Cooperative Docking Procedures for a Lunar Mission

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Abstract

There are few existing robots that perform exploratory tasks in extraterrestrial environments, namely Mars or Moon. To use these robots efficiently they can perform certain tasks autonomously. However, no robot system consisting of multiple mobile units performing cooperative tasks has yet been deployed on a celestial body. In this paper we present and evaluate a scenario for cooperation in a space mission using two mobile robots: a six-wheeled rover and an eight-legged scout robot. Additionally a scaled down mockup of a landing unit with a robotic arm and a sensor tower is used in the presented project LUNARES[a)]. Figure 1 depicts the three units in the artificial crater environment we set up to evaluate the system's performance. The mission goal is to extract a sample from the bottom of a lunar crater and return it to the lander unit. Figure 2 shows a CAD model of the artificial crater environment, and Figure 3 illustrates the mission from start till reaching the crater bottom.

In this project, by making use of heterogeneous mobile robots with a strong physical linkage, we are able to increase the overall capability concerning mobility and exploration gain of the system. The physical linkage is created by a docking mechanism mounted on the wheeled rover to carry the legged scout on the rover. This configuration has two main advantages:

- The system can cover long distances in an energy efficient way (rover with docked scout)
- The system provides high mobility and is able to negotiate difficult terrain with slopes up to 35° (scout) - a typical scenario for lunar crater environments

This paper focuses on the presentation of docking procedures in the lunar scenario. The project LUNARES comprises two such docking procedures. The first procedure covers the autonomous approach of the rover to the landing unit in order to reach a position for payload exchange. The other covers the collaborative docking procedure to dock the scout to the rover.

For the payload exchange, the rover has to be in a known position relative to the landing unit. For that purpose, the landing unit uses a 3D laser scan to locate the nearby rover. From the extracted rover position a trajectory is generated and the rover follows the computed path until half of the trajectory has been cleared. This process will be repeated until the position of the rover is sufficiently close to a predefined reference position.

The docking procedure between the two mobile units is based on a visual servoing approach. Firstly, the rover uses its video camera to estimate the pose of the scout; a set of four distinguishable markers provides the necessary features. Subsequently the rover uses the estimated pose to generate relative displacement commands for the scout. The rover terminates the process when the scout reaches a predefined pose relative to the rover. Figure 4 depicts the scout's relative displacement during the docking procedure. This known position is then used as starting point for a semi-autonomous docking procedure in which the scout connects to the docking adapter. Once the connection has been established, the scout is lifted onto the rover.

This paper presents the experimental results for the two mentioned docking procedures in the artificial crater environment. Repeatability and robustness are evaluated. The paper provides a conclusion and an outlook on future developments of collaborative multi-robot systems at the DFKI.

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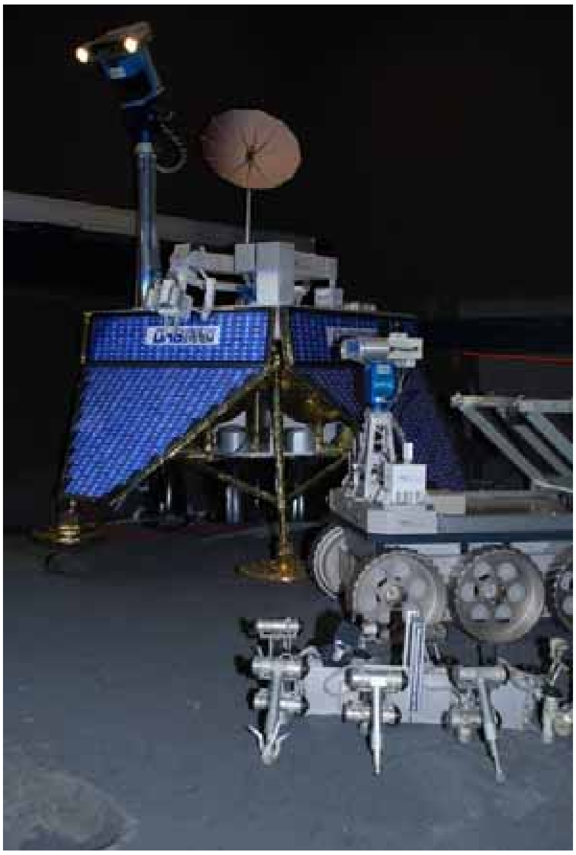

Figure 1: Landing unit with robotic arm and sensor tower, wheeled rover and legged scout (back to front)

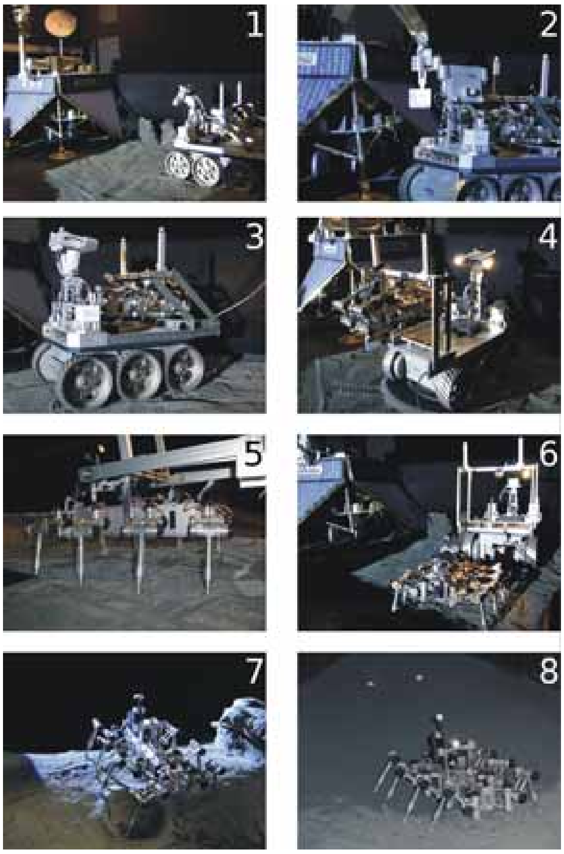

Figure 3: Mission steps in LUNARES:

1) Initial position of rover before docking;
2) P/L-Exchange;
3) Locomotion on moderate terrain;
4) Deployment of scout;
5) Undocking;
6) Scout heads for crater rim;
7) Scout on crater rim;
8) Scout enters crater bottom to pick up a sample

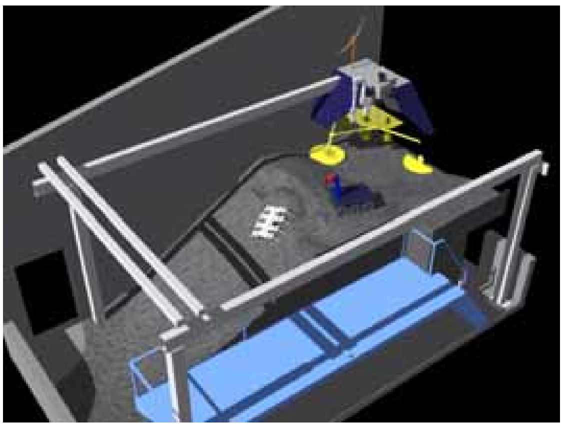

Figure 2: CAD-Model of artificial crater

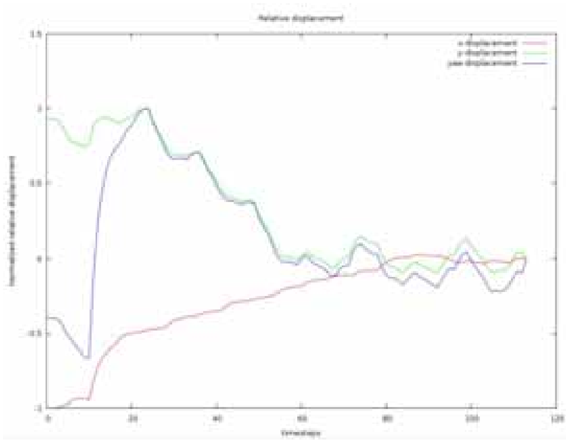

Figure 4: Relative displacement of scout's target position regarding three degrees of freedom during rover-scout-docking procedure