ES – 637 MATHEMATICAL FOUNDATIONS FOR COMPUTER VISION AND GRAPHICS ASSIGNMENT 1

Iterative closest point

Introduction

ICP is used to iteratively minimise the difference between two rigid point clouds. In ICP, one point cloud , the reference cloud is kept fixed while the source cloud is linearly transformed to match the reference. With each iteration the algorithm refines the transformation matrix, thereby minimising an error metric, usually the Euclidean distance between the coordinates of the matched pairs.

Algorithm

1. For each point in the source point cloud, match the closest point in the reference point cloud by using a feature descriptor (e.g. SIFT, SURF).(p and q are matched points)
2. Compute the weights corresponding to each matched point using gaussian metric. Matched points with higher distance is given lower preference.
3. Compute the weighted centroids of both the point sets:
$\hat{p} = \sum_{i=1}^{n} w_i p_i / \sum_{i=1}^{n} w_i$ and $\hat{q} = \sum_{i=1}^{n} w_i q_i / \sum_{i=1}^{n} w_i$
4. obtain the corresponding mean shifted point sets :
$x_i = p_i - \hat{p}$, $y_i = q_i - \hat{q}$
5. Compute the cross-covariance matrix, S of X, W, Y and compute the SVD of the covariance matrix
$S = XWY^T$ and $S = U\sum V^T$
6. Obtain the rotation matrix by the following relation:
$$R = VU^T$$
7. Translation matrix is obtained by
$$T = \hat{q} - R * \hat{p}$$
8. Transform the source points using the obtained transformation : $\acute{p} = R * p + T$
9. Iterate over the transformed points until the error (Euclidean norm) stops changing.

Implementation details

- Implemented in python 2.7, OpenCV 3.3.0. FLANN and SIFT have been removed in OpenCV version 3 and above. Therefore using OpenCV contrib python 3.3.0 packages.
- Used FLANN with SIFT for feature extraction with nearest neighbour = 2.

- Used gaussian metric to compute the distance. Since the distance between the matched points is of the order of 100, use of sigma = 30 gives good results.
- Used Euclidean norm to estimate error between point sets.
- Iterations are done until the change in error(Euclidean norm of point sets) < 0.001.

Results

source image 1(467.png)

source image 2(472.png)

transformed image 1

transformed image 2

reference image 1(472.png)

reference image 2(480.png)

References

- https://github.com/ClayFlannigan/icp
- https://docs.opencv.org/trunk/dc/dc3/tutorial_py_matcher.html
- https://docs.scipy.org/doc/numpy-1.13.0/reference/index.html
- http://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_tutorials.html