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A Review of Performance of Surface Reconstruction Algorithms

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Abstract— Surface reconstruction is the process to achieve three-dimensional complex surface model quickly and accurately from three-dimensional data obtained as a sample, that is widely used in reverse engineering. Reverse engineering of geometric shapes is the process of converting a large number of measured data points into a concise and consistent computer representation. Reconstruction of a 3-D object surface from sample of points has a wide range of applications such as computer-aided design (CAD) design, virtual reality, medical imaging, and movie industry. Surface reconstruction is challenging as the topology of the real surface is unknown, acquired data can be non-uniform and contaminated by noise, and reconstructing surfaces from large data sets can be prohibitively expensive in terms of computations or memory usage.

Keywords— accurately, reverse engineering, reconstruction, topology, contaminated.

I. INTRODUCTION

1.1 Surface Reconstruction

Surface reconstruction [13] is the process to achieve three-dimensional complex surface model quickly and accurately from three-dimensional data obtained as a sample, that is widely used in reverse engineering. Three-dimensional data collected by measuring device is usually dense, so it is called Point Cloud data. **Point cloud data** can be considered as an aggregation of the points in three-dimensional space, and each point cloud data has three axis of x, y, z. According to the different forms of data, point cloud data can be differentiated 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 mainly. In practice, due to the limitation of gathering devices or the different collecting ways, there is no such specific type of the points, so the points are known as scattered point cloud. For these scattered point cloud, if the reconstructed surface display the shape of the original point cloud, it is regarded as the result of the surface reconstruction.
Surface reconstruction is challenging as the topology of the real surface is unknown, acquired data can be non-uniform and contaminated by noise, and reconstructing surfaces from large data sets can be prohibitively expensive in terms of computations or memory usage. A lack of information about the surface orientation at the acquired samples may further complicate the problem[2].

1.2 GOAL

Reconstruction of a 3-D object surface from sample of points has a wide range of applications such as computer-aided design (CAD) design, virtual reality, medical imaging, and movie industry. The sample of points used for reconstruction can be classified as structured or unstructured based on connectivity information between points, according to the device used [3]. We focus our attention to the unstructured approach, where the input data are point clouds in space. Given a real surface and a set of points sampled from it, the goal is to create a surface model approximating the real model. That is, a desirable surface reconstruction algorithm must be able to recover both geometry and topology to fit the data correctly.

1.3 Use of 3d Scanner

Three-dimensional (3D) scanning is the process of acquiring a digital copy of a physical object. A 3D scanner is used to sample points on the surface of the object (the so-called underlying surface) and acquire their Cartesian coordinates, after which a surface reconstruction algorithm is applied to generate a surface based on this sample set. The problem is, of course, ill-posed, as this is basically an interpolation or approximation problem. Most current methods can be roughly classified into two approaches. The first is based onVoronoi diagrams and their Delaunay duals, starting with [Boi84], and later developed extensively (e.g. [KSO04, ACK01, AB98]). These triangulate the input point set in hope of achieving a triangle mesh approximating the underlying surface. But this method is sensitive to noise and requires a dense point set to give good results[5].

1.4 Using Crust Algorithm

Surface Reconstructing 3D surfaces from point samples is a well studied problem in computer graphics [6]. It allows filling of scanned data, surface holes and re-meshing of existing models. Solid surface models are desired for many purposes including input of existing physical parts to CAD/CAM systems for modification, automatic creation of machine tool paths, error inspection, and input to finite element systems. If such models do not exist, they may be created from point clouds sampled from the surface by the use of different technologies such as laser scanners . Reverse engineering of such geometric shapes is the process of converting a large number of measured data points into a concise and consistent computer representation . Therefore, it is the inverse of the traditional CAD/CAM procedures, that creates physical objects from CAD models [6].Triangulating scattered point-sets is a very important problem of reverse engineering. Given a set of unorganized points that lies approximately on the boundary surface of a three-dimensional object, and without a prior information on the topology, our aim is to reconstruct the surface by building a triangular mesh using the given points as vertices. Previous algorithms have used many interesting ideas. Few basic algorithms work by projecting the points to a carrier surface and creating triangulation in the parametric domain of the carrier surface. These methods are however limited for disconnected surface portions and objects with positive Genus. Delaunay-based surface reconstruction approaches were mainly developed in the field of computational geometry. This technique functions more when it is possible to control the sampling density over the surface. Amenta, Bern and Kamvysselis proposed the first algorithm (called crust) which provides theoretical guarantees on the reconstructed surface . It presented the feature point technique as in for large cloud points of a image surface reconstruction according to the local feature size, It implies a new fast and effective method that not only give good reconstruction to the smooth areas of the given surface, but it also recovers the sharp features originally existed in the source surface model provided that a reasonably nice sampling point cloud is given. Now we compared for time taken by the algorithm for surface reconstruction and we calculate the different parameters of time.

II. LITERATURE SURVEY

The various approaches used for the surface reconstruction are described below:

A. Efficient Surface Reconstruction using Generalized Coulomb Potentials

This process is provided by Andrei C. Jalba[2] in 2007 geometrically adaptive method for surface reconstruction from noisy and sparse point clouds, without any orientation information. The method involves a fast convection algorithm to attract the evolving surface towards the data points.

B. An Adaptive Learning Approach for 3-D Surface

The author Agostinho de Medeiros Brito Júnior[3] in 2008 propose a multiresolution approach for surface reconstruction from clouds of unorganized points representing an object surface in 3-D space. The method uses a set of mesh operators and simple rules for selective mesh refinement, 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 points, mainly the object boundary. Successive refinement and motion of vertices are applied leading to a more detailed information of surface,in a multiresolution, iterative scheme. Reconstruction was explained with several point sets, including different shapes and sizes. Result show generated meshes very close to the object final shapes. It include measures of performance and discuss robustness.

C. 3D Surface Reconstruction Using a Generalized Distance Function

The author R. Poranne1, C. Gotsman1 and D. Keren2[5] in 2010. A physically motivated method for surface reconstruction proposed that can recover smooth surfaces from noisy and sparse data sets. For this no orientation information is required. With a new technique based on regularized membrane potentials the input sample points are aggregated, that leads to improved noise tolerability and outlier removal, without allowing much with respect to detailed recovery. After collecting the sample points on a volumetric grid, iterative algorithm is used that classify grid points as exterior or interior to the surface. The algorithm is based on intrinsic properties of the smooth scalar field on the grid that emerges after the aggregation step. Secondly, a mesh-smoothing paradigm based on a mass-spring system is introduced. By enhancing the system with a bending-energy minimizing term we ensure that the final triangulated surface is smoother than the piece wise linear. According to the terms of speed and flexibility, the method compares effectively with respect to previous data. Most parts of the method are implemented on modern graphics processing units (GPUs). That results in a wide variety of settings is presented, ranging from surface reconstruction on noise-free point clouds to grayscale image segmentation.

D. An Orientation Inference Framework for Surface Reconstruction From Unorganized Point Clouds

The author Yi-Ling Chen, Student Member, IEEE, and Shang-Hong Lai, Member, IEEE[11] in 2011 implements ,Surface reconstruction is to find a surface from a given finite set of geometric sample values. In most applications, the sample values are the points. Reverse engineering of different geometric shapes is the process of converting a large number of measured data points into a concise and consistent computer representation. The "feature points" techniques are used to create mesh from the extracted points. The present work is to develop a system for image reconstruction from scattered cloud points. Various algorithms like crust algorithm and Delaunay algorithm will be implemented and compared for time taken by the algorithm for surface reconstruction.

E. Reconstructing Open Surfaces via Graph-Cuts and its algorithms

The author Min Wan, Yu Wang, Egil Bae, Xue-Cheng Tai, and Desheng Wang[12] in 2013 presented an orientation inference framework for reconstructing implicit surfaces from unoriented point clouds. The method starts from building a surface approximation hierarchy consisting of a set of unoriented local surfaces, that are represented as a weighted combination of radial basis functions. It formulate the determination of the globally consistent orientation as a graph optimization problem by treating the local implicit patches as nodes. An energy function is defined as to penalize inconsistent orientation changes by checking the sign consistency between neighbouring local surfaces. An optimal naming of the graph nodes indicating the orientation of each local surface can therefore be obtained by minimizing the total energy defined on the graph. The local inference results are travelled over the model in a front-propagation fashion to obtain the global solution. The reconstructed surfaces are used by a simple and effective inspection procedure to locate the erroneously fitted local surfaces. A reconstruction algorithm that iteratively includes more oriented points to improve the fitting accuracy and efficiently updates the RBF coefficients is done.That demonstrate the performance of the proposed method by showing the surface reconstruction results on some real-world 3-D data sets with comparison to those by using the previous methods. The author Neha Rathore, Richa Gupta in 2014 proposed [15]. Surface reconstruction is to find a surface from a given finite set of geometric sample value. Surface reconstructing 3D surfaces from point samples is a well studied problem in computer graphics. All algorithms, aim to solve this problem must overcome several problems. One of which is related to the size and quality of the input, under sampling, and noise. The main aim of this research paper is to study different algorithm for image reconstruction from scattered cloud points. Many of the surface reconstruction algorithms discussed came from the computer graphics community.

TABLE

AUTHOR & YEAR	TECHNIQUE / ALGORITHM	FINDINGS
Andrei C. Jalba in 2007	Surface Reconstruction using Generalized Coulomb Potentials	It can be formulated as a convection problem of a surface in a velocity field generated by generalized Coulomb potentials
Agostinho de Medeiros Brito Júnior in 2008	multiresolution approach	The threshold can be set by the user to produce meshes with more or less triangles, allowing a better refinement control, when compared with other and traditional multiresolution methods.
R. Poranne1, C. Gotsman1 and D. Keren2 in 2010	unoriented 3D point set	Embedding data in a higher-dimensional space using socalled *kernels*, to enable easier processing, is a common technique in machine learning
Shitu Bala in 2011	image reconstruction from scattered cloud points	Crust is the best Surface Reconstruction Algorithm.
Shivali Goel in 2013	Crust algorithm with umbrella Filtering	image will be taken only of pts extension
Neha Rathore, Richa Gupta in 2014	Image reconstruction from scattered cloud points	Power crust algorithm can reconstruct the surface from low density point clouds

III. CONCLUSIONS

Surface reconstruction using generalized Coulomb Potential can be formulated as a convection problem of a surface in a velocity field generated by generalized coulomb potentials. Different algorithms are viewed like Crust Algorithm with umbrella filtering , power crust. It is based on Multi resolution approach in which the threshold can be set by the user to produce meshes with more or less triangles, allowing a better refinement control when compared with other traditional multiresolution methods. Various techniques for surface reconstruction are reviewed.

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