Master's Thesis

Physics-Informed Neural Networks for Modeling Poroelastic Media

Background

Porous sound-absorbing materials such as foams and fibrous media play a vital role in noise control applications. Their complex acoustic behavior arises from coupled interactions between the solid matrix and air within the pores. These materials are often described using poroelastic models, such as the Biot or Biot-Johnson-Champoux-Allard (BJCA) models (Luu et al., 2017). Traditionally, solving poroelastic problems relies on the Finite Element Method (FEM), which can be computationally demanding, especially for inverse problems or when estimating uncertain material properties. Furthermore, recent studies (e.g., Cuenca et al., 2022; Bonfiglio et al., 2018) emphasize the challenge of obtaining reproducible, accurate transport and elastic parameters of porous media from experimental data. Physics-Informed Neural Networks (PINNs) offer a powerful alternative by embedding the governing physical laws directly into the training of neural networks. PINNs can solve forward and inverse problems, even in the presence of sparse or noisy data, as recently demonstrated in acoustics by Schmid et al. (2024) and others.

Objectives

The goal of this thesis is to explore and validate a PINN-based framework for modeling the acoustic behavior of poroelastic materials such as melamine foam and fibrous materials. Tasks include the implementation of a forward solver for poroelastic wave propagation and an inverse solver for parameter identification. The framework should incorporate known constitutive models, such as Biot or BJCA, and be benchmarked against experimental data (e.g., impedance tube measurements).

Your Tasks

- Study the fundamentals of poroelasticity (Biot theory) and the principles of Physics-Informed Neural Networks (PINNs).
- Implement a PINN framework in Python to solve poroelastic wave propagation problems.
- Extend the framework to inverse modeling for estimating material parameters from synthetic or experimental data.
- Validate the PINN results against reference solutions (e.g., FEM) and assess the influence of noise, data sparsity, and network architecture.
- Compile your work into a formal master's thesis (in English), documenting your methodology, implementation, results, and scientific insights.

Requirements

- Interest in acoustics, computational mechanics, and machine learning.
- Basic knowledge of PDEs and poroelastic modeling (helpful but not mandatory).
- Programming knowledge in Python and basics in working with PyTorch/TensorFlow.

Contact

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Key references:

J. Cuenca et al., “Deterministic and statistical methods for the characterisation of poroelastic media from multi-observation sound absorption measurements,” MSSP, 2022.
P. Bonfiglio et al., “How reproducible are methods to measure the dynamic viscoelastic properties of poroelastic media?” JSV, 2018.
H.T. Luu et al., “Three-dimensional reconstruction of a random fibrous medium: Geometry, transport, and sound absorbing properties,” JASA, 2017.
J.D. Schmid et al., “Physics-informed neural networks for acoustic boundary admittance estimation,” MSSP, 2024.