MTRN4110 - Project #1, Part B

The objective of this project is obtaining experience about using our sensors' data. This type of processing is intended to be performed in real-time (i.e. when it is actually needed). However, in this project, we start playing in an off-line fashion, i.e. we use data we recorded before, and we process it, under no real-time constraints. In subsequent projects, you will adapt and use these programs for processing sensors' data in an on-line fashion (i.e. when the action actually occurs).
Project 1 is divided in two parts. Part A focuses on integrating the gyroscopes (initially, in a simplified context). Part B involves processing images from a 3D camera. Both sensors are intensively used in subsequent projects and are instrumental for the robot's perception component.

In this part of Project 1, you are required to process the camera's depth images for inferring the floor inclination respect to the camera which was installed on a hexapod. This inclination is time varying, due to body's oscillations when the hexapod walks. The camera was installed having certain inclination, which can be modified by us, when we use the platform; consequently, we cannot assume a fixed value.
For that purpose, you are required to solve the following steps,

0) Read the provided program, to understand how to use the data. Show the raw data (3D points cloud).
1) Choose a region of interest (ROI) in the image (express it in pixels coordinates), so that it usually covers an area ahead the robot, covering the floor ("usually", but not necessarily “always”).
2) Show the boundaries of the ROI, in the 3D image, when the 3D pints cloud is visualized.
3) Use the ROI's associated 3D points for obtaining estimates of the inclination of the floor (relative to the sensor).
   3.1) Obtain an estimate of the normal of the floor's plane.
   3.2) Show the estimated normal vector; e.g. show the vector at one of the points associated to your ROI. You may need to scale the vector, so it appears easily visible.
   Use a regression method for solving this part. You must understand the approach you apply. Recommended approaches: Least Squares, SVD or other well-known method for linear regression.
   Assume that all the points which are covered by the ROI are part of the floor.
4) Based on the results obtained in (3), estimate the camera's roll and pitch. Considering the estimated angles, rotate the original set of 3D points, in a way that the floor would appear aligned horizontally. We call those points the “aligned 3D points”. Show the aligned points in a figure. The figure must be refreshed for each new depth image being processed.
5) Refine items 3 and 4. In this case, you will not assume that the ROI is always fully composed by floor's points. Consequently, you only accept the estimates of the normal vector, if you are sure that all the points of the ROI seem to belong to the same surface/plane.
   Hint: Well-known methods for linear regression usually provide information for indicating the quality of the approximation. Exploit that capability.

You need to investigate, and propose, how to estimate the plane that contains the set of points that you specify. As the points are noisy and because the ROI may be covering surfaces that are not part of the floor, a perfect solution would not exist. However, you can obtain an approximation (e.g. through least squares or similar approximating process). You assume that all those points (defined by the pixels associated to the ROI) are part of the same plane (even if some of them are not part of the floor).
However, you must not include pixels/points whose depths were clearly faulty (camera failed to measure their distances). Faulty pixels are those having depth=0.

Validation of 3.1: at this stage, we will not validate these estimates against other sources (e.g. integrating gyroscopes' measurements). In this project, you will just verify, visually, that the estimated normal vector "looks" consistent (e.g. perpendicular to the floor).
If item 4 is implemented, the transformed 3D points would show the floor's surface almost horizontal.

Demonstration / Validation of results:

You will need to show evidence that your program is solving the required processing. You are required to apply your processing at a rate not lower than 1Hz. Each time that a depth image is processed, the results will be shown graphically, via Matlab's graphics. In one figure, the raw data (3D points, expressed in the camera's coordinate frame) will be shown as blue dots, and the normal vector through a red arrow (or a red segment). The size of the vector should be scaled, in order to be easily visible among the 3D points cloud.
You will also print (in text, in the console) the last estimated Roll and Pitch angles, expressed in degrees. You may, alternatively, display them using graphic objects, in your GUI, in place of printing them in the console.
For showing that you are calculating and applying the proper rotation, for compensating the estimated camera's roll and pitch, you will plot the rotated 3D points. In that image, the floor will appear to be almost horizontal.
This set of aligned 3D points can be shown in a different figure; alternatively, you may show them in the same figure used for the original data, selecting the mode of visualization by using a button or a checkbox, for showing the original (unrotated) or for showing the aligned 3D points.

Relevance (expressed as a percentage of Project1.PartB)

Item 0:	0% (it is provided by the Lecturer)	;	Items 1 and 2:	20%
Item 3:	32%	;	Item 4:	32%
Item 5:	16% (you can demonstrate this item during week 5, if you need more time.)			

(These percentages correspond to the items considering them well solved.)

Available data from experiments, for this task: "DepthData01.mat".
These images were taken from a depth camera, installed on one of MTRN4110's hexapods.

This task must be done during weeks 3 and 4, jointly with Part A.
You will give a demonstration of your program, on week 4 (during your lab session), and you will submit your program by the end of the same day. The submission will be done electronically, via Moodle. Instructions about the format of the submitted files will be given in week 3.
Part B represents 50% of the marks of Project 1.

If you have questions, ask the lecturer via MTRN4110's Moodle Forum or by sending an email (Email: j.guivant@unsw.edu.au).

A brief explanation about this task will be provided during the lecture.

Short video: https://youtu.be/5oclepKhwCo
