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A Review on: Multi Body System

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Abstract- Multibody system is the study of the dynamic behavior of* rigid and/or flexible bodies interconnected by kinematic joints*, each of which may undergo large rotational and translational displacements. The proper treatment of the dynamic behavior* rigid and/or flexible bodies interconnected by kinematic joints *has led to a large number of important multibody formalisms in the field of mechanics. The simplest elements or bodies of a multibody system were treated by Newton and Euler. The main objective of the survey is to summarize the capabilities of HOTINT Simulator software and the study and analysis of current implementation of HOTINT,dynamic and static solver class and the components of the multibody system.

Keywords-Multibody,HOTINT,Solver,Object-oriented.

I. INTRODUCTION

Multibody system is an assembly of several bodies connected to each other by joints and acted upon by forces. A body, that can be rigid or flexible, is composed by a collection of material points. A joint allows for certain degrees of freedom and constrains others. In practice, joints are connection devices such as bearings, rod guides, etc., which from mathematical point of view are denominated as revolute joints, translational joints, etc.,according to the relative degrees of motion permitted. The forces can have different sources and different levels of complexity. Multibody systems dynamics is related to classical and analytical mechanics. The most simple element of a multibody system is a free particle introduced by Newton (1686) in his "Philosophiae Naturalis Principia Mathematica" or simply "Principia". The essential element, the rigid body, was defined by Euler (1776) in his contribution entitled "Nova methodus motum corporum rigidarum determinandi". For the modeling of constrains and joint, Euler already used the free body principle resulting in reaction forces. The equations obtained are known in multibody dynamics as Newton-Euler equations of motion, also called translational and rotational equations of motion.

II. MULTIBODY SYSTEM CONCEPT

In a simple way, it can be said that a general multibody system embraces two main characteristics, namely:

(*i*) mechanical components that describe large translational and rotational displacements and
(*ii*) kinematic joints that impose some constraints or restrictions on the relative motion of the bodies.

In other words, a multibody system (MBS) encompasses a collection of rigid and/or flexible bodies interconnected by kinematic joints and possibly some force elements. The bodies that belong to a multibody system can be considered as rigid or flexible.
A body is said to be rigid when its deformations are assumed to be small such that they do not affect the global motion produced by the body. In the two-dimensional space, the motion of a free rigid body can be fully described by using three generalized coordinates associated with the three degrees of freedom. In turn, when a body includes some amount of flexibility, it has three rigid degrees of freedom plus the number of generalized coordinates necessary to describe the deformations. The expression flexible multibody system refers to a system holding deformable bodies with internal dynamics. In fact, rigid bodies are a representation of reality because bodies are not absolutely rigid in nature. However, in a good number of common applications, the bodies are significantly stiff and, therefore, their flexibility can be disregarded and the bodies can be considered to be perfectly rigid.

III. DEGREES OF FREEDOM

Prior to establish the equations of motion that govern the dynamic behavior of multibody systems, it is first necessary to select the way how to describe them. The description variables must be able to characterize, at any instant of time, the configuration of the system, that is, the position of all the material points that compose the bodies. The description variables, also called generalized coordinates, must uniquely define the position of the system components at any instant of time during the multibody system analysis. The expression generalized coordinates is employed to include both linear and angular coordinates.The minimum number of variables necessary to fully describe the configuration of a system is denominated as degrees of freedom (DOF) of the system, or simply mobility.When the configuration of a multibody system is completely defined by the orientation of one of its bodies, the system is said to have one degree of freedom.The number of degrees of freedom can also be defined as the number of independent generalized coordinates required to uniquely describe the configuration of a system. The number of degrees of freedom of a multibody system can be evaluated as the difference between the system coordinates and the number of independent constraints. For planar multibody systems, the mathematical expression that summarizes this concept is known as the Grüebler-Kutzback criterion and is written as

$$DOF = 3nb - m$$

where nb represents the number of rigid bodies that compose the multibody system and m is the number of independent constraints.

IV. CONTROL ALGORITHMS TO PROVIDE HIGH QUALITY TRACKING CONTROL

An industrial robot is a high non-linear dynamic system because of interconnections between links. That is why a simple decentralized control cannot successfully deal with the case of fast movements of the end-effector and high requirements to the quality of the tracking. Therefore, it is necessary to apply some advanced control algorithms to provide high quality tracking control. There are two different methodologies. The first one is to design a robust controller using minimum information about the dynamics (MRAC, Sliding Mode Control). However, these techniques allow to compensate non-linear effects only after the tracking error has occurred. The second methodology – Computed Torque Control – is based on the use of the inverse dynamic model of the robot that is as close as possible to the real one. The method allows to use prior information such as desired acceleration during the tracking and configuration of the robot, to predict and feed-forward counteract the various non-linear effects to avoid any tracking error. The main drawback of the second approach is the need for an accurate plant model. There are many identification techniques that can be divided into two categories. The first one includes the methods that are based on the classic presentation of the robot dynamics (i.e. Newton–Euler formulation). The methods related to the second one are based on the use of universal approximators such as fuzzy logic and neural network methodologies. Although these methods seem to be very attractive because in the ideal case they allow to model the dynamic effects even 'bad'-modeled, for example, friction. However, a huge number of search parameters and absence of physical meaning of the last ones lead to great difficulties in the case of practical implementation. Since the classic methods take the robot configuration into account the number of search parameters is considerably smaller than in the case of universal approximators.

VI. RELATED WORK

A. HOTINT – C++ ENVIRONMENT FOR THE SIMULATION OF MULTIBODY DYNAMICS SYSTEMS:

A multibody dynamics system simulation code HOTINT is presented. The software has been developed for research purpose during the past ten years and has some consistently different features as compared to other commercial and research software. The simulation software originates from a pure time integration code that was able to solve differential algebraic equations of motion. Five years ago, a multibody system kernel has been attached to the time integration code and a 3D visualization engine has been developed. At the current stage the software is able to solve dynamic or static problem consisting of a general system of objects. The objects are represented by classical first or second order differential equations, algebraic equations and inequalities, which all of them can be nonlinear. The general kernel is not only able to manage the equations, but also to handle data of the objects for direct editing and storage in a file, as well as graphical representation of the system and export of resulting quantities of the system. The solver contains specific solvers for open and closed loop multibody systems, all of them based on redundant multibody formulations. The solver is especially adapted to second order differential equations and does not intend to factorize the mass matrix of the system in any time step.

B. HIGH-ORDER IMPLICIT RUNGE–KUTTA METHODS FOR DISCONTINUOUS MECHATRONICAL SYSTEMS:

An arbitrary order implicit Runge–Kutta time integration algorithm for the solution of stiff, differential-algebraic, discontinuous and nonlinear dynamic problems is presented. A large number of industrial applications are known which include discontinuities, like contact, friction, plasticity, hydraulics, switching external forces, control, electronic and electric devices. Effective strategies for high order time-integration methods (up to 20) are used to efficiently integrate the equations from a mechatronical system. While the continuous part of the solution can be solved efficiently by the high order of the method, in the case of highly nonlinear or discontinuous effects the time step is chosen to be small. The implementation of the nonlinear system of equations for every implicit Runge–Kutta step is shown in detail, where special attention is paid to the system of mixed first and second order differential and algebraic equations. Especially, the mass matrix is not inverted within the solution procedure, as it has to be done for explicit methods. While the freely available time integration codes like DASSL, ODEPACK or RADAU5 are written in FORTRAN, the presented code HOTINT, is written in C++ and takes advantage of object oriented methods.

C. AUTOMATIC PARAMETER IDENTIFICATION FOR GENERIC ROBOT MODELS:

High speed motion of robots and exact positioning demand of robots require highly accurate robot simulations. In existing generic models for different robot types, the choice of optimal parameters is a very important factor to obtain correct simulation results. The aim of this paper is to increase the accuracy of mechatronic simulations of generic robots by use of an automatic identification algorithm, which allows an easy identification of mechanical, drive and controller parameters. The use of algebraic least square methods based on dynamic equations is state of the art in robotics, however, different genetic algorithms have shown excellent performance in many different applications in the past. In robotics the genetic algorithm is applied mainly in the area of trajectory optimization and the search of the optimal controller parameters. In the present paper a special automatic parameter identification algorithm, based on the principle of genetic optimization without parameter crossover, is described. Furthermore, a method is shown which considers multiple local minima of the simulation error. For verification of the algorithm the exactly known parameters of a simulated belt drive model are identified up to high accuracy. Finally, the algorithm is applied to measurement data of a real robot with parallel kinematics to identify certain drive parameters of the generic robot model, including the time delay of the measured torque.

D. COMPUTER IMPLEMENTATION OF THE ABSOLUTE NODAL COORDINATE FORMULATION FOR FLEXIBLE MULTIBODY DYNAMICS:

Deformable components in multibody systems are subject to kinematic constraints that represent mechanical joints and specified motion trajectories. These constraints can, in general, be described using a set of nonlinear algebraic equations that depend on the system generalized coordinates and time. When the kinematic constraints are augmented to the differential equations of motion of the system, it is desirable to have a formulation that leads to a minimum number of non-zero coefficients for the unknown accelerations and constraint forces in order to be able to exploit efficient sparse matrix algorithms. In the absolute nodal coordinate formulation, no infinitesimal or finite rotations are used as nodal coordinates. The configuration of the finite element is defined using global displacement coordinates and slopes. By using this mixed set of coordinates, beam and plate elements can be treated as isoparametric elements. As a consequence, the dynamic formulation of these widely used elements using the absolute nodal coordinate formulation leads to a constant mass matrix. It is the objective of this study to develop computational procedures that exploit this feature. In one of these procedures, an optimum sparse matrix structure is obtained for the deformable bodies using the QR decomposition.

E. THEORY AND APPLICATIONS OF MULTIBODY SYSTEMS:

Multibody system dynamics is an essential part of computational dynamics a topic more generally dealing with kinematics and dynamics of rigid and flexible systems, finite elements methods, and numerical methods for synthesis, optimization and control including nonlinear dynamics approaches. In particular, the wear of railway wheels of high-speed trains and the metabolical cost of human locomotion is analyzed using multibody system methods.

VII. SUMMARY OF VARIOUS SCHEMES OF MULTI BODY SYSTEM

Author Name	Approach	Findings
JOHANNES GERSTMAYR	Multibody System Simulation Software HOTINT	The software HOTINT is composed of a Windows user interface, numerical solvers for static and dynamic problems and a multibody kernel, which allows the easy handling and extension of objects in the multibody system. The advantages of the solution procedures are based on a reordering of the equations of motion for tree-like multibody systems. A second advantage is the avoidance of factorization of the mass matrix in the implicit time integration methods.
JOHANNES GERSTMAYR, MICHAEL STANGL	Different IRK Schemes	A general solver "HOTINT" for DAE problems has been presented. In this solver a large number if different IRK schemes have been implemented and tested with real multibody systems. The efficiency of the method for stiff and discontinuous systems is competitive with existing codes.
RAFAEL LUDWIG AND JOHANNES GERSTMAYR	Automatic Parameter Identification For Generic Robot Models	A strategy for optimizing more than one (local) minimum of the simulation error is shown.The introduced optimization algorithm is tested at an identification of nominal belt drive parameters, which are exactly known. Finally, the algorithm is applied to identify several drive parameters of a real parallel robot based on recorded drive data.
AHMED A. SHABANA	Computational Finite Element Procedures	new computational finite element procedures are developed for the computer-aided analysis of flexible multibody systems. These procedures, which are based on the absolute nodal coordinate formulation, lead to an optimum sparse matrix structure and allow for easy addition of constraints and forcing functions. Further more, the new procedures can be used for the large deformation analysis of flexible multibody systems, and as such, they do not suffer from the limitations of the floating frame of reference formulation.
WERNER SCHIEHLEN	Analytical And Recursive Multibody Dynamics For Rigid And Flexible Bodies	multibody dynamics is an excellent foundation for multivariable vibration analysis and sophisticated control design. As an engineering application the wear analysis of railway wheels is presented characterized by a multi-time-scale approach. The human locomotion is introduced as a challenging biomechanical problem where the muscle action requires extended models for the estimation of metabolical cost which is essential for the improvement of prosthetic devices.

VIII. CONCLUSION

HOTINT provides us easy graphical user friendly interface.It provides numeric solver for static and dynamic problems.Hoint general solver can solve differential algebraic equations problems.Algorithm based on the theory of genetic optimization can be applied to identify several drive parameters of real parallel robot. Absolute nodel coordinate formulation procedure can be used for computer aided analysis of flexible multibody system.

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