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Triangulation Method in Process of 3D Modelling from Video

Svetlana Mijakovska[1], Filip Popovski[2], Roberto Pasic[3], Ivo Kuzmanov[4]

[1]*(Faculty of Technical sciences at University of Bitola, st. Makedonska Falanga 33, Bitola 7000, North Macedonia.*
[2]*(Faculty of Technical sciences at University of Bitola, st. Makedonska Falanga 33, Bitola 7000, North Macedonia*
[3]*(Faculty of Technical sciences at University of Bitola, st. Makedonska Falanga 33, Bitola 7000, North Macedonia*
[4]*(Faculty of Technical sciences at University of Bitola, st. Makedonska Falanga 33, Bitola 7000, North Macedonia*

ABSTRACT : The aim of this paper is to give a definition of the triangulation method and how it is used in the process of 3D modeling from video. The input date was video which was then processes as point cloud date. The points in cloud were connected with triangulation method and build 3D model. We made several experiments of using triangulation and getting 3D models.

Keywords – Point cloud, Polygonal triangulation, Structure from motion (SfM), Surfaces, Triangulation, 3D model.

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1. INTRODUCTION

3D models are used in many fields such as animation, computer games, virtual reality, film industry, computer vision, etc. The generating of 3D models can be done in many ways, from a series of images, manually and also 3D models can be generated from video. The video as input data has the advantage because of the high quality that you can get and its flexibility. The process of 3D modeling of the video consists of several steps: feature detection and matching, structure and motion recovery, stereo mapping and modelling.

3D models actually represent 3D objects as a collection of points in 3D space, connected with geometric objects (triangles, lines, curved surfaces, etc.). So, the first task is getting the cloud of 3D points that will then be connected to a network through a process of triangulation (which is a standard process for converting a set of points in the polygonal model). The cloud of 3D points obtained from the reconstruction of the video is affected by several factors that affect the feature detection and matching. Therefore, using corner detectors (as points of interest) and descriptors that are prerequisite to connect the points from one frame of video.
3D modelling from video is a process where the data information is taken from video. Then date is processed into a point cloud date. That means we got a lot of points, which must be connected with some method. In this paper we use triangulation method to connect these points in 3D model.

The 3D reconstruction can be divided into 4 main tasks:

1.Feature detection and matching: The objective of this step is to find out the same features in different images and match them.

2.Structure and Motion Recovery: This step recovers the structure and motion of the scene (i.e. 3D coordinates of detected features; position, orientation and parameters of the camera at capturing positions).

3.Stereo Mapping: This step creates a dense matching map. In conjunction with the structure recovered in the previous step, this enables us to build a dense depth map.

4.Modeling: This step includes procedures needed to make a realistic model of the scene (e.g. building mesh models, mapping textures).[1].

Feature detection and matching is process that detects and match features in different images. Video sequence is created of more images so in this step we must find interested points (point feature), i.e. detectors and descriptors. [1]

There are more techniques for robustly creating surface meshes from sparsely populated 3D point clouds. One of them is image–consistent triangulation is used within the framework of a simulated annealing algorithm to iteratively modify an initial naive mesh. The algorithm is capable of producing meshes that accurately represent the scene even in the presence of significant numbers of outliers. [3].

2. TRIANGULATION

The information in a sparsely populated cloud of 3D points, all known to lie on the surface of an object, is not sufficient to determine which, of the many possible surfaces that pass through the points, best represents the actual surface of the object.

However, in the case of point clouds produced by SfM (Structure from Motion), there is additional information that can be exploited in the form of a sequence of images and the corresponding camera projection matrices. 3D modelling from video is a process where the data information is taken from video. Then date is processed into a point cloud date. Point cloud would be divided into many regions before projection. Finding a good project plane is a key factor of reconstruction performance.

A sequence of images of an object is merely a series of projections of the surface of that object into R2. Each image is dependent on the parameters of the camera at that viewpoint, which in turn are encapsulated in the relevant camera projection matrix. As the camera moves, so the parameters of the camera change, and the 2D projection (image) does likewise, thereby giving a different view. If an exact representation of the surface of the object is found, and the lighting and reflectance modelled perfectly, then the projection of this surface into any of the images should be identical to the actual image. This is the underlying assumption upon which image–consistent triangulation is based.

When searching for the triangular surface mesh that best fits a cloud of 3D points, although the triangulation being searched for is in R3, it is perfectly acceptable to search for it as a 2D triangulation of the points projected into one of the images.

There are a large number of algorithms which have been developed for triangulating a surface. These can be categorized as structured and unstructured (Frey and George, 2000). A structured triangulation is an approximation that is generally uniform and has a noticeable pattern, where as an unstructured triangulation is the opposite. An example of each can be seen in Figure 1.[4]

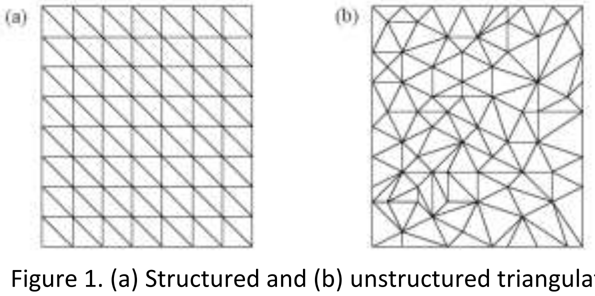

Figure 1. (a) Structured and (b) unstructured triangulation.

3. POLYGONAL TRIANGULATION

A classic problem in computer graphics is to decompose a simple polygon into a set of triangles. Every simple polygon admits a triangulation, where a simple polygon with n vertices consists of exactly n-2 triangles [4]. Although there are many different algorithms available for polygon triangulation.

By definition, a simple polygon is an ordered sequence of n vertices $p_0, \ldots, p_{n-1}$. It is assumed that the vertices are orientated in anti-clockwise order. Each consecutive pair of vertices is connected by an edge $\underset{e}{\rightarrow} = (p_i, p_{i+1})$, (where i is treated as modulo n, i.e. $x_n = x_0$). A simple polygon edge can only intersect at the vertices and each vertex is incident to exactly two edges (Figure 2.2).

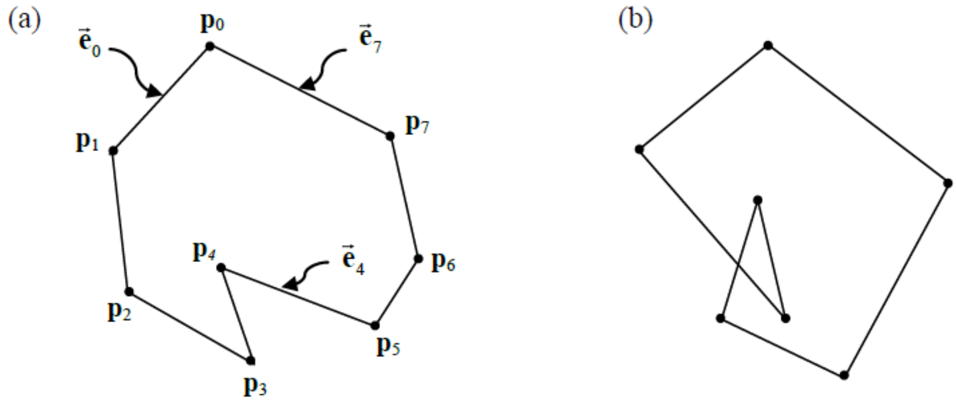

Figure 2. (a) Simple polygon. (b) Non-simple polygon.

An ear of a polygon is a triangle formed by consecutive vertices p_i, p_{i+1}, and p_{i+2} where no other polygon vertex lies within the triangle. Vertex p_{i+1} is the ear tip, and the line joining vertices p_i and p_{i+2} is called a diagonal Figure 2.(a). Once an ear is found, the triangle is constructed by inserting a diagonal and removing the ear tip, forming a new polygon with n-1 vertices. This process is continued until only three vertices remain. Due to the nature of this method, the triangulation generated is not necessarily unique, as a different starting vertex could remove ears in a different order, thus altering the final triangulation. Figure 3 shows a working example of this method performed on a polygon with n = 7 vertices.

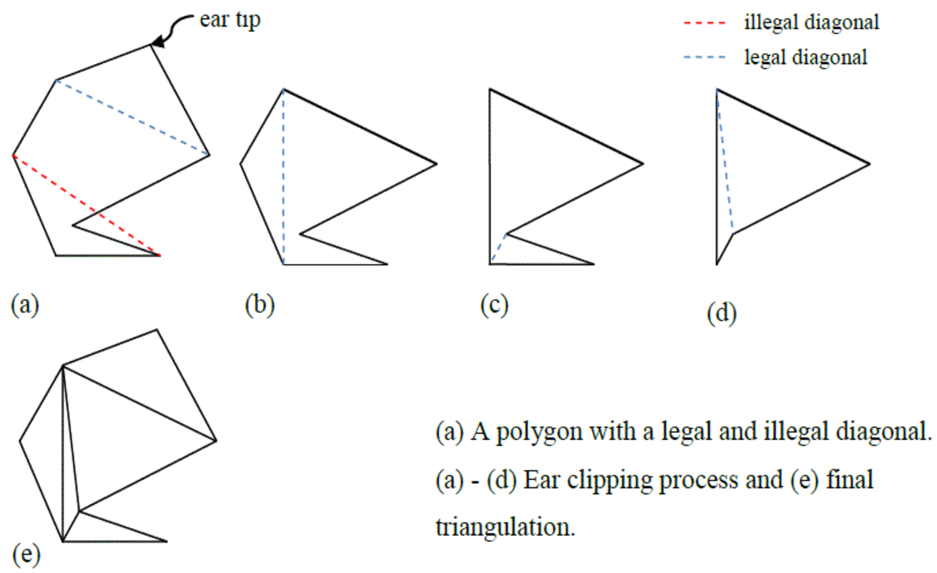

Fig.3 Ear clipping

4. DELAUNAY TRIANGULATION

Another recognized problem in computer graphics is to generate a non-intersecting set of triangles from a set of n 2D points $P=p_0,\ldots,p_{n-1}$, where the points of P form the vertices of the triangles. This can be achieved by using the Delaunay triangulation technique, which was first proposed by Boris Delaunay in 1934. Delaunay triangulation maximizes the minimum angles in triangles and avoids skinny triangles.

Although the Delaunay triangulation method was originally created to triangulate an unstructured set of points, the method has been adopted into some existing algorithms for generating a triangulation from a trimmed surface. Properties of Delaunay triangulation are:

- Local empty-circle property:
  The circum-circle of any triangle in Delaunay triangulation does not contain the vertex of the other triangle in its interior,
- max-min angle property,
- There is a unique Delaunay triangulation from a set of points,
- External edges of Delaunay triangulation make the convex hull of the point set.

Sheng and Hirsch (1992) present a method for triangulating a trimmed parametric surface, based on partitioning the parameter space and a Delaunay triangulation. First, a maximum 2D triangle edge size, Ω, is determined by using a „flatness criteria‟ (Peterson, 1994). This ensures that when the triangle is mapped into 3D it does not deviate from the surface by more than some user specified tolerance.

Once the surface and trimming curves have been subdivided, the points located within the trimming region are identified and triangulated using a Delaunay triangulation. Piegl and Richards (1995) generalized this method for trimmed NURBS surfaces. In addition, the points located within the trimming region are established by using a simple scan-line-type algorithm, as used in raster graphics to fill polygons (Foley et al., 1995). As the Delaunay triangulation of surfaces is complex and not the main focus of this thesis, full details of existing algorithms have been omitted. However, a comprehensive survey of existing methods for triangulating a trimmed surface using a Delaunay triangulation can be found in Frey and George (2000).

The moment, that all the points are visible in the image being used as a basis for the triangulation, and that the object contains no holes, then the surface will be topologically planar. If the 2D triangulation found accurately represents the true surface in 3D, then it follows that the same connectivity of the 2D points in the other images will represent the same surface. If it is additionally assumed that there is Lambertian reflectance and constant lighting, then comparing the projection of the proposed surface in one or more of the images with the corresponding actual images allows the error between the proposed triangulation and the ideal triangulation to be represented. [3]

Triangulation gives the minimum squared difference over all pixels between the actual and predicted image, for all images, is the most image–consistent triangulation and hence provides the best approximation of the surface given those input images, camera matrices and points. Therefore, the 3D points can be projected into one of the images using the appropriate camera projection matrix and these 2D points triangulated [6].

5. RESULTS OF TRIANGULATED 3D MODELS FROM VIDEO

For practice we use several objects with objects with right angles and curved objects. In every case we can see how triangulation is used in process of connecting the points into 3D model. For every object we gave example of 3D model and 3D model with triangulation represented. Triangulation is used to connect points that lies on the model (inliers) and not take points that don`t lies on the model (outlies). The accuracy of the resulting 3D models are very high even for the curved objects.

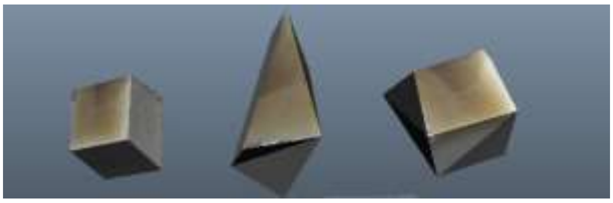

Figure 4. 3D models from video

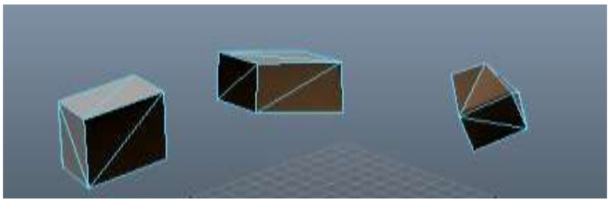

Figure 5. 3D models from video with triangulation

Figure 6. 3D models from video

Figure 7. 3D models from video with triangulation

Figure 8. 3D models from video

Figure 9. 3D models from video with triangulation

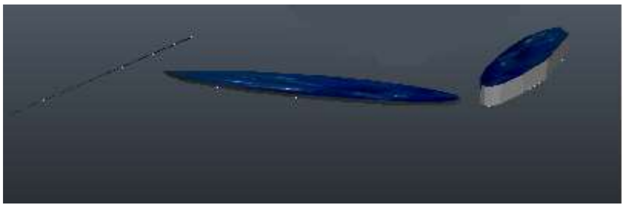

Figure 10. 3D models from video

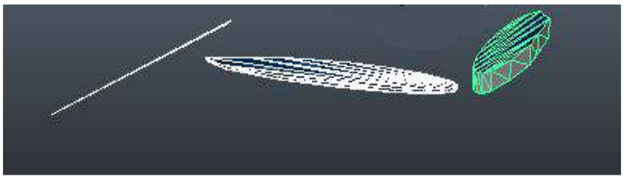

Figure 11. 3D models from video with triangulation

6. CONCLUSION

Triangulation, i.e., finding the three-dimensional location of a point observed from two or more viewpoints, is a fundamental problem in computer vision. This technique is process of determining the location of a point by measuring only angles to it from known points at either end of a fixed baseline, rather than measuring distances to the point directly as in trilateration. The point can then be fixed as the third point of a triangle with one known side and two known angles.

From our experiments we can conclude that Delaunay triangulation algorithms build a unique triangulation from a set of points and they are accurate and reliable. That's why we used these algorithms in the process of getting 3D models from video.

7. REFERENCES

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Corresponding Author:* *Svetlana Mijakovska (Faculty of Technical sciences at University of Bitola, st. Makedonska Falanga 33, Bitola 7000, North Macedonia.

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