Computational Modelling of drug delivery in multi-component brain tissue

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ABSTRACT

For the treatment of brain tumours, a direct infusion of a therapeutic solution into human brain tissue represents a promising medical application, cf. [1]. Simulations can help to contribute to the success of a planned clinical intervention. For example, by the estimation of the temporal and spatial spreading of the therapeutic agent and the study of coupled effects due to the pressure-driven infusion.

In the proposed contribution, we will discuss the problem-specific application of suitable model-reduction techniques to obtain an efficient numerical simulation of therapeutic infusion processes within multi-component brain tissues. For this purpose, a compact summary of the underlying theoretical multi-component brain-tissue model is firstly introduced in the framework of the Theory of Porous Media (TPM), cf. [2]. Typically, the straight-forward monolithic solution of the arising coupled system of equations leads to immense numerical costs. Therefore, the primary aim of this contribution is to apply the method of proper orthogonal decomposition (POD) for a simplified model and the POD in combination with the discrete-empirical-interpolation method (DEIM) for a general nonlinear model in order to reduce the required computation time significantly, cf. [3].

In this regard, the required adaptations are derived for both brain-tissue models by customising the POD(-DEIM) such that the different temporal behaviour of the primary variables is represented, while the system's block structure is preserved. Finally, several numerical simulations are discussed in terms of efficiency, accuracy and parameter variations.

REFERENCES

[1] R.H. Bobo, D.W. Laske, A. Akbasak, P.F. Morrison, R.L. Dedrick and E.H. Oldfield, "Convection-enhanced delivery of macromolecules in the brain", *Proceedings of the National Academy of Sciences*, Vol. **91**, pp. 2076–2080, (1994).

[2] W. Ehlers and A. Wagner, "Multi-component modelling of human brain tissue: a contribution to the constitutive and computational description of deformation, flow and diffusion processes with application to the invasive drug-delivery problem", *Computer Methods in Biomechanics and Biomedical Engineering*, Vol. **18**, pp. 861–879, (2015).

[3] D. Fink, A. Wagner and W. Ehlers. "Application-driven model reduction for the simulation of therapeutic infusion processes in multi-component brain tissue", *Journal of Computational Science*, Vol. **24**, pp. 101–115, (2018).