Valentina Scharpf
CS 639 – Introduction to Computer Vision
Project Proposal – Report II

Computer Vision - Proposal Report
End of Line Inspection of Spirit (bubble) Levels

This project proposes a computer vision system to automate the process of end-of-line inspection of spirit levels' bubble. It checks that the bubble is accurately placed according to specific requirements.

This report is divided in two parts.

- The first part explains research I had to perform in order to understand the problem.
- The second part summarizes progress so far.

Research Performed

Before I could start working on this project, I had to make sure I understand what is needed. Research had to be done, in order to find the best way to complete the project. I researched several levels, resolution and quality of cameras needed, possible lenses, as well as several other instruments and tools that could possibly help.
The information acquired follows:

Levels

- **Empire e75 "TRUE BLUE" 2G magnetic 24" level**

https://www.empirelevel.com/box-level_e75-series.php
This level has a published accuracy of "0.0005 inches/inch" or 0.029 degrees.

- **650-24 aluminum box level.**

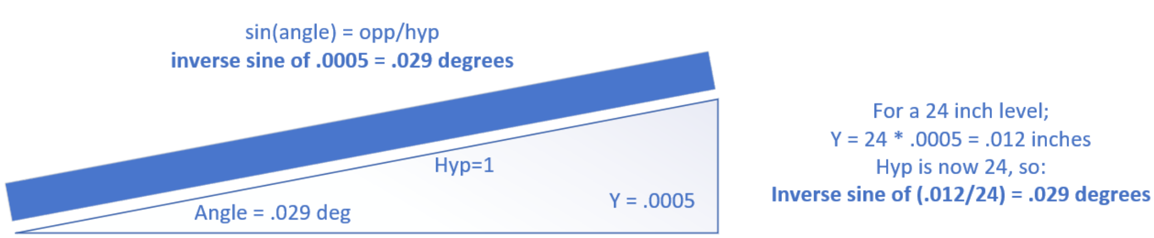
  https://www.empirelevel.com/box-level_650-series.php
  This level does not have a published accuracy and is a slightly lower quality level. Printed on the level is "0.0005 inches/inch" or 0.029 degrees, however, it is unclear why the company website does not reflect this.

- It is generally accepted that the levels that use the blue vials are generally more accurate and higher quality than the levels that use the yellow vials. The colored liquid (mineral spirits) helps the user in choosing a level.

- Accuracy in the world of levels is typically given in "inches per inch", but this really is expressing an angle, and the "inches" numerator is basically the Y direction (height) of a right triangle, so if you take the arcsine of .0005 you end up with approximately .029 degrees.

- The goal is to make a measurement of the bubble and convert this to an "inches per inch" unit to verify the accuracy specified.

Level Accuracy Industry Standard is in units of "inches per inch".
Example: .0005 *inches per inch accuracy specification. This is basically a slope.*
For every inch of level length, Y increases by .0005 inches.



In this case, the manufacturer is indicating that their level is accurate to within +/- 0.029 degrees!

Cameras and Lenses

The goal is to discover the most reliable and repeatable method in which to capture images of the bubble in the vial of a level and repeatedly measure its location in relation to the marks. Since the user relies on the bubble / line alignment, it is critical that this be as accurate as possible. If the image captured is not accurate due to reflections, poor lighting, or other conditions, the software will find false-measurements and results will not be reliable.

Issues:

Camera quality and resolution

In order to acquire accurate images, the following have been identified as crucial requirements:

1. **Camera resolution.**
    a. The number of pixels available will limit the ability of the software to correctly identify a line or edge, as well as any distance measurements required.
    b. More pixels are preferred, however higher pixel count may result in slower image acquisition, as well as increased cost.
    c. Balance has to be made between these two parameters.

2. **Camera quality.**
    a. This goes without saying, there are very expensive "off the shelf" cameras available which will provide a high resolution, but these generally cost thousands of dollars.

        As an example:

https://www.cognex.com/products/machine-vision/2d-machine-vision-systems/in-sight-9000-series

    b. These are typically complete systems which include their own software and are beyond the scope of this project due to cost.

3. **Camera color**
   a. I learned that converting to a black and white image, or removing some of the color, appears to help in the clarity of the picture.

4. **Lens**
   a. This is apparently a critical element. It is recommended that the system uses what is known as a "Telecentric lens". This normalizes the image such that items further way do not appear smaller. It eliminates shadows and ghost images created by things such as the back of the vial, or the lines in the back of the vial.

https://en.wikipedia.org/wiki/Telecentric_lens

   b. A telecentric lens is costly, and is not in the scope of this project, but would have to be used if this were a proposed solution.

5. **Lighting.**
   a. This proved to be a critical item and turned out to be most helpful in achieving the needed results. Much experimentation has been done to obtain the most optimal lighting conditions, including:
      i. Lighting dispersed from top and sides.
      ii. Lighting directly from the rear (through the bubble).
      iii. Combination of lighting and angles to reduce reflections.
   b. The most significant issue found was that any lighting tends to create some reflections on the plastic surfaces, which show up as edges, shadows, or other anomalies when using techniques to pick out edges. In turn, these influence the accuracy of the measurements.

Methods chosen / attempted.

Laptop camera (live image)

An attempt was made to emulate a "live" image, which means the level was placed in front of the camera, and the processing was performed on that image in real time. This would have reduced processing.

I was able to install the Image Processing Toolbox in Matlab and acquire the image, but its quality was considerably worse than what the cellphone camera provided.

Cell phone camera.

Since I did not have a high end vision system available, I attempted to take images at various angles and positions, and then save the images to files. These images were post processed using techniques learned in class. This could emulate a real life situation in which a camera would take the image, and a computer would process that image, providing operators with a pass/fail indication.

A note about standard zero level

Another interesting piece of research was to learn about the fact that it is almost impossible to achieve a zero level.

The most challenging aspect is to determine what is “level”. While this may sound trivial, it is not as easy as it sounds. The best case in the industry is to use a reference level and a granite surface, to “normalize” your surface to 0. Keep in mind that even this equipment will have tolerances. For example, this level meter costs in excess of $50,000, and must be returned to the manufacture on an annual basis for re-calibration.

https://www.statuspro.com/machine_tool_alignment/flatness_and_level/

There are many off the shelf levels, inclinometers, sensors, accelerometers, etc.. that claim to measure level or angle (inclination), but further investigation shows that none of these have the accuracy required to verify a good bubble level.
Even if using this, the surface must be free of imperfections. Granite works the best because a metal surface will warp with temperature changes. Granite is stable.
For these reasons, it is implied, for this experiment, that the user has already “found” a perfect level surface. In other words, the fixture which will measure the level bubble is already at “perfect level”.

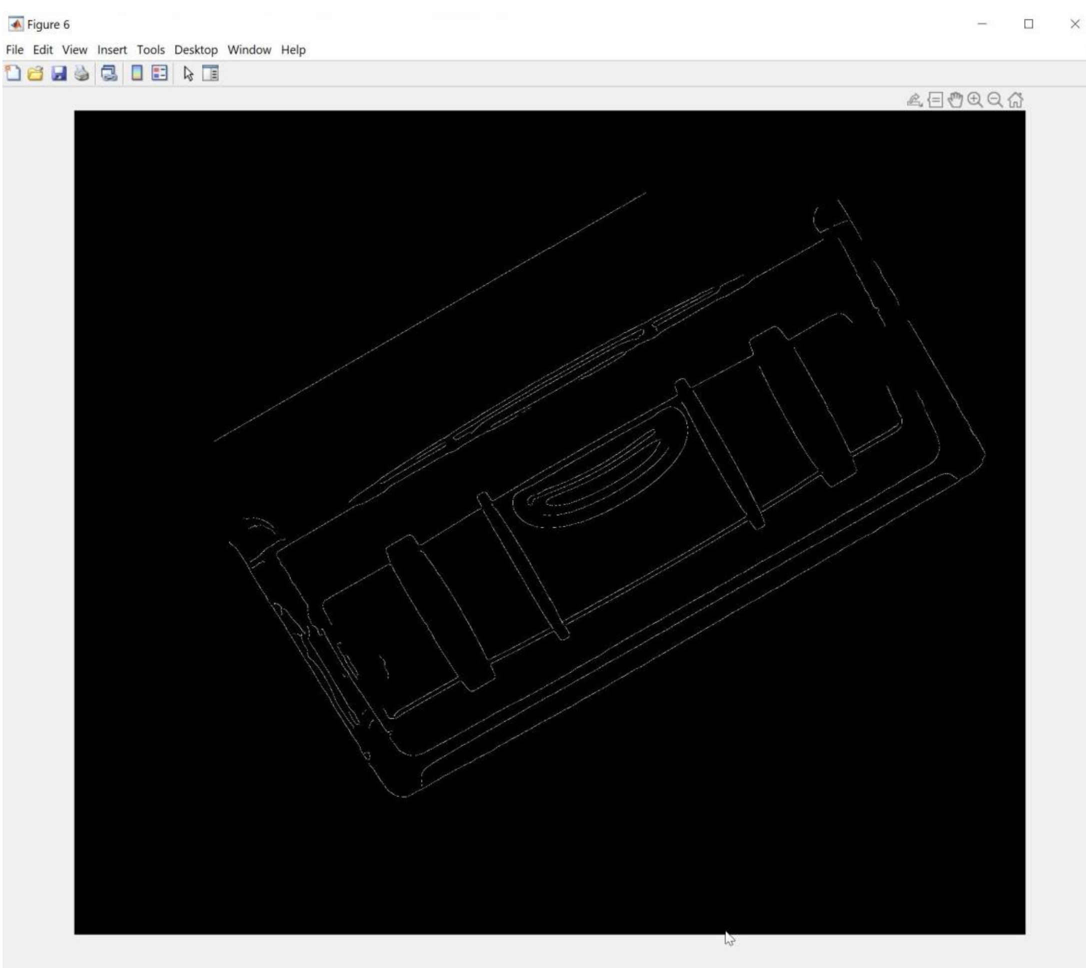
Testing and Development

I decided to use Matlab for building this project.
While I am still not completely comfortable with all it has to offer, I realized that it is advantageous.

The application I built so far acquires images of levels from a set directory, it processes them applying several techniques learned in class, and in the end it calculates degrees off center of the bubble.

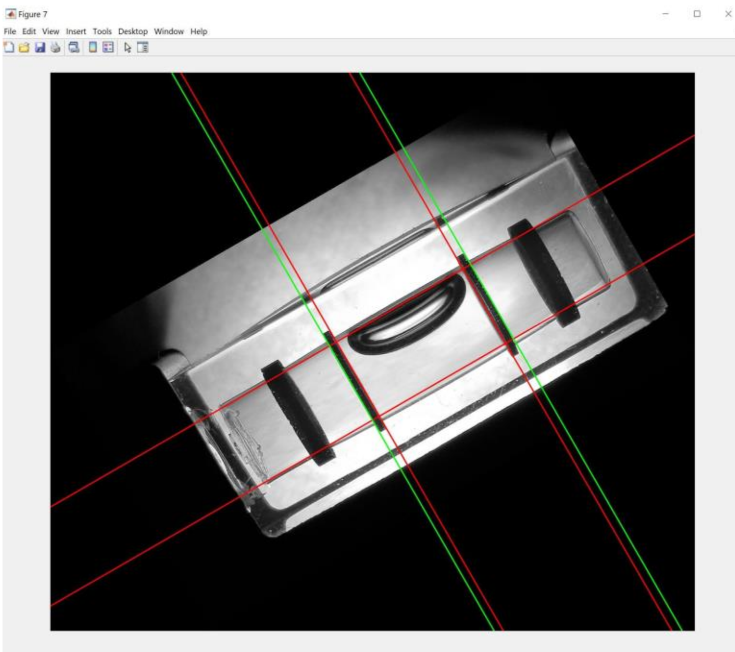
Processing the image

In order to find the bubble, images are read and then rotated to a specific angle, in order to more accurately find the edges. A Gaussian 2D filter is applied to filter out possible noise, after which the image is converted to grayscale. At this point we are ready to find the edges. I used the 'Canny' method offered by Matlab.

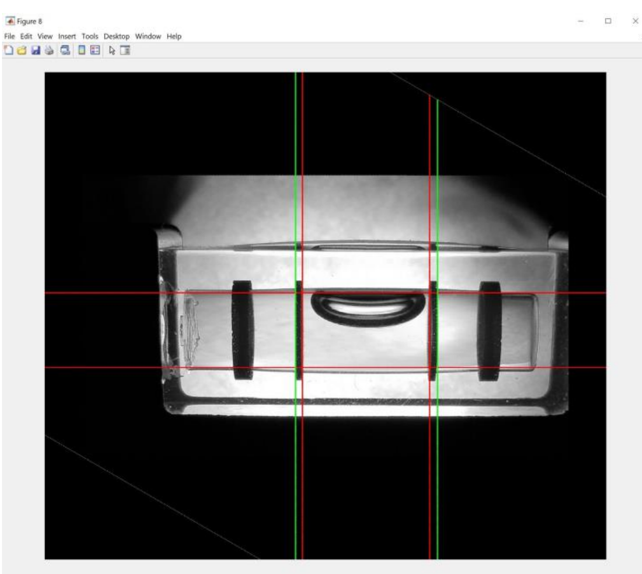


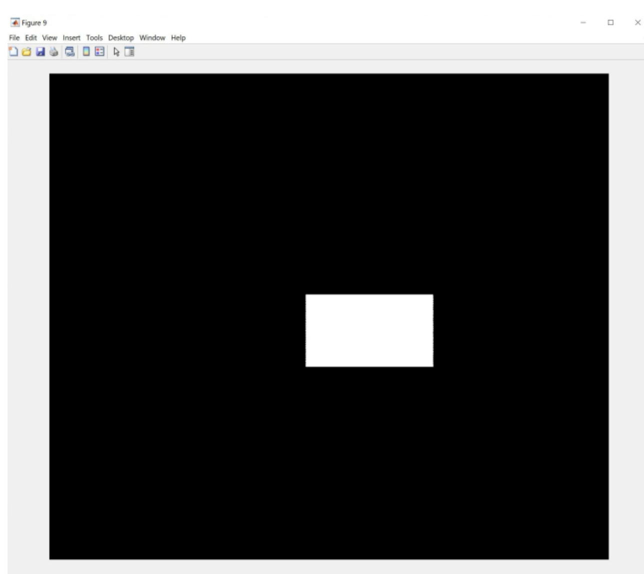
Valentina Scharpf

Using the 'hough' method offered my Matlab and studied in class, I was able to find the markers of the level that surround the bubble.

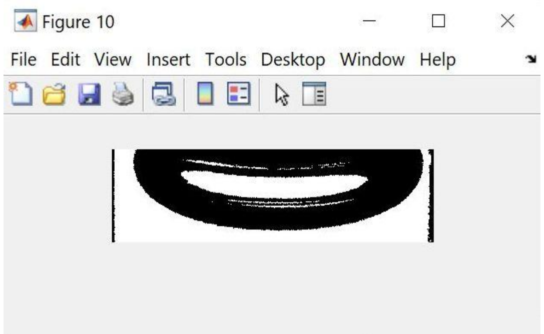


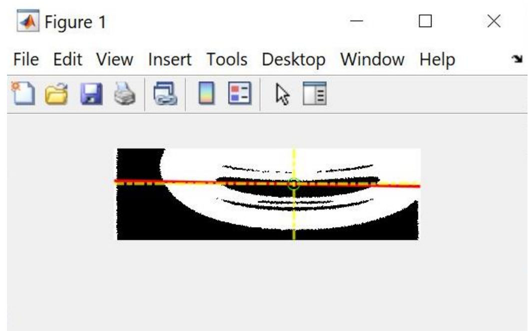
After correcting the position of the image (rotating back to horizontal), a mask is obtained.





Finally, using 'activecontour' I can find the bubble and measure the needed distances.





Next phase

- **Calibration of measurements**
    - find perfect zero angle using a reference source
    - measure total distance of bubble travel
    - create scaler to convert distance to degrees
- **Improve vision acquisition**
    - better light
    - better camera
    - experiment with different setups
- **Take multiple samples in multiple conditions**
- **Create website**

REFERENCES

- Some information in this report was provided by Jeff Scharpf – Principal Engineer at Milwaukee Electric Tool