Automatic detection of cylindrical objects from unorganized point cloud

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1. Introduction

Extracting a 3D primitive geometric shape such as a sphere and a cylinder from a point cloud is an important research topic. Especially, most of CAD models are composed of such primitives, and extraction of geometric parameters of each primitive plays a key role in reverse engineering and registration. Among the primitives, cylinders are frequently used in practice to represent pipe-like objects. Recently, there are various methods for detecting multiple cylindrical objects from an unorganized point cloud, but they still have a limitation of detecting multiple cylinders and the elbow parts where two cylinders are connected.

In this work, we present an automated robust method of detecting any types of multiple cylindrical objects from an unorganized point cloud and estimating a complete pipe structure consisting of multiple cylinders. We focus on a method of extracting a parabolic patch at each point using the points in the neighborhood and computing a radius from the patch to consider a virtual sphere of that radius at that point. We compute such spheres at all the other points and trace the centroids of the detected virtual spheres to find the axis of each cylinder. The orientation of the axis of the cylinder is computed from the mean-filtered centroids. Each cylinder is separately obtained, and the joints of the cylinders are estimated to form a complete pipe. The proposed method is tested with various examples.

2. Technical approach

Detecting multiple cylinders from a given point cloud consists of three steps. First, a quadric patch is fitted at a point with the points in the neighbourhood using the method in [1], to obtain a mathematical model. Because the fitting method is based on the least-squares approach, the target point where curvature should be computed is not likely to lie exactly on the fitted patch. To solve this problem, we find a point on the patch that is closest to the target point, compute a curvature using the patch, and assign it to the curvature value of the target point. The point on the patch closest to the target point is obtained by projecting the target point on the patch using the normal vector to F of Equation 1 that can be calculated by the method of [2]. Given the curvature values at all the points in the point cloud, we can efficiently extract the points that are likely to be part of a cylinder based on the computed differential properties. Second, we create a histogram for radii to check the existence of a cylinder and select the radius that corresponds to the local maximum in the histogram. To verify the shape parameters, the RANSAC (RANdom Sample Consensus) algorithm [3] is considered because it is robust against outliers and noise. Spheres can be detected with the extracted radii and their centroids are gathered. The centroids of the detected spheres require further thinning to obtain a 1D structure and we apply the Mean Filter for thinning. The orientation of the axis can be extracted via PCA (Principal Component Analysis). It is based on a discriminant of [4]. The orientation of the axis would be curved if the discriminant is bigger than the user-defined threshold. The axis modeling is completed separately depending on the orientation of the mean-filtered centroids.

$$\mathrm{F}(\mathrm{x},\mathrm{y},\mathrm{z}) = \mathrm{a}x^2 + \mathrm{a}x^2 + \mathrm{a}x^2 + 2exy + 2fyz + 2gzx + 2lx + 2my + 2nz + d = 0 \quad (1)$$

3. Experimental results and Conclusion

A synthetic point cloud is considered for an experiment. We have made three different cylindrical objects with different positions and radii. Gaussian noise with zero mean and 0.01 standard deviation is added to the surface of the cylindrical objects and no information including the number of cylindrical objects and their radii is provided. Using the proposed method, all cylindrical objects from the point cloud are successfully detected as shown in Figure 1. It takes about 4(s) to detect all the objects from the given point cloud using a computer with 3.6GHZ Intel Core i7 and 16GB RAM.

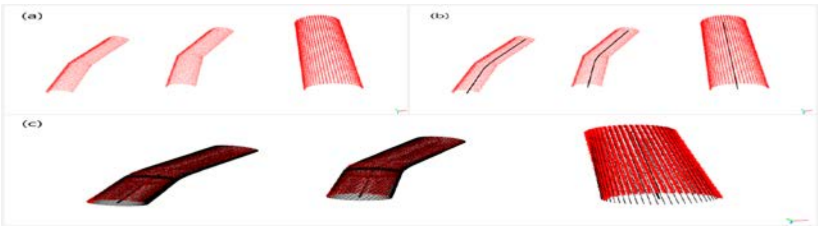

Figure 1. The result of multiple cylindrical objects detection. (a) is a synthetic point cloud, (b) is a result of axis modeling and (c) is a result of reconstruction. The number of points is about 44k.

In this paper, we propose a method for detecting multiple cylindrical objects from an unorganized point cloud. The proposed method automatically detects any types of cylindrical objects with no further information on their locations, the number of objects and radii. The method can be extended to detect all 3D primitive geometric shapes such as sphere, plane and cone, which is recommended for future work.

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