Computer Kit for Development, Modeling, Simulation and Animation of Mechatronic Systems

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Abstract: *The aim of the paper is to propose the effective tools for the computer synthesis of the real-time mechatronic control systems. Realization of the programming kit enables to model static and mobile mechanisms as the objects of control, to simulate control algorithms and, moreover, the kit will offer the platform for the development of the true control system for the real objects. The goal is to work out the proposition methodology of the new mechatronic control systems, to offer an effective tool for modeling of the static and the mobile objects of control and to create an environment for the control algorithms simulation with the aim of its step by step verification. The kit should provide the new control systems development and realization with the true objects of control as well as with the simulated ones for training or educational purposes.*

Keywords: *Kinematic semigroup, Virtual Reality, Animation, Real-Time Control*

I INTRODUCTION

Introducing robotic applications into modern technologies leads to the qualitatively new approaches to the analysis of motion dynamics of mass objects in the area of the robotic systems control research. On the contrary of the classical methods when objects with relatively small dimensions and of relatively small mass move in a non-inertial way in accordance with kinematic restrictions, and the gravitational action may be neglected, in applications demanding relatively speedy motion of the massive, i.e. inertial, objects, the situation is qualitatively different. The complex of the kinematically restricted objects yields not only to the gravitation but especially to the inertia and from the point of view of control becomes to be an extraordinary complex system, which dynamical motion is the solution of the complicated system of vector differential equations.

Mutual motion of bodies, even if mass points, within such a system is not satisfactory solved, not even in the case when the mutual action forces are central (with the exception of the two point subsystem), not speaking about mutual moments.

Another merely partially solved problem is the problem of the rigid body rotation, namely free and kinematically restricted rotation in a force field. Partial solutions are concerned with special cases (Euler, Lagrange, Kovalevskaya, Goryachev-Chaplygin). In general, only two or three constant integrals are known, respectively. Considering the system of several rigid bodies acting on each other by mutual forces as well as moments, the approximation of the solution is not trivial, too.

II PARTIAL GOALS

1. Creating of the internally consistent model of the dynamic system consisting of point masses acting on each other by mutual forces. The essence of the approach lies in the universality of the model in the sense that the mutual action of each pair is a superposition of partial mutual forces of any origin depending on the mutual position and the mutual velocity.
2. Building up a hierarchical structure of the system of point masses based on the principle of multiple decomposition of the set of point masses into disjuncted subsets. The goal of the presented conception is to prove the limit existence of the isolated subsystems which translational motion is undetectable within the subsystem.
3. Effective method of the approximation of the point masses motion based on the principle of the constant invariants conservation.
4. An idea of the rotating orthonormal base of the vector space generated by the unit vector.
5. Analytic solution of the orientation development of the free rotating dynamically symmetric rigid body.
6. Computer animation realization of the motion development in the system with the option of the motion observation from the point of view of an internal and external observer within partial subsystems.

III TIMETABLE AND COOPERATION

The programming system originates from the virtual reality real-time animation experience acquired by the team during the work on the international British-Portugal-Czech-Slovak project INCO-COPERNICUS 960174 *VIRTUOUS: Autonomous Acquisition of Virtual Reality Models from Real World Scenes* (1997-1999), a project VEGA 2/7102/21 *Automatic generation and computer animation of the linked body motion* and the project *Computer animation of the rigid bodies dynamic motion* VEGA 2/3131/23 now finished.

In the first period of the project we will work parallely on the problem of the dynamic system of point masses without kinematic constraints and, independently, on the free and kinematically constrained rotation of the rigid body. The programming system of the kinematically constrained motion of bodies will be ready to incorporate dynamic effects into the kinematical trajectories.

The following items will be the parts of the system:

1. Input files consisting of the data concerned with the partial members of the set of concrete systems to be animated and its hierarchical structure. For example the point mass data: mass, position, velocity, partial force type, class of equivalence

membership, etc. Principal moments of inertia, orientation and angular velocity of the rigid body will be added in the second period of the project.

2. Inner cycle of the central motion approximation calculation (in the second period, rotation of rigid bodies will be added). The precision of the approximation is defined by the repetition number.
3. Outer cycle of the displayed or otherwise monitored data calculation, a record of the motion development history included. The duration of the actual sequence of animation is defined by the repetition number.
4. Displayer executing the graphic interpretation of the actual data subset recorded in the outer cycle, either online, in each step of the outer cycle (i.e. in the corresponding scale of the real-time), or offline, at the end of the outer cycle (according to the chosen mode).

IV CENTRAL AND MUTUAL QUANTITIES CONCEPT

Conception of central and mutual energy and conception of mutuality in the kinematically constrained multibody systems will be introduced in the field of theory. Conception of mutual inertia for single mass objects based on their mass and the total mass of the system will allow to determine constant invariants of the dynamically symmetric rotating link of the kinematic chain. A mathematical model based on tensor representation expressing the vector base invariance of the characteristic quantities of dynamics will be developed. Next, the effort will be devoted to dynamic model of the rotational kinematic pair of the rigid links and to vector differential equation invariant quantities expression. Approximation of the motion solution of the two body system under mutual forces action in a joint mechanism, decomposition of the problem into the analytically solvable linear part and numerically approximable nonlinear part of the solution will be used for program realization of the two body system dynamics computer animation and real-time visualization of the dynamic motion by means of the virtual reality.

In the second period, central and dynamic characteristics conception, mutuality principle providing to express the energy as well as other characteristic quantities of the dynamic system of bodies by central quantities in respect of the center of mass and the same dynamic characteristics based on mutual quantities without using the position of the center of mass will be introduced. Dynamic model of kinematic mechanism consisting of the system of rigid bodies will be created and, central forces based on the mutual force and torque action of single components will be defined. Approximation methods of the motion solution of mechatronic systems consisting of the inertial rigid bodies under the mutual forces and torques action will be proposed. The mechatronic system will be decomposed into the kinematically independent subsystems which motion dynamics is mutually influenced. Constant invariants of the rigid links kinematic chain vector differential equation, which are, from the point of the dynamics, symmetric as well as dynamically asymmetric, will be derived.

Conclusion

Open source programming tools will be used preferably during the program realization. The project proposers have got a lot of programming experience with operating system Linux and its modifications supporting the hard real-time. These tools will used to realize computer animation of a rigid link kinematic mechanism with no regard on the symmetry and asymmetry of the rigid links. The final goal is to provide a tool for development and realization of a new control system of real objects as well as a simulator, for which the controlled objects are simulated. During the development process, the simulated objects will be replaced by real ones.

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