CS 4610/5335: Robotic Science and Systems (Spring 2021)
Northeastern University

Robert Platt

Due:

HW 7: Point Clouds

Please remember the following policies:

- Submissions should be made electronically via the Canvas. Please ensure that your solutions for both the written and/or programming parts are present and zipped into a single file.
- Solutions may be handwritten or typeset. For the former, please ensure handwriting is legible.
- You are welcome to discuss the programming questions (but *not* the written questions) with other students in the class. However, you must understand and write all code yourself. Also, you must list all students (if any) with whom you discussed your solutions to the programming questions.

Install MVTB-4.3 from `https://petercorke.com/toolboxes/machine-vision-toolbox/` and make sure your version of robotics toolbox for MATLAB is 10.4

V1. Plane fitting (**5 points**).
In this question, you are given a set P of 100 points and asked to fit a plane to these points. The output of these functions should be a point intercept of the plane (a 1×3 vector called "center") and the plane surface normal (a 1×3 vector called "normal").

(a) hw7(1): Fit a plane by calculating the sample mean and covariance matrix of the points. You will need to obtain the Eigen values and vectors of the covariance matrix in order to complete this question.

(b) hw7(2): Run hw7(2) to see how your least squares fit plane works in the presence of outliers. How is this different from the result in part (a) and why?

(c) hw7(3): Fit a plane using a ransac based method. What are the strengths and weaknesses of each approach?

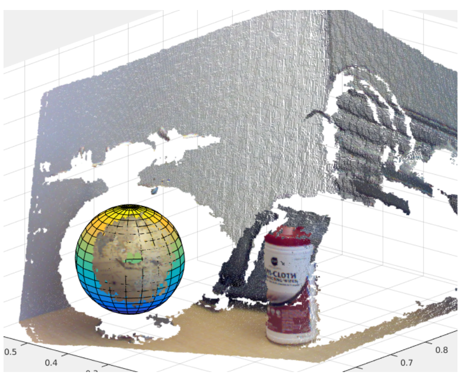

Figure 1: (a) the sphere localized in Q1.

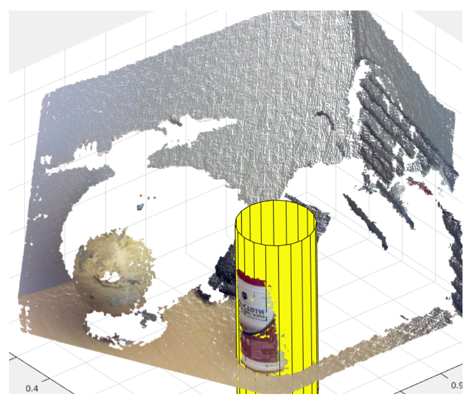

Figure 2: (b) the cylinder localized in Q2.

V2. Sphere fitting (**5 points**).
hw7(4): In this question, you must use RANSAC to localize a sphere given point cloud data. The point cloud contains a ball that is only partially visible to the sensor. The position of the center of the ball is unknown. The radius is unknown, but between 5cm (0.05m) and 11cm (0.11m). Write a function in Q1.m that calculates these two quantities. You can test your code using the cropped point cloud (see commented hw3.m). But, you should submit code that works on the entire point cloud without cropping. Important: please do NOT use the built-in Matlab function for sphere fitting. However, you MAY use the built-in function for computing surface normals, PCNORMALS.

Hint: one way to generate sphere hypotheses is as follows:

(a) sample a point from the cloud;

(b) sample a radius of the candidate sphere between 5 and 11cm;

(c) project a vector from the sampled point in the direction of the associated surface normal for a distance equal to the sampled radius. This point would be at the center of the candidate sphere.

V3. Cylinder fitting (**5 points**).
hw7(5): Same as V3 except for a cylinder. This question is harder because you need to calculate the center, the orientation, and the radius (between 0.05m and 0.1m). The orientation should be returned in the form of a unit vector pointing along the axis of the cylinder (either direction is fine). You only need to solve this problem for the segmented cloud, as implemented in the code.

Hint: one way to generate cylinder hypotheses is as follows:

(a) Sample a radius for the candidate cylinder between 5 and 10 cm.

(b) Sample two points from the cloud

(c) Set the cylinder axis direction equal to the direction of the cross product between the surface normals associated with the two sampled points.

(d) Pick one of the sampled points from the cloud and use it to estimate a candidate center, just as you did in Q1.

(e) Project the points in the cloud onto the plane orthogonal to the axis you just calculated. You can do this projection by multiplying the points in the cloud by this matrix: $I - \hat{a}\hat{a}^T$, where $\hat{a}$ is equal to the axis of the cylinder. Also project the candidate center into this plane in the same way.

(f) Evaluate number of inliers in the plane for a circle with the given projected center and the sampled radius.