CSCE 681 600: SEMINAR REPORT 3

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2nd February 2022

Paper Citation: Jyh-Ming Lien, John Keyser, and Nancy M. Amato. 2006. Simultaneous shape decomposition and skeletonization. In Proceedings of the 2006 ACM symposium on Solid and physical modeling (SPM '06). Association for Computing Machinery, New York, NY, USA, June 2006, Pages 219–228. DOI:https://doi.org/10.1145/1128888.1128919

1. SUMMARY:

a. Problem Statement:

The work in this paper is based on shape decomposition and skeletonization. The process of visually dividing a model into different meaningful components is called shape decomposition whereas the process of representing the shape of an object using an object of lower dimension is known as skeletonization. The authors have presented a novel iterative approach that can perform both the tasks of generating hierarchical shape decomposition and generating skeletons of multiple resolutions simultaneously. Their main motivation behind this work lies in their assumption that there are several common properties and applications between skeletonization and shape decomposition although they are considered as independent computations in general. In their proposed method, the authors are extracting the skeleton of the model from its decomposition components. In this way, interdependency between both the processes and the quality of their results is acknowledged. Until the quality of the extracted skeleton has not met some user-defined criteria, the process of simultaneous shape decomposition and skeletonization is iteratively repeated in this proposed method.

b. Proposed solution:

For the problem statement, the authors had proposed the algorithm named SSS (Simultaneous Shape decomposition and Skeleton extraction). The algorithm constructs the entire model of the skeleton from the local extracted skeletons of each of the decomposition parts of the model. The algorithm performs an evaluation of the local skeleton components and continues the refinement of the decomposition of the model and the local skeleton extracted from it until the local skeleton has an acceptable quality. As an example, the authors had mentioned a threshold 'tau' which is tunable and is used to measure the quality of the extracted skeletons. If the error estimate of the local skeleton of a decomposition component is less than 'tau' then it has an acceptable quality. Their algorithm has three important parts: (1) skeleton extraction from a particular component of the model, (2) quality evaluation of the local extracted skeleton, and (3) decomposition of this component into further smaller components if the local skeleton doesn't meet the quality criteria.

For the first part of the algorithm, the authors have defined 2 different processes for local skeleton extraction. These local skeletons can be joined together to form the global skeleton. First, the authors have presented the centroid method where the skeleton of a component is generated by connecting the centroids of the openings (when a component is divided into smaller components during the decomposition process, openings are generated) to the centroid of the component. The centroid method however cannot represent all types of shapes. Second, the authors have presented a method that uses the principal axis of a component. In this method, the skeleton is generated by connecting the centroids of the openings of the component and centroid of the component to the principal axis of the component which is enclosed in the convex hull of the component. This is a more computationally expensive process.

For the second part of the algorithm, the authors have described three methods for measuring the extracted local skeleton quality: (1) the first method checks penetration of the skeleton, that is whether the skeleton intersects with the boundary of the respective component. This returns zero if there is no intersection, otherwise returns a large number (2) the second method checks the centeredness of the skeleton by calculating the skeleton offsets from level sets of distance map on the component boundary. (3) the third method measures the convexity which is defined as the volume of the component divided by the volume of the convex hull of the component, which is then used to compute the error. The error is given as the convexity subtracted from 1.

For the third part of the algorithm, the authors have used Approximate Convex Decomposition (ACD). ACD decomposes a component into further smaller components by cutting this given component along its features which are most concave. The union of the decomposed smaller components gives the larger component and all the smaller components are disjoint to each other. This decomposition is done when the quality of the local extracted skeleton does not meet the required criteria.

c. Results:

The authors have done several experiments to exhibit the robustness and efficiency of their SSS method. From their experiments on several kinds of models, they concluded that their method works very well for models with a huge number of triangles and takes very little time (less than thirty seconds for thousands of triangles) to handle them. To further demonstrate the efficiency of their method, the authors compared their outputs with two other recent and efficient methods for this process. They found that their SSS method produces almost similar outputs with the other two methods, but SSS produces the outputs a lot faster than those other methods.

The authors have also demonstrated the robustness of their method by demonstrating through their experiments that the output skeleton and shape decomposition remain almost invariant even when the input model is deformed or perturbed. To measure the skeleton similarity, the authors used a method known as graph edit distance. This method returns the computation cost required in order for conversion between two graphs.

The authors in their experiments have also shown that their method can be used readily for animation generation and motion planning.

2. CRITIQUE:

a. Pros:

i. The authors have provided a novel approach to tackle the task of both shape decomposition and skeletonization together which will save a lot of computation power.

ii. The authors have also shown that their method is robust and efficient even when deformed or perturbed.

iii. The method proposed by the authors can be used for both polygons (2D) and polyhedra (3D).
iv. Their generated skeleton does not vary when rotated, translated, or scaled and its sensitivity to boundary noise is also low
v. Since the authors are applying their refinement method on regions of the model which are more complex and not on areas that have less variation, their divide and conquer algorithms for shape decomposition and skeletonization can have more efficiency.
vi. Compared to other processes, the method proposed by the authors does not require pre-processing (such as model simplification) and post-processing (such as skeleton pruning) techniques.
vii. Their method generates skeletons of multiple resolutions which have detail levels varying from coarse to fine. These skeletons can be used for different applications.

b. Cons:

i. It is quite possible that their method might not work for all 2D and 3D models i.e., the divided components of a model may not necessarily lead to the proper skeleton of the model
ii. The quality of the skeleton depends on the threshold value 'tau' which is tuned manually. A large value of 'tau' will provide bad results whereas a smaller value would require greater computation time and power. Careful consideration of the value of 'tau' is required.
iii. The two processes used to extract local skeletons from the components of a model have their own disadvantages. The method using centroids does not work for all shapes and the method using the principal axis is computationally expensive.
iv. The Approximate Convex Decomposition method might not always yield the best results for decomposition.
v. It is not always required to get the shape decomposition and skeleton of the model together. In such cases, either the shape decomposition or the skeletonization is an extra computation cost in this method that can be reduced by using other methods where both are not computed together.
vi. It is not possible to obtain 1D skeletons for all kinds of models.

3. FOLLOW UP:

i. Instead of Approximate Convex Decomposition, Deep neural networks can be trained and used for the decomposition process.
ii. Similarly, for the local skeleton extraction process, Convolutional Neural Networks can be trained to approximate the skeleton for a given component. Such a method to approximate would be much more efficient.
iii. Research can be done in establishing more efficient methods of quality evaluation of the extracted skeletons and shape decomposition. This would eventually result in a further increase in the quality of the outputs.
iv. The proposed method produces the outputs based on a general idea, however new methods can be implemented which generate the outputs based on certain specific requirements and applications.
v. This research can also be used in the rendering of real-time video game model movements and simulations.