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A Survey of Surface Reconstruction

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***Abstract*— Surface reconstruction means that to get back the data by scanning an object using a device such as laser scanner and construct it using computer to gain back the soft copy of data on that particular object. Surface reconstruction is reverse method. It is very useful when on a particular object original data is missing without doing any backup. Convert the discrete sampling data representation of physical object into a continuous surface of digital representation in computer is known as surface reconstruction. The main objective of this survey paper is to study and analyze Various algorithms like crust algorithm, power algorithm and Delaunay algorithm will be compared for time taken by the algorithm for the surface reconstruction.**

Keywords- Surface Reconstruction, Crust Algorithm ,Partical Filtering, Umbrella Filtering, Point Clouds, 3D

I. Introduction

Surface reconstruction is process in which atoms at the surface of a crystal assume a different structure i.e the bulk. Surface reconstructions are important they help in the understanding of surface chemistry of various materials, especially in the case of where another material is adsorbed onto the surface.

1.1 Basic Principles

The equilibrium position of infinite crystal of each individual atom is determined by the forces exerted of all the other atoms of the crystal, resulting of a periodic structure. If the surface is introduced to the system by terminating the crystal given a plane, forces are altered, changing the equilibrium positions of the remaining atoms. This is most noticeable for the atoms of near the surface plane, as they now only experience inter-atomic forces from one direction. This is imbalance results in the atoms near surface assuming positions with different spacing and/or symmetry from the bulk atoms and produce a different surface structure. This change in equilibrium positions near the surface can be categorized either a relaxation or a reconstruction.

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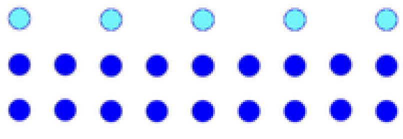

Relaxation is used to change the position of entire layers of atoms relative to the bulk positions. Often this is purely normal relaxation i.e the surface layers move in a direction normal to the surface plane, usually resulting of smaller than interlayer spacing. This makes intuitive sense, as a surface layer that experiences no forces of the open region can be expected to the contract towards the bulk. Most metals experience has type of relaxation.[1] Some surfaces also experience of relaxation of the lateral direction as well as the normal, so that the upper layers is shifted relative to further layer in order to minimize the positional energy.

Reconstruction is the process to change of the two dimensional structure from the surface layers, in addition of changes in the position of the complete layer. For example, in a cubic material of the surface layer might restructure itself to suppose a smaller two dimension spacing between the atoms of the forces from adjacent layers are reduced. The general symmetry of a layer may also change, in the case of Pt (100) surface, which reconstructs of a cubic to a hexagonal structure.[2] A reconstruction can be affect one or more layers at the surface and either conserve the total number of atoms in a layer (a conservative reconstruction) have a greater and lesser number in the bulk (a nonconservative reconstruction).

A 3-D object surface reconstruction from sample of points has a wide range of applications such as computer-aided design (CAD), medical imaging, virtual reality, and movie industry. The sample of points used for reconstruction can be defined as structured or unstructured based on the connectivity information between points, according to the sampling device used [1]. We focus to the unstructured approach, where the input data are point clouds in space. A real surface and a set of points sampled from it is given, the goal is to create a surface model approximating the real model. Hence, a desirable surface reconstruction algorithm should be able to recover both geometry and topology to fit the data correctly.
Fig. 1 shows the computational flow diagram.In this, First, the input sample points (assumed to be without any information is allocate to grid cells, using cloud in cell (CIC) interpolation (first step in Fig. 1).(Step 2) perform aggregation of the sample points from computing regularized-membrane potentials on the grid.Alabeling algorithm, which follow increasing paths of the scalar field

(starting from the bounding box and marching from the data points) are used to classify the grid points into exterior and interior of the surface, thus defining an implicit surface (step 3). Prior of polygonization, we use diffusion potentials, but at this time with the purpose of producing a smooth implicit surface. Then, employ Bloomenthal's polygonizer to turn the implicit surface into triangulated one (step 4), and use a mass spring system, improved with a bending energy minimizing term, in the order to obtain a larger degree of surface smoothness (step 5)[4].

2. CRUST ALGORITHM

There are many algorithms for the surface reconstruction for example alpha shape, ball pivoting algorithm [10] but the most approach is built of crust algorithm. In Crust algorithm, firstly compute the Voronoi diagram of the sample and select the poles of the Voronoi vertices to estimate the medial axis, then compute the Delaunay triangulation from the combined point set to the samples and poles, in the end choose the triangles whose vertices are all samples.

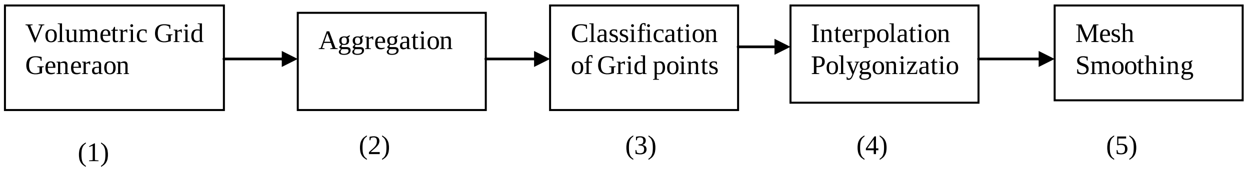

Fig.1 Flow diagram of proposed surface reconstruction method

The past few decades have many applications of 3D data acquisition technologies. For example, in the computer graphics is required to capture complex 3D shapes on site using portable laser scanner for computer simulation and animation. X-rays, Computed Tomography and Magnetic Resonance Imaging (MRI) scanning are typical data acquisition applications in the medical field. In all these applications, data sources of various data acquisition devices consist discrete sampling data, which could be divided into different categories are unorganized data, contour data, volumetric data and range data . Convert the discrete sampling data of physical object into a continuous surface of digital in computer is known as surface reconstruction[8].

The discrete sampling data has more resolution to represent the scanned model surface, surface reconstruction would be recover topology and geometry of model surface. The general pipeline of the 3D data acquisition and processing of the initial physical object in the real world to the final digital model in computer-world is shown in Figure 2. The first stage involves acquisition of discrete sample from a physical object through 3D data acquisition system.The geometric model in place, various application specific modeling and the digital processing can be launched in third stage. The stages of data acquisition and processing, surface reconstruction stands out the most significant and challenging task is obtaining the digital model by the physical object[8].

Some triangles from three-dimensional crust aren't correct .It means it contains many bad poles so apply filtering on this algorithm which is based on the number of edges, number of vertices and orientation. Then power shape is formed of image which has smooth surface.

3. CHALLENGING FOR SURFACE RECONSTRUCTION

Surface Reconstruction to unorganized point clouds are challenging problem because the topology of real surface can be complex and obtained data may be changed sampled and the data may be impured by noise. In addition, the quality and accuracy of the data sets are strongly depend upon the acquisition methodology. Furthermore, the computational cost of reconstructing surface of large data sets can be prohibitive. Most of the existing reconstruction methods were developed postulating precise and noise free data is present. Therefore, they cannot meet the demands posed by noisy and/or sparse data[4].

4. PROBLEMS IN SURFACE RECONSTRUCTION

- **Missing Some Point Normal:** The points may not be provided with point normal, which is indicate the orientation of the local shape.
- **Incomplete Sampling:** The surface may not be well sampled. This commonly goes to holes, that are to be filled additional efforts.
- **Holes:** Holes from the insufficiently sampled regions, may need to be filled.
- **Boundaries:** The boundary of surface need to be preserved.

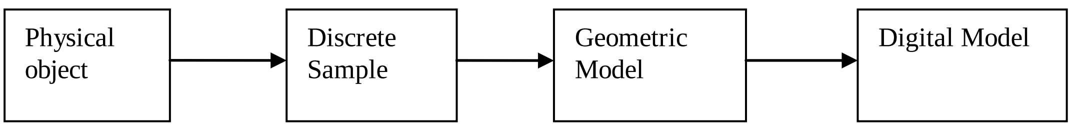

Figure 2: The General Pipeline of 3D Data Acquisition and Processing

- **Non Manifold Surface:** It contain surface junctions and surface boundaries, which cannot be

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reconstructed correctly using the surface reconstruction algorithms.

- **Fair Mesh:** The triangles of the resulting mesh should be well shaped. It is need by some follow up operations of the mesh, such as Finite Element Analysis.
- **Noisy Points:** The location of points may be disturbed by unknown levels of noise.
- **Sharp Features:** Sharp edges secured and corners should be preserved, even though they break the assumption of smoothness[8].

5. SURFACE RECONSTRUCTION APPLICATION FIELDS

- In CAD applications, for example, the user is interested to obtaining a very accurate model for the real object. In many cases, the available scanning device may not allow the user to perform a detailed sampling of the object [6], but it only allows it on the most representative points of the surface, such as high curv edges. In this case, deterministic approaches as crust [7], cocone [8] and spectral reconstruction [9] are the best choice, because they are best suited to drive the reconstruction such kind of data.

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- In medical applications, the scanning devices used computerized tomographs, magnetic resonance scanners (MRS) and 3D ultrasounds. Here, the user focuses his attention on the shape information of internal tissues on a given patient [10]. There must exist a tradeoff between accuracy and speed, since slow but in the exact methods may be unpractical use. Well-established methods such as the one developed by Hoppe [1] may demand hours of work.

- On the other hand, for real-time reconstructions, the user's interest is focused on speed. In such applications, the reconstructed model have few elements as necessary for surface representation. A typical example is a remote control of vehicles [11]. By using stereovision, it is possible to obtain the different maps between a pair of images taken from video cameras and, using these maps, the positions of points in 3D space. This reconstruction must be done with a fast surface reconstruction algorithm to achieve real time. The remote operator can guide the vehicle on remote terrain, using the virtual reality environment with mixed reality [11]. Environments with mixed reality are virtual spaces where there exist digital representations of both real and simulated objects.

- In such application, surface reconstruction is used for stereoimage pairs of building map of the real environment.Therefore stereomatching usually generates 3D points that are scattered, irregularly distributed, and missing in large areas [12], surface reconstruction algorithms for real-time applications are required to be less sensitive to such features. This scenario can be easily addressed by the proposed method.

- In real-time applications, such as the one described previously, the multiresolution approach is most attractive. If the user is interested only in a coarser view of the scene, the reconstruction generates a coarser model giving faster visual feedback with less processing time. If the user is interested in some specific detail, he can explore the scene model at the finer resolutions to obtain the desired result. With the method proposed in this paper, the user is able to adjust the level of detail to be presented in the reconstructed scene.

6. LITERATURE SURVEY

Different Surface Reconstruction techniques described below:

A. 3-D Surface Reconstruction From Point Clouds

This process provided by Agostinho de Medeiros Brito Júnior [1] in 2007 is used to multiresolution approach for surface reconstruction of clouds of unorganized points representing an object surface in 3-D space. The proposed method uses set of mesh operators and simple rules for the selective mesh refinement, with a strategy based on the Kohonen's self organizing map (SOM). Self adaptive scheme is used iteratively moving vertices of an initial simple mesh in the direction of set of points the object boundary. Successive refinement and movement of vertices are applied to leading more detailed surface, in multiresolution, iterative scheme. Reconstruction was experimented with several point sets, different shapes and sizes. Results produced meshes very close to object finalshapes. We measures of performance and discuss robustness.

B. Orientation Inference Framework From Unorganized Point Clouds

The author Yi-Ling Chen in (2011-2) implement a new method [7] which provides an orientation inference framework for reconstructing implicit surfaces from unoriented points clouds. The proposed method start from building a surface approximation hierarchy comprising of unoriented local surfaces, which described as a weighted combination of radial functions. We formulate the determination of globally consistent orientation as a graph optimization problem by treating of the local implicit patches nodes. The energy function is defined to as penalize inconsistent orientation changed by checking the sign consistency between the neighboring local surfaces. An optimal labeling of the graph nodes indicating the orientation of every local surface can be obtained by minimizing the total energy defined on the graph. The local inference results are produced by the model in a front propagation fashion to get the global solution. The reconstructed surfaces are joined by simple and actual inspection procedure to fix the fitted local surfaces. A progressive reconstruction algorithm i.e iteratively includes more points to improve fitting accuracy and efficiently updates the RBF coefficients proposed. Demonstrate to performance of proposed method showing the surface reconstruction results in some real world 3D data sets using comparison of those by using the previous methods.

C. State of the Art from Point Clouds

The author Matthew Berger in 2014 proposed approach [10] which provides the traditional problem of addressed by surface reconstruction to get back the digital representation of a physical shape has been scanned, where scanned data contains the wide different types of defects. While much of the earlier work has been focused reconstructing given piece wise smooth representation of the original shape, recent work has been taken on more specialized priors of address significantly challenging data faults, where the reconstruction can be give different representations are not necessarily explicit geometry. State of the art report surveys aera on the surface reconstruction i.e providing categorization with respect to priors, data faults and reconstruction output. By considering of surface reconstruction that report provides detailed characterization of the field and highlights exactly between diverse reconstruction techniques and provides by directions for future work of surface reconstruction.

D. Using Scattered Point Cloud with Crust Algorithm

This process provided by Shivali Goel [8] in 2013 is used to retrieve the data by scanning object using a device i.e laser scanner and construct using the computer to obtain back the soft copy of data on the particular object. Surface reconstruction is the reverse method. It is very useful when in the particular object the original data is missing without any backup. The author developed a system for surface reconstruction using scattered cloud points. Crust algorithm with umbrella Filtering is implemented. Crust algorithm plays an important role in the guaranteed quality of the triangular mesh generation. Crust algorithm monitors has various parameters of mesh generation which evaluates the performance of algorithm by calculating parameters. The main aim of algorithm to filter out insignificant data while preserving an acceptable level of output quality[8].

E. Comparison of Delaunay Algorithm and Crust Algorithm

Comparison of Delaunay algorithm and Crust algorithm provided by Vikas Chauhan[5] in 2011 is used to compared these algorithm for the time taken in surface reconstruction. The purpose of surface reconstruction to find a surface from a given finite set of geometric sample nvalues[5].

F. 3D Cloud Points Delaunay and Crust Triangulation based Algorithm

The author Shitu Bala in (2011-1) proposed approach [6] which is used to find the surface of a given finite set of geometric sample values. In many applications , points are the sample values. Reverse engineering of geometric shapes is process of converting a large number of measured data points convert into concise and consistent of the computer representation. The “feature of points” techniques are used to create mesh of the extraction points. The present work is develop a system for image reconstruction using scattered cloud points. Crust algorithm and Delaunay algorithm be implemented and compared for time taken of algorithm for surface reconstruction..

G. Using Generalized Coulomb Potentials

That process is provided by Andrei C. Jalba [2] in (2007-1) is used to method of surface reconstruction by noisy and sparse point clouds, without orientation information. These method fast convection algorithm to attract the evolving surface of the data points. The force field in which the surface heavier based on generalized Coulomb potentials evaluated of adaptive grid using a fast algorithm. Formulating reconstruction of convection problem in a velocity field produced by Coulomb potentials offers the number of advantages.Which is compute the distance of the data set to the implicit surface, which are sensitive noise due to very reliance on the distance transform, the method is highly resilient to shot noise global, generalized Coulomb potentials can be used the presence of outliers due to noise. Coulomb potentials represent long range interactions i.e consider all data points at once and they convey global information that is crucial in the fitting process. Both spatial and temporal complexities of spatially adaptive method are proportional to the size of the reconstructed object, which create method compare favorably with respect to the previous approaches in terms of speed and flexibility. Experiments of sparse as well as noisy data sets and show that method is capable of delivering crisp and detailed smooth surfaces.

H. Using Regularized Membrane Potentials

This process is provided by Jos B. T. M. Roerdink [4] in 2009 is used for surface reconstruction is proposed that can be recover smooth surfaces from noisy and sparse data sets. Orientation information not required. By a new technique based on the membrane potentials input sample points are aggregated, leading to noise tolerability and outlier removal, without sacrificing with respect to feature recovery. After aggregating of sample points of a volumetric grid and a novel iterative algorithm is used to classify grid points exterior or interior to the surface. This algorithm relies on the intrinsic properties of the smooth scalar field on the grid which is emerges after the aggregation step. Secondly the mesh smoothing paradigm based on the mass spring system is introduced. By this system with the bending energy minimizing term we are ensure the final triangulated surface smoother than by piecewise linear. In terms of speed and flexibility consider with respect to the previous approaches. Most parts of this method are implemented by modern graphics processing units (GPUs). Results of a wide variety of settings are presented by ranging surface reconstruction in noise free point clouds to gray image segmentation.

I. Reconstructing Open Surfaces via Graph-Cuts

Reconstruction Open Surfaces via Graph-Cuts provided by Min Wan [9] in (2013-1) proposed for reconstructing open surfaces from unarranged point sets. Through a Boolean operation on the crust around of the data set, the open surface problem is translated to watertight surface problem within a restricted region. Integrating variational model, Delaunay based on mesh and multiphase technique, the proposed method can be reconstruct open surfaces robustly and effectively. Surface reconstruction method using domain decomposition is presented, i.e based on the new open surface reconstruction method. This method can be hold more general surfaces, such as nonorientable surfaces. These algorithm is designed to parallel friendly way and necessary measures are carried to move cracks and conflicts between subdomains. Numerical examples are contained to demonstrate the robustness and effectiveness of proposed method in watertight, open orientable, open nonorientable surfaces and combinations of such

J. Real time Volumetric Surface Reconstruction and Dense Tracking On The Mobile Phones

This process is provided by Peter Ondr´uˇska. [11] in 2015 is used to the first pipeline real time volumetric surface reconstruction and dense 6DoF camera running purely of the standard off the shelf mobile phones. With the embedded RGB camera, our system allow users to scan the objects of varying shape, size, and seem in seconds, using real time feedback during the capture process. The state of the art methods, which create only point based 3D models on the phone or require cloud be based on processing our hybrid GPU/CPU pipeline is unique in that it create a connected 3D surface model directly on device at 25Hz. In each frame, we can perform dense 6DoF tracking, i.e continuously registers the RGB input of the incrementally built 3D model, minimizing a noise inform photoconsistency error metric. This is followed from efficient key frame selection and dense per frame stereo matching. The depth maps are fused volumetrically with this method KinectFusion, producing compelling surface models. For each frame, the complete surface is extracted for live user feedback and pose opinion. We can demonstrate scans of a variety of objects, and compare to a Kinect based on baseline, showing on the average 1:5 cm error.Qualitatively compare to state of the art point based mobile phone method, demonstrating order of the magnitude faster scanning times, and fully connected to surface models.

TABLE

Author Name	**Year**	**Technique**	**Finding**
Agostinho de Medeiros Brito Júnior	2007	An Adaptive Learning Approach for 3-D Surface Reconstruction From Point Clouds	to produce meshes with more or less triangles, allowing a better refinement control, when compared with other and traditional multiresolution methods.
Andrei C. Jalba and Jos B. T. M. Roerdink Senior Member	2007-1	Efficient Surface Reconstruction using Generalized Coulomb Potentials	more efficient smoothing of implicit surfaces on non-uniform grids based on curvature flows and/or (anisotropic) diffusion, and improving the overall performance of the polygonization method.
Agostinho de Medeiros Brito Júnior, Adrião Duarte Dória Neto	2008	An Adaptive Learning Approach for 3-D Surface Reconstruction From Point Clouds	to produce meshes with more or less triangles, allowing a better refinement control, when compared with other and traditional multiresolution methods.
Andrei C. Jalba and Jos B. T. M. Roerdink	2009	Efficient Surface Reconstruction From Noisy Data Using Regularized Membrane Potentials	to perform reconstruction starting from particle systems, contours or even grayscale volumetric data leading to image segmentation.
Vikas Chauhan, Manoj Arora and R. S. Chauhan	2011	Comparison of Delaunay Algorithm and Crust Algorithm for the Optimization of Surface Reconstruction System	the simulation are in the form of graphs of time taken to complete surface reconstruction v/s the number of cloud points.
Shitu Bala, Gianetan S. Sekhon	2011-1	A Comparative Study of Surface Reconstruction Algorithms based on 3D	improvements are greater in Crust than in the Delaunay, therefore it can be concluded

		Cloud Points Delaunay and Crust Triangulation	that Crust is the best Surface Reconstruction Algorithm.
Yi-Ling Chen, Student Member, IEEE, and Shang-Hong Lai, Member, IEEE	2011-2	An Orientation Inference Framework for Surface Reconstruction From Unorganized Point Clouds	improve its computational performance since much of the matrix computation required in the RBF fitting can be greatly accelerated by GPUs.
Shivali Goel1 & Rajiv Bansal2	2013	Implimentation of surface reconstruction using scattered point cloud with crust algorithm	After filtering number of bad poles are reduced and we obtain the smooth surface. improve its efficiency by dealing with another image format.
Min Wan, Yu Wang, Egil Bae, Xue-Cheng Tai, and Desheng Wang	2013-1	Reconstructing Open Surfaces via Graph-Cuts	Parallel implementation of this domain decomposition method and investigation of its efficiency is one of our future research interests
Matthew Berger1 Andrea Tagliasacchi 2 Lee M. Seversky1 Pierre Alliez3 Joshua A. Levine4 Andrei Sharf5 Claudio T. Silva6	2014	State of the Art in Surface Reconstruction from Point Clouds	surface reconstruction has grown from methods that handle limited defects in point clouds while producing detailed reconstructions, to methods that handle substantial artifacts and produce high-level surface representations.
Peter Ondr´uˇska, Pushmeet Kohli and Shahram Izadi	2015	MobileFusion: Real-time Volumetric Surface Reconstruction and Dense Tracking On Mobile Phones	produce only point-based 3D models on the phone, or require cloud-based processing, our hybrid GPU/CPU pipeline is unique in that it creates a connected 3D surface model directly on the device at 25Hz.

CONCLUSION

Various paper have been studied for surface reconstruction. Adaptive Learning Approach for 3D Surface Reconstruction From Point Clouds to create meshes with more or less triangles, allowing a better refinement control, when compared with other and traditional multiresolution methods. Efficient Surface Reconstruction using Generalized Coulomb Potentials more efficient smoothing of implicit surfaces on non-uniform grids based on curvature flows and/or (anisotropic) diffusion, and improving the overall performance of the polygonization method. Implimentation of surface reconstruction using scattered point cloud with crust algorithm this process approach to filtering number of bad poles are reduced give the smooth surface its efficiency is improved by dealing with another image format.

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