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Non-intrusive global-local method for the poroelasticity model with localized pressure effects

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In many poroelasticity applications, which involve the coupling of mechanics and fluid pressure in porous media, the effects of pressure are often restricted to a limited local region within the entire domain. Thus, solving the poroelasticity system across the entire domain can be computationally inefficient and possibly unnecessary. Alternatively, one can consider solving the full poroelasticity problem only in a local domain where the pressure effect is significant, while solving a simpler linear elasticity problem elsewhere. The resulting model can be seen as an elasticity-poroelasticity interface problem with appropriate transmission conditions.

We propose a non-intrusive global-local algorithm for solving the coupled elasticity-poroelasticity model. In this framework, we iteratively solve the elasticity problem in the entire (global) domain and the poroelasticity problem in the local domain, while ensuring that the transmission conditions across the original interface are satisfied. Although the concept of the global-local algorithm has been previously utilized to address localized nonlinearities in single-physics problems, this study extends the approach to a coupled multi-physics system.

Our approach greatly reduces computational cost, especially when the size of the local domain is much smaller than the global domain. Additionally, the fact that the elasticity problem is solved in the entire domain without compromising accuracy makes this method an attractive alternative to traditional numerical methods, such as domain decomposition methods—particularly when the local domain varies with time or its geometry is complex.

Numerical experiments demonstrate the robustness and accuracy of the proposed method, showcasing its potential for providing scalable and efficient solutions in multi-physics problems where the effect of a single physical process is localized.

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References

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