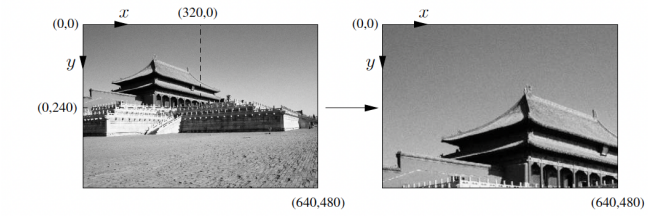
CS 682 Computer Vision Exam (J. Košecká), Spring 2024

YOUR NAME:

HONOR SYSTEM: This examination is strictly individual. You are not allowed to talk, discuss, exchange solution, with other fellow students. Furthermore, you are ONLY allowed to use the book and your class notes. You may only ask questions to the class instructor. Any violation of the honor system, or any of the ethic regulations, will be immediately reported according to George Mason University honor court.

1. (5) Image cropping. Compute coordinate transformation between pixels of the same points between two images, where image 2 is obtained by cropping by half in both x and y direction and then upsampling to the original size. Original image is of size 640×480 pixels it is cropped by half ad then upsampled to original 640×480.

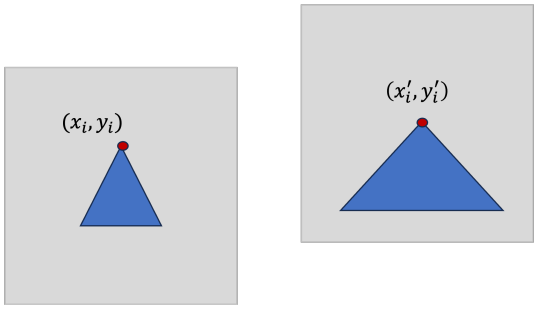


2. (5) The Sobel filters S_x and S_y are given below and are related to a particular approximation of Gaussian kernel G_S:

$$S_x = \begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix} \qquad S_y = \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix} \qquad G_S = \begin{pmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{pmatrix}$$

Show that if the input image is I and we use G_S as our Gaussian filter, taking the horizontal-derivative I_x of the Gaussian-filtered image, can be approximated by applying the Sobel filter (i.e., computing $I * S_x$).

3. (12) Consider two images with two sets of corresponding points related by special transformation A, that is parametrized by translation $[t_x, t_y]$ and scaling s_x and s_y along x and y axes respectively (see figure).



(2) Write down an equation relating two image coordinates $[x_i, y_i]^T$ and $[x_i', y_i']^T$ are related by this transformation A.

(2) How many point correspondence do you need to estimate this transformation ?

(3) Write down linear constraint in the form of $A\boldsymbol{x} = b$ used for estimating the unknown parameters.

(3) Describe how the RANSAC algorithm could be used to estimate parameters of this transformation. In two sentences explain the main idea behind RANSAC and write in words the pseudo-code of such algorithm.

(2) How many samples are needed in order to obtain the estimate of the affine transform with .95 accuracy assuming that the points are contaminated with 30% of outliers ?

4. (10p) **Estimating Planar Essential Matrix.** Suppose that you have two views of a scene captured by a camera which undergoes a planar motion. Assume for simplicity that the optical axis of the camera is z, y-axis is pointing down and x-axis is pointing to the right. In this setting the camera moves in $x - z$ plane and can rotate around y-axis.

   (a) (4) Write down the essential matrix corresponding to the planar motion, *i.e.* write down the individual entries of the matrix as a function of motion parameters.

   (b) (2) What is the minimal number of corresponding points needed to estimate the planar essential matrix ?

   (c) (4) Given the planar essential matrix come up with a simplified way to decompose it into rotation and translation (using basic trigonometry).

5. (15) Short questions and explanations

(3) What is depth of field in computer vision, and how does it relate to the concept of focus? How can depth of field be controlled through the use of camera parameters such as aperture, focal length, and distance to the subject, and what are the trade-offs associated with each parameter?

(3) What is a difference between Gaussian smoothing and median filtering? How would you decide to use one vs. another ?

(3) What is a characteristic scale of image location and how to compute it ?

(3) Consider an image with multiple corner detections obtained using the Harris corner detector. Due to noise or other factors, some of these detections may be false positives, and some may be duplicates of the same corner. Describe how non-maximum suppression can be used to obtain a list of only the most confident and non-overlapping corner detections.

(3) What are separable filters in computer vision ? How can separability be utilized to improve the computational efficiency of image filtering operations, and what are some examples of commonly used separable filter kernels in computer vision applications?

6. (8) Consider a multi-class logistic regression parameters for classification for the classes A, B, C with the weight vectors $w_A = [1, -4, 7]^T, w_B = [2, -3, 6]^T, w_C = [7, 9, -2]^T$ Suppose a new example arrives, which has feature vectors $f(x) = [-2, 1, 3]$ and label B.

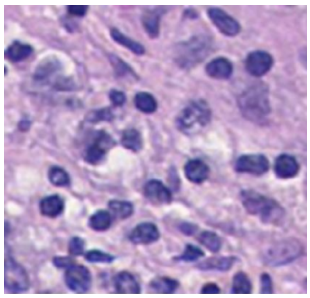
   (2) Show how is the example classified and why.

   (3) In this second step consider the following weight update of the multi-class classifier and use the new example, where you i is the correct class of the example and j is the incorrectly class in case the example was incorrectly classified. Assume $\alpha = 1$. What are the resulting weights w_A, w_B, w_C after the update ?

   $w_i = w_j + \alpha f(x_i)$
   $w_j = w_j - \alpha f(x_i)$

   (3) Mention three advantages of using Support Vector Machines for linear classification problem ?

7. (4) Consider a problem of designing computer vision algorithm for automated analysis and counting of the cells captured by microscope. An example image is below. Describe a method based on techniques discussed in the class that takes the images and detects the cells and their size and counts them.



(4) Consider a problem of applying computer vision technique for processing the video data from a camera perched above a conveyor belt on which customers place their produce (apples, oranges, broccoli, etc), and automatically computes the bill. Your response should be a list of concise, specific steps, and should incorporate at least two techniques covered in class thus far. Specify any important assumptions your method makes.