Lab4: Autonomous Driving, Due 11/21/17 11:30 AM

1. We are going to be using the camera on the GoPiGo to do lane following on a test-track roadway. The test-track is in Room 611 CEPSR, and you can also create your own test track if needed, but final testing will be on the 611 CEPSR track.
   NOTE: CEPSR Building is open during the day but locked at night. You may be able to get in after hours by following someone in, but we will not be granting access out of 8-6 time frame.
2. Follow the yellow line: Your GoPiGo will be placed on the track, with a yellow lane marker in view. Treat this yellow marker as the centerline of the lane, and move the robot around the track following this yellow line. Your program should also stop when you see an orange marker (stop sign) on the track. If you see the orange marker, then your robot will rotate 180 degrees and follow the yellow line back to another orange stop marker. Your program should do the following:
   a. Precalculate a homography from your image camera plane to the planar roadway. Your roadway grid will have a known metric distance that you can define (e.g. 100 pixels = 2 inches). This will allow you to take any camera pixel coordinates and transform them to roadway coordinates. You can calculate the homography by clicking on 4 known points in the image and mapping them to the roadway grid. The code below takes 4 points (**pts_source** array) you mouse click on the input camera source image (**im_source**) and maps them to 4 known metric points (**pts_roadway** array) that you have pre-defined on the roadway grid image **im_roadway** (such as the 4 corners of the roadway image). This gives you a 3x3 transform matrix to warp any point in the source image to the roadway image

      transform, status = cv2.findHomography(pts_source, pts_roadway)

   You can transform the entire input image to the roadway grid image (of size width, height):

      im_roadway = cv2.warpPerspective(im_source, transform,(width,height))

   You can also transform single points in the source image to the roadway image.

   Just multiply the 3x3 transform matrix by the 3x1 source point (homogeneous 2D coordinate with third coordinate = 1). This gives you a new 2D homogenous point in the roadway grid. Don't forget to divide each of the new x,y roadway coordinates by the scaling factor to get the actual roadway pixel coordinates.

      source_point = np.array([source_x, source_y, 1)

      roadway_point = transform.dot(source_point)

      roadway_x = int(roadway_point[0]/roadway_point[2])

      roadway_y = int(roadway_point[1]/roadway_point[2])

b. Now start driving! Take a pic and warp it (homography) to the roadway grid - think of this as the image projected onto the flat 2D roadway.
c. Do color filtering/thresholding for yellow center lane marker. You may want to use erosion/dilation here also to remove small color artifacts
d. Find the edges in the filtered image from step c above (e.g. you may use the cv2.canny () function). Note there are a number of parameters in the edge detector (edge thresholds etc.) that will affect the edge finder's performance.
e. You may use cv2.hough() function to find center line from the edge image in step d above.
f. The center line has already been projected onto the roadway image, so your robot's location with respect to the rotation angle (want to stay parallel to the centerline) and horizontal distance of the robot from centerline can be computed and used to move the robot accordingly to stay in the center of the road and move forward.
g. Repeat steps b-f above.

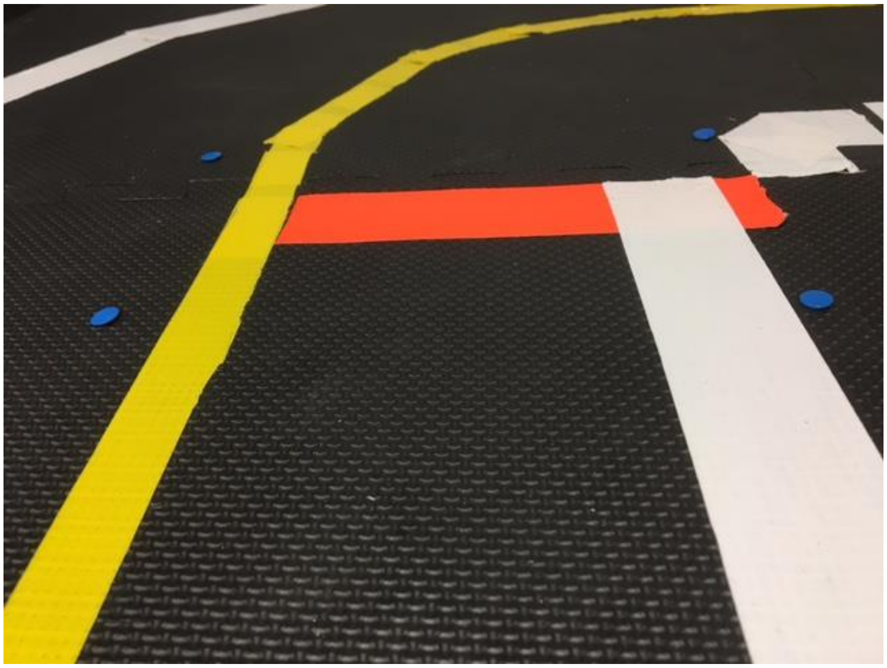
3. EXTRA CREDIT (10 points) : Full credit for this lab is earned by following the yellow lane on a straightaway, and rotating 180 degrees when an orange line is found and following the yellow line again.

   For extra credit, have the robot follow the yellow line all around the track, even on curves. You may ignore the orange stop lines for this part.

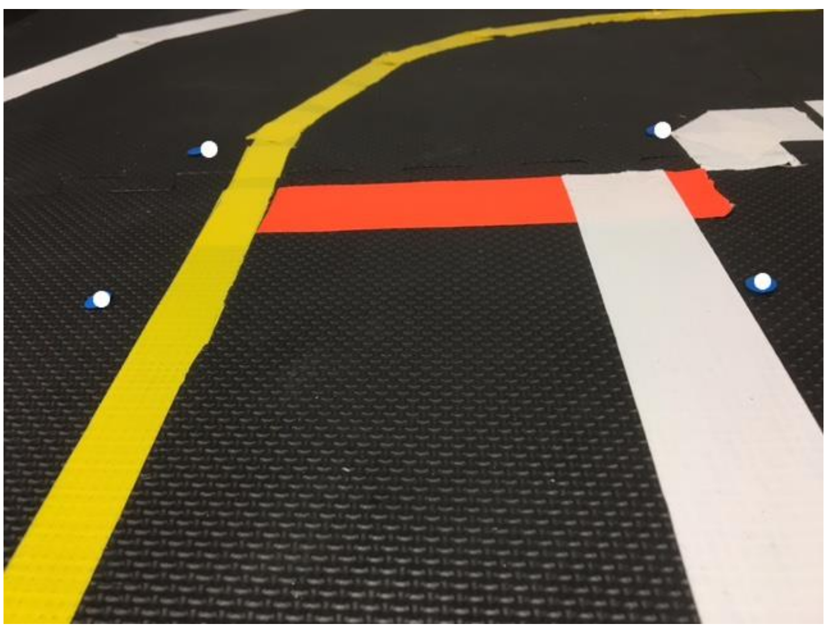
4. Notes:
   a. You should mount your camera up higher where the sonar sensor is. You can remove the sonar sensor and servo (leave in blue tool box) and mount the camera there.
   b. The camera needs to point downward for best performance. You can use some tape or other method to point the camera slightly downward to properly image the track.
   c. Below are some images showing the sequence of processing leading to a centerline detection in the roadway grid, and computing the robot's position relative to that centerline.
   d. Video of yellow line following with orange stop sign direction reversal:
      https://www.youtube.com/watch?v=GTETX7lfr9U&feature=youtu.be
   e. Build your own track! Here are the exact orange and yellow tapes we used:

https://www.amazon.com/gp/product/B002TOL414/ref=oh_aui_detailpage_o05_s00?ie=UTF8&psc=1

https://www.amazon.com/gp/product/B002TOL45U/ref=oh_aui_detailpage_o05_s00?ie=UTF8&psc=1

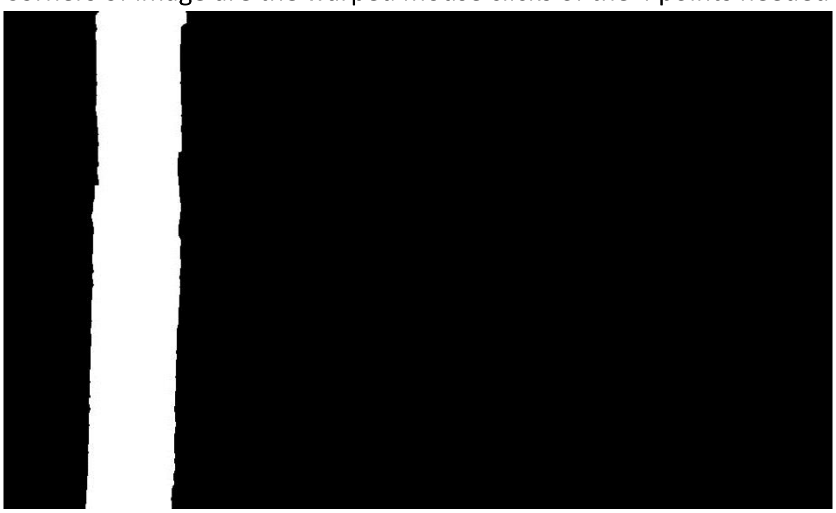


Original image

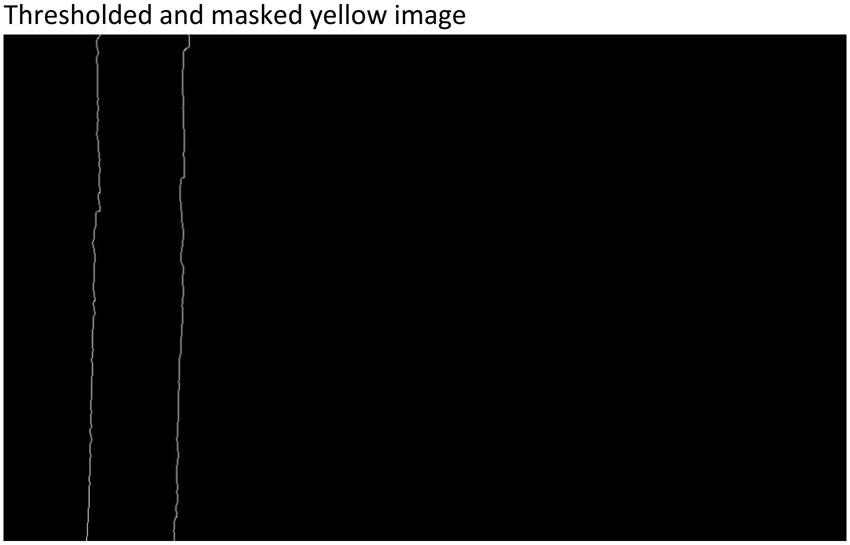


Original image with mouse clicks (white dots) for 4 point homography. Known points are the location of the 4 blue thumbtacks in the previous image.

Original image warped onto roadway grid after homography. White circles at
Corners of image are the warped mouse clicks of the 4 points needed for the homography

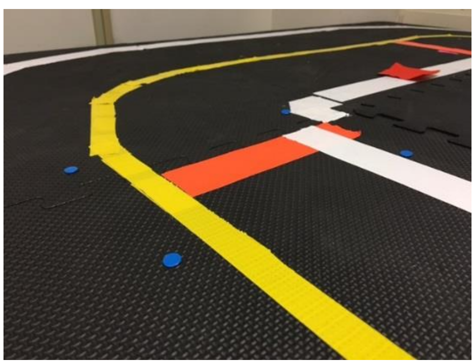


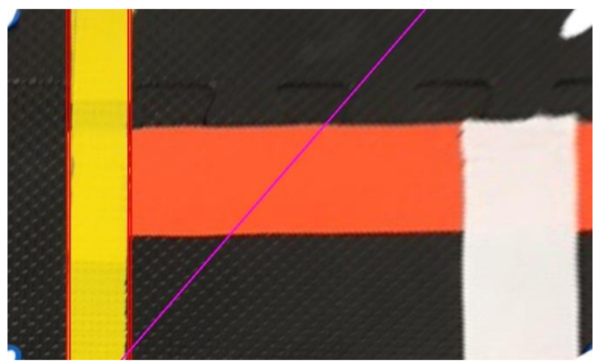
Thresholded and masked yellow image



Canny edge detector applied to thresholded and masked yellow image

Hough transform line detector (red lines) overlaid on roadway image. The magenta line is the orientation (direction of travel) of the robot relative to the grid when the picture was taken. If we extend this line back from the bottom of the image we can also find out the robot's position on the roadway.





Left: Here is another image taken from an angle. Right: the homography and the mapping of the robot's direction of travel onto the grid. The angle between the magenta line and the red hough line on the yellow centerline can be used to re-orient your robot to move parallel to the centerline. The magenta line is calculated by taking the vertical line in the middle of the original image and transforming it with the homography matrix into a line whose coordinates are now in the roadway grid.