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Inverted Pendulam and Applications

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Abstract:

An inverted pendulum is a physical consisting in a cylindrical bar (usually of aluminum) free to oscillate around a fixed pivot. The pivot is mounted on carriage, which in its turn can move on a horizontal direction. The carriage is driven by a motor, which can exert on it a variable force. The bar would naturally tend to fall down from the top vertical position, which is a position of unsteady equilibrium.

The goal of experiment is to stabilize the pendulum (bar) on the top vertical position. This is possible by exerting on the carriage through the motor a force which tends to contrast the 'free' pendulum dynamics. The correct force has to be calculated measuring the instant values of the horizontal position and the pendulum angle (obtained e.g. through two potentiometers).

The inverted pendulum is a traditional example (neither difficult nor trivial) of a controlled system. Thus it is used in simulations and experiments to show the performance of different controllers (e.g PID controllers, state space controllers, fuzzy controllers…..) The Real - Time Inverted Pendulum is used as benchmark, to test the validity and the performance of the software underlying the state – space controller algorithm, i.e. the used operating system.

Actually the algorithm is implement from the numerical point of view as a set of mutually co-operating tasks, which are periodically activated by the kernel, and which perform different calculations. The way how these tasks are activated (e.g. the activation order) is calleding Scheduling of the tasks.

It is obvious that a correct scheduling of each task is crucial for a good performance of the controller, and hence for an effective pendulum stabilization. Thus the inverted pendulum is very useful in determining whether a particular scheduling choice is better than another one, in which cases, to which extent, and so on.

INTRODUCTION

An inverted pendulum is a pendulum which has its mass above its pivot mounted on a cart that can move horizontally and may be called a cart and pole. Whereas a normal pendulum is stable when hanging downwards, a inverted pendulum is inherently unstable, and must be actively balanced in order to remain upright, either by applying a torque at the pivot point horizontally as part of a feedback system. A simple demonstration is achieved by balancing an upturned broomstick on the end of one's finger.

A second type of inverted pendulum is a tilt meter for all structures which consists of a wire anchored to the bottom of the foundation and attached to a float in a pool of oil at the top of the structure which has devices for measuring movement of the neutral position of the float away from its original position.

Providing a reasonable, effect explanation for the inverted pendulum is very important to any effort to explain how standing and walking animals can keep their balance so very well. Thus the inverted pendulum it is of great significance to the design of robots as well.

This program is a demonstration of hierarchical control, an application to a classical control problem. A Pendulum is mounted on a cart so it can swing through 360 degrees. A motor on the cart can accelerate it left and right, and sensors are provided for linear acceleration, velocity, and position of the cart, as well as angular acceleration, velocity, and position of the cart, as well as angular acceleration, velocity, and position of the pendulum. A five – level hierarchical control system controls bob position relative to a reference position the user can set with mouse, as follows:

1. The bob's angular position error is corrected by varying the angular velocity reference signal.
2. The bob's angular velocity error is corrected by varying the angular acceleration reference signal.
3. The bob' angular acceleration error is corrected by varying the car's position reference signal (with gravity providing the acceleration)
4. The cart's position error is corrected by varying the cart's linear velocity reference signal.
5. The cart's velocity error is corrected by varying the cart's linear acceleration reference signal.
6. The cart's linear acceleration is varied by varying the motor torque.

Inverted Pendulum Configurations

This configuration could be controlled open – loop with the use of a stepper motor which is the base of the design of this project.

In the linear case, a motor is used to move a cart along a straight tract as shown . The Pendulum is attached to the cart by a pin joint. The axis of rotation of the pendulum link about the pin joint is horizontal and perpendicular to the cart's direction for travel. The input to the system is the force applied to the cart, via the motor. Full derivations of the system dynamics for a linear inverted pendulum can be found in Dorf and Bishop and Franklin. A reproduction of the diagram is shown. Where F is the input force. X is the linear displacement and θ is the angular displacement of the pendulum link.

Some of the literate considers swinging the pendulums from the stable position (all links down) to the all up position using the motor input torque. This is called swing – up control. Some of the literature only considers controlling the system once it is already in the upright position. One could assume that in these cases, the pendulum link is held upright and stationary by the experiments while the controller is initialized. In this project, like the latter one, consider that the pendulum link ins held upright.

CONCLUSION

We first examined the behavior when the PID controller related to the x position was omitted, since the transfer is known, we can determine the dynamics by simply injecting sinusoidal inputs From this perspective, stability of the upright fixed point means that the input and responds frequencies are the same and instability means that the frequencies are different. Instability of the upright position was characterized by a difference between the input and response frequency. However, we observed that even in the hunting regime the stick remained upright albeit with oscillatory dynamics.

Human Stick balancing

For stick balancing at the fingertip, there are two ways the stick can fall, and hence, as fro mechanical stick balancing, two control problem.: (1) the vertical displacement angle θ becomes too large and (2) the position of the hand drifts out of reach of the arm. Our focus here is on the first control problem and, in particular, on the natural of the control that occurs on time scales equal to or les than the neural latency.

Human Postural sway

Two concept are important for understanding the control of human balance during quiet standing. Center of mass the net location of the Com in three dimensional space, and COP, the weighted average of the location of all download (action) forces acting on the standing surface. Typically, COM is computed by making a weighted average of the COMs of each body segment using a total body model, whereas COP is measured using a force platform.

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