Abstract: Flexible Unfolding of Circular Structures for Rendering Textbook-style Cerebrovascular Maps

Leonhard Rist[1,2], Oliver Taubmann[2], Hendrik Ditt[2], Michael Sühling[2], Andreas Maier[1]

[1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany
[2]CT R&D Image Analytics, Siemens Healthineers, Forchheim, Germany
leonhard.rist@fau.de

Comprehensive, contiguous visualizations of the main cerebral arteries and the surrounding parenchyma offer considerable potential for improving diagnostic workflows in cerebrovascular disease. Instead of manually navigating through Computer Tomography Angiography volumes, e.g. in time-critical stroke assessment, a 2D overview would allow for rapid examination of vascular topology and lumen. Unfolding the brain vasculature into a 2D vessel map is, however, infeasible using the common Curved Planar Reformation (CPR) due to the circular structure of the Circle of Willis (CoW). Additionally, the spatial configuration of the vessels typically renders them unsuitable for mapping onto simple geometric primitives. We propose CeVasMap [1], a flexible mesh-based solution for mapping multiple vascular structures, including circular ones, and their surroundings into a two-dimensional representation. It extends the As-Rigid-As-Possible (ARAP) deformation algorithm by a smart initialization of the required 3D readout mesh which is fitted to the CoW. Depending on the resulting degree of distortion, it is also possible to merge neighboring arteries directly into the same view. In cases of high distortion, these neighboring vessels are instead unfolded individually and attached to the main structure, creating a textbook-style overview image. An extensive distortion analysis is provided respectively for each vessel, comparing global and local gradient norms of the 2D-3D vector field of individual and merged unfoldings with their CPR representations. In addition to enabling the unfolding of circular structures and allowing more realistic curvature preservation, our method is on par in terms of incurred distortions to optimally oriented CPRs for individual vessel unfoldings and comparable to unfavorable CPR orientations when merging the complete CoW with a median distortion of 65 µm/mm. Compared to row-wise constant distortion in CPR, unfolding with CeVasMap results in a high ratio of distortion-free image parts whereas the occurring distortions are close to the centerlines.

References

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Informatik aktuell, https://doi.org/10.1007/978-3-658-44037-4_7