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Curve Reconstruction of Digitized Surface using K-means Algorithm

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Abstract

The K-means algorithm has good ability to handle the large number of scanned data. It is best suited for creation a desired shape curve-likes shape for near-best approximation of the scanned data point set. It presented an approximate set of scanned data points with a simple curves or surfaces. In this paper, the reverse engineering use for scanning the spur gear using 3D laser scanner and data is stored in point cloud format. Using this scanned data, reconstructing the smooth curve is achieved by proposed algorithm in MATLAB environment. In this study, scanned geometry and curve reconstruction technique suggested and it has been demonstrated to tooth curve reconstruction of spur gear as a complex surface object. Result of methodology is helpful to recreate the 3D CAD model of scanned object, which can be improve in work efficiency and reduce the product development cycle time with the application of CAD/CAE/CAM tools.

Keywords: K-means algorithm; reverse engineering; digitized surface; spur gear tooth surface; curve reconstruction

1. Introduction

Reverse Engineering refers to the process of creating engineering design data from existing parts [1]. However the reconstructing the curves or surfaces using point set is one of the most important problems in the reverse engineering for geometric models. The use of reverse engineering in product design has markedly increased day per day. To capture the designer's intent, through reverse engineering, into an accurate CAD model is an important and fundamental step in product re-design cycle [2, 3]. As product varieties increase and life cycles shorten, it is necessary to reduce product development time becomes more critical to maintain competitiveness in the market.

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Both reverse engineering and rapid prototyping are emerging technologies through logical aspect that can play a promising role to reducing the product development time [4, 5]. The laser scanner has emerged as an effective non-contact tool for digitizing 3-D surfaces. The 3D laser scanner has further improved the scanning efficiency from the point laser scanning with white coated surface. Recently, the laser scanner has been utilized for part inspection by assessment the recreated accurate surface profile of the scanned objects. In computer graphics a large variety of geometry representations has been used for reconstruction, modeling, editing, and rendering of 3D CAD objects [6]. In recent years there has been a marked shift from using triangles to modeling primitives of object in computer graphics applications [7]. A scanned model usually contains millions of points and can be saved it in stl. Or any desired file formats [8]. Knowledge for 3D scanning actually comprises several steps, which are Considering the whole process from data collection to final 3D CAD model, a rough distinction may be made as follows:

- 3D scanning and control the scanning parameter
- Point Processing of point cloud data,
- Module selection for fitting of primitives to the point cloud,
- Creation of complex surface models,
- Recreation of 3D CAD model using any modeling software

Some of the fundamental operations performed on a freshly scanned point-cloud data set include the computation of surface normal in order to be able to illuminate the scanned object. The output obtained from some sorts of scanner devices, as commonly done for reverse engineering applications. The most common surface representation in real world applications our aim is to reconstruct the surface from the scanned data. For surface reconstruction there are two stages have been follow as surface parameterization and surface fitting. PSO is applied to determine all relevant surface data from set of 3D data points assumed to lie on an unknown NURBS surface of a certain order [9]. The any type of noise removal from the scanned parts is the tools that are registered of scanned-model into the desired level with the help of generated program or other preferable tool. These data point may be edited by inbuilt scanning software [10]. The generation of product curve profile is obtained by the k means algorithm for each point in point cloud data set and genetic algorithm method also addressed for the surface reconstruction problem [11]. There are two important distinctions from other applications where the computation of neighbors is required. First, when neighbors need to be computed for all points in the dataset. Second, no assumption can be made about scanned dataset. In this work, focus on the reconstruction of a curve from an unorganized point cloud having no ordering of the point elements using the K-means algorithm, which takes a point cloud dataset as an input and computes the k nearest distance for each point and finally produce the part profile in MATLAB environment. However, this algorithm has some limitations:

- It is not easy to determine the size of pixel of the image. For the too small pixel the point set is to be separated into several different components. If the pixel is too large, the current position axis may not represent the best approximation curve of the point set.
- In open curves, current position axis does not represent the shapes of the point set near the end points of the curve.

2. Laser scanning and spur gear setup

The 3D scanning system has been implemented with a laser beam and a motorized rotary table. The laser scanner is a stripe-type device with a rotating table and three orthogonal transportation axes. For part scanning from any direction, overall system has six degrees of freedom, out of them four degrees of freedom has for laser device and the remaining two degrees of freedom for rotary table. For better scanning and registration of captured data the spur gear correct setup process is must. The spur gear should be white coating and fixed on the motorized rotary table. Before that, each axis of the rotary table should be aligned with the axis of the laser scanner. The spur gear part will be located with a specially designed fixture and attached on the rotary table.

3. Spur gear digitization and preprocessing

In reverse engineering, digitization and collection of existing object coordinates values for every point to point cloud data form can be classified as: contact type (Mechanical type) and noncontact type (Optical type) digitized techniques. A huge number of different 3D-digitization systems have been developed, among which the most prominent are coordinate measuring machines (CMM), laser scanners, CCD-cameras, computer tomography (CT). In present work, the point cloud data is acquired by scanning the spur gear teeth form of x, y and z co-ordinates of the multiple point curve showing in figure 1 using PICZA 3D laser scanner (Roland LPX60).

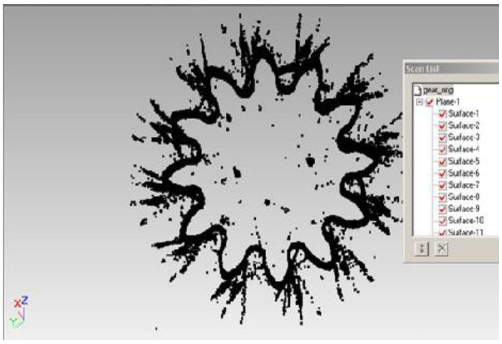


Fig.1. Point cloud data of spur gear after scanning.

The modern 3D-digitization systems have been generating a large amount of scanned points. Therefore, before the surface reconstruction process, it is necessary to prepare the scanned data. This preparation is usually described by the term pre-processing. In pre-processing phase can imply different processes, such as noise and error filtering, data smoothing, data reduction, data segmentation, data regression, etc. Among them, noise filtering, data smoothing and data reduction are typically competed. In this work, the 3D editor (version 2.0) tool of Dr. PICZA3 has been used for editing the data and for removing the noise in surface models. Science for the spur gear complex surfaces generally needs to be subdivided into many sections. After the subdivision, the point cloud data can be simplified to create the tooth curve profile as shown in figure 2. The noise less data has been saved as point cloud data in ASCII file format.

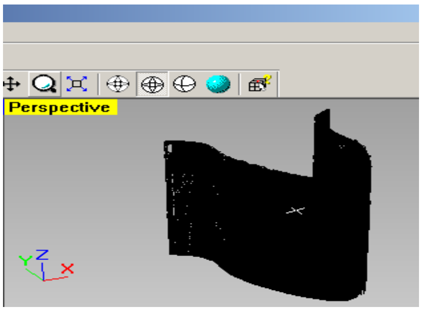


Fig. 2. Point cloud data of spur gear after scanning.

4. Recreation of spur gear tooth profile

Although, a point cloud acquired from a object have exact surface profile data but does not in the mathematical sense, the data usually carries adequate logical information for reverse engineering. To generate a CAD model satisfying the original aesthetic and functional design, it is essential to recreation of CAD model using scanned data can be completed in two ways:

4.1. Using stl data

Surface Modeling and Solid Modeling of the part is done from the stl data using modeling packages like Pro-E and CATIA.

4.2. Using point cloud data

A point cloud model usually contains millions of points. The set of a point-cloud is collection of scanned points and may not contain any topological information. Using the preprocessed point cloud data, a surface model can be generated either making the curve profile based method or by polygon based method. However, most of the topological information can be deduced by applying suitable algorithms on the point clouds based to point to point connect generate curve profile [12, 13]. In this paper, the K-means algorithm is used, which takes a point cloud dataset as an input and computes the K-means neighbors for each point in data set to generate spur gear tooth profile.

4.3. Recreation of spur gear tooth profile by K-means neighbors

The digitized data is obtained by the noncontact scanning method is generate too large data, which is very difficult for reconstruction of curve in spite of recent advancement in the scanning technologies. In present work, the K-means algorithm can be reduced by making use of the approximate nearest neighbors scanned points curve. The approximation is achieved by making use of an error-bound which restricts the ratio of the distance from the query point to an approximate neighbor and the distance to the actual neighbor to be within range. A fast k means nearest algorithm is presented that makes use of the locality of successive points whose k points are required to significantly reduce the time needed to compute the primitive operation. The basic methodology flow chart of algorithm is shown in figure 3.

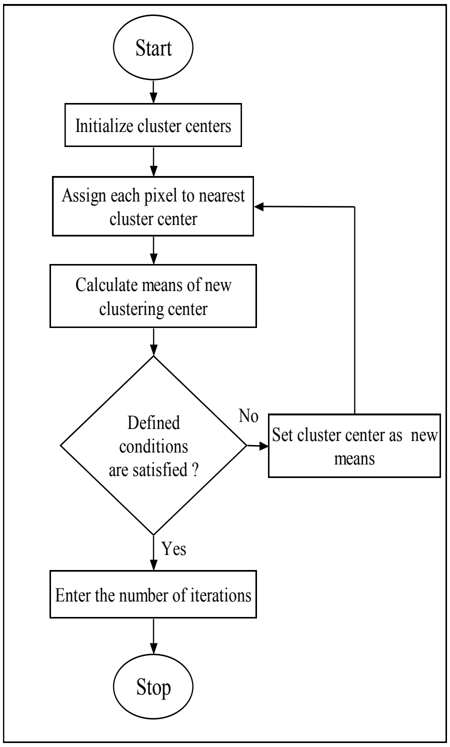
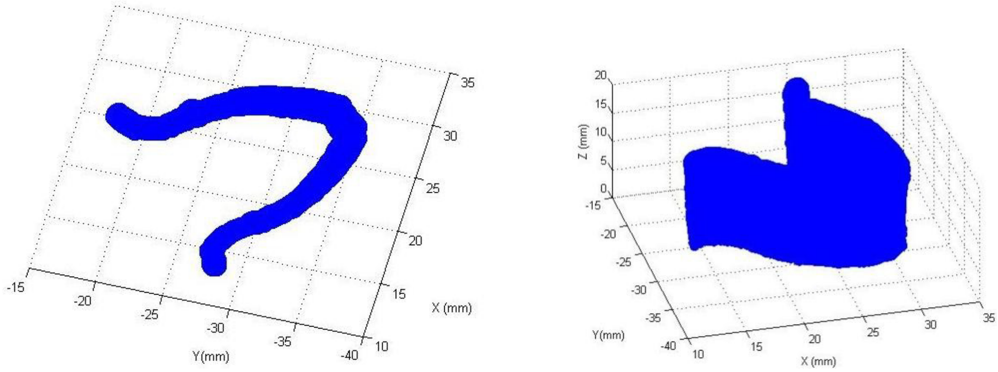


Fig. 3. Basic flow chart of the algorithm.

K-means algorithm is the clustering algorithm used for the scanned data in ASCII format as an input data. Clustering methods have been used in many computer graphics applications to reduce the complexity of scanned 3D objects. To alleviate the best curve fitting, a surface-based clustering approach can be used, where clusters are build by collecting neighboring samples by regarding the nearest sampling points from cloud data. Here, two distinguish general approaches are used for building clusters. First, an incremental approach, where clusters are created by region-growing, and second a hierarchical approach that splits the point cloud into smaller sub-sets in a top-down manner. In this work, the second method is used for create a set of clusters, each of which is replaced by a representative sample, typically its centroid, to create the simplified scanned data curves profile. After the clustering, the refine data is further used for define the new clustering center point. If the define point is satisfied for all nearest point then, new clustering center point is correct, otherwise it will try for new clustering center point. Figure 4 (a and b) presents the spur gear tooth surface profile for correct clustering center point. Figure 4(a) and (b) have been taken from the running the algorithm in MATLAB 2008 and represent the XY axis and XYZ axis respectively.



(a) Represent the XY axis (b) Represent the XYZ axis

Fig. 4. Recreated spur gear tooth profiles.

5. Conclusion

Reconstructing a curve or a surface of geometric models from a point set is one of the most important problems in the reverse engineering. In present work, some steps such as, data acquisition, data pre-processing, teeth profile generation has been performed using the K-means algorithm has been pointed. The K-means algorithm yielded in improvement of several orders of magnitude for distance sensitivity. It takes much less time to execute the reconstruction of spur gear tooth data which is having approximately forty thousand points. Although, our focus was on application of the algorithm to create the spur gear tooth profile using noise free scanned data. Further Application of K-means algorithm can also be applied to other type of reconstruction work with approximate k neighbors points set. The curves and surfaces are widely employed to represent free-formed surface object in CAD models and graphics world. Since 3D model representation technology is still in its infancy, there should be much more researched have been carried out in various fields such as, surface representation, surface analysis, inspection and quality control. Developed technique may be helpful to recreate the 3D CAD model of scanned object, which can be improve in work efficiency and reduce the product development cycle time with the application of CAD/CAE/CAM tools.

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