Advanced testbed and simulation environment for planetary exploration and mobility investigations

*Bernhard Rebele, Armin Wedler, Max Apfelbeck, Heiko Hirschmüller, Sebastian Kuss, Andreas Gibbesch, Bernd Schäfer (German Aerospace Center (DLR))

Contact Author: Bernhard Rebele
Affiliation: German Aerospace Center (DLR)
Address: Münchener Strasse 20, 82234 Wessling, Germany
Email: bernhard.rebele@dlr.de
Phone:
FAX (optional):
Presentation Preference (oral or poster): oral
Keywords: testbed, planetary exploration, rover

Extended Abstract

Since several years space missions are more and more focusing on promoting mobile systems for planetary exploration. ExoMars (Mars), MoonNEXT (Moon) or even Marco Polo (asteroid mission) are promising highest scientific return. Dealing with the hostile environment and reliably operating in an unknown and unstructured terrain are the key features of such missions. Mapping, transportation, servicing and sample collection or handlings are typical tasks and involve traversing areas of soft soil, steep slopes, cliffy canyons or craters in a reliable manner. Mainly wheeled rovers are dedicated for such operation but also walking robots or lander based manipulators are suitable. These systems require a high level of autonomy and flexibility and must be able to cope with the wide variety of possible scenarios, and they shall be fully operational far beyond the nominal operating conditions. Exhaustive testing and simulation are therefore indispensable and must go hand in hand from the very beginning. Since several years already, DLR is advancing mobile systems for terrestrial and space applications, focusing also on demonstrations by using own testbeds with high precision measurement devices. This paper gives an overview of the entire test environment, which covers all aspects in a unique way: starting from the evaluation of soil parameters via detailed world modeling up to a detailed evaluation of the mobility performance by a combination of tests and simulation.

Autonomously operating mobile robotic systems require complex task and navigation algorithms and high performance sensors. In particular robotic systems used for planetary exploration strongly rely on local autonomy e.g. due to the long signal roundtrip time. Moreover, local autonomy is dedicated to support telepresence operated systems e.g. by handling subtask like obstacle avoidance or optimizing the configuration. The new test laboratory at the robotic institute of DLR is used for testing a wide variety of mobile robotic systems and applications. Actually the test campaign concentrates on a six-wheeled ExoMars type rover. Moreover, testing additional rover concepts as well as the DLR six legged crawler are foreseen in the near future.

The testbed is 10 m long and 5.5 m wide and it can be split in different sections to cope with different scenarios or terrains. Different soil types like Martian soil simulants are available. A soil measurement device, a so called Bevameter allows the characterization of the soil properties [1], e.g. by means of the well known Bekker parameters. The laboratory is equipped with a high end optical 3D-pose tracking system [2] which allows tracking of different targets simultaneously and consequently measuring complex kinematic chains or cooperating robots. Simulation, odometry and navigation rely on a Digital Elevation Model (DEM). With the Semi-Global Matching (SGM) algorithm [3] a 2.5 dimensional surface elevation model is computed using images taken automatically from above the testbed. The SGM technique has been already successfully used to process the image data, acquired by aircrafts, satellites or space missions to generate elevation models from mountains, rocky regions or surface models of planets (e.g. Mars). The use of such technique in the DLRs testbed allows obtaining an environment very closed to the real one and simulation and navigation will strongly benefit. Further more, a hand hold device, the so called 3DMo [4], completes the world modelling capabilities. The 3DMo has been developed at DLR and is merging camera and laser sensor information. It is favourable when a fully 3 dimensional model is required or to increase the resolution where required e.g. in case of critical objects or regions. The SGM and 3DMo generated models can be combined in a single DEM model of the terrain.

A detailed evaluation of the characterization of the rover performance is a fundamental part of the overall test environment. Typically, the cross-country capability, gradeability, speed, energy and power consumption are of major interest. Another important measure is the available free pulling force, the so called drawbar-pull and a special measuring device has been developed. Besides measuring the joint positions and motor current, all actuators can be equipped with 6D force torque sensors. This allows a comprehensive analysis of the locomotion performance and first results will be presented. All tests are supported and evaluated by 3DS simulation. Importing the DEM into the simulation environment allows evaluating exactly the same setup by means of simulation and testing.

Planetary exploration has to deal with a wide range of terrains and the exact terrain properties can be hardly predicted. To cover the entire range of possible operations and conditions, simulation is inevitable. Therefore, the set-up is completed by a comprehensive simulation environment. It allows a cost-efficient and fast evaluation of the influence of varying terrain properties or mission scenarios in large numbers and design modifications, and optimizations can be studied from the very beginning. Next, it enriches the test campaign by studying critical or worst case scenarios or operating under extreme conditions without risk. The multibody simulation is based on a commercial multi-body system tool. Special attention is drawn on the precise modeling of the wheel-soil contact. Two contact modules are implemented to represent the different nature of soft soil and rigid bodies: The so-called Polygonal Contact Module PCM for solely rigid contact and the Soil Contact Module SCM for contact between rigid bodies and soft soil [5].

[1] M. Apfelbeck, S. Kuss, A. Wedler, A. Gibbesch, B. Rebele and B. Schäfer, A novel terramechanics testbed setup for planetary rover wheel-soil interaction, 11th European Regional Conference of the International Society for Terrain-Vehicle Systems. Bremen, Germany, October 2009

[2] ART http://www.ar-tracking.de

[3] H. Hirschmüller, Stereo Processing by Semi-Global Matching and Mutual Information, in IEEE Transactions on Pattern Analysis and Machine Intelligence, Volume 30(2), February 2008, pp. 328-341

[4] M. Suppa, S. Kielhöfer, J. Langwald, F. Hacker, K. Strobl, G. Hirzinger, The 3D-Modeller: A Multi-Purpose Vision Platform. In: Proceedings . IEEE. International Conference on Robotics and Automation, Rome , Italy, April 2007

[5] R. Krenn, A. Gibbesch, and G. Hirzinger, “Contact dynamics simulation of rover locomotion,” 9th International Symposium on Artificial Intelligence, Robotics and Automation for Space, Universal City, USA, 2008.