HAMILTONIAN APPROACH TOWARD EFFICIENT MODELING OF LARGE-SCALE MULTIBODY SYSTEMS WITH FRICTION AND TOWARD REAL-TIME SIMULATIONS OF ROBOTIC SYSTEMS

DESCRIPTION FOR THE GENERAL PUBLIC

In the analysis, design, and optimization of numerous mechanical systems, there is a need for automatic modeling and investigation of complex multibody systems, having a large number of bodies and degrees of freedom. In this class of systems the multibody modeling methods are widely used both in engineering branches as well as scientific research. The analyzed mechanical or interdisciplinary objects are becoming increasingly complex. The mentioned systems can be frequently found in such areas as robotics (dynamics of manipulators), automotive (testing of car components and complete vehicles), railroad (e.g., traffic safety), defense (e.g., design of tracked vehicles), aerospace (e.g., analysis of unmanned aerial vehicles or their formations). The multibody models are often used in control systems of many mechanical systems, e.g. in robotics. The developed models allow one to predict the behavior of such systems in order to achieve the desired response. The natural applications of MBS methods emerge in space and exploratory robotics as well.

Multibody modeling techniques play a particularly important and vital role in applications wherein the examination of phenomena occurring in the actual system is expensive, time-consuming or very difficult in technical realization. The analysis and simulation of large-scale multibody systems require significant numerical expenses. Simultaneous enforcement of computational efficiency and requirement for high-fidelity physical models is sometimes difficult to obtain or it is completely unattainable for contemporary computational tools. However, recent studies suggest that the use of the Hamilton's formalism for the description of multibody system behavior may enhance the performance and significantly increase the efficiency of such computations, and in consequence, may reduce certain barriers associated with real-time applications. In addition, fast calculations with parallel computers, equipped with multi-core processors and GPU card arrays, allow one for the analysis of systems with much greater complexity—with the number of degrees of freedom approaching tens of thousands (biomolecular systems) or even millions of bodies (granular media).

The proposed project takes the challenge of achieving essential speedup in multibody dynamics simulations, while maintaining an accurate representation of physical phenomena associated with the motion, such as friction. The way to achieve the expected goals is associated with many formal methods and tools (e.g. analytical mechanics, control theory and optimization, linear algebra) and many engineering branches (e.g. machine dynamics, robotics, tribology). In this project the Hamiltonian approach is intended to be used. The developed methods will be designed in such a way to exploit the benefits associated with multi-processors. Research on friction modeling will be oriented in such a way to propose a model predestined for large-scale multibody systems simulations. The theoretical considerations will be verified and accompanied by experimental studies concerning applications of new methods in the areas related to the control and modeling of complex robotic systems.

The expected result of the project is to provide tools that allow for efficient and accurate analysis of medium- and large-scale multibody systems. For certain classes of complex systems, for which such analyses are currently unavailable, it will be possible to model their dynamics in real-time. The developed methods, in addition to the typical applications in modeling complex technical objects, may be applied in hardware-in-the-loop simulations, in virtual reality technologies using haptic devices or in design and verification of innovative control strategies for complex robotic systems.