Mines Paris — PSL
Intelligence Artificielle, Systèmes et Données (IASD)
Nuages de Points et Modélisation 3D
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Question 1: How well does ICP perform on those examples? What is the difference between the aligned cloud and the reference cloud? In the last example (Notre Dame), which cloud should be the reference and why?

1. By taking the files *bunny_original.ply* and *bunny_perturbed.ply*, we have an almost perfect match (something observable from *Figure 1*). Using Cloud Compare, we calculate the RMS at 2.98e-09.

(a) (b)

Figure 1: (a): The two .ply files before ICP is performed on them. The yellow graphic represents the reference and the red one represents the one to be aligned. (b): After ICP is performed, where there's almost a perfect match.

2. In this case, the two plots, *bunny_original.ply* and *bunny_returned.ply*, we observe that the distance is bigger between the points, meaning that ICP will probably take longer. After the tryout using Cloud Compare, ICP not only took longer, but it also didn't achieve a good score of RMS, managing to get 0.0133531. This is observable in *Figure 2*, where we don't have good alignment of the bunnies, except on its torso.

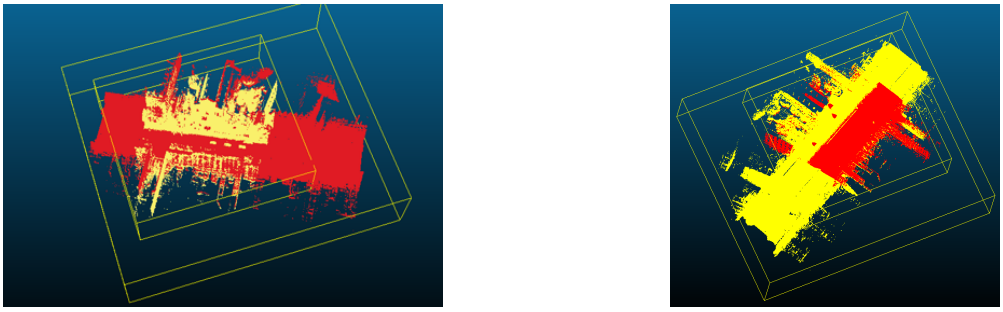
3. In the case of the *Notre_Dame_Des_Champs_1.ply* and *Notre_Dame_Des_Champs_2.ply* files, we have of problem of size, as they don't match each other, as the first .ply file is a lot bigger. In this case we proceed with two different cases.

(a) (b)

Figure 2: (a): The two .ply files before ICP is performed on them. It's easily observed from before that it will be a harder task to perform ICP as the graphics don't match. (b): After ICP is performed. The result is not ideal, but a big area is aligned.

Case 1: We align with the bigger .ply and use the smaller one as a reference. This lead to a very bad RMS value of 12.646.

Case 2: We align with the smaller .ply and use the bigger one as a reference. This proves to be the better case, as it manages to perform a lot better, achieving an RMS of 1.320.



(a) (b)

Figure 3: (a) **Case 1**: We see that the bigger graphic needs to be aligned (Red) and the reference takes only a small part of it. (b) **Case 2**: The smaller one now needs to be aligned, making it easier to connect its dots as the reference is bigger.

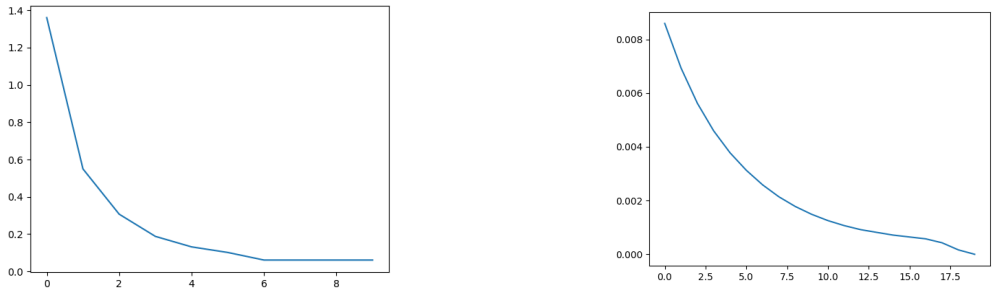
As it's clear from the results of the two cases, it's better for the reference should be the big cloud because the smaller cloud points are close to the points they need to be matched with in the bigger cloud. The opposite is not true: the big cloud has more points and some on the edge do not even match with the smaller cloud

leading to a problematic and flawed alignment. In other words, it's better to have *Notre_Dame_Des_Champs_1.ply* as the reference. If we choose the bigger cloud as reference, some of the points on the edge eventually become outliers because the loss in ICP takes them into account square distances terms, even though we do not want to match them.

Question 2: Report the RMS errors obtained. Why did the alignment worked while CloudCompare ICP could not align those two clouds? Would this function align the 3D scans of "Notre Dame des Champs"? Why?

By using our custom optimization implementation, the point clouds match, and the RMS changes from 0.161 to 0.000. The alignment works because every point on cloud reference has a matching point on cloud source. It is not the same as Cloud Compare ICP, as it iterates this optimization on closest points of source to the reference. The algorithm, on the other hand, has an analytical solution for matching point clouds. Being that the case, it cannot work for Notre Dame since the number of points do not match.

Question 3: Plot the RMS during ICP convergence for those two examples (2D and bunny).



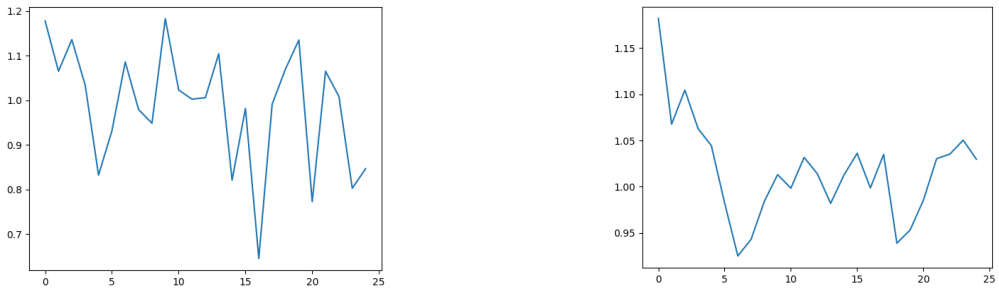
(a) (b)

Figure 4: (a): Convergence plot for *ref2D.ply* and *data2D.ply*. (b): Convergence plot for *bunny_original.ply* and *bunny_perturbed.ply*

Question 4: Comment on the two previous curves.

The 2D case (a) converges faster, as seen from the sharp initial drop and early stabilization. The bunny case (b) exhibits a slower convergence, due to higher dimensionality and surface complexity. The ICP algorithm is more efficient for simpler cases like 2D point clouds, whereas in 3D, especially with complex surfaces, more iterations are needed for alignment.

Question Bonus: Plot the RMS (computed on all points) during ICP convergence for the "Notre Dame Des Champs" clouds with 1,000 and 10,000 points used at each iteration. What do you think of those curves?



(a) (b)

Figure 5: (a): Convergence plot of *Notre_Dame_Des_Champs_1.ply* and *Notre_Dame_Des_Champs_2.ply* for 1,000 points. (b): Convergence plot for 10,000 points.

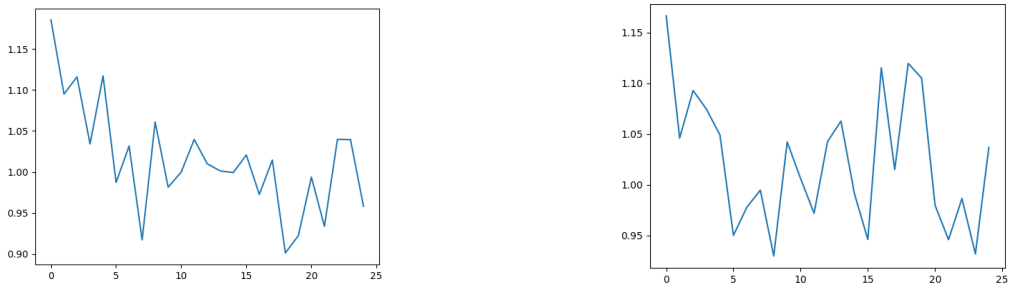


Figure 6: Additional attempts for 10,000 points

From *Figure 5* we observe that there is no convergence for 1,000 and 10,000

points. There is a great deal of instability on both. One main difference that we can note, by adding more tryouts to the 10,000 points, is the fact that we can observe that it is slightly more stable for 10,000 points, but it achieves higher RMS than with less points. Finally, we come to the conclusion that, while this trick can work for clouds that require a high computational time, in the case of these two clouds that consist of a lot of points, it does more harm than good.

In the case of even more points, we conducted a trial of 100,000 of them. The result, seen in *Figure 7* was still problematic, with a higher RMS than 1000 points and still no sign of convergence. But the graph manages to be a little more stable.

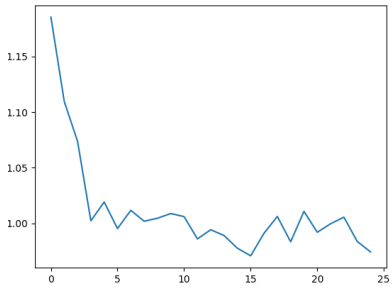


Figure 7: Convergence graphic for 100,000 points