PID Control of Inverted Pendulum Using Adams and Matlab Co-Simulation

Abdullah Çakan
Selçuk University
Mechanical Engineering Department
Konya-TURKEY
acakan@selcuk.edu.tr

Fatih Mehmet Botsalı
Selçuk University
Mechanical Engineering Department
Konya-TURKEY
fbotsali@selcuk.edu.tr

Mustafa Tınkır
Necmettin Erbakan University
Mechanical Engineering Department
Konya-TURKEY
mtinkir@konya.edu.tr

ABSTRACT

This research is aimed at developing a multi-body simulation model and control of an inverted pendulum. A virtual prototype of the inverted pendulum is built by using MSC Adams software and the plant model is exported to MATLAB. It is co-simulated in both MATLAB and MSC Adams softwares together. Proportional-integral-derivative (PID) controller is designed and implemented in order to use in pendulum angle control simulations. The modelling and control results shows that the Proportional-integral-derivative (PID) controller can successfully achieve pendulum angle control of the inverted pendulum. Controlled pendulum angle results are simulated and given in the form of the graphics.

CCS Concepts

• Computing methodologies→Control methods • Computing methodologies→Modeling and simulation

Keywords

Inverted pendulum, Modeling and control, PID Control, Matlab, MSC Adams, Simulation

1. INTRODUCTION

The inverted pendulum system is an example commonly used in control system studies to compare control and optimization algorithms as a benchmark problem. It is unstable without control that is why the pendulum is easily fallen over if the cart is not moved to balance it. The inverted pendulum is a nonlinear dynamic system aim of the control system is to balance the inverted pendulum by applying the force to the cart.Variations on inverted pendulum include multiple links, allowing the motion of the cart or wheel to be commanded while maintaining the pendulum, balancing and rotating arm with a pendulum at the end [1-4].There are different type control algorithms such as PID and LQR, neural network based fuzzy logic control [5-6]. Variety of optimization algorithms such as Genetic Algorithm and The Bees algorithm [7-8]. The inverted pendulum is used to understanding of simple robotics, rocket or missile guidance and rockets attitude control at launch [9]. Inverted pendulum problem is also used in the technology of the Segway PT which is a self-balancing transportation device [10].

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Virtual prototype of inverted pendulum is built using Adams software shown in Figure 1. to obtain dynamic behavior and using Matlab/Simulink software to design controller. Thus, two engineering softwares are used to achieve different type modeling and control technique without mathematical model. A proportional–integral–derivative (PID) controller is designed in Matlab/Simulink for pendulum angle control and controller gain parameters are manually tuned by trial error merhod according to input and output of closed loop block diagram. Control simulation is realized and controller performance is given in the form of the graphics.

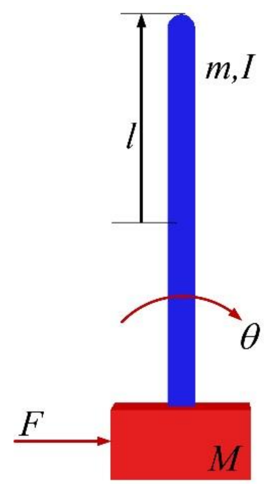

Figure 1. Inverted pendulum system built by Adams

2. MODELING AND CONTROL

Modeling and control methodology of this paper is given in Figure 2. Difference of study from literature works is differential equations of motion of inverted pendulum system is not used and all system dynamics are obtained by using ability of Adams and MATLAB softwares. Also control simulations are realized with this way.

Table 1. Inverted pendulum parameters

M	Mass of the cart	0.5 kg
m	Mass of the pendulum	0.2 kg
l	Pendulum center of mass length	0.3 m
I	Pendulum mass moment of inertia	0.006 kgm^2
F	Force applied to the cart	N
x	Cart position coordinate	M
θ	Pendulum angle	degree

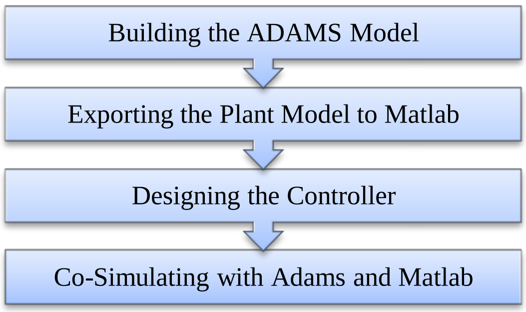

Figure 2. Working strategy of the paper.

In inverted pendulum modeling, we assumed that the input of the system is the bidirectional force F applied to the cart and the outputs are pendulum angle θ and position of the cart x. The pendulum and cart are assumed to be rigid. The parameters of inverted pendulum used in system are given in Table 1. This model is built in Adams and Matlab/Simulink model of inverted pendulum system is exported from Adams that is given in Figure 3.

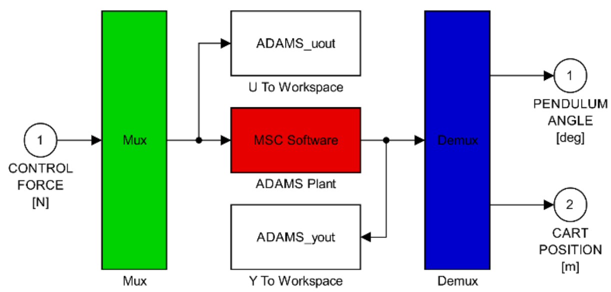

Figure3. Matlab/Simulink model exported from Adams

In this system control force is used for horizontal motion of the cart to balance pendulum angle position. Control block diagram is shown in Figure 4. Pendulum angle is controlled using manually tuned PID controller.

For this aim; 1-Nsec impulse is applied to the cart as a disturbance source given in Figure 5. and detailed in Figure 6. to see pendulum angle control performance of proposed controller. Also PID controller gain parameters are manually tuned by trial error method according to system response and found as Kp=100, Ki=5 and Kd=20.

3. RESULTS AND DISCUSSION

Desired pendulum angle is 0 after impulse function applied to the cart in 0.5 seconds given in Figure 5. and Figure 6.

PID controlled pendulum angle response is shown in Figure 7. As seen from Figure 7 it can be said that PID controlled system reached to desired pendulum angle in 1.5 seconds. From this result, pendulum angle of a pendulum system is achieved successfully using manually tuned PID controller.

Moreover cart position of inverted pendulum system is given in Figure 8. From these results it can be said that inverted pendulum reached to desired 0. In addition PID controlled force change is given in Figure 9.

According to Figure 9. it can be said that designed PID controller is balanced pendulum angle effectively with the control force output of the PID controller. Step by step captured snapshots of simulation seen in Figure 10

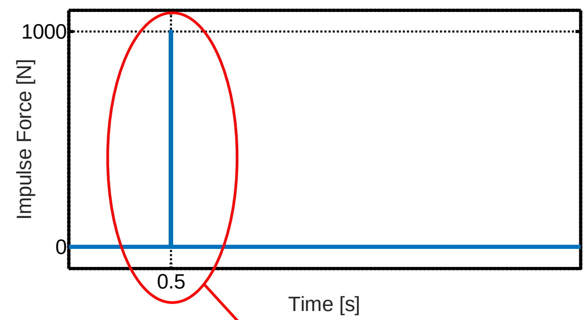

Figure 5. 1-Nsec impulse disturbance applied to the cart

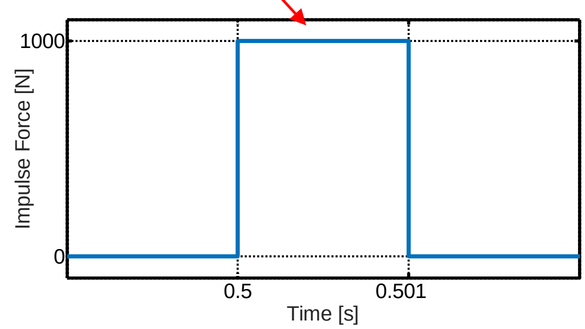

Figure 6. Detail of 1-Nsec impulse disturbance

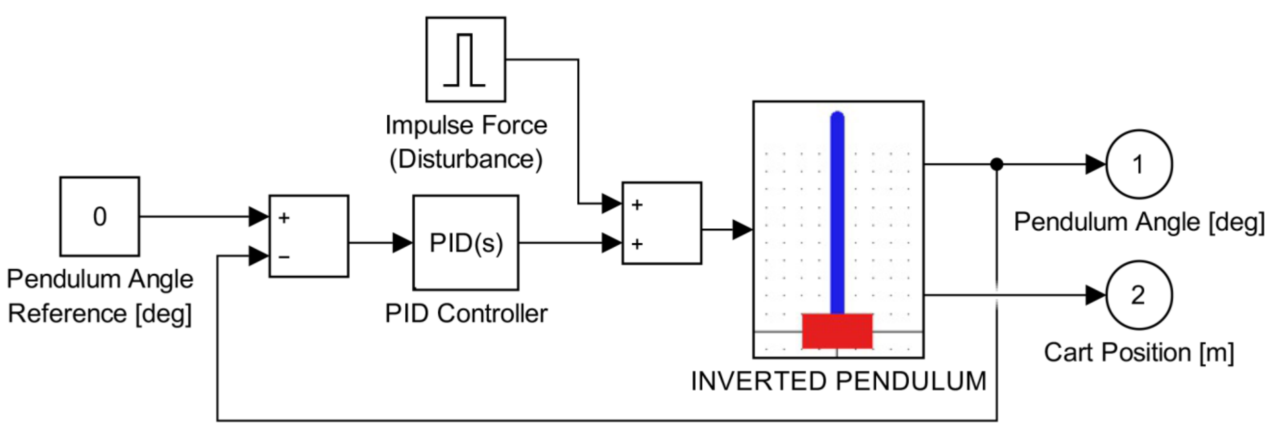

Figure 4. PID control block diagram of Inverted Pendulum

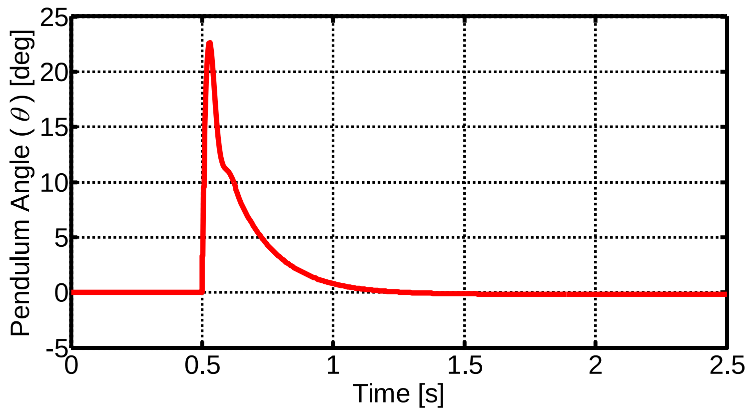

Figure 7. Pendulum Angle of inverted pendulum system

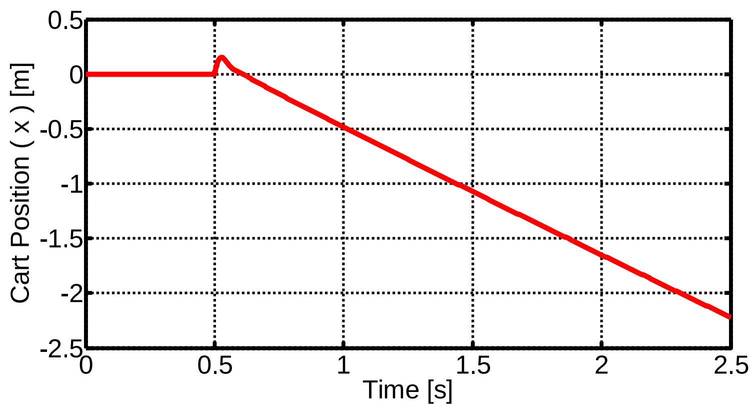

Figure 8. Cart position of inverted pendulum system

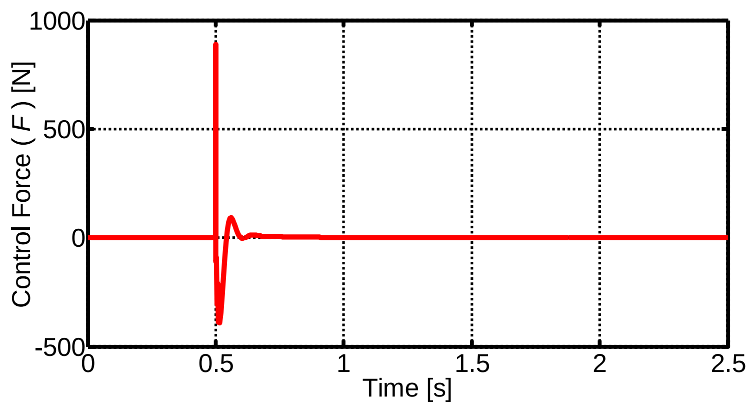

Figure 9. Control Force of PID controlled system

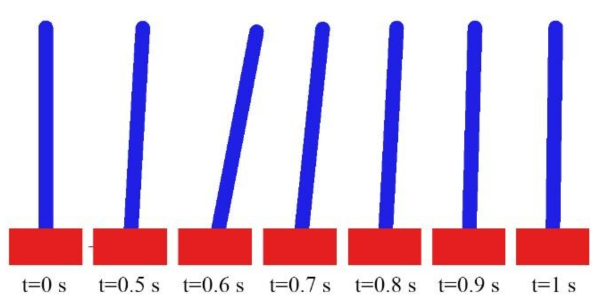

Figure 10. Step by step captured snapshots of simulation

4. CONCLUSION

In this paper, modeling and pendulum angle control of an inverted pendulum system is realized. For this aim; virtual prototype of inverted pendulum is built using Adams software to derive dynamic behavior, plant model is exported to Matlab and PID controller is designed using Matlab/Simulink software. And it is co-simulated using Adams and Matlab/Simulink together. Thus, two engineering programs are used to achieve different type modeling technique without mathematical model. A proportional–integral–derivative (PID) controller is designed in Matlab/Simulink software for pendulum angle control and controller gain parameters are manually tuned by trial error method according to input and output of closed loop block diagram. As a result of the paper, accuracy of proposed modeling technique is verified by simulations. Also controller's performance and effectiveness are investigated and examined; pendulum angle control results of the proposed system are presented in the form of graphics.

The main contribution of the paper to the literature is that different type modeling approach is implemented and PID controller is designed and used in control methodology.

5. ACKNOWLEDGMENTS

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