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A Survey on Surface Reconstruction Algorithms for 3-D Unorganized points

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Abstract---Reconstruction of a 3-D object surface from sample of points has a wide range of applications such as computer-aided design (CAD) design, medical imaging,virtual reality and movie industry. The problem of approximating a surface from a given set of sample is known as surface reconstruction. This paper reviews the well-known algorithms used to reconstruct the topology surface from sample points in three dimensional spaces. The sample points can be obtained from photogrammetry technique, laser scanner or any other mathematical function. Generally, the sample points will describe the shape and topology surface of the object. On application of the surface reconstruction algorithm on the sample points, the 3D model of the object can be obtained. A comparative study is done between the most eminent computational geometry based surface reconstruction algorithms. These algorithms are the Crust, the Power Crust, the Tight Cocone and the Ball Pivoting algorithm. The key issues for the comparison are the quality of the reconstructed surface, the execution time, and the speed.

Keywords---Surface reconstruction,point clouds,CAD,reverse engineering,crust algorithm.

I. INTRODUCTION

Surface reconstruction is the process to achieve three-dimensional complex surface model quickly and accurately from three-dimensional data taken as a sample, and it is mostly used in reverse engineering[3].Reverse engineering is the process of converting a large number of measured data points into concise and consistent computer representation[4].Three-dimensional data collected by measuring device is generally dense, therefore, it is called Point Cloud data.

Point cloud data can be considered as an accumulation of the points in three-dimensional space, and each point cloud data has three coordinates of x, y, z[3].

According to the different types of data, point cloud data can be categorized into two forms:

I. Ordered point cloud

II. Scattered point cloud.

Reconstruction of ordered point cloud is that constructing the surface of points sample from the verge of object to approximate the original surface. In practice, due to the shortcoming of gathering devices, there is no specific type of the points, so the points are known as scattered point cloud. For scattered point cloud, if the reconstructed surface can show the shape of the original point cloud, we regard it as the outcome of the surface reconstruction[3].

A.SURFACE RECONSTRUCION PHASES

Surface Reconstruction phases include:

Phase 1: Initial Surface Estimation

Phase 2: Mesh Optimization

Phase 3: Smooth Surface Optimization

Phase 1: Initial surface estimation: From an unorganized set of points, phase 1 builds an initial dense mesh. This phase determines the topology of the surface and generates an initial estimation of its geometry.

Phase 2: Mesh optimization: Starting with the dense mesh generated in phase 1, phase 2 alters the number of faces by reducing them and improves the fit to the data points. This problem is formulated as optimization of an energy function that explicitly models the trade-off between the competing goals of accuracy and preciseness. The number of vertices in the mesh, their connections, and their respective positions are taken as free variables in optimization.

Phase 3: Smooth surface optimization: In this phase , the surface representation is transited from a piecewise linear one (meshes) to a piecewise smooth one. A new piecewise smooth representation based on subdivision is introduced. These surfaces are ideal for surface reconstruction because they are simple to implement, model sharp features precisely and can be fit using an extension of the phase2 optimization algorithm[3].

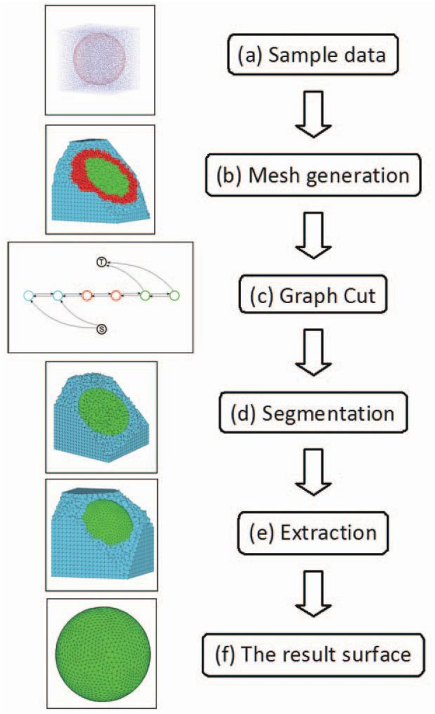

Figure 1. reconstruction phases

B. SURFACE RECONSTRUCTION APPLICATION FIELDS

In practice, surface reconstruction methods are very useful to recover the shape of real objects through reverse engineering.However, each application has its own requirements for the model to be achieved.

For example:

- In CAD applications, the user is interested in obtaining a very accurate model for the real object.
- In medical applications, the scanning devices employed are the computerized tomography (CT), magnetic resonance scanners (MRS), or 3-D ultrasounds[3].

II. CRUST ALGORITHM

The Crust Algorithm is a recently proposed algorithm for surface reconstruction problem. This is the algorithm used for reconstruction of surfaces of arbitrary topology from unorganized sample points in 3d[1].The Crust algorithm for surface reconstruction is also called Voronoi filtering. All the new algorithms rely on voronoi diagrams and their elaunay[3].The algorithm is the first one for this problem with provable guarantees[4]. Given a "good sample" from a smooth surface, the output is expected to be topologically correct and convergent to the original surface as the sampling density increases.The definition of a good sample is interesting in itself, the required sampling density varies locally and rigorously captures the intuitive notion that featureless areas can be reconstructed from fewer samples[1].

The problem of creating a CAD model for an existing physical object from a given set of points of the object surface is important in many fields of science and industry. Many methods exist for solving this problem. These methods are based on a great set of principles, and inhibit properties, that in numerous cases allows choosing the most suitable algorithm for a given task. There are primarily two problems which often arise in practice. The first one is that we generally deal with very large clouds of points (for example, clouds representing buildings, big sculptures, landscapes, etc.). Processing these point clouds often leads to the problem of lack of machine resources even for modern robust computers. In general, this problem is a special case of the problem of minimization of the cost of surface reconstruction. The second problem can be formulated as “What can be done, if an algorithm does not reconstructs a CAD-model completely The problems are found both: separately and together[8].

Surface reconstruction states that an algorithm takes a cloud of sampled points as an input data and produces a CAD-model as a result.

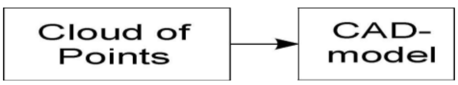

Figure 2. CAD Model

Oftenly,the actual technique applied can be depicted as-

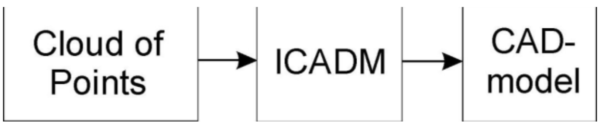

Figure 3. ICADM(incomplete CAD model).

III. RELATED STUDY

Vikas Chauhan et. al.[1] In this paper comparative studies on Delaunay algorithm and Crust algorithm are done.The algorithms are compared for the time taken for the surface reconstruction. The goal of surface reconstruction is to discover a surface from a given finite set of geometric sample values.

Min Wan et. al. [2] This research paper addresses novel graph-cuts-based method for reconstructing open surfaces from point sets that are unordered. The crust around the data set is implemented with a boolean operation which translates the open surface problem into a watertight surface problem within a restricted region. The variational model, Delaunay-based tetrahedral mesh and multiphase technique are integrated, to reconstruct open surfaces robustly and effectively.

Shivali Goel et. al. [3] Surface reconstruction refers to the retrieval of data by scanning an object using a device such as laser scanner and constructing it using the computer to gain back the soft copy of data on that object. Surface reconstruction is known to be the reverse method. It is of great advantage when an object's original data is missing without doing any backup. The missing data can be recollected and can be stored for future purposes. In this research paper, a system has been developed for image reconstruction from scattered cloud points. Crust algorithm in combination with umbrella Filtering is be implemented and compared for time taken by the algorithm for surface reconstruction. The main aim of the algorithm is to filter out left insignificant data while preserving an acceptable level of output quality.

Shitu bala et. al. [4] Surface reconstruction is to find a surface from a given finite set of geometric sample values. In numerous applications, the sample values are points. Reverse engineering of geometric shapes is the process of transforming a large number of measured data points into a precise and consistent computer representation. The techniques known as “feature points” are used that create a mesh from the extraction points. This paper aims to develop a system for image reconstruction.Algorithms like Delaunay and crust algorithm are implemented

Agostinho de Medeiros Brito Junior et. al.[5]In this paper, the author has proposed a multiresolution approach for surface reconstruction from clouds of unorganized points representing an object surface in 3-D space. A set of mesh operators and simple rules are employed for selective refinemen of mesh, with a technique based on Kohonen’s self-organizing map (SOM). Basically, a self-adaptive scheme is used for iteratively moving vertices of an initial simple mesh in the direction of the set of points, basically the object boundary.

Andrei C. Jalba et. al.[6] This paper proposes a physically motivated method for surface reconstruction that can recover smooth surfaces from noisy and sparse data sets. No orientation information is required. A new technique that relies on regularized-membrane potentials, the input sample points are subjected to aggregation,that results in improved noise tolerability and removal of outlier, without compromising much with respect to detail (feature) recovery..

R. Poranne et. al.[7] The paper introduces a generalized distance function on an unoriented 3D point set and describe how it may be used to reconstruct a surface approximating the given points. The distance function is depicted as a Mahalanobis distance in a higher-dimensional embedding space of the points, and the outcome of the algorithm ia an extension of the classical Radial Basis Function (RBF) approach. Experimental results have been shown to indicate superiority of the reconstruction algorithm to RBF and other methods in a variety of practical scenarios.

Abhishek Bansal et. al.[8] Reverse engineering of geometric shapes is the process of converting a large number of measured data points into a concise and consistent computer representation. In this context, it is the inverse of the traditional CAD/CAM procedures that generate physical objects from CAD models. Triangulating scattered point-sets is a very important problem of reverse engineering.This research paper aims to reconstruct the surface by building a triangular mesh using the given points as vertices.

Renoald Tang et. al.[9] This paper reviews the well-known algorithms used to reconstruct the topology surface from sample points in three dimensional spaces. The sample points can be generated from laser scanner, photogrammetry technique or some mathematical function. In most cases, the sample points will describe the shape and topology surface of the object. By applying the surface reconstruction algorithm on the sample points, the 3D model of the object can be generated. The algorithms discussed in this paper will be applied to various models.

A.S. Hussein et. al.[10]In this paper, a comparative study is performed between the most eminent computational geometry based surface reconstruction algorithms. These algorithms are the Crust, the Power Crust, the Tight Cocone and the Ball Pivoting algorithm.The experiments showed that applying any of the four algorithms on a non-uniformly distributed cloud may create poor quality surface. To deal with such clouds, an enhanced algorithm based on Ball Pivoting algorithm and Radial Basis Functions is proposed. The enhanced algorithm has the capability of filling any detected hole within the surface reconstruction process. This algorithm exhibited high robustness in reconstructing objects with non-uniform sampling and migregistrations.

Table 1.Comparision of various surface reconstruction algorithms

SR NO.	CRITERIA	CRUST	POWER CRUST	TIGHT COCONE	BPA(ball pivoting algorithm)	BPA AND RBF(radial basis function)
1.	Definition	Only prerequisite for crust is that given data set must satisfy all previously mentioned sampling criterion.	It is a subset of another construction,called power diagram(weighted voronoi diagram)	The output of a cocone algorithm is initial surface to tight cocone algorithm	It is closely related to α-shapes and output mesh is formed incrementally one triangle at a time	It involves BPA for surface reconstruction and RBF as an interpolation tool
2.	Execution time	Linear	Linear	Linear	Linear	1.Linear 2.Minimum execution time
3.	Speed	Slow	Faster than crust	2*speed of power crust 2.4*speed of crust	High speed 3*speed of tight cocone	Fastest
4.	Noise effect	Less	Highly affected	Moderately affected	Least affected	Removes noise in 3D surface
5.	Mesh size(No. of surfaces)	Dense	Dense	Moderate	Small	Smallest
6.	Output	Triangles	2D faces	2D faces	2D faces	2D faces
7.	Advantages	Simple Theoritically prominent	Simple	1.No extra points need to be added. 2.Generates watertight reconstruction	1.Efficient 2.Advancing front algorithm	No effect of noise in 3D surfaces.
8.	Disadvantages	Doesn't works properly in presence of sharp edges or non-uniform sampling.	1.Mesh very dense. 2.Not triangular.	1.Algorithm is sensitive to noise. 2.Surface holes are avoided only if undersampling is local and detectable.	1.Can produce holes if sampling improper. 2.Requires normal on the surface at each input point.	1.Equilibrium must be maintained between number of centres and amount of training data.

In all the above algorithms,it is to be noted that only size of the input matters NOT shape.The first three algorithms are based on Delaunay/Voronoi algorithms whereas power crust and tight cocone are known to generate watertight reconstructions.

IV. CONCLUSIONS

This paper compared and analysed the surface generated by well-known surface reconstruction algorithms. The comparison had shown the topology surface generated by these algorithms is based on the density of point clouds.. PowerCrust algorithm can reconstruct the surface from low density point clouds, but the surface created is not smooth. The number of surfaces generated by BPA algorithm is less than the number of surfaces generated by Delaunay/Voronoi based algorithms. Hence, the generating of 3D surface by using BPA algorithm will faster than Delaunay/Voronoi based algorithms.The Crust and Power Crust algorithms showed a balanced trade-off between execution time. The Ball Pivoting algorithm exhibited minimum execution time, followed by the Tight Cocone. The two drawbacks of the Power Crust reconstructed mesh are that it is very dense and not triangular.BPA achieves better results in all the considered aspects. The only problem of the BPA is that it requires the normals on the surface at each input point. It is recommended to use the BPA when the normals are available or easy to compute. Another problem with the BPA is that it may produce holes in the reconstructed surface if the sample is not uniformly distributed. An enhanced algorithm that combines the BPA with a hole filling technique based on RBF interpolation is mentioned. The new system showed good results on real samples and exhibited high robustness in reconstructing objects with non-uniform sampling.

REFERENCES

[1] Vikas Chauhan, Manoj Arora and R. S. Chauhan "Comparison of Delaunay Algorithm and Crust Algorithm for the Optimization of Surface Reconstruction System", 2011.

[2] Min Wan, Yu Wang, Egil Bae, Xue-Cheng Tai and Desheng Wang "Reconstructing Open Surfaces via Graph-Cuts" IEEE, February 2013.

[3] Shivali Goel and Rajiv Bansal "Surface reconstruction using scattered cloud points", May 2013.

[4] Shitu Bala and Gianetan S. Sekhon "A Comparative Study of Surface Reconstruction Algorithms based on 3D Cloud Points Delaunay and Crust triangulation",October 2011.

[5] Agostinho de Medeiros Brito Júnior, Adrião Duarte Dória Neto, Jorge Dantas de Melo and Luiz Marcos Garcia Gonçalves "An Adaptive Learning Approach for 3-D Surface Reconstruction From Point Clouds", IEEE

[6] Andrei C. Jalba and Jos B. T. M. Roerdink "Efficient Surface Reconstruction From Noisy Data Using Regularized Membrane Potentials" IEEE,May 2009.

[7] R. Poranne1, C. Gotsman and D. Keren "3D Surface Reconstruction Using a Generalized Distance Function", 2010

[8] Abhishek Bansal,Vishal Arora and Niraj Madaan "Enhanced Surface Reconstruction Algorithm Using Umbrella Filtering", December 2012.

[9] M. S. Abdel-Wahab, A. S. Hussein, I. Taha, M. S. Gaber "An Enhanced Algorithm for Surface Reconstruction from a cloud of points"IGCST, December 2005.

[10] Renoald Tang,Setan Halim,Majid Zulkepli "Surface Reconstruction Algorithms:Review and Comparasion"ISDE,2013.

