Using TubeTK to Automatically Merge Volumes

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Abstract

This article describes implementation of a CLI module to merge an image into the space of another adjacent image using the Insight Toolkit. The algorithm constructs a smoothly stitched image out of two or more smaller images. The overlapping regions of the images are used to align the images. The registration method is derived from ITK's Registration framework. The algorithm works with 2D and 3D images.

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1 Introduction

TubeTK's MergeAdjacentImages is an image stitching algorithm based on the ITK's registration framework. The technique combines mutual information metrics with euclidean distance mappings to minimize boundary artifacts and achieve smooth transitions between overlapping images.

The motivation for this technique is the frequent need to generate a holistic, high-resolution visualization of a specimen that is larger than the field-of-view of the imaging modality being used. In microscopy, a common solution to this problem is to mount the specimen on a motorized stage and to acquire tiled images of the smaller subvolumes. Often the accuracy provided by the motorized stage and the luminosity uniformity across the field of view are sufficient for composing a larger image without the need for image processing. However, even with stages for some applications, sub-image registration may be needed and luminosity variations may need to be considered to achieve an accurate recomposition. Additionally, in other commonly used modalities, such as 3D ultrasound, the use of motorized stages is challenging or impossible, and the registration of a sequence of adjacent scans from those systems will involve various amounts of rotation and translation.

2 The Implementation

The algorithm has two distinct parts: registration of the second image into the space of the first, and blending the two images.

2.1 Registration

The registration is aided by the user, who provides the registration algorithm with a maximum expected initial misregistration, in terms of rotation and offset. These parameters, along with the moving and fixed images, are passed to a registration framework, developed for Slicer, which will look for an optimized rigid transformation between the two images, using their overlapping regions.

2.2 Blending

Once registered, the intensities in the overlapping regions will need to be smoothly blended, as a function of their distance from the edges of the overlapping regions, to remove visible ”seams” due to exposure differences.

The blending uses the distance from region edges as well as distance from the image edges, as follows. ITK provides an N-dimensional distance transform that computes a Voronoi map and a vector distance map as well, using the implementation from the seminal paper by Danielsson [1]. That filter is used to compute the distance to the nearest overlapping region edge. The distance to the nearest edge of the final output image is also computed. For each overlapped set of voxels, a ratio of those distances is calculated for blending.

The overlap distance and output distance are represented by the variables *vDist* and *oDist* respectively. The *iVal* voxel is set from the output of the registration operation, after the resampling into the new image space. The *oVal* voxel is set from the original fixed image, before any resampling. For each voxel, the following ratio is computed:

$$r(vDist, oDist) = \frac{|vDist|}{2(|vDist| + oDist)} + \frac{1}{2} \tag{1}$$

At this point, if the overlap distance is positive, the output voxel value is computed as:

$$finalVal = r(vDist, oDist)iVal + (1 - r(vDist, oDist))oVal \tag{2}$$

If the overlap distance is negative, the *iVal* and *oVal* are switched:

$$finalVal = r(vDist, oDist)oVal + (1 - r(vDist, oDist))iVal \tag{3}$$

Finally, if the voxel lies on one of the edges of the overlap map (meaning the *vDist* is equal to zero, and the distance of this point from the edge of one image is the same as the distance to the edge of the other), the average between the two values is taken:

$$finalVal = \frac{iVal + oVal}{2} \tag{4}$$

The end result is the final intensity of every pixel in the resampled image is influenced more by the image within which it is more fully contained, or from which it lies farther from the edge.

3 Experiments and Results

This application was used in the preprocessing stage of a study on liver biomatrix scaffolds. A method of 3D functional ultrasound imaging was developed at UNC in the labs of Paul Dayton to enable non-destructive assessment of extracellular matrix scaffolds prepared by decellularization protocols, with the intention of recellularization to create hepatic organoid. The challenge of assessing the crucial microvascular structure of the organoids was met with this method of stitching together both acoustic angiography and b-mode scans to create a field of view without interference from slight variability in exposure [2].

For the purposes of comparison, a command line switch is built into the application which disables this blending algorithm, choosing instead to average the intensities of all overlapping pixels.

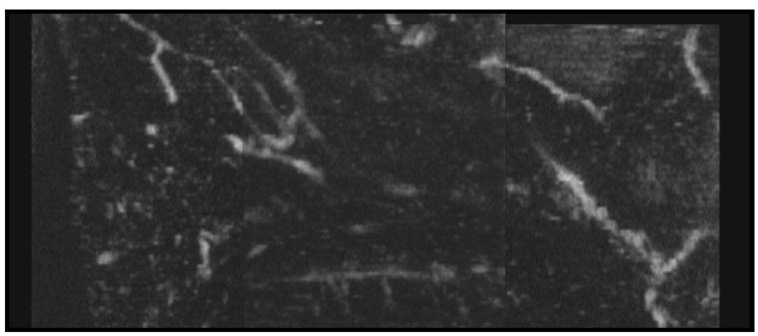

Figure 1: Results of simply averaging intensity values. Notice the "seam" in the upper distal vessel of the liver.

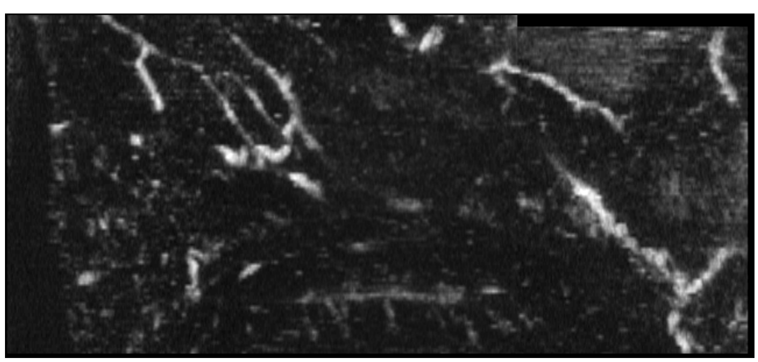

Figure 2: Results of the MergeAdjacentImages application in TubeTK.

Figure 1 can be generated by merging the left and right images with the `--averageOverlap` flag.

Figure 2 can be generated with the same command, omitting the `--averageOverlap` flag.

4 Source Code and Testing

The code for the MergeAdjacentImages application is a part of the TubeTK toolkit, and can be found at https://github.com/TubeTK/TubeTK/tree/master/Applications/MergeAdjacentImages.

Current dashboards can be viewed at http://open.cdash.org/index.php?project=TubeTK.

References

[1] P.E. Danielsson. *Euclidean distance mapping*. Computer Graphics and Image Processing, 14:227-248 1980 2.2

[2] R.C. Gessner, A.D. Hanson, S. Feingold, A.T. Cashion, A. Corcimaru, B.T. Wu, C.R. Mullins, S.R. Aylward, L.M. Reid, P.A. Dayton *Functional ultrasound imaging for assessment of extracellular matrix scaffolds used for liver organoid formation*. Biomaterials, 34.37:9341-9351 2013 http://dx.doi.org/10.1016/j.biomaterials.2013.08.0332 3