University at Buffalo
Department of Computer Science and Engineering
CSE 473/573 - Computer Vision and Image Processing

Fall 2024

Homework #1
Due Date: 9/24/2024, 11:59PM

Instructions

- Answer the questions below, and provide as much of your work as necessary.
- Export or scan your homework and store it as a PDF version before submitting online to UBLearns.

1 Intrinsic Matrix (15 points)

Suppose we have the following intrinsic parameters of the camera above: focal length is 2, the coordinate of camera center on the image plane is [7, 7]. There is unit aspect ratio and no skew of the pixels. The image plane and the objects are in the same side of the camera center.

- Determine the intrinsic matrix. (5 points)
- If the coordinate of a point is $[2, 2, 5]$ in the camera coordinate, calculate its coordinate on the 2D image plane in the form $[x, y]^T$. (10 points)

2 Extrinsic Matrix (15 points)

Suppose the rotation matrix R and the translation vector t of a camera are as follows:

$$R = \begin{bmatrix} 0.1 & 0.1 & 0.5 \\ 0.4 & 0.2 & 0.2 \\ 0.2 & 0.5 & 0.3 \end{bmatrix}, \quad t = \begin{bmatrix} 10 \\ 20 \\ 30 \end{bmatrix}$$

- Determine the extrinsic matrix. (5 points)
- If the coordinate of a point is $[60, 40, 50]$ in the world coordinate system, calculate its coordinate in the camera coordinate system. (10 points)

3 Convolution (15 points)

Suppose we have an input image which is $\begin{pmatrix} 1 & 1 & 2 \\ 1 & 2 & 1 \\ 2 & 1 & 1 \end{pmatrix}$ and a convolution kernel which is $\begin{pmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix}$

Assume we set stride as 1.

- Determine the padding needed so that we can keep the image size unchanged before and after convolution. (5 points)
- Determine the output of the convolution using the padding you get from first part, we add 0s for padding. (10 points)

4 Morphology (20 points)

Suppose we have an input image which is $\begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$ and a mask which is $\begin{pmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{pmatrix}$

- Performer an Erosion operation on the input image with the given mask. (10 points)
- Performer an Dilation operation on the input image with the given mask. (10 points)

5 Image Formation (15 points)

1. Please name all the possible shapes produced in an image under perspective of:
   - A scene containing one disk, you may assume the disk has a non-zero radius, and the disk is very thin. (5 points)
2. Suppose you have a camera (unit aspect ratio, optical center at (0,0), no skew) that takes a picture here on earth. Now suppose we have a new world where everything is half (1/2) as large, including distances between objects. Assuming perspective projection, compare the two images and provide your explanation as to how the two images differ from each other with proper reasoning. (10 points)

6 2D Transformations (20 points)

There are two steps in the house transformation shown below to map a point (x, y) to (x', y'): translation, and rotation.

The transformation between the first and the third 2D coordinates is

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = R \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}, \text{ where } R = R_{\text{rotation}} \cdot R_{\text{translation}}.$$

Suppose $P_1 = (7, 15)$ in the first coordinate and $\theta = 45°$, calculate the transformation matrices $R_{\text{translation}}$, R_{rotation}, and R (5 points each for $R_{\text{translation}}$, R_{rotation}, 10 points for R).

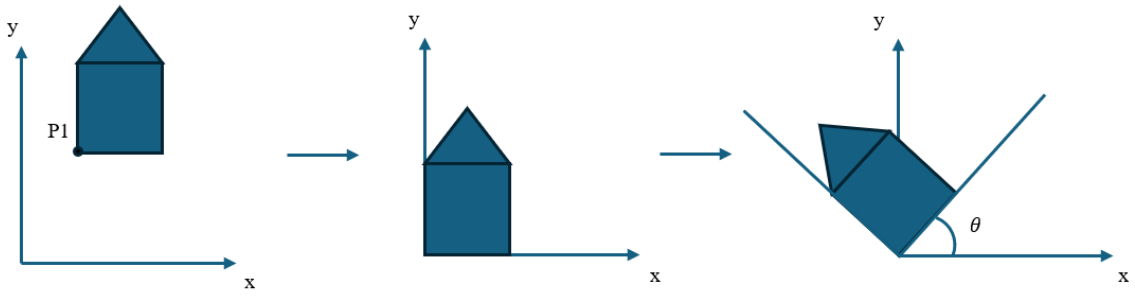

Figure 1: Transformation steps