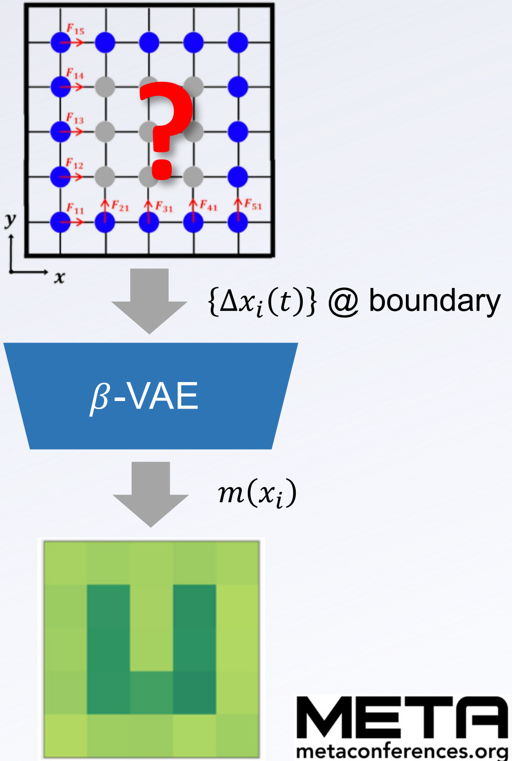
Acoustic imaging assisted by unsupervised learning

Jiawei XI[1], Yongzhong Li[1], Jensen Li[1]
[1] The Hong Kong University of Science and Technology



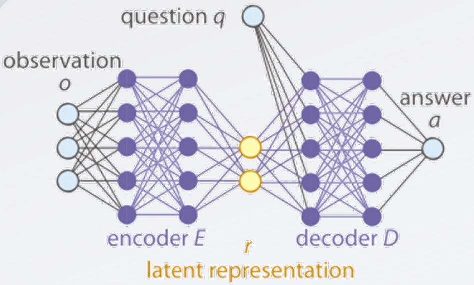
Abbreviated abstract:

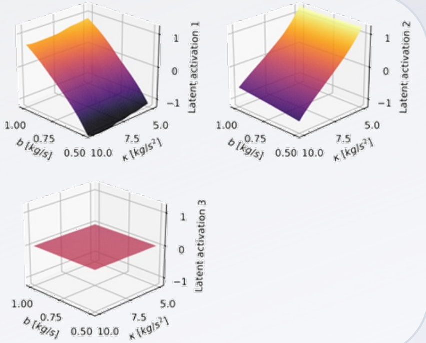
- We demonstrate extraction of material profiles by using ***unsupervised neural network*** in learning the ***data structure of the wave propagating data*** from acoustic wave equation. A 2D spring mass model is used as a simplified version for acoustic imaging.
- Mathematically, the approach discovers ***spatially dependent PDE coefficients*** as the minimal representation of the wave propagation data, without prior knowledge of scattering mechanism and is applicable to inverse scattering.

Related publications:

– Li, Y., Xi, J. *et al*, Physical Review Applied 16 (6), 064039 (2021)

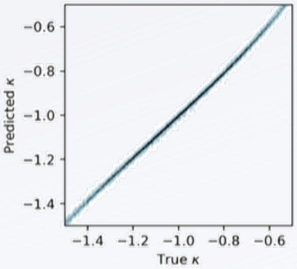
Background and Motivation



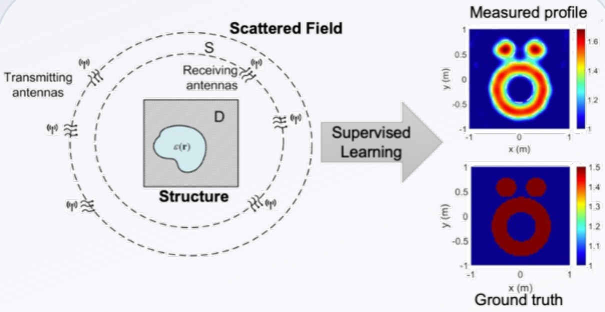


Iten, R. et al, Physical review letters, 124(1), 010508 (2020)

$$i\frac{\partial\psi}{\partial t} = -\frac{1}{2}\partial_x^2\psi + \boldsymbol{\kappa}|\psi|^2\psi$$



LU, P.Y. et al. *Physical Review X*, 10(3), 031056(2020)



Wei, Z., Chen, X., IEEE Transactions on Geoscience and Remote Sensing, 57(4), 1849-1860 (2018)

- Variational autoencoder (VAE) can *find the minimal representation of data automatically* in an *unsupervised* approach
- PDE coefficient can be well extracted from the wave data by using VAE
- *Discover spatially dependent PDE coefficients = Imaging*

Acoustic Wave Equation

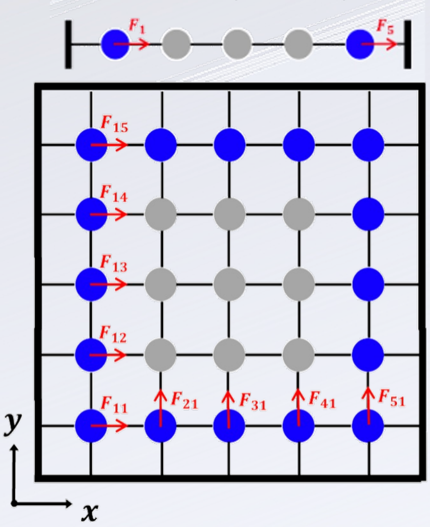
$$\partial_x p + \partial_t(\boldsymbol{\rho}\, v) = 0$$
$$\partial_x v + \partial_t(\boldsymbol{\beta}\, p) = 0$$

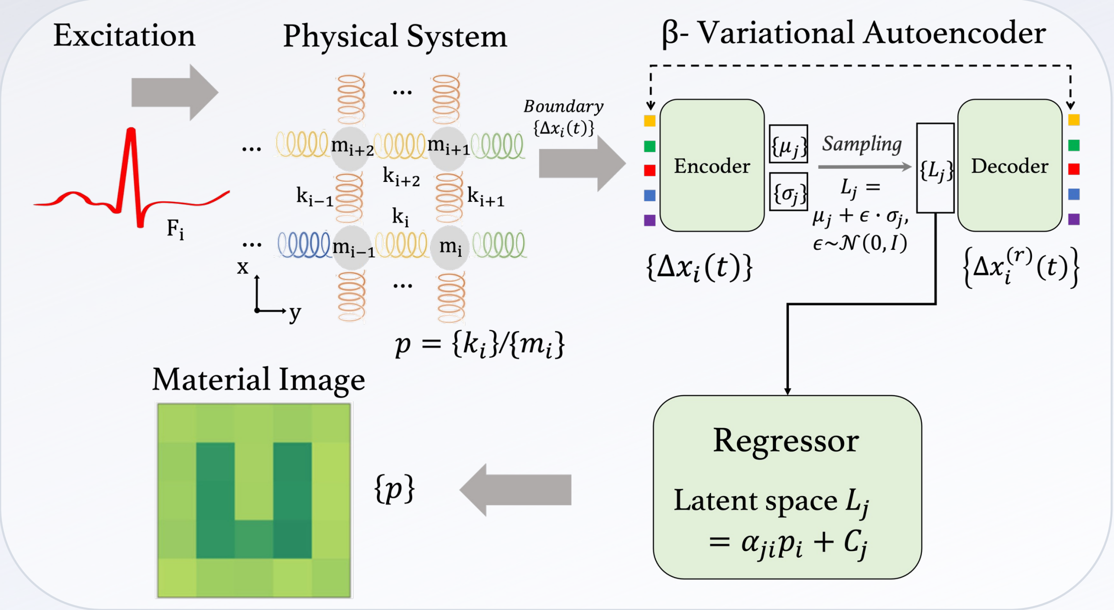
- Classical inverse scattering problem can be solved by using *supervised* learning but often with *large labeled data* and *several assumptions*
- To solve inverse scattering and imaging problem in acoustics by using VAE

Feature Extraction Approach for Inverse Imaging

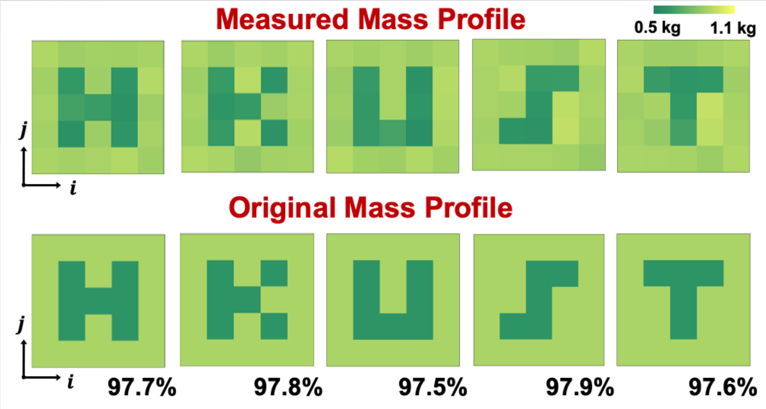
- Acoustic imaging represented by spring-mass model
- Excite boundary nodes and obtain masses of internal nodes
- Random mass profiles to train β-VAE to discover the features of data

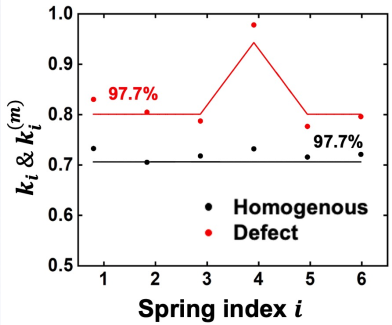
Excitation Method(1D&2D)





Key Results and Conclusions





Test data with **10%** additive white **gaussian noise**

- 2D imaging of mass profile achieved for different configurations.
- Spring constant in additional to mass profile can be imaged.
- The location and the size of the defect in the background profile can be probed.
- Training is robust against noise, with overall accuracy > 97%.

Conclusions:

- Successfully discover spatial dependent PDE coefficients using unsupervised learning approach.
- Applied on a spring-mass model as a simplified version of acoustic inverse imaging.
- Minimal representation of propagation data obtained by VAE = Imaging.