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Author: Prof. Arun Misra
McGill University, Canada, arun.misra@mcgill.ca

4TH PAOLO SANTINI MEMORIAL LECTURE: DYNAMICS MODELING AND CONTROL OF FLEXIBLE SPACE MANIPULATORS

Abstract

Robotic manipulators have been playing an important role in many space operations in the last three decades. The first manipulator to be used in space was the Shuttle Remote Manipulator System (RMS). This was followed by the Space Station Remote Manipulator System (SSRMS) which was used for the assembly of the space station itself. Since then several other space manipulators such as the European Robotic Arm (ERA), Japanese Experiment Module RMS (JEM-RMS), Special Purpose Dexterous Manipulator (SPDM) have been launched. It is anticipated that robotic activities in space will increase in the future because of their role in active debris removal and servicing of disabled satellites. The field of space robotics is vast. It involves many issues such as dynamics modelling, guidance, navigation control, actuators sensors, trajectory planning, obstacle avoidance, and so on. This paper focuses on two issues; it discusses the state of the art in the areas of dynamics modeling and control of space manipulators containing structural flexibility. A space manipulator is a multi-body system. For dynamical analysis it can be modeled as a kinematic chain of interconnected rigid and flexible bodies. This kinematic chain can be simple or complex, and open or closed. Various modeling approaches have been proposed to analyze the dynamics of such kinematic chains. This paper briefly reviews these approaches and comments on their advantages and disadvantages. Control of a space manipulator can be quite challenging, especially if one or more links have structural flexibility. The space manipulator does not have a fixed base. Also, the dynamics involves widely separated time constants due to the slow link rotations combined with the fast elastic oscillations. Furthermore, because of practical considerations, the dynamical system model and the control system consider only a finite number of modes. This might lead to "control spillover" and "observer spillover" of the uncontrolled / unmodeled modes. These issues are discussed in the paper. Contact dynamics plays an important role in space robotic operations such as capture of a non-cooperating object. This area is yet to reach maturity. The paper discusses several issues related to contact dynamics.