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Multibody Dynamics: Bridging for Multidisciplinary Applications

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The design requirements of advanced mechanical and structural systems and the real-time simulation of complex systems exploit the ease of use of the powerful computational resources available today to create virtual prototyping environments. These advanced simulation facilities play a fundamental role in the study of systems that undergo large rigid body motion while their components experience material or geometric nonlinear deformations, such as vehicles, deployable structures, space satellites, machines operating at high speeds or robot manipulators. If in one hand the nonlinear finite element method is the most powerful and versatile procedure to describe the flexibility of the system components on the other hand the multibody dynamic formulations are the basis for the most efficient computational techniques that deal with large overall motion. Therefore, it is no surprise that many of the most recent formulations on flexible multibody dynamics and on finite element methods with large rotations share some common features. In multibody dynamics methods body fixed coordinate frames are generally adopted to position each one of the system components and to allow for the specification of the kinematic constraints that represent the restrictions on the relative motion between the bodies. Several formalisms are published suggesting the use of different sets of coordinates, such as Cartesian [1], natural [2] and relative coordinates [3]. Depending on the type of applications pursued by the user, on the experience of the developer or on any specific objectives each one of the referred types of coordinates has advantages and disadvantages relative to the others. Due to their ease of computational implementation, their physical meaning and the wide spread knowledge of their features all the formalisms presented in this work are based on the use of Cartesian coordinates. However, it must be noted that the same formulations can also be developed with any other type of coordinates selected to describe the multibody systems. The equations of motion of the multibody systems are obtained using the Euler–Lagrange equations and the principle of virtual works [1]. To kinematic constraints that restrict the relative motion between the different components of the system are added to the equilibrium equations by using Lagrange multipliers. The set of equations obtained in this manner, together with the acceleration constraint equations, are solved to obtain the system accelerations. The system state variables are then integrated in time, using typically a variable order and variable time step integration algorithm [4] for a pre-defined period of time. The methodological structure of the equations of motion of the multibody system obtained allows the incorporation of the equilibrium equations of a large number of disciplines and their solution in a combined form. The description of the structural deformations exhibited by the system components by using linear [5] or non-linear finite elements [6] in the framework of multibody dynamics is an example of the integration of the equations of equilibrium of different specialities. Of particular importance in the applications pursued with the methodologies proposed is the treatment of contact and impact which are introduced in the multibody systems equations either by using unilateral constraints [7] or by applying a continuous contact force model [8]. The readily availability of the state variables in the multibody formulation allows for the use of different control paradigms in the framework of vehicle dynamics, biomechanics or robotics and its integration with the multibody equations [9]. The coupling between the fluid and structural dynamics equations allows for the development of applications where the fluid-structure interaction is of importance, especially for cases where the large absolute motion of the system or the large relative rotations between the system components are of importance [10, 11]. The research carried at IDMEC and the different collaborative works developed with other research groups provide the examples offered in this presentation. Application cases involving the modelling of realistic mechanisms, passive safety of road and rail vehicles, impact and human locomotion biomechanics, automotive and railway dynamics and the control of multibody systems are used to demonstrate the developments listed in this presentation. In the process of presenting the different applications several possibilities for future developments are discussed.

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