MBS MODELLING WITH SIMMECHANICS: CASE STUDIES IN RESEARCH AND EDUCATION

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Abstract

This paper briefly informs about the application of Matlab/Simulink/SimMechanics in the design, modelling and control of particular mechatronic systems. Particullar problems are introduced and application of SimMechanics is mentioned. The obtained results prove, that besides the other tools, the automatically built models of MBS dynamics and kinematics can significantly speed up the design and ensure the validity of the verified analytical model.

1 Introduction: multibody system modelling

Many mechatronics systems such as vehicles, manipulation devices, industrial and mobile robots and others include a spatial mechanical subsystem.

Mechanical part can be often modelled as a set of rigid bodies connected by joints – so called multi-body system (MBS). The dynamics of MBS is described by equations of motion, mathematically expressed as system of nonlinear ordinary differential equations (ODE).

The effective derivation of equation of motion for spatial mechanical system is still a challenging issue in scientific community. The practical problem of dynamics modelling can be solved solved using two basic approaches:

Manual approach – the engineer should derive equations of motion using "pen and paper". There are two main wellknown methods: the Lagrange equations of the second kind and the Newton approach. The appropriate CAS (Computer algebra software) such as Maple, MathCAD, Mathematica can be used for the symbolic manipulations and so for reduction of "hand work". But still, the derivation of equations for more complex system is, . . . chalenging.

Automatical derivation of equations – the procedure based on Lagrange or Newton methods mentioned above is algorithmized and implemented in so-called multibody dynamics formalism. The user specifies the geometry and topology (bodies, joints) of the system and algorithm prepare the mathematical model. Since 2002, the SimMechanics is such software implemented in Simulink environment.

Naturally, the automatically built models are more convenient for practical implementation. However, certain applications such as kinematics implemented on microcontroller or the MIMO control using inverse dynamics requires the analytical models.

2 SimMechanics used in the design, modelling and control: an overview

The next section deals with particular examples of the use of SimMechanics in mechatronics. The following unified principles are applied in individual cases:

- The first mechanical model is built in SimMechanics. Usually the procedure is easy, in certain cases (eg. rolling contact) the reduction method is used for the simplification.
- If the analytical model is required (eg. the kinematic model compact enaugh to be implemented in microcontroller), the SimMechanics is used as a reference during verification (very usefull).
- For the linear control the analytical model is not necessary. The standard Simulink `linmod` linearization can produces state space model. Then, common control algorithms can be used. Resulting controller is backwards tested on nonlinear SimMechanics model.

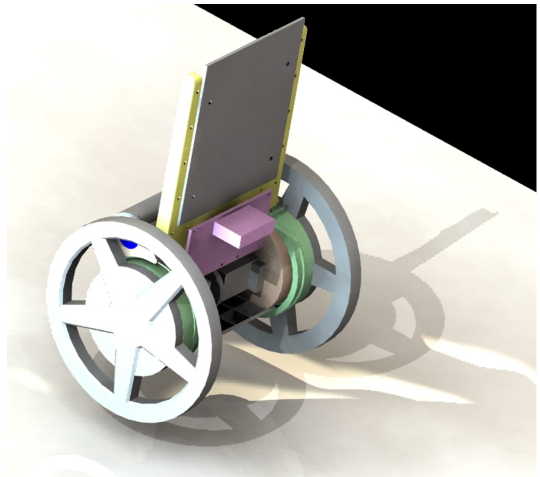


Figure 1: Keywatko: the CAD visualization

3 Case studies

3.1 The Keywatko: an unstable mobile device

The Keywatko II. is student project inspired by the projects nBot, Joe le Pendule and commercial Segway. First, we modelled the dynamics of system in SimMechanics and we applied the LQR implemented in Control System Toolbox.

After that, we prepared more complex simulation model which includes: accelerometer modelling, sensory processing model with appropriate dellays, discrete LQ controller, state observer and virtual reality visualization.

More information about Keywatko project is included in the contribution *Simulation, Control Design And Experimental Testing Of Unstable Mobile Device* in this proceedings.

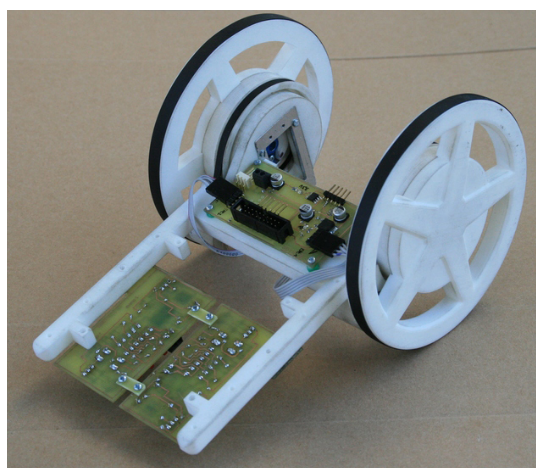


Figure 2: Keywatko: the physical experimental model

3.2 Rotational pendulum

Rotational pendulum is the variation on clasic inverted pendulum which is well-known as educational and scientifical platform for the testing of control algorithms.

The system has two degrees of freedom and one of them is actuated only. As a sensors we use two incremental encoders. The task is the same as in normal inverted pendulum control: the pendulum should remain upright and required angle of actuated motor shaft should be reached.

The standard approach to solve this problem requires two different controllers: so-called ”swing up” controller and the ”upright” controller. The appropriate algorithm switches between them. The ”upright” controller can works on linearized model, so the procedure used in previous case can be employd (automatical linearization of SimMechanics model and LQR design).

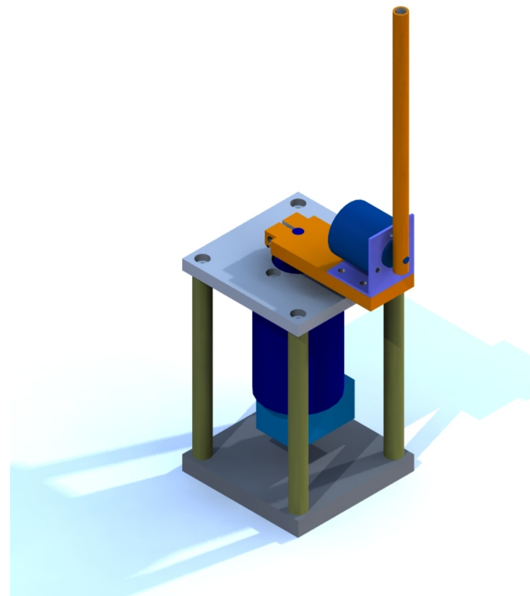


Figure 3: Rotational pendulum (CAD)

Current simulation results proves the functionality of upright controller up to aprox. 0.6 rad initial angle of pendulum, which is satisfactory.

3.3 Jaromír, the four legged robot

In this project we used the kinematics built in SimMechanics during the development. The robot was controlled directly from Simulink environment through serial line.

After the years of the using of rather simple kinematics, in 2007 new spatial kinematical model has been built. We can now control the movement of robot body in all six dof which allows the implementation of several algorithms for stabilization based on sensory information.

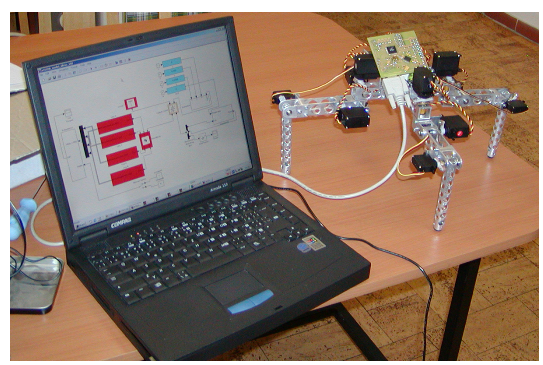


Figure 4: Four legged walking robot Jaromr controlled from Simulink

The algorithm for the new kinematics is based on homogenous coordinates and transformation matrixes. The inverse task is solved numerically using Jacobian. During the development in Matlab, automatically built kinematics in SimMechanics was used as reference.

3.4 Circuit breaker

The case of circuit breaker analysis shows one of the main SimMechanics advantage which is its extensibility and integration into Simulink environment.

SimMechanics does not provide any block for unilateral constraint problem, but thanks to integration into Simulink, the custom development of arbitrary functional block is possible and easy.

The unilateral constraints in MBS represents, in general, difficult problem. One of the most common approaches widely used in MBS softwares is based on Hertz contact model (in fact, the contact is modelled through spring and damper).

Such model for planar task was implemented and sucessfully tested for the particular problem of electrical circuit breaker switching.

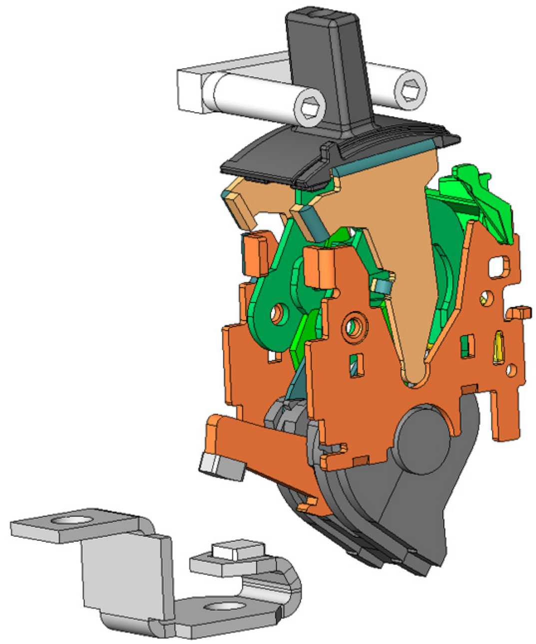


Figure 5: The visualization of modelled circuit breaker

3.5 Modelling of dynamics of soccer robot

Robotic soccer is one of the popular platforms for the testing of recent technology level. Realtime algorithms for image processing, path and trajectory planning and control developed here can play interesting role in industrial or scientific applications.

The recent robots has highly dynamic behavior and good control algorithm should include the dynamics into acount.

With the cooperation with Robohemia team we develop the computer model of robot dynamics including the possibility of lateral and longitudinal slipping. After parameter identification, the model can be used as a virtual prototype for new control algorithms testing.

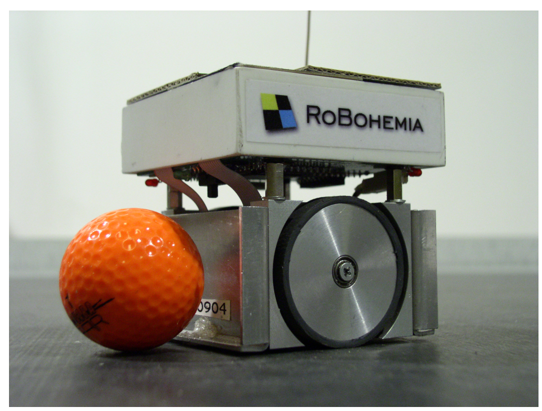
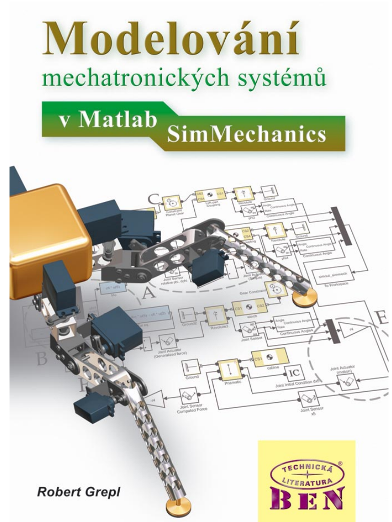


Figure 6: Soccer robot from Robohemia team

4 Conclusion



In the all mentioned projects the SimMechanics has been sucessfully used for kinematics or dynamics modelling. When the analytical models was required, the automatically built ones has been employed for the verification.

The two significant contributions have been obtained: the development time was shorter and we could garantee the validity of analytical (as well as linearized) models.

We would like to inform the reader, that the experiences with modelling in SimMechanics are available also in new publication by BEN – technická literatura: *Modelování mechatronických systémů v Matlab/SimMechanics*.

Acknowledgement

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