UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING COLLABORATION WORKSHOP

NATIONAL ENERGY TECHNOLOGY LABORATORY

Reduced order model for Guided Wave propagation on gas pipelines to enable real time simulation

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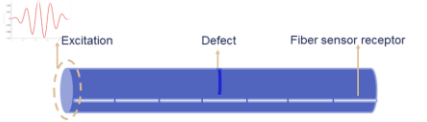
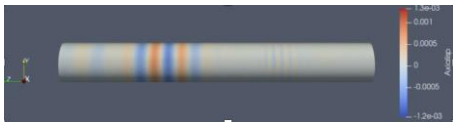
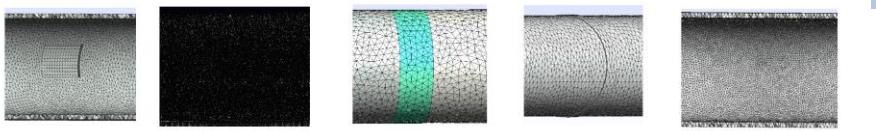
Outline:

Reduced order model for simulation of Guided wave propagation is presented here. The utilization of reduced order models ensures efficient data generation for a variety of parameters where it takes huge computational effort to simulate, crucial for timely monitoring and decision-making. Autoencoder based reduced order models are proposed here, which are trained on simulated data from open-source finite element framework, Firedrake.

$$\mu\nabla^2\boldsymbol{u} + (\lambda+\mu)\nabla(\nabla\cdot\boldsymbol{u}) = \rho\left(\frac{\partial^2\boldsymbol{u}}{\partial t^2}\right) \quad M\ddot{u} + C\dot{u} + Ku = F \quad u \sim F(M, C, K, \Phi)$$

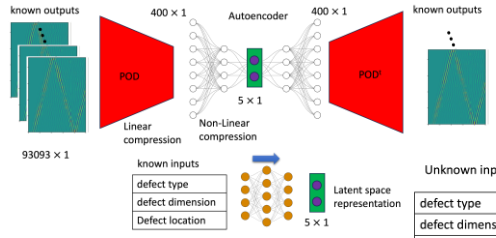






(a) (b) (c) (d) (e)

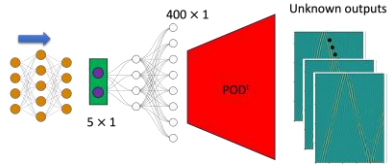
Pipe feature	(a) Localized (120)	(b) General (120)	(c) Clamp (120)	(d) Welding (120)	(e) Pitting (60)
Data file	data_1 (93093, 120)	data_1 (93093, 120)	data_3 (93093, 120)	data_4 (93093, 120)	data_5 (93093, 60)
Variable L (12)	Cir_length: $[\frac{\pi}{32}R \sim \frac{12\pi}{32}R]$ (R: 5.5 inch inner radius) (Increase step: $\frac{\pi}{32}R$)	Axial length: [0.25 feet ~ 3 feet] (Increase step:3 inch)	Axial length: [0.5 inch ~ 6 inch] (Increase step : 0.5 inch)	Damping ratio 80%~135%pipe damping (Increase step: 5%)	Pitting radius: [5.08 mm ~ 8.26 mm] (Increase step: 0.635 mm)
Variable d (10)	Location: [20 inch ~ 56 inch] (Increase step: 4 inch)	Location: [20 inch ~ 56 inch] (Increase step: 4 inch)	Location: [20 inch ~ 56 inch] (Increase step: 4 inch)	Location: [20 inch ~ 56 inch] (Increase step: 4 inch)	Location: [20 inch ~ 56 inch] (Increase step: 4 inch)



Offline Training of Autoencoder based ROM

ROM Building procedure

- Latent space learning $u \rightarrow \tilde{u}$
- Defect mapping $\tilde{u} \rightarrow \Phi$



Online Training of Autoencoder based ROM

Key Points

- **ROM time: 0.00387(s)**
- **HFM time: ~30 mins(s) ~1800(s)**
- **Speed up: 465116x ~ 47000 times faster**

ROM inference procedure

- Find latent space for a given defect config $\Phi \rightarrow \tilde{u}$
- Project latent space to full space $\tilde{u} \rightarrow u$

Defect type	Defect variable	Defect location
Localized	$\frac{\pi}{32}(R = 5.5)$	44

Sample Test Input