Point Clouds and 3D Modelling
TP6: Modelling

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Question 1 The major plane in our point cloud will be the floor. With around 135.000 points on average. Detected by classical RANSAC. (with initial settings : $NB\_RANDOM\_DRAWS = 100$ and $threshold\_in = 0.05$)

Question 2 Let C be a point cloud and $F \subset C$ be the subset of this point cloud containing the points from the floor.

The probability that a random point $x \in C$ picked randomly belongs to the floor is thus $\Pr(x \in F) = \frac{|F|}{|C|}$. We note p this probability.

One can consider that the floor plane is detected by RANSAC if and only if the three random points x_1, x_2, x_3 randomly picked to initialise the plane are in F. Define the event $A = (x_1 \in F \cap x_2 \in F \cap x_3 \in F)$.

The probability of this event is:

$$\begin{aligned}\Pr(A) &= \Pr(x_1 \in F)\Pr(x_2 \in F)\Pr(x_3 \in F) \quad \text{since those events are mutually independent} \\ &= p^3\end{aligned}$$

Assume that RANSAC algorithm computes T planes and chooses the best. Note A_t the probability that the floor is selected the t-th time.

Since the floor is the best plane the algorithm could ever produce, the probability that it is chosen is:

$$\begin{aligned}\Pr\left(\bigcup_{t=1}^{T} A_t\right) &= 1 - \Pr\left(\bigcap_{t=1}^{T} \bar{A}_t\right) \\ &= 1 - \prod_{t=1}^{T} \Pr(\bar{A}_t) \qquad \text{since the } A_t\text{s are mutually independent} \\ &= 1 - (1-p^3)^T \qquad \text{since } \forall t, \Pr(A_t) = \Pr(A) = p^3\end{aligned}$$

Then, this probability is more than 99% iff:

$$\begin{aligned}1 - (1-p^3)^T > 0.99 &\iff (1-p^3)^T < 0.01 \\ &\iff T\log(1-p^3) < -2 \\ &\iff T > \frac{-2}{\log(1-p^3)}\end{aligned}$$

There are approximately 135000 points in the floor, and 412756 points in the total point cloud. We thus approximate $p = |F|/|C| \simeq 0.33$.

Therefore, one must choose $T > \frac{-2}{\log(1-0.33^3)}$, i.e. $T_{\min} = 126$.

Question 3 The Multi-Ransac always selects the floor but also selects horizontal planes whereas one would like to select the walls (see figure 1.

The problem is the general shape of our model is flat and therefore has more points horizontally than vertically. Even if we are not selecting the floor, a horizontal slice of the wall has at least 25.000 points (can be increased if taking diagonal slice) and a vertical slice of the walls has less then 20.000 points. An other bias is that with this general flat shape, we are more likely to randomly select a horizontal plane.

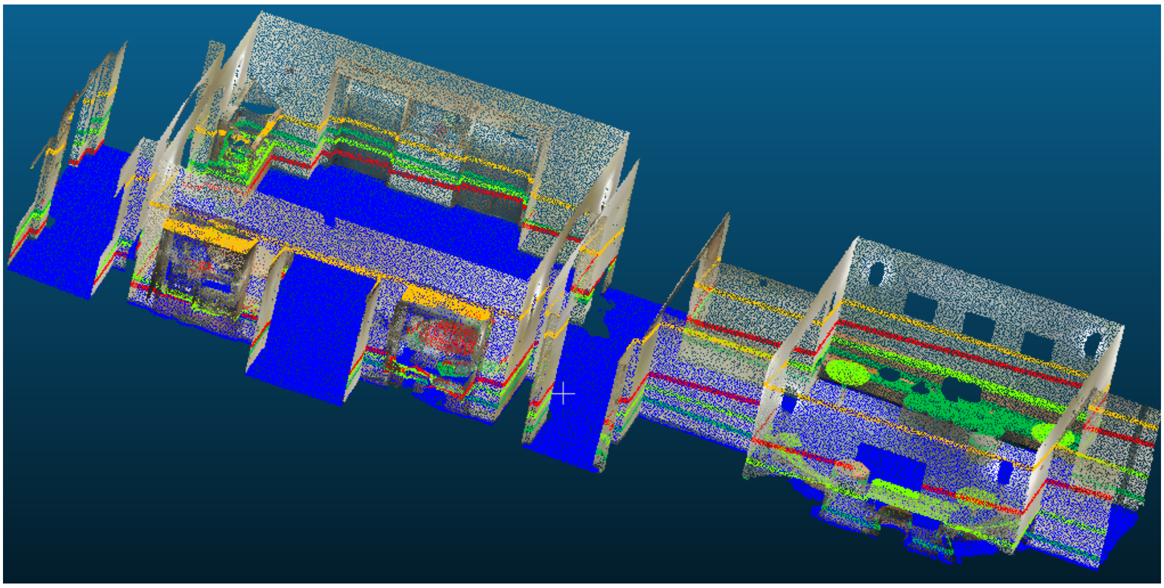

Figure 1: CloudCompare visualization of the planes detected by RANSAC algorithm ($m = 5$).

Question 4 The choice of the radius depends on the density of the point cloud, since if it is too small, some parts of the point cloud cannot be reached from any seed. In the other hand, if the radius is too high, the number of neighbors at each step is huge and the probability that some of them are false positives increases. Therefore, some different planes can be seen as the same one, and some details can be lost.

The distance threshold between point and plane should be adjusted depending on how smooth the surfaces are, and how precise the scans are. If this threshold is too small, a quite irregular surface (e.g. like an old brick wall) could not been detected as a single plane. In the other hand, if it is too big, important details like windows could be confused with the plane they lie on, even if they are not clearly part of it.

The normals angle threshold is quite complementary to the distance threshold, since it enables to separate two planes when there is an edge. If it is too high, the edge will not be properly rendered, and on the other hand if it is too small planes detection can be compromised, especially when data is noisy.

Finally, the queue threshold indicates the tolerance one accepts to determine whether a surface is a plane or not. Therefore, if it is high only very regular planes will be considered as ones (e.g. noisy data will not be covered) whereas if it too low the risk is that even surfaces that are not planes could be detected as ones.

Question 5 The problem when choosing a random seed is that this point may not belong to a plane; then trying to build a plane from that point is meaningless and cannot work.

A good way to be almost certain that the seed belongs to a plane could be to choose the seed as the point with highest planarity, since this descriptor is designed to be maximal when the point belongs to a plane.

Question 6 Figure 2 shows a screenshot of 20 planes detected by the Region Growing algorithm. In order to have a better visualization, one can zoom in or visualize the point clouds by running

`cloudcompare.Cloudcompare *.ply`

in folder `results/RegionGrowing` (choose `plane_label` in the "Scalar" field=.

The first big advantage of Region Growing compared to RANSAC is that it works in situations in which RANSAC fails (see figure 1). Moreover, it does not implies some random steps and is thus deterministic, contrary to RANSAC. Moreover, it is a quite fast algorithm, which is quite easy to implement. An other advantage is that there are more parameters, so even if it can be more painful to finetune them, it is in practice very convenient to be able to control to what extent the algorithm accept irregular surfaces, etc. (refer to question 4 for more details about those parameters).

However, even if choosing seeds by maximal planarity reduces the probability to choose bad seeds, this descriptor is highly dependent of the radius used and is also sensitive to noise, then so is the main algorithm. In the other hand, RANSAC is not sensitive to noise since it just chooses the plane containing the more points with high probability.

Moreover, planes computed with Region Growing algorithm do not have clear mathematical guarantees, whereas one can measure the probability that RANSAC returns the best plane to some sense.

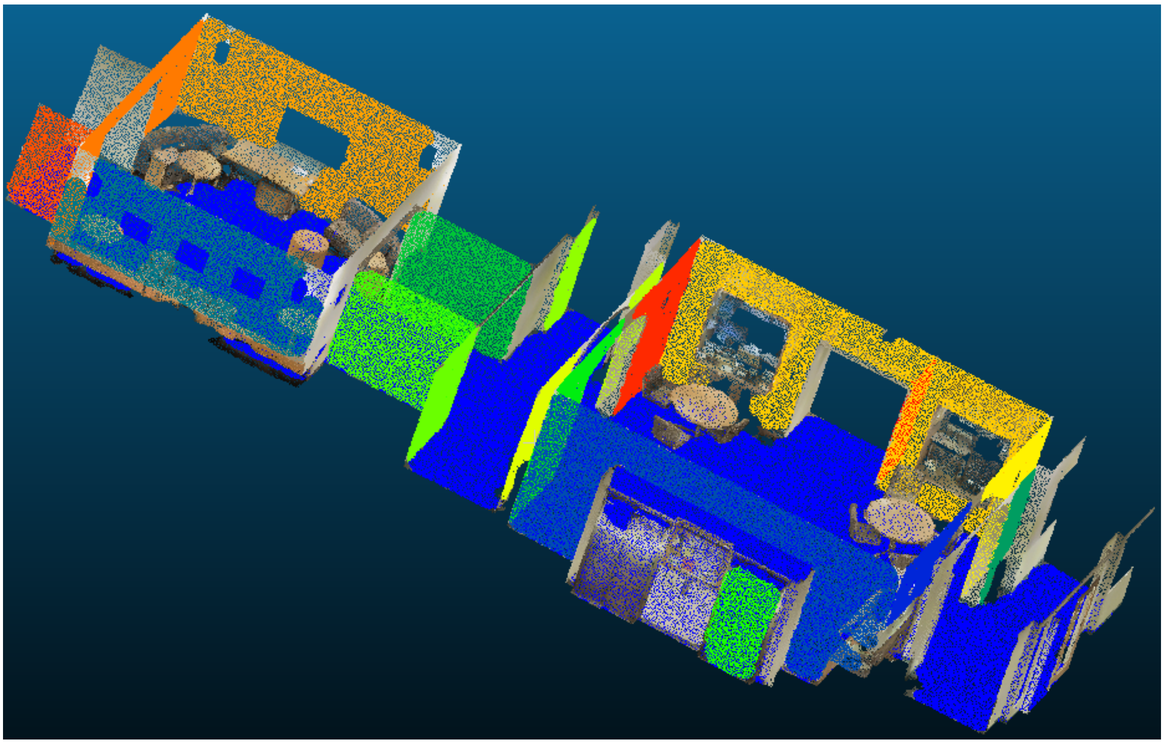

Figure 2: CloudCompare visualization of the planes detected by Region Growing algorithm ($m = 20$).