

# Vision Based Control of an Inverted Pendulum on a Rotating Platform

Salman Haq, Xiaobo Tan, Fumin Zhang, P. S. Krishnaprasad

## INTRODUCTION

### What is an Inverted Pendulum?

The idea behind an Inverted Pendulum is basically the same as trying to balance a broomstick or baseball bat on the palm of your hand. The goal of this experiment is to stabilize the pendulum in the upright position.

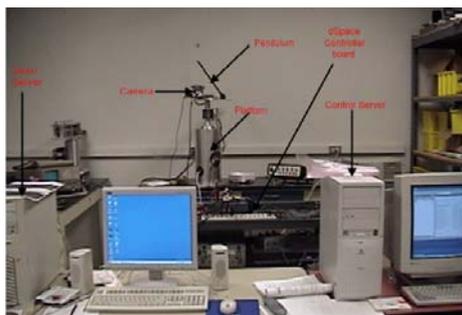
### What is Computer Vision (CV)?

CV can be loosely defined as the use of a computer to acquire, process, and understand images. In this case, we use CV to detect the position of the pendulum relative to the vertical.

### Why is this interesting?

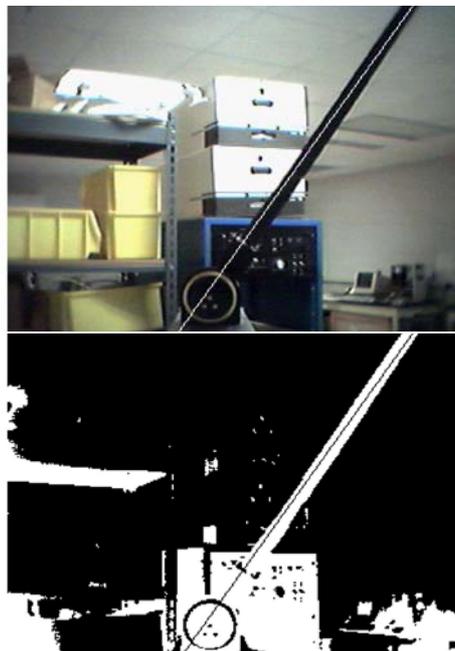
This experiment integrates computer vision, limited-bandwidth communication and real-time control. Lessons learned here can be used in many different applications.

## FRAMEWORK



The pendulum and camera are affixed to a beam that is mounted on a platform capable of rotating. Two computers are used, one is dedicated for image processing (Vision server) and the other is used for control (Control server). The housing of the platform hides the motor, tachometer, and position encoder. Serial communication is used to transmit data from the Vision server to the control server. All processing is done in the Matlab / Simulink computing environment.

## SENSING



The top picture is the actual view from the camera. The bottom picture is obtained by converting the former to a grayscale image and thresholding it. Our problem is to find the pendulum in this binary image and to accurately estimate its angle. The angle estimation and communication must happen very fast.

### Solution

The base of the pendulum is fixed in the image plane. We search along several lines extending from the base.

The angles of these lines lie on a log-based scale so that the highest resolution is obtained near the vertical position with poorer resolution further away. A summation is performed along each line, and the highest value obtained yields our estimate for the angle.

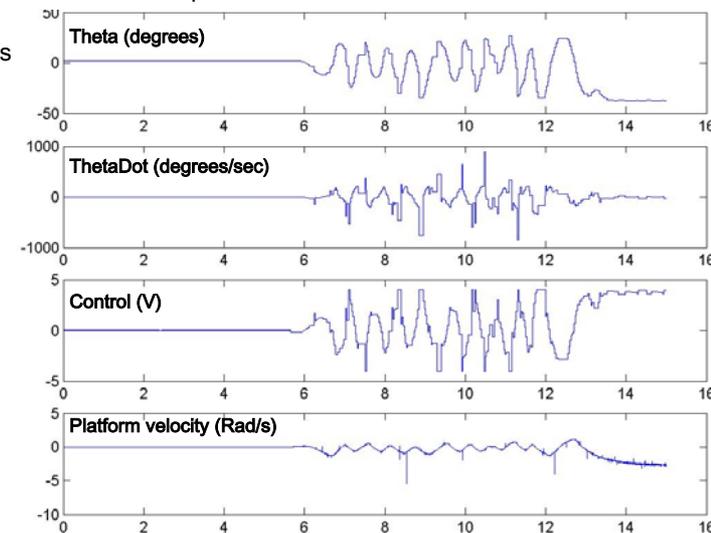
To communicate the estimated angle, we map the angle to an integer between -127 and +128 and transmit it as a single byte via the serial port to the Control server which then uses the inverse mapping to obtain the angle. This mapping is based on logarithmic quantization and it affords us the benefit of using a set of integers to represent a set of floating point numbers. Thus, we have a precision of two decimal places for angles near the vertical while only transmitting a single byte.

## CONTROL

The platform is controlled by applying a suitable voltage to the DC motor. A simple Proportional-Derivative (PD) control law, based on the estimated angle and its derivative is used.

$$\text{Control} = (K_p * \text{Theta}) + (K_d * \text{ThetaDot})$$

$K_p$  and  $K_d$  are specified by the user. See below for some experimental results.



## FURTHER WORK

We need to improve our control law. The momentum of the platform causes it to overshoot which must not happen. A better controller will model the actual dynamics of the system. Also, an improved calculation for the time derivative of the pendulum angle is required.