Stony Brook University  
The Graduate School  

Doctoral Defense Announcement  

Abstract  
Shape-Based Analysis  

By  
Krishna Chaitanya Gurijala

Shape analysis plays a critical role in many fields, especially in medical analysis. There has been substantial research performed for shape analysis in manifolds. On the contrary, shape-based analysis has not received much attention for volumetric data. It is not feasible to directly extend the successful manifold shape analysis methods, such as the heat diffusion, to volumes due to the huge computational cost. The work presented herein seeks to address this problem by presenting two approaches for shape analysis in volumes that not only capture the shape information efficiently but also reduce the computational time drastically.

The first approach is a cumulative approach and is called the Cumulative Heat Diffusion, where the heat diffusion is carried out by simultaneously considering all the voxels as sources. The cumulative heat diffusion is monitored by a novel operator called the Volume Gradient Operator, which is a combination of the well-known Laplace-Beltrami operator and a data-driven operator. The cumulative heat diffusion is computed by considering all the voxels and hence is inherently dependent on the resolution of the data. Therefore, we propose a second approach which is a stochastic approach for shape analysis. In this approach the diffusion process is carried out by using tiny massless particles termed shapetons. The shapetons are diffused in a Monte Carlo fashion across the voxels for pre-defined distance (serves as single time step) to obtain the shape information. The direction of propagation for the shapetons is monitored by the volume gradient operator. The shapeton diffusion is a novel diffusion approach and is independent of the resolution of the data. These approaches robustly extract features, objects based on shape.

Both shape analysis approaches are used in several medical applications such as segmentation, feature extraction, registration, transfer function design and tumor detection. This work majorly focuses on the diagnosis of colon cancer. Colorectal cancer is the second leading cause of cancer related mortality in the United States. Virtual colonoscopy is a viable non-invasive screening method, whereby a radiologist can explore a colon surface to locate and remove the precancerous polyps (protrusions/bumps on the colon wall). To facilitate an efficient colon exploration, a robust and shape-preserving colon flattening algorithm is presented using the heat diffusion metric which is
Insensitive to topological noise. The flattened colon surface provides effective colon exploration, navigation, polyp visualization, detection, and verification. In addition, the flattened colon surface is used to consistently register the supine and prone colon surfaces. Anatomical landmarks such as the taeniae coli, flexures and the surface feature points are used in the colon registration pipeline and this work presents techniques using heat diffusion to automatically identify them.

Shape analysis in graphs is vital to represent and visualize relationships between data items. Graph embedding methods play an important role in visualizing the data items and their relationships by providing an automatic and clutter free layout. A novel graph embedding approach is presented that will compute the global characteristics of a graph, such as hyperbolic or parabolic type, and also the Ricci curvature in the local neighborhood, which can analyze the structure of the graph. The method has three stages. In the first stage, the graph is embedded on a topological surface. In the second stage, it is embedded on a Riemann surface by computing the Ricci flow and finally in the third stage, it is embedded onto a surface in three dimensional Euclidean space. The approach is general, practical, and theoretically rigorous.

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<td>Dissertation Advisor:</td>
<td>Dr. Arie Kaufman</td>
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<tr>
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