

Lab 1: Error Analysis and Orientation

1 Introduction

During this term, you and your teammates will gain an experimental understanding of physics concepts using devices typically employed in engineering applications. During the semester, you and your team will have to find your own solutions to specific problems formulated in the context of engineering projects. The solutions to these projects will require a clear understanding of the underlying physics concepts as well as skills in the engineering implementation of such solutions.

2 Assignment

Every measurement you take has an inherent unreliability called uncertainty. Uncertainties arise from systematic and random errors in experiments. Whenever you use a measurement with an uncertainty in a calculation, the uncertainty of the resulting value is determined through propagation of error.

The Visualization Studio at your lab station is equipped with a tracking camera (see section 4.1). This camera can measure and record (in pixel units) the positions of tracking stickers in the camera frame. For this lab, your team has been tasked with using the tracking camera to measure the area of square (in pixel² units) and propagating the uncertainties in your measurements. To accomplish this, you may place stickers in three corners of the square to measure length and width. Your team should collect a large data set and move the square while collecting data.

3 Deliverables

Your team is to submit a lab report presenting your findings. 10% of your lab report grade will be based on following the guidelines in the lab report template. Another 10% of the lab report grade will be for the report's Abstract and Introduction. The remaining 80% will be determined by including the following content in your report:

- [20%] a description of the process your team used to take data, with particular attention to describing how your team computed the width and length of the square from the pixel position data
- [20%] the average length and width of the square (in pixels) that your team measured, along with the uncertainty associated with these measurements
- [20%] histograms (see section 4.2) showing your data for the length and width of the square
- the calculated area of the square (in pixels²) along with the uncertainty associated with this measurement. This should be done in two different ways:
 - [10%] using your average length and average width, and propagating uncertainties from these measurements
 - [10%] calculating area for *each reading*, then taking an average and uncertainty from the results

4 Technical Information

4.1 Using the tracking camera

The tracking camera records the positions of stickers in frame and can do different operations with this data. Each sticker is tracked by color, so you should not use more than one sticker of the same color at any given time. There are several Python scripts available in the `examples/tracking` directory that perform different functions with the tracking camera. You should run some of these and get familiar with using the camera. To run a Python script from the terminal you can run the command:

```
python3 the_name_of_the_script.py
```

Most of these scripts will produce some sort of output, like a `.png` or `.csv` file. The `examples` directory is write protected and will not let the script write an output to this location. In general, it is a good practice to copy the script out to a new location before running it. For the purposes of this lab, you will likely want use the script `4_track_and_print_with_camera_input.py` to take your measurements.

The `.csv` file output by the tracking camera script will have many column headers like the ones shown below:

```
frame_no, timestamp, size_px-darkorange, position_px_x-darkorange, position_px_y-darkorange,  
rx-darkorange, ry-darkorange, vx-darkorange, vy-darkorange, ax-darkorange, ay-darkorange
```

In the headers shown above, `darkorange` refers to the specific sticker being tracked. The `position_px` columns refer to the position of the sticker, in pixel units. There should be one column for x components and one for y components. The columns for `rx`, `ry`, `vx`, `vy`, `ax`, and `ay` are for quantities that we will use in another lab and should not populate in your `.csv` file for this lab.

4.2 Histograms

A histogram is a type of plot used to show how data is distributed. The x-axis of a histogram contains ‘bins’ of data, and the y-axis shows how many data points fit in each bin (i.e., the frequency). These bins can be a single value or a range of values, depending on the data being represented. For an example, you could count how often words of a particular length show up in this paragraph. The results, when plotted as a histogram, would look like the following:

