Iowa Initiative for Artificial Intelligence

Final Report

Project title:	AI-enhanced microscope imaging of collagen bundles in vascular tissues
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Other investigators:	
Date:	

Were specific aims fulfilled:	Y
Readiness for extramural proposal?	Y
If yes … Planned submission date	6/20/2024
Funding agency	NSF
Grant mechanism	
If no … Why not? What went wrong?	

Brief summary of accomplished results:

LOGISMOS software can segment collagen fiber in 3D using confocal images.

Research report:

Aims (provided by PI):

Initially, the goal was optical quantification by microscope, to obtain statistical features of collagen fibers. This turned out to be challenging. From LOGISMOS's result, it was clear that we need to fall back to the confocal imaging. The proposal ended up relying on confocal images, focusing on mechanical behavior not optical quantification.

Data:

High-resolution imaging modalities such as confocal imaging have been used to image college fibers. The image data saved as .czi files exported by the microscopy devices can be read by various open-source software tools. The 3D image data can be visualized in its 3D context as shown in Fig. 1. It shows that the 3D shape of fiber strands is clearly visible.

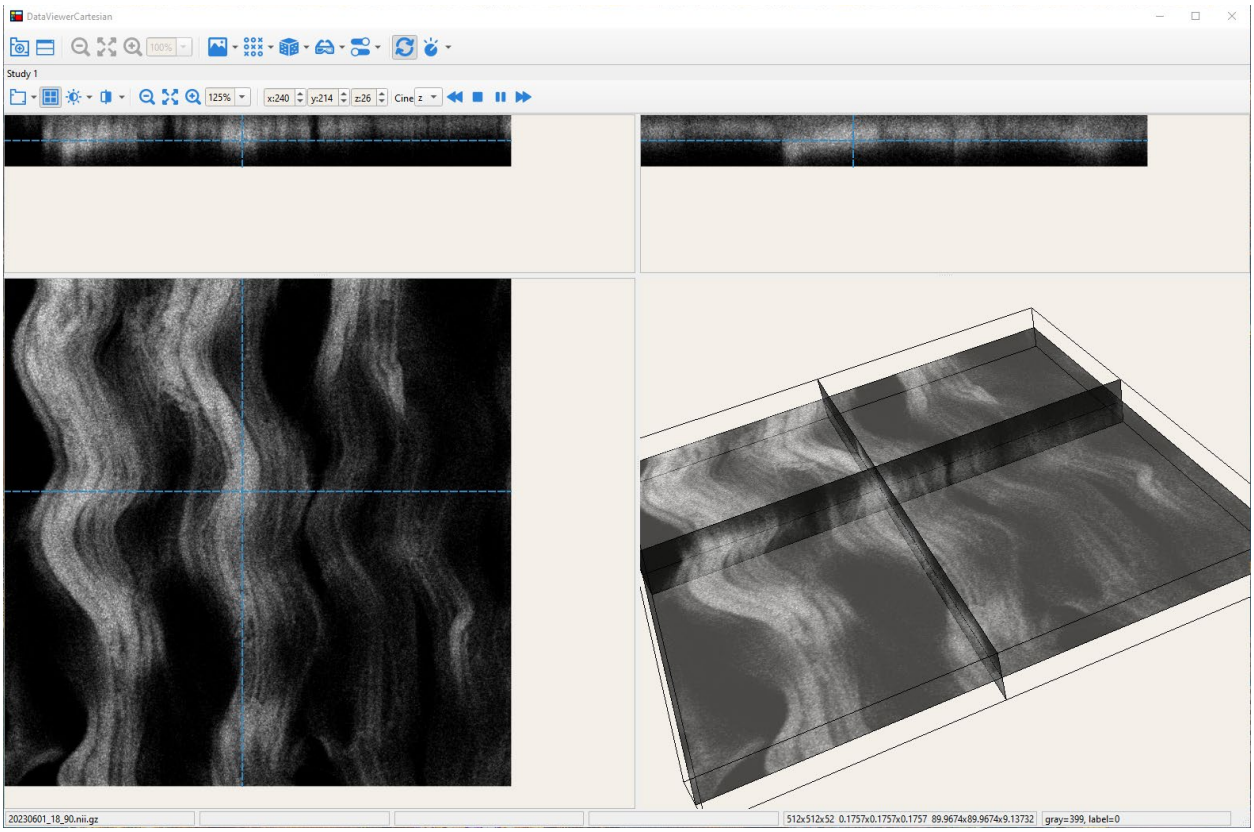


Fig. 1. 3D microscopy image visualized by three orthogonal views in their 3D context.

AI/ML Approach:

Due to lack of confocal images, no machine learning approaches was used.

Experimental methods, validation approach:

Segmentation

Based on the observation that the appearance of fiber strands in microscopy image is very similar to that of blood vessels in CT or MR images, The feasibility of segmenting fiber strands in 3D is demonstrated using an application called LogismosVessels that was originally designed to perform semi-automatic segmentation of blood vessels [1-4]. The first step of fiber strand segmentation is to manually create approximate strand shapes in 3D. As shown in Fig. 2, the user manually defines a set of 3D control points along the centerline of the strand. The complete centerline is then formed from the control points using Cardinal spline. A tubular 3D surface with configurable radius is created and visualized as overlay onto the image. The centerline also enables a cylindrical visualization of the image appearance around the centerline in the bottom row of images in Fig. 2 depicting cross-sectional and longitudinal views. The cylindrical views allow the user to check the quality of the centerline and make necessary adjustments (add, delete, or change locations) to the control points. In the example shown in Fig. 2, multiple centerlines are defined and each of which only requires about 10 control points specified by the user within one minute.

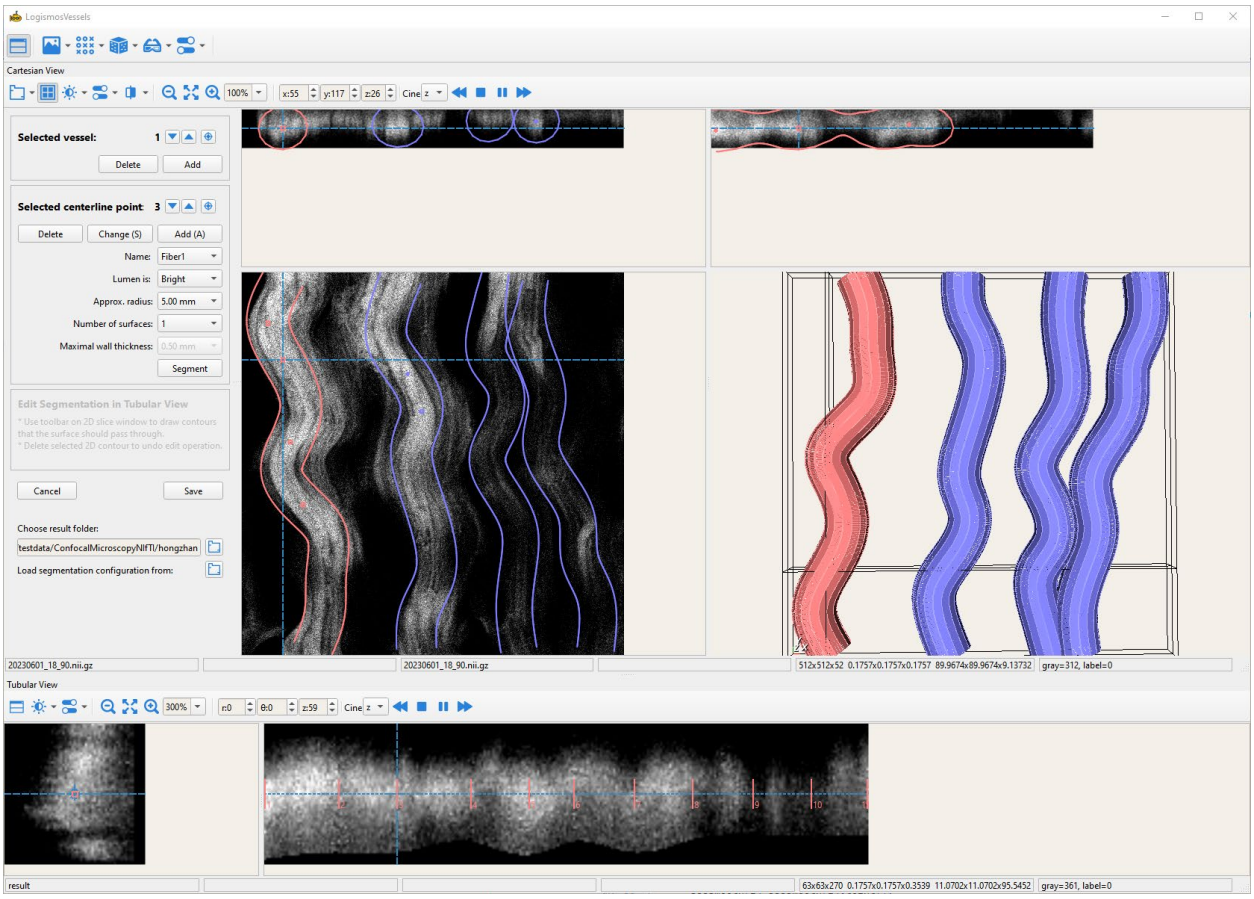


Fig. 2. Initial manual approximation of strand shape.

Once the approximate strand shapes are defined, the strands are automatically segmented by LOGISMOS algorithm that takes about 5 seconds per strand in the example shown in Fig. 3. When the automated results have local errors, the user also has the choice to employ Just-Enough Interaction (JEI) mechanism [5] to correct them intuitively and efficiently in 3D. The starting and ending portions of the red strand surface in Fig. 3 are pink indicating outcome of two JEI operations performed by drawing two 2D contour on longitudinal view of the strand. After the segmentation, the more accurate centerline of the strand can be computed from the result and used to determine the wavelength of the fiber strands.

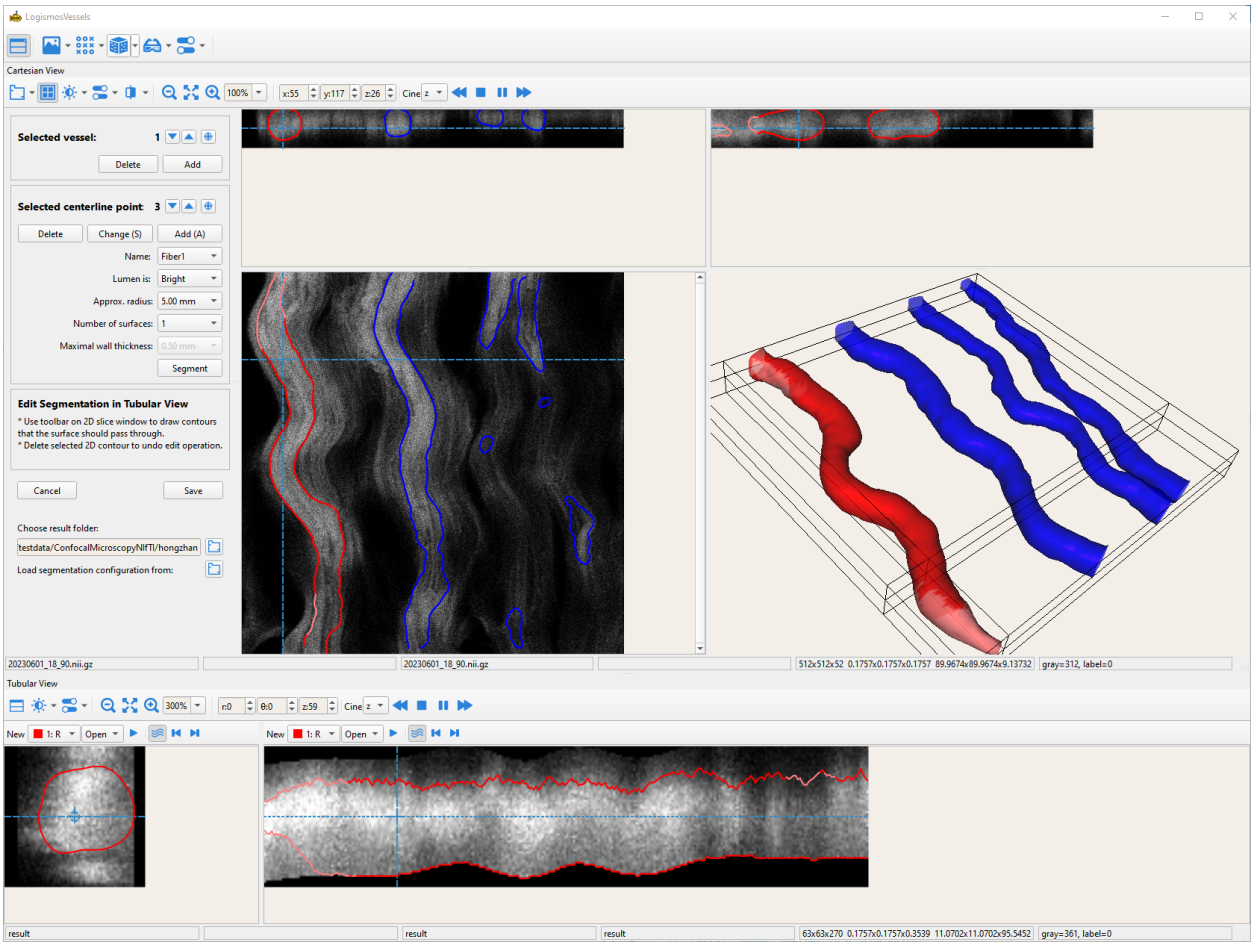
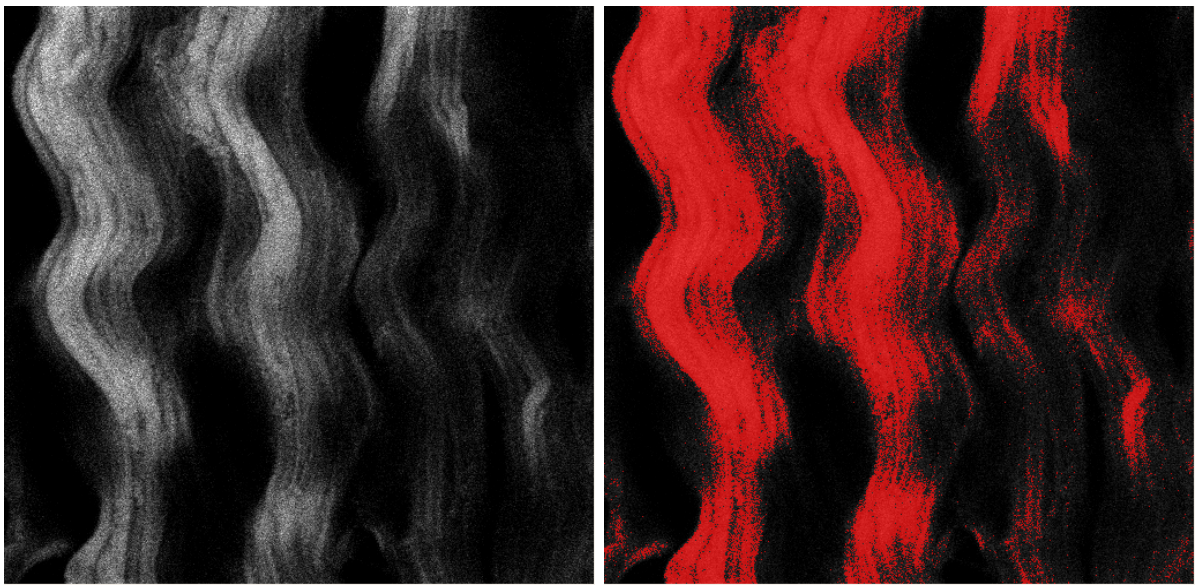


Fig. 3. Segmentation results of fiber strands.

Results:

Fiber Feature Analysis

Simple threshold methods can be applied to estimate total fiber volumes as shown in Fig. 4.



(a) (b)

Fig. 4. Estimate total fiber volume. (a) Microscopy image. (b) Result of Otsu thresholding.

It is also possible to extract various 2D and 3D shape and texture features from the strand segmentation results using PyRadiomics [6].

References

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