1. (15p) You are given a camera with adjustable focal length. Describe how it could be used for size constancy; i.e., to make different objects appear to have the same image sizes. Show the relevant math.
2. (30) You are given the following binary image.

Assume that a coordinate system with $x$-axis pointing right and a $y$-axis pointing up is added. The coordinates of the left bottom pixel are $(0, 0)$. Compute the following parameters:

a) (3p) area,

b) (3p) perimeter (describe your algorithm),

c) (4p) center of mass,

d) (10p) second order moments $M_{11}$, $M_{20}$, and $M_{02}$.

e) (10p) central moments $\mu_{11}$, $\mu_{20}$, and $\mu_{02}$.
3. (15p) You are given the following gray level image.

All nonzero pixel values are equal to 2. Assume that a coordinate system with \(x\)-axis pointing right and a \(y\)-axis pointing up is added. The coordinates of the left bottom pixel are \((0, 0)\).

a) (5p) Use symmetric difference masks to compute partial derivatives in \(x\) and \(y\) directions.

Recall that \(f_x = \frac{1}{2}(f(x+1, y) - f(x-1, y))\), and \(f_y = \frac{1}{2}(f(x, y+1) - f(x, y-1))\).

b) (5p) Compute gradient magnitudes at all image points.

c) (5p) Compute gradient directions at all image points.

You can use these grids to show your results:
4. (50p) You are given a template $N$ and a binary edge image $M$.

   a) (5p) Represent $N$ so that it can be used by the GHT (Generalized Hough Transform) algorithm.

   b) (15p) Use GHT to find $N$ in $M$. How many matches did you find? You can use the grid above for the GHT accumulator array.

   c) (10p) Use forward/backward pass algorithm to compute the distances of all points in $M$ from the edge points of $M$. You can assume that the distance between any pair of 8-neighbors is 1.

   d) (15p) Use Chamfer matching to find $N$ in $M$. Show all placements with scores lower than 10. You can assume that the placement of $N$ is at the position of the topmost pixel of $N$. What are the best matches?

   e) (5p) Show how the distance transform array could be used to perform a Hausdorff distance matching on $N$ and $M$. Show the best match(es).

   Template $N$, edge image $M$, and the GHT scores.
Distance transform and Chamfer match scores

forward pass

backward pass

match score

Hausdorff distance matching