Visualization, Classification and Interactive Exploration of Risk Criteria for Cerebral Aneurysms

Monique Meuschke

Data & Knowledge Engineering Group, School of Electrical, Information and Media Engineering, University of Wuppertal, Germany

This poster presents methods to visually explore risk criteria of cerebral aneurysms, which bear the risk of rupture, whereas treatment is also risky. Growth and rupture seem to depend on various factors such as genetics, morphological conditions and hemodynamics, where the exact processes are not well understood. Patient-specific hemodynamics can be obtained by CFD simulations. Due to the complexity of this data and the lack of clearly derived risk factors, only morphological criteria are used in clinical routine to assess the aneurysm state. However, this allows no reliable risk assessment. For the patient-specific risk evaluation and treatment analysis, the interaction of morphological and hemodynamic factors has to be analyzed. Therefore, we developed several novel techniques to classify and visualize simulated blood flow data comprising wall-related properties and intra-aneurysmal flow patterns. We use linked 2D, 2.5D and 3D depictions of the aneurysm together with flow information that enables the simultaneous exploration of wall characteristics and hemodynamic attributes during the cardiac cycle.

Exploration of Wall and Flow Properties [1]

Motivation: Experts are interested in correlations between wall properties, e.g., deformation and thickness, and flow attributes like pressure and near-wall flow (NWF).

Method: A linked 2.5D and 3D view enables an occlusion-free, simultaneous exploration of wall properties and blood flow. Color and hatching are used to encode two scalar parameters simultaneously.

Results: Our methods provide a fast overview about the complex data and enable a detailed exploration of rupture-prone parameters.

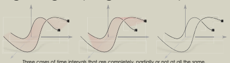
In 3D the outer and inner vessel wall with internal flow are displayed. On the inner wall two parameters are encoded. The 2D map ensures an occlusion-free aneurysm visualization with a 3D bar chart to show a third parameter.

Visualization of NWF. Blue areas indicate that flow comes close to the wall, whereas in red regions the path lines have a greater distance to the wall.

Clustering of Aneurysm Flow [2]

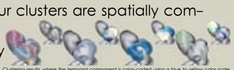
Motivation: Flow patterns are manually extracted to investigate their influence on the aneurysm state, where patterns more distant to the wall are easily overlooked.

Method: We present an automatic path line clustering for grouping unsteady flow. A similarity measure is used that considers the temporal overlap of lines.



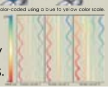
Three cases of time intervals that are completely, partially or not at all the same.

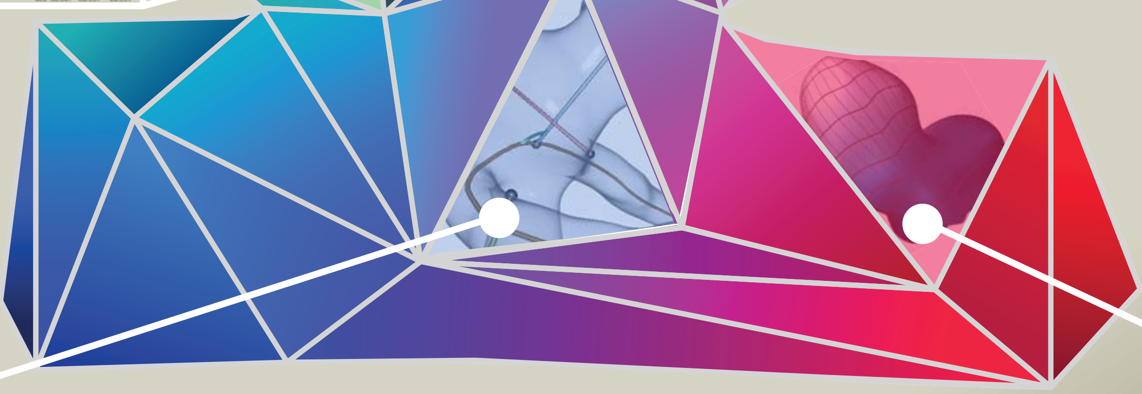
Results: Our clusters are spatially compact and temporally coherent.



Clustering results, where the temporal component is color-coded using a blue to yellow color scale.

Instable patterns that reoccur over time are reliably grouped even if noise exists.





Glyph-Based Visualization of Stress Tensors [4]

Motivation: Wall stress, described by a 3x3 tensor, influences rupture. Stress tensor visualizations are needed to transfer findings to clinical discussions.

Method: For the tensor depiction, we evaluate four glyph-based techniques, which enable a comparative visualization of tensors between the inner and outer vessel wall.

Superquadrics (SQ) and kites (K) showing the local tensor on the inner (yellow) and outer wall (blue), streamlines (SL) indicating the tensor main direction for the inner (yellow, purple) and outer wall (blue, green) and scatterplots (SP) showing the distribution of the main directions within a surface region.

Results: Glyphs are differently suitable depending on the task. SL provide an overview. SQ and K show strong local changes of the main direction. SP are most suited to analyze the tensor data quantitatively within a region.

Rotating kites over time.

Simultaneous Exploration of Scalar Fields [5]

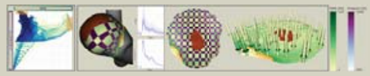
Motivation: Multiple unsteady scalar fields have to be compared between cases to evaluate rupture risk and treatment options, which is a difficult task.

Method: We developed a tool to visually compare datasets. Several views allow an efficient analysis of unsteady attribute correlations. A novel 2D plot provides a temporal overview about attribute correlations. Statistical plots linked to a 2D map and a 3D view combined with novel glyphs allow a more detailed analysis. This is further supported by a time-dependent clustering of attributes.

Visual comparison of pre-and post-treated aneurysm using statistical plots.

2D plot to show attribute correlations within brushed surface regions.

Results: Our tool improves risk evaluation and decision-making. Physicians were able to perform a more in-depth analysis yielding different or more certain assessments of rupture risk and treatment options.



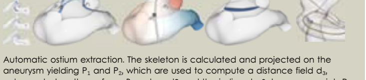
Analysis of an aneurysms with a size of 2.8 mm that was assessed as less rupture-prone based on morphological features. It shows suspicious wall regions with an increased WSS.

Automatic Extraction of Morphological Criteria [3]

Motivation: Physicians use morphological criteria to assess the rupture risk, which in turnrely on a stable ostium detection–both are manually extracted. This time-consuming and error-prone process is incompatible with the high clinical workload.

Method: We provide an automatic extraction of the ostium and various morphological criteria that are visualized within the aneurysm.

Results: The automatic results are very similar to manual results, where possible deviations can be corrected quickly. Manual measurements for the aneurysm diameter and width show strong inter-observer variations. It is difficult to manually find a maximum extent in 3D, which is reliably determined by our method yielding objective results.

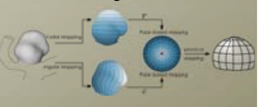


Automatic ostium extraction. The skeleton is calculated and projected on the aneurysm yielding P_1 and P_2, which are used to compute a distance field d_3, color-coded on the surface. Based on d3 and the isoline $d_3=0$, two more points P_3 and P_4 are determined. P_1 to P_4 are connected to extract the ostium. Based on the ostium, morphological criteria are calculated and visualized in the aneurysm.

Automatic Classification of Flow Patterns [6]

Motivation: Medical studies manually classify flow patterns, where different types were observed in ruptured and unruptured cases. This is a time-consuming process with a high interobserver variability and no reliable comparibility of datasets is given.

Method: Flow Patterns are classified automatically. First, the aneurysm is mapped to a hemisphere by calculating polar-based coordinates and flow-representing lines are clustered. The polar-based coordinates are assigned to the points of the cluster representative. Using this, the representative is classified according to one of six predefined types.



Generating polar-based coordinates. For each vertex on the aneurysm a radius and an angle are calculated, which represent a position on a hemisphere with a radius of one.

Results: Our classification leads to objective and reproducible results. Physicians were able to find correlations between rupture-relevant flow patterns and risky wall regions, which supports the establishment of general risk factors.

Based on the cluster representatives, one of six predefined types is assigned to each flow pattern.

BERGISCHE UNIVERSITÄT WUPPERTAL

IZMD Interdisziplinäres Zentrum Machine Learning and Data Analytics

BIT Bergische Innovationsplattform für Künstliche Intelligenz

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