMX activities and the planed next steps for common analog activities with an outlook on the DLR research mission strategies.

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