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Impact of Noise and Redundancy Threshold on Power Crust Implementation

Nidhi Sharma*
CSE&Kurukshetra
University Haryana,
India

Abstract--- In this paper,one of the most eminent algorithms,basically,Crust and Power crust have been studied. The power crust employs the integration of a sample of points from the surface of a three-dimensional object and producing a surface mesh and an approximate medial axis.Initially,approximation of the medial axis transform (MAT) of the objec is done followed by using an inverse transform that produces the surface representation from the MAT. In this paper, we use the power crust implementation for power shape simplification of the image knot by various noise and redundancy thresholds which proves to be robust for realistic and even difficult samples enhancing quality.

Keywords---Surface reconstruction,point clouds,computer graphics,crust algorithm,power crust.

I. INTRODUCTION

IN the area of surface reconstruction the purpose is to obtain a digital representation of a real or physical object or phenomenon described by a cloud of points, that are sampled on or near the object's surface[13]. The growing interest in this field is due to the increasing availability of point-cloud data, such as may be extracted from medical or laser scanners, vision techniques (e.g., range images).It is a well-known problem in computer graphics[4].As the data is usually dense,that's why it is called point cloud data. In computer vision, shape recovery is a classical problem that aims to derive a 3-D scene description (e.g., surface normal and surface depth) from one or more 2-D images.All techniques for shape recovery are commonly called "shape-from-X," where X can be shading, stereo, texture, or silhouettes, etc.. For example, in the stereo problem,initially features are extracted (e.g., corners, lines, etc.) from a collection of input images and then the correspondence problem is solved, i.e., matching features across images. After the depth information at the locations of the extracted features is obtained,the reconstruction of the surfaces of the objects present in the scene is required. One way of achieving this is by employing techniques that reconstruct surfaces from point clouds[13].
Reconstructing a surface from unorganized point clouds is a challenging problem because the topology of the real surface can be very complex, the acquired data may be nonuniformly sampled and the data may be contaminated by noise. In addition, the accuracy and quality of the data sets strongly depend upon the acquisition methodology. Furthermore, the computational cost of reconstruction from large datasets can be prohibitive. Most of the present reconstruction methods were developed postulating that precise and noise-free data is available.So, they cannot meet the demands posed by noisy and/or sparse data[13].

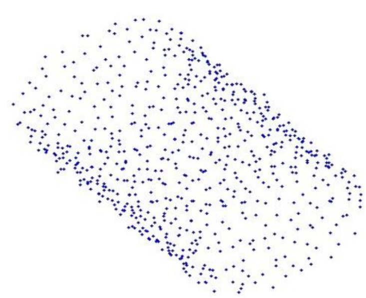

Figure 1. Point cloud

Problem Definition-

The problem of surface reconstruction can be defined as follows: Let S be a surface of object O, and assume that S is a smooth twice-differentiable two-dimensional manifold, embedded in Euclidean three-dimensional space ℝ3 . Given a discrete set of points

P , pi∈P⊂ℝ3 , i=1, ... , N , that take surface S as a sample, search a surface S' which approximates S, using the data set P. The reconstructed mesh S' must be topologically equivalent to the surface S of the original object.
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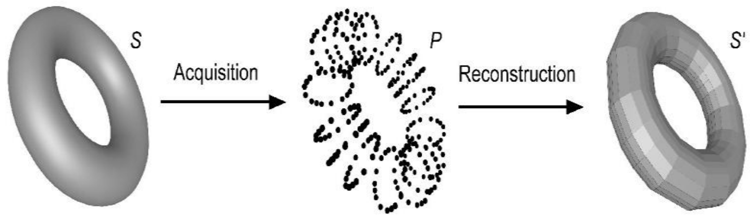

Figure 2.Overview of problem of surface reconstruction.

A.SURFACE RECONSTRUCION PHASES

Reconstruction of ordered point cloud is that constructing the surface of points sample from the verge of object to approximate the actual surface. In practice,there are no particular type of the points,as a result of shortcoming of gathering devices, therefore, the points are known as scattered point cloud.If the reconstructed surface can show the shape of the original point cloud, we consider it as the result of the surface reconstruction[15].

The surface reconstruction aims to find a surface from a given finite set of geometric sample values[14]

Phases of Surface Reconstruction:

Our reconstruction method employs three successive phases:
Phase 1: Initial Surface Estimation
Phase 2: Mesh Optimization
Phase 3: Smooth Surface Optimization

The main aim of Three Phase Surface Reconstruction is:
•Determine the topology of the surface
•Improve accuracy of mesh and conciseness.
•Explore piecewise smooth surface fitting on the data.

II. THE CRUST AND POWER CRUST ALGORITHM

Two famous algorithms from Delaunay based methods are the Crust and the Power crust Algorithm[8].It can be described as follows-

1.The Crust Algorithm

The first algorithm in the present study is the Crust algorithm by Amenta et al. [10]. The only prerequisite of the Crust is that the input data set should satisfy the previously mentioned sampling criterion. It was named Crust because the word "crust" is the formal name of the
geometric structure which this algorithm constructs as an approximation to the required surface. The worst case complexity of three-dimensional Voronoi diagram construction or Delaunay triangulation is $O(n^2)$. Since the Voronoi diagram and Delaunay triangulation computations are the main steps of the algorithm, the algorithm complexity is too $O(n^2)$[5]. Notice that the Voronoi diagram is constructed for n points, while the Delaunay triangulation is computed for at most 3n points. It is noteworthy that the worst-case complexity for the three-dimensional Delaunay triangulation almost never arises in practice[5].

Advantages-

•The Crust algorithm has the advantage of being theoretically prominent.

Disadvantages -

•The Crust does not work properly in the case of non-uniform sampling or in the presence of sharp edges. If the given cloud is non-uniformly sampled, the Crust faces difficulty and may create holes[5].

2. The Power Crust Algorithm

This algorithm was named after the structure that it builds—the "power crust" structure which is a geometrically and topologically correct piecewise-linear approximation to the surface[5]. The power crust is a subset of another construction, called the power diagram, which can be thought of as a weighted Voronoi diagram.

Voronoi diagrams, the power diagram is computed for weighted points (balls; points with radii) rather than ordinary points.The power diagram computation is the dominant factor in determining the time complexity of the Power Crust. Since the power diagram is a variant of the Voronoi diagram, it has the same quadratic time complexity $O(n^2)$, and so does the Power Crust. Therefore, the Power Crust and the Crust algorithms have the same worst case quadratic time complexity $O(n^2)$. Note that the power diagram is computed for atmost 2n points, hence, the Power crust is faster than the Crust in practice[5].

Advantages-

•The Power Crust algorithm is theoretically guaranteed and works under the same sampling criterion of the Crust.
•No 'clean up' operations—as holes filling or manifold extraction—are needed to modify the reconstructed surface.
•Also, the generated mesh is a watertight surface, which makes this algorithm suitable for CAD applications.

Disadvantages-

•The output surface mesh is very dense and usually needs to be simplified.
•In addition, the output surface consists of a set of two-dimensional faces, not triangles[5].

III. RELATED STUDY

Nina Amenta et. al. [1] In this paper,an algorithm is given that employs voronoi diagram of sample points to give the distance of output surface from original sampled surface,ensuring the quality of sample density is good enough.It also proves that the output surface is homeomorphic to original surface.

Zhou Min et. al. [2] This paper presents a new approach to the surface reconstruction. The proposed method finds the basic parts of the surface and blends surfaces between them. Each basic geometric part subdivision into triangular patches calls for comparision using normal vectors for face grouping.After that,the basic geometric surfaces are implemented to the infnitive surface. The infnitive surface's intersections are trimmed by boundary representation model reconstruction. The proposed methodology has numerous advantages such as computational effciency and automatic functional modelling in reverse engineering.

Bharti Sood et. al. [3] The Crust Algorithm is an algorithm for the surface reconstruction from unorganized cloud points in 3D. For a given point cloud from a smooth surface, the output ensures to be topologically correct and as the sampling density increases it moves towards a common point to the original surface.The paper discusses crust algorithm for surface reconstruction and time calculation.The algorithm is based on the three-dimensional Voronoi diagrams.

B.Mederos et. al. [4] A new scheme is presented for implicit surface reconstruction in this paper. Similarly to the multilevel partition of unity (MPU) method,the domain is hierarchically divided to obtain the local approximation for the object on each part, and then patch all together to get a global description of the object.The new scheme uses ridge regression and weighted gradient one fitting techniques to get better stability on local approximations.

M.S. Abdal Waheb et. al. [5] In this paper, most eminent computational geometry based surface reconstruction algorithms are analysed.The Crust, the Power Crust, the Tight Cocone and the Ball Pivoting algorithm are analysed. The key issues for the comparison are the quality of the reconstructed surface, the reconstruction time, and the total memory usage. an enhanced algorithm based on Ball Pivoting algorithm and Radial Basis Functions is proposed.The detected hole within the surface reconstruction process are filled in the enhanced algorithm. The proposed algorithm exhibited high robustness in reconstructing objects with non-uniform sampling and misregistrations.

Renoald Tang et. al.[6] This paper reviews the well-known algorithms used to reconstruct the topology surface from sample points in three dimensional spaces.After the surface reconstruction algorithm on the sample points is applied, the 3D model of the object can be generated. The algorithms depicted in this paper are applied to various models. Analysis of the topology surface generated from each algorithm is analysed.The problem and the idea to develop the new surface reconstruction are proposed based on the analysis done.

Hugues Hoppe et.[7] The paper discusses an algorithm that takes as input an unorganized set of points on or near an unknown manifold M, and an output is produced as a simplicial surface that approximates M. The topology, the presence of boundaries, and the geometry of M are assumed to be unknown in advance — all are inferred automatically from the data.

Oliver Schall et. al. [8] The paper delivers a brief overview of recent developments in the field of surface reconstruction from scattered point data. Methods of computational geometry, implicit surface interpolation techniques, and approaches of shape learning are main concerning issues that are studied in this paper.

Ming-Ching Chang et. al. [9] This paper proposes an algorithm for surface reconstruction from unorganized points based on a view of the sampling process as a deformation from the original surface.The algorithm looks for a sequence of transformations of the MS(medial scaffold) to invert this process.A greedy algorithm that iteratively transforms the MS by ''removing" suitable candidate MS curves (gap transform) from a rank-ordered list sorted by a combination of properties is proposed.

M.Kamvysselis et. al. [10] A new algorithm for the reconstruction of surfaces from unorganized sample points is proposed. The algorithm is the first for this problem with provable guarantees. Given a "good sample" from a smooth surface, the output is known to be topologically correct and convergent to the original surface as the sampling density increases.The algorithm relies upon the three-dimensional Voronoi diagram.

Agostinho de Medeiros Brito Junior et. al.[11] In the following paper,a multiresolution approach for surface reconstruction from clouds of unorganized points representing an object surface in 3-D space is given.Reconstruction is experimented on with numerous point sets of varying shapes and sizes. The outcome proves to be promosing by generating meshes that are close to object final shapes.

S.Choi et. al. [12] In this paper,the theory is used to develop a power crust implementation which is indeed robust for realistic and even difficult samples.Models with sharp corners, sparse and unevenly distributed sample points,holes and noise are taken as inputs that demonstrate good empirical results.

Andrei C.Jalba et. al. [13] The paper discusses physically motivated method for surface reconstruction is proposed that can recover smooth surfaces from noisy and sparse data sets. There is no need of orientation information.By a new regularized-membrane potential technique, the input sample points are accumulated resulting in considerable improvement of noise tolerability and outlier removal, without compromising much with respect to detail (feature) recovery.
Abhishek Bansal et. al.[14] The paper presents a method to reconstruct the surface by building a triangular mesh using the given points as vertices. The resulting polyhedron may become the input of further procedures like surface fitting, or visualization can be done with a number of different textures. (For example, in computer-animated movies, the characters are often created as clay models first, then for visualization purpose,we use 3D scanned and triangulated models.)
Shivali Goel et. al. [15]The paper develops a system for image reconstruction from scattered cloud points. Crust algorithm in combination with umbrella Filtering is implemented and compared for time taken by the algorithm for surface reconstruction. The algorithm aims to filter out left insignificant data while preserving an acceptable level of output quality.

IV. PROPOSED WORK

[1] To estimate whether the voronoi cells are well shaped or not for handling noise.
[2] Removal of all unlabeled poles.
[3] Right orientation of the faces.
[4] To reverse the orientation of incorrect faces.
[5] A variant of spectral graph partitioning to decide whether each polyhedral is inside or outside the original object.

V.RESULTS AND DISCUSSION

The implementation is done in linux based C. The output is produced in geomview software which is used for displaying 3 dimensional objects.Initially calculation of total number of poles is done using modumbrella program that creates pc.off file for the image.After that, using power crust algorithm,the filtration is done to compute the total number of points removed due to noise and redundancy threshold.

Steps to run the script:
STEP 1: In Ubuntu first open the terminal and then go to the modumbrella folder.
STEP 2: Then write the command:
./modumbrella –i knot.pts
In this command,
Modumbrella- is the name of the program that takes set of 3-D points as input and produces a polygon surface**-i** name of the input file.
STEP 3: Filtration-Write the command-
./simplify –-i poleinfo –o simp_poles –n 0.5 –r 0.1
Where-
Simplify-used for power shape simplification.
o-name of output file.
n-noise threshold.
r-redundancy threshold.
Poleinfo-input file for simplify.
Simp_poles-output file for simplify
STEP 4: Then type geomview which is the software for displaying 3-dimensional objects. Input file is just a list of 3D (x,y,z) point coordinates, in ASCII.

Table 1. Computation of Bad Points removed using Image Knot using different values of noise and redundancy threshold.

Noise Threshold	Redundancy Threshold	Points Removed(n)	Points Removed(r)
0.5	0.1	0	165
1.0	0.2	0	166
1.5	0.3	35	154
2.0	0.4	861	5
2.5	0.5	1270	0

This table shows that on the different noise and redundancy threshold values for the image knot.pts.As the noise threshold increases,more points are removed enhancing the quality of image.As the redundancy threshold value increases,the number of points removed eventually decreases indicating that the redundant points no longer exist,hence the making image smooth filtering out insignificant data

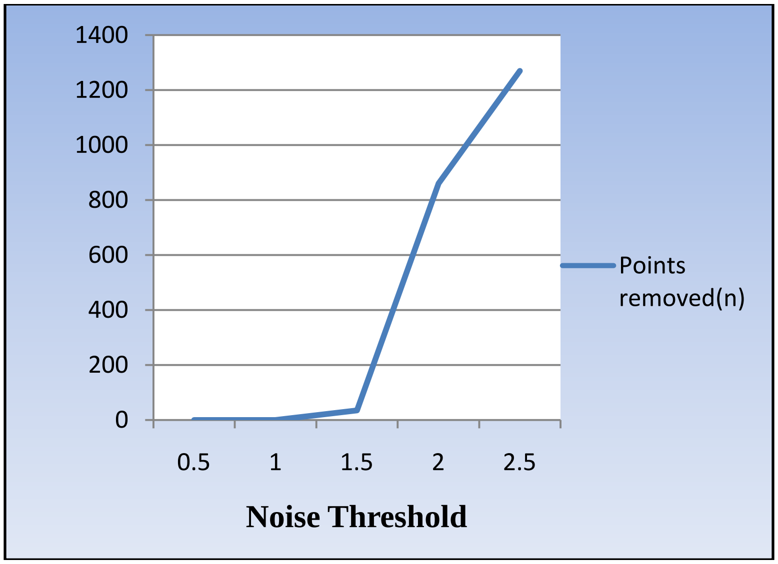

Fig 3. Performance Evaluation of Number of Points removed by noise threshold of Image Knot

This graph shows the number points removed by the noise threshold value. Initially the image is noisy and size of image is very large. As the value of threshold is increased,the number of points removed increases which shows that surface is smooth on the threshold value 2.5.

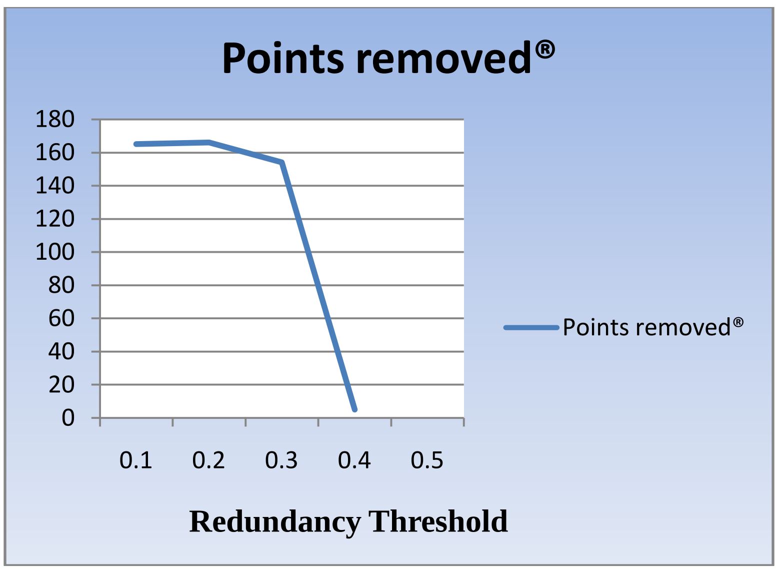

Fig 4. Performance Evaluation of Number of Points removed by redundancy threshold of Image Knot

This figure shows the number of points removed compared with the redundancy threshold value. Initially the when the threshold value is 0.1,then the number of points removed is 165.As the value increases,the points removed decreases gradually resulting in 0.Hence,the filtration results in smooth surface formation.

VI. CONCLUSION

Power crust is a piecewise linear approximation of the surface over the points using Medial Axis Transform deduced from the weighted Voronoi Diagrams. The Power Crust is built by the MAT and therefore its faces are not triangles (faces are built by points of intersection between the balls in 3D space).As this method is an interpolating method, its vertices are not necessarily sample

points as well as not all sample points are necessarily vertices of the reconstructed surface. The Power Shape can be deduced from the Power Crust using 3D Delaunay Triangulation and is therefore a triangulation mesh.The power crust does the filtration for the image knot by putting it on various noise and redundancy thresholds.The resulting image,thus,converges to a smaller size with enhanced quality.

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