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Title

Parameter estimation of vascular network structures

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Abstract

The complex and hierarchical structure of the vascular system constitutes the main challenge in blood flow modelling. Recent publications suggests that large vessels may be represented with a graph structure and Poiseuille flow in graph edges, and the intricate mesh of microscale capillaries as a porous medium with Darcy flow. However, the requirement of a coupling between scales that is both mathematically and physiologically sound is a remaining challenge. Due to limited resolution in medical imaging devices, there is a large number of vessels below the scale of pixel size whose structure is unknown. Hence, only assumptions can be made about the flow distribution from macroscale to microscale vessels. In this work we have investigated whether a complex network may be replaced by a set of model parameters, thus eliminating the need to know the exact mesoscale network structure. On three different graph structures we calculated a set of *transfer conductivity parameters.* A coarse network approximation based on these parameters was used in an idealized model for blood flow in brain. The coarse model was compared with a reference model using the same graph to represent the mesoscale network. The error in the coarse model was found to be small in all three cases given small pressure gradients in the porous domain. Also, we found that the transfer conductivity is highly dependent on the parameters of single graph edges, indicating that a coarse model may be used for diagnostic purposes, as many medical conditions involve changes in brain vascular structure.

Figures

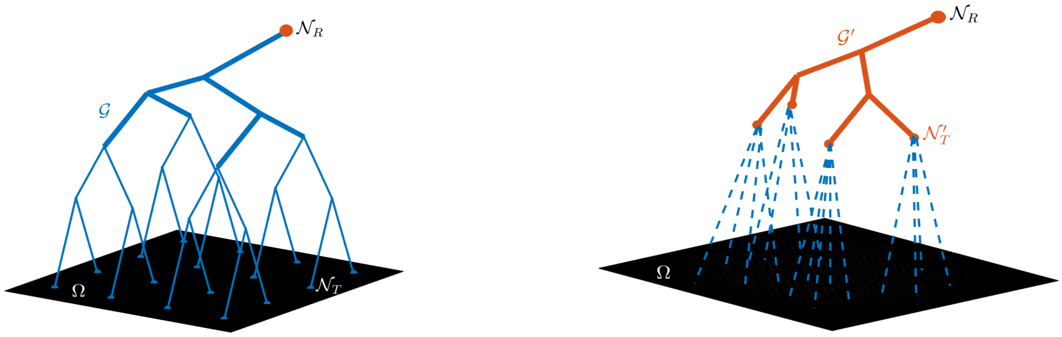

Figure 1: Illustration of how the mesoscale network in the exact model (left) is replaced by a coarse model (right). The network is cut at the point where the vessels become invisible in pictures, and a linear flow model including the network transfer conductivity is used to approximate the flow between the vessel terminals and the porous domain Ω.

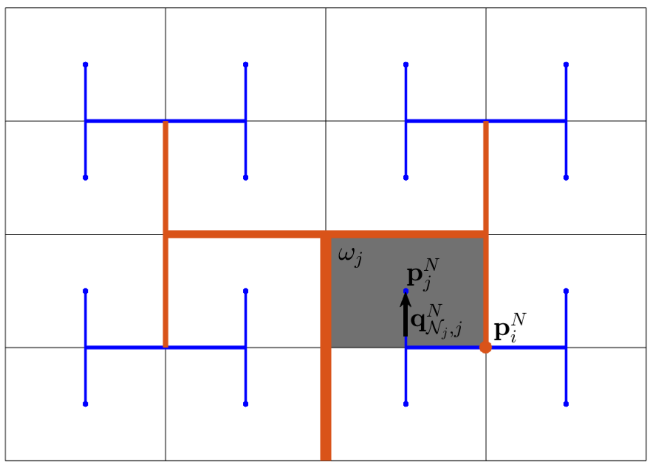

Figure 2: The transfer conductivity from a macro terminal node (red dot) to a micro terminal node is calculated according to Equation (reference) using the pressure at the visible macro terminal node (red dot), pressure in the invisible micro terminal node (blue dot in gray area), the flux in the invisible terminal edge (arrow) and the area of the impact field (gray area).

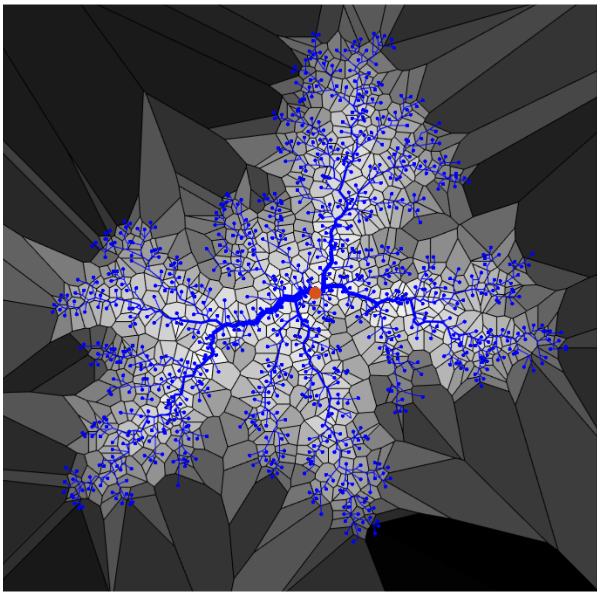

Figure 3: Illustration of how the transfer conductivity is distributed in a network. Lighter colors indicate higher values.

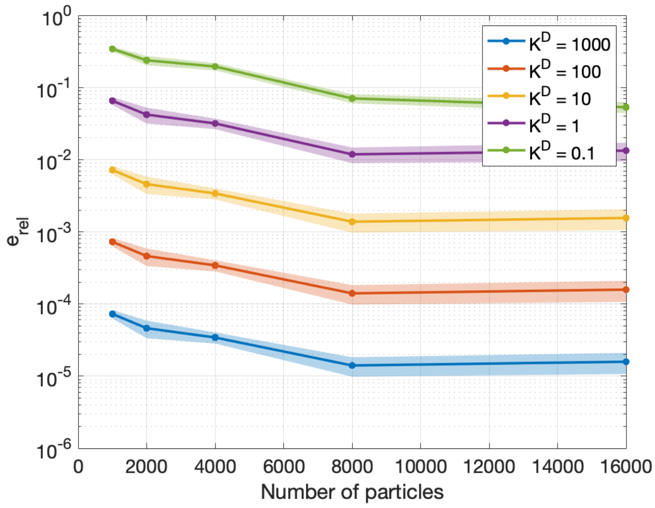

Figure 4: The error in the coarse approximation when comparing the pressure in the porous domain obtained with the two different models.