Introduction

User's manual

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The program package "Universal Mechanism" (UM) is designed to automate the analysis of mechanical objects, which can be represented as a multibody system (MBS). Within such systems, bodies represented as rigid objects are connected by means of kinematic and force elements. Examples of MBS can be a complex automobile, a locomotive, a railway car, or simple robot and excavator manipulators and different mechanisms for devices (medical device).

Certainly, UM can be applied to any system that can be model as a multi- body system with a understanding of the underlying limitations imposed. The range of problems, which can be solved with the help of this package, is vast. In fact, UM operates on a majority of systems which involve theoretical and applied mechanics in two or three dimensions. An engineering analyst using UM, can successfully solve and analyze, direct and inverse problems of kinematics, dynamics and control. As a matter of fact, there are no limits to the number of bodies in a particular system.

Complex mechanical systems with large numbers of bodies pose a degree of difficulty, not only in the analysis of the equations, but also their generation and even the description of the object's structure. The architecture of UM eases this task.

The architecture of UM is designed to automate procedures. This simplifies the process of a simulation and speeds up the productivity time a engineering analyst. Consider a system consisting of dozens of bodies, entering the usual data to describe its inertial and kinematic properties can be time consuming. UM provides a method of building subsystems which (if the version of UM has the corresponding module) facilitates the task tremendously, especially with a system containing a few similar subsystems. For example, consider multi-body system of a train consisting of a locomotive and twenty similar cars. It is only necessary to enter the data for the locomotive and one car, grouped as a subsystem. In turn, this subsystem of locomotive and one car, can be further described with a number of separate subsystems, some of which may be kinematically identical. Thus the advantage of building a singular subsystem, which lends itself to repetitive use with follow on time saving and reduced errors.

UM software is periodically programmed with the latest computer graphics algorithms to ensure excellent visual animation of a multi-body system. Three dimensional motion of the system occurs both during the process of numerical integration of the motion equations and analysis of results.

Universal mechanism allows a user to describe a multibody system according to a simple set of rules, and automatically performs the rest of the simulation setup. Universal mechanism achieves this through specialized procedures, which represent equations of motion in a symbolic form. The advantage of this automation is perhaps best observed when consideration is paid to the large number and complexity of the motion equations needed to describe even a simple multi- body system. The task becomes more highly involved with a complicated multi-body system. For example writing down the mathematical equations motion for a robot with six rotational degrees of freedom (d.o.f.), would take a few pages.

This software is created based on modern techniques of computer-aided modeling of mechanical systems. Additionally, incorporated are a number of new methods and formalisms de-

veloped by the authors. These greatly increase the practical effectiveness of the package operation in all its parts. The principal formalisms, which are published in scientific journals, include:

- an optimal analysis formalism for systems with closed kinematical loops;
- generalized models of kinematical constraints;
- a method for economical coding of symbolic motion equations;
- a method of subsystems and formalisms for optimal numerical solving of the motion equations of large dimensions;
- effective modifications of multi-step Adams-Bashfort-Moulton and BDF methods for the direct solving of non-stiff differential-algebraic equations of motion;
- a Park method for the direct solving of stiff differential-algebraic equations of motion;
- formalisms for fast computing Jacobian matrices for stiff equations of motion.

The inclusion of these formalisms within the framework of UM as allowed a substantial increase in the effectiveness of modeling, input of data, preliminary analysis, generation of motion equations and numerical solution and analysis.

There are two key principles lying in the foundation of UM's ideology. These are the principles of universality and hierarchical optimization. The practical incarnation of the first principle broadens the area of application of the package. It embraces various aspects of problems from classical dynamics (for instance, dynamics of rigid bodies) to locomotives and automobiles; from the kinematics of plane lever mechanisms to the dynamics of spatial aeronautic truss structures containing hundreds of bodies; from the vibrations of a point mass attached to a spring to the direct and inverse robot manipulator control problems.

Universal mechanism is simple and friendly to work with. A well designed graphical user interface and purposeful concealment of the complex 'mathematics of multi-body systems ' inside the package, makes it easy to work with in today's industrial environment. Like any other software program the engineer is encouraged to develop a understanding of UM ideology, its 'habitat' and its language, to study the fundamentals of programming in the environment of UM. This done, proceed to model a complicated technical system. To facilitate the process of learning UM considerable attention has been put into writing the user manual.

The manuals are written by the authors in a manner which, through user trials, pointed to the easiest path for a user to understand the software capabilities. Therefore it is recommended a user reads it through at least once as if it were a usual monograph. On the other hand, care as been taken to allow reference to any of its sections independently.

Finally, the authors would like to acknowledge UM is by no means free of errors and common with any other commercial program, there is at least one error. The authors request and will be thankful for feedback on such errors. Please help us, by providing a description of the steps done which caused any errors and email the corresponding data file. UM is continuously being updated, should a need for the latest versions arise, please get in touch UM. The authors are happy to offer their considerable experience to assist with any difficulties in solving your problems with the help of UM. Please, do not hesitate to contact the authors.

I wish you success,
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