Heterogeneous Robotic Teams for Exploration of Steep Crater Environments

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Extended Abstract

I. Introduction

Within the project LUNARES[1] (Lunar Exploration System), DFKI RIC, EADS Astrium, and OHB System created a terrestrial demonstrator for a lunar sample return mission. The task of fetching a soil sample from within a permanently shadowed lunar crater had to be accomplished by a heterogeneous team of robots consisting of a wheeled rover and a legged scout. By means of different locomotion principles, the unique skills of these systems have been combined in order to increase the overall performance in the team. The follow-up project RIMRES[2] (Reconfigurable Integrated Multi-Robot Exploration System) develops a new rover and a six legged scout in a co-design process. The key idea remains: Robots with different locomotion capabilities cooperate as a team, in order to explore permanently shaded craters at the lunar poles.

II. LUNARES

The wheeled rover with its energy efficient locomotion transports the legged scout – DFKI's Scorpion robot, [1] – from the landing site to the crater rim. The highly mobile, legged scout then enters the inside of the crater where steep slopes, partly covered with rocks and small impact craters occur. At the bottom of the crater, one leg of the scout acts as manipulator for picking up a small stone. It is deployed in a sample container onboard the scout. After successful sampling, the vehicle climbs back up to the crater rim and rejoins the rover in an autonomous docking procedure. The rover carrying the scout then drives back to the lander where the sample container is transferred to the landing unit. In [2], the Lunares mission and the systems are described in more detail. Figure 1 presents selected scenes of a LUNARES mission demonstration.

[1]The project LUNARES is funded by the German Space Agency (DLR, Grant number: 50RA0706) and the Investment Association Bremen (BIG, Grant number: INNO1036A) and is a cooperation between DFKI RIC Bremen, EADS Astrium GmbH, and OHB-System AG.

[2]The project RIMRES is funded by the German Space Agency (DLR, Grant number: 50RA0904). RIMRES is a cooperation between the DFKI RIC Bremen and ZARM – Center of Applied Space Technology and Microgravity.

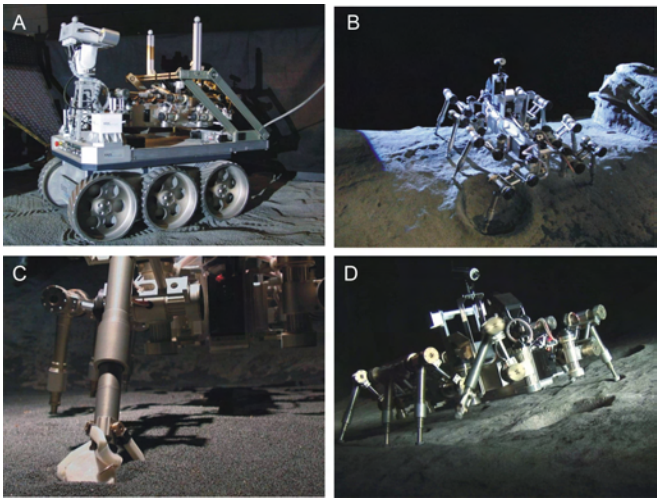

Fig. 1. Scenes from the LUNARES mission. A: Rover and scout on their way to the crater rim; B: Scout is about to climb into the dark crater; C: Scout takes sample at crater bottom; D: Scout climbs back up to the rover.

The feasibility of this approach with a wheeled and a legged robot acting as a team for lunar crater exploration has been tested and successfully demonstrated in an artificial lunar crater environment. The crater design was derived from pictures of Apollo missions and data from real craters at the lunar south pole. It provides slopes between 30° and 45° within the crater and a slope of 15° at the outer rim. The crater has been set up in a laboratory of $45\,\text{m}^2$. Figure 3 shows a CAD model of the artificial lunar crater environment with a grandstand for observing the experiments.

The systems used in the LUNARES project have not been designed specifically for the project but are robots that existed before. They have been modified in order to work together in a heterogeneous robotic team. The rover, for example, is a modified industrial transportation platform. However, the general approach of a sample return mission with a team of wheeled and legged systems was successfully demonstrated in the LUNARES project.

III. RIMRES

RIMRES is the successor of the LUNARES project and additionally addresses the modularity capabilities of the systems. The purely mechanical connection of rover and

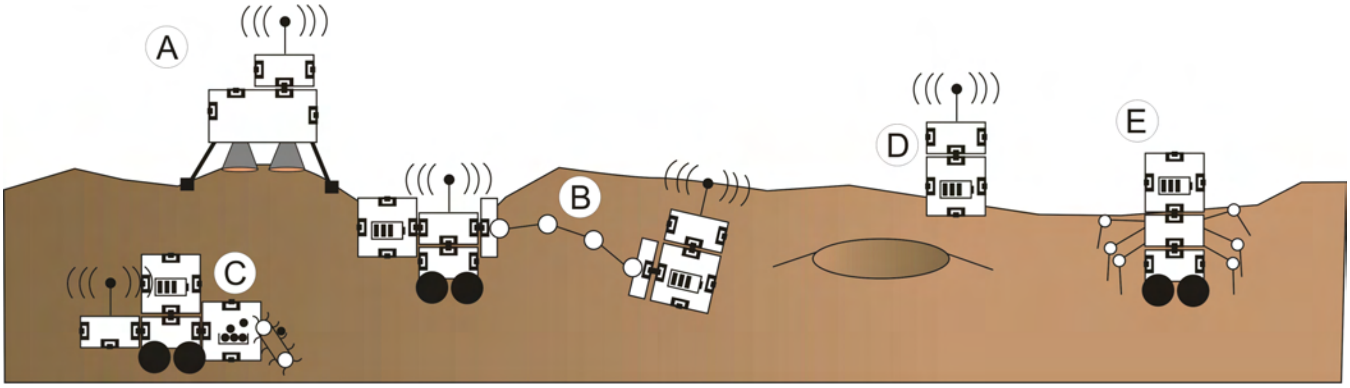

Fig. 2. Illustration of the RIMRES system. A: Landing unit with radio module and free module slots; B: Rover with radio module and additional battery module deploys radio beacon; C: Rover with additional battery and radio module makes use of a sampling module; D: Operating radio module stack; E: Connected rover and scout on their way to a crater for exploration.

scout in LUNARES is extended by introducing a mechatronic interface. It provides a mechanical connection as well as data and energy connections. The adoption of such a type of interface allows the robots to act as one single system if connected and as two independent individual systems when needed.

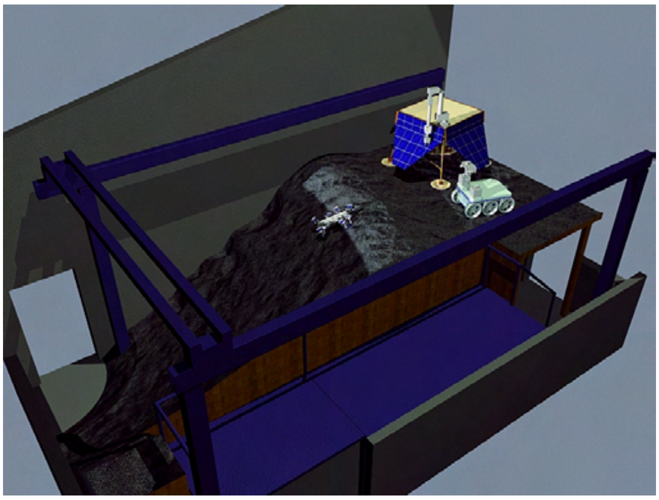

Fig. 3. CAD model of the artificial crater environment. The environment provides slopes of 30° to 45° in the interior of the crater and a small plateau for rover movements. Floodlights with narrow angle simulate lighting conditions at the lunar poles.

Because the new mobile units are meant specifically for the purpose of forming a tightly coupled team, this requirement may be considered in the design phase already. This also means that a docking adapter like the one required by the LUNARES systems is not needed in RIMRES. Moreover, parts of the subsystems can be deactivated during connection to safe energy, i.e. the legs of the scout and parts of its sensors not needed when coupled with the rover can be shut down. By exploiting the tight coupling of the two systems, the scout could take over control of the rovers actuators when needed, for example in case of rover's sensor faults. Additionally, the scout's sampling capabilities can also be used when coupled to the rover.

Along with two mobile units, the RIMRES system provides immobile payload modules that can be attached to the rover as well as to the scout. The modules can be stacked using the mechatronic interface and deployed by the rover itself. This way, more complex scientific packages may be setup more easily in order to be deployed on the lunar surface. Figure 2 outlines a sample scenario for the RIMRES system. Like the LUNARES systems, RIMRES systems will be tested in a similar, yet bigger artificial lunar crater environment.

IV. Conclusions

We reviewed the LUNARES project and the achievements of this first approach of a heterogeneous team of robots for space application. A more detailed presentation includes video footage and experimental results from mobility experiments in the crater testbed. The autonomous docking procedure is presented as well. We furthermore presented the RIMRES project and gave an overview of the ongoing system design process. A more detailed overview includes a short presentation of the SpaceClimber[3] robot [3] that is likely to be the antetype of the RIMRES scout.

References

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[3] Sebastian Bartsch, Timo Birnschein, Florian Cordes, Daniel Kuehn, Peter Kampmann, Jens Hilljegerdes, Steffen Planthaber, Malte Roemmermann, and Frank Kirchner. Spaceclimber: Development of a six-legged climbing robot for space exploration. In *Proceedings of the 41st International Symposium on Robotics and 6th German Conference on Robotics, (ISR Robotik-2010)*, 2010, accepted.

[3]The project SpaceClimber is funded by the German Space Agency (DLR, Grant number: 50RA0705) and the European Space Agency (ESA, Contract no.: 18166/04/NL/PA)