# DYNAMIC PLANT MODEL IN VIRTUAL REALITY

Samuel BARTOŠ, Bachelor Degree Programme (3)
Dept. of ACS, FEI, STU Bratislava, Slovakia
E-mail: samo@kasr.elf.stuba.sk

Supervised by: Ing. Martin Foltin, Dr. Ivan Sekaj

## ABSTRACT

The work deals with the design of a bridge crane dynamic model, which can be simultaneously controlled and 3D visualized. The model is nonlinear with time variant behavior. The simulation scheme has been developed in the Matlab-Simulink environment and the visualization is realized using the Virtual Reality Toolbox. The virtual model is suitable for verification and presentation of various types of control algorithms. In our case a control structure with three autonomous PID controllers has been designed. The parameters have been optimized by means of genetic algorithms.

## 1    INTRODUCTION

The computation and graphical capabilities of today's PCs allow for modeling technological processes that are complex with respect their mathematical model or their dynamic behavior, and to animate their motion in a virtual 3D world. This is important for the user because it allows him to use the model outside real conditions or a laboratory, and enables to better imagine and understand the modeled object than if using 2D graphs and their time responses.

The result of the submitted work is a model of a bridge crane situated in a production hall. It was developed in the Matlab-Simulink environment in combination with the graphical instrument VR-Toolbox. The model enables control in manual or automatic modes using various types of control approaches. Considering the fact of multidimensional nonlinear dynamic system (MIMO) with time variant parameters the model allows using diverse approaches of control from the classical ones (fixed structures with constant parameters), robust methods of controller design, adaptive control methods, up to solutions based on artificial intelligence. The model also allows development of various scenarios of events or generating random obstacles, which apply in situational control or in control of events.

## 2    VRML+MATLAB=VR TOOLBOX

To be able to visualize a simulation using the VR-Toolbox, it is necessary to create a world (scene) in the VRML language. It is a markup language in ASCII format, which code

can be written directly (for example in Notepad) or using diverse visual programs. In the created scene objects dealt with later on are defined (named).

The visualization process is realized by sending vectors of values representing e.g. position of some object in determined moments, to the VR-Sink block associated with the designed world. The illusion of dynamic actions arises by continuously changing these values.

Generally, the visualized model can be designed in two ways: from the already generated and used model, or by adding the system description to a diagram, allowing the manipulation with selected parts of the VR-scene.

## 3    CRANE

The modeled object is a crane which is moving on suspended construction in the direction of two axes, $x$ and $z$. In addition, it is possible to reel the rope and change the weight of the transported load in the direction of the axis $y$. In the 3D scene is also possible to set up a chosen scenario of events. The model consists of three parts: mathematical model of crane dynamics, control subsystem and visualization (graphs + VRML).
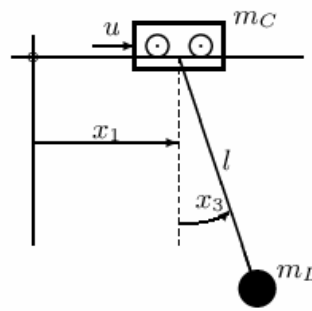


**Fig. 1:**    *Crane model*

The mathematical model of the dynamics considers the following state variables (Fig.1): $x_1$ – crane position, $x_1'=x_2$ – crane velocity and $x_2'$ - crane acceleration, $x_3$ – angle of the hangings, $x_3'=x_4$ – angle velocity and $x4'$ - angle acceleration. The length of the rope $l$, the load weight $m_L$ and the crane weight $m_C$ are parameters which can be changed by the user.

The controlled object dynamics is described by the following differential equations

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = f_1(x_3,x_4)+g_1(x_3)u$$

$$\dot{x}_3 = x_4$$

$$\dot{x}_4 = f_2(x_3,x_4)+g_2(x_3)u$$

$$f_1(x_3,x_4)=\frac{\left(g\cos x_3 + lx_4^2\right)m_L \sin x_3}{m_C + m_L \sin^2 x_3}$$

$$f_2(x_3,x_4)=\frac{-\sin x_3\left[m_L\left(g+lx_4^2\cos x_3\right)+gm_C\right]}{l\left(m_C + m_L \sin^2 x_3\right)}$$

$$g_1(x_3)=\frac{1}{m_C + m_L \sin^2 x_3}$$

$$g_2(x_3)=\frac{-\cos x_3}{l\left(m_C + m_L \sin^2 x_3\right)}$$

The control block provides the load position control. This subsystem can be simply modified or replaced by the user, who can in this way verify chosen control algorithms. The currently used control structure comprises three PID controllers (axis x, axis z of the position and rope length). These conventional controllers can be replaced by other arbitrary control structures. In our case the parameters have been designed by genetic algorithms.

The visualization block consists of two parts:

- 3D plant visualization through VR-Sink
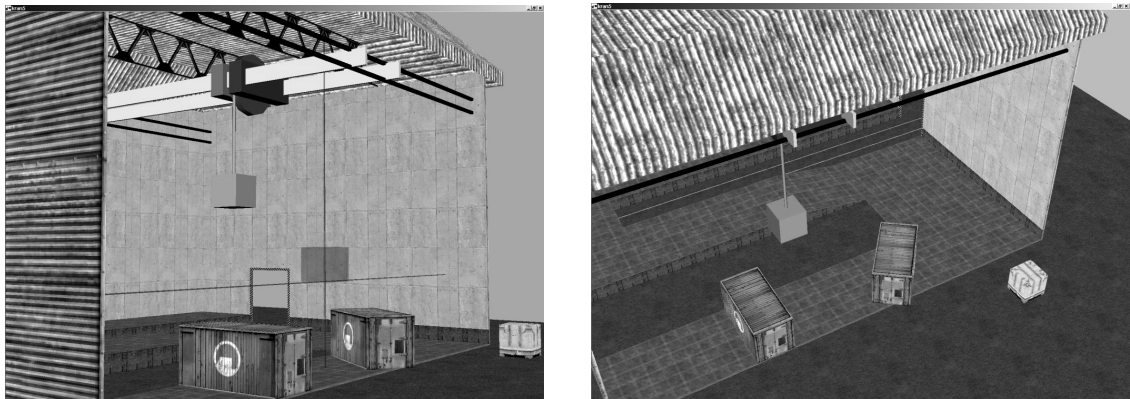
- time-responses of state variables



**Fig. 2:**  *Model visualization in VRML*

## 4   CONCLUSION

The developed virtual model of the crane imitates the real dynamics of the machinery from the mathematical as well as from the visualization point of view. Compared with common 2D presentation tools it allows to better imagine the real plant. It is flexible - the user can adapt it to his needs. It can be used in development and/or verification tasks for teaching, research or for diverse presentations.

**REFERENCES**

[1] M.Botto, J. Da Costa:  Constrained predictive control of a multivariable feedback linearized system: Application to a crane container, Technical University of Lisbon, 1998

[2] J. Žára: VRML97, Computer press, 1999

[3] Mathworks: Matlab user guide, version 6.5

[4] Humusoft: VR-toolbox – Reference guide, Praha, 2000

[5] D. Goldberg: Genetic algorithms in optimization, search and machine learning, 1989