Report on the project challenge: Inverted Pendulum

Team -1

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INVERTED PENDULUM

Objective: Build a self balancing inverted pendulum.

Constraint: The CG of the pendulum should be approximately located at least two feet above the support pivot.

Approach:

To build the self balancing inverted pendulum we chose a linear model. The model basically consisted of a motor driven cart that moved along on axis, particularly in the axis about which the pendulum was free to oscillate. The pendulum was mounted on the cart. The basic concept of our approach was to move the cart in the direction of the pendulum's fall in order to create a pseudo force in the opposite direction to bring back the pendulum to its inverted position.

Details of the component selection:

Micro-controller: Arduino uno(1)

Sensor: Potentiometer(10k)

Actuators: Motors(2) (Geared, 150 rpm, 6V-12V)

Motor Driver: L293D(1) H-bridge

Locomotives: Rear Wheels(2) and in front castor wheel(1)

Mount platform: Chassis of the cart

Pendulum: Wooden (Mass-150-170grams, Length-2.17ft)

*(Uniform distribution of mass- flaw in selection)

The whole model involved three major aspects

- Modeling, Mechanics and the dynamics of the system
- Control systems and controller design
- Coding section

Modeling, Mechanics and dynamics of the system

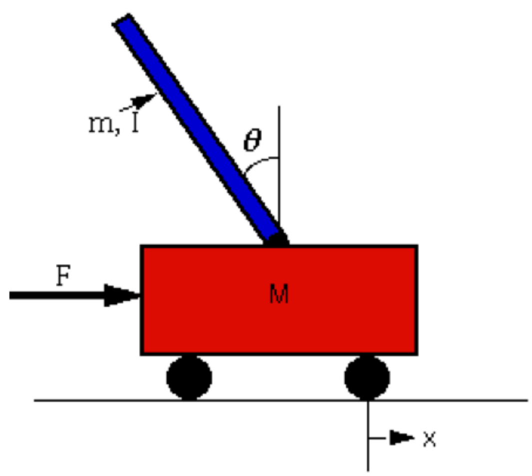
The model of the cart includes a chassis two motors and the two wheels. The others components of the system like arduino, H-bridge, potentiometer and pendulum were mounted on the chassis. The velocity of the cart was one of the vital aspects that had to be controlled. Depending on the rpm of the motors the control was calibrated. The rpm control s discussed in the coding section.

The governing equations of the model were

$$(M+m)\ddot{x}+b\dot{x}+ml\ddot{\theta}\cos\theta-ml\dot{\theta}^2\sin\theta=F$$
$$(I+ml^2)\ddot{\theta}+mgl\sin\theta=-ml\ddot{x}\cos\theta$$

The force acing on the cart is the velocity.

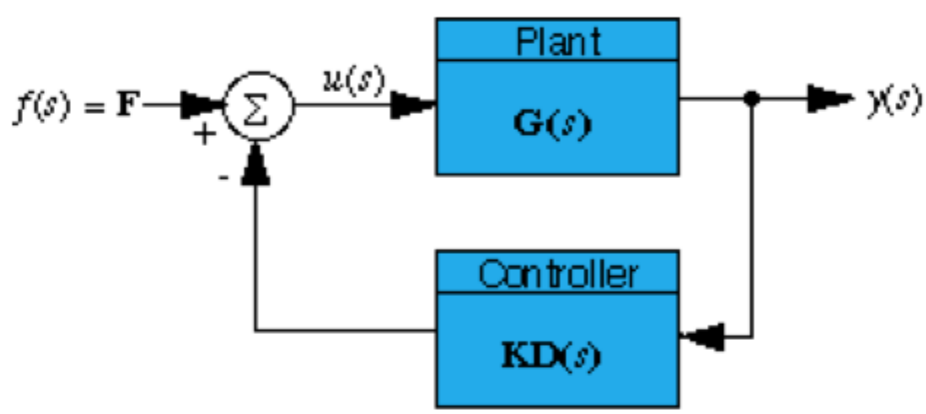
The sketch of the inverted pendulum



Control systems and controller design

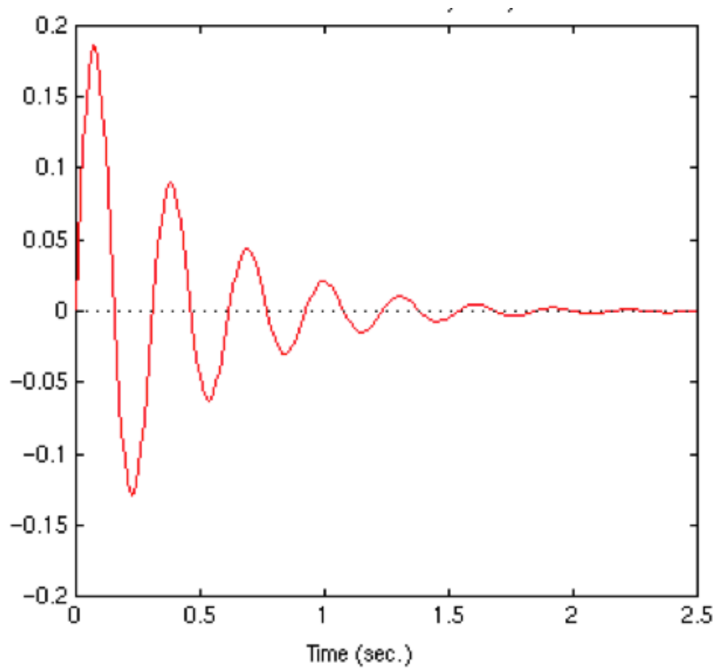
We wanted to include PID controller into the system. We succeeded in designing proportional controller kp. We also designed the integral control ki but could not implement into the system. However, The proportional control involved continuous error checking. A potentiometer was used as the sensor. It was the pendulums shaft over which the pendulum was oscillating. So the controller design involved the calibration of the potentiometer. The pendulum was set upright and that particular was the set point of the pot. Any deviation from the set point was considered as error. The proportion controller managed this error. Depending on the amount of error the velocity of the cart was varied.

The basic closed loop of the system is as shown below.



The integral controller included the summation of the present error and the previous errors and stabilizing the system. So basically it was designed to remove cumulative error so that the pendulum gets back into its position quickly. We could not implement the in the system since we encountered a small error which we could not debug and set it right due to time constraint.

The response of the system with the proportion controller:

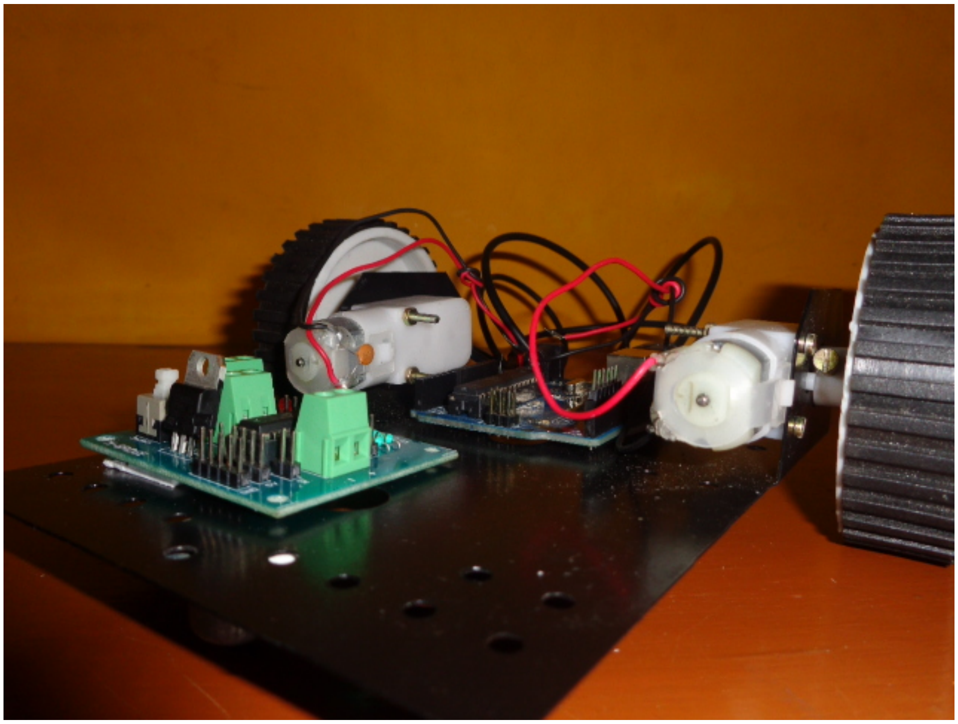


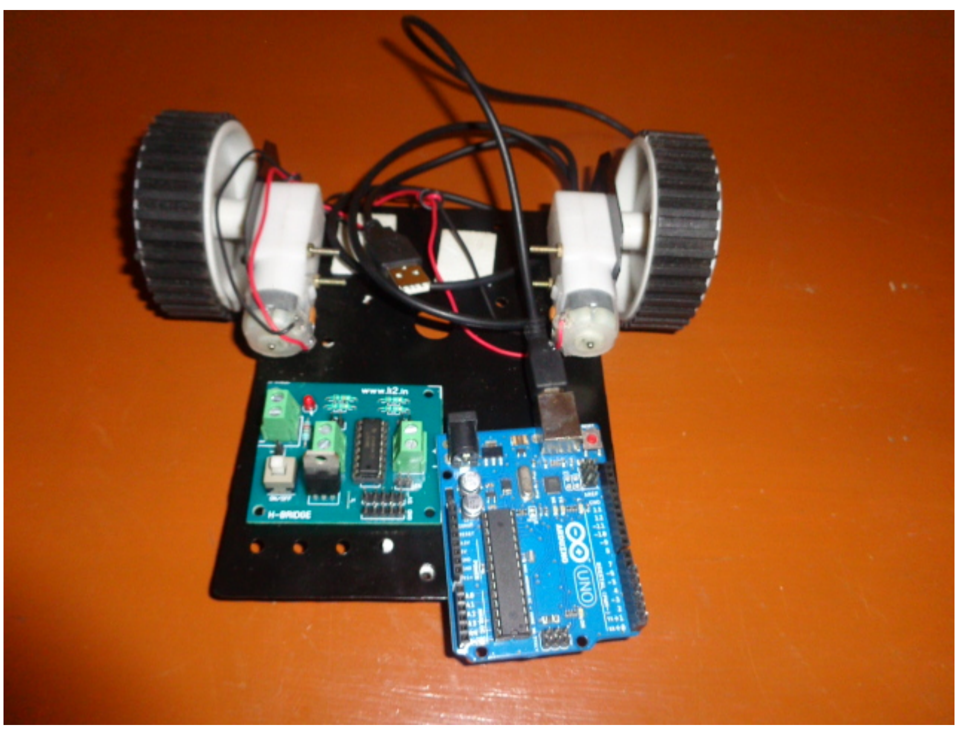
Coding Section:

Arduino platform was used for coding. The arduino was connected to a H-bridge which intern drove the motors. The input to the arduino was the potentiometer reading. Depending on this input the error was calculated on. Depending on the amount of error the actuators were driven. The velocity of the cart was controlled by manipulating the duty cycle of the clock input to the h-bridge. This in turn reduced the rpm of the motor. This method known as PWM controlled the velocity of the cart in order to balance the pendulum. Few constants were used in the code in order to calibrate the system for different mass and lengths of the pendulum. But the approach was unorthodox. It was not designed from the transfer function. This was based on trail and error method.

All together made up the entire system that worked fairly well.

Few pictures of the cart





The pictures of the entire system were not taken.