INTRODUCTION

The program package "Universal Mechanism" (UM) has been designed to automate the analysis of mechanical objects, which can be represented as rigid body systems (or multibody systems – MBS), whose bodies are connected by means of kinematical and force elements. An automobile, a locomotive, a railway car, robot and excavator manipulators, different mechanisms and devices are examples of such systems.

Certainly, using only rigid body systems when modeling imposes some limitations on the range of problems, which can be solved with the help of the package. However, this range is big enough. In fact, UM operates with a majority of systems with which theoretical and applied mechanics deal. With the help of UM the user can solve the direct and inverse problems of kinematics, dynamics, and control. A mechanical system with two or three dimensions can be analyzed successfully. As a matter of fact, there are no limits to the number of bodies in a particular system.

For complex mechanical systems with large numbers of bodies not only the analysis of the equations but also their generation and even the description of the object's structure are difficult. UM makes it possible to automate these procedures, which raises considerably the productivity of the designer's work. If an object consists of over two dozens of bodies, entering usual data for the description of its inertial and kinematical properties takes a lot of time. The method of subsystems available with UM (if the version of UM has the corresponding module) facilitates this tremendously, especially when a system containing a few similar subsystems is under consideration. E.g., if you have to model a train consisting of a locomotive and twenty similar cars, it is only necessary to enter data for the locomotive and one car. In its turn, the locomotive and the car can also be divided into separate subsystems, some of which might turn out to be alike or kinematically identical, speaking more rigorously. Of similar subsystems you have to describe only one. This spares your time and helps you avoid a number of errors.

UM widely applies update methods of computer graphics both to display the 3D motion of the system during the process of the numerical integration of the motion equations and when analyzing the obtained results.

The motion equations are generated by a special procedure of the software in a completely symbolic form. For some problems, the number of equations is so huge that it is virtually impossible to obtain them with a pencil and paper, although there is not much sense in obtaining them analytically. E.g., if one had to write down the motion equations for a robot with six rotational degrees of freedom (d.o.f.), it would take a few pages. Therefore it makes no sense to analyze them visually. So, the user just describes his system according to certain simple enough rules, and the rest is performed automatically.

When creating this package, the authors, on the one hand, were taking into consideration the modern technique of computer-aided modeling of mechanical systems. On the other, they have developed a number of new methods and formalisms, which greatly increased the effectiveness of the package operation practically in all its parts. Among the principal formalisms that were published in scientific journals there are:

- 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 multistep 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 development of novel formalisms within the frameworks of UM allowed the substantial increase of the effectiveness of modeling in all its parts such as: entering data and their preliminary analysis, the motion equations generation, their 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 one gave width to the area of application of the package, which embraces various aspects from problems of 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.

To learn to work with UM is simple. That all the 'mathematics' is hidden inside the package makes it easy to work with the program even for students and even senior schoolchildren. Certain efforts have to be applied here anyway. As any complex structure, UM has its own ideology, its 'habitat' and its language. To model complicated technical systems it is urgent to study the fundamentals of programming in the environment of UM. This manual is intended to facilitate the process of learning UM.

The manual is written in a manner, which seemed to the authors the easiest for understanding the software capabilities. The authors therefore would recommend the user to read it through at least once as if it were a usual monograph. On the other hand, one can refer to any of its parts directly.

Finally, UM is by no means free of errors and shortcomings. As you know, in any program as short as possible there is at least one error. The authors will be thankful if you let them know when you find any errors and send them the corresponding data file or a file with the description of what you have done that revealed them. Besides, UM is being quickly accomplished and developed. If you need latest versions, please get in touch with the authors. If, by any chance, you have difficulties in solving your problems with the help of UM, do not hesitate to contact the authors.

I wish you success.
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