BERKELEY LAB

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U.S. DEPARTMENT OF ENERGY

Office of Science

Shieldbox Number ML

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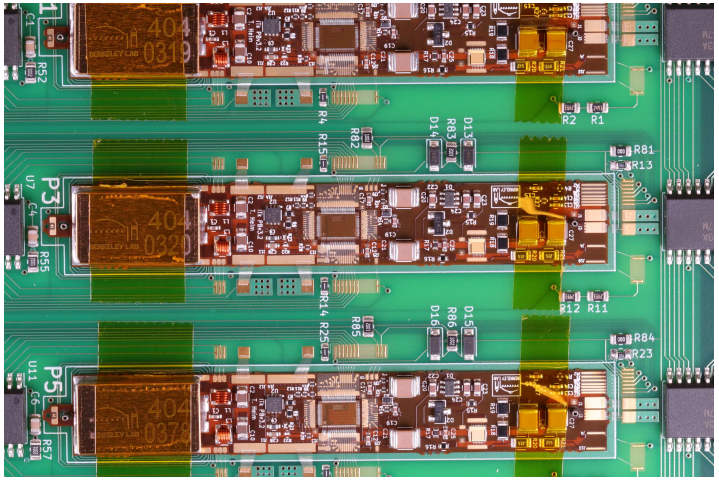
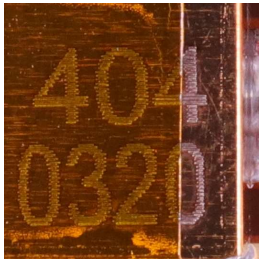
(under direction of Timon Heim and Zhicai Zhang)

Objective 1: Shieldbox



A

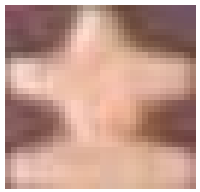


B

4
4
320

1a: Cropping the shieldbox

- Input image taken during the visual inspection stage of the Powerboard Quality Control Procedure
- Goal of algorithm is to identify shieldbox top-left and bottom-right corners using fiducials
  - Crops image using location of corners
- Good crop should eliminate all other text and clearly include all 7 shieldbox numbers



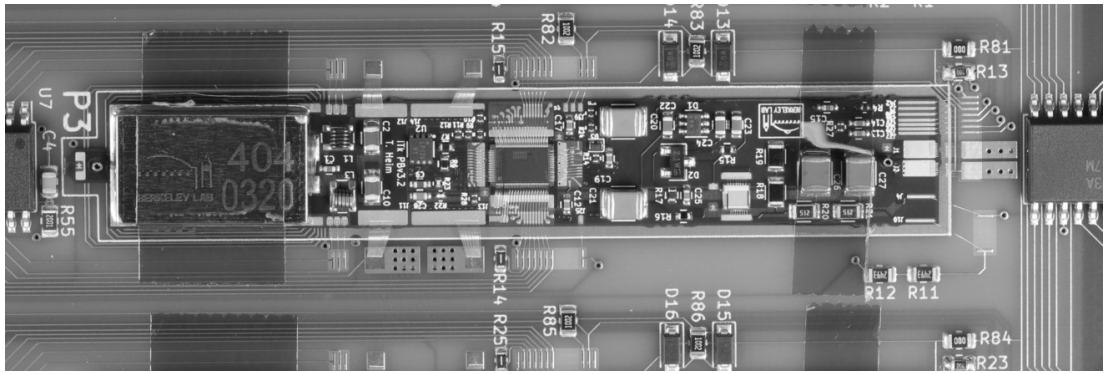
One of the five fiducials on a powerboard

A discolored fiducial

1a: Cropping the shieldbox

Opening the input image and template

- Open the image using cv2.imread
- Make the image black and white using cv2.IMREAD_GRAYSCALE
- Crop the image to the pixel range (1000:3000, 0:6000)
- Open the template using cv2.imread
- Make the template black and white using cv2.IMREAD_GRAYSCALE



1a: Cropping the shieldbox

Locating fiducials

- Using eval('cv2.TM_CCOR_NORMED') as method for template matching
- Check how close fiducial template is to actual fiducials using cv2.matchTemplate
- Record pixel coordinates of regions matching the template
  - Arbitrary threshold of "matching" set high enough to remove false fiducials, but low enough to account for variation

$$R(x,y) = \frac{\sum_{x',y'}(T(x',y') \cdot I(x+x',y+y'))}{\sqrt{\sum_{x',y'} T(x',y')^2 \cdot \sum_{x',y'} I(x+x',y+y')^2}}$$

with mask:

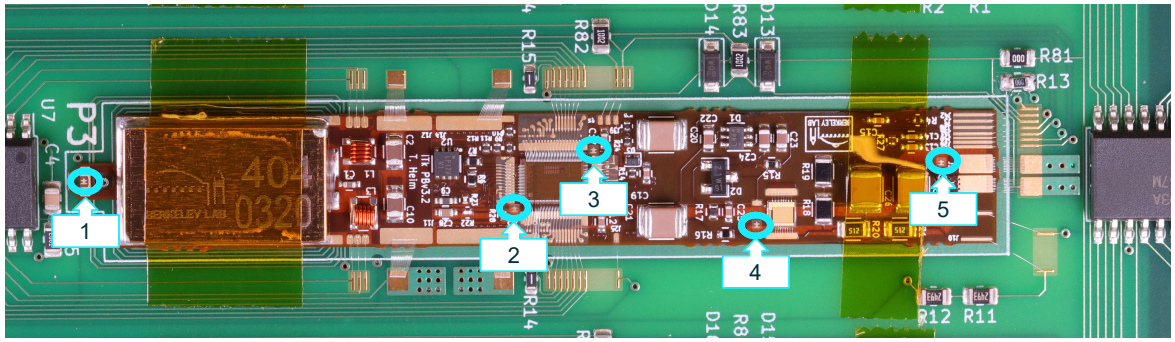
$$R(x,y) = \frac{\sum_{x',y'}(T(x',y') \cdot I(x+x',y+y') \cdot M(x',y')^2)}{\sqrt{\sum_{x',y'} (T(x',y') \cdot M(x',y'))^2 \cdot \sum_{x',y'} (I(x+x',y+y') \cdot M(x',y'))^2}}$$

Template matching operation for TM_CCOR_NORMED

1a: Cropping the shieldbox

Determine pair of fiducial

- Use the coordinates of the first two fiducials stored
- Find the distance between the x- and y-coordinates of the fiducials respectively
- Find the ratio between the x- and y-coordinates of each fiducial, and the y-coordinates of both fiducials
- Using these values, establish parameters to determine which fiducials are stored
  - 10 cases (1-2, 1-3, 1-4, 1-5, 2-3, 2-4, 2-5, 3-4, 3-5, 4-5)



1a: Cropping the shieldbox

Sort and remove duplicate fiducials

```
        priorpt = (0,0) #initiate as upperleft corner of image
        for pt in zip(*loc[::-1]): #for every located fiducial
            if 600 < pt[0] < 2000: #if it's in the range of the shieldbox (where there should be no fiducials),
                continue #skip
            elif pt[0] > 5500: #if it's way to the right of the far-right fiducial,
                continue #skip
            elif abs(priorpt[0] - pt[0]) > 100: #if the located fiducial is far enough away from the prior pt to not be the same one
                overlap = 0 #initiate variable
                for i in range(len(appxloc)): #for all potential fiducials
                    if abs(pt[0] - appxloc[i][0]) < 50: #if the current pt and the iterated pt in the list are close enough
                        overlap += 1 #increase variable
                if overlap == 0: #if the current pt doesn't already exists in the list i.e. is far enough from preexisting pts
                    appxloc.append(pt) #add it to the list
            priorpt = pt #update the current pt to prior pt
    appxloc.sort(key=lambda a: a[0]) #sort the list by x coordinates
```

- If less than five fiducials found, repeat Slides 5-7 using discolored fiducial as template image

Attempt 1: Intuition

Crop shieldbox

- Use determined fiducial pair and coordinate values/distances/ratios to find top-left and bottom-right corners
- Corner = (fiducial_x + constant*dx, fiducial_y + constant*dy)
  - Constants determined experimentally
- Crop shieldbox from corner to corner
- Full code available on GitLab
- Benefits:
  - It kind of works (crops shieldbox region for 238/239 images)
  - What I initially thought of
- Why this failed:
  - Not consistent enough (i.e. varying crop sizes)
    - Doesn't account for rotation of image or zoom correctly

vs.

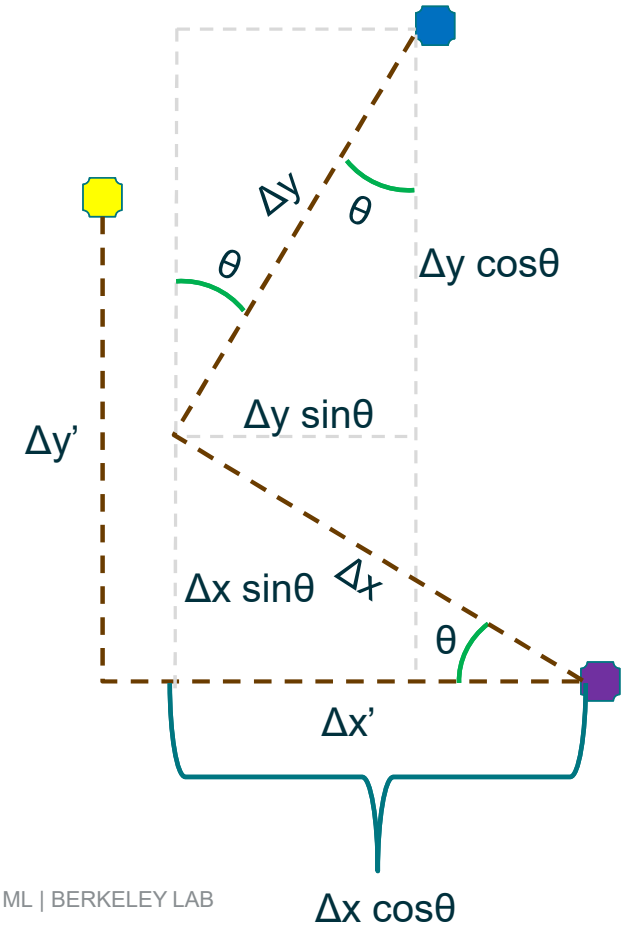
Rotating the image

Let’s make a function

```
11 def rotate_image(image, angle): #I wonder what this does
12     height, width = image.shape[:2] #get image dimensions
13 
14     rotation_matrix = cv.getRotationMatrix2D((width / 2, height / 2), angle, 1) #calculate the rotation matrix
15 
16     rotated_image = cv.warpAffine(image, rotation_matrix, (width, height)) #apply the rotation to the image
17 
18     return rotated_image #I wonder what this is
```

- Need to get angle

Angle Attempt 1: Trig



"Solution":

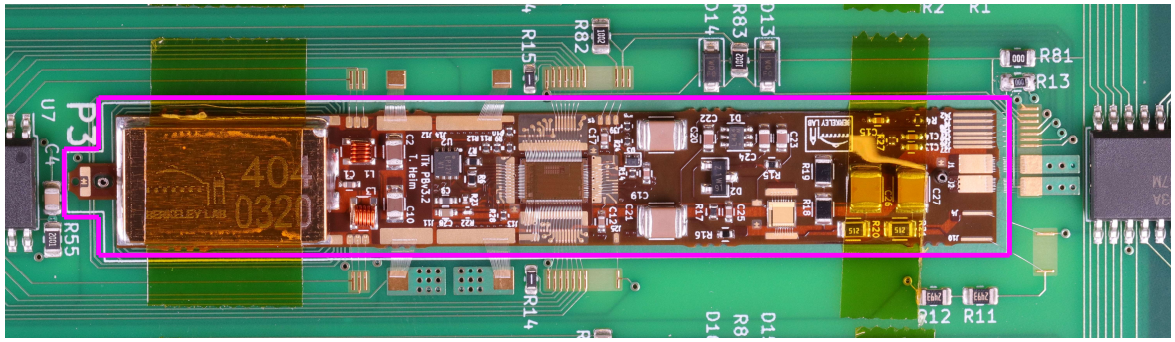
- $\Delta x' = \Delta x \cos\theta - \Delta y \sin\theta$
- $\Delta y' = \Delta x \sin\theta + \Delta y \cos\theta$
  - Sub trig for 1st order Taylor

Why this failed:

- It was wrong
- That is not how geometry works
- Everything but the solution eqs was fine
  - But even the diagram assumes the image rotates around the second fiducial (false)

Angle Attempt 2: Finding the white border

- Use cv2.HoughLinesP to locate longest white line on image
- Find angle between that line and the horizontal
- Why this failed:
  - Not consistently locating the white border
    - Too many other lines on image
    - Reducing the pixel range scanned did not help



Angle Attempt 3: Revenge of the Trig

Vector time

- When making slides for this presentation, I realized we were doing the trig incorrectly
- Asked a robot for help

```
178         dot_product = dx_original * dx_rotated_scaled + dy_original * dy_rotated_scaled
179         cross_product = dx_original * dy_rotated_scaled - dy_original * dx_rotated_scaled
180         rotation_angle = np.arctan2(cross_product, dot_product)*180/np.pi
181
182         rotated_image = rotate_image(img, rotation_angle)
```

- Why does this work?
  - Can think of our two sets of ordered pairs as vectors
  - $\tan\theta = \frac{\|v \times w\|}{v \cdot w}$
  - np.arctan2 takes the arctangent of a value with a numerator and denominator

Correcting the zoom

It’d be too easy if the camera zoom was the same every time

```
244     scale_factor = np.sqrt(dx_original**2 + dy_original**2) / np.sqrt(dx_original**2 + dy_original**2)
245
246     new_width = int(image_color.shape[1] * scale_factor) #use the scale to scale
247     new_height = int(image_color.shape[0] * scale_factor)
248
249     resized_image = cv.resize(rotated_image, (new_width, new_height))
```

- Why does this work?
  - Scale factor is the ratio of the distances between the original image points and the crooked/zoomed image points

The end…?

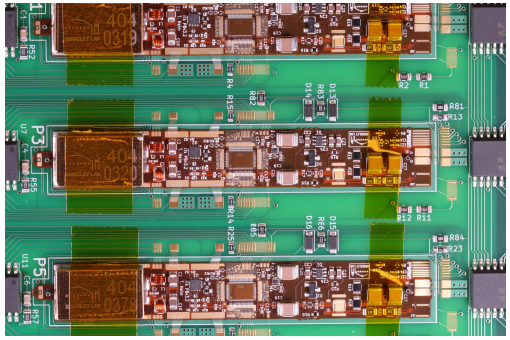
At least for Sam at LBNL

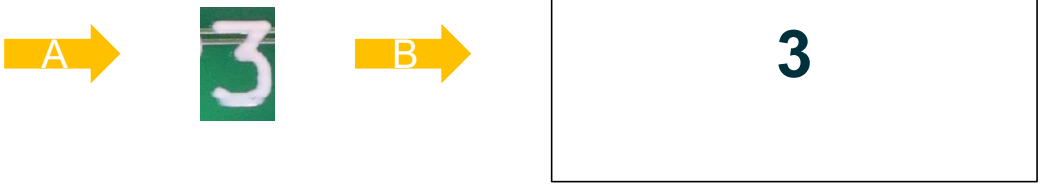
- Surprise! I'm leaving 😜
  - Starting grad school at Davis in the fall
  - My two-year reign of being funny at the lab concludes
- But this project isn't done?
  - You're right
  - Steps left to do:
    - Crop the zoomed and straightened image
      - Can either be done:
        - » by aligning the first registered fiducial with the first registered fiducial on a perfectly-straight image
        - » by manually assessing the cropped region based on how far the fiducial pairs are from each other (see Slide 8)

The end…?

At least for Sam at LBNL

- More steps left to do:
  - Run a machine learning algorithm to identify the shieldbox numbers
    - A skeleton code will be uploaded to Github by EoD
      - » Does not currently run due to lack of cropped images thus far, but has general idea
  - Transfer these steps to Objective 2: Powerboard #
    - Should be extremely easy, just a simpler version of cropping the shieldbox numbers and a simpler ML algorithm (since the number is printed vs. etched on)





Questions now?

For questions later, message on: Mattermost (@sakelly), email (samanthakelly@berkeley.edu)