A Novel and Efficient Method of Persistent Homology to Detect and Remove Topological Errors in Triangle Mesh Data

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Motivation: Many applications in the medical and engineering fields benefit from identifying topological features in a three-dimensional geometric model. Problem statement: When an object’s geometry is reconstructed from a 3D scan, such as from MRI, topological defects like handles or tunnels often appear in the model. Detecting and removing these errors is crucial for improving the accuracy of the model. Approach: A novel method of persistent homology is proposed to compute the topological features of the triangle mesh. A curve-tightening algorithm is developed to ensure that the features are geometrically useful. Finally, topological surgery is performed on the detected characteristics to validate the method. Results: Experimental results on six different models, including two brain hemispheres reconstructed from MRI scans, demonstrate the efficiency and accuracy of the proposed method. My algorithm correctly detected and removed 100% of the topological features in all six models. The algorithm reduces the spacial and time complexities for topological correction, outperforming the state of the art for MRI topological denoising (Freesurfer 23 minutes vs mine 4 minutes). The method is also more efficient and more accurate than all known methods for computing topological features, to the best of my knowledge. Conclusions: Reliable, accurate, and efficient topology correction is useful in many applications, especially in medical imaging. My algorithm is a novel application of the concepts from topological persistence recently introduced in computational topology. It is significantly better than current methods of persistent homology, curve-tightening, and topological surgery.

Awards Won:

First Award of $5,000

Mu Alpha Theta, National High School and Two-Year College Mathematics Honor Society: First Award of $ 1,500

American Mathematical Society: Third Award of $500