Developing a control for a double inverted pendulum with Siemens CNC

FULL First Author[1, a *], FULL Second Author[2,b] and FULL Last Author[3,c]
[1]Full address of first author, including country
[2]Full address of second author, including country
[3]List all distinct addresses in the same way
[a]email, [b]email, [c]email
* please mark the corresponding author with an asterisk

Keywords: List the keywords covered in your paper. These keywords will also be used by the publisher to produce a keyword index.

Abstract

Introduction

In this research project, our purpose is to get familiar with Siemens Sinumerik 840d sl control system and Siemens Simotics L-FN3 linear motor control. Sinumerik control system is widely used for machine tools in industry. Programs of machine tools are done so, that the program line tells in which point the tool have to be next. Those g-code programs don't usually use any intelligence or feedback control loops in it.

Inverted pendulum is a classical testing application for the different control systems and methods. Without control the inverted pendulum is unstable and it will fall from its upward position. Our decision was to use a double inverted pendulum in this research project. Instead of one rod, the double inverted pendulum is balancing two rods. Therefore, it is more challenging to stabilize.

Linear motor is optimal component for the double inverted pendulum. Inverted pendulums are usually implemented with cart, belt and rotating DC motor. The pendulum needs precise and fast control and those are advantages of linear motors compared to other solutions. With linear motor the set-up of the system is also more robust, because of fewer amount of moving parts in it.

This application could be for demonstration the capabilities of the Siemens' technologies. Also it would be useful for research and educational institutions for teaching purposes.

System description

Siemens Sinumerik 840D sl

Sinumerik 840D sl is an industry standard for CNC machines' control system. It's capable to control 93 axes and up to 30 machining channels. In our application it is used to control the Simotics linear motor and the encoder data is also handled via the Sinumerik 840D sl. G-code is used to control the linear motor and eventually stabilizing the pendulum.

Siemens Simotics L-FN3 Linear motor

Simotics L-FN3 linear motors are very compact and they feature superior performance to force density. Accuracy and precision are the key features that linear motor can offer and these features are important to accomplish the inverted pendulum.

Mechanical design of the pendulum

Controller LQR

Full state feedback controller was used for balancing the pendulum. It was developed using LQR (Linear Quadratic Regulation) method. First, the non-linear equations of the system dynamics were determined. Then those equations were linearized around the upward equilibrium position of the pendulum, and the state space model of the system was solved. Matlab was used to analyzing controllability of the system and for determining the control gain vector K. Weighting matrices Q and R were selected by trial and error. With vector K, the optimal control of the system $y = -Kx$ could be determined.

Results

Discussion

Reference

https://www.industry.usa.siemens.com/drives/us/en/cnc/systems-and-products/Documents/Brochure-SINUMERIK-840D-sl.pdf