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An Introductory Review to Surface Reconstruction

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Abstract. Surface reconstruction can be defined as the process of data retrieval via scanning of the object with certain device such as laser scanner and etc. as well as the process of reconstructing the object using the retrieved data. The process of surface reconstruction begins with the type of input data being collected. The types of input data can be unstructured or structured. Artefacts can be defined as the properties of the data retrieved and they indirectly affect the output obtained at the end of surface reconstruction. The different types of input data can be treated by selecting different methods for the process of surface reconstruction. These methods basically fall under the categories of implicit surface, explicit surface and lastly soft computing methods. However, each of these methods for the process of surface reconstruction had their own advantages and disadvantages but they are not discussed thoroughly here. The selection of methods for surface reconstruction lies solely in the interest of studies for other researchers as each method for the process of surface reconstruction can be explored and researched upon viably. This paper highlights a brief introduction and review on previous researches with the aim of providing basic knowledge involved in the process of surface reconstruction.

1. Introduction

The importance of surface reconstruction can be reflected thoroughly in the field of Computer Science as re-modification and re-creation can be performed. Surface reconstruction can be defined as the process of data retrieval via scanning of the object as well as the process of reconstructing the object using the retrieved data [1]. It is a challenging task in reconstructing the object successfully as the data retrieved can be affected by artefacts. Artefacts can be defined as the properties of the data retrieved and they are important criteria in understanding the behavior of methods of surface reconstruction [2].

The data retrieved is not only important for surface reconstruction, but they also indirectly affect the selection of the methods for surface reconstruction [1]. Apart from that, the data retrieved via the scanning of the object usually is obtained in the form of point clouds can be categorised as structured or unstructured [3]. The different type of input data can be treated by the selection of different methods for the process of surface reconstruction and the resulting data may changes drastically [3].

Surface representation can be defined as the analytical representation of the surface when it is performed in the studies of computer science. The surface representation of these methods can be categorised in general as implicit surface or explicit surface. Not only that, the surface representation can also be categorised as approximation, interpolation, isotropic as well as anisotropic depending on the method selected for the process of surface reconstruction [3]. In summary, the type of data retrieved,

the surface representation as well as the selection of the method for the process of surface reconstruction are intertwined with each other as they affect the whole process of surface reconstruction. The aim of this paper is the introductory review of the process involved in surface reconstruction starting from the type of data retrieved towards the selection of method for the process of surface reconstruction. A flow diagram showing the relationship between the type of data retrieved until the selection of the method for the process of surface reconstruction is shown here in Figure 1.

This paper is written as such that the next section, Sect. 2 in which the type of input data retrieved are discussed. The next section which is Sect. 3 will discuss the artefact that potentially appear in the data retrieved or collected via the scanning of the objects. Section 4 will describe the methods of surface reconstruction selected based on the type of input data retrieved. Lastly, a general conclusion summarising the paper will be drawn at the last section.

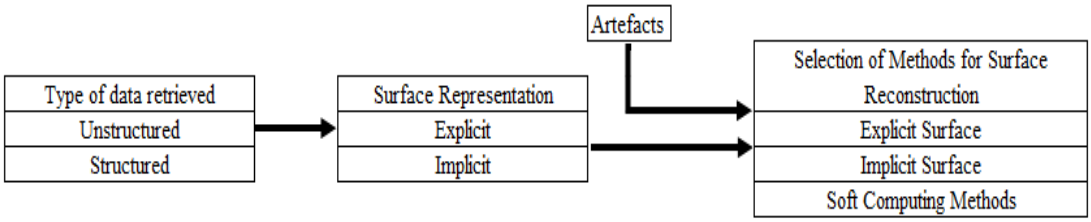

Figure 1. The flow diagram for the process of surface reconstruction.

2. Type of Input Data and Surface Representation

As stated earlier in the previous section, the type of input data retrieved or obtained can be classified into structured or unstructured. The information regarding the connectivity of the input data is available in structured type whereas the unstructured type of data does not contain this information. The correct connectivity for the data is important when dealing with unstructured type of data as the result of the reconstructed surface relies on it.

Apart from that, the surface representation mentioned earlier in the previous section which was categorised into either implicit surface or explicit surface in general is discussed here. Surface representation is the representation of a surface in the field of computer science performed analytically or mathematically. Implicit surface can be defined as radially symmetric basis functions or volumetric representation of the surface. However, the implicit surface suffers from symmetrical issue as they cannot represent the surface like edge and corners properly [3]. Explicit surface can be defined as an information pertaining the precise location of a surface. This mean that a point cloud lies on the reconstructed surface based on the actual data obtained via scanning of the object.

Not only that, the other categories of surface representation in the form of interpolation, approximation, isotropic and anisotropic are discussed here as well. The interpolated surface can be defined as surface that potentially suffer from non-uniformity or undesired hole from the input data being used [3], whereas the approximated surface is obtained when none of the input data being used lie in the corresponding surface of the object. Isotropic surface can be defined as surface containing no sharp edge or corner and it is smooth whereas anisotropic surface is surface with distance of the points along a sharp corner varies with its respective counterpart of those points across the sharp corner. In general, almost all explicit surface is considered interpolated surface whereas implicit surface is considered as approximated surface [3].

3. Type of Artefacts

As mentioned earlier in the Sect. 1, the input data retrieved or obtained via scanning of the object can be affected by artefacts. Artefacts can be defined as the properties of the data retrieved and they are important criteria in understanding the behavior of methods of surface reconstruction [2]. There are 5

types of artefacts that are obtained from the retrieval of input data. They are noise, misalignment, outliers, sampling density and lastly missing data.

The distribution of sampling point cloud on the surface of a model is the definition for sampling density [2]. A neighbourhood of sampling point can and must be defined as it is important in the process of surface reconstruction. The sufficient description of local geometry by the point clouds can be defined clearly by a large enough neighbourhood. The preservation of the local feature of the point clouds can be done by having a small enough neighbourhood. The point clouds that are distributed or scattered randomly near the surface of the model can be defined as the noise. The optical measuring device as well as the orientation of the surface or the distance in relation to the optical measuring device are one of the potential causes to this random distribution of point clouds. Certain methods of surface reconstruction that employ smoothing in the output are common in handling noise [2].

Next, point clouds that are distributed far from the true surface of the model can be defined as outliers. If the structural information regarding the connectivity of the object are not properly defined, this will happen in the process of data retrieval. Misalignment will occur when the optical measuring device cannot properly capture the registration of range scans. The sequential scans taken at different times of a single object is most likely to be the cause of misalignment. Lastly, the limitation of the optical measuring device or other unknown factors in the environment is the main cause of missing data.

4. Selection of Methods of Surface Reconstruction

In this section, the selection of methods for the process of surface reconstruction is discussed. The selection of methods basically falls in three categories mainly explicit surface, implicit surface and lastly, other soft computing methods.

4.1. Explicit Surface

Methods of surface reconstruction that employs the use of explicit surfaces are triangulated surface, quadrangulated surface and lastly parametric surface. Parametric surfaces are consisted of Non-Uniform Rational B-Spline (NURBS) and B-Spline.

Delaunay Triangulation (DT) and its counterpart, Voronoi diagram (VD) is a method of computational geometry [4]. The assumption that the data of point clouds is dense as well as free of noise is made. The sample of point clouds are used for the generation of the vertices of the triangle meshes which will be called as “crust” if a set of triangles is generated. General data set can still be dealt with this method and most of the point clouds can be covered by the triangle mesh. However, this method is incapable of overcoming problems of non-uniform data as well as noisy data and the quality of the reconstructed surface of the object relies heavily upon the quality of the input point clouds.

Quadrangulated surface have also become widely available in the recent years [5]. There are two main approaches when quadrangulation is used to process surface reconstruction. The domain of quadrangulation or rectangular mesh is first meshed using triangle mesh when an indirect approach is taken. Direct approach of using quadrangulation or rectangular mesh involve the quadrangulation or the rectangular meshes placed onto the surface of the model directly without undergoing the process of triangle meshing.

Parametric surfaces are used to solve the problems of surface reconstruction by fitting the local surface patches using parameter values. Since, the whole shape of the curve shape can be affected by the movement of control points and modification of the Bézier curves cannot be done locally, thus, B-Spline has been proposed by Bezier to overcome the limitations and it can contain up to C^2 parametric continuity [6]. Previous works related to the studies of B-Spline are studied and discussed. It had been used heavily in process of reverse engineering and geometric modelling. However, simple curve such as circles and ellipse cannot represented using the method of B-Spline.

Non Uniform Rational B-Spline (NURBS) is a hybridization of both B-Spline and Bézier [7]. NURBS are developed due to the limitations of Bézier and B-Spline as conic or circular curve cannot be represented by them properly and requirement of higher order of Bézier curves needed for representation of complicated shapes. NURBS is the standard type of mathematical approximation for

the process of surface reconstruction in modern computer graphics. It is also popular in the academic and commercial world of geometric modelling.

4.2. Implicit Surface

Methods that implore the use of implicit surface are Least Square, Poisson surface reconstruction, Partial Differential Equation (PDE) as well as Level Set method.

The method of least square is used in their works [8]. A solution approximated closely to the absolute result of an undetermined problem is found using the method of Least Square. The difference between the data provided as well as the value provided by the object can be referred as the error in the method of Least Square. An implicit function which combine both local and global fitting schemes in general define clearly the method of Poisson surface reconstruction [9]. All data of the surface are taken into consideration by the method of Poisson surface reconstruction at the same time.

Good results in interpolation of images and compression can be obtained by using Partial Differential Equation [10]. PDE and modelling of differential geometry are used to reconstruct continuous models. Not only that, the changes in topological of geometry are overcome by the authors through using a simple grid of rectangular mesh to solve the function of PDE. The construction of parameterization grid is developed by using parameterisation method of PDE. The time taken for the calculation of solution can be decreased by using PDE. Level set is both theoretical and numerical method for implicit surfaces. Not only that, complex geometrical topology and noisy data can be handled easily by level set method as shown.

4.3. Other Soft Computing Method

Methods that implore the use of other soft computing methods are Differential Equation (DE), Genetic Algorithm (GA) and Particle Swarm Optimisation (PSO).

John Holland introduce the method of Genetic Algorithm (GA) in year 1975 [11]. The method of GA is built on the principle of genetics and evolution. It is useful in solving the problem of optimisation and problem of searching point clouds. Operations with several techniques are contained inside GA in order to perform surface reconstruction. Introduction of proper operation techniques will result in a boost in the performance of GA. The optimization problems are solved in hope of obtaining better and preferred results.

Storn and Price introduces the method of Differential Evolution (DE) in 1997 as a method of stochastic direct search [12]. It is a search strategy for population-based data and method of multidimensional functions for mathematical optimization. The populations are initialised like method of GA and procedures such as crossover, selection and mutation are performed in order to obtain the minimisation of the objective function. The ways of operations and its performance are different as compared to GA even though the operations are the same. DE is a new evolutionary method which requires fewer parameters for the process of surface reconstruction.

Kennedy and Eberhart develop the method of Particle Swarm Optimisation (PSO) in 1995 [13]. It is a method of stochastic optimisation for global optimisation and population-based which is based on flocks of birds flying and schools of fish swimming. The set of population containing the particles are initialised similarly to method of GA and DE as well.

5. Conclusions

In this paper, an introductory review on the process of surface reconstruction is presented. The type of input data retrieved as well as the surface representation will affect the selection of methods for the process of surface reconstruction. As stated earlier in the section above, the 5 type of artefacts does affect the result acquired from the process of surface reconstruction in general. Thus, some pre-processing steps are needed to be performed in order to have better result for the process of surface reconstruction. Not only that, the methods for the process of surface reconstruction covering the explicit surface, implicit surface and soft computing are reviewed. However, each of these methods for the

process of surface reconstruction had their own advantages and disadvantages but they are not discussed more in this paper.

In conclusion, the selection of methods of the process for surface reconstruction lies solely in the interest of studies for other researchers as each method for the process of surface reconstruction can be explored and researched upon viably. The author' sole wish in this introductory review paper is that more people will join this field of studies with the intention of research and development.

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