ISSN: 2347-6540

International Journal of Latest Research In Engineering and Computing (IJLREC)
Volume 3, Issue 3 , Page No. 1-5 May-June 2015
www.ijlrec.com

REVIEW OF MULTIBODY DYNAMIC SYSTEM USING HOTINT

ASHWANI KUMAR KAUSHIK[1] & RAMNARAYAN MUNI[2]

[1] Research Scholar, Deptt. of Mech. Engg,, SDDIET, Barwala, (Panchkula) India

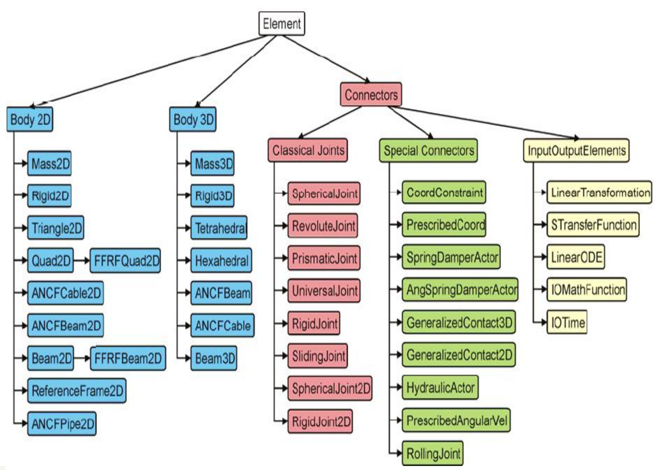
[2]Faculty Mechanical Engineering, Deptt. of Mech. Engg. SDDIET, Barwala (Panchkula) India

ABSTRACT

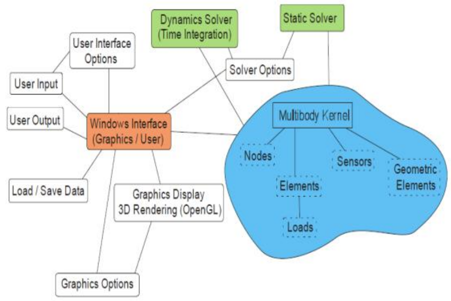
A multibody dynamics system simulation code HOTINT is reviewed in this paper. The HOTINT software has been consistently used for different research purpose during past years with different features as compared to other commercial and research software. Differential algebraic equations of motion can be solved with the help of this simulation software. These problems are in the form of first or second order differential equations, algebraic equations and inequalities, which may or may not be nonlinear. The main objective of this review is simulation study of HOTINT& multibody dynamics systems with some details developed by different researchers.

INTRODUCTION

The C++ code HOTINT has been originally developed in order to simulate multibody dynamics systems for academic use. The library of the code, which is of basic importance, is obtained by solving static nonlinear finite element problems which have been developed within a diploma thesis in 1997 [1]. The code is divided into two large parts; the first (shown in red) is the windows or user-interface. It is not available in Unix-platforms as it frequently uses windows functions.



In order to make the code portable, this part of the code is maintained in a separate library with only a small interface to the multibody kernel. The multibody kernel and the solvers are in another library and do not uses other feature than standard C++ functions. There are two main classes of elements; the first class of objects consists of two dimensional and three dimensional bodies, having fixed volume, mass, a position and some physical parameters. The second class of objects represents connectors.



LITRATURE SURVEY

Various authors have worked on Mechanics of multibody system. Brief descriptions of these are described below:-

A. Equation of motion for Constrained Multibody System

J. W. Kamman and R. L. Huston in 1984 [15] presents a new automated procedure for obtaining and solving the governing equations of motion of constrained multibody systems .The procedure is applicable when the constraints are either (a) geometrical (for example, "closed-loops") or (b) kinematical (for example, specified motion). The procedure is based on a "zero eigenvalues theorem," which provides an "orthogonal complement" array which in turn is used to contract the dynamical equations. A unified approach for inverse and direct dynamics of constrained multibody systems that can serve as a basis for analysis, simulation, and control is provided by Farhad Aghili in 2013 [14]. The main advantage of the dynamics formulation is that it does not require the constraint equations to be linearly independent.

B. ANCF, Finite element formulation & implicit time integration scheme/algorithm

An arbitrary order implicit Runge–Kutta time integration algorithm for the solution of stiff, differential-algebraic, discontinuous and nonlinear dynamic problems is given by J. Gerstmayr, M. Stangl in 2004 [2] whereas E. Hairer and G. Wanner in 1999 [4] presents Radau IIA methods as successful algorithms for the numerical solution of stiff differential equations. Absolute nodal coordinate formulation (ANCF), finite element (FE) formulation and time-integration schemes for the efficient simulation of multibody systems are proposed by J. Gerstmayr, J. Schoberl in 2003 [3]. The absolute nodal coordinate formulation is chosen. In the discretized form, a constant mass matrix and a nonlinear stiffness matrix follow from a variational formulation. According to the classical assumptions of Multibody systems, only small deformations but large rotations are taken into account. J. Gerstmayr in 2013 [12] says that absolute nodal coordinate formulation (ANCF) is advantageous since in general, the ANCF leads to a constant mass matrix while K. Nachbagauer & P G Gruber in 2011 [13] proposes three-dimensional nonlinear finite element for thin beams within the absolute nodal coordinate formulation (ANCF).

C. Simulation Software for Multibody System

Inherent discrepancies are found by Daniel Montrallo Flickinger in 2013 [16] in the contemporary software systems used in the dynamic simulation of rigid bodies regarding their accuracy, performance, and robustness. He presents a geometrically accurate constraint formulation, the Polyhedral Exact Geometry method. This method is then analyzed and compared with the well-known Stewart-Trinkle and Anitescu-Potra methods. The behavior and performance for the methods are discussed. Johannes Gerstmayr in 2009 [1] presents a multibody dynamics system simulation code HOTINT. 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. Hierarchy of the code is also presented and introduction is given into some concepts, which might be interesting for other developers. It is also shown, what is necessary to add a new object, such as a mechanical body or a constraint condition. While the code is not available open source, a part of the software is available as a freeware and can be downloaded as well as some examples that have been solved with the software.

A. Reducing System Size for Flexible Multibody System

A method for treating a complex structure as an assemblage of distinct regions or substructures is provided by R. R. Craig Jr. and M. C. C. Bampton in 1968 [9] using basic mass & stiffness matrices for substructures together with conditions of geometric compatibility along substructure boundaries . The method employs two forms of generalized coordinates. Boundaries generalized coordinates give displacements & rotations of points along substructure boundaries & are related to displacement modes of sub-structure known as "constraint modes". All constraint modes are generated by matrix operation from substructure input data. Substructure normal mode generalized coordinates are related to free vibration modes of the substructure relative to completely restrained boundaries. The definition of substructure modes & requirement of compatibility along sub structure boundaries lead to coordinate transformation matrices that are employed in obtaining system mass & stiffness matrices from the mass & stiffness matrices of substructures. Provision is made through a Rayleigh-Ritz procedure for reducing the total number of degree of freedom of a structure while retaining accurate description of its dynamic behavior. Substructure boundaries may have any degree of redundancy. A standard technique to reduce the system size of flexible multibody systems is the component mode synthesis (CMS) and is proposed by J. Gerstmayr and A. Pechstein in 2011 [10]. Selected mode shapes are used to approximate the flexible deformation of each single body numerically. Conventionally, the (small) flexible deformation is added relatively to a body-local reference frame, which results in the floating frame of reference formulation (FFRF). The coupling between large rigid body motion and small relative deformation is nonlinear, which leads to computationally expensive non-constant mass matrices and quadratic velocity vectors.

B. Accurate Robot Simulation

R. Ludwig and J. Gerstmayr in 2011 [5] uses automatic identification algorithm to increase the accuracy of mechatronic simulations of generic robots whereas simulation results as per existing generic models for different robot types will be accurate only if optimal parameters are chosen. It 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. 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. The simulated torque with optimized parameters shows high conformance with the real drive torque.

SUMMARY OF VARIOUS METHOD

Following table contains all the methods that are explained previously and also contains the requirements of each method, their features, on which the particular method is based. The table containing all these is shown below.

S.No.	Author/Year	Technique/algorithm used	Finding
1.	Johannes Gerstmayr & Michael Stangl In 2004 [2]	Implicit Runge–Kutta Methods for discontinuous Mechatronical systems	The efficiency of the method for stiff and discontinuous systems is competitive with existing codes. The equations of motion can be generated easily in Maple or Mathematica and transfered automatically written into HOTINT Format
2.	Ernst Hairer & Gerhard Wanner In 1999 [4]	Radau IIA methods	Implicit Runge–Kutta time integration algorithm are ideal methods for the solution of stiff, differential -algebraic & step size selection which is very crucial for highly nonlinear or discontinuous problems can be done efficiently
3.	J. Gerstmayr and J. Schoberl In 2003 [3]	Finite Element (FE) Formulation and Time-Integration Schemes	Green strain tensor leads to a stiffness matrix which is multiplicatively composed of the rotation matrix of the rigid body rotation and the small strain stiffness matrix, which has to be computed only once.
4.	J. Gerstmayr In 2009 [1]	Multibody Dynamics System Simulation Code HOTINT.	The multibody system simulation software HOTINT is composed of a Windows user interface, numerical solvers for static & dynamic problems and a multibody kernel, which allows the easy handling & extension of objects in the multibody system.
5.	Rafael Ludwig & Johannes Gerstmayr In 2011 [5]	Automatic Identification Algorithm	Genetic Algorithm based strategy is best for optimizing more than one (local) minimum of the simulation error & for the selection of optimal parameters which is a very important factor to obtain correct simulation results.
6.	P. G. Gruber, K. Nachbagauer, Y. Vetyukov, and J. Gerstmayr [6]	Bernoulli–Euler beam finite element based on the absolute nodal coordinate formulation (ANCF)	Thin beam finite elements do not suffer from geometrical singularities in contrast to already existing 3-D ANCF elements.

7.	Ahmed A. Shabana, Olivier A. Bauchau and Gregory M. Hulbert[7]	Gluing algorithms (GAs), The finite element based direct integration method (FEBDI), & The multi body system based direct integration method (MSBDI)	Existing finite element and multibody system algorithms have are no longer effective in solving detailed and complex models. The analysis of these detailed and complex models require the successful integration of large deformation finite element and multibody system algorithms.
8.	Andre Laulusa & Olivier A. Bauchau [17]	Coordinate Reduction Techniques, Index Reduction Techniques (Maggie's formulation, null space formulation, Udwadia & Kabala's formulation)	Best approach for the solution of DAEs is to reduce their index & these methods only differ by the numerical process used to compute the null space of the constraint matrix.

CONCLUSION

This paper has presented a comprehensive review of the theoretical foundations used for the simulation of multibody dynamic systems. An arbitrary order implicit Runge–Kutta time integration algorithm for the solution of stiff, differential-algebraic, discontinuous and nonlinear dynamic problems. Radau IIA methods are successful algorithms for the numerical solution of stiff differential equations. Simulations of Generic Robots can be done with increased accuracy by using an automatic identification algorithm, with the help of which mechanical, drive and controller parameters can be easily indentified.

Algebraic least square methods based on dynamic equations have been conventionally used in robotics; however, as per experience, different genetic algorithms have shown excellent performance in many different applications. Existing finite element and multibody system algorithms are no longer effective in solving detailed and complex models requires the successful integration of large deformation finite element and methods like gluing algorithms (GAs), the finite element based direct integration method (FEBDI), and the multibody system based direct integration method (MSBDI) have been successfully implemented for this.

REFERENCE

1. J. GERSTMAYR, "HOTINT: A C++ Environment for the simulation of multibody dynamics systems and finite elements" Proceedings of the Multibody Dynamics Eccomas Thematic Conference, 1-20, 2009.
2. JOHANNES GERSTMAYR and MICHAEL STANGL, "High-Order Implicit Runge–Kutta Methods for Discontinuous Mechatronical Systems" Proceedings of 32nd summer school, APM' 2004, June 24 – July 01.
3. J. GERSTMAYR AND J. SCHOBERL "A 3D Finite Element Solver for Multibody Systems Based on Implicit Runge- Kutta Schemes" Proc. Appl. Math. Mech. 3, 154–155 (2003)
4. ERNST HAIRER and GERHARD WANNER "Stiff differential equations solved by Radau methods" Journal of Computational and Applied Mathematics 111 (1999) pp. 93 – 111.
5. RAFAEL LUDWIG and JOHANNES GERSTMAYR "Automatic parameter identification for generic robot models" Proceedings of the Multibody Dynamics Eccomas Thematic Conference, 4-7, 2011.
6. P. G. GRUBER, K. NACHBAGAUER, Y. VETYUKOV and J. GERSTMAYR "A novel director-based Bernoulli–Euler beam finite element in absolute nodal coordinate formulation free of geometric singularities" Journal of Mechanical Sciences, Vol. 4,page 279–289,Aug. 2013
7. AHMED A. SHABANA, OLIVIER A. BAUCHAU AND GREGORY M. HULBERT, "Integration of Large Deformation Finite Element and Multibody System Algorithms", Journal of Computational and Nonlinear Dynamics, Vol. 2, October 2007, pp. 351-359
8. ERNST HAIRER, CHRISTIAN LUBICH and MICHEL ROCHE "The numerical solution of differential-algebraic systems by Runge-Kutta methods" Springer Verlag 1989, ISBN 3540518606, 9783540518600
9. M. C. C. BAMPTON and R. R. CRAIG, JR. "Coupling of substructures for dynamic analyses." AIAA Journal, Vol. 6, No. 7 (1968), pp. 1313-1319.
10. J. GERSTMAYR and A. PECHSTEIN "A Generalized Component Mode Synthesis Approach for Multibody System Dynamics Leading to Constant Mass and Stiffness Matrices" Proceedings of 8th international conference on multibody system, Non linear Dynamics, August 28 -31, 2011.
11. P. MASARATI "Direct Eigen Analysis of Constrained system Dynamics" Journal of Multibody Dynamics, Vol. 223, No. 4, pp. 335-342, December 01, 2009
12. K. NACHBAGAUER and J. GERSTMAYR "Structural and Continuum Mechanics Approaches for a 3D Shear Deformable ANCF Beam Finite Element: Application to Buckling and Nonlinear Dynamic Examples" Journal of Computational & Nonlinear Dynamics, Vol. 9, No. 1, Oct. 2013.

13. K. NACHBAGAUER, P G GRUBER, Y. VETYUKOV and J. GERSTMAYR, "A spatial thin beam finite element based on the absolute nodal coordinate formulation without singularities" Proceedings of the ASME 2011 International Design Engineering Technical Conference, Page 28-31, Aug. 2011

14. FARHAD AGHILI , "A unified approach for inverse and direct dynamics of constrained multibody systems based on linear projection operator: applications to control and simulation", IEEE Transactions on Robotics, Vol. 21, No. 5, pp. 834-849 (2013)

15. J. W. KAMMAN and R. L. HUSTON, "Dynamics of Constrained Multibody Systems" Journal of applied mechanics, Vol. 51, No. 4, pp. 899-903,Dec 01,1984

16. DANIEL MONTRALLO FLICKINGER, JEDEDIYAH WILLIAMS AND JEFFREY C. TRINKLE, "Evaluating the Performance of Constraint Formulations for Multibody Dynamics Simulation", Volume 7A: 9th International Conference on Multibody Systems, Nonlinear Dynamics, and Control Portland, Oregon, USA, August 4–7, 2013

17. ANDRE LAULUSA & OLIVIER A. BAUCHAU, "Review of Classical Approaches for constraint enforcement in Multibody Systems" Journal of Computational and Nonlinear Dynamics,