ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 5, Issue 5, May 2016

A Review on 3D Model Reconstruction In Reverse Engineering

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Abstract— **Reconstruction of surface in three dimensions uses point clouds for removing noise. It is done by reverse engineering. Reverse engineering of geometric shapes is the technique of converting a large number of measured data points into a concise and consistent computer representation. The approximation of surface from a given set of samples is called surface reconstruction. Surface reconstruction methods are very helpful to recover the shape of real objects through reverse engineering. A surface is constructed from unorganized point clouds in three dimension space and can be converted into any geometrical shape. This paper reviews various algorithms used for the reconstruction of surfaces from cloud points in different geometrical shapes. Various topologies are possible like ring ,bus and mesh etc. There are number of techniques used to obtain the sample points photogrammetry technique, laser scanner, reflection technique and other. The main advantage of surface reconstruction approach is a much improved robustness with respect to noise. The algorithms used are half maximum length algorithm, advancing front algorithm, crust algorithm. The main issues compared are complexity, repeating points, quality of the surface reconstructed and execution time.**

***Index Terms*— CAD, point cloud, CARE, CAE, BPA**

I. Introduction

In the field of surface reconstruction the aim is to obtain a digital representation of a real, physical object or thing described by a cloud of points, which are sampled on or near the surface of the object. The growing interest in this field is because of the rising occurence of point-cloud data, which can be obtained from medical scanners, laser scanners, vision process (e.g., range images), and other modalities[2].

Reconstructing a surface from cluttered point clouds is a challenging problem because the topology of the original surface can be very complex, the collected data may be nonuniformly sampled and the data may be corrupted by noise. In addition, the quality and efficiency of the data sets strongly depend upon the acquisition methodology. Also, the computational cost of reconstructing surfaces from large data sets can be prohibitive. Most of the prevailing reconstruction methods were developed estimating that precise and noise-free data is available. Therefore, they cannot meet the demands required by noisy and/or sparse data[2].

Reconstruction of a 3-D object surface from segment of points has large number of applications such as computer-aided design (CAD) design, virtual reality, medical imaging, and movie industry. Reverse engineering of geometric shapes is the method of transforming a large number of measured data points into a clear and consistent computer representation. In this sense, it is the inverse of the conventional CAD/CAM procedures, which forms physical objects from CAD models. The sample of points used for reconstruction can be classified as structured or unstructured based on associated information between points, according to the sampling device used. Given a real surface and a set of points sampled from it, the aim is to develop a surface model approximating the real model. That is, a preferable surface reconstruction algorithm must be able to regain both geometry and topology to fit the data correctly[1].

Reverse engineering of geometric shapes is the technique of converting a large number of measured data points into a brief and consistent computer representation. In this sense, it is the inverse of the conventional CAD/CAM procedures, which forms physical objects from CAD models. The advantage of CAD/CAM is that the existence of computer models provides opportunities for developing the quality and performance of a design and is convenient for manufacture. Reverse engineering starts with calculating an existing object using a laser scanner, and then the evaluating data is used to construct a surface or solid model[5]. Triangulating scattered point-sets is a very essential problem of reverse engineering. Provided a set of unorganized points that lie generally on the boundary surface of a three-dimensional object, and without any information on the topology, our aim is to rebuilt the surface by building a triangular mesh using the given points as vertices. The derived polyhedron can be the input of another procedures like surface fitting, or can be visualized with different textures. (For example, in computer-animated films the characters are usually created as clay models first, and after that 3D scanned and triangulated models are used for visualization. All algorithms aiming to solve this problem must overcome various difficulties. The first one is related to the size and quality of the input. Modern 3D scanners make it possible to have several (ten) millions of sample points on the object's surface[3]. .

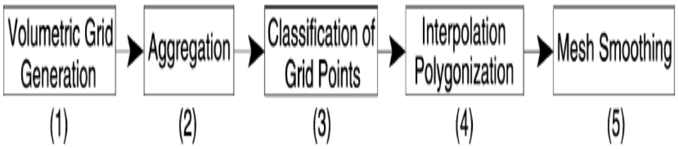

Fig. 1 Flow diagram of surface reconstruction method

The famous cooperative stereo algorithm introduced by Marr and Poggio made two basic and important assumptions followed by numerous researchers. We observe the conventional framework can also be applied when considering the orientations of surface primitives of 3-D geometric models.

1) *Uniqueness*: The orientation of each surface primitive is uniquely defined with respect to the entire surface model.

2) *Continuity*: The orientations of neighboring surface primitives vary smoothly in a model.

Thus, formulate the determination of orientation as labeling Markov random fields (MRFs) with the unoriented surface primitives treated as nodes[4].

The main research area of reverse engineering is based on two methods: the edge-based method and the face-based method. The course of the edge-based method is data acquisition, preprocessing, segmentation, surface fitting and formation of the CAD model. In the data acquisition part of the edge based method, the main object of the method is the geometric stage of reverse engineering. Data structures for representing shape can vary from point clouds to the boundary representation models. However, there exist various problems such as accuracy, accessibility and occlusion[5].

What Is Computer-aided Reverse Engineering?

CAE through CAD and CAM technologies is the computerization of engineering and fabrication, where a design represent ideas through computer modeling and then construct those models into real-world objects. CARE moves in the opposite direction. CARE develop a computer model of an object through measurements of the object or thing, as it occurs in the real world. Here, CARE is described as the *reversal* of CAE or the ability to produce a CAD model from a real-world tangible object. The figure below illustrates the flow. The disc brake appears on the left side of this figure and its CAD model is shown on the right. Here a laser-based range scanner is used to create the CAD model of junkyard brake. This model is metrically accurate to be within a few millimeters of the original junkyard brake. By comparison, one might take this capability as a 3-D fax. Just as a facsimile (fax) machine transforms a hand-written document into digital form, it has converted a distinct object (the disc brake) into a computer model. This figure illustrates the definition of CARE. To be more accurate, CARE is defined in terms of the geometry and shape of an object[8].

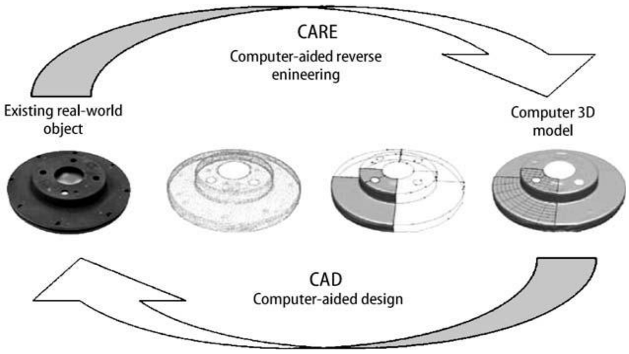

Fig. 2 Computer-aided reverse engineering (CARE) process

The general approach includes interpreting contour information as points in 3D. Recent advances in computer graphics have presented a number of methods for creating surface models from sets of unstructured, unconnected 3D points that sample some underlying surface. This exploits these advances in point set surfaces to provide a contour-based surface reconstruction technique that can completely handle noisy input contours. The technique can produce smooth 3D models from this kind of data and that the errors originate from approximating, rather than interpolating, surface are controllable and sufficient. Results and analysis based on various examples are provided. In addition, once a 3D model is created we are able to randomly slice the 3D model in order to develop new sets of contours parallel to a user-specified cutting plane[7].

Contour Stitching

Mostly research on contour-based surface reconstruction focus on methods for connecting (stitching) the vertices of nearby contours into a mesh. There are three typical problems that contour stitching attempts to solve:

Correspondence – Provided a set of vertices in contour A and a set of vertices in contour B, a correspondence (connection) between the vertices in A must set up to the vertices in B.

Branching – Branching is a serious problem in mesh-based approaches. It happens when one contour slice contains only one closed contour, while the next slice enclose two or more closed contours. Robust techniques must be used to determine what branches are formed between the two slices. Different methods have been suggested for this problem, while other reconstruction techniques ignore it.

Tiling – Tiling creates a mesh between two adjacent slices. The tiling process connects two slices by forming a strip of triangles using the correspondences between vertices. Great progress in mesh-based approaches has been made in this area[7].

II. RELATED STUDY

Thomas Schops et.al. (2015) presents a system that utilize the device's GPU to compute depth maps using plane sweep stereo.It combine the depth maps into a typical model of the environment represented as a truncated signed distance function in a dimensionally hashed voxel grid.

David Page et.al. presented a processing pipeline for creating CAD models using these scanners. This processing involve tasks such as view registration, surface integration, patch reconstruction, model fitting, noise removal, and other functions.

Agostinho de Medeiros Brito Júnior et.al presented a multiresolution method for surface reconstruction from clouds of unorganized points representing an object surface in 3-D space. The suggested method uses a set of mesh operators and simple rules for selective mesh refinement, with a scheme based on Kohonen's self-organizing map (SOM). Mostly, a self-adaptive scheme is used for iteratively moving vertices of an basic simple mesh in the path of the set of points, ideally the object boundary. Successive refinement and motion of vertices are adapted leading to a more detailed surface, in a multiresolution, iterative scheme.

Vikas Chauhan et.al(2011) studied the Delaunay algorithm and Crust algorithm and compared these algorithm for the time taken for the surface reconstruction. The main aim of surface reconstruction is to find a surface from a given finite set of geometric sample values.

Andrei C. Jalba and Jos B. T. M. Roerdink(2009) worked on a new technique based on regularized-membrane potentials the input sample points are aggregated, leading to improve noise tolerability and assembling removal, without sacrificing much with respect to detail (feature) recovery. After combining the sample points on a volumetric grid, a novel, iterative algorithm is used to distribute grid points as exterior or interior to the surface. This algorithm depends on intrinsic properties of the smooth scalar field on the grid which appears after the aggregation step. Second, a mesh-smoothing paradigm based on a mass-spring system is introduced. Most parts of the method are implemented on modern graphics processing units (GPUs).

Yi-Ling Chen and Shang-Hong Lai(2011) worked on orientation inference framework for reconstructing implicit surfaces from unoriented point clouds. The presented method begins from building a surface approximation hierarchy comprising of a set of unoriented local surfaces, which are expressed as a weighted combination of radial basis functions. A progressive reconstruction algorithm that iteratively carries more oriented points to improve the fitting accuracy and efficiently updates the RBF coefficients is proposed.

Zhongshan Polytechnic et.al.(2011) worked on a new approach to the reconstruction of a surface. The presented methodology finds the basic parts of the surface and fuses surfaces between them. Each basic geometric part is splitted into triangular patches which are compared using normal vectors for face grouping.. Each primary geometric surface is then implemented to the infinitive surface. The infinitive surface's intersections are clipped by boundary representation model reconstruction.

Ilya Braude et.al. focused on a technique interprets the pixels that forms the contours as points in R3 and employs Multi-level Partition of Unity (MPU) implicit models to develop a surface that almost fits to the 3D points. Since MPU implicit models also require surface normal information at each point, an algorithm that evaluates normals from the contour data is also explained. Contour data frequently involves noise from the scanning and delineation process.

Nidhi Sharma reviews the various algorithms used to reconstruct the topological surface from sample points in three dimensional spaces. The sample points can be achieved from photogrammetry technique, laser scanner or any of the mathematical function. A comparative study is done between the most prominent computational geometry based surface reconstruction algorithms. The algorithms are the Crust, the BPA(ball pivoting algorithm), the Tight Cocone and the Ball Pivoting algorithm. The main issues for the comparison are the quality of the surface reconstructed, the execution time, and the speed.

Algorithm	Author	Definition	Conclusion
SOMs: Kohonen Algorithm	Agostinho de Medeiros Brito Júnior, Adrião Duarte Dória Neto, Jorge Dantas de Melo, and Luiz Marcos GarciaGonçalves	It move vertices coordinates of mesh points toward the "surface" data sample.	Increase in the number of triangles required to keep the surface in a good shape.
Crust Algorithm	Vikas Chauhan, Manoj Arora and R. S. Chauhan(2011)	The Crust Algorithm is a new reconstruction algorithm for the construction of surfaces of random topology from unorganized sample points in 3d.	The output is topologically rigorous and convergent to the actual surface as the sampling density increases.
Advancing-Front Algorithm	Yi-Ling Chen, Shang-Hong Lai(2011)	It is an algorithm that traverse the unchecked regions of the model until all the surfaces have been properly aligned.	Traverse all the leaves among the octree in the order of connected components of visited cells.

Delaunay Algorithm	Vikas Chauhan, Manoj Arora and R. S. Chauhan(2011)	An important geometric data structures that are built on the notion of "nearness", provide a tool to approximate the neighborhoods in the discrete domain.	Provides a tool to approximate the neighborhoods in the discrete domain, defined for a point set in any Euclidean space.
Tight cocone algorithm	Nidhi sharma	The output of cocone algorithm is initial surface to the tight cocone algorithm	It generates watertight reconstruction surface. Algorithm is sensitive to noise.
Half Maximum Height (HMH) Algorithm	Bruno Dutailly, Helene Coqueugniot, Pascal Desbarats, Stefka Gueorguieva, Remi Synave.	HMH algorithm Is for precise length measurements	The precise determination of interface points, i.e. boundary points between two non-identical tissues, by applying a profile of densities along a segment crossing the two tissues.
BPA (ball pivoting algorithm)	Nidhi Sharma	BPA is an efficient form of Advancing front algorithm	It is closely related to α-shapes and output mesh is formed incrementally one triangle at a time.

III. Conclusion

This paper compares the various algorithms that are used for surface reconstruction. The comparison shows that the topology of surface generated by these algorithms is based on the density of point clouds. The number of surfaces generated by BPA algorithm is lower than the number of surfaces generated by Delaunay/Voronoi based algorithms. Hence, 3D surface generation by using BPA algorithm will fast than Delaunay/Voronoi based algorithms. The Ball Pivoting algorithm exhibited minimum execution time, followed by the Tight Cocone. In Crust algorithm ,as the sampling density increases the , the output is more precise to the original surface. Advancing-Front Algorithm tracks through all the leaves in the order of connected components of visited cells. Half Maximum Height (HMH) algorithm accurately determines the interface points, i.e. boundary points between two distinct tissues, by using a profile of densities along a segment passing through the two tissues.

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