ScienFIST.org

INTERNATIONAL JOURNAL OF INFORMATION TECHNOLOGIES, ENGINEERING AND MANAGEMENT SCIENCE

Possibilities of object reconstruction from a point cloud as a tool for 3D object acquisition

Pavol Kudela, Michal Palčák
University of Žilina, University Science Park, Slovak Republic
pavol.kudela@uniza.sk, michal.palcak@uniza.sk

Abstract

Digitization, as one of the forms of object mapping, requires the proper definition of procedures where it always has to consider every single step and planned as accurate as possible. In scanning, it is necessary to take into account the environmental conditions and scanned object itself. In scanning, it is necessary to take into account the environmental conditions and scanned object itself. In the output, the scanning offers point clouds which capture real conditions. The points, that subject to the further process, poses essential information needed for subsequent work. The subject of this article is to describe the processing and mathematical procedures that exist in surface reconstruction. Also, the paper defines differences, in terms of the importance of input data, and the ability to process point clouds. This article points out the algorithms and rules that need to follow.

Keywords: reconstruction, surface, meshing.

Introduction

Currently, there are more and more scanning devices that are used to retrieve the surrounding data. Their pricing policy has reached a very affordable level, which means that it is possible and especially affordable to purchase such a device.

The additional functions help to facilitate the work of the user and also offering the possibility to use virtual reality in the data processing.

However, in most cases, the data acquisition function is based on beam transmission, where the device measures the time and speed of the beam. A set of points obtained from a scanning device relative to their location creates a network that is being processed and is the basis for the triangulation of the mesh. After registration, the main problem of the final mesh is the unequal point's distribution resulting in higher data volume and an increase in the hardware requirement needed for further data process. Such objects or scans can't be used to mobile devices. The further data processing is very difficult. For this reason, it is necessary to simplify and optimize the data to make the subsequent work easier.

However, in recent decades, the reconstruction and proposals to achieve the most accurate model have been presented several times.

For this reason, the article deals with the definitions of surface reconstruction and discusses the reconstruction of models for their further processing.

Surface reconstruction

One of the tasks of model reconstructing surfaces is to obtain a 3D model of the scanned object, respectively using a scanning device The obtained points are scattered based on the scanner location and the scanning distance. They carry out the coordinate's information of every single point or added values such as RGB, normal, and so on.

Before the reconstruction, a point clouds are analysed, and the undesirable effects, or defects of scanning are removed such as noise etc.

Currently, there are more and more scanning devices that are used to retrieve the surrounding data. Their pricing policy has reached a very affordable level, which means that it is possible and especially affordable to purchase such a device.

The additional functions help to facilitate the work of the user and also offering the possibility to use virtual reality in the data processing.
However, in most cases, the data acquisition function is based on beam transmission, where the device measures the time and speed of the beam. A set of points obtained from a scanning device relative to their location creates a network that is being processed and is the basis for the triangulation of the mesh. After registration, the main problem of the final mesh is the unequal point's distribution resulting in higher data volume and an increase in the hardware requirement needed for further data process. Such objects or scans can't be used to mobile devices. The further data processing is very difficult. For this reason, it is necessary to simplify and optimize the data to make the subsequent work easier.
However, in recent decades, the reconstruction and proposals to achieve the most accurate model have been presented several times.
For this reason, the article deals with the definitions of surface reconstruction and discusses the reconstruction of models for their further processing.

Surface reconstruction

One of the tasks of model reconstructing surfaces is to obtain a 3D model of the scanned object, respectively using a scanning device The obtained points are scattered based on the scanner location and the scanning distance. They carry out the coordinate's information of every single point or added values such as RGB, normal, and so on.
Before the reconstruction, a point clouds are analysed, and the undesirable effects, or defects of scanning are removed such as noise etc.
These points are further processed, in the reconstruction of the model, and the appropriate method is selected. The triangulation method is the one, mostly used, where the individual network triangles are joined by edges and the nearest points. Therefore, it is essential to set the right method to avoid obtaining the results with diametrical differences to the original.

The model reconstruction can be carried out through the point vertices, which are the junctions, and the surfaces connected through these points represents the vertices of the triangles. This method can have two types:

- The first one, it is a deformation through simple shapes such as balls, plane, and curves and so on. This method can be used only on simple planar models, and not on rugged ones, where the division would have to be composed of several basic shapes.
- The second one is the triangulation, where the object's surface is formed by the nearest adjacent points.

Another way of reconstruction is to create a surface that is defined by the isotopes of scalar functions. It is about finding a function that is appropriate to create the model as accurately as possible based on the points obtained from the scanning device.
Model surfaces are the sum of radially symmetric base functions. As in the previous case, there is also a problem if it is a rugged surface. The ruggedness and edges cause defects and thus incorrect representativeness of the edges against the scanned object. Partial differential equations use the Hausdorff distance as methods for calculating areas. In terms of a scanned surface defect, the reconstruction, with not having any model point on the surface, can be understood as an estimated surface, thus overshadowed area. Alternatively, the reconstructed defect can be counted as a new one, but it will contain at least a small subset of the model's point field.

Restrictions of model reconstruction

In model reconstruction, some problems start with input data, and also some devices already work with a certain deviation. Another problem is the accuracy of defined points when registering scans. Unstructured data containing only point information with coordinates is very difficult to process because of the uneven characterization of the input data. Also, they have less information resulting in high inaccuracy and also increased hardware processing requirements. Besides, the resulting data can show large distortions which, in the end, can be identified as a diversity of outputs, compared to the real background.
Another problem with the reconstruction is the size of the scanned object. Not every software environment can handle a large number of scanned points. Devices with better hardware configuration are not always able to process data due to a poor data structure. These configurations have some data throughput limits, not always suitable for reconstruction. However, we are currently encountering a high number of points gained from the scanned area. It put high demands on the hardware configuration, mentioned above. At the same time, the high number of points can lead to higher accuracy and thus to a better 3D model. In cases, if using unstructured data, linked to other sub-data, the reconstruction can take a long time. In some cases, the simplification of the point field or filtration may be used to make the reconstruction possible,

where the filtration may remove unwanted parts, such as noise. Simplification either reduces an existing point pattern with a uniform pattern or replaces an existing spot pattern with a new one.

The problem with the reconstruction is usually data, in the registration, that may contain local extremes. These points may result in that scan is not being matched with the actual object, creating local deformation, or even it will be impossible to reconstruct the object. However, in cases where several local extremes occur, filtering may help to reduce points or to create new points. But, if the scan is not to compete yet, it causes another problem. It usually happens when the object has some deep holes or if there is a reflection.

Methods of surfaces reconstruction

Nowadays, there are many ways how to reconstruct a scanned object. These methods are divided into two main groups. The first one is an implicit group that is more stable, with better results. The second one is an explicit group which compromises between precision and reconstruction. An explicit method helps us to understand how to reconstruct through triangulation or parameterization. Triangulation is currently the most common way of model reconstruction, and it has different possibilities that we can achieve.

- The oldest method is the Delaunay approach (figure 1), which does not include a point from the point area when creating a triangulation.

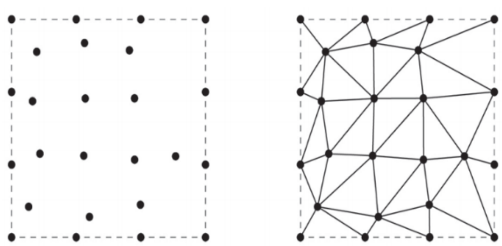

Figure 1 Delaunay triangulation [1]

- Voronoi approach is another method based on the Euclidean plane, where every single point falls on the surface. This space is divided into small surfaces from the main area, and the size depends on the point distance,

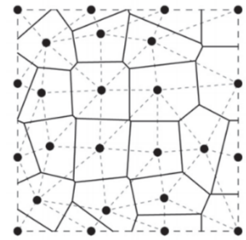

Figure 2 Voronoi diagram [1]

- As described above, the ball-pivoting aims to reconstruct the point cloud from the opposite side. These are adjacent three points that create the mesh. The radius that is set by the user will create a sphere into which any other point may not interfere, except for three given points,
- Once created, the sphere rotates around the imaginary edge until it touches another point to form another triangle. Different sphere radiuses are used to achieve the best result since the data obtained from the scanning device does not carry an equal distribution of each point of the scanned object,

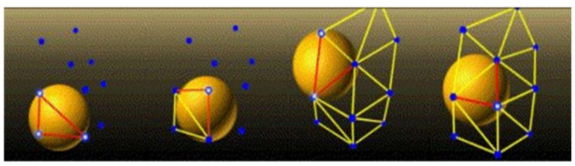

Figure 3 Ball pivoting[2]

- The combination of the Delaunay and Voronoi method has been already the subject of several improvements where the first method filters out unwanted triangles. Another way, based on incremental triangulation, tries to create a mesh object from the scanner. To be able to achieve the desired mesh, it is necessary to calculate the normal for each point, and after to select a subset of the points that make up the peak points. After defining the vertices, in step 2, the Delaunay method is used, and a mesh object created in the last step,
- The second method uses the algorithm to estimate the transformation of the media axis and the opposite transformation to restore the surface.

The previous methods are mainly useful in terms of surface reconstruction. Also, some methods exist where local deformations or absence of points occur and thereby creating blank spaces.

There is a way to calculate, by interpolation of the free space, where this space will be filled in. This procedure first creates a pre-healing of the surface and then completes this opening area. Another method, based on Delaunay approach, uses for reconstruction algorithm a selection of triangles located around the opening area. Another Delaunay-based method uses for reconstruction a selection of triangles located around the opening area. Subsequently, based on typology, it selects some triangles, which will use it for unloading the area and filling the free spaces.

There is another method based on triangles construction of the reconstructed surface, where triangles begin to connect to the triangles at the edge. After reaching the point, where it is not possible to use a new triangle, the algorithm will stop counting.

In the dynamic surface reconstruction of unstructured data that exhibits deformation, there is a method consisting of two procedures.

In the first one, a determined algorithm simplifies the reconstructed surface by refining or compacting and is based on the geometric convection of the indicated dot pattern.

In the second one, the distance or surface, on which the algorithm should be applied is defined.

Currently, one of the advanced and modern methods is the method based on the Delaunay algorithm that simplifies the surface by using a filter, which reduces the distance between the actual given points and the triangles of the reconstructed surface. Explicit methods of the reconstructed surface are based on two modifiers such as deformation and combination.

Both modifiers aim to ensure, that the standard shapes such as balls, cylinder, cube, etc.) or their plane will be useable for reconstructed surfaces. However, mentioned parametric modifiers are based on linear interpolation of two shapes. Another way of reconstructing a surface is to use an implicit method that precedes the triangulation method.

- A Marching Cube algorithm is a method used for surface reconstruction. It uses a typical or variation model. Where in the variation model, the estimation of the reconstructed output, by a combination of different functions, is used.
- The implicit method combinations enable to obtain approximation surfaces from the unstructured ones. These methods do not require any additional information, about points or topology, because data is derived from the input.
- This kind of method can calculate the reconstruction without losing sharp edges and corners based on another algorithm. This approach aims to recognize the main points around the reconstructed surface, to recognize anisotropy, and then to approximate the surface.
- There is a method based on variation and combination of partial differential equations, using the original data and coming from different point distances. So, firstly, the preliminary reconstruction is created, and after a surface smoothing algorithm is used.
- Also, there is another method based on surface approximation, but using a mechanism on the local differential geometry of the smallest square. This technique can eliminate local extremes created by various influences in the scanning process in the reconstruction process or can calculate areas where points are absent.
- Use of partial differential equations and distance functions through the Laplacian smoothing filter is applied to smooth the surfaces directly, but at the same time maintains the topology. First, the coarse model is calculated. And after, the surface will be improved and refined as much as possible, to be like an original.
- Voronoi diagram method, which is a surface reconstruction tool, uses a tensor array of points to determine the direction of normals to the surface through axes and eccentricity. Then, the algorithm determines the gradient function in order to find the best approximation to the axis.

The most common method of model reconstruction by default is Poisson's method, which is resistant to noise. This method is also improved in several ways, for example, so that it uses smooth, default polygon mesh surfaces.

Conclusion

One of the main procedures for creating cloud-point models is surface reconstruction. This article aims to outline some techniques that are useful in surface reconstruction. Many techniques are implemented in various software, but some of them defined through the SDK interface. Despite these options, there are some obstacles and issues that need to be tackled before, to make the resulting model smooth. However, at the same time, it is necessary to realize that some decisions affect accuracy and efficiency. So, accuracy increases the time needed for the calculation of the reconstruction and the right to computing hardware. On the other hand, efficiency affects accuracy, which is not always the requirement. In summary, it is essential to realize that some techniques cannot preserve inner edges and corners. In reconstruction, some of the parameters may be neglected, and so, to achieve a proper reconstructed surface, only some basic information about points are needed. The main issue is noise, which occurs when digitizing the object. If the digitized object contains a large part of this noise, it is optimal to reduce this noise first to get as close as possible to the optimum finalized surface. But it should be taken into account, that the issues of object reconstruction in 3D digitization and calculation algorithms must be continually improved, in achieving the best results.

Acknowledgements

This publication was realized with support of Operational Program Research and Innovation in frame of the project: ICTproducts for intelligent systems communication, code ITMS2014+ 313011T413, co-financed by the European Regional Development Fund.

References

[1] Voronoi diagrams – rod structure research models in architectural and structural optimalization [Online]. Available: file:///C:/Users/Science%20park/Downloads/msr_19_rokicki_i_gawell.pdf

[2] Ball pivoting algorithm [Online]. Available: https://slideplayer.com/slide/4773919/

[3] Surface reconstruction from unorganiyed point cloud data via progessive local mesh matching: [Online]. https://ir.lib.uwo.ca/cgi/viewcontent.cgi?article=1384&context=etd

[4] Feature-Preserving Surface Reconstruction and Simplification from Defect-Laden Point Sets [Online]. Available: http://asdf.geometry.caltech.edu/pubs/DCAGD13.pdf

[5] A mesh reconstruction algorithm driven by an intrinsic property of a point cloud [Online]. Available: http://repository.ust.hk/ir/Record/1783.1-21872

[6] Spectral Surface Reconstruction from Noisy Point Clouds [Online]. Available: http://sites.fas.harvard.edu/~cs277/papers/eigencrust.pdf

[7] Reconstructing Surfaces Using Anisotropic Basis [Online]. Available: Functionshttp://openaccess.city.ac.uk/6151/

[8] Surface Reconstruction based on Lower Dimensional Localized Delaunay Triangulation [Online]. Available: https://vgc.poly.edu/~csilva/papers/eg2000.pdf

[9] D. Kim and S. Lee, "Advances in 3D camera: time-of-flight vs. active triangulation," in Intelligent Autonomous Systems 12. Heidelberg: pp. 301-309, Springer, 2013