Generation of View Representation from View Points on Spiral Trajectory

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Summary. In this paper the new method of view representation generation is proposed. View points in the method are located on spiral trajectory enlaced view sphere. Additionally the arrangement of view point is more evenly then in other known similar methods and can be formulated by only one parameter. The number of view points follows from the required scanning resolution.

1 Introduction

Methods of generating $3D$ multiview representation of polyhedron for object visual identification are described in several papers e.g [1]. Some of them - concerning models for convex polyhedrons only and called *iterative methods* (e.g. presented in [3]), can be described by a series of repeated steps (iteration). Firstly, central views corresponding to object features chosen for identification are generated. Then, *single-view areas* are calculated on the *view sphere*. They correspond to views generated earlier. In each step the covering of the whole viewing sphere by with single-view areas is checked. This process is repeated untlil we get a complete cover of view sphere.

Papers [6, 7] concern methods called *noniterative*, which are better because they are faster. Complete representation is obtained by covering the viewing sphere precisely with single-view areas without loop, but in spiral way and controlling "edge" register (of not covered area). When the register is set to "empty" the generation of representation is completed. The representation used is complete, which results from the generation method used. However, to achieve complete representation you must calculate single-view areas on viewing sphere and carry them out in a given order. Without single-view areas it is not possible to find a complete set of views. All described methods produce convex polyhedron views only.

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Next group of methods [4, 8] does not use any single-view areas, so are faster than the previous ones. They are use a concept of *complementary cone* which rotates around faces normals and records every *visual event* to obtain all views. This event occurs as a result of a new normal versor entering the scanning cone or by disappearance of a versor. The outcome of such a routine is a set of vectors faces that can be seen from the view sphere. However, they were tested for convex polyhedrons only [8].

In [9] authors extend this method (the algorithm and its implementation) for monotonous polyhedrons (monotonous polyhedrons are a class of nonconvex polyhedrons including also convex polyhedra). However this implementation do not include shadows in the views. Implementation presented in [10] just includes shadows in the views also. The idea of matching view representations and range images was presented in [12].

For representation generation and obtaining a view we use viewing sphere with perspective projection (*K-M view model* [3]). For the following conditions have to be met:

1. Models are accurate - every model is equivalent to B_{rep} model.
2. Models are viewing models - it is possible to identify object from any view.

We consider polyhedrons that are non transparent and monotonous. As we use a viewing sphere with central projection as a projection space, we allow simple view standardization.

1.1 View Generation Space - Basic Concepts

Let object be a monotonous, non transparent polyhedron without holes or pits. Consider its faces as feature areas, those areas will be used as a foundation for accurate multiview $3D$ model determining. This model is a set of accurate views, acquired through perspective projection from viewing sphere, according to the model from [3].

The concept of generating $3D$ multiview representation based on assumed generation space model is as follows:

- Circumscribe a sphere on a polyhedron. The sphere is small (radius r) and its center is at the polyhedron center.
- On this sphere place a space view cone (vc) with angle of flare 2α . This is the *viewing cone*. The vertex of this cone is a model *viewing point* VP. The distance between polyhedron center and model viewing point - R. Viewing axis always goes through sphere (and the same object) center.
- Unconstrained movement of the cone vertex, where the cone is tangent to the small sphere creates a large sphere with radius R. This sphere is called *viewing sphere* (Fig. 1). Each object has its own viewing sphere, the same for all views of this particular object.

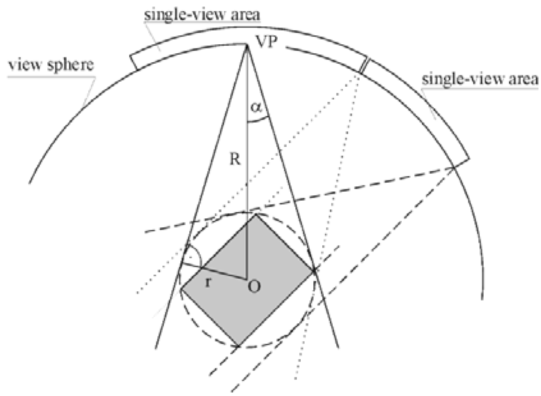

Fig. 1. Concept of view sphere and „single view areas", [3]

- Generate views, taking into account only object features selected for identification i.e. faces. Faces visible in the viewing cone create *a view*, external edges from this view create *view contour*.

The dependency between r and polyhedron vertices coordinates (Xvi, Yvi, Zvi) and: R, α, r and angle of view cone vc flare are:

$$r = max_{i=1,\cdots,k}\sqrt{X_{vi}^2 + Y_{vi}^2 + Z_{vi}^2},\ R \geq \frac{r}{\sin\alpha},\quad \angle(vc) = 2\alpha.$$

Changing one view to the other is a *visual event*. This event occurs as a result of point VP movement and is manifested by appearance of a new feature in a view, disappearance of a feature or both (Fig. 1). *Complementary cone* (cc) is a cone defined by current viewing axis (it's collinear with its height) and has an opposite direction of flare to the viewing cone. It intersects viewing cone with angle $\pi/2$, so its angle of flare is: $\angle(cc) = \pi - 2\alpha$.

View is created by faces that are visible in the viewing cone at a certain viewing point VP position. External edges of a view create a viewing contour. On Fig. 2 the view sphere divided into "one-view" areas is shown. A some view associated with region are also shown.

The other group of method use the idea of obtaining views from view point uniformly distributed on view sphere.

2 Uniformly Distributed View Points on View Sphere

The problem of uniform distribution n points on the sphere has been studied in many branch of science, [5]. Such distribution is useful for generation of view representation (we put view points on the sphere). One of the most popular approach is putting view points in vertices of regular polyhedron (octahedron, tetrahedron,icosahedron) and next we quadrisect of each faces (triangles). Quadrisection of a triangle consists of inserting a new vertex in

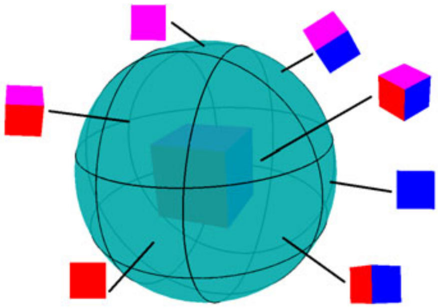

Fig. 2. Some views of a cube and corresponding "one-view" areas on the view sphere

a half of each edge in a such way that original triangle is split into four subtriangles (see Fig. 3). We iterate this process until we get required resolution. Clearly, icosahedron provides the best approximation to the sphere and has been studied in the most cases [2]. Advantages of this method include clear way of obtaining new points (easy to implementation). Nevertheless, this approach has some disadvantages.

Firstly, there is a significant difference between angles (due to the fact that angle $\angle V_{01}V_{12} = \angle V_{12}V_{20} = \angle V_{20}V_{01}$ is grater then angle $\angle V_0V_{01} = \angle V_{01}V_1 = \angle V_1V_{12} = \angle V_{12}V_2 = \angle V_2V_{20} = \angle V_{20}V_0$ see Fig. 3) so the spread of view point is clearly not uniform. The respective values (the most convinient

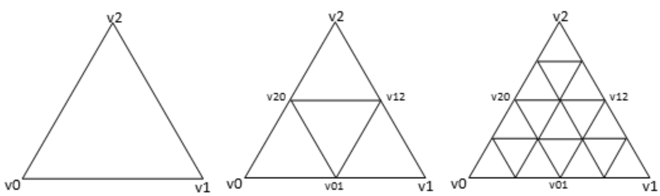

Fig. 3. Quadrisection of a triangle

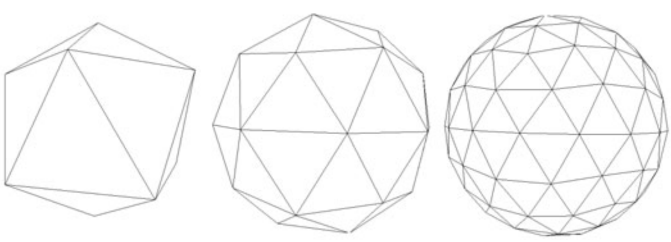

Fig. 4. Division of a icosahedron in iteration process

Table 1. Differences in minimal angles between points on view sphere in quadrisection of triangle method

Iteration number	Min. angle	Max. angle	Difference
0	1.1071	1.1071	0%
1	0.554	0.628	11.9%
2	0.277	0.326	15.2%
3	0.138	0.164	16.0%

case, the worst case and difference) for angles in successive three iterations of quadrisection of icosahedron are shown in table 1.

Secondly, in each step of iteration the resolution is approximately ~ 0.5 of previous value. So that, in most cases we have to many points to achieve required resolution. For example if we need a cover of view sphere with minimal angle between points equal to 0.5 one subdivision (iteration) is not sufficient (see Table 1) and we have to perform two iterations which ensure subdivision accuracy 0.326.

Last (not least) disadvantage is the fact that the set of view points is not ordered. The process of quadrisection of icosahedron is shown on Fig. 4. View points are located in vertices of generated polyhedron from regular icosahedron.

2.1 View Points on Spiral Path

The idea of spiral scanning of view space on view sphere from which a single face can be visible (and in this way obtaining all views including the considered face) has been shown in [11]. Start point has been coincided with intersection of normal vector of the face and view sphere. Then a spiral scanning (with the constant value between consecutive coil of spiral) was executed. After the spiral motion a full rotation of the complementary cone around face's normal has been performed. During scanning views and visual events have been registered. New views has been added to the database of views of the polyhedron. This process has been repeated for each face of polyhedron and after removing repeated views the complete set of views for a given polyhedron has been produced.

The weakness of a mentioned method which can be easily observed is the fact that some regions on view sphere are scanned many times (as many as number of faces which can be viewed from this region) because the scanning ranges for different faces often overlap (see Fig. 5).

2.2 Uniformly Distributed View Points on Spiral Path

We propose a new method to overcome enumerated difficulties. Our idea is put view points on spiral trajectory in a such way that distribution of points

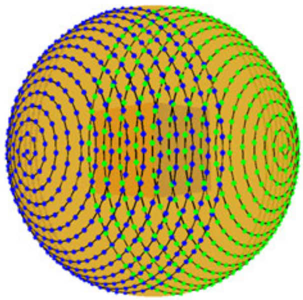

Fig. 5. Overlaped regions in scanning two faces surroundings in spiral way method [11]

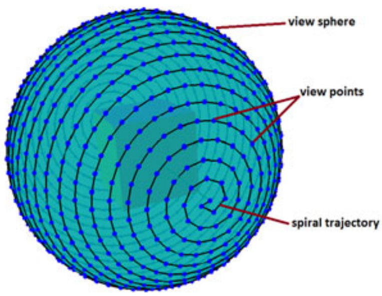

Fig. 6. View points located on spiral trajectory

is uniform (to a certain extent). The formula for spiral trajectory can be defined as follows, [11]:

$$\begin{cases} x = \cos(kt)\sin(t) \\ y = \sin(kt)\sin(t) \\ z = \cos(t) \end{cases} \tag{1}$$

where $t \in [0, \pi]$ denotes a parameter and $2k$ is the number of full rotation around z-axis. Hoverer, arrangement of view points determined by the equation (1) is definitely not uniform (more dense at poles and rare on the equator). If we put

$$\begin{cases} t = \arccos(1 - s);\ for\, s \in [0, 1] \\ t = \pi - \arccos(s - 1);\ for\, s \in (1, 2] \end{cases} \tag{2}$$

than the points is more uniform distribution. The angle between successive coins of the spiral (the required resolution res) is equal to $res = \frac{2\pi}{k}$ whole length of spiral path defined in (1) is equal to $2k$.

Hence, the formula for the number of view points can be defined as follows:

$$n = \frac{4\pi}{(res)^2} \tag{3}$$

where *res* is the required scanning resolution. This resolution may depend on technical parameter of device acquired data or complexity of polyhedron. The view points on sample spiral trajectory enlaced view sphere are shown on Fig. 6.

We obtain views from view points using the concept of view sphere with perspective projection introduced in section 1.1.

3 Results

The proposed method has been tested on number of polyhedron and we obtain the same complete set of views as generated by other methods. Hoverer we have following advantages:

1. The idea introduced in this paper extends the method of scanning space above each face and due to one scanning we avoid overlaps and the number of view points is significantly less.
2. The number of view point (defined in eq. 3) are determined more accurately (in classical quadrisection of triangle method in each step resolution is approximately 2 times less).
3. The set of view points on view sphere generated by our method is ordered (which can be used for generation of aspect graph).
4. The set of view points on view sphere are more evenly distributed (in comparition to the method of quadrisection of triangle and scanning above each face).

For example, for required scanning resolution 0.2, 97.5% of points differ from each other only by only 3% (the value is the minimal angle to any point on view sphere) (see Fig. 7) so that the view points are more evenly distributed compared to the quadrisection of triangle method (differences can reach ≈ 16% in this case) .

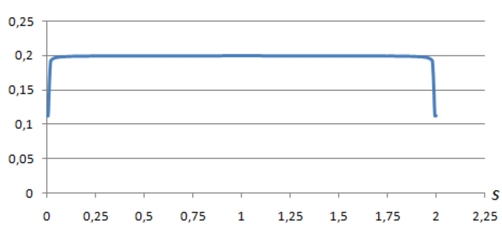

Fig. 7. Distribution of minimal angle to any other point on view sphere depending on parameter value s (eq. 2)

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