A Volumetric Contact Model for Space Robot and Planetary Rover Application

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A volumetric contact dynamics model has been proposed by Gonthier et al. for the purpose of rapidly generating reliable simulations of space-based manipulator contact dynamics. Forces and moments between two bodies in contact can be expressed in terms of the volume of interference between the undeformed geometries of the bodies. Friction between bodies is modelled by a bristle model for both tangential friction and spinning friction torque.

Unlike point-contact models, this model allows for the modelling of contact between complex geometries and scenarios where the contact surface is relatively large, while being less computationally expensive than finite element methods. Rotational effects such as rolling resistance, spinning friction torque, and the Contensou effect are also included.

Experimental validation of the model has been performed for metal-on-metal contact. Modelling the normal contact force as proportional to volume of interference was found to be a reasonable approximation for spherical and cylindrical payloads in quasi-static experiments. A hysteretic damping factor was found to be inversely related to impact velocity, as predicted by the model. Coefficients of friction between metals were found to be consistent between pure translation and pure rotation. Friction forces from combined translation and rotation demonstrate that the Contensou effect is accurately described by the volumetric contact model.

For the purposes of simulating hard-soft contacts or contacts between two deformable bodies, a nonlinear volumetric contact model based on a hyperelastic foundation model has been developed. The results are closed-form contact force and moment expressions in terms of nonlinear functions of the volume of penetration, the so called hypervolume of the contact geometry. These hypervolumes are dependent on the goemetries of the colliding bodies and it is shown that an exact solution can be found for certain nonlinear functions. However, in the most general case a numerical solution is used to determine the hypervolumes.

For the simulation of next-generation planetary rovers, a wheel-soil interaction model is required to properly capture the dynamics of both the tire and the soft soil. For this purpose, an off-road tire model based on the nonlinear volumetric contact model is developed to simulate the contact between a planetary rover wheel and an elastic terrain. This novel rover wheel model is simulated and compared against experimental data gained from a single wheel test bed. To show the use of this off-road tire model in planetary rover dynamics simulations, it is included into a four-wheeled planetary rover model and simulated for various driving manoeuvres.