Visualizing Blood Flow in Perfusion Angiography

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Abstract

Visualization of blood flow are essential for the diagnosis and treatment evaluation of cerebrovascular diseases. Perfusion angiography is a methodological framework for the quantitative analysis and visualization of blood flow parameters from DSA images [6]. However, animated flow visualization in angiography remains to be an unexplored field. In this literature review, we lay out our proposed method for visualizing blood flow through dynamic vector fields generated from input angiography frames. We also plan to release a web-based application that abstracts the implementation and provides a simplistic interface for researchers to drag and drop angiography files to be visualized.

1 Introduction

The primary contribution of our work include:

1. Learning the vector field of our angiography videos through frame-by-frame *skeletonization* and computing gradients.
2. Applying a JavaScript-based animation rendering that follows the vector field of our angiography blood flow.
3. Perform clustering algorithms to smooth the vector field curves for better animation results
4. Release a web application that allows researchers to upload their angiography videos and see it being animated in real time.

2 Related Works

While dynamic animation of blood flow has not been explored thoroughly, there are several works related to visualizing blood flow. Scalzo and Liebeskind [6] have visualized cerebral blood flow (CBV) in 2D perfusion angiography by learning perfusion parameters from the angiography video (modeled as a mixture of gamma) through EM algorithm. For vesselness extraction, Ding et. al [3] have proposed a machine learning approach to isolating vessel centerlines from cerebral angiograms. For vesselness enhancement, Frangi et. al [4] has produced work related to skeletonization, an effective way of isolating a vessel.

3 State-of-the-Art Implementations

3.1 Learning vector fields

We can learn vector fields by first identifying the direction of flow in the blood vessels via perfusion angiography [6]. Similar methods to enhance angiography include Digital Subtraction Angiography (DSA) [2], but a major drawback for DSA is that it cannot visualize blood flow. Scalzo and Liebeskind showed that we can find the amount of agent, C_u, passing through vessel u via deconvolution: $C_u(t) = C_a(t) \otimes h(t)$.

After some mathematical formulations, we find the relationship to be

$$C_u = \Delta t CBF C_A R$$

Where C_u, $R \in \mathbb{R}^N$, and C_A is expanded into a Toeplitz matrix [1]. Now, we recover R via SVD, and the remaining parameteres (CBF, CBV, MTT, TTP, T_{max}) via obtaining the MLE of the flow intensity modeled as a gamma-mixture distribution.

3.2 Flow animation

We plan on overlaying the angiography video with a vector field visualization written in JavaScript using the library D3.js. While there are static visualizations that show intensity of flow in vessels, we have not seen animated blood flow, similar to that of wind animations in weather apps.

3.3 Clustering smoothing algorithm

K-means clustering is an appropriate unsupervised learning algorithm for reducing anomalies in data by clustering them [5]. In our case, we hope to cluster vectors pointing in a similar direction to remove outliers.

3.4 Web Application

While there are customized software from companies that uses the Software-as-a-Service (SaaS) model to distribute their work for angiography visualization, there have not been any web-based applications that allow for direct drag-and-drop of angiography files to be visualized online in a user-friendly web interface. Our paper analysis and links to resources for this project are on our website: `http://kfrankc.me/cs188`

References

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