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HOTINT – Open Source Multibody Simulation Software

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Abstract

Over the past two decades, HOTINT has emerged from a master thesis [1] to a multi-purpose simulation software for both research and industrial applications [2, 3]. The core functionality of HOTINT focuses on a detailed mechanical representation of complex multibody systems comprising both rigid and flexible members, based on which both transient and static analyses as well as a modal analysis. The main features have been extended beyond a purely mechanical perspective towards the modeling and simulation of mechatronic systems which contain not necessarily mechanical components as various kinds of sensors, actuators and the control system connecting the former.

The basic concept of HOTINT concerning the numerical modeling of multibody systems is that of a redundant coordinate formulation. As opposed to approaches based on a minimal set of coordinates, each body is represented by an unconstrained component at first. This allows an independent development of implementations for various kinds of rigid bodies and finite elements by means of so-called (C++) computational objects. Kinematic constraints, which restrict the absolute or relative motion of bodies, are realized by means of separate computational objects that can be added to the multibody system. This allows an independent development of constraint objects, as well. Despite the larger number of degrees of freedom and the necessity of solvers that can handle differential algebraic equations (DAE), such approach enables an accurate representation of joints in real-world applications whose behavior often differs significantly from the notion of idealized constraints even in case of classical multibody systems as industrial robots. Besides such idealized kinematic pairs, which are represented by algebraic constraint equations, HOTINT enables the modeling of joints with finite, possibly anisotropic stiffnesses, non-linear characteristics, and dissipative properties such as damping and friction. Such joint properties, which are usually unknown in real multibody systems, can be identified from experimental data using genetic identification and optimization algorithms [4].

The object library for the modeling of multibody systems ranges from point masses and rigid bodies, for which different kinds of rotational parameters are implemented, to a large variety of finite elements available for the modeling of flexible components. Among the latter, beam, plate and shell elements based on the absolute nodal coordinate formulation (ANCF) [5] play an important role. These 2D and 3D finite elements are implemented for both slender (Bernoulli-Euler) and moderately thick (Timoshenko) beams that are capable of undergoing large deformations. For some beam elements, implementations for non-linearly elastic (finite strain) and elasto-plastic constitutive behavior are available in HOTINT. An integrated mesh preprocessor facilitates setting up complex geometries using ANCF elements, which are based on the interpolation of slope-vectors in addition to nodal positions.

HOTINT also offers conventional solid finite elements such as tetrahedral, hexahedral, prism and pyramid elements for arbitrarily shaped 3D flexible bodies.

The combination of features of rigid bodies and finite elements enable the realization of modal reduction techniques completely within HOTINT without the use of external analysis tools during the workflow. In addition to the conventional approach based on the floating frame of reference formulation (FFRF) and component mode synthesis (CMS), a novel approach entirely based absolute displacements referred to as generalized component mode synthesis (GCMS) [6] is available in HOTINT. In contrast to classical FFRF-based CMS, GCMS retains the linear structure of the inertia terms which reduces the computational complexity and facilitates the implementation of advanced numerical concepts such as energy and momentum conserving time integration [7] or a projection onto the constraint-nullspace in order to get rid of algebraic constraint equations [8].

Other recent features of HOTINT include fluid-structure interaction realized by means of co-simulation with a fluid code based on smoothed particle hydrodynamics (SPH) [9]. The same TCP/IP interface is

used for the coupling with MATLAB/Simulation for the realization of real-life control systems.
From the user's perspective, the graphical user interface (GUI) allows an intuitive implementation and manipulation of multibody systems as well as an online visualization of the simulation results. However, a more powerful technique for the construction of flexible multibody dynamics models is available via an integrated script language. The script language allows to define bodies, constraints, loads, sensors, control and other objects by means of a hierarchical structure, using a powerful mathematical programming language. The creation of large models is simplified by programming features such as *for*-loops, *if*-conditions, file-*include* and other helpful commands. Once the model is setup, it can be verified in the GUI as well as by means of its 3D visualization.
Since the end of 2013, the code is fully open source. More than 600 registered downloads show the need and importance for open source software in flexible multibody dynamics. The code offers a detailed description and reference manual for the script-language-based creation of multibody models on more than 300 pages as well as a manual for the usuage of the open source code. The paper will show the current status, including an overview of existing bodies and constraints and will explain the structure of the scripting language. The paper will also focus on some future concepts, which shall help to simplify the implementation of computational objects and to enable parallelization.

References

[1] J. Gerstmayr. Entwicklung eines objektorientierten Programmes in C++ zur Berechnung ebener Tragwerke und Scheiben mit Hilfe eines allgemeinen Finite Elemente Kerns. Diploma Thesis, Johannes Kepler University Linz, 1997.

[2] J. Gerstmayr. HOTINT – A C++ Environment for the Simulation of Multibody Dynamics Systems and Finite Elements. In K. Arczewski, J. Fraczek, M. Wojtyra (Eds.) ECCOMAS Thematic Conference on Multibody Dynamics, Warsaw, Poland, 2009.

[3] J. Gerstmayr, A. Dorninger, R. Eder, P. Gruber, D. Reischl, M. Saxinger, A. Humer, K. Nachbagauer, A.S. Pechstein and Y. Vetyukov. HOTINT – a script language based framework for the simulation of multibody dynamics systems. In Proceedings of the ASME 2013 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE), Portland (OR), USA, 2013.

[4] R. Eder, J. Gerstmayr. Special Genetic Identification Algorithm with smoothing in the frequency domain. Advances in Engineering Software, Vol. 70, pp. 113–122, 2014.

[5] J. Gerstmayr, H. Sugiyama, A. Mikkola. Review on the Absolute Nodal Coordinate Formulation for Large Deformation Analysis of Multibody Systems Journal of Computational and Nonlinear Dynamics, Vol. 8, No. 3, 031016 (12 pages), 2013.

[6] A.S. Pechstein, D. Reischl, J. Gerstmayr. A Generalized Component Mode Synthesis Approach for Flexible Multibody Systems with a Constant Mass Matrix. Journal of Computational and Nonlinear Dynamics, Vol. 8, No. 1, 011019 (10 pages), 2013.

[7] A. Humer, J. Gerstmayr. Energy-Momentum Conserving Time Integration of Modally Reduced Flexible Multibody Systems. In Proceedings of the ASME 2013 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE), Portland (OR), USA, 2013.

[8] A. Humer, F. Naets, W. Desmet, J. Gerstmayr. A generalized component mode synthesis approach for global modal parameterization in flexible multibody dynamics. In Proceedings of the 3rd Joint International Conference on Multibody System Dynamics (IMSD2014), Busan, Korea, 2014.

[9] M. Schörgenhumer, P. Gruber, J. Gerstmayr. Interaction of flexible multibody systems with fluids analyzed by means of smoothed particle hydrodynamics. Multibody System Dynamics, Vol. 30, No. 1, pp. 53–76, 2013.