Sensitivity analysis of 1D vascular models

Benjamin Jordan with Dr Benemerito acting as supervisor

INSIGNEO
Institute for *in silico* Medicine

Background

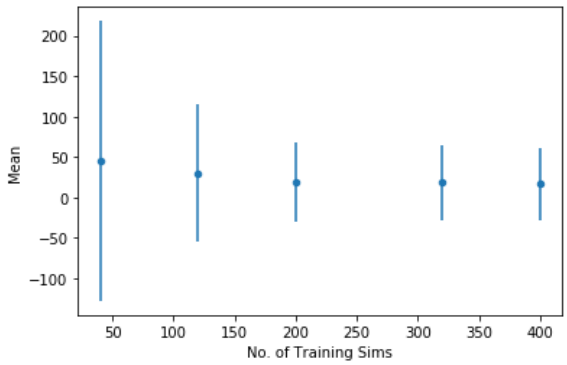
The aim of this project is to develop 1D blood flow modelling techniques to aid clinical planning. Cerebral Vasospasm (CVS) and Ischaemic Stroke (IS) are both cardiovascular conditions which can cause cell damage and even necrosis. In this project, 1D flow models have been used to study the blood flow when these pathologies are present, and deduce which of the input parameters are significant, through a sensitivity analysis. A gaussian process emulator (GPE) is trained and used to mimic the behavior of the complex system to reduce computational time.

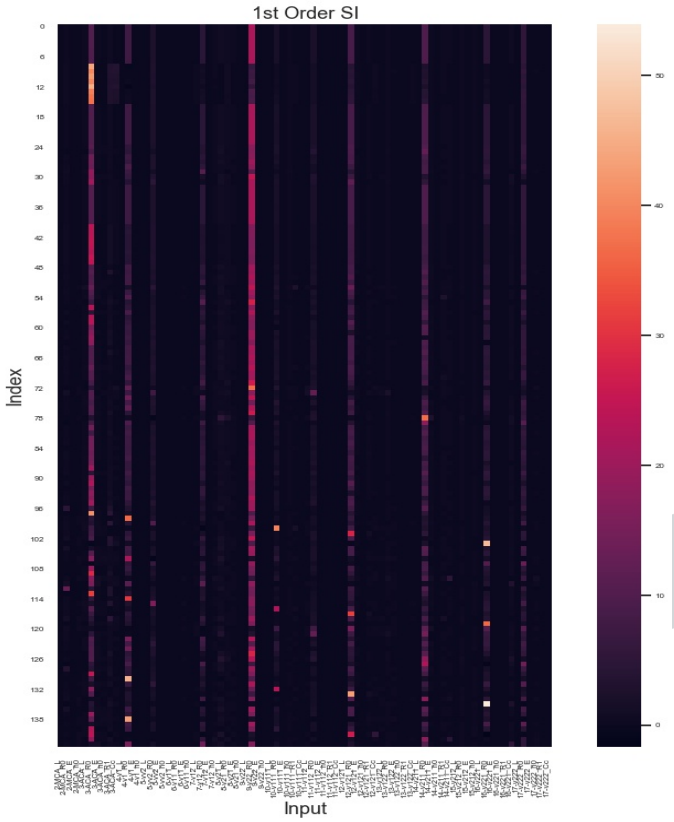
Methods

- Run Python script which creates input text files which sample the input space using latin hypercube sampling (LHS) for a given number of training simulations and validation simulations, provided as arguments
- Run simulations using INSIGNEO in-house blood flow model OpenBF in Julia in the Atom IDE with a multi-threading technique to decrease computational time
- Train the GPE on the training data, use this to estimate outputs for many simulations and compare results with validation simulations in the form of a mean absolute percentage error (MAPE)
- Complete first, second and total order sensitivity analysis using SALib module in Python to obtain Sobol indices. Plot these in a heatmap format using the Seaborn and pandas modules to allow simple interpretation of the indices

Results

When completing the final part of the placement, obtaining the results to the sensitivity analysis, it became clear that the MAPE was too high for the results to be given any validity. MAPE vs No. of simulations used is shown below, while an example of a heatmap is shown to the right.





Conclusions

Limited conclusions could be determined due to the high MAPE. However, some conclusions could be determined from a brief manual first-order sensitivity analysis looking at the effect of IS and CVS on the flow properties. A selection are shown below:

- CVS - Pressure and flow rate in the more distal vessel was shown to increase monotonically as the radius of the vessel decreased
- In a progressive CVS - Mean velocity was significantly more sensitive to changes in the vessel from which the outputs were being taken
- IS – Effect on MCA pressure decreases as the position of the blockage becomes increasingly distal, opposite true of flow rate
- IS – Maximum effect was an increase of 34% in the pressure when the blockage was in vessel 11

I will continue to work on a similar project for my FYP.

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The University Of Sheffield.

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