Critique for CS448B: Geometric Modeling

# Progressive Simplicial Complexes

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## 1. Citation for Paper

*Progressive Simplicial Complexes*, Joan Popovic, Hugues Hoppe. **Proc. Siggraph 1997**, pp. 217-224.

## 2. Synopsis

This paper details a proposed format, referred to as "Progressive Simplicial Complexes (PSC)," for storing and transmitting triangulated geometric models. The idea behind the PSC format is to provide a unified approach to mesh simplification and mesh compression. Mesh simplification and compression accelerates graphical rendering, decreases the required storage, and reduces the transmission costs of geometric models. In addition, this representation allows for the smooth transition (geomorphs) of different level-of-detail (LOD) models. A method to construct PSC models using only the generalized vertex unification and the generalized vertex split is also given.

## 3. Summary

### 3.1 Problem Statement

**Input:** A highly complex triangulated model given as a tuple (K, V, D, A) where:

K = abstract simplicial complex
V = set of vertex positions in $R^3$
D = discrete attributes which associate a material identifier $d_s$ with each simplex $s \in P(K)$ [principal simplices of K].
A = set of areas $a_s \in A$ associated with each simplex $s \in P_{01}(K)$ [principal simplices of dimension 0 and 1].

**Output:** A sequence of approximations starting from a model with a single vertex ($M^1$) to the original triangulated model ($M^n$). There exists a total of $n$-1 approximations to $M^n$, where each representation $M^i$ ($1 \leq i \leq n$) has exactly $i$ vertices. All of the approximations are related by the generalized vertex unification ($M^i \leftarrow M^{i+1}$) and its inverse the generalized vertex split ($M^i \rightarrow M^{i+1}$).

## 3.2 Contributions

The major contribution of this paper is the "Progressive Simplicial Complexes" format for representing triangulated geometric models. The representation starts with a simple base mesh $M^1$ and through *n*-1 generalized vertex splits can recover the original model $M^n$. In addition, the representation of principal vertices as spheres and principal lines as cylinders gives a better representation of the geometry at extremely coarse resolutions. To some extent, the work in this paper is a generalization of the second authors previous work on "Progressive Meshes (PM)." In contrast to PM, PSC allows for changes in the topologic type of the underlying abstract simplicial complex K. The key benefit of this is that every triangulated model can be reduced to a base mesh $M^1$ which consists of only a single vertex.

## 4.0 **Comments**

The paper does a good job of describing in detail the proposed PSC representation. Initially, the groundwork is laid defining the relevant terminology and concepts from algebraic topology. The idea of the PSC representation is to generalize the PM representation. Specifically, the PM can only be used to represent meshes (triangulations that correspond to orientable 2-dimensional manifolds) and requires all of the approximations to be of the same topologic type. The PSC improves on both of these shortcomings. There are four key properties discussed in the paper with regard to mesh compression and mesh simplification:

1. Levels-of-detail. For rendering, when an object approaches the viewer more detailed is desired. When the object recedes from the field of view, usually less detail is acceptable. The PSC representation is useful since it provides a total of *n*-1 different approximations to a triangulated geometric model.
2. Geomorphs. Smooth transitions between different LOD are possible using PSC since there exists a correspondence between the vertices of the approximating models.
3. Progressive transmission. Since the base approximation ($M^1$) always consists of a single vertex, it can be sent as a fixed-size record. The detail of the model can then be improved by sending a stream of the generalized vertex splits.
4. Model compression. The PSC format lends itself to a compact representation, and the storage requirements can be further reduced by arithmetic coding.

The paper describes a scheme for iteratively constructing PSC representations. The proposed method is "time-intensive" since the goal was to produce high quality approximations. In fact, this is an issue of critical importance since fast methods (such as randomly selecting the vertices to collapse) can lead to rather poor approximations. Since considering all possible pairs of vertices would be prohibitively large, only a smaller subset is considered.  Specifically, they include the original 1-simplices of K and a subset of 1-simplices of a delaunay triangulation of the vertices of $M^n$.  The problem of choosing the candidate vertices to collapse is then cast as a problem of minimizing an energy function. That is, the pair that can be collapsed for the least $\Delta E$ is unified and so on until there is only one remaining vertex in the model ($M^1$).

Not being personally familiar with the area of mesh simplification, one of the best parts of the paper was the discussion on related work.  With a total of 30 references, and an overview discussion of the significant alternative methods, this paper can easily be the springboard to understanding the area of mesh simplification and mesh compression.

## 5.  Discussion Questions

The proposed method for creating the PSC representation is extremely time-intensive.  Does the assumption that the approximations can be calculated offline cover the most widely used applications for mesh reduction?  Would it be useful to have a faster algorithm which creates representations with less accuracy?

Does the mathematical nature of the paper (e.g. algebraic topology) facilitate the explanation of key ideas?

What are the advantages and disadvantages of unifying mesh simplification and mesh reduction?