Uncertainty Visualization of Stenotic Regions in Vascular Structures

Gordan Ristovski
Jacobs University, Bremen, Germany

Horst K. Hahn
Fraunhofer MEVIS, Bremen, Germany
Jacobs University, Bremen, Germany

Lars Linsen
Jacobs University, Bremen, Germany
Westfälische Wilhelms-Universität Münster, Germany

Abstract
Stenosis refers to the thinning of the inner surface (lumen) of vascular structures. Detecting stenoses and correctly estimating their degree is crucial in clinical settings for proper treatment planning. Such a planning involves a visual assessment, which in case of vascular structures is frequently based on 3D visual representations of the vessels. However, since vessel segmentation is affected by various sources of errors and noise in the imaging and image processing pipeline, it is crucial to capture and visually convey the uncertainty in a 3D visual representation. We propose a novel approach for visualizing the shape deviation of different probability levels in vascular data, where the probability levels are computed from a probabilistic segmentation approach.

Motivation
- Detecting abnormal vessel narrowings (stenoses) is a main aspect of clinical vessel assessment
- Correct assessment of the stenotic severity is of crucial importance for clinical decisions
- Uncertainties in the medical visualization pipeline make correct assessments difficult
  - Noise errors
  - Imaging artefacts
  - Bias fields
  - Segmentation assumptions
  - Visualization interpolations
- ... Report that small changes in the transfer function may lead to different assessments

- Case 1: MR TOF data segmented using modified Fuzzy C-means for a patient with obstructed flow in one vertebral artery
- Case 2: MR TOF data segmented using modified Fuzzy C-means for a patient with obstructed flow in one vertebral artery
- Case 3: CT data classified using Random Forests for a patient with bone obstructing the vertebral artery

Idea
- Probabilistic segmentation of vessel lumen
- Captures the accumulated uncertainties until this pipeline step
- Creates a probability field around the most likely segmentation
- Render a single opaque surface for the most likely case (50% probability)
- Non-obstructive visualization
- Easy detection of stenotic regions
- Intuitive assessment of the stenotic level
- Traverse the probability field around it and convey different information to the surface itself
  - We capture the 25% variability around the 50% surface (in analogy to box plots)

Method 1: Color Coding Distance
- Capture the traversed distance through the probability field
- Color-code the information on the surface

Method 2: Color Coding Shape Difference
- Capture the maximal deviation along the projection path with the propagation direction
- Color-code the information on the surface

Method 3: Texture Mapping Surface Distortion
- Capture the change in the tangential direction
- Apply equidistant texture along the surface parametrization
- Show the texture distortion

Results
- Case 1: MR TOF data segmented using modified Fuzzy C-means for a patient with obstructed flow in one vertebral artery
- Case 2: MR TOF data segmented using modified Fuzzy C-means for a patient with obstructed flow in one vertebral artery
- Case 3: CT data classified using Random Forests for a patient with bone obstructing the vertebral artery

This work is supported by the Deutsche Forschungsgemeinschaft (DFG) under grant LI-19/1.