ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

A Review on Mesh Segmentation Techniques

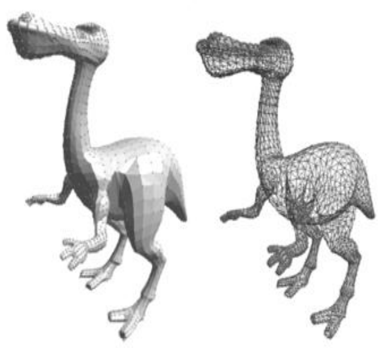
Medhat Rashad, Mohamed Khamiss, Mohamed MOUSA
Faculty of Computers & Informatics, Suez Canal University, Ismailia, Egypt

Abstract*—Mesh segmentation plays a major role in modeling, shape compression, simplification, texture mapping, and skeleton extracting. The main goal of the mesh decomposition techniques is to segment the shape into parts in the preprocessing step. Each part acts as a dependent object which can identify the logic characteristics of the shape, in the preprocessing step. The techniques can be based on human perception (meaning components), geometric attributes or mesh components (vertices, edges, faces). This paper presents a comprehensive comparative study of the mesh segmentation techniques in terms of features and limitations. Finally, we figure out the most important challenges and recommendations for the mesh segmentation techniques.

***Index Terms*— Mesh segmentation.**

I. INTRODUCTION

Mesh segmentation is the process of partitioning the shape of a given mesh into a meaningful subparts. The segmentation techniques improve the solution of many computer graphics problems such as: modeling [18], shape compression [3], simplification [11], texture mapping [39], skeleton extraction [33], and metamorphosis [21], [74]. The segmentation techniques can be based either on a geometric description or on a logic component. In the first class, the mesh is divided into a number of pieces that is stable with respect to some particular geometrical attributes, such as curvature and geodesic distance as in [19], [56], [11], [72], and [22]. However, in the second class, the mesh is divided into subparts that match the related features of the shape based on human perception [40], [33], [43], and [32]. In this review, we provide a comprehensive and comparative study of some famous and familiar techniques which used in mesh partitioning. To establish a helpful representation of the mesh, there should be a relationship between the three main mesh's elements (vertices; edges; faces) in the representation. Shamir [60] proposed a promising mesh boundary representation, see (Figure 1).



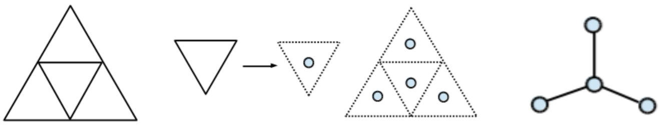


Fig 2: Constructing dual graph.

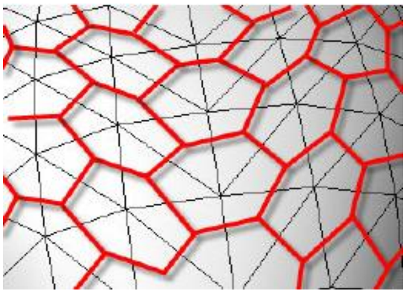


Fig 3: Red line represented the dual graph

For instance, in 3D meshes approximating 2-manifold objects, the area around each point is homeomorphic to a disk. The simple form of the boundary mesh representation can be described as follows:

- A 3D mesh can be represented as the graph $G = (V; E; F)$, where the triple V, E and F are the sets of vertices, edges and faces, respectively. The closed boundary representation is used to describe 3D volumetric meshes as the tetrahedron. The set of faces, F, is also called the surface of the mesh.
- Mesh partitioning is simplified to partitioning the graph G into a set of sub graphs G_i. Each G_i consists of its own vertices, edges and faces $(V_i; E_i; F_i)$.

To this end, the segmentation techniques rely on locating the dual graph of the graph G which is described with basic formulation $G = (V; E; F)$ [14], (Figure 2). Let f Gig be the set of sub graphs of G. We construct the dual graph (DG) of G by identifying each component in G_i as a node in DG and determining the edges connecting these nodes in DG by the neighboring relationship extracted from G, (Figure 3). In the following, we will list the geometric features and decomposition limitations which usually used by numerous segmentation methods. The policy, used to decide which attributes to apply, has a significant effect on the segmentation results. In addition, this policy is often application based policy. I.e. Depending on the problem, in which we apply the segmentation, a set of application based features is emerging. The rest of this review was structured as follows. Section 2 presents the set of common features and their limitations of mesh segmentation. Section 3 states the major categories of mesh segmentation techniques. Section 4 explains the various segmentation techniques in each category. Section 5 discusses the remaining challenges. Section 6 summarizes and concludes the paper.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

II. THEORETICAL BACKGROUND

There are many challenges facing the mesh segmentation techniques. These challenges are focused around the following three constraints picked out from the mesh.

- Cardinality constraints (crd).
- Geometrical constraints (geo).
- Topological constraints (top).

In fact, there is no technique satisfying all of these constraints at the same time. However, these constraints generate a set of attributes used for determining which components belong to the same part. In the following subsections, we will illustrate these constraints and attributes.

A. Segmentation constraints

- Cardinality constraints: The cardinality constraints are a set of conditions affecting the number of generating subparts and the number of components in each subpart. These constraints allow us to set the maximum (or minimum) number of components in each subpart. In addition, they enable us to produce a balanced partitioning using the main ratio between the minimum and the maximum number of components in each subpart.
- Geometric constraints: The geometrical constraints are a set of conditions applied to the mesh regions. These conditions may sometimes be reduced to an optimization problem (maximization or minimization). For example, we can minimize the following geometrical attributes: distances, region diameters, and areas, for balancing the partitioning. Otherwise, these conditions may be more complicated attributes such as region convexity or volumetric conditions.
- Topological constraints: The topological constraints are a set of conditions concerning the layout of the whole mesh. For example, some techniques prefer the partitions to be equivalent to a disk to simplify the further processing on the segmentation. In addition, the number of connected components of the produced sub-parts affects the whole segmentation process.

B. Mesh Features

There are many mesh features [61] used to clarify and optimize the implementation of the mesh segmentation techniques. We can summarize (Figure 4) this set of features as follows:

1) *Planarity of various mesh forms (linear planar characteristics) (Lnpr),*
2) *The highest point in geometry perspective, (cones, quadrics, spheres, cylinders) (Geo),*
3) *Difference in normal of vertex (angles between two plane faces "dihedral") (Ang),*
4) *Surface attributes of a mesh*
   a- Curvature (Crv) *b- Geodesic distances (Gds)*
5) *Slipping (Slp),*
6) *Symmetry (Sym),*
7) *Convexity or Concavity (Cnv),*
8) *Medial axis (MA) and medial axis transform (MDT), Shape diameter function (SDF), and*
9) *Motion characteristics.*

The most common feature utilized for mesh segmentation is the planarity of its surface. This feature assists for further goals such as parameterization [29], simplification [11], texture mapping [39], and many others. Many researchers have applied various types of norms to determine planarity of pieces the mesh. Considering that each part is a cluster of components, this part can be interpreted by the equation of the plane $Ax+By+Cz+D=0$; i.e., to check whether all the vertices v_i are on the same plane.

On the other hand in [3], using the primitives as (the cylinder, the cone, and the sphere) tries to find the valid fitting primitive in the least square perspective. Surface normal play a central role as the difference in normal (angles between the faces), is one of the most significant approaches. It is used for clustering non-planar areas by simply measuring the differences of normal orientation angles between mesh elements. (Figure 5). According to this difference, a plane or curved part can be created. There are two types of the extremely helpful procedure in numerous mesh partition methods are the surface characteristics of the shape. The first characteristic is meshed curving or curvature (Figure5a), there are several and differences procedures used for curvature computations either utilizing discrete approaches or using regionally matching a quadratic procedure and using its shape as the curvature at the appropriate point, see example in [48], [1], and [12]. The average geodesic distance (AGD) is another feature type which is based on the geometrical topology (Figure 5b). The AGD is measured as the average distance between two distinct points on the mesh. This means, the points lie in the center of the shape will hold weak AGD value, and other points that lie on the boundary will have a high value. In [34] measuring the AGD is commonly carried out by computing the distances from the whole vertices to the others. Another mechanism discussed in [20] is slippage analysis. Slipping off a shaped, output a rotation and interpret regular shapes such as a cylinder, a sphere, and a plane, which are often found as elements of engineering parts. In [54], similarity analysis has applied to a mesh to segment it into elements. We being with the main objectives of symmetry plane of a shape are found rely on sampling. Then, for various faces and for every similarity planes, apply measurement of the point to which the face presents symmetric with respect to a plane is provided. In [24], volume is a convex or a concave is usually relative to shape partitioning. The primary difficulty of convex partitioning of polyhedral surfaces should be classified first [9], [5], and [8]. Such partitioning is very expensive to be creating and representing results. Several approaches measures the convexity where it is used to produce extra efficient partitioning. In [41], the approach convex decomposition (ACD) marks the cavity (the volume within the convex hull and its original parts). But in [36]

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

calculates the average length of all sub-parts triangle to the sub-parts convex hull. On the other ways, medial axis transform (MAT) and the medial axis are significant approaches used the topological feature of the shape [2], [15], and [10]. On the other side, MAT provides with the knowledge on the structure and also the volume of the shape and utilized as guidelines for the mesh segmentation. The same as, different curve skeletons [13] had been applied to explain some features of the shape.

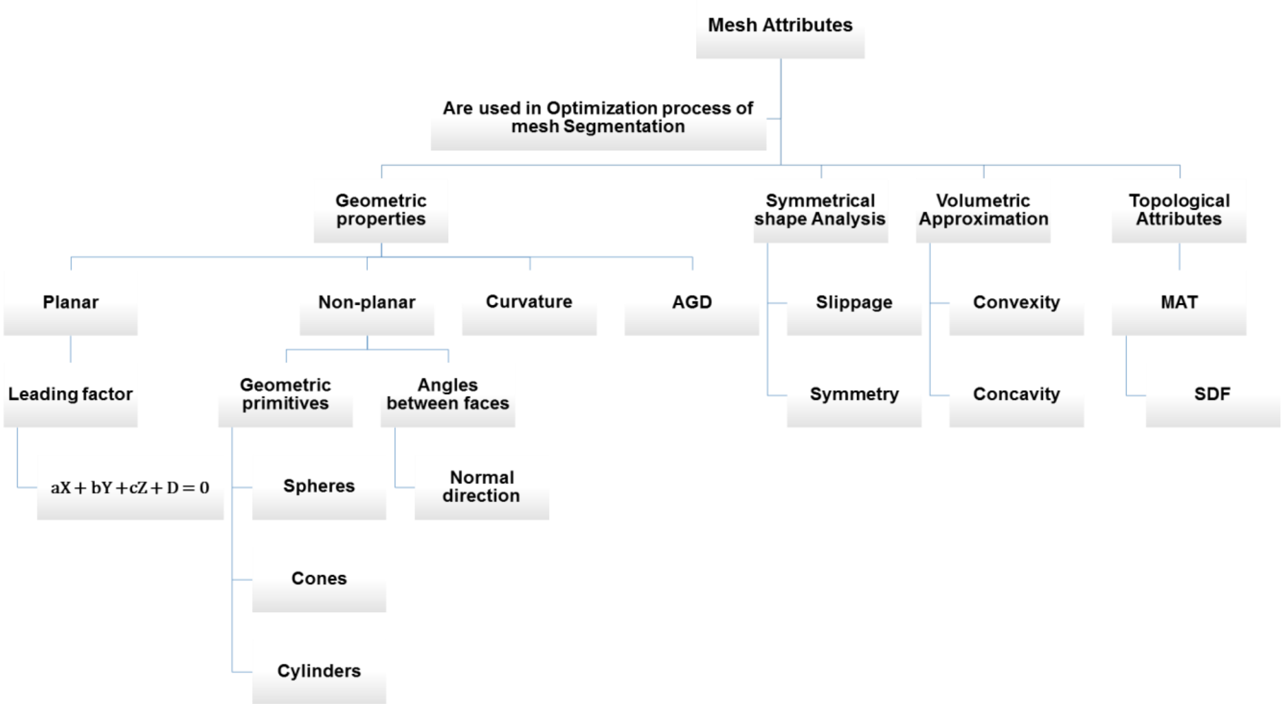
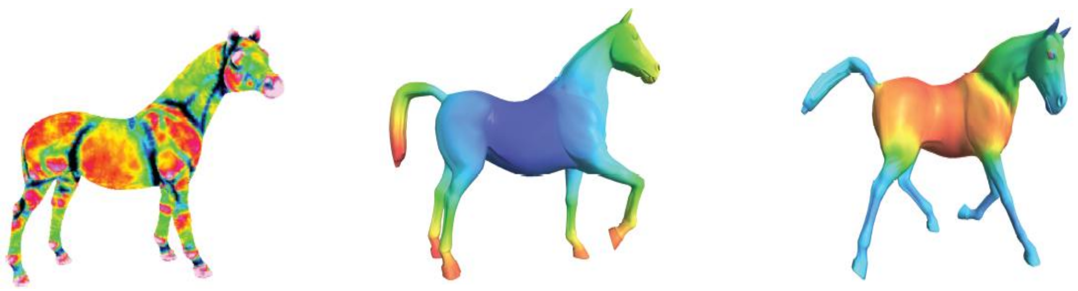


Fig 4: Summary of mesh attributes



(a) Minimum Curvature (MC). (b) Average Geodesic Distance (AGD). (c) Shape Diameter Function (SDF).

Fig 5: Mesh features used for partitioning.

In reality, skeleton extraction "skeletonization" and mesh Segmentation is always complementary. Partitioning the

The object can directory skeleton extraction [33] and vice versa. Extracting the skeleton can directory to mesh segmentation. A feature relative to the MAT is illustrated in [62] known as the shape diameter function (SDF). This approach identifies the local diameter of a given object at points on its edge rather than the local radius (length of the medial axis). The function values at a point lying on the mesh boundary is equal to the length of beams sent from the point inside to the other side of the mesh (Figure 5c). The SDF presents a perfect contrast, among thick and thin segments of the object. It has been applied for region-type partitioning. An extra benefit the SDF values of points on the mesh stay mostly invariant although the confusing changes to the object.

And finally, while the shape or mesh being segmented is dynamic or live, various works had used dynamic characteristics of vertices in the mesh partitioning. It has been applied in a motion sequence for compression [38], [58] or for ray-tracing acceleration [23].

III. SEGMENTATION TYPES

There are differences between the types of mesh partitioning, see (Table I), first is Part Type Segmentation (PTS), and the second is Surface Type Segmentation (STS). The major variation among the two classes has relied on a separate detail and the view that the object being partitioned,

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

both a 2D surface representation and a 3D volumetric representation (Figure 6a). The first one, is region type segmentation, is aimed for segmenting the mesh to semantic parts. [6], [49], in general, used in volumetric parts. While the second, generally used the surface geometric features of the mesh such as planned or curve for creating the patches. In CAD mesh partitioning and inverse architecture [59], [27], [67], where a shape is segmented to geometric fundamentals like the plane, cylinder patches, and rounded part. Likewise, when patch based characteristics are used for partitioning an object into volumetric exact and logical parts, like the minimum curvature rule [24], [25]. Hence, the mesh decomposition goals that participate both segmentation prototypes. In usual, patch type and region type segmentation refer to different goals, next we will list the various goals.

A. *Part-Types Segmentation (PTS)*

The PTS are utilized in studying of human understanding. Testing human image perception several attempts mean that perception and shape recognition are based on structure mesh segmentation the shape into smaller components or sub-parts [25], [6], [24]. Because of this purpose, PTS segments a 3D mesh to separate parts that oftentimes matched to the bodily 3D semantic components of an object. New comparable studies on the outcomes of some region type mesh decomposition procedures can be located in [4]. In [50], [51], region type decomposition is generated relied on investigating the junction curves/sweeps of the ball concentrated nearly all vertices. The investigation partitions a shape into related parts that are either body's parts or extended characteristics, like protrusion characteristics. PTS was useful in modeling by collecting the object's parts to inspire modern layout [18]. As well, utilized for generating toys as in [55]. Segmenting, recognizing and matching object parts can serve shape identifying and retrieval, and shape restoration [75], [52], [53]. This part identification can be utilized in morphing [64].Lastly, segmenting object into parts has also assisted in skeleton creation [33], [68], and [49], which was utilized in object deformations as well as object animation.

B. *Surface-Type Segmentation (STS)*

The STS is also known as patch type, it's always utilized in texture mapping [56], [65], [70], creating charts [39], [72] and geometrical creation of an image [57]. Every application decomposed the mesh into parts that must be topologically equal to the object/disk furthermore have not force high deformation after parameterization. Parameterization was driven mesh division, also applied in [26]. Other applications that STS is used for re-meshing as well simplification [19], [63], [75], and [11]. In morphing, complicated conversions among shapes can be interpreted by decreasing the conversions among sub-patches [74], and [75]. In compression designs by spooky analysis in [31], the prime motive for segmenting the shape into small parts is to minimize a volume in the Laplacian form.

IV. SEGMENTATION TECHNIQUES

Here we will discuss mesh segmentation techniques. We can classify the techniques according to the approximation way which is used to get the solution. There are two classes as shown in (Table II), the first is non-parametric techniques, which the number of resulting segments is unknown, while the other class is parametric techniques where the number of parts is provided first. The minor mesh segmentation problem is assigning the primitive mesh components to sub-parts, recognized as traditional clustering issues.

Comparison	Surface Type Partitioning	Part Type Partitioning
Based on	Geometrical properties	Human perception (semantic part)
Applied on	2D Surface View	3D Volumetric View
Result	Create a set of surface patches	Create a set of volumetric parts
Applications used	Texture mapping Geometry image creation Re-meshing and simplification In CAD, reverse engineering Morphing and Modeling	Recognition and Shape understanding Semantic segmentation Modeling and Morphing Shape matching, Retrieval, and Recognition
Precautions	In both types of segmentation, the following points of view should be satisfied: • All sub mesh parts / patches must be an equivalent topological to a dish • Eliminating too large or too small parts / patches	

Table I: Comparison between types of segmentation.

Non-parametric techniques	Parametric techniques
Region Growing Algorithm (RGA). Multiple Source Region Growing Algorithm (MSRGA). Watershed Region Growing Algorithm (WRGA). Hierarchical Clustering Algorithm (HCA).	Iterative Clustering Algorithm (ICA). Graph Cut Algorithm (GCA).

Table II: Parametric and non-parametric techniques.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

A. Region Growing Algorithm

In [47] present the prime algorithm used for mesh segmentation. RGA begins with a seed component from *P* and dilates a sub-part incrementally as:

Algorithm 1: Region growing [47].

Initial state a preference queue *E* of components;
repeat
  Select a seed component and add to *E*;
  Make a cluster C from seed;
  repeat
    Get the next component *s* from *E*;
    if p can be segmented into *C* **then**
      Segment *p* into *C*;
      Add *p* neighbors to *E*;
      Join small Segments into neighboring ones;
    end
  until *Q* is empty;
until all components are segmented;

The main difference within various procedures which apply RGA is the principle that defines which a component may be joined to the current cluster. The critical issue in RGA is the way of selecting the seeds, and another issue of that algorithm dealing with small regions. The seed randomly selected in face super technique [29] cluster criteria based on face distance and the face normal with respect to geometric constraint which prevent the face from folding-over. [37] Curvature is the criteria which are used in growing. While in [7] convex decomposing of mesh with random selection of the growing seed. Convex parts are extracted by growing the parts from seed triangle [36] measure the convexity and the-compactness.

1) Multiple Source Region Grow Algorithm

This method begins with many origin seeds and the whole of them work in parallel. The essential concept is to produce Voronoi spots on a mesh, thereafter apply the dual of the spots as the standard mesh triangulation.

There are many limitations on these patches [17]:

- *All patches must be equal to the real disk, there are not*
- Two *or extra patches can share extra than one logical edge*
- *More than three patches are connected at a vertex.*

An estimate of the geodesic distance among faces is accepted as the priority for picking faces. The procedure begins with a seed and then repeatedly insert another seed in spots, where one of the limitations are broken till the previous limitations are satisfied.

The watershed algorithm used for mesh segmentation and also in RGA with multiple seeds/sources. The height function defined on the mesh used for mounting and determining the-seeds. The method determines and lists each regional minimum of that function. Every minimum assists as the beginning seed for a shape domain. Subsequently, a region is increased from every seed till it extent maximum in the function, therefore segmentation the function split into subparts (watersheds).

Algorithm 2: Multiple source region grow [17].

Initial state a preference queue *E* of pair;
Select a group of seeds components p_i;
Create a cluster C_i from each seed p_i;
Add the pair $<p_i,C_i>$ to *E*;
repeat
  Find the next pair $<p_k,C_k>$ from *E*;
  if p_k is not clustered already and p_k can be clustered into C_k **then**
    cluster p_k into C_k;
  end
  for all un-clustered neighbors pi of p_k **do**
    Insert $<p_i,p_k>$ to *E*;
  end
  Merge small clusters into neighboring ones;
until *E* is empty;

There are several differences of watershed algorithm. The main disadvantage in RGA is the dependency on the primary seed pick. Utilizing watershed formularization it is done by beginning at function minimum [73] the important points of the AGD, are using vertices as seeds. In real work sometimes a maximum function may not be specified, the arbitrary seed selection is utilized and several results in a poor partition.

2) Watershed Region Growing Algorithm

There are different definitions for the watershed region growing algorithm, such as [73] using the AGD as a height function, while in [45], [46] the function relies on vertex discrete curving estimations. The main drawbacks in RGA is its depending on the beginning seed pick, by applying WRGA its solve this problem by starting in differing functions as we said before e.g. in [73].

B. Hierarchical Clustering Algorithm

The same as region-growing, the variation within the-hierarchical segmentation Located essentially in the merge criteria and the preference of components in the queue. This algorithm viewed as Bottom-Up construction tree. Hierarchical clustering initials any face with its separate part. While segmenting, all pairs of segments are allocated a price for joining parts to a sub-part while the lowest price pair is joined. Hierarchical surface segmentation [19]. This applies a bias expression to inspire rotational consolidated part shapes by applying the proportion within the square of the edge. While in [3] use a restricted set of appropriate fundamentals (planed, sphere, cylinder) and the price of merging a collection of triangles into one segment is the minimal of the estimated error measured toward the primitives. Decomposition relied on slipping analysis [20] also, applies hierarchical segmenting to subjoin points to greater regions relied on slipping identity objective.

Algorithm 3: Hierarchical clustering [19].

Initial state a preference queue *E* of pair;
Create a totally valid component pair to *E*;
repeat
  Get the next pair *(a,b)* from *Q*;
  if *(a,b)* can be merged **then**
    merge *(a,b)* into *C*;

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

end
Create totally valid pairs of *C* to *E*;
until *E* is empty;

C. Iterative Clustering Algorithm

The prior techniques are explained as non-parametric, as the most numerous of producing parts are indeterminate. In a parametric, the number of parts is provided at first. The mesh decomposition can be expressed as a variation issue of determining the optimal decomposition by repeatedly seeking for the good decomposition for the assigned numerous clusters. The primary procedure is the *k- means* [44], [16]. The recursive method starts with k agents, realizing k-clusters Every component is attached to a cluster of the k-clusters. Finally, the k agents are re-computing from the k-clusters and the appointment procedure start repeatedly. The procedure ends when the agents aren't changed:

Algorithm 4: Iterative Clustering [44].

Initial state *c* representatives of *c* clusters;
repeat
for each component p **do**
Find the best agent *g* for *p*;
Assign *s* to the g^{th} cluster;
end
for each cluster *g* do
Compute a new agent;
end
until Representatives do not change;

We cannot use Euclidean distances among components to select a component to a cluster. Hence, Geodesic distances are exceedingly suitable for measuring the mesh distances, but the measuring is costly. And so, utilize the agents as seeds for the RGA relieves the calculated price. To produce a fit decomposition of differing objects for morphing views, a k-means established surface clustering procedure is presented in [64].

D. Graph Cut Algorithm

This type of algorithm considers Top-Down procedure and done by finding the best boundary among sub-parts. It has been used in [33], [54]. The last segmentation is made by using GCA within the fuzzy region to refine its boundaries between the segments.

Algorithm 5: Graph Cut [33].

Create a root group P_r having all components;
Insert P_r to a priority queue *E*;
repeat
Get the top group *P* from *E*;
if *P* can be divided **then**
divided *P* into P_i;
end
Insert all P_i to *E*;
until *E* is empty;

V. DISCUSSION

In [Table III], we summarize the various segmentation solutions in words of segmentation techniques, kinds, and the used features. No actual link to whatever appropriate technique and the segmentation character. As presented in the several examples, the identical features have been utilized via numerous procedures to describe the decomposition. However, there exist a powerful relationship among the features utilized and the aim of decomposition. Planned, the normal and angles between two faces also curvature can be utilized when STS is researched, however, the higher common fundamentals and skeletonization are used for PTS. Geodesic distances, is like the topological features that utilized together. The most essential problems in the mesh partitioning is the trade-off in decomposition quality and the numerous of the parts. The greatest optimization principals are better met by the small parts. The general parametric algorithms like the ICA or the GCA and non-parametric algorithms like RGA or HCA, need to apply post-processing for smoothing and refine the edges that separating the parts as that tend to rely strongly on the mechanism of triangulation than on the real mesh subdivision. Finally, the execution performance of the mesh partitioning problem is an important issue that has been discussed in many research papers [42], [3], and [71]. Using a high-performance computing environment will improve the execution time of the partitioning algorithm which works on processing large-scale data. A high-performance computing environment executes the parallel algorithms of the mesh partitioning on a distributed environment. A distributed environment can be applied using the GPU (Graphics Processing Unit). Several research papers have shown that the GPU can achieve a better performance improvement for the parallel algorithms in [30].

VI. CONCLUSION

Both PTS and skeleton extraction of the shape are powerfully related issues. Various techniques [55] start with extracting a skeleton and then part the object relied on a segmentation of the skeleton. [40] First, skeletonization, then a plane orthogonal to the skeleton parts is swept over the mesh and sharp points are distinguished. All sharp skeleton points are utilized to set a segment, which utilize the sweep plane to divide the mesh into disjointed parts. If the goodness of the skeletonization is not reached, it is improved hierarchically to create an ACD of the shape.

Technique	*Seg. type*	*Features*							
		Lnpr	*Geo*	*Ang*	*Crv*	*Gds*	*Top*	*Cnv*	*Slp*
RGA	*STS*	[29]		[29]	[37]	[70]	[70]	[7]	
RGA	*PTS*							[36]	
MSRGA	*PTS*				[51]	[17]	[17] [51]		
MSRGA	*STS*			[39]		[39]	[39]		

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

WRGA	*STS / PTS*			[75]	[45] [46] [37]	[73]		
WRGA	*STS*		[52]	[35] [52] [66]	[35] [52]			
HCA	*STS*	[19][26][56]		[26]			[56]	
HCA	*PTS*		[3]					
HCA	*STS / PTS*			[63]	[63]		[63]	[20]
ICA	*PTS*		[69][28]	[64]		[64]		
ICA	*STS*	[11]		[11]				
ICA+GCA	*STS*			[33]		[33][32]		

Table III: Summary of segmentation techniques.

REFERENCES

[1] Pierre Alliez, David Cohen-Steiner, Olivier Devillers, Bruno Lévy, and Mathieu Desbrun. Anisotropic polygonal remeshing. In ACM Transactions on Graphics (TOG), volume 22, pages 485–493. ACM, 2003.

[2] Nina Amenta, Sunghee Choi, and Ravi Krishna Kolluri. The power crust, unions of balls, and the medial axis transform. Computational Geometry, 19(2):127–153, 2001.

[3] Marco Attene, Bianca Falcidieno, and Michela Spagnuolo. Hierarchical mesh segmentation based on fitting primitives. The Visual Computer, 22(3):181–193, 2006.

[4] Marco Attene, Sagi Katz, Michela Mortara, Giuseppe Patané, Michela Spagnuolo, and Ayellet Tal. Mesh segmentation-a comparative study. In Shape Modeling and Applications, 2006. SMI 2006. IEEE International Conference on, pages 14–25. IEEE, 2006.

[5] Chanderjit L Bajaj and Tamal K Dey. Convex decomposition of polyhedra and robustness. SIAM Journal on Computing, 21(2):339–364, 1992.

[6] Irving Biederman. Recognition-by-components: a theory of human image understanding. Psychological review, 94(2):115–147, 1987.

[7] Bernard Chazelle, David P Dobkin, Nadia Shouraboura, and Ayellet Tal. Strategies for polyhedral surface decomposition: an experimental study. In Proceedings of the eleventh annual symposium on Computational geometry, pages 297–305. ACM, 1995.

[8] Bernard Chazelle and Leonidas Palios. Decomposition algorithms in geometry. In Algebraic Geometry and its applications, chapter 27, pages 419–447. Springer, 1994.

[9] Bernard M Chazelle. Convex decompositions of polyhedra. In Proceedings of the thirteenth annual ACM symposium on Theory of computing, pages 70–79. ACM, 1981.

[10] Hyeong In Choi, Sung Woo Choi, and Hwan Pyo Moon. Mathematical theory of medial axis transform. Pacific journal of mathematics, 181(1):57–88, 1997.

[11] David Cohen-Steiner, Pierre Alliez, and Mathieu Desbrun. Variational shape approximation. ACM Transactions on Graphics (TOG), 23(3):905–914, 2004.

[12] David Cohen-Steiner and Jean-Marie Morvan. Restricted delaunay triangulations and normal cycle. In Proceedings of the nineteenth annual symposium on Computational geometry, pages 312–321. ACM, 2003.

[13] Nicu D Cornea, Deborah Silver, and Patrick Min. Curve-skeleton properties, applications, and algorithms. IEEE Transactions on Visualization & Computer Graphics, (3):530–548, 2007.

[14] Hervé Delingette. General object reconstruction based on simplex meshes. International Journal of Computer Vision, 32(2):111–146, 1999.

[15] Tamal K Dey and Wulue Zhao. Approximating the medial axis from the voronoi diagram with a convergence guarantee. In Algorithms ESA, pages 387–398. Springer, 2002.

[16] Richard O Duda, Peter E Hart, and David G Stork. Pattern classification. John Wiley & Sons, 2012.

[17] Matthias Eck, Tony DeRose, Tom Duchamp, Hugues Hoppe, Michael Lounsbery, and Werner Stuetzle. Multiresolution analysis of arbitrary meshes. In Proceedings of the 22nd annual conference on Computer graphics and interactive techniques, pages 173–182. ACM, 1995.

[18] Thomas Funkhouser, Michael Kazhdan, Philip Shilane, Patrick Min, William Kiefer, Ayellet Tal, Szymon Rusinkiewicz, and David Dobkin. Modeling by example. ACM Transactions on Graphics (TOG), 23(3):652–663, 2004.

[19] Michael Garland, Andrew Willmott, and Paul S Heckbert. Hierarchical face clustering on polygonal surfaces. In Proceedings of the 2001 symposium on Interactive 3D graphics, pages 49–58. ACM, 2001.

[20] Natasha Gelfand and Leonidas J Guibas. Shape segmentation using local slippage analysis. In Proceedings of the 2004 Euro graphics/ACM SIGGRAPH symposium on Geometry processing, pages 214–223. ACM, 2004.

[21] Arthur Gregory, Andrei State, Ming C Lin, Dinesh Manocha, and Mark A Livingston. Interactive surface decomposition for polyhedral morphing. The Visual Computer, 15(9):453–470, 1999.

[22] Sumanta Guha. 3d mesh segmentation using local geometry. International Journal of Computer Graphics & Animation, 5(2):37, 2015.

[23] Johannes Günther, Heiko Friedrich, Ingo Wald, Hans-Peter Seidel, and Philipp Slusallek. Ray tracing animated scenes using motion decomposition. In Computer Graphics Forum, volume 25, pages 517– 525. Wiley Online Library, 2006.

[24] Donald D Hoffman and Whitman A Richards. Parts of recognition. Cognition, 18(1):65–96, 1984.

[25] Donald D Hoffman and Manish Singh. Salience of visual parts. Cognition, 63(1):29–78, 1997.

[26] Keisuke Inoue, Takayuki Itoh, Atsushi Yamada, Tomotake Furuhata, and Kenji Shimada. Face clustering of a large-scale

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

cad model for surface mesh generation. Computer-Aided Design, 33(3):251–261, 2001.

[27] Cheuk Yiu Ip and William C Regli. Manufacturing classification of cad models using curvature and svms. In Shape Modeling and Applications, 2005 International Conference, pages 361–365. IEEE, 2005.

[28] Dan Julius, Vladislav Kraevoy, and Alla Sheffer. D-charts: Quasidevelopable mesh segmentation. In Computer Graphics Forum, volume 24, pages 581–590. Wiley Online Library, 2005.

[29] Alan D Kalvin and Russell H Taylor. Super faces: Polygonal mesh simplification with bounded error. Computer Graphics and Applications, IEEE, 16(3):64–77, 1996.

[30] Young-Min Kang. A parallel approach to object identification in large-scale images. In The Second International Conference on Electronics and Software Science (ICESS2016), Japan 2016, 2016.

[31] Zachi Karni and Craig Gotsman. Spectral compression of mesh geometry. In Proceedings of the 27th annual conference on Computer graphics and interactive techniques, pages 279–286. ACM Press/Addison-Wesley Publishing Co., 2000.

[32] Sagi Katz, George Leifman, and Ayellet Tal. Mesh segmentation using feature point and core extraction. The Visual Computer, 21(8-10):649– 658, 2005.

[33] Sagi Katz and Ayellet Tal. Hierarchical mesh decomposition using fuzzy clustering and cuts, volume 22. ACM, 2003.

[34] Ron Kimmel and James A Sethian. Fast marching methods on triangulated domains. In Proceedings of the National Academy of Science, volume 95, pages 8341–8435, 1998.

[35] AF Koschan. Perception-based 3d triangle meshes segmentation using fast marching watersheds. In Computer Vision and Pattern Recognition, 2003. Proceedings. 2003 IEEE Computer Society Conference on, volume 2, pages II–27. IEEE, 2003.

[36] SHEFFER A KRAEVOY V., JULIUS D. Shuffler: Modeling with interchangeable parts. tech. rep. tr- 2006-09,. Technical report, Department of Computer Science, University of British Columbia, 2006.

[37] Guillaume Lavoué, Florent Dupont, and Atilla Baskurt. A new cad meshes segmentation method, based on curvature tensor analysis. Computer-Aided Design, 37(10):975–987, 2005.

[38] Tong-Yee Lee, Ping-Hsien Lin, Shaur-Uei Yan, and Chun-Hao Lin. Mesh decomposition using motion information from animation sequences. Computer Animation and Virtual Worlds, 16(3-4):519–529, 2005.

[39] Bruno Lévy, Sylvain Petitjean, Nicolas Ray, and Jérome Maillot. Least squares conformal maps for automatic texture atlas generation. ACM Transactions on Graphics (TOG), 21(3):362–371, 2002.

[40] Xuetao Li, Tong Wing Woon, Tiow Seng Tan, and Zhiyong Huang. Decomposing polygon meshes for interactive applications. In Proceedings of the 2001 symposium on Interactive 3D graphics, pages 35–42. ACM, 2001.

[41] AMATO N. M. LIEN J.-M. Approximate convex decomposition of polyhedra. tech. rep. tr06-002, parasol lab. Technical report, Dept. of Computer Science, Texas A&M University, January 2006.

[42] Guilin Liu, Yotam Gingold, and Jyh-Ming Lien. Continuous visibility feature. In 2015 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pages 1182–1190. IEEE, 2015.

[43] Rong Liu and Hao Zhang. Segmentation of 3d meshes through spectral clustering. In Computer Graphics and Applications, 2004. PG 2004. Proceedings. 12th Pacific Conference on, pages 298–305. IEEE, 2004.

[44] Stuart P Lloyd. Least squares quantization in pcm. Information Theory, IEEE Transactions on, 28(2):129–137, 1982.

[45] Alan P Mangan and Ross T Whitaker. Surface segmentation using morphological watersheds. In Proc. IEEE Visualization, 1998.

[46] Alan P Mangan and Ross T Whitaker. Partitioning 3d surface meshes using watershed segmentation. Visualization and Computer Graphics, IEEE Transactions on, 5(4):308–321, 1999.

[47] Andrew Mehnert and Paul Jackway. An improved seeded region growing algorithm. Pattern Recognition Letters, 18(10):1065–1071, 1997.

[48] Mark Meyer, Mathieu Desbrun, Peter Schröder, and Alan H Barr. Discrete differential-geometry operators for triangulated 2-manifolds. In Visualization and mathematics III, pages 35–57. Springer, 2003.

[49] Michela Mortara, Giuseppe Patané, and Michela Spagnuolo. From geometric to semantic human body models. Computers & Graphics, 30(2):185–196, 2006.

[50] Michela Mortara, Giuseppe Patané, Michela Spagnuolo, Bianca Falcidieno, and Jarek Rossignac. Blowing bubbles for multi-scale analysis and decomposition of triangle meshes. Algorithmic, 38(1):227–248, 2004.

[51] Michela Mortara, Giuseppe Patané, Michela Spagnuolo, Bianca Falcidieno, and Jarek Rossignac. Plumber: a method for a multi-scale decomposition of 3d shapes into tubular primitives and bodies. In Proceedings of the ninth ACM symposium on Solid modeling and applications, pages 339–344. Euro graphics Association, 2004.

[52] David Lon Page, Mongi A Abidi, Andreas Koschan, and Yan Zhang. Object representation using the minima rule and super quadrics for under vehicle inspection. In Proceedings of the 1st IEEE Latin American Conference on Robotics and Automation, pages 91–97, 2003.

[53] Sylvain Petitjean. A survey of methods for recovering quadrics in triangle meshes. ACM Computing Surveys (CSUR), 34(2):211–262, 2002.

[54] Joshua Podolak, Philip Shilane, Aleksey Golovinskiy, Szymon Rusinkiewicz, and Thomas Funkhouser. A planar-reflective symmetry transform for 3d shapes. In ACM Transactions on Graphics (TOG), volume 25, pages 549–559. ACM, 2006.

[55] Roni Raab, Craig Gotsman, and Alla Sheffer. Virtual woodwork: Making toys from geometric models. International Journal of Shape Modeling, 10(01):1–29, 2004.

[56] Pedro V Sander, John Snyder, Steven J Gortler, and Hugues Hoppe. Texture mapping progressive meshes. In Proceedings

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 8, February 2017

of the 28th annual conference on Computer graphics and interactive techniques, pages 409–416. ACM, 2001.

[57] Pedro V Sander, Zoë J Wood, Steven J Gortler, and H Hoppe. Multi-chart geometry images. In Symposium on Geometry Processing Proceedings: Aachen, Germany, 2003.

[58] Mirko Sattler, Ralf Sarlette, and Reinhard Klein. Simple and efficient compression of animation sequences. In Proceedings of the 2005 ACM SIGGRAPH/Euro graphics symposium on Computer animation, pages 209–217. ACM, 2005.

[59] Jami J Shah, David Anderson, Yong Se Kim, and Sanjay Joshi. A discourse on geometric feature recognition from cad models. Journal of Computing and Information Science in Engineering, 1(1):41–51, 2001.

[60] Ariel Shamir. A formulation of boundary mesh segmentation. In 3DPVT, volume 4, pages 82–89, 2004.

[61] Ariel Shamir. A survey on mesh segmentation techniques. Computer graphics forum, 27(6):1539–1556, 2008.

[62] Cohen D. Shapira L., Shamir A. Consistent partitioning of meshes. Technical report, The interdisciplinary Center, 2005.

[63] Alla Sheffer. Model simplification for meshing using face clustering. Computer-Aided Design, 33(13):925–934, 2001.

[64] Shymon Shlafman, Ayellet Tal, and Sagi Katz. Metamorphosis of polyhedral surfaces using decomposition. In Computer Graphics Forum, volume 21, pages 219–228. Wiley Online Library, 2002.

[65] Olga Sorkine, Daniel Cohen-Or, Rony Goldenthal, and Dani Lischinski.Bounded-distortion piecewise mesh parameterization. In Proceedings of the conference on Visualization'02, pages 355–362. IEEE Computer Society, 2002.

[66] Yiyong Sun, David Lon Page, Joon Ki Paik, Andreas Koschan,and Mongi A Abidi. Triangle mesh-based edge detection and its application to surface segmentation and adaptive surface smoothing. In Image Processing. 2002. Proceedings. 2002 International Conference on, volume 3, pages 825–828. IEEE, 2002.

[67] Tamas Varady, Ralph R Martin, and Jordan Cox. Reverse engineering of geometric models an introduction. Computer-Aided Design, 29(4):255–268, 1997.

[68] Fu-Che Wu, Wan-Chun Ma, Rung-Huei Liang, Bing-Yu Chen, and Ming Ouhyoung. Domain connected graph: the skeleton of a closed 3d shape for animation. The Visual Computer, 22(2):117–135, 2006.

[69] Jianhua Wu Leif Kobbelt. Structure recovery via hybrid variational surface approximation. In Computer Graphics Forum, volume 24, pages 277–284. Wiley Online Library, 2005.

[70] Eugene Zhang, Konstantin Mischaikow, and Greg Turk. Feature-based surface parameterization and texture mapping. ACM Transactions on Graphics (TOG), 24(1):1–27, 2005.

[71] Jieyi Zhao, Min Tang, and Ruofeng Tong. Mesh segmentation for parallel decompression on gpu. In Computational Visual Media, pages 83–90. Springer, 2012.

[72] Kun Zhou, John Synder, Baining Guo, and Heung-Yeung Shum. Isocharts: stretch-driven mesh parameterization using spectral analysis. In Proceedings of the 2004 Euro graphics/ACM SIGGRAPH symposium on Geometry processing, pages 45–54. ACM, 2004.

[73] Yinan Zhou and Zhiyong Huang. Decomposing polygon meshes by means of critical points. In Multimedia Modelling Conference, 2004. Proceedings. 10th International, pages 187–195. IEEE, 2004.

[74] Malte Zöckler, Detlev Stalling, and Hans-Christian Hege. Fast and intuitive generation of geometric shape transitions. The Visual Computer, 16(5):241–253, 2000.

[75] Emanoil Zuckerberger, Ayellet Tal, and Shymon Shlafman. Polyhedral surface decomposition with applications. Computers & Graphics, 26(5):733–743, 2002.