Enhanced CT Analysis Using Volume Flattening

C.S. Parker[1], W.B. Seales[1]

[1]University of Kentucky, 329 Rose Street, Lexington, KY, 40506

Aims

Systematic analysis of complex CT scan data can be very difficult. Volumetric rendering is effective, but analysis is viewpoint dependent and locating features of interest in 3D can be difficult. In such circumstances, a simplification of the dataset into a flattened representation can help drive analysis. We present a technique for volumetric flattening and resampling as part of our Virtual Unwrapping pipeline and discuss how this technique can be used in areas other than document preservation.

Method

The Virtual Unwrapping pipeline is a volumetric analysis pipeline built to non-invasively open and read damaged textual documents. Through the steps of Segmentation, Flattening, and Texturing, this pipeline is able to take CT scans of highly damaged and distorted documents and produce readable images suitable for textual scholarship. Our volumetric flattening and resampling technique makes use of the first two stages of this pipeline, but replaces the Texturing phase with a Resampling phase.

In the Segmentation phase, we generate a representation of the document's surface as a triangular mesh. In the Flattening stage, this mesh is flattened using a choice of geometric parameterization (aka flattening) algorithms, producing a new 2D mesh. In the Resampling phase, we warp the original CT volume into a new, flattened representation by mapping volume coordinates through the transformation generated by flattening. This resampled volume can then be used for analysis that otherwise would be impossible.

Results

We applied this technique to a CT scan of a papyrus scroll constructed for document imaging experiments (Fig. 1). The papyrus needed to be curved to fit into our scanner, but we wanted to analyze the writing on its surface using volume rendering. The induced curvature made analysis using the original CT data difficult.

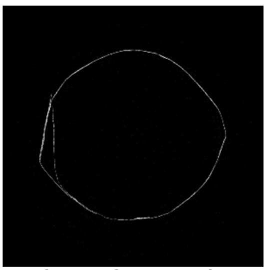

Figure 1: Slice from a CT scan of a papyrus scroll

The resulting resampled volume (Fig. 2) shows some artifacts at the edges of the volume, but these are mostly due to errors in the construction of the original 3D mesh. A "face-on" reslice of the flattened volume (Fig. 3) demonstrates the clarity of the resampled volume.

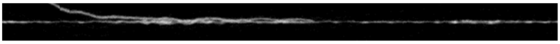

Figure 2: Flattened, resampled version of the papyrus scroll scan data (cropped for scale)

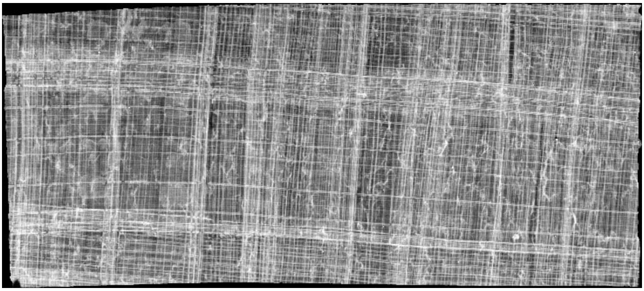

Figure 3: “Face-on” reslice of the resampled, flattened volume

We also analyzed how the choice of flattening algorithm affected the quality of the Texturing and Resampling phases of our pipeline using data from a previously analyzed scroll, the En-Gedi Scroll. Not all surfaces can be mapped to a 2D plane without introducing some sort of distortion, and different algorithms minimize different types of distortions. While the effects of these distortions are often small, our results show that care must be taken in selecting a flattening algorithm suited to the surface being analyzed (Fig. 4).

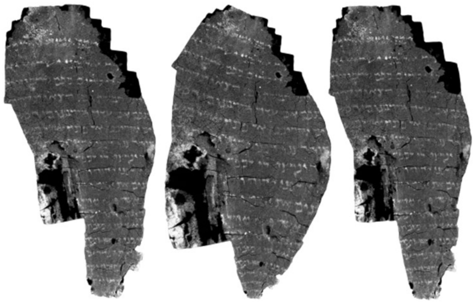

Figure 4: A surface from the En-Gedi scroll, flattened using different methods: Angle-based Flattening (left), Least Squares Conformal Maps (middle), and Cloth Modeling (right). Note the extreme distortion introduced by Least Squares Conformal Maps.

Conclusion

Our volume resampling technique is simple and provides a useful tool for analyzing objects with complex surfaces. While we here applied the technique to documents, it is a small leap to consider how it might be adapted to other fields. In the textile industry, this technique could be used for CT analysis of fabric fiber structures. In medicine, CT scans of arterial walls could be flattened in order to detect problems in the circulatory system. Further work is required to develop systems tailored to the unique needs of industries, but we believe that volumetric flattening and resampling is a tool worth exploring.