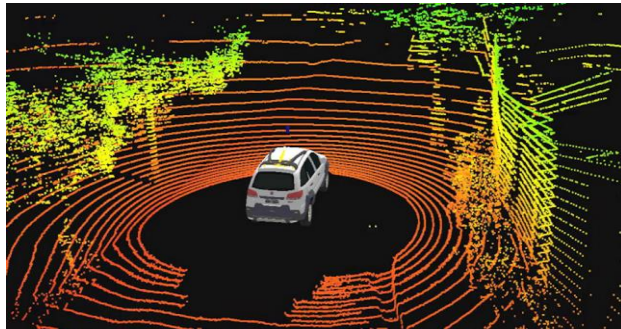


Prerequisites and preparation

In this work, the goal is to develop a C/C++ program to solve an engineering problem related to Artificial Sensor-based Perception: which finds applications in autonomous driving and mobile robotics navigation. In particular, a **ground/road detection system** will be developed having as input data from a 3D LiDAR sensor. The figure below shows, on the left, a point-cloud from a LiDAR (the Velodyne HDL-32 mounted on the roof of a car); on the right, the most usual Velodyne LiDAR models are depicted.



Point Cloud – the LiDAR is mounted on the car roof



LiDAR sensors from Velodyne

This practical assignment is divided in two parts. The **first part involves POSIX routines**, implemented in C, and the objective is to guarantee that the **threads do not run at the same time**. Therefore, it is necessary to explore and **understand the concept of Synchronization services**, namely **mutex** (it can be understood as a kind of **binary semaphore**). The second part requires the ROS (Robot Operating System) framework, and programming languages will be C/C++.

Practical Implementation (part I)

In this assignment we will write a program (in C), following POSIX routines [Ref1], to perform **detection of ground/road points from 3D Point-clouds**. This work comprises the following tasks:



1) write a code in C to open the file (*point_cloud1.txt*), read the values from the file and pass the values to arrays/matrix inside a **struct variable** (created by you). The values, organized in columns in the file, represent the 3D Cartesian (**x,y,z**) points of a Point-Cloud from a LiDAR with 16 channels/layers (ie, from the Velodyne VLP-16 sensor). Considering the LiDAR points-values in the **struct variable**, the program has to **calculate and print: the number of points**; the **minimum**, the **maximum** and the **average** values of each coordinate-axis (x,y,z); and also the **stand-deviation**. It is recommended to create a **function that receives** (as one of its arguments) **the file name and returns (the output) a pointer to the struct variable**. Using the same program, repeat the process for the files: *point_cloud2.txt* and *point_cloud3.txt*.



2) create another function that takes as input a pointer to the **struct variable** from the program developed previously (item 1). This function has to perform a “pre-processing” stage, namely:
2.1) remove all the points that are located in the “back/behind” part of the car with respect to the sensor (ie, negative values of **x**). Consider the **X axis is the longitudinal axis** and it is pointing ahead the car.



2.2) detect and remove two groups (clusters) of points that are located very close to the car - in the car forepart - **using any technique that you think may be necessary** (suggestion: a

visualization/display interface would facilitate this problem-solving: use Matlab or any software of your choice).

2.3) discard those points that clearly do not correspond to the ground/road (ie, the *Outliers*). The output of this function/routine, ie a processed point-cloud, should be write to the same *struct* variable that has been used throughout the exercise.

3) using, as input, the *struct* variable from before, developed a new function/routine to detect the points that belong to the drivable area with respect to the car, ie LIDAR points that belong to the ground/road.

4) Calculate (using *clock_gettime* based solution) and print the computation time associated to each of the three functions developed before. It should be guaranteed that the total computation time, considering all the *functions*, is less than 95 ms.

5) Write a program to run, in separate *threads*, each of the functions developed in the previous exercises: items 1, 2 and 3. It is mandatory to avoid all the three threads access the “*point-cloud variable*” at the same time (ie, to avoid they read-write data concurrently in the same memory location associated with the so called *struct* variable). Therefore, it is necessary to use synchronization primitives (eg, *mutex*). In other words, only one *thread* can access or write in the *struct* variable while the other threads should wait their turn to work on the *struct* variable.

Notes:

The *threads* will be activated in a sequential manner: thread#2 will process the data after thread#1 concludes its operation, and so on. The activation frequency is 10Hz (ie, a new Point-Cloud is available every 100ms) and it is the same for all *threads*.

Practical Implementation (part II)

This part of the exercise requires the ROS (Robot Operating System) framework, and programming languages will be C/C++. First, install ROS Kinetic on your Laptop. Alternatively, you can use the Desktop machines available in the Lab. It is recommended to install ROS under a LTS Ubuntu release (16.04): <http://wiki.ros.org/kinetic/Installation/Ubuntu>

It is only necessary the “Desktop Install” version: *sudo apt-get install ros-kinetic-desktop*

Note: for more details, see the [Ref2] ‘*Supp_material1_ROS.pdf*’

6) Adapt the program(s)/code(s), for the first *thread*, in order to perform the conversion of the message type *sensor_msgs::PointCloud2* (LIDAR sensor message format) to the message format *sensor_msgs::PointCloud*. Moreover, the output of the third *thread* should be published, as *geometry_msgs::PointCloud*, to a topic named “output_results”: this will allow offline visualization using Rviz.

Notes:

- An example of ROS implementation is provided in [Ref2]
- See http://docs.ros.org/api/sensor_msgs/html/namespacesensor__msgs.html (convertPointCloud2ToPointCloud)
- The PointCloud (global) from the Rosbag file has to be passed to the (local) *struct* variable.

References

[Ref1] The IEEE and The Open Group. [POSIX Specification] The Open Group Base Specifications Issue 7; IEEE Std 1003.1TM-2008, 2008. [Online]. Available: <http://www.opengroup.org/onlinepubs/9699919799/>.

[Ref2] L. Garrote, C. Premebida; “Robot Operating System (ROS)”. Supplemental material; File: ‘Supp_material1_ROS.pdf’.

[Ref3] Rui Araújo; “Sistemas de Tempo Real: Apontamentos Teóricos (Parte I)” ; File: ‘actstr17.pdf’.

[Ref4] Rui Araújo. “Sistemas de Tempo Real - 2014/2015”. [Online]. Available: <http://home.isr.uc.pt/~rui/str/str1415.html>.

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