Proceedings of Introduction to Mechanical Systems for Mechatronics
ME 102A: Team Tec-no
Due: April 12, 2017, Berkeley, USA

LAB 4

BALL CONTROL: IR PROXIMITY SENSOR

Adolfo Tec
Undergraduate Student
Mechanical Engineering
University of California
Berkeley, California 94720

Cozmo Nakamura
Undergraduate Student
Mechanical Engineering
University of California
Berkeley, California 94720

Katherine Hom
Undergraduate Student
Mechanical Engineering
University of California
Berkeley, California 94720

ABSTRACT

This lab utilizes the same ping pong ball tower used in the previous lab, but with vision acquisition from a PlayStation Eye camera used to measure and control the position of the centroid of the ball. LabVIEW's Vision Assistant block and several vision filters were used to accurately find the ball's centroid. The ping pong ball's position and the fan voltage were correlated using a linear equation to implement position control of the ball. This controller yielded results less accurate than our previous PID control for the IR sensor, but was still accurate enough to control the ping pong with a fairly close level of accuracy.

INTRODUCTION

Perhaps the most common sensor outside of technical uses, cameras capture light coming into its lens to create an image. However, videos are more complicated to extract data from due to their 3 dimensional nature (2 dimensional frame image and the different frames (time dimension)), versus the typical 2 dimensional (scalar voltage and time) readings common in the sensors analyzed before.

To account for the additional time dimension, various image analysis tools have been designed throughout the years. However, their levels of accuracy vary depending on the type of image captured, as uncontrolled backgrounds relative to the object of interest can easily skew the data collected.

In attempts to understand the image collection and analysis problem, the previous ball control setup with an IR sensor was analyzed with a camera sensor instead of an IR sensor. The goal was to create a system on par with, if not better than, the IR sensor system.

Due to the unexpected accuracy of the IR sensor in the previous lab and the known difficulties of the camera sensor, it was hypothesized that the data collected by the camera would be more accurate. However, the difficulty in controlling the fan voltage led to an overall slightly inferior control design.

THEORY

1. Digital Camera Sensors

Digital cameras capture light coming through the lens, pass it through a sensor, and return it as an image. These sensors are based on silicon wafers that record the light patterns through photolithography, where a selected material, the photoresist, coated on the wafer reacts to the light exposure. Each light sensitive cell is called a pixel, measuring the the amount of photons that arrive at that particular location. This charge is converted into a signal, which is then amplified and translated into a number, generally between 0 and 255. These pixels cannot differentiate between different colors. Thus, a set of pixels can only produce a grayscale image [6].

For the RGB (red, green, blue) color model, different light filters are placed over the the sensor to generate the values for the red, blue, and green colors. The green filter requires twice the filters to account for the greater sensitivity human eyes have for green. Each set of filters creates a different set of values, again between 0 and 255. Together the numbers form a full color image. Generally, fully-colored capturing devices are more expensive due to this complication [6].

Among the wide variety of camera sensors available, complementary metal-oxide semiconductor (CMOS) sensors are used in the PlayStation Eye. They are known to be capable of a faster frame rate than their long competitors, charge-coupled devices (CCD) [2]. This is due to their lower power usage, enabling them to work more efficiently with less power [6]. However, CCDs are known for their better image quality, with better dynamic range and noise control. CMOS sensors have only relatively recently become capable of overcoming CCD options [5].

2. Image Data Processing Challenges: Image Recognition

Image data is a form of multidimensional signals, whether in the form of photographs, videos, or other image types. However, images generally contain more than just the desired information, i.e. the background image behind the subject of interest. An ongoing challenge is to create a recognition system that can accurately identify an assortment of objects, motions or patterns, separate from the background [3].

An assortment of models have been designed to identify and/or modify parts of the image, though each have their individual faults and situational requirements. In this lab, the LabVIEW NI Vision Assistant will be used to extract data from the image. NI Vision Assistant functions include a variety of filters such as luminance and color detection along a defined axis of interest, and edge detection. After feeding it an image captured in the LabVIEW VI, it can perform a set of designated functions to output either an image or a numeric interpretation of the image. Other functions are also available, though they are outside the scope of this lab [4].

3. Uncertainties

Statistical analysis of error shows that there are multiple ways of estimating a measurement errors based on using different probability distributions, the number of samples taken on a measurement, and the level of confidence, among other things [1]. Uncertainties for each sensor were found using the T-distribution uncertainty model given by Eqn. (1):

$$P_x = t_{\frac{\alpha}{2},\nu} \frac{S_x}{\sqrt{n}} \tag{1}$$

Where P_x is the precision uncertainty, α is the level of significance, S_x is the estimate for the mean of the data sets, n is the number of data sets, and t is the probability density function coefficient specific to the number of measurements taken [1].

This uncertainty model was employed due to the fact that not a large number of experiments were ran (i.e. greater than 30 experiments).

PROCEDURES

1. Equipment

- ☐ PXI-4110 controllable DC power supply
- ☐ National Instruments LabVIEW
- ☐ Test Stand
  - ☐ Fan
  - ☐ Tube with Airflow holes
  - ☐ Ping pong ball
  - ☐ Half-Inch Increment Tape Ruler
  - ☐ Breadboard
  - ☐ Brown construction paper

2. Testing

To begin the lab, the test stand is powered with the DC power supply. The Playstation Eye USB camera is plugged into the lab station computer, and is taped to a position where a large portion of the test stand tube is visible. On LabVIEW, the Vision Acquisition function is used to capture and record an image into LabVIEW from the camera.

Using the image output from the Vision Acquisition function as the reference, the test stand is covered with construction paper from the back, top, and sides to reduce glare and background disturbances.

The rest of the LabVIEW VI is then set up to output a line profile based on the luminance of the image after a negative filter is applied. The negative filter takes the image and inverts the colors, making the lightest areas dark, and the darkest areas light. Colors are also reversed into their complementary colors. Taking the luminance value along a line profile provides an indication of how bright the image is along the profile.

The dark areas (with a luminance value of 0) are where the white ping pong ball is, and the bright areas (with a luminance value of 255) are where the background (originally brown construction paper) is. Taking the minimum value of the luminance along the line profile provides the location of the ball near, but not exactly at, its centroid. Due to the shadow on the ball, the minimum luminance value is skewed according to the shadow. The skew can be corrected by adding or subtracting a constant value.

The position of the ball in pixels can then be converted to the scale indicated on the side of the test stand tube, indicating the position in half-inches. This is done by determining the half-inch scale equivalent of certain pixels, and applying a linear conversion.

To control the ball position, the voltage of the fan was characterized in terms of the ball position in the tube. The ball was set at different positions by altering the voltage of the fan, and a linear fit was approximated to generate a position vs voltage relationship. Input positions in terms of half inches are then converted using this equation in order to change the voltage value of the DC power supply.

3. Precautions

- ☐ Don't forget to turn on (and later off) all of the equipment. Make sure to power all of the needed sensors before attempting to take measurements.
- ☐ When creating fits with MATLAB code, remember to copy as many decimal points as possible. This especially applies when the coefficients are small, as the significant figures become important.
- ☐ Verify that each piece of equipment functions, and does so with reasonable accuracy, before proceeding with the lab. This should be done for every different sitting and every piece of equipment, to debug which pieces of equipment are damaged.

RESULTS AND DISCUSSION

The resulting LabVIEW VIs are shown in Fig. (1) and Fig. (2). As seen in the front panel, the image has a clear differentiation between the ball and the background in the Luminance Signal waveform plot. The XY Graph shown is LabVIEW's representation of Fig. (3). As shown in the block diagram, the image is taken from the Vision Acquisition function and modified in the Vision Assistant, producing a line profile. This line profile is converted to the appropriate height value according to the upper and lower bound half-inch heights seen in the Image Out panel input by the user The desired height is used to roughly determine the power needed for the fan, according to a fan to height calibration.

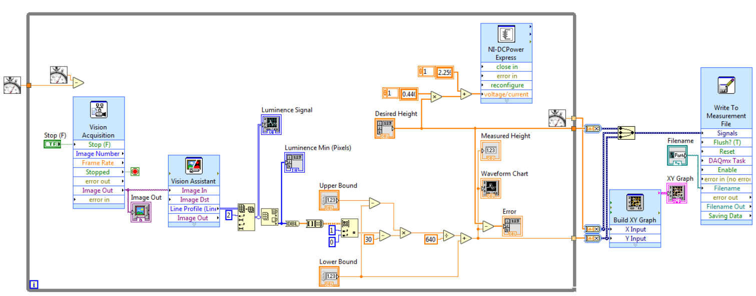

FIGURE 1: BLOCK DIAGRAM OF LABVIEW VI USED TO RECORD AND CONTROL BALL POSITION

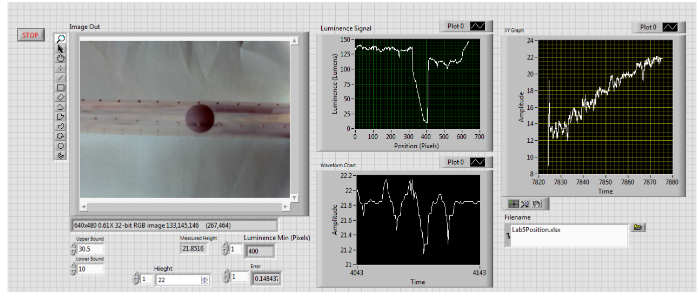

FIGURE 2: FRONT PANEL OF LABVIEW VI USED TO RECORD AND CONTROL BALL POSITION

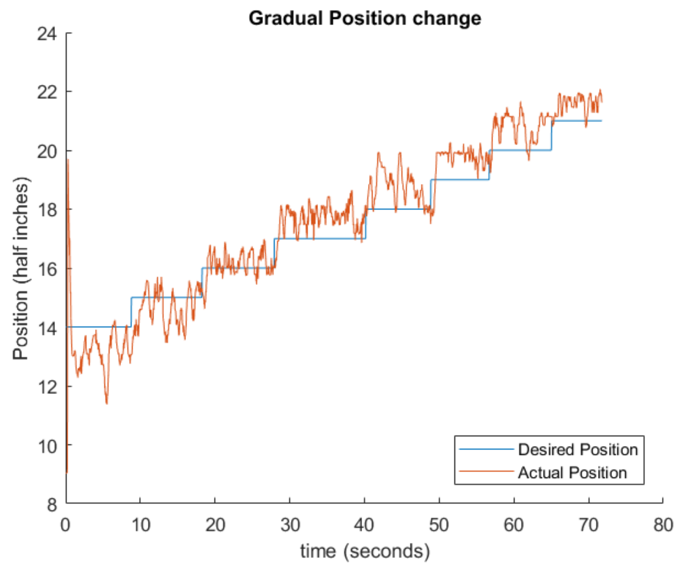

FIGURE 3: POSITION VS TIME OF BOTH DESIRED AND ACTUAL POSITION FOR GRADUAL POSITION CHANGE

Fig. (3) and Fig. (4) display plots of the position change of the ball. The blue lines are the input desired positions and the red lines are the actual positions of the ping pong ball.

Fig. (5) and Fig. (6) show the errors of the position control. For both the gradual and rapid position change, the maximum errors after steady state conditions are around one inch. Although the error plots show very little errors in steady state situations, for some segments of the control the ball is consistently around 1 inch away from the desired position. In future renditions of the position algorithm, it may be better to utilize a PID control so that the error eventually reaches a value closer to 0.

CONCLUSION

The image data processing method proved to be more accurate than the IR sensor when determining the location of the ping pong ball. However, the control system implemented was not as efficient as the PID system implemented with the IR sensor. The PID system was not implemented to the imaging system due to difficulties correlating the current position to the fan voltage.

To improve this lab, a PID control system should have been designed for this process prior to completing the lab, so that the

FIGURE 4: POSITION VS TIME OF BOTH DESIRED AND ACTUAL POSITION FOR RAPID POSITION CHANGE

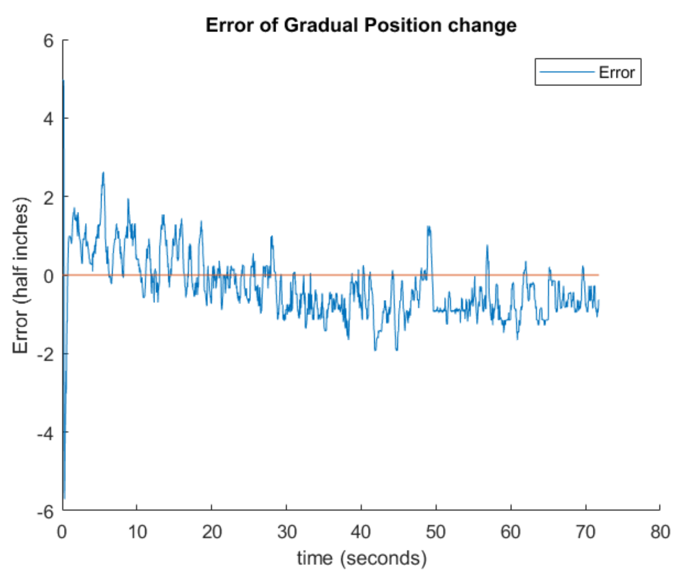

FIGURE 5: ERROR VS TIME FOR GRADUAL POSITION CHANGE

image processing system and the IR sensor system could be compared with less variables changed. During the time available to discuss the control possibilities, it was difficult to realize a better control system.

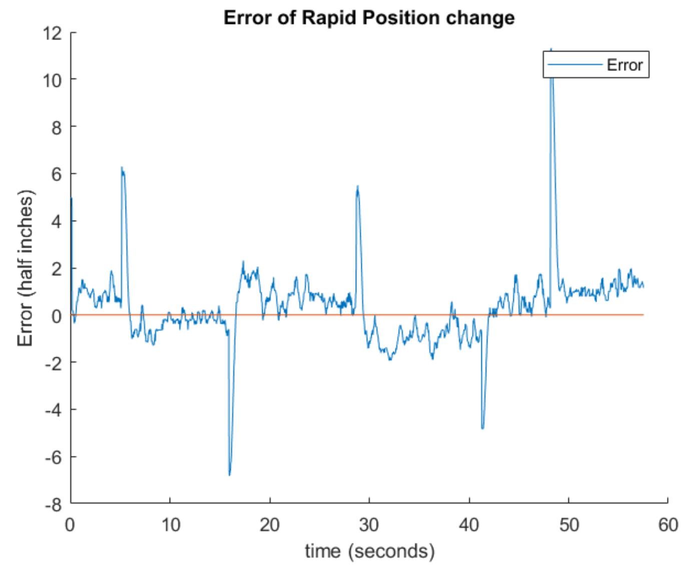

FIGURE 6: ERROR VS TIME FOR RAPID POSITION CHANGE

REFERENCES

[1] Beckwith T.G., Marangoni R.D., and Lienhard J.H., 1993 *Mechanical Measurements*, 5th ed., Addison-Wesley Publishing Company, Inc., Boston

[2] engadget.com, 2015 *Sony PlayStation Eye* https://www.engadget.com/products/sony/playstation/eye/specs/

[3] Huang T.S. and Aizawa K., November 1993 *Image processing: Some Challenging problems* Proceedings of the National Academy of Sciences of the United States of America

[4] National Instruments, NI.com *NI Vision - NI Vision Assistant Tutorial* http://www.ni.com/pdf/manuals/372228m.pdf

[5] TechHive, 2011 *CMOS Is Winning the Camera sensor Battle, and Here's Why* http://www.techhive.com/article/246931/

[6] What Digital Camera, 2017 *Digital Camera Sensors Explained* http://www.whatdigitalcamera.com/technical-guides/technology-guides/sensors-explained-11457