Multibody simulation of a spacecraft landing in a microgravity environment by means of ESA's DCAP software

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Abstract

The investigation of planets, moons and small bodies, including comets and asteroids, can contribute substantially to our understanding of the formation and history of the Solar System.
Few examples can effectively illustrate the diverse challenges of such exploration missions: JAXA Hayabusa mission attempted to take samples from the surface of the asteroid Itokawa and successfully returned it to Earth in 2010; ESA's cornerstone mission Rosetta [1] has been the first to rendezvous with a comet and to deploy the lander Philae on the comet's surface in 2014; Marco Polo mission [2] is being considered as a sample return mission to a near-Earth asteroid to be jointly developed by JAXA and ESA, with launch planned in the 2018-19 timeframe.

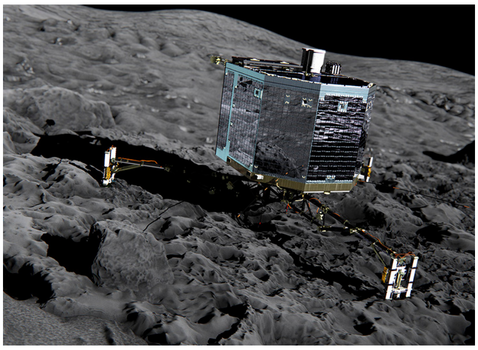

Figure 1: Rosetta's Philae lander (Image credit: ESA/ATG medialab)

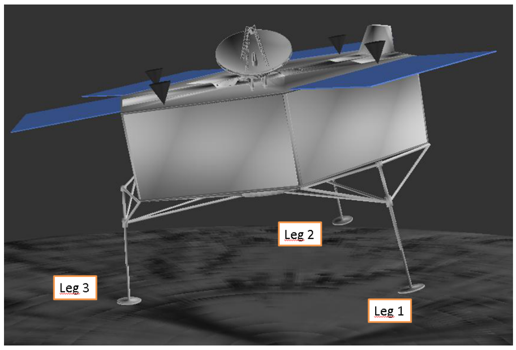

Figure 2: Spacecraft multibody cad and legs configuration

While preparing for these type of complex missions, the need of accurately anticipating hardware performance and correlating testing results with mathematical models more and more often translates in a strong interest of applying multibody simulations in support to the design and verification process of the various aerospace systems.

This work discusses a simplified multibody model to perform studies of the landing of a spacecraft on the surface of an asteroid in a microgravity environment using the European Space Agency's DCAP software [3]. Complex and time consuming approach could be used for this task [4] but the purpose here is focused on simple and immediate multibody model in order to speed up the feasibility concept design.

The 362 kg spacecraft is mainly composed of a main body linked to 3 rigid legs as shown in Figure 2. Crushable devices [5] are used in the legs hinges in order to reduce the shock at the impact and to decrease the tip-over behaviour. On the top of the spacecraft 4 thrusters are mounted to push down the lander after the impact with the surface in order to increase the friction with the ground.
The most crucial features needed for the simulation are hereinafter summarized:

- a contact model capable of reproducing the interaction between the soil and the landing gears;
- a friction model capable of simulating the behaviour of the crushable devices;
- a sloshing model of the tank propellant, implemented by means of a pendulum attached to the spacecraft CoG using a torsional springs [6], in order to consider the effect of the remainder fuel into the lander tanks;

- a numerical integrator of the software capable of varying both the time step and the algorithm order [7], in order to provide enough accuracy for contacts detections;

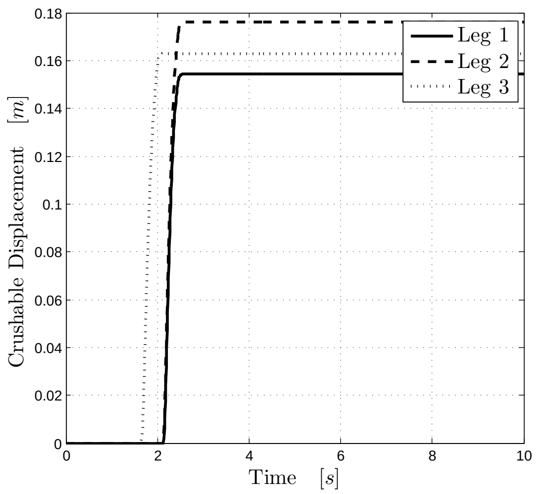

Figure 3: Crushable displacements of lander legs

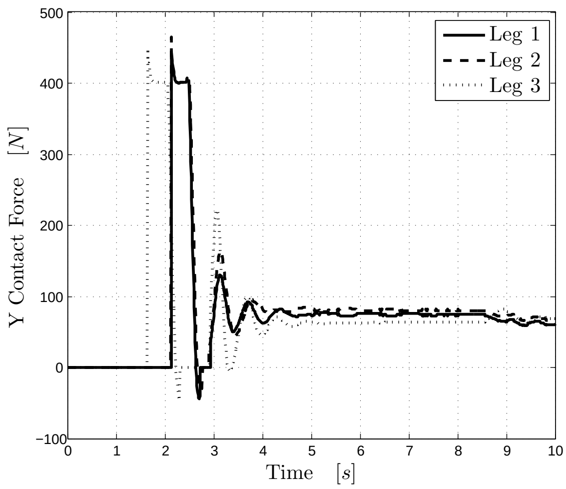

Figure 4: Contact forces on vertical direction expressed in leg reference frame

In Figures 3 are reported the displacements of the lander legs after the touchdown while in Figures 4 are reported the forces acting on the spacecraft structure because of the impact.

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