A Deep Learning Approach for Direct Mesh Reconstruction of Intracranial Arteries

Layman Summary

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The Circle of Willis (CoW) is an important group of vessels located in the base of the brain that are connected to each other. It plays a crucial role in redistributing the cerebral blood flow throughout the brain. The shape and configuration of these vessels can vary significantly between individuals, which can also affect the risk and progression of brain diseases. To analyze and understand the different shapes, 3D surface models of the vessels can be used, such as surface meshes, which can also enable the extraction of vascular geometry features.

Traditionally, accurately reconstructing surface meshes from brain scans has been a complex and time-consuming process. This process could be simplified by using an artificial intelligence technique, called geometric deep learning (GDL). This technique allows to directly obtain surface meshes from brain scans, making it easier and faster to study their structures. A specific type of brain scans called magnetic resonance angiography (MRA), is usually used to obtain a clear visualization of the blood vessels. In this way, a GDL model was used, which takes as input an MRA crop and a template mesh which is adjusted into the desired CoW vessel shape. Several experiments were performed on five crops representing different vessels and bifurcations to capture both stability and variability within the CoW.

Our results showed that this method increases the accuracy of the reconstructed mesh when using anatomy-specific templates instead of a general 3D sphere, and when enhancing the image features. Moreover, incorporating the curvature characteristics of the meshes showed promising capability of handling complex geometries and sharp edges. However, achieving a consistent performance across CoW regions remains a challenge, due to the natural variability in vessel shapes and sizes. In the future, this approach could potentially be extended with a CoW bifurcation detection model to initialize multiple template meshes and further create a complete surface reconstruction of the CoW vasculature. Such advancements could facilitate a deeper understanding of the CoW's geometric characteristics, crucial for assessing neurovascular pathologies.