PDES 2016—14th IFAC INTERNATIONAL CONFERENCE on PROGRAMMABLE DEVICES and EMBEDDED SYSTEMS

Cyber-Physical System Implementation into the Distributed Control System

A. Jadlovská, S. Jadlovská, D. Voščec
Technical University of Košice,
Faculty of Electrical Engineering and Informatics,
Department of Cybernetics and Artificial Intelligence, Košice, Slovakia

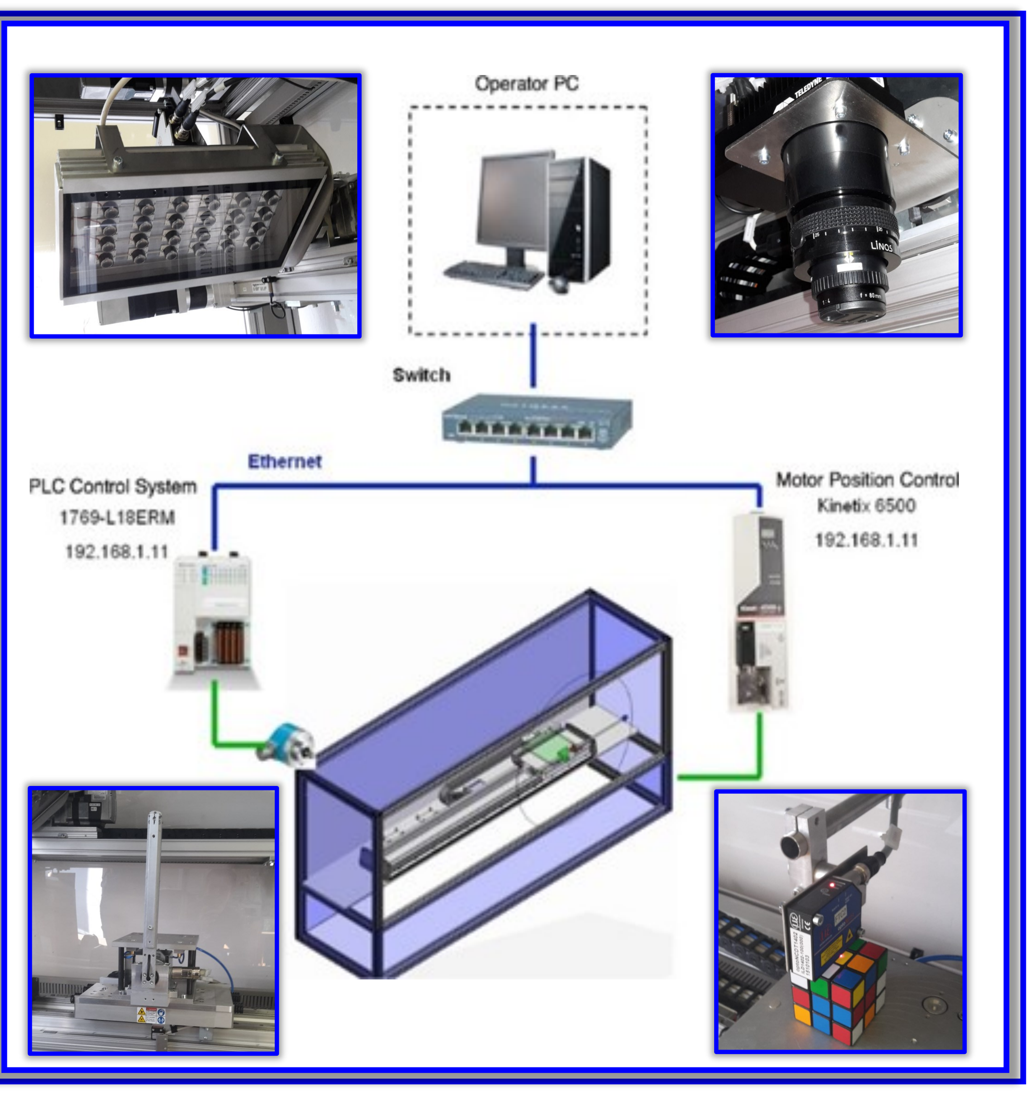
Real Single Inverted Pendulum with LSM

Possible applications

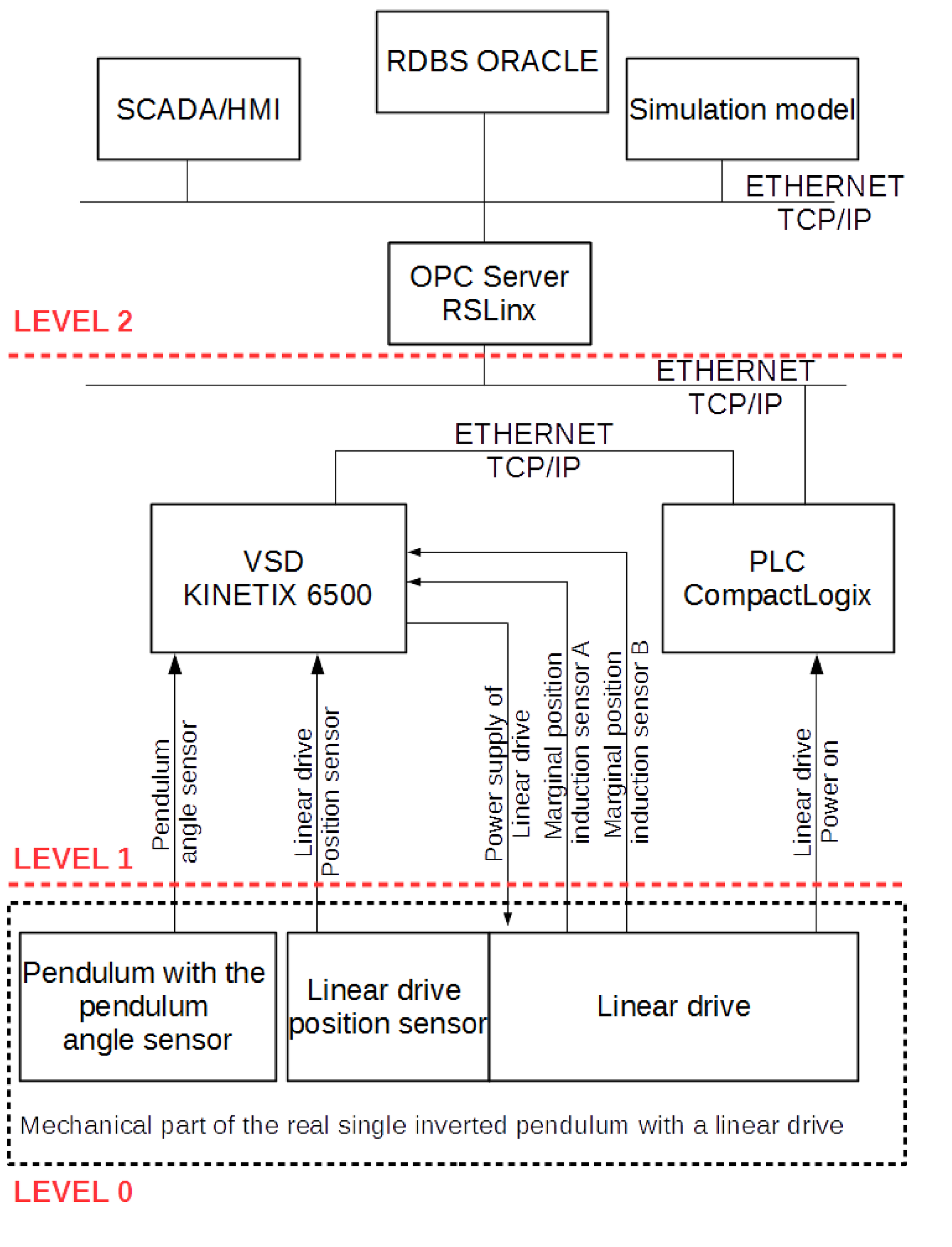
- Analytical identification of underactuated systems
- Experimental identification of underactuated systems
- Hybrid control of underactuated systems

Technical equipment:

- Servomotor KINETIX 6500 with frequency converter
- CompactLogix PLC
- IRC sensor for motor position
- KINAX-2W2 programmable angle converter
- RSLogix 5000
- DDE protocol
- MATLAB/Simulink

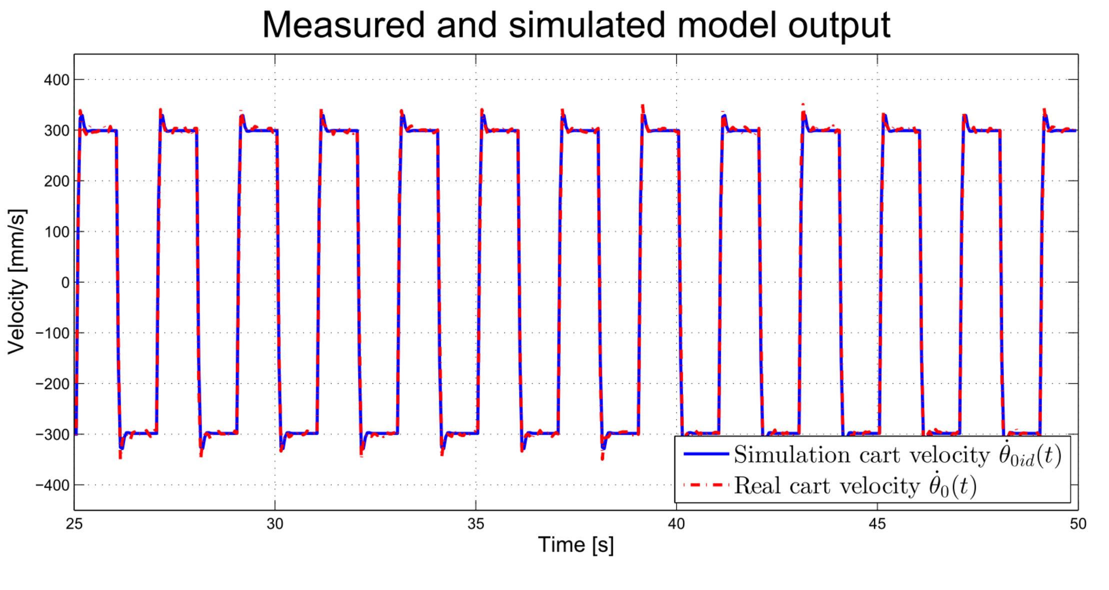


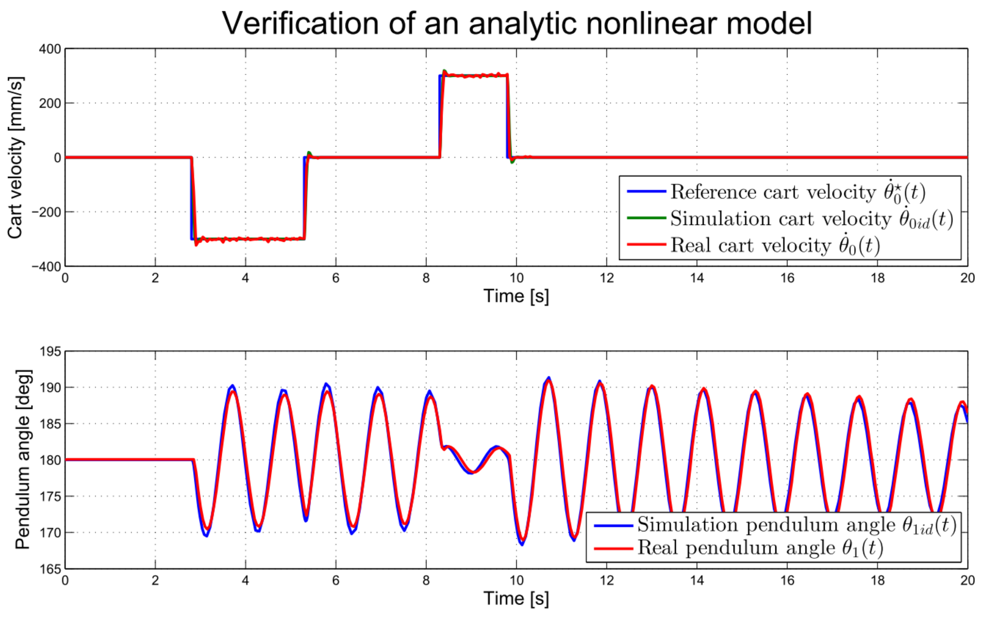
Implementation of the Real Single Inverted Pendulum with LSM into the Distributed Control System



Identification of the Real Single Inverted Pendulum with LSM

Firstly, the unknown parameters of the cart equation were identified using ARX function. Then, the damping coefficient of the pendulum equation was identified to obtain the complete nonlinear model.





Hybrid Control of the Real Single Inverted Pendulum with LSM

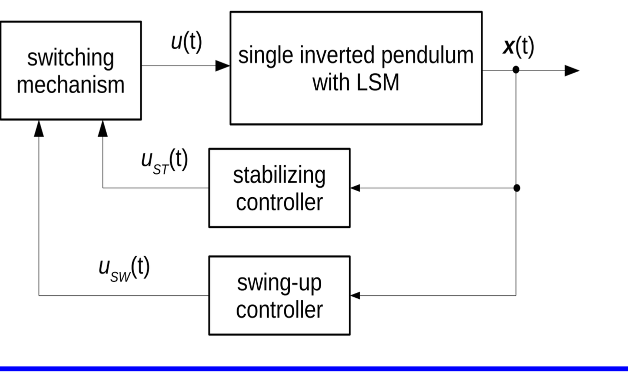
Hybrid control consists

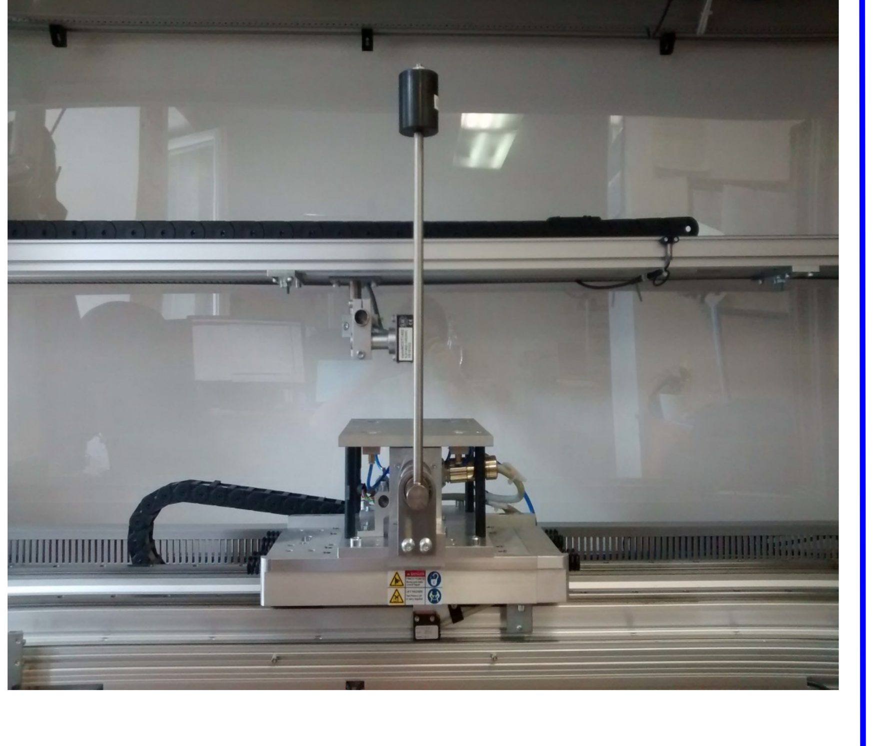
- swing-up (based on nonlinear model) and
- stabilization(based on linear model)

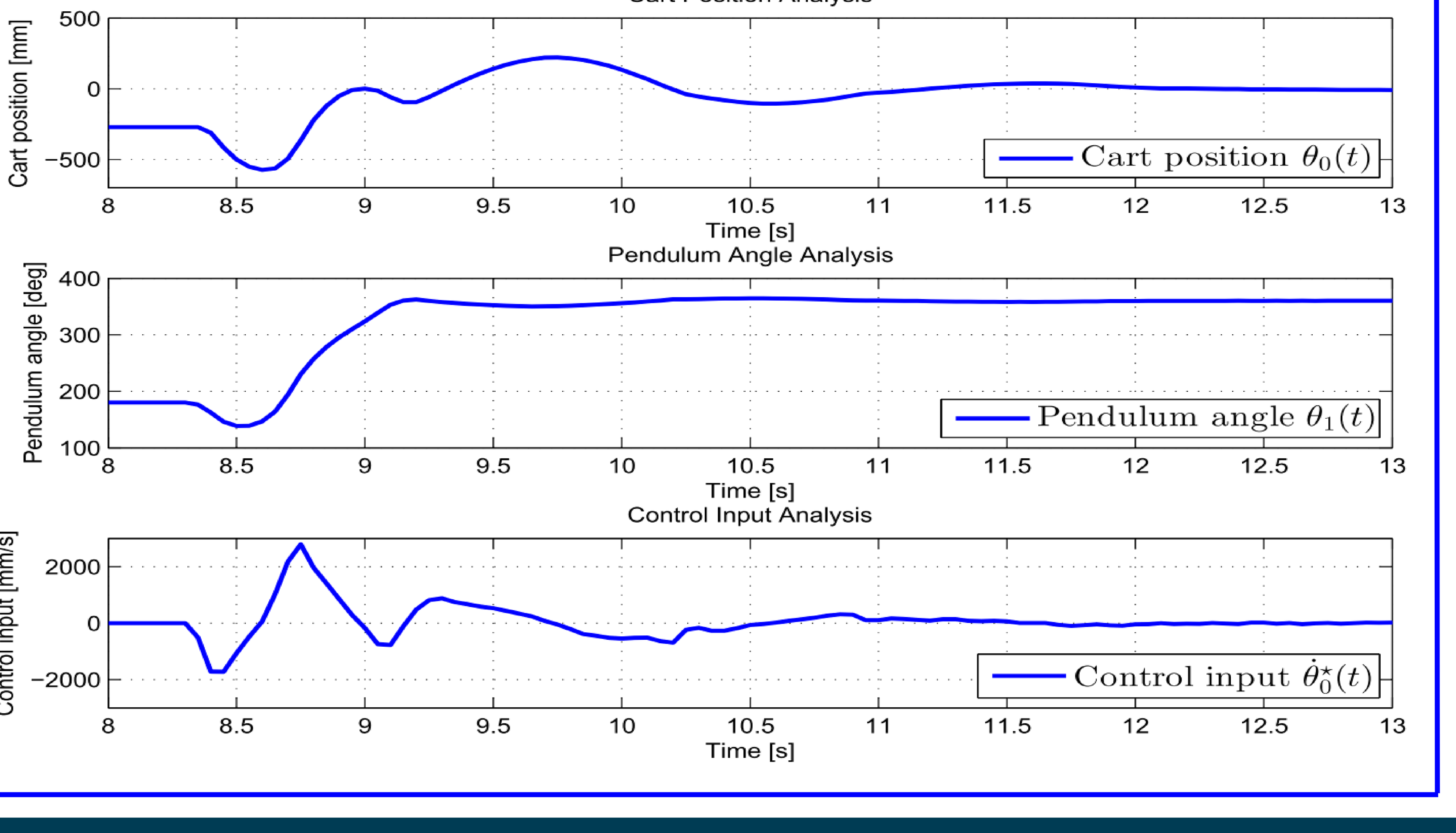
control objectives

Linear approximation for the Real Single Inverted Pendulum with LSM

$$\dot{\mathrm{x}}(t)=\underbrace{\begin{bmatrix}0&1&0&0&0\\a_{21}&a_{22}&0&0&a_{25}\\0&0&0&1&0\\0&0&0&0&1\\0&0&0&a_{54}&a_{55}\end{bmatrix}}_{\mathbf{A}}\mathrm{x}(t)+\underbrace{\begin{bmatrix}0\\0\\0\\0\\b_5\end{bmatrix}}_{\mathbf{B}}u(t)$$

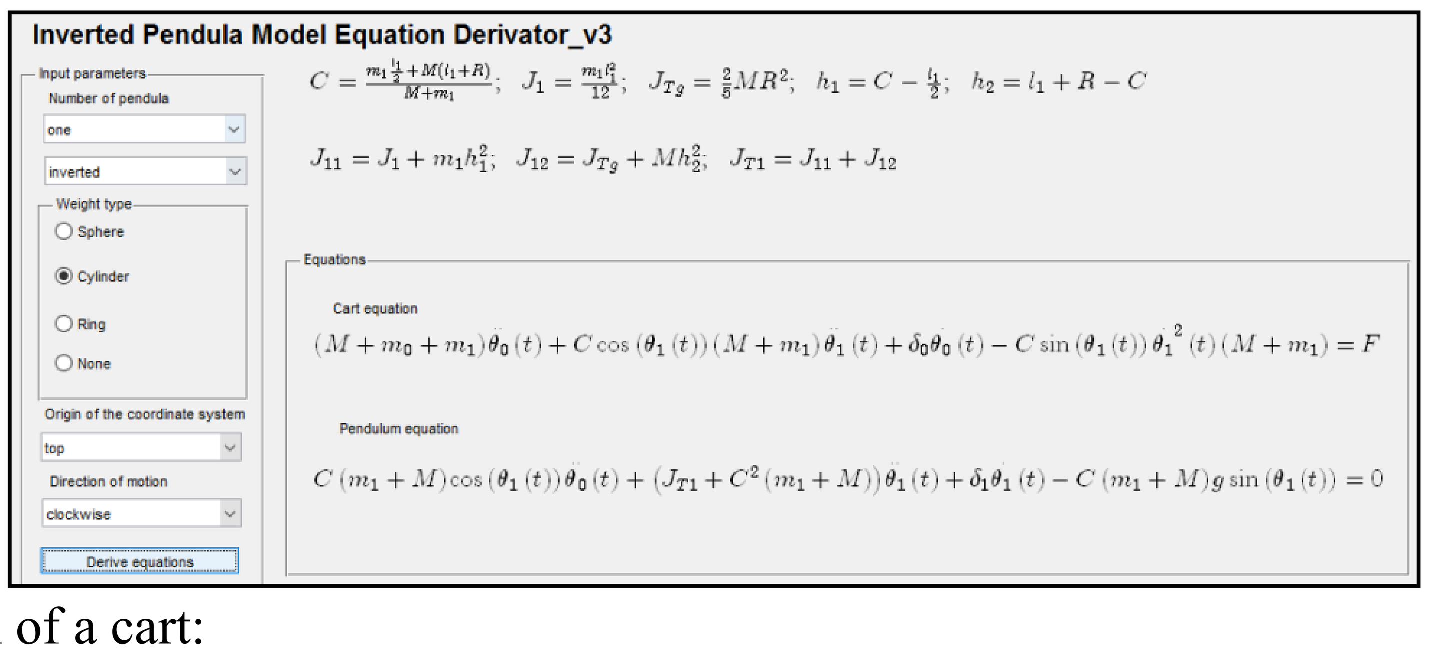






Mathematical Model of Single Inverted Pendulum with LSM

Mathematical model of the single inverted pendulum was obtained with the help of GUI Inverted Pendula Model Equation Derivator v3



Equation of a cart:

$$(M+m_0+m_1)\,\ddot{\theta}_0(t)+C\cos(\theta_1(t))\,(M+m_1)\,\ddot{\theta}_1(t)+$$
$$+\,\delta_0\,\dot{\theta}_0(t)-\,C\,\sin(\theta_1(t))\,\dot{\theta}_1^2(t)\,(M+m_1)=F(t)$$

Equation of a pendulum:

$$C\,(m_1+M)\,\cos(\theta_1(t))\,\theta_0(t)+J_1\,\theta_1(t)+$$
$$+\,\delta_1\,\dot{\theta}_1(t)-C\,(m_1+M)\,g\,\sin(\theta_1(t))=0$$

Since the laboratory model does not allow force input on the system, the equation for the cart has to be modified into the form:

$$\frac{d}{dt}\begin{bmatrix}\theta_0(t)\\\dot{\theta}_0(t)\\\ddot{\theta}_0(t)\end{bmatrix}=\begin{bmatrix}0&1&0\\0&0&1\\0&-q_0&-q_1\end{bmatrix}\begin{bmatrix}\theta_0(t)\\\dot{\theta}_0(t)\\\ddot{\theta}_0(t)\end{bmatrix}+\begin{bmatrix}0\\0\\p_0\end{bmatrix}\dot{\theta}_0^*(t)$$

ACKNOWLEDGEMENTS: This work has been supported by the Research and Development Operational Program for project: Innovation Applications Supported by Knowledge Technology, ITMS:26220220182, co-financed by the ERDF (80%) and project KEGA - 001TUKE-4/2015 (20%).