The motion formalism for flexible multibody dynamics: A practical introduction

Olivier A. Bauchau, Alfonso Callejo and Valentin Sonneville
Department of Aerospace Engineering
University of Maryland
College Park, MD, USA

General information

The course provides a practical introduction to the motion formalism for flexible multibody dynamics. Theoretical foundations and numerical aspects will be covered. The course targets researchers in the field of flexible multibody dynamics who are interested in efficient simulation tools.

The course will take place on June 23--24, 2018, right before The Fifth Joint International Conference on Multibody System Dynamics -- IMSD 2018 in Lisbon, Portugal. Lectures will be taught in English. Detailed lecture notes and illustrative software will be provided to the attendees of the course.

Topics to be covered

One of the core difficulties in multibody dynamics simulation is the kinematic description of the system. The traditional approach has been to decompose motion into displacement and rotation fields, using the rotation tensor to represent the latter. In contrast, the motion formalism treats motion as a unified quantity. Several kinematic representations are available, such as homogeneous transformation matrices, dual quaternions, and screws. This unified framework comes with powerful mathematical tools that enable a deeper understanding of kinematics. Most derivations can be carried out in a non-parameterized framework, downplaying the importance of motion parameterization. The motion formalism opens the door to novel, efficient numerical methods. In particular, it offers a simple and consistent manner to describe rigid-body transformations. The proper description of rigid-body transformations leads to the definition of frame invariant relative motions in kinematic joints and deformation measures in flexible components. It also enables the formulation of frame invariant equilibrium equations, called intrinsic equilibrium equations, which filter out geometric nonlinearities and lead to significantly reduced computation costs.

The following topics will be covered in this course:

1. Motion formalism: Geometric description, representations, and parameterizations.
2. Flexible multibody formulation: Finite element (FE) approach. Intrinsic equilibrium equations.
3. Element library: Kinematic joints (lower pair joints). Modal element (modal reduction, floating frame of reference). Geometrically exact beams (kinematics, FE interpolation).
4. Solution methods: Time integration. Inverse dynamics. Domain decomposition and parallel computing.

Schedule

Saturday June 23	Lecture	Content
9:00	Introduction	Outline of the course Motivation
9:30	**Rigid body motions I**	Geometric description
10:30	Coffee break	
10:45	**Rigid body motions II**	Representations
11:45	Coffee break	
12:00	**Rigid body motions III**	Equations of motion Parametrization
13:00	Lunch break	
14:00	**Rigid body motions IV**	Numerical implementation
14:45	Coffee break	
15:00	**Kinematic joints I**	Flexible joint Lower pair joints
16:00	Coffee break	
16:15	**Kinematic joints II**	Numerical implementation
17:00	**Summary & outlook**	

Sunday June 24		
9:00	**Modal superelement I**	Modal reduction Floating frame of reference
10:00	Coffee break	
10:15	**Solution methods**	Time integration Inverse dynamics
11:15	Coffee break	
11:30	**Modal superelement II**	Numerical implementation
12:30	Lunch break	
13:30	**Geometrically exact beam I**	Kinematics Equations of motion Finite element interpolation
14:30	Coffee break	
14:45	**Geometrically exact beam II**	Numerical implementation
15:45	**Closure**	