RIMRES: A Project Summary

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Extended Abstract

I. INTRODUCTION

The Moon has been a subject of interest of space agencies, being seen as a candidate to establish a permanent outpost in space [1]. However, in order to reach this goal with reasonable efforts, the utilization of local resources which are available on the Moon is an essential requirement. The access to water-ice is of main interest, since it would provide a local source for oxygen and hydrogen, and thus make a costly transport of breathable air and fuel from earth dispensable.

The formation of water-ice on the Moon can be due to different mechanisms [2], e.g. reactions of sunwind particles with locally present oxides which can be found in Moon regolith. Further theories explain the presence of water-ice with out-gassing of the Moon's core, or consider meteoroids or comets as possible carriers. Meanwhile, the missing atmosphere and exposure to the sun leads to evaporation and thus a reduction of water-ice on the lunar surface. This leads to the conclusion, that water-ice can be only present in so-called cold traps, permanently shadowed polar regions, and LCROSS mission [3] successfully provided evidences for the presence of water-ice in these regions.

In order to allow for a direct, local examination and exploration of polar regions, more complex and technological challenging missions are required. These missions will comprise a higher risk than remote sensing missions – commonly the deployment of mobile robotic systems is considered which need to be capable of locomotion in demanding crater regions [4]. Despite a higher operational risk, such missions provide a high scientific value, since they will allow a thorough exploration of the polar regions of the Moon, e.g. to analyse the presence of volatile matter and distribution of this matter [5].

Motivated by these requirements and building upon experiences gained in LUNARES [6], the project RIMRES has developed a modular, reconfigurable, heterogeneous multi-robot system to serve as a terrestrial demonstrator for lunar crater exploration missions. The capability of reconfiguration is one of the essential design aspects of the project RIMRES leading to a flexible approach to (re)use of available resources. This reconfigurability can be exploited for nominal operation and in conditions of failure, and provides a means to increase the system's overall efficiency while still maintaining redundancies.

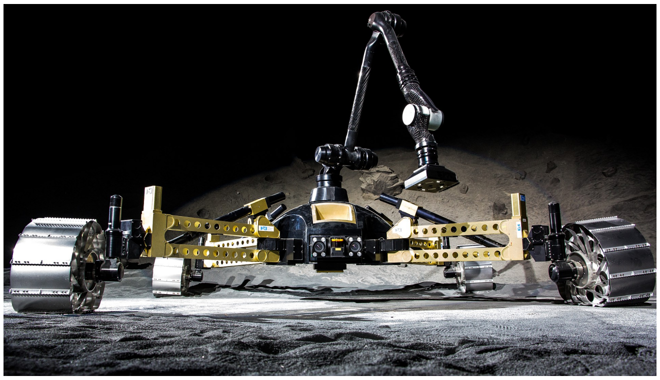

Fig. 1. The planetary rover Sherpa in a flat stance configuration of its the active locomotion platform.

II. RIMRES

This paper presents the results of the project RIMRES and discusses the core achievements in the areas of hardware as well as in software. As a baseline for the development in RIMRES the following main requirements have been derived from a mission scenario: 1) a wheeled rover to provide an energy efficient transport over long distances for another legged scout, e.g. to a crater rim 2) a scout robot specialized on locomotion in crater regions, i.e. locomotion in steep terrain and allowing for sample extraction 3) an electro-mechanical interface to allow a modular design of the multi-robot system, so that subsystems can be interconnected 4) design of immobile so-called payload-items to serve as general purpose containers which can host scientific equipment and can be dynamically combined to form subsystems 5) a robotic arm to allow manipulation of payload-items and exploitation of modularity by reconfiguration

The main outcomes of the hardware development process are the leg-wheeled rover Sherpa (Sherpa: Expandable Rover for Planetary Applications), the six-legged robot CREX (CRater EXplorer), and the design for payload-items. Figures 1,2 and 3 illustrate the development results. To allow for reconfiguration each of these systems is at least equipped with one standardized electro-mechanical interface.

Subsequent to the presentation of the achievements of hardware design and low-level control, we illustrate the software architecture which is capable to manage the heterogeneous and modular robotic hardware system by looking at the inter-robot and intra-robot design. The software architecture uses a model-based approach [7] and achieves a balance between specialization and generalization, so that the same software foundation has been deployed on each of the (sub)systems of the robot team. Furthermore, the

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Fig. 2. The six-legged walking robot CREX which acts as scout in the aspired mission scenario of RIMRES.

Fig. 3. Two payload-items: a camera payload-item on the left hand side and a battery payload-item on the right. Both are equipped with visual markers on top to allow for visual servoing as part of stacking procedures.

software architecture supports a distributed and dynamic team structure. As part of the control approach for the team of robots, we detail the integration of the robot team into a mission control system which consists of a ground-based human operated control center and a lunar-based system control.

The design of the multi-robot system has been validated with typical task sequences executed by each of the robotic systems and an overall realistic mission sequence involving ground-based control. This approach allowed verification of the main reconfiguration capabilities: stacking and docking. While stacking describes the capability of composing a payload from multiple payload-items using the rover's manipulator, docking describes the semi-autonomous approach of attaching CREX to Sherpa. Furthermore, using a mixture of tele-operation and semi-autonomous operation, the project demonstrated the suitability of the control approach for the multi-robot system.

ACKNOWLEDGEMENT

The project RIMRES completed end of 2012 and has been funded by the German Space Agency (DLR, Grant number: 50RA0904) with federal funds of the Federal Ministry of Economics and Technology (BMWi) in accordance with the parliamentary resolution of the German Parliament. RIMRES was a cooperation between the DFKI Bremen – Robotics Innovation Center and ZARM – Center of Applied Space Technology and Microgravity. Further partners were DLR-RY, EADS Astrium, and OHB System.

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