BIOS7718 Introduction to Biomedical Image Analysis
Assignment Two
Due: April 7, 11:59PM

Submit source codes and a report to Canvas. The source codes should be properly documented such that they are readable.

P1 (40%) In this problem, we want to use RANdom SAmple Consensus (RANSAC) to estimate the inliers in the presence of a number of outliers.

P1.1 (20%) Suppose that there is a 3D line as follows

$$\begin{aligned} x^o + 2y^o + 3z^o &= 1, \\ x^o - y^o &= 0. \end{aligned} \tag{1}$$

Generate $n = 30$ data points $\{(x_i^o, y_i^o, z_i^o)\}_{i=1}^n$ from this line by setting $x_i^o = 0.4, 0.41, 0.42, ..., 0.69$. Each of these inliers is then corrupted with Gaussian noise $(\delta x_i, \delta y_i, \delta z_i) \sim \mathcal{N}(\mathbf{0}, 0.03^2\mathbf{I}_3)$, where $\mathbf{I}_3$ is a 3×3 identity matrix. Generate 100 outliers that are uniformly distributed between $(0, 0, 0)$ and $(1, 1, 1)$.

Set the desired probability of choosing at least one trial free from outliers as 0.99. Select a proper number of trials k and a threshold t for identifying a point that fits well. Please use RANSAC to estimate the inliers. Plot all the input data points (including both true inliers and outliers) in one figure, and mark the *estimated* inliers with a different color. How many true inliers are detected? How many outliers are classified as inliers? Please also plot the estimated line in the same figure.

P1.2 (20%) Suppose that there is a second 3D line as follows

$$\begin{aligned} x^o + y^o + z^o &= 1, \\ x^o - y^o &= 0. \end{aligned} \tag{2}$$

where $m = 20$ points are generated by setting $x_i^o = 0.4, 0.41, 0.42, ..., 0.59$. The inliers are then corrupted with Gaussian noise $(\delta x_i, \delta y_i, \delta z_i) \sim \mathcal{N}(\mathbf{0}, 0.01^2\mathbf{I}_3)$. In total we have $n + m = 50$ inliers in two structures and 100 outliers like before. Can you use RANSAC to iteratively (one line after the other) to estimate both lines? Show estimated inliers (use different colors to represent two structures) in one figure. Draw the two estimated lines in the same figure.

P2 (30%) Object detection using Hough transform.

P2.1 (15%) Apply Hough transform to circle detection, i.e., finding two car wheels in the *P2_car.png* image (given as a separate file). You might want to use a Gaussian filter to smooth the image before edge detection, which will be used for the Hough transform. Please draw the detected circles on the original image.

P2.2 (15%) Apply Hough transform to nucleus detection, i.e., localizing individual nuclei in the *P2_nuclei.png* image. You can convert the RGB image to a grayscale one (e.g., using cv2.cvtColor in Python or rgb2gray in Matlab) and then detect individual nuclei. Please mark the detected centers on the original image and provide the number of detected nuclei.

P3 (30%) Object segmentation using watershed transform.

P3.1 (20%) Apply marker-controlled watershed to image segmentation for *P3_coins.png* [1]. You might want to use the erosion morphology operation to find the markers. Please draw the segmented boundaries/contours on the original image and mark the contours with different colors, one per segment.

P3.2 (10%) Apply watershed (you can use any method to detect the markers) to object segmentation on another image, i.e., *P3_particles.png* [2]. Show and comment the segmentation results.

References

1. https://homepages.inf.ed.ac.uk/rbf/. Last accessed March 2019.
2. C. Park *et al.*: Segmentation, Inference and Classification of Partially Overlapping Nanoparticles, IEEE Transactions on Pattern Analysis and Machine Intelligence **35**(3), 669–681 (2013).