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Experimental Validation of Multibody Algorithms for Dynamics Analysis of Mobile Robots

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Planetary exploration is one of the most challenging applications of mobile robotics. The nature of the task requires the ability to operate in unstructured environments, involving interaction with soft soil, non-homogenous terrain and sloped and rocky surfaces. In this context, simulation and analysis tools can be very important to characterize the mobility of the system under various terrain conditions [1]. The algorithms used need to be able to generate a multibody model of the rover together with meaningful wheel-terrain interaction representations. In this work a multibody software tool was developed in MATLAB for investigation of wheeled robots. It incorporates wheel-terrain interaction models such as the terramechanics relations [2, 3] to determine the reaction forces at the wheel-terrain interfaces.

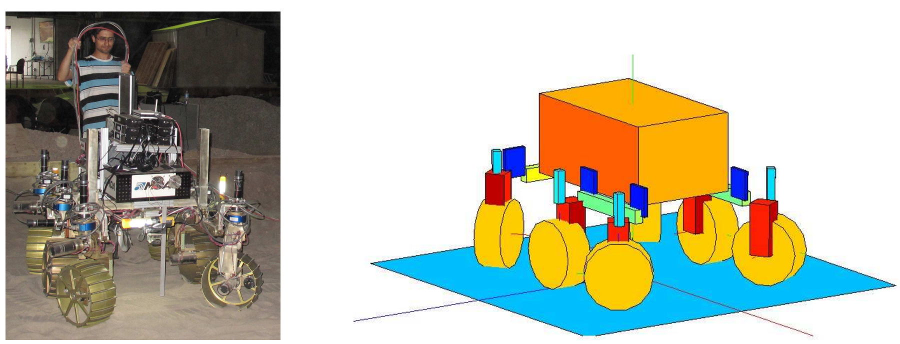

Figure 1. Rover prototype used in the experiments (left) and its computer model used in simulations and analysis (right)

Validation of the simulation tool and the models is a critical step. To this end, a series of experiments was designed to test whether the modelling environment is able to represent the important aspects of the operation of a rover. The experiments were carried out using Rover Chassis Prototype (RCP), a six-wheeled robot developed by MDA Brampton, and shown in Fig. 1. The RCP is equipped with encoders and force/torque sensors; every wheel of the rover can be steered and driven independently. Identification of the rover parameters and calibration of the force/torque sensors were carried out prior to running the experiments.

The first dynamic test consisted of straight-line motion on flat terrain. The path designed for the experiments included three different surfaces: hard wooden plate, hard compacted terrain and soft soil.

The readings from all the force/torque sensors and the encoders of the wheels, as well as the velocity of the centre of mass of the chassis obtained using a set of GoPro cameras were recorded and stored. The obtained forces and torques were compared to the ones predicted by the simulation of the same manoeuvre using terramechanics models.

In the experiment described above, only low slip values were observed. In order to test the behaviour of the system under a higher range of slip values a new set of experiments was designed. The slip ratios of the wheels were independently controlled by applying a different actuation torque to each of them. The terrain reaction forces were reconstructed based on the readings of the force/torque sensors. Based on the obtained results, the effect of different slip ratios on the behaviour of the rover was studied.

In the next test a variable external force was applied to the rover chassis and its value was measured with a digital scale. The objective was to study how the external load affects the traction force and slip developed at each wheel and whether this is captured in the simulation correctly. The rover travelled on both hard and soft sandy terrains with different ranges of external load applied to the chassis in each run. Incorporating this external applied force in the simulation and applying the same actuation torques to the wheels, the motion and the reaction forces obtained via simulation were compared to experiments. Also, in these tests the position of the centre of mass of the rover was modified using a set of additional mass elements. This gave basis to analyze the effect of mass distribution on the behaviour of the system both in experiments and in simulations.

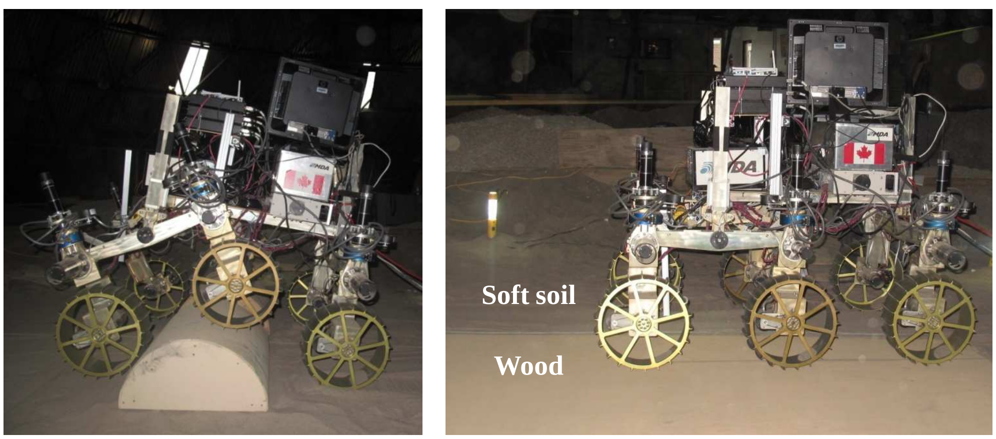

Figure 2. RCP negotiating irregular (left) and non-homogeneous (right) terrain.

Finally, manoeuvres involving complex curved trajectories, overcoming obstacles and motion on uneven terrain were performed (Fig. 2). The purpose of this group of experiments was to assess the ability of the simulation environment to accurately deal with three-dimensional motion.

In this presentation, we will give a detailed illustration of the experiments and the results obtained from comparing simulations and experiments. Based on these, we will also comment on several aspects of model development for planetary exploration rovers.

References

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