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Author: Dr. Albert Peiret
McGill University, Canada, albert.peiret@mail.mcgill.ca

Dr. Francisco Gonzalez
Spain, f.gonzalez@udc.es
Prof. Jozsef Kovecses
McGill University, Canada, jozsef.kovecses@mcgill.ca
Mr. Andreas Enzenhoefer
CMLabs Simulations, Inc., Canada, andreas.enzenhofer@cm-labs.com
Dr. Marek Teichmann
CMLabs Simulations, Inc., Canada, marekt.soc@gmail.com

SIMULATION OF SPACE ROBOTIC CONTACT TASKS

Abstract

Simulation plays a pivotal role in space robotics for design, control, mission planning, and astronaut training. These require representative dynamics models and algorithms, and both offline and real-time simulations. Contact tasks represent a particular challenge for dynamics modelling and simulation. These include a variety of contact operations such as insertion, tool manipulation, and grasping, which typically involve complex contact scenarios with complicated geometries and multiple simultaneous contacts.

Beside the intricacies of the contact task itself, the overall space robotic system model is also very complex. The modelling and simulation of the whole system using one monolithic representation can be very difficult and can present many challenges, such as multiple time scales associated with the different physical phenomena. Therefore, a subsystem level approach and implementation can offer multiple benefits. In this approach the whole system is first divided to subsystems, the models and simulation implementations are developed separately and interfaced with each other through a co-simulation setting. This can make it possible to achieve high-fidelity space robotic contact simulations. For efficient and real-time simulation non-iterative co-simulation interfacing is often the best possible approach. The stability of the interfacing can present a challenge for that case.

In the proposed co-simulation approach the contact subsystem is separated from the rest of the robotic system. For this subsystem, the detailed contact dynamics formulation and solution algorithms are developed and implemented for the general multiple-point contact case. This subsystem is then interfaced with the model of the rest of the robotic system through a non-iterative co-simulation setup where a co-simulation manager oversees the exchange of information between the subsystems. We propose a novel, model-based coupling scheme where only reduced-order interface models are communicated between the subsystems at the interface. This technique significantly improves the accuracy, efficiency, and stability of the overall simulation.

An important aspect of the proposed approach is the development of the reduced-order interface model for the contact subsystem that generally represents a structure-varying, non-smooth mechanical system. We developed a method and related algorithm to determine the active contact pairs for each macro time step, and based on that compute the effective reduced interface model of the contact subsystem.

We illustrate the results in the simulation of insertion and grasping tasks using a model of the Special Purpose Dexterous Manipulator of the International Space Station, and also demonstrate the capability of our approach to represent such phenomena as jamming and unjamming.