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Real Time Monitoring System for Surface Reconstruction Using Delaunay Algorithm

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Abstract
Delaunay triangulation algorithm plays an important role due to its guaranteed quality of mesh generation. It proposes optimization of mesh reconstruction system from 3D cloud point. The process monitoring is emerging as a valuable tool and real-time monitoring systems are being used to enhance operational efficiency. It is possible to develop real-time applications by generating the mesh from 3d point cloud which actually enables to describe the details of surface reconstruction and determines the surface reconstruction progress. In this paper Delaunay Algorithm simulates the mesh generation criteria. It monitors the various parameters of mesh generation and evaluates the performance of Delaunay surface reconstruction algorithm.
Keywords-3d point cloud; mesh reconstruction; performance evaluation.

1. Introduction

Boissonnate[1]appeared to be the first researcher proposing a Delaunay-based surface reconstruction algorithm that removes tetrahedral and triangles from the set of Delaunay triangles according to certain geometric rules. The Delaunay based “sculpting” method proposed by Boissonnat tetrahedrizes the input data and progressively removes the non-surface triangles of the tetrahedral according to geometric criterion. The cell subdivision scheme consists of subdividing the bounding space divided by the input data set into disjoint cells and reconstructing the surface from these cells. One typical method is marching cube algorithm [2][3] proposed by Lorensen in which a travel strategy is used to find the surface from the selected cells through a pre defined lookup table. Another well known method, called alpha shapes[4],introduced by Edelsbrunner and Mucke represents the surface through a finite set of points at different levels of detail. Guo improved the result from alpha shapes using visibility algorithms [5].

Curless and Levoy[6]used least square method to build an initial surface by estimating a local tangent plane for each 3D point and build a volumetric function for voxel grid. The surface is created by triangulating the zero-set of the signed distance function for laser range data. Some surface reconstruction methods, such as Deformable Models [7], establish the topology of the mesh beforehand.The limitation of these methods concerns target shapes that cannot be obtained by deforming an initial mesh. For example, when the initial mesh is a sphere and the target shape is a torus. Other well established surface reconstruction methods, propose solutions based on geometric techniques [8], [9], [10]. Some of them [9], [10] use Delaunay triangulation as a base for the final triangulation. These methods are complex and time consuming, however Delaunay triangulations guarantees reconstruction features, such as maximizing the minimum angle. Since 3D Delaunay triangulation does not always represent the boundary of the target object, a subset of this triangulation is chosen. For example, in [9], this subset is the crust of the object. Definitions for the Delaunay triangulations of domains in R^2 can be found in the literature [11], however, for immersed surfaces in R^3, given as 2-manifold meshes,the definition for the Delaunay triangulation is not so clear [12].

Delaunay triangulation of piecewise flat surfaces is presented in [13]. Since the surface reconstruction method presented in this paper produces 2-manifold meshes, it is based on the local Delaunay criterion proposed in [13].Gopi proposed [14] a method to triangulate the surface points with a localized Delaunay triangulation method which projects the local points to a local plane and Delaunay triangulation in 2D space. Converting point cloud [15][16] representation into a mathematical surface representation is known as surface reconstruction. In surface reconstruction desired surface is required to interpolate the sample points.

Adamy proposed [17] an umbrella filter algorithm coupled with a topological post-processing based on linear programming. Gong[18] analyzed the common Delaunay triangulations methods, especially the divide-and-conquer method, a faster algorithm for constructing Delaunay triangulations is presented. It divides the point set by self-adaptive grid, constructs and merges the sub-triangulations Lin presented [19] an improved method based on an intrinsic property of the point set and tried to overcome the limitation of user specified parameters. Another region growing method[20][21] by picking triangles from Delaunay triangles .The region growing approaches that the reconstructed surface mesh is highly dependent on the choice of the seed triangle and an appropriate hole-filling post processing method is needed for constructing a closed surface mesh. More algorithms have been proposed by Edelbrunner[22] known alpha shape algorithms. Andriy[23] proposed that in the absence of external boundaries, the algorithm maintains a Delaunay mesh M; at any iteration it Selects a triangle from the queue of unsatisfactory triangles, then computes the circumcenter pi of this triangle and C(pi) and ƋC(pi) is calculated. then all triangles in C(pi) are deleted from M and the triangles which are obtained by connecting pi with every edge in ƋC(pi) are added to M.

The incremental [24] surface reconstruction methods build up the object surface using the surface-oriented properties of the input points. Aiming to speed up the computation in the simulation, Xiao[25]proposed a revised Delaunay algorithm which makes a good balance of quality of tetrahedra, boundary preservation and time complexity, with many improved methods. Delaunay algorithm and the revised Delaunay Algorithm is processed based on the simulation criteria. Sheng proposed a mesh growing [26] process in an efficient way that takes input as an unorganized set of points.

The main idea[27] by Wang to build triangular mesh by finding new edges circularly. Most of the calculations are concentrated on searching the discrete points coincident with the requirements from a large number of data points. Therefore, the efficiency of building triangular mesh would be greatly improved if the technique of searching points could be mended.Yung presented a Delaunay [28] based algorithm driven by Umbrella Facet matching. A full umbrella was constructed for every point from its Delaunay triangle set and then optimizing the umbrella into a fully matched umbrella which gives the guarantee for generation of a topologically correct mesh without the need for hole-filling post-processing.

This Paper is organized as follows: Section II describes the surface reconstruction process. Section III describes the results and readings of different parameters. Finally we conclude in section IV. In this paper mesh reconstruction system is optimized using Delaunay algorithm from point cloud and it presents the corresponding settings and execution times, which demonstrates the efficiency of real time monitoring systems and evaluates the performance of Delaunay surface reconstruction algorithm.

2. SURFACE RECONSTRUCTION PROCESS

In this section, we consider a surface reconstruction process from 3D scattered points. Contour surface reconstruction firstly based on polygon technique, with a triangular piece fitting for curved surface, the triangular piece are produced from sampling points of contour.

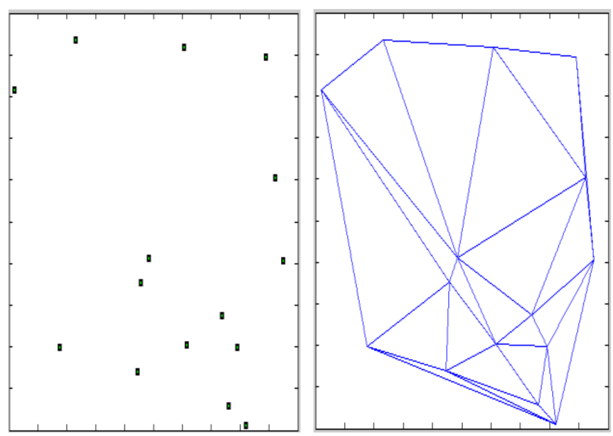
A. Delaunay Algorithm

After Extraction and sampling of contour lines, we obtained a series of scatter of object surface. Reconstruction of the surface is to take advantage of those representative points, use some polygon techniques to connect all the points accordance with certain rules The most common way is the Delaunay triangulation also known as the DT algorithm, which is a special kind of triangulation. DT algorithm has two important characteristics, maximum-minimum angle characteristics and space circumscribes characteristics. In 2-dimensional case, above characteristics help to avoid a long thin unit generated for reason of a small angle. Therefore it is especially suitable for finite element mesh generation. To illustrate Delaunay triangulation, it is necessary to firstly introduced Delaunay edge. Assuming an edge e, $e \in E$ with two endpoints a, b, if e meets the following conditions then it is the Delaunay edge. The condition is that there is a circle through points a and b, none point of set V exists inside the circle. For example, using the meshgrid command, we can get the cross-ordinate vector set of certain two-dimensional piece. All the points of horizontal and vertical vector coordinates are processed by Delaunay function, the return value is $m \times 3$ matrix. Each row members of the matrix are three vertexs for a triangle mesh grid of DT algorithm. Figure 1 is a triangulation result for 15 random points in use of Delaunay function. Delaunay triangulation is a standard for subdivision, a variety of algorithms achieve it.

B. Optimization

Basic steps for algorithm optimization are as followed:

- Construct a super-triangle contains all scatter, and put them into the triangle list.
- Find out its circum circle contains the insertion point of the triangle in the triangle list to, delete the public side of the triangle, connect all vertices of the as well as the Insert point, thus completing a inserted in the Delaunay triangle list.
- Optimized the newly formed local triangle under optimization criterion then add it into Delaunay triangle list.
- Continue step 2 until all scatter finished insert.



(a) 15 random points (b) Triangulation result

Figure 1. Triangulation result for 15 random points

3. Data Analysis

TABLE I. Execution time computations using Delaunay Algorithm

To compute the different parameters time calculation instructions are used. Then all the parameters are defined with their functions and give the result by execution of the Delaunay triangulation.

4. Results and Discussions

This section presents the results of the experiments carried out by Delaunay Algorithm. Firstly we present the visual results of the experiments. Then, we present the parametric readings for the reconstructed meshes.

C. Real Data Objects

The real data object is the Vertebra. The results are depicted in Fig.4. The results show the original point cloud, surface reconstruction using Delaunay and Performance evaluation graph. Fig.3 is formed by the points.Fig.4 is formed by the intersection of all the circum circles. Fig.2 shows the Performance evaluation graph of Delaunay Algorithm.

D. Parameters and Computations

To demonstrate the efficiency Real time monitoring system is being optimized. It monitors the various parameters of mesh generation and evaluates the performance of Delaunay surface reconstruction algorithm. As the results are depicted in Fig.2 and Fig.4, corresponding settings and execution times are presented in Table I. For analysing the triangulation efficiency real time monitoring systems are implemented [29]. It describes the details of surface reconstruction and computes the execution times.

Parameters	Delaunay Algorithm
Scatter Added	0.1649 s
Triangulation	6.6881 s
Triangle Connectivity	244.2118 s
Circumcenters Tetraedroms	0.3698 s
Intersection factor	0.1815 s
Walking through whole scatter	24.8932 s
Total Time using Delaunay	277.7930 s

4. Conclusion

In this paper Delaunay algorithm optimizes the mesh reconstruction system from point cloud and it presents the corresponding settings and execution times. Delaunay triangulation algorithm plays an important role due to its guaranteed quality of mesh generation. It proposes optimization of mesh reconstruction system from 3D cloud point. The process monitoring is emerging as a valuable tool and real-time monitoring systems are being used to enhance operational efficiency. It is possible to develop real-time applications by generating the mesh from 3d point cloud which actually enables to describe the details of surface reconstruction and determines the surface reconstruction progress. Real time monitoring system demonstrates the efficiency. It monitors the various parameters of mesh generation and evaluates the performance of Delaunay algorithm.

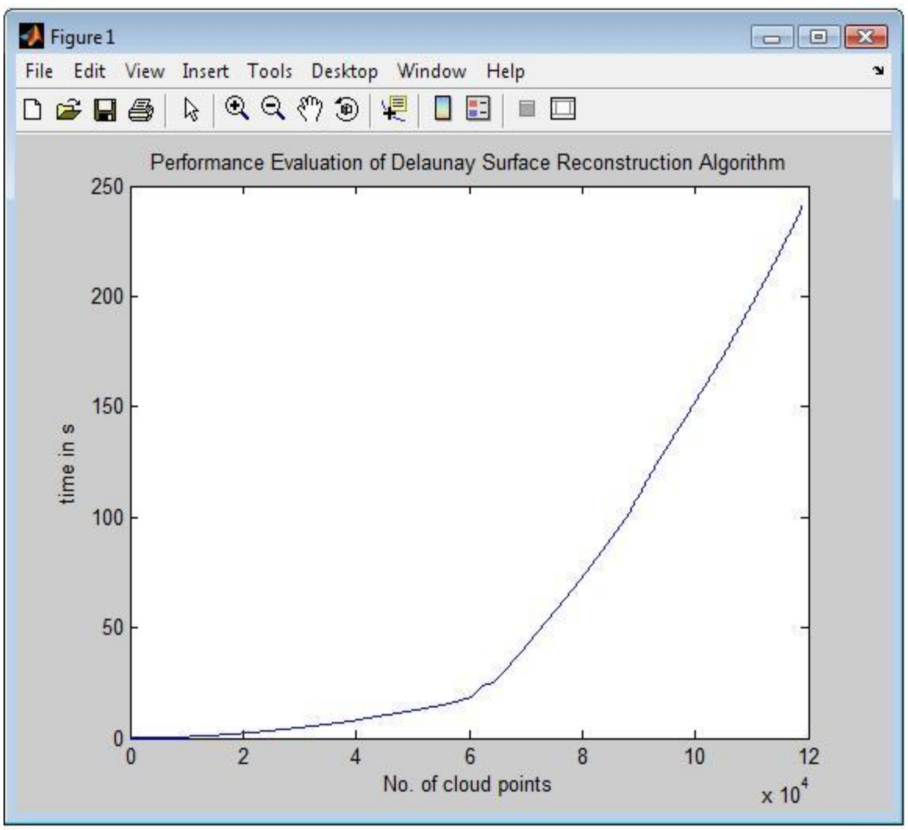


Figure 2. Performance Evaluation of Delaunay surface Reconstruction algorithm

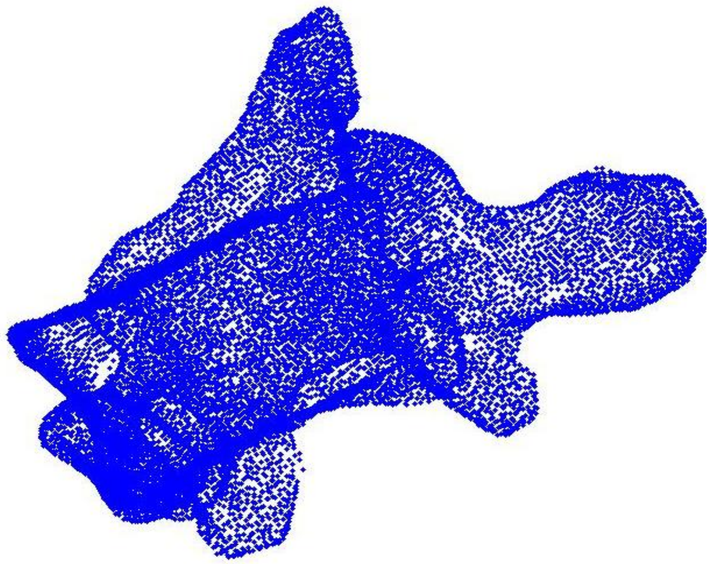


Figure 3. Surface reconstruction using Original point cloud.

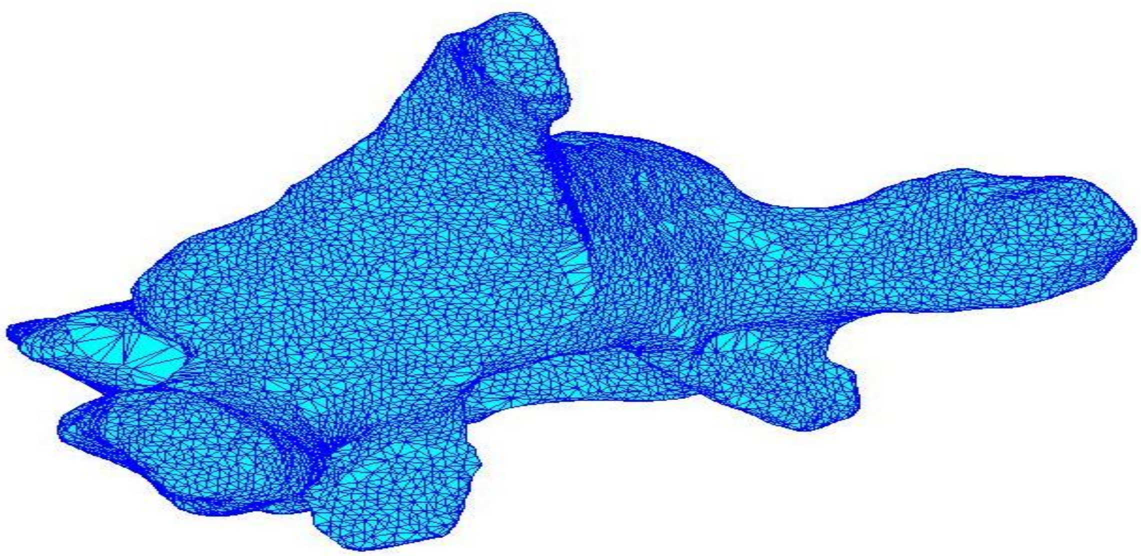


Figure 4. Surface reconstruction using Delaunay Algorithm

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