Approximate Convex Decomposition of Polyhedra

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1 Introduction

Decomposition is a technique commonly used to break complex models into sub-models that are easier to handle. Convex decomposition, which partitions the model into convex components, is interesting because many algorithms perform more efficiently on convex objects than on non-convex objects. One issue with convex decompositions, however, is that they can be costly to construct and can result in representations with an unmanageable number of components. In many applications, feature details are not crucial and in fact considering them could obscure important structural information and add to the processing cost. In such cases, an approximate representation of the model that captures the key structural features would be preferable.

Motivated by such issues, we propose a partitioning strategy that decomposes a given model into *"approximately convex"* pieces. We propose a simple algorithm that computes an *approximate convex decomposition* (ACD) of a polygon or a 3D polyhedron. It proceeds by removing (*resolving*) the non-convex features in order of importance. Due to the recursive application, the resulting decomposition is an elegant hierarchical representation, similar to that in [Katz and Tal 2003]. We have implemented our general approach for computing ACDs for polygons in the plane [Lien and Amato 2004] and for polyhedra in three dimensions [Lien and Amato 2003]. In the following, we briefly describe our approach and then present some experimental results. Please see the above cited papers for more details.

2 Our Approach

Our approach is based on the premise that for some applications, some of the non-convex (concave) features can be considered *less significant*, and allowed to remain in the final decomposition, while others are more important, and must be removed (resolved). Our goal is to generate τ*-approximate* convex decompositions, where each component in the decomposition has concavity less than a tunable parameter τ.

The success of our approach depends critically on the quality of the methods we use to measure and then prioritize the importance of the non-convex features. The concavity measures we consider for computing ACDs identify features using global properties of the boundary. In particular, we define the *concavity of a point* x on P as the distance from x to H, the convex hull of P. Then, the *concavity of* P is defined as the maximum concavity of its vertices. For polygons, a notch (concave feature) x is enclosed by exactly one line segment β of the convex hull H and we measure the concavity by computing the distance from x to β. For polyhedra, a notch x may be enclosed by more than one facet of the convex hull of P. To determine which hull facet is associated with x, we project the hull facets onto P and find the facet $\mathcal{F}$ that covers x. As with polygons, concavity is measured as the distance from x to $\mathcal{F}$. Then, the model is decomposed if its concavity exceeds the threshold τ. A polyhedron can be decomposed into *solid* components by iteratively bisecting it at the most concave notch, or into approximately convex *surface patches* by cutting it along "concave" paths on the model's surface.

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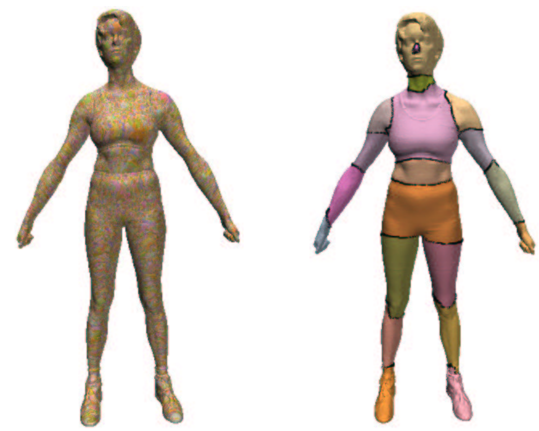

Figure 1: This model has 141,837 notches. Left: Exact convex surface decomposition – 44,461 components. Right: Approximate convex surface decomposition – 20 components (concavity < 0.05).

3 Summary

In summary, if an application can tolerate some concavities in the resulting model, then the decompositions produced by our approach should be useful because they can contain fewer components than an exact convex decomposition in significantly less time. Figure 1 shows the difference between exact and approximate convex *surface* decomposition [Chazelle et al. 1995]. The approximate convex decompositions produced by our algorithms can be used in applications in areas such as collision detection, skeletonization, model simplification, shape identification, and rendering.

References

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