Assignment 3

1. You are required to analyze the feasibility of designing a vision system for the robot gas station attendant. Assume that the driver parks the car so that the flap and the cap are in a predetermined workspace of 36 in (length) \times 24 in (height) \times 24 in (depth). Recall that the two main functions of the vision system are:
   - to locate the gas flap, and (possibly) the hinge, so that the robot arm with an end effector equipped with suction cups can open the flap; and
   - to locate the gas cap so that the robot arm with another suitable end effector unscrews the gas cap.

a) Develop specifications for the performance of the vision system for each of the two tasks. In other words, identify the specific parameters (e.g., position of the target, orientation of the target, shape of the target, size of the target) that will have to be returned to the robot control system in order for the robot to perform its task. Also try to estimate the allowable errors in these parameters for the task.
b) For each task, determine the sequence of operations (algorithms) and hardware that are required for the vision system. Examples of algorithms include edge detection, contrast operator, and pose estimation. Examples of the hardware set up include one CCD camera, two CCD cameras, or one camera with structured light.

2. Explore the ability of any one of the edge operators (others optional) using the ideal image shown in the figure and compare them to each other and the Roberts operator.

- One-dimensional edge operators
  \[ E_1 = |I - E| + |E - A| \]
  \[ E_2 = |F - E| + |E - D| \]
  \[ E_3 = |H - E| + |E - B| \]
  \[ E_4 = |G - E| + |E - C| \]

- Contrast operator
  \[ Contrast = E - \frac{A + B + C + D + F + G + H + I}{8} \]

- Sobel operator
  \[ S_E = \sqrt{(A + 2B + C - G - 2H - I)^2 + (A + 2D + G - C - 2F - I)^2} \]

where the letters refer to the intensity of the image at each pixel according to the schematic below:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td>G</td>
<td>H</td>
<td>I</td>
</tr>
</tbody>
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The simplest way is to program the operators on a spreadsheet (e.g. Excel) with the ideal image. Do you have to use different thresholds for each operator to determine the edges?
3. Robot A and Robot B are both electric robots powered by dc servo motors with identical geometry. Robot A is equipped with high accuracy, low friction potentiometers at the joints and a 12 bit A/D (analog to digital) card. Robot B is equipped with 512 line encoders (with quadrature) at the motor shafts. Both robots have digital controllers. Therefore, the joint position information has to be fed back to the controller as a digital signal. Find the resolution for each robot at the joint? Which one has a superior resolution?

4. A commercial robot has the structure consisting of revolute (pin) joints shown in the figure below. The first axis is vertical, the second intersects the first at 90 degrees and is horizontal, and the third is parallel to the second. See, for example, the first three joints of the Kawasaki JS series. The two link lengths (the distance between the second and third axes and the distance between the third axes and the tool center point) are 1 meter each. In other words, , \( a_2 = a_3 = 1 \) meter. Each joint is driven by a dc servo motor with a peak continuous torque rating of 100 in lbs, a 70:1 harmonic drive reduction and a 512 line optical encoder with quadrature.

\[ \text{Axis 1} \quad \text{Axis 2} \quad \text{Axis 3} \]

(a) Estimate the resolution (control resolution) when the end point at the workspace (outer) boundary.
Hint: Calculate the joint resolution at each joint. The joint resolution in radians multiplied by the distance to the tool end point gives the linear resolution at the end point. The inaccuracies of joints 2 and 3 will add because they are parallel. The worst case resolution is when the arm is completely outstretched.

(b) The robot manufacturer claims an accuracy of 0.007 inches. Do you believe this claim?

(c) If no force sensors are used, do you think this robot can be used (with a suitable end effector to grasp a cap) to screw on caps for bottles or jars typically found with such food products as jelly and peanut butter? Make appropriate assumptions on the accuracy with which the bottle or jar needs to be positioned. What kind of control strategy would you suggest?