Experimental verification of performance improvement strategies for planetary exploration rovers

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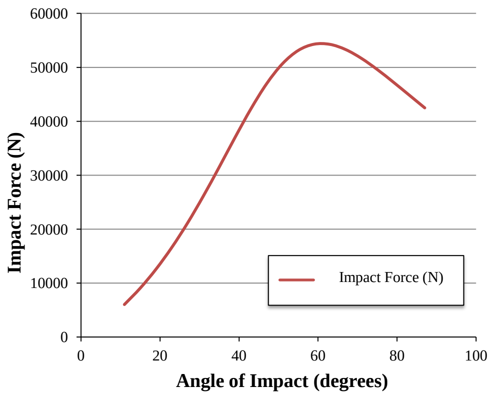
Abstract
Analysis and improvement of the performance of complex systems such as rovers on soft terrain require modelling the system and its interaction with the environment. One approach is to use detailed models which can predict the behaviour of the system close to reality. An alternative approach is the development of models that are primarily intended to represent how parameter changes can influence the performance of the system. Irrespective of which approach is chosen, validation of the model is a necessary part of the process. In this work, three strategies for rover performance improvement were experimentally verified. To this end, several experiments were designed and conducted on a rover prototype called RCP (Rover Chassis Prototype) of MacDonald-Dettwiler and Associates (MDA).

(a) (b)

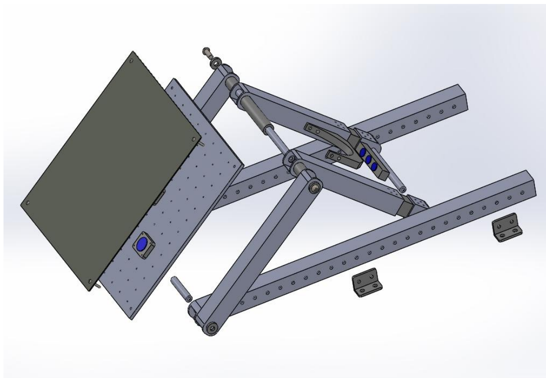
Figure 1: (a) Winch used to enforce steady-state operation conditions and (b) RCP with pneumatic actuators mounted between the main body and the side bogies to provide redundant actuation.

The first set of experiments aimed at studying the effect of normal force distribution on rover mobility [1]. In this series of tests the overall traction force developed by the RCP during its forward motion on soft terrain was measured and used as an indicator of the rover mobility. A winch imposed a constant forward velocity on the RCP during motion to ensure steady-state conditions. The force required to maintain this constant velocity was measured between the rover and the winch. This force equals the overall traction developed by the rover wheels. Normal force distribution among the wheels of the vehicle was changed by means of displacing the position of the centre of mass and applying redundant actuation. The former was achieved by attaching a set of weights at different locations on the platform of the rover. For the latter, however, we had to mounted a pneumatic linear actuator at each side of the rover. One end of each actuator was connected to the main body and the other end to the side bogie. This design modification enabled us to change the internal forces in the system, which in turn changed the load distribution among

the six wheels of the rover. The use of pneumatic actuators made it possible to vary the normal force distribution for different parts of the rover trajectory. This set of experiments provided us information on the effect of normal force distribution on the total traction force that the RCP was able to develop.
The second set of experiments performed using the RCP explored the relationship between maximum contact force and system configuration during the onset of contact when negotiating obstacles. A prediction of this relationship obtained via dynamic simulation is displayed in Fig (2a). During the experiments, the RCP would be driven with a given velocity towards an obstacle on which an impact plate was mounted. The impact plate would rest at a given angle on a set of force sensors, with which the impact force could be recorded. Challenges in the construction of this "intelligent obstacle" were to isolate the desired normal force from the impact and transmit its magnitude and direction accurately to the impact sensors while protecting the sensors from the rover's contacting grousers. The obstacle had to adjust to and maintain a range of angles, and also to withstand side loads and moments created by the impact. The force sensors chosen for the application were piezoelectric quartz sensors which, due to their high frequency response characteristics, are well suited to impact applications. Experiments were performed on hard and soft terrain, and data were recorded from the obstacle impact sensors, the RCP sensors, and from cameras recording from three different angles.



(a)



(b)

Figure 2: (a) Simulation with the Hunt and Crossley contact model [2] demonstrates the relationship between maximum impact force and angle of impact, and (b) exploded view of the intelligent obstacle.

During planetary exploration, in absence of GPS and distinguishing landmarks for absolute positioning measurements, an accurate relative localization technique is necessary. For the third set of experiments, our objective was to detect wheel slip and reduce the accumulation of error by analyzing kinematic and dynamic models and applying sensor fusion techniques.
For the purpose of these experiments, a 10 m $\times$10 m square trajectory was drawn on a flat, soft terrain. The RCP was controlled manually via joystick, and was driven along the square path. Two tests were carried out to study the following steering strategies of the RCP: the dual Ackermann steering mode and the center-point turning mode. Angles of wheel rotation about the driving and steering axes were measured by 12 encoders mounted on the six wheels and legs of the rover. Forces and torques acting on each of the six legs were measured by 6-DOF force sensors installed on the RCP legs. Wheel driving torques were collected by measuring wheel motor current and voltage, and finally the true position of the rover was obtained from the video recording of the measuring tape located on the trajectory. This set of measurements enabled us to develop and evaluate kinematic and dynamic models for RCP localization.

References

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