Advanced Science and Technology Letters
Vol.67 (Multimedia 2014), pp.43-47
http://dx.doi.org/10.14257/astl.2014.67.11

Automatic Pipeline Generation by the Sequential Segmentation and Skelton Construction of Point Cloud

Ashok Kumar Patil, Seong Sill Park, Pavitra Holi, Young Ho Chai

Graduate School of Advanced Imaging Science, Multimedia and Film, Chung-Ang University, #221 Heuksuk-Dong, Dongjak-Gu, Seoul, Republic of Korea
ashokpatil03@hotmail.com, pssil1321@gmail.com, pavitraholi@hotmail.com, yhchai@cau.ac.kr

Abstract. Point clouds are the main output of automatic data collection using laser-scanner technologies. The large numbers of points scanned from pipeline plants make the plant reconstruct very difficult. We have developed a system based on the Point cloud Library (PCL), to find, recognize and reconstruct 3D pipes within point-clouds fully automatically. The proposed approach consists of pre-processing point cloud data, segmentation, skeleton extraction and automatic cylinder fitting for pipeline. The presented results shows that the proposed method enables reliable 3D models of pipelines, which could be successfully incorporated into the reconstruction of a plant information modelling method and utilized for, assist maintenance and expansion of existing plants.

Keywords: Point clouds, laser scanning, segmentation, pipeline plant reconstruction, curve skeleton, cylinder fitting.

1 Introduction

Virtual three-dimensional (3D) scene reconstruction with the aid of laser scanning has attracted considerable for a wide variety of purposes, including plant operation, maintenance, and expansion of existing facilities. The aim of this study is to propose a fully automated process that allows construction of a 3D model of an entire pipeline structure from laser-scanned data. The rest of the paper is organized as show in the below Fig 1. (1) The pre-processing of point cloud is done by downsampling and grid-based region of interest (ROI) to speed up the computation of reconstruction of 3D pipeline [1]. (2) Segmentation process for clustering of point cloud belongs to same region [2] and [5]. (3) Skeletonization based on approximating medial axis [3]. (4) Automatic cylinder fitting on pipeline point cloud data [4] and [6].

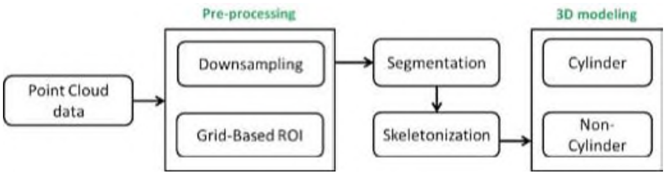

Fig. 1. Point cloud processing workflow diagram.

ISSN: 2287-1233 ASTL

2 Filtering point cloud data based on voxelgrid algorithm

The massive point cloud data obtained through the scanner is uneven in density together with a lot of noise, which will greatly affect the surface reconstruction. Firstly, 3D voxelgrid is created for the massive point cloud data approximating other points inside the voxel with the centroid of all points; then, the neighbourhood of discrete points is analysed statistically, calculating average distance of every point to its neighbouring points and filtering the outliers outside the reference ranges of average distance from the data set. Below figure shows a part of a big pipeline plant data filtered with voxelgrid algorithm based on PCL [1].

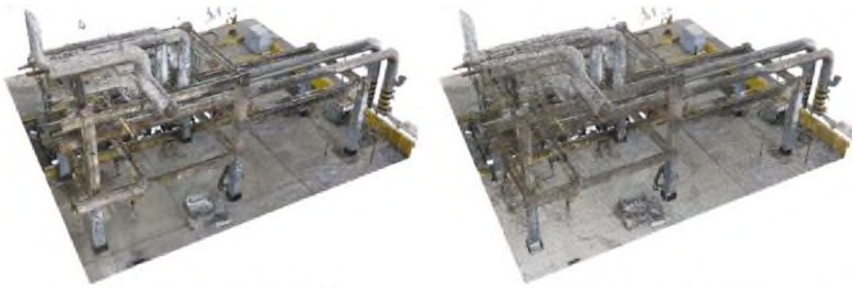

Fig. 2. Downsampling point cloud data.

3 Segmentation of point clouds using smoothness constraints

Segmentation is one of the most fundamental procedures for the automation of point cloud processing. It is a points labelling process for point cloud data sharing similar properties are grouped together. This method performed using the smoothness constraints proposed by T. Rabbani et al., [2] and it has two steps: Normal estimation and region growing.

The normal at each point is estimated as the normal to the fitting plane obtained by applying the total least square method to the K nearest neighbours (KNN) of the point in the point cloud. As the number of points K is fixed, the method adapts the area of interest according to the point density. This method always uses the given number of points and avoids degenerate cases.

The region growing process starts from the first point, when the process meets an unlabelled point cluster, a new region is initiated, and the current unlabelled point cluster is added to the stack points. Then each time points pops one point and finds its KNN within a given residual threshold distance and grows the current region on the basis of calorimetrical similarity. The current growing process terminates when points is empty in input point cloud data. The result of segmented matched clouds is shown in Fig 3(a).

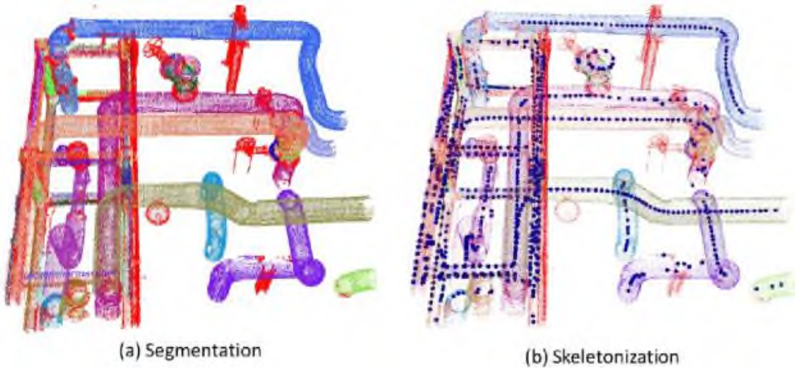

Fig. 3. Results of point clouds: (a) Segmentation of a matched cloud. (b) L_1- medial skeleton extracted from point cloud data.

4 Skeletonization by approximating the medial axis.

Skeletonization of the segmented point cloud is performed using the L_1 – medial skeleton proposed by Hui Huang et al., [3]. A skeleton is a one-dimensional description of the object structure, it represents a unique global center of a given set of points. The structure can be seen as a localized center of the shape, i.e., a medial curve skeleton. Given an unorganized and unoriented set of points, investigate the following equation for L_1-medial skeletons that leads to an optional set of projected points.

$$\sim\sim \;||-\;||\sim\sim\sim - \sim\sim\sim + (), \quad \in \; \in \qquad (1)$$

Where the term R(X) regularizes the local point distribution of *X*, *I* is the projected points *X*, and *J* is the set of input points *Q*. The weight function () = $-^{2}/\sim h2\sim$ is a fast decaying smooth functions with support radius *h* defining the size of the supporting local neighborhood for L_1- Medial skeleton construction. Fig 3(b) shows the skeleton from the L_1 medial skeleton construction.

5 Automatic cylinder fitting for point cloud data.

The proposed technique for reconstructing the cylindrical shapes within the 3D point cloud is processed by creating plane slices at the start and end of the skeleton data and computing the average radius from point clouds intersect on plane to the skeleton data. Construct the 3d pipes with cylinders using PCL function applying computed radius and direction from start to end of skeleton data. For more accurate visualization for complicated 3D pipes, the plane slices are increased in predetermined interval along the skeleton point data. The results of the automatic cylinder fitting is show in the below Fig 4.

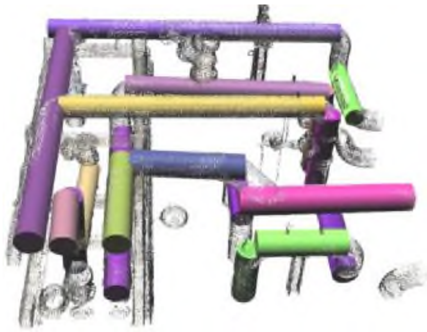

Fig. 4. Generated cylinder model

6 Conclusions

In this paper we proposed a method that can automatically fits the cylinders for the pipeline point clouds from laser-scanned data. The 3D point clouds are pre-processed with voxelgrid downsample for fast processing. The segmentation of the laser-scanned point cloud data is performed on the basis of the smoothness constraint. The extracting skeleton from the segmented unorganized point cloud is computed by L_1-medial skeleton. The automatic cylinder fitting is constructed on the classified segmented skeletons with corresponding radii. Thus, future research will be focused on the automatic cylinder fitting for pipeline point cloud using NURBS surface and constructing 3D model for pipes other shapes such as elbow and T-Junction.

Acknowledgments. This work was supported by Commercialization Promotion Agency for R & D Outcomes - Grant funded by the Korean Government (Ministry of Science, ICT and Future Planning - 2013A000019)

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