

Computer Vision AI – Assignment 1

Iterative Closest Point - ICP

April 11, 2014

The practical course consists of three assignments which will be combined under one final report at the end of the course (exact date of delivery will be specified later). The analysis, the conclusions and the source code must be included in the final delivery. Students should work on the assignments in groups of three. Students are supposed to work on this (first) assignment for two weeks.

README file contains the information about the provided data for this assignment.

1 Iterative Closest Point - ICP

ICP algorithm is first introduced by Besl and McKay (See [1] for details). Considering two point-clouds A_1 (base) and A_2 (target), ICP tries to find a spatial transformation that minimizes the distance (e.g. Root Mean Square (RMS)) between A_1 and A_2 which can be defined as

$$RMS(A_1, A_2, \psi) = \sqrt{\frac{1}{n} \sum_{a \in A_1} \|a - \psi(a)\|^2} \quad , \quad (1)$$

$$\min_{\psi: A_1 \rightarrow A_2, t \in \mathbb{R}^d, R \in SO(d)} \sum_{a \in A_1} \|Ra - t - \psi(a)\|^2 \quad . \quad (2)$$

where R , t and $SO(d)$ are the rotation matrix, the translation vector and the set of special orthogonal matrices in d dimensions, respectively. ψ is one-to-one matching function that creates correspondences between the elements of A_1 and A_2 . R and t that minimize above equation are used to define camera movement between A_1 and A_2 .

1.1 Implementation

In this assignment, student will implement the ICP algorithm and some of its variants to estimate the camera poses for given point-clouds (#####.pcd). First, the basic ICP algorithm will be implemented:

1. Initialize $R = I$ (identity matrix), $t = 0$.
2. Find the closest points for each point in the base point set (A1) from the target point set (A2) using brute-force approach.
3. Refine R and t using Singular Value Decomposition (See doc1, Section 2.3, for details).
4. Go to step 2 unless RMS is unchanged.

There are different ways to improve the efficiency and the accuracy of ICP. Some of these techniques are discussed in [2]. In this assignment, students should also analyze various aspects such as accuracy, speed, stability and tolerance to noise by changing the point selection technique. Using all the points, uniform sub-sampling, random sub-sampling in each iteration and sub-sampling more from informative regions can be used as the point selection technique. Students are expected to implement these variants and report their findings in the final report.

Students can use existing k-d tree search implementations to speed up ICP process (<http://www.vlfeat.org/overview/kdtree.html>).

2 Merging Scenes

2.1

Estimate the camera poses using each two consecutive frames of given data (ICP implemented in Section 1.1). Using the estimated camera poses, merge the point-clouds of all the scenes into one point-cloud and visualize the result.

Does the merging produce sufficient result? Discuss why.

Now, estimate the camera pose and merge the results using every 2^{nd} , 4^{th} , and 10^{th} frames. Does the camera pose estimation change?

2.2

Iteratively merge and estimate the camera poses for the consecutive frames (point-clouds). Supposed there are N frames ($frame_1, frame_2, \dots, frame_N$). First, estimate the camera pose of $frame_2$ (target) from $frame_1$ (base). Next, merge $frame_1$ and $frame_2$ into $frame_{1,2}$. Then, estimate the camera pose of $frame_3$ (target) from $frame_{1,2}$ (base) and use it to merge $frame_{1,2}$ and $frame_3$ into $frame_{1,2,3}$ and so on until reaching the final frame ($frame_N$). Do the estimated camera poses change in comparison with the previous estimates (Section 2.1)? **Does this estimation produce better results?**

3 Questions

1. **What are the drawbacks of the ICP algorithm?**

2. How do you think the ICP algorithm can be improved, beside the techniques mentioned in [2], in terms of efficiency and accuracy?

References

- [1] P.J. Besl and Neil D. McKay. A method for registration of 3-d shapes. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 14:239–256, 1992.
- [2] Szymon Rusinkiewicz and Marc Levoy. Efficient variants of the ICP algorithm. In *Third International Conference on 3D Digital Imaging and Modeling (3DIM)*, 2001.