Chapter 11

Bond Graph Modeling and Computational Control Analysis of a Rigid–Flexible Space Robot in Work Space

Amit Kumar
Indian Institute of Technology Roorkee, India

Pushparaj Mani Pathak
Indian Institute of Technology Roorkee, India

N. Sukavanam
Indian Institute of Technology Roorkee, India

ABSTRACT

The combination of a rigid and a flexible link in a space robot is an interesting field of study from modeling and control point of view. This paper presents the bond graph modeling and overwhelming trajectory control of a rigid-flexible space robot in its work space using the Jacobian based controller. The flexible link is modeled as Euler Bernoulli beam. Bond graph modeling is used to model the dynamics of the system and to devise the control strategy, by representing the dynamics of both rigid and flexible links in a unified manner. The scheme has been verified using simulation for a rigid-flexible space manipulator with two links.

1. INTRODUCTION

The flexible manipulators will be useful for space application due to their light weight, less power requirement, ease of maneuverability and ease of transportability. Because of the light weight, they can be operated at high speed. For flexible manipulators flexibility of manipulator have considerable influence on its dynamic behaviors. The flexibility of the link as well as flexibility of joint affects the overall performance of the system. The control of such flexible manipulator is very much

DOI: 10.4018/978-1-4666-3634-7.ch011
influenced by the non-linear coupling of large rigid body motions and small elastic vibrations. In case of space robots the position and orientation of the satellite main body will change due to manipulator motion. The motion of the space robots also induces vibrating motions in structurally flexible manipulators. The combination of a rigid and a flexible link in a space robot is an interesting field of study from modeling and control point of view. A free-floating space robotic system is one in which the spacecraft’s position and attitude are not actively controlled using external jets/thrusters. It does not interact dynamically with the environment during manipulator activity. For such systems, the linear and angular momentum is conserved. Thus, due to conserved linear and angular momenta, the spacecraft moves freely in response to the dynamical disturbances caused by the manipulator’s motion. This disturbance of the base results in deviation of the end-effector from the desired trajectory. Moreover, the angular momentum conservation constraints are non-integrable rendering the system to be non-holonomic (Nakamura & Mukherjee, 1991).

Cartesian coordinates offer a better choice when it comes to specifying a task or defining an obstacle in workspace. The obstacles and the trajectory followed by the end-effector can be expressed in terms of simple homogeneous transformations in Cartesian space. In this method the user specifies the desired position and orientation of the end-effector with respect to the robot base frame, as a function of time $t$ in terms of robot parameters. Taking time derivative of such equations gives us the velocity equations.

Kane (1961) presented a general method for obtaining the differential equations governing motion of both holonomic and nonholonomic systems. Yamada and Tsuchiya (1987) derived the equation of motion of multibody system such as space structure, whose base is free to move. They derived the equations of motion of a single rigid body by using position of the center of mass ($CM$) of the body as generalized coordinate. These equations were derived based on the Kane’s method. Passarelllo and Huston (1973) improved upon the Kane’s method. The advantage was automatic elimination of nonworking constraint forces and avoiding computation of the vector components of acceleration. The method also provides the arbitrary choice of dependent variables so that it may be applied to a variety of nonholonomic systems. Hemami and Weimer (1981) developed a feedback model of nonholonomically constrained dynamic system. The model was used for analysis, control and understanding of the nonholonomic constrained systems under impulsive and friction forces. In this model, the forces of constraint are explicit function of states and inputs. Fuyang, Hongtao, and Hongli (2009) used fast efficient integration method to solve complex differential equation of the dynamics of space flexible robots. Zhang and Yu (2004) developed the dynamic equations of planar cooperative manipulators with link flexibility in absolute coordinate with the help of Timoshenko beam theory and the finite element method.

Umetani and Yoshida (1989) developed a control method for space manipulators based on the concept of resolved motion rate control to continuously control the end-effector of a space manipulator mounted on a space vehicle. Yoshida (2003) demonstrated the concept of generalized Jacobian in ETS–VII. Yokokohji, Toyoshima, and Yoshikawa (1993) presented efficient computational algorithms for the trajectory control of multi arm free-flying space robots. The motion of the aircraft during manipulation is considered in order to obtain an accurate trajectory control using generalized Jacobian. Watanabe and Nakamura (1998) proposed a free-flying space robot having a special kinematic structure and mass
Related Content

Are Robots Autistic?
www.igi-global.com/chapter/robots-autistic/65828?camid=4v1a

Sliding Mode Control of a 2D Torsional MEMS Micromirror with Sidewall Electrodes
www.igi-global.com/article/sliding-mode-control-of-a-2d-torsional-mems-micromirror-with-sidewall-electrodes/87478?camid=4v1a

Effects of Human-Machine Integration on the Construction of Identity
www.igi-global.com/chapter/effects-of-human-machine-integration-on-the-construction-of-identity/84951?camid=4v1a

Kinematic Isotropic Configuration of Spatial Cable-Driven Parallel Robots
www.igi-global.com/article/kinematic-isotropic-configuration-spatial-cable/61157?camid=4v1a