Uncertainty Visualization of Stenotic Regions in Vascular Structures

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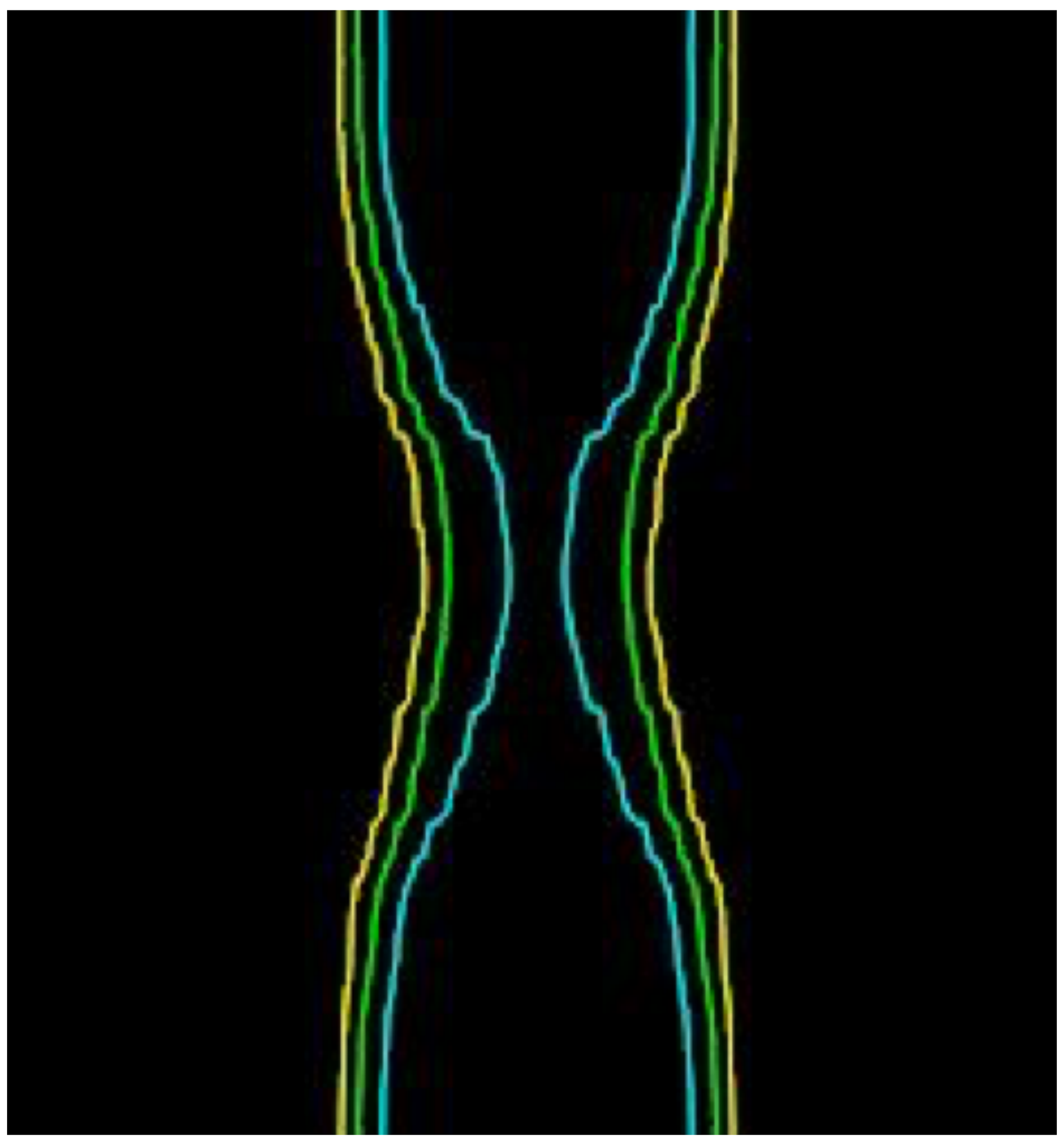
Abstract

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
  - …



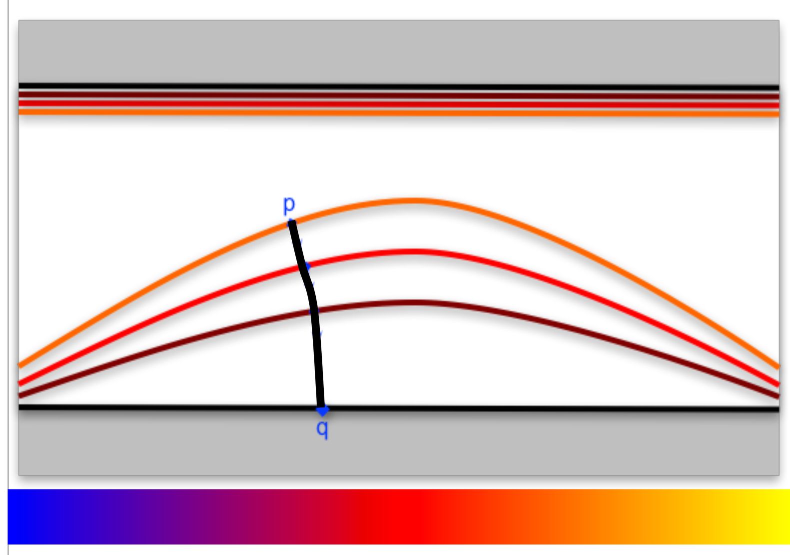
- Reported that small changes in the transfer function may lead to different assessments

Idea

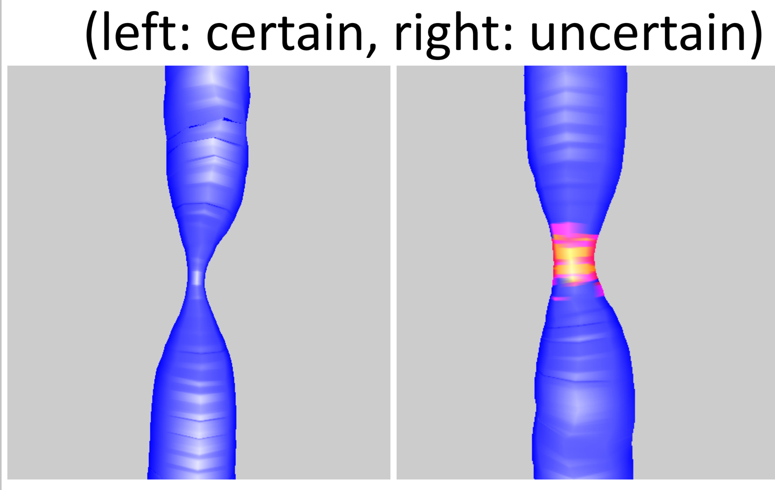
- Probabilistic segmentation of vessel lumen
- Captures the accumulated uncertainties until this pipeline step
- Creates a probability field around the most likely segmentation
- Render a single opaque surface for the most likely case (50% probability)
  - Non-obstructive visualization
  - Easy detection 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

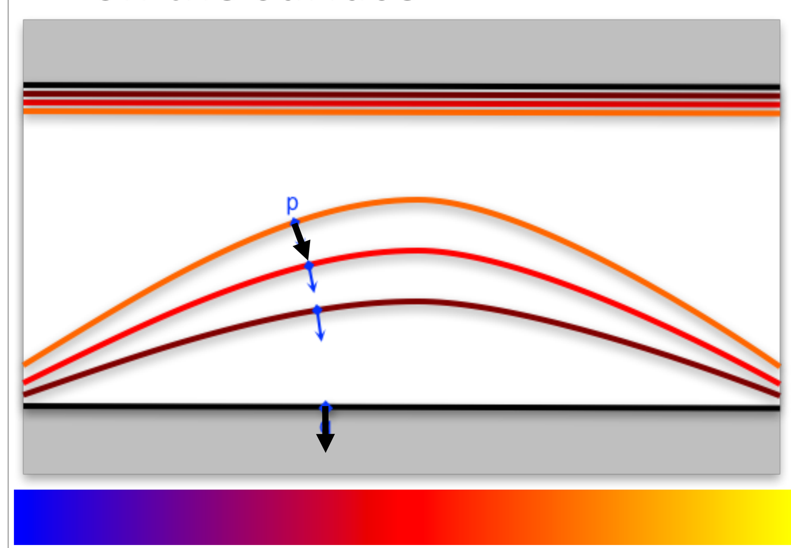


- Results (synthetic) (left: certain, right: uncertain)



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



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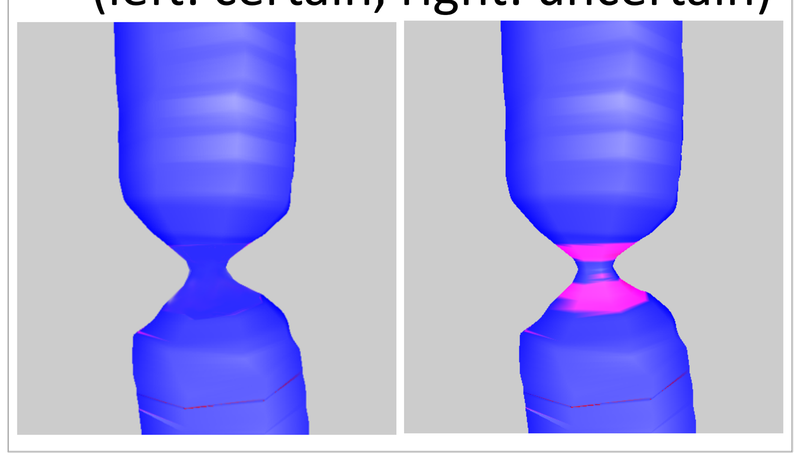
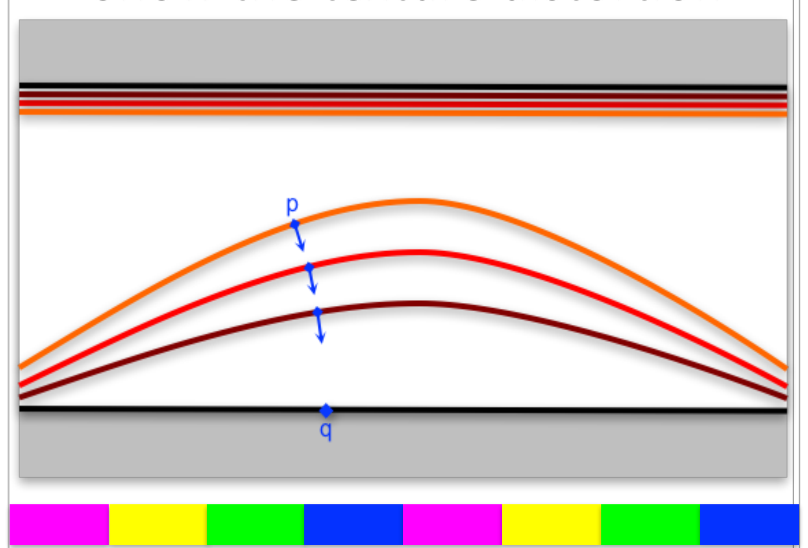
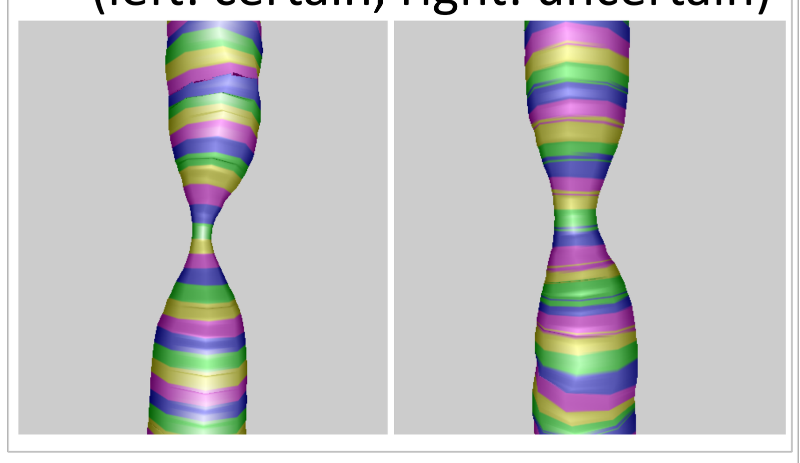


Method 3: Texture Mapping Surface Distortion

- Capture the change in the tangential direction
- Apply equidistant texture along the surface parametrization
- Show the texture distortion

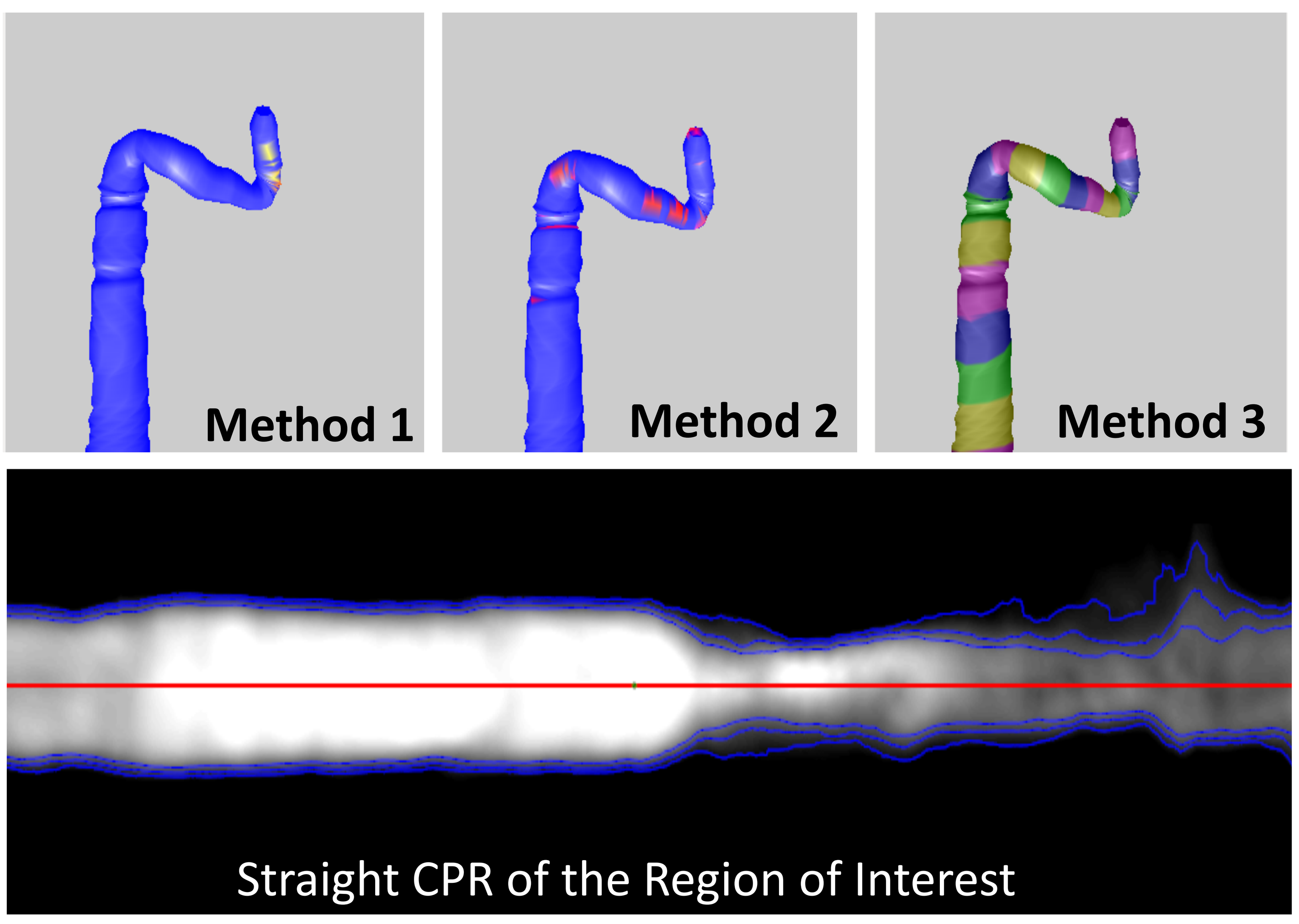


- Results (synthetic) (left: certain, right: uncertain)

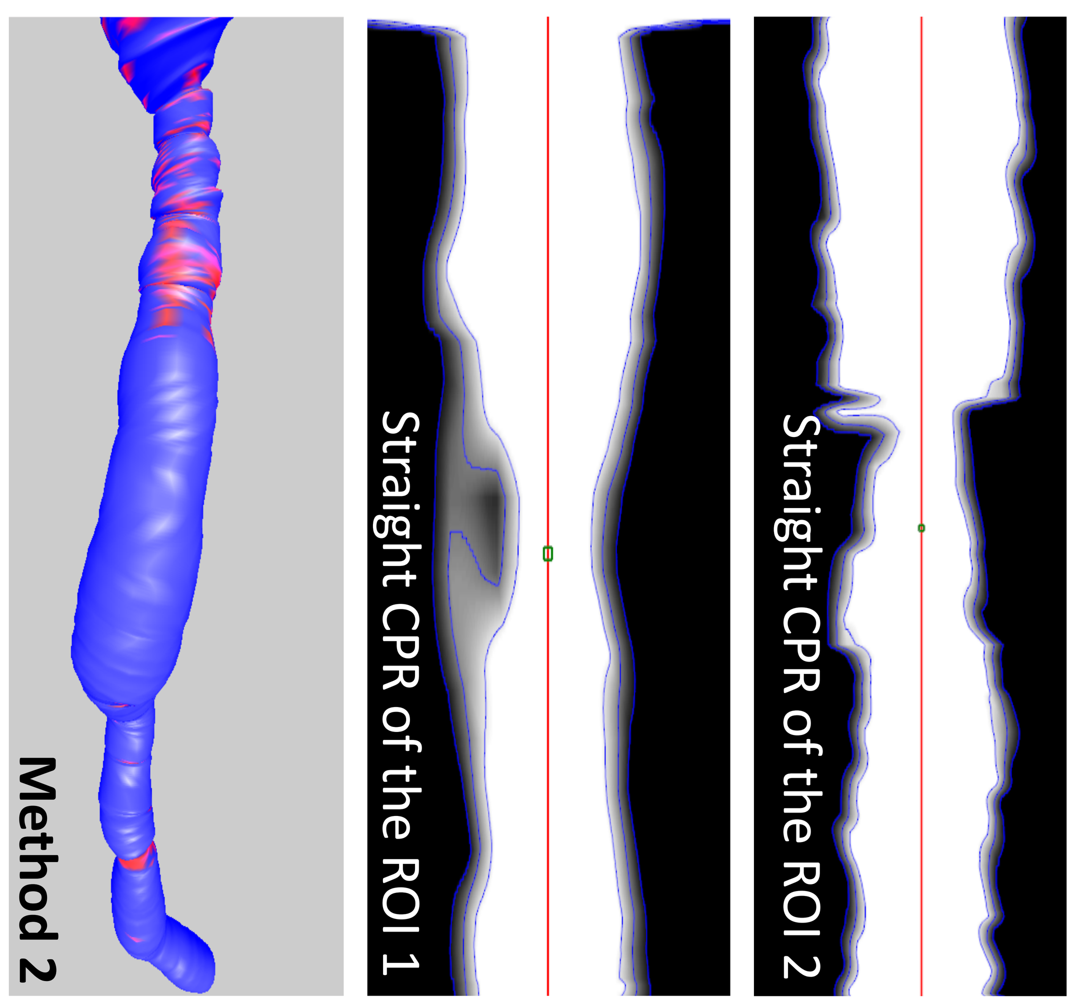


Results

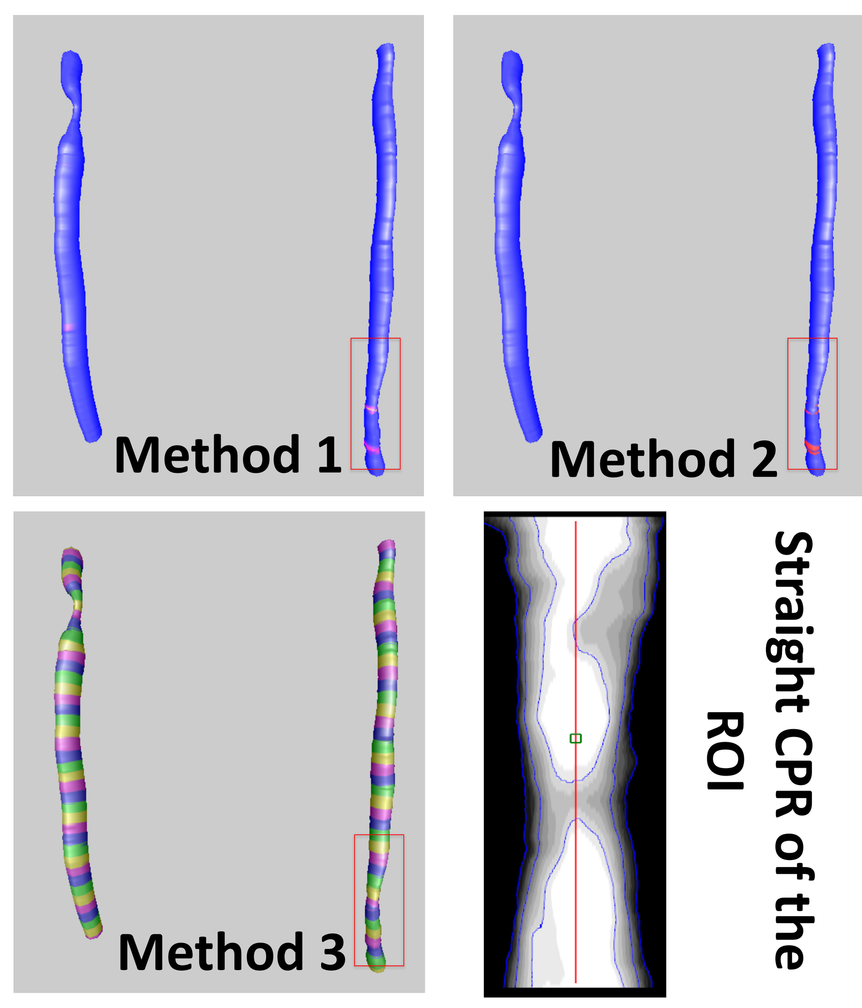
Case 1: MR TOF data segmented using modified Fuzzy C-means for a patient with obstructed flow in one vertebral artery



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



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