Acquisition of a threedimensional model through Microsoft Kinect



The Microsoft Kinect

- RGB camera sensor
- IR projector and sensor
- Microphones array
- Three axis accelerometer



The Microsoft Kinect

30 fps:

• RGB: 640 x 480 pixels; 24 bits.

• Depth: 320 x 240 pixels; 11 bits.



The Point Cloud Library

The Point Cloud Library (PCL) is a standalone, large scale, open project for 2D/3D image and point cloud processing, released under the terms of the BSD license, and thus free for commercial and research use.

The Point Cloud Library

- filtering
- feature estimation
- surface reconstruction
- registration
- segmentation





The process workflow

- data acquisition
- data elaboration



Data acquisition



<u>Step I: outliers removal.</u>

StatisticalOutlierRemoval uses point neighborhood statistics to filter outlier data.

The algorithm follow this steps:

- compute the average distance that each point has to its nearest k neighbors.
- threshold: mean + multiplier*standard_deviation.
- classify each point as inlier or outlier.

Step I: outliers removal.

Step 2: downsampling.

VoxelGrid creates a 3D voxel grid over the input point cloud data. Then, in each voxel, all the points present are approximated with their centroid.

Step 3: smoothing.

MovingLeastSquaresOMP is a performance oriented class implementing the MLS algorithm used for smoothing surfaces.

<u>Step 4: surface normal estimation.</u> NormalEstimationOMP estimate surface normal of a point from the surrounding point neighborhood support of it, enclosed in a predefined radius.

Step 5: keypoints detection.

A keypoint is simply a point that has been identified as a relevant in some way.

A good keypoint detector will find points which have the following properties:

- Sparseness;
- Repeatiblity;
- Distinctiveness.

Step 5: keypoints detection.

SIFTKeypoint finds local extrema in a difference-of-Gaussians (DoG) scale-space computed based on several parameters:

- the size of the smallest scale;
- the number of times the scale doubles;
- the number of scales in between each doubling;
- the minimum absolute DoG value needed to qualify as a keypoint.

Step 6: features estimation. FPFHEstimationOMP attempts to capture as best as possible the sampled surface variations by taking into account all the interactions between the directions of the estimated normals.

Step 7: initial alignment.

It computes the rotation-traslation matrix to find the absolut minim using the RANSAC algorithm.

RANdom SAmple Consensus.

Iterative, non-deterministic, method to estimate parameters of a mathematical model from a set of observed data.

Assumption:

data contains inliers + outliers and noise.

Two phases:

- hypothesis generation;
- hypothesis evaluation.

<u>Step 7: initial alignment.</u> Steps:

- I extract P points from the N cloud features;
- 2- search the same P features in the N-I cloud;
- 3- compute an RT matrix;
- 4- compute the FitnessScore (the error).

The previous steps are repeated several times and the best RT matrix is chosen.

<u>Step 7: initial alignment.</u> RANSAC Pros and Cons:

+ Robust estimation;

- No time limit;
- Many iterations;
- Setting thresholds.

Step 8: refining initial alignment. IterativeClosestPoint class provides a base implementation of the ICP algorithm. The aim is to find transformation matrix associated to the rigid transformation of the cloud.

Step 8: refining initial alignment.

Starting from initial guess ICP iterate this steps:

- compute the cloud P transormation using a RT matrix;
- for each point on M, find closest point on P.

$$E(\mathbf{R}, \Delta t) = \sum_{i=1}^{N_m} \sum_{j=1}^{N_d} w_{i,j} \left| \left| \mathbf{m}_i - \left(\mathbf{R} \mathbf{d}_j + \Delta t \right) \right| \right|^2$$

Step 8: refining initial alignment.

The algorithm has several termination criteria:

- Number of iterations;
- Difference between the previous and the current transformation is smaller than a user defined value;
- The sum of euclidean squared errors is smaller than a user defined threshold.

Next..

- CUDA feature extraction;
- surfaces estimation;
- objects segmentation;
- objects detection and exportation.

PROCESSING PHASE	ΤΟΡΙϹ	PAPER
Preprocessing	Statistical Outlier Removal (Noise)	R. B. Rusu, Z. C. Marton, N. Blodow, M. Dolha, and M. Beetz. Towards 3D Point Cloud Based Object Maps for Household Environments Robotics and Autonomous Systems Journal (Special Issue on Semantic Knowledge), 2008.
	Voxel Grid Filtering (Downsampling)	-
	Smoothing	Shachar Fleishman, Daniel Cohen-Or, Claudio T. Silva Robust Moving Least-squares Fitting with Sharp Features
Initial Alignment	SIFT Detector	David G. Lowe, "Distinctive image features from scale-invariant keypoints," International Journal of Computer Vision, 60, 2 (2004), pp. 91-110
	SIFT Descriptor	 R.B. Rusu, N. Blodow, M. Beetz. "Fast Point Feature Histograms (FPFH) for 3D Registration." In Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Kobe, Japan, May 12-17 2009. R.B. Rusu, A. Holzbach, N. Blodow, M. Beetz. Fast Geometric Point Labeling using Conditional Random Fields. In Proceedings of the 22nd IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), St. Louis, MO, USA, October 11-15 2009
	RANSAC	Fast Point Feature Histograms (FPFH) for 3D Registration," Rusu et al.
Refine Alignment	Iterative Closest Point	Paul J.Besl, Member, IEEE, and Neil McKay A Method for Registration of 3-D Shapes