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Proposal – Bachelor Thesis

A Multiscale Model Reduction Approach for Deformable Saturated Porous Media of Thin Layers

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Fluid-saturated solid porous materials undergoing elastic deformation are pervasive in many natural and industrial applications. Examples of such material are soil and biological tissues. Based on the Theory of Porous Media [2], the dynamics in such materials are described using a complex biphasic model consisting of strongly coupled differential equations of different primary variables, namely fluid pressure and solid displacement. Consequently, these equations are of high computational complexity, mainly, for large heterogeneous porous media, nondeterministic models, or data driven evaluations where the model has to be repeatedly solved. Therefore, applying model reduction methods is crucial whenever it is possible.

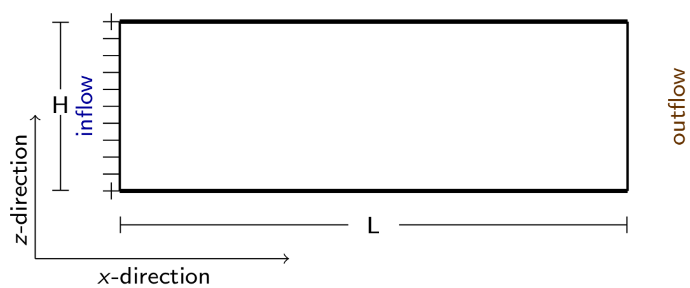

Fig. 1. Illustration of a vertical cross-section of a thin domain.

Of special interest for many applications are porous media of thin layers structure, where fluid flow and solid deformation are almost in the horizontal direction, see Figure 1. For nondeformable porous media, this structure has been utilized to integrate models over the vertical coordinate [3, 4, 6, 7]. This reduces the complexity of the model as the dimensionality is reduced. However, this approach have tendency to overestimate the dynamics, mainly in heterogeneous layered domains. Consequently, different approaches that modifies the dimensionality reduction approach have been suggested [1, 5, 8]. This thesis focuses on the Multiscale model approach [5] for CO2 sequestration in saline aquifers. The model consists of a coarse scale equation (1D equation for the vertically averaged pressure) and a fine scale equation (2D equation for the other primary variable). The two equations are coupled using an operator that reconstructs the coarse scale pressure in the vertical direction.

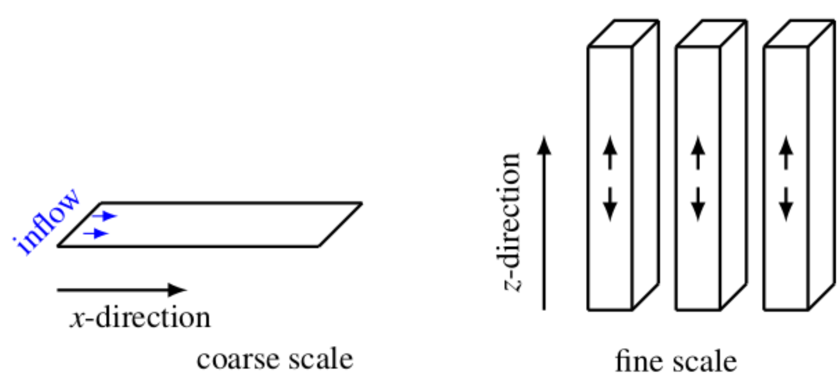

Fig. 2. Illustration of the coarse and fine scales in the Multiscale model.

It is the aim of this thesis to extend the Multiscale model approach to fluid–saturated deformable solid porous materials. Here, the coarse scale model consists of two coupled 1D equations for the vertically averaged pressure and horizontal displacement. The fine scale model consists of two coupled 2D equations for horizontal and vertical solid displacement. In addition, a suitable operator for reconstructing the pressure in the vertical direction needs to be determined.

Tasks:

1. Identify the coarse and fine scale equations in the Multiscale model for the case of thin deformable porous materials.
2. Set up a finite-element scheme for both the Multiscale model and the original biphasic model.
3. Implement both models using a suitable programming language.
4. Show the numerical efficiency of the Multiscale model by performing different numerical comparisons with the original biphasic model.

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