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Forward and inverse modeling of wave propagation combining classical and machine learning approaches

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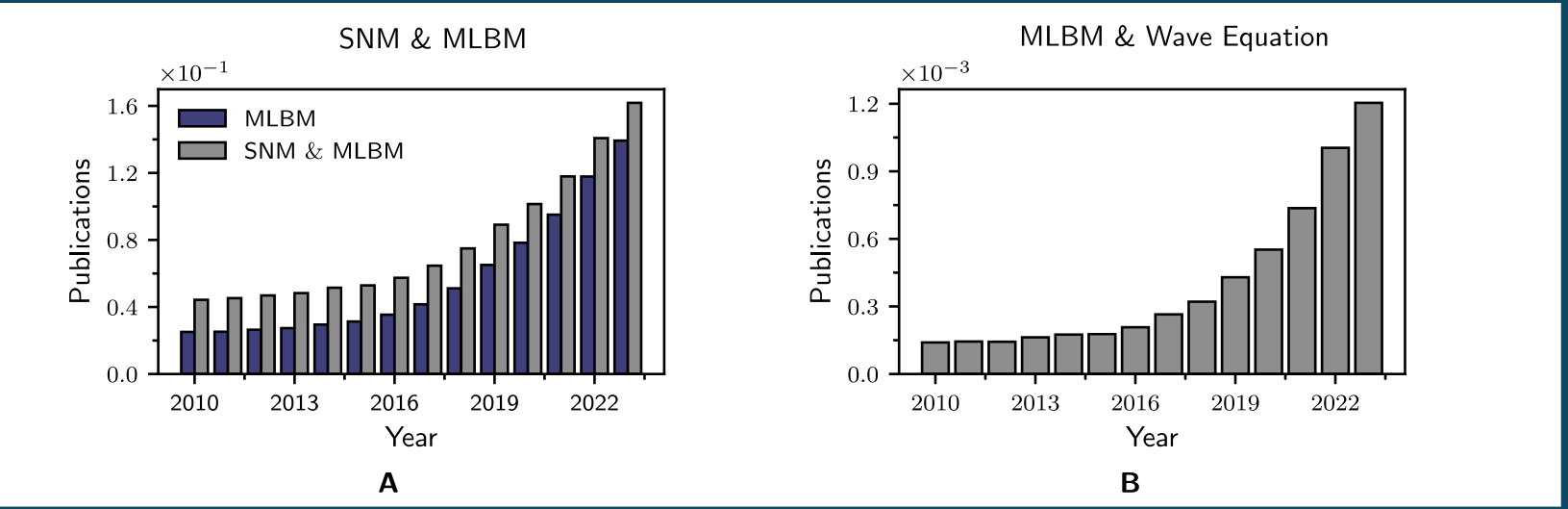
Introduction

The growth of literature related to machine learning and wave propagation modeling is shown.



Machine learning-based methods (MLBM) and standard numerical methods (SNM) (A), as well as MLBM specifically associated with wave propagation modeling (B).

Possible causes

- ❑ Hardware
  - GPU
  - Storage
- ❑ Available data
- ❑ Open-source packages
  - Tensorflow
  - PyTorch
  - JAX

https://github.com/oscar-rincon/review-elastic-waves/tree/main/main/publications_number_year

Research Question

What machine learning techniques have been applied to model the wave equation in computational seismology?

Forward Problem

Surrogate models

MLBM & SNM

Inverse problem

Justification

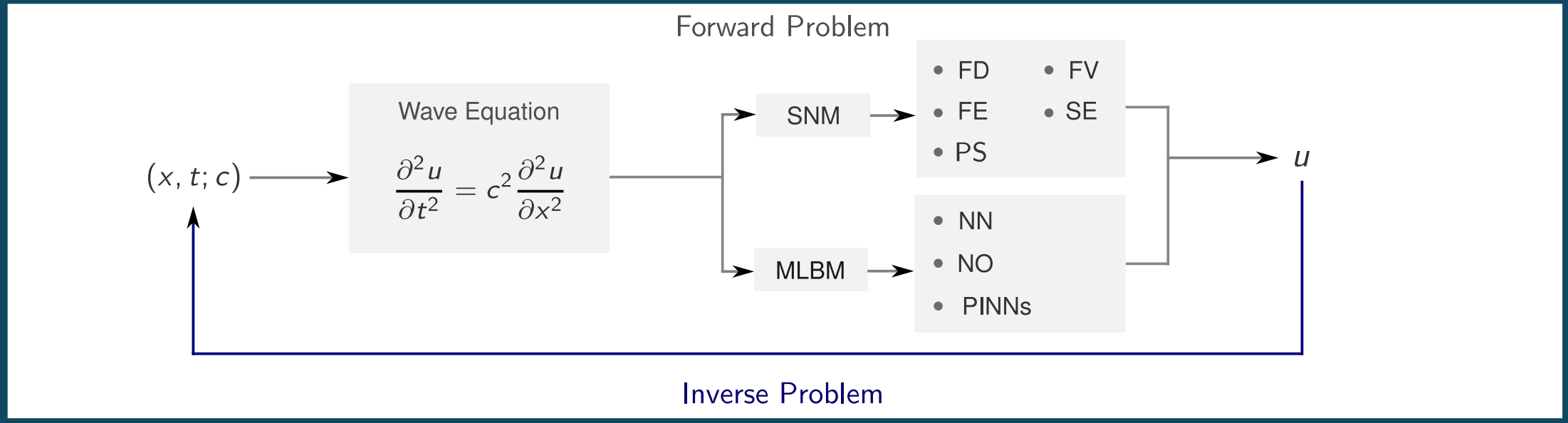
In principle, machine learning can offer a promising balance between computational cost and accuracy.

Given the rapid growth of the field:

1. Uncertainty about what machine learning based methods have been applied and demostrated to be an efficient complement or alternative to standard numerical methods.

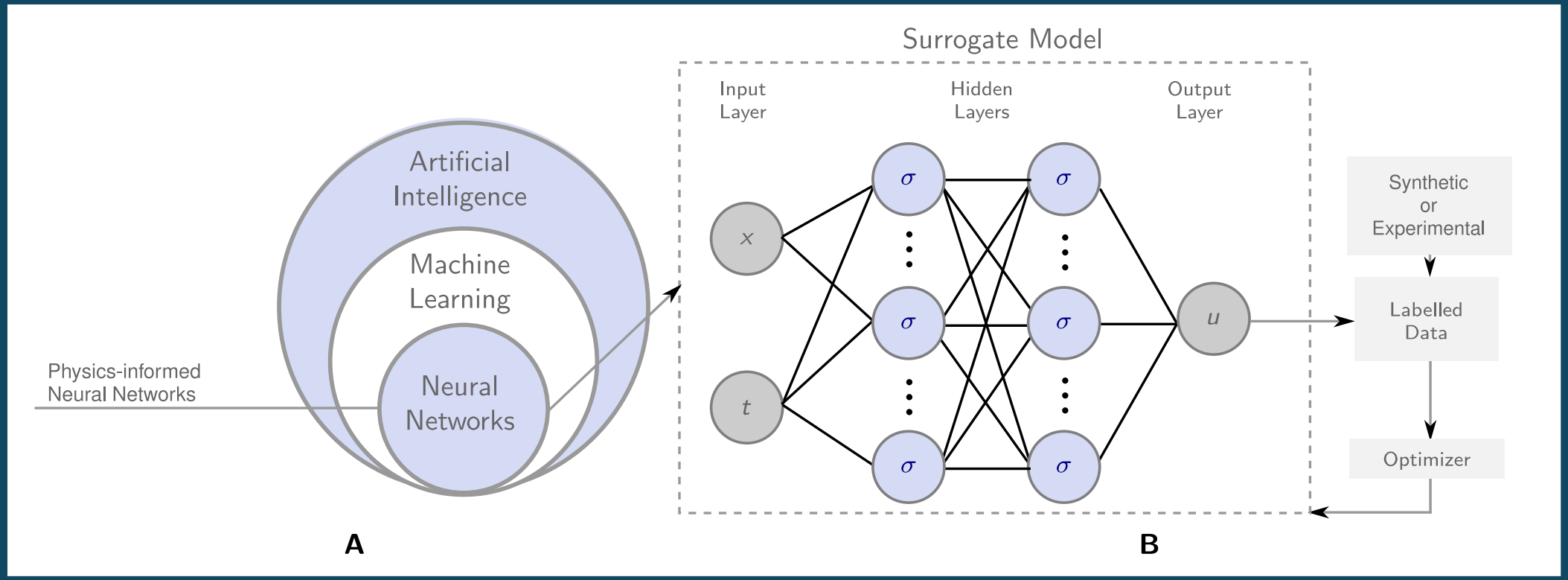
2. Already proposed methods may still haven’t been fully explored in the context of seismic wave propagation modeling.

Modeling of Wave Propagation



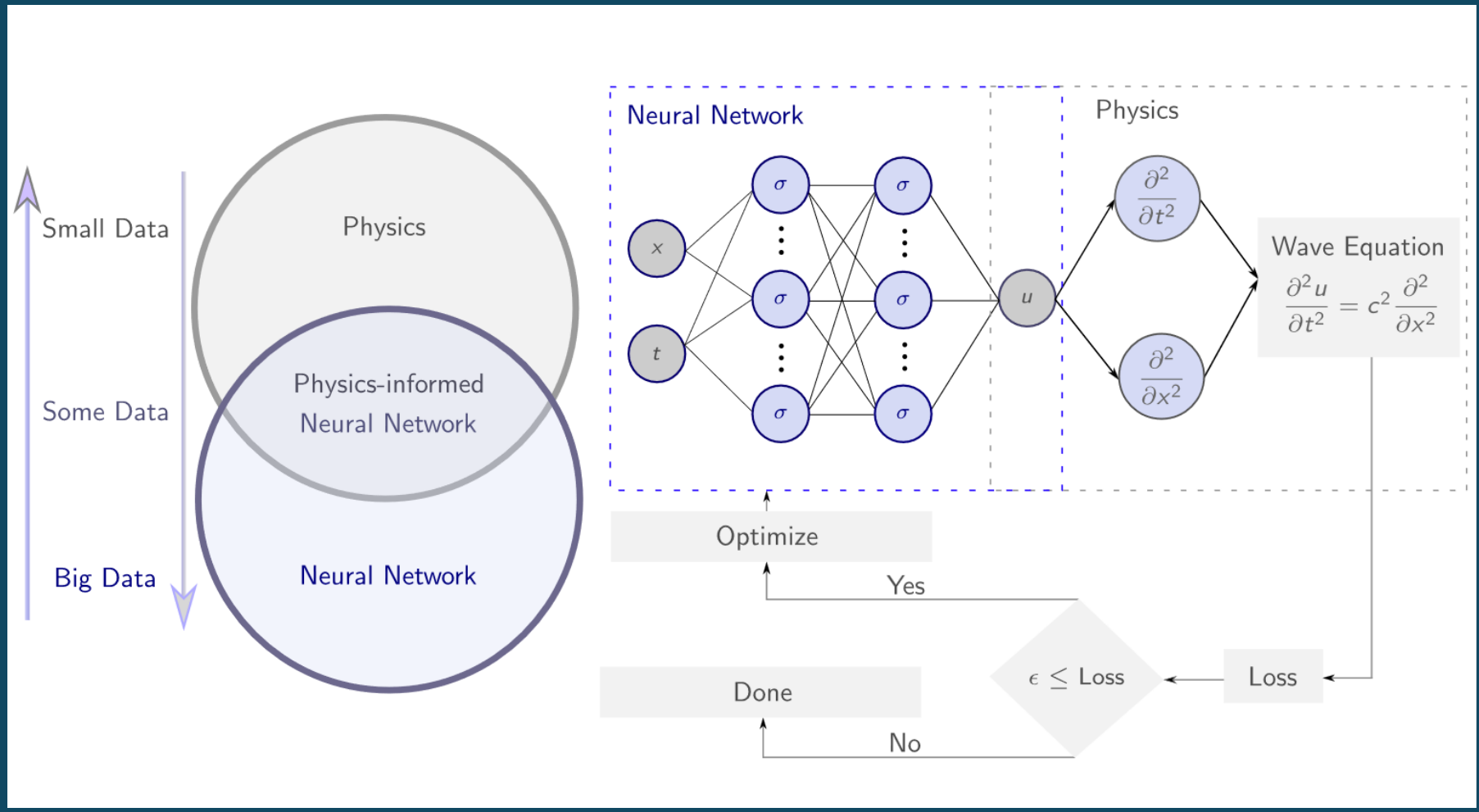
Scheme of the forward and inverse problems encountered in solving partial differentialequations. In the forward scenario, the inputs (x, t; c) are employed to characterize a model across PDEs.

Machine learning Based Methods



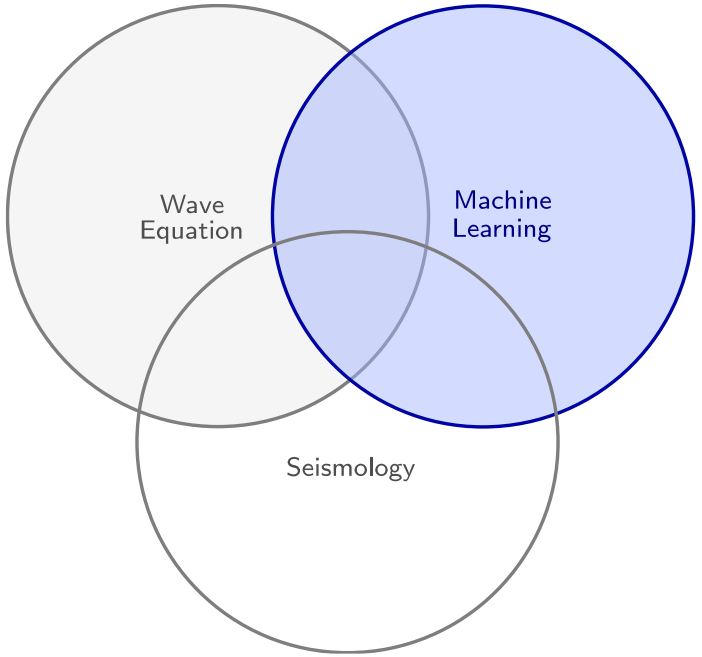
Artificial Intelligence subsets and artifical neural networks. (A) Deep learning as a subsetof machine learning and artificial intelligence and (B) basic architecture of artificial neural networks.

Machine learning Based Methods



Physics-informed neural networks scheme applied to the wave equation.

Applications

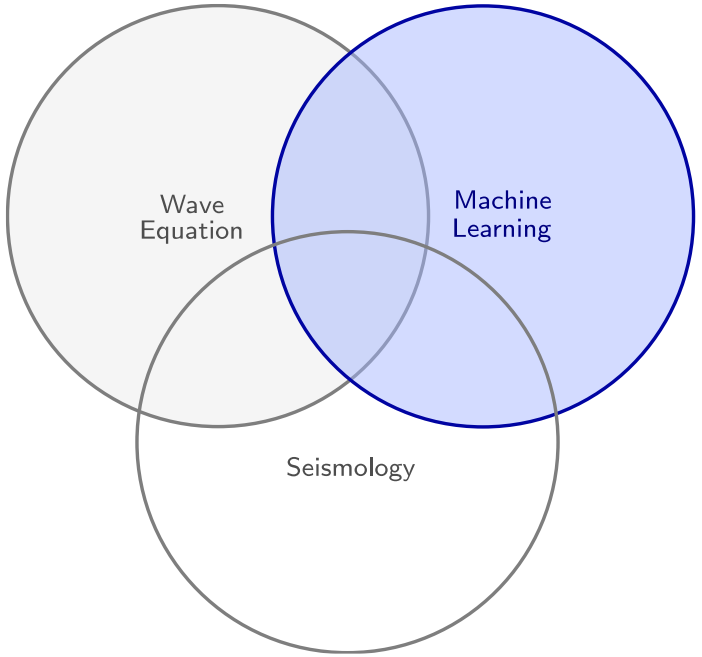


Inclusion criteria

We <u>considered</u> studies that:

- Machine learning methods applied to computational seismology.
- Incorporate descriptions of physical phenomena through partial differential equations.
- Reported a quantitative ora supported qualitative comparison of the implemented model's computational efficiency relative to standard numerical methods.
- Are applied to solve inverse problems.

Applications



Exclusion criteria

We not considered studies that:

- Did not provide a comparison at all.
- Compared their results only to other machine learning methods.
- Focused on accuracy comparisons without addressing computational times were also excluded.
- Are outside the scope of computational seismology.

Search strategy

Query

("machine learning" OR "deep learning" OR "neural networks") AND ("seismic" OR "seismology") AND "wave equation" AND (modeling OR modelling OR model OR simulation)