

>>> SymAE: An Autoencoder With Embedded Physical Symmetries
>>> Applications To Passive Time-Lapse Monitoring

Pawan Bharadwaj

Earth Resources Laboratory Annual Meeting, 20 May 2020

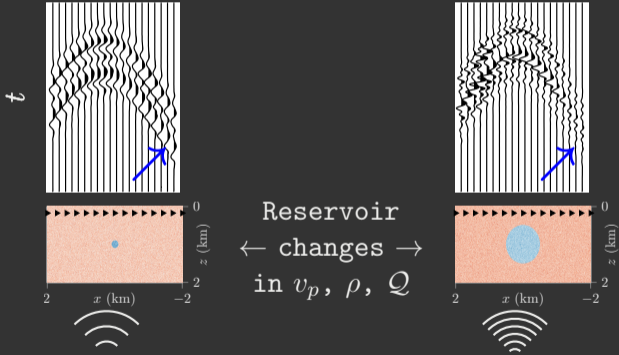
Massachusetts Institute of Technology

Thanks to my collaborators Matt Li and Laurent Demanet

>>> SymAE's Code Disentangles Source And Path Effects

Baseline records

Monitor records

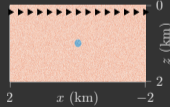
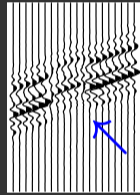
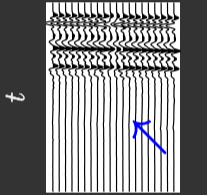


Problem: Non-stationary source signature

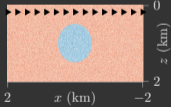
>>> SymAE's Code Disentangles Source And Path Effects

Baseline records

Monitor records



Reservoir
← changes →
in v_p, ρ, Q



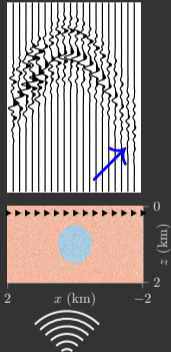
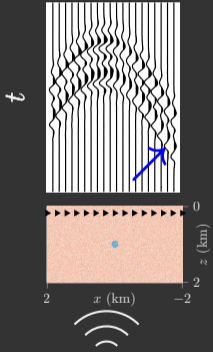
Problem: Non-stationary direction of arrival (DOA)

>>> SymAE's Code Disentangles Source And Path Effects

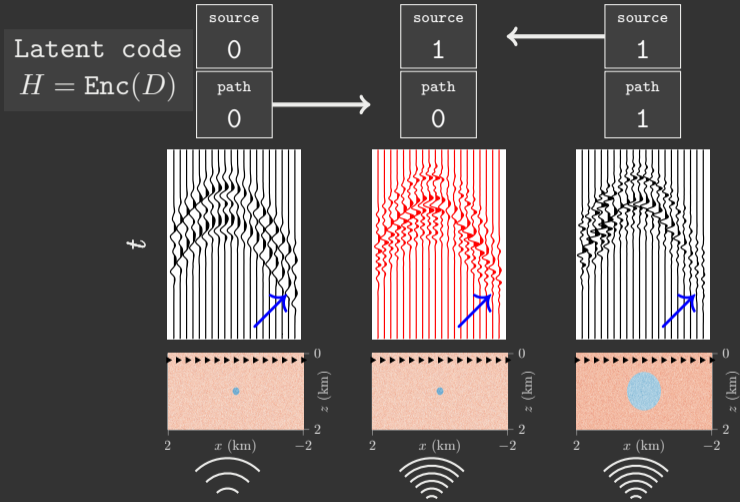
Latent code
 $H = \text{Enc}(D)$

source
0
path
0

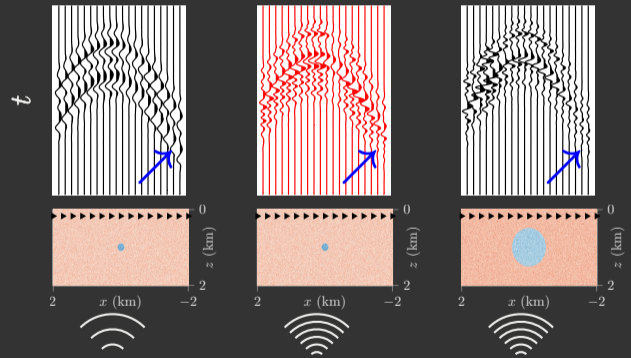
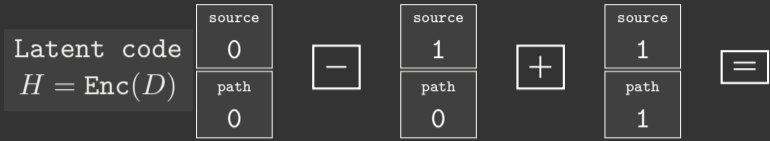
source
1
path
1



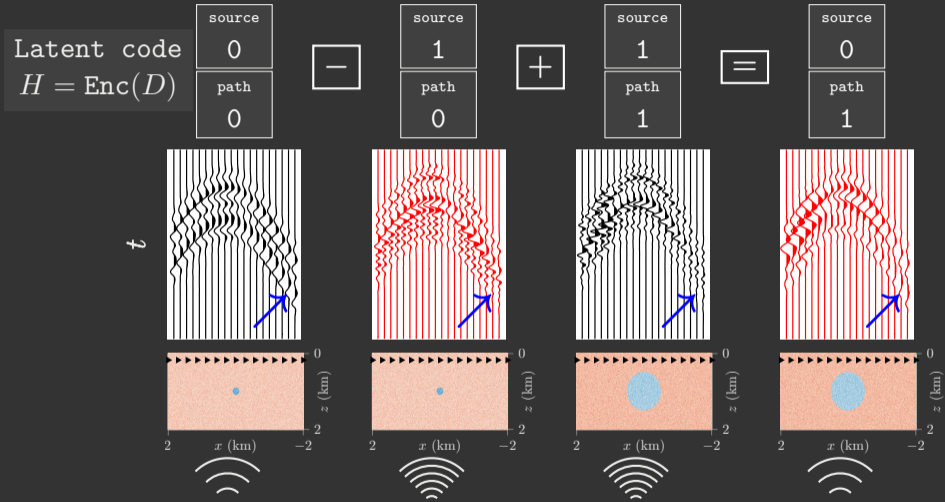
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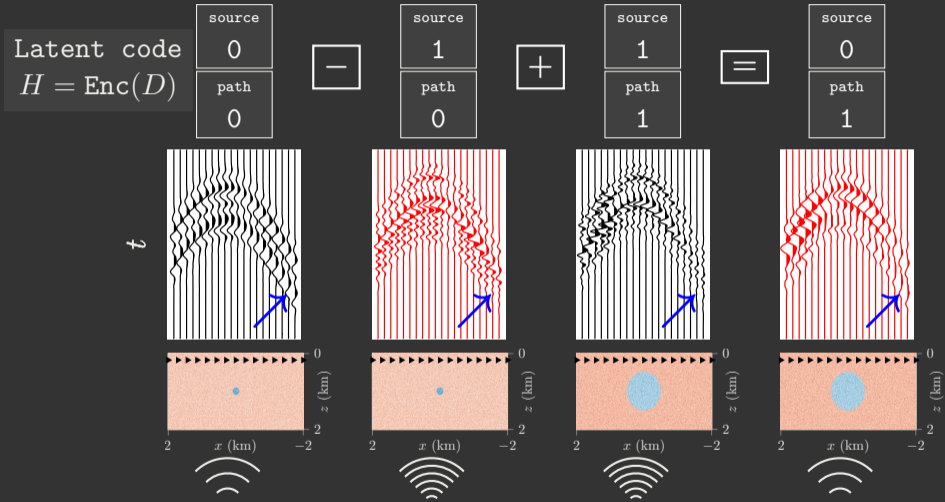
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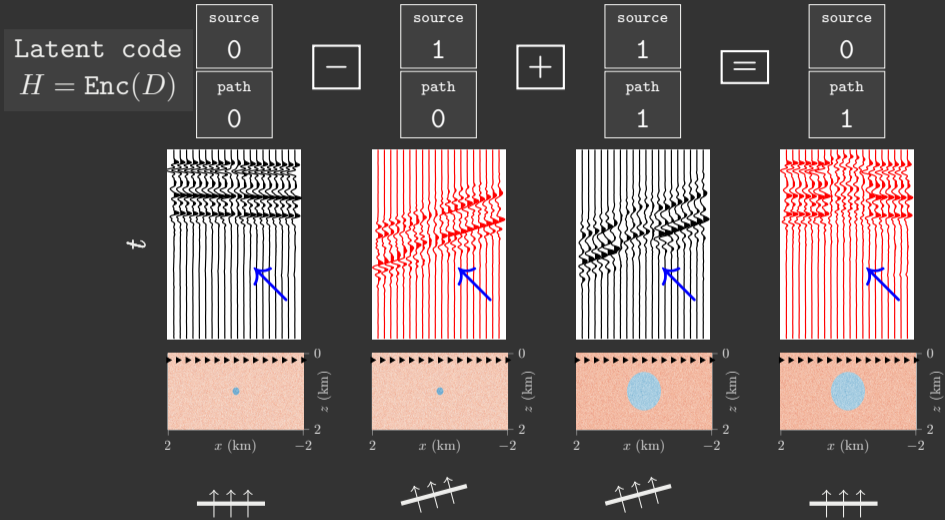


>>> SymAE's Code Disentangles Source And Path Effects



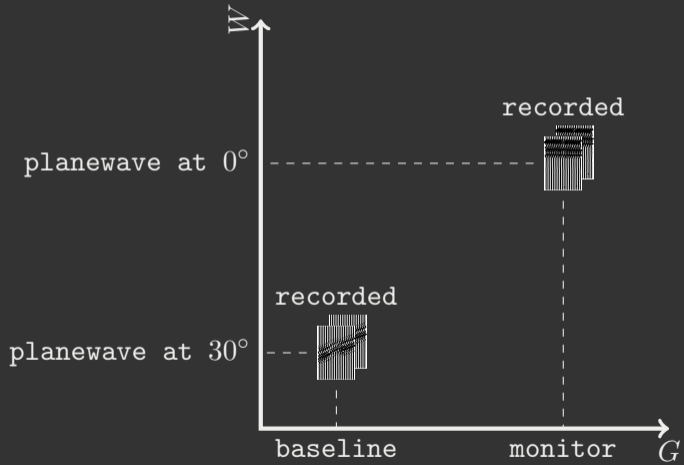
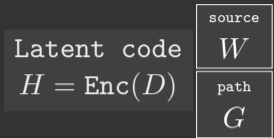
Solution: SymAE's hybrid records have identical source signature

>>> SymAE's Code Disentangles Source And Path Effects

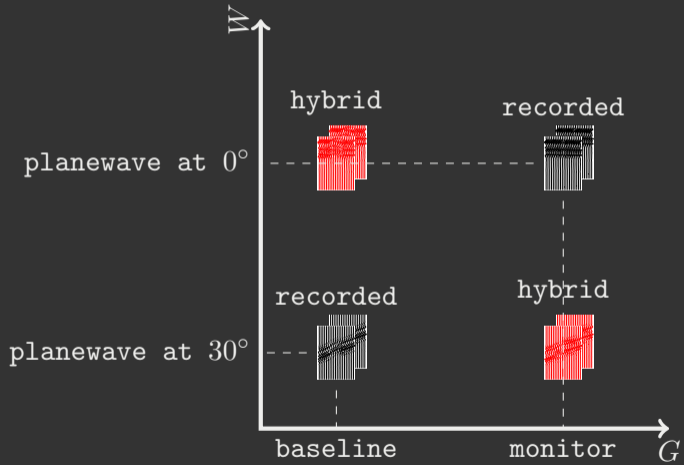
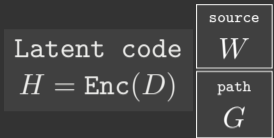


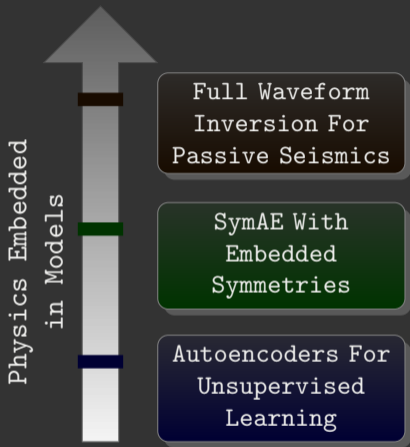
Solution: SymAE's hybrid records have identical direction of arrival (DOA)

>>> SymAE's Latent-space Structure

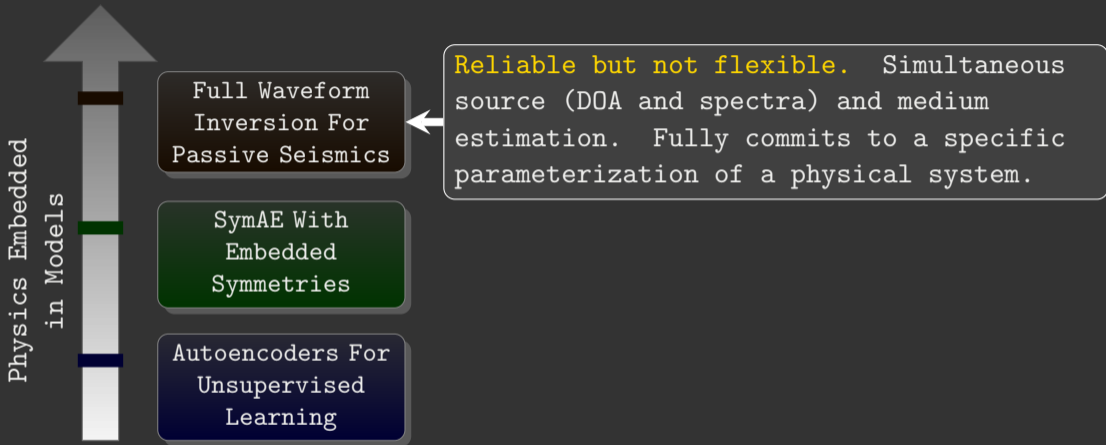


>>> SymAE's Latent-space Structure

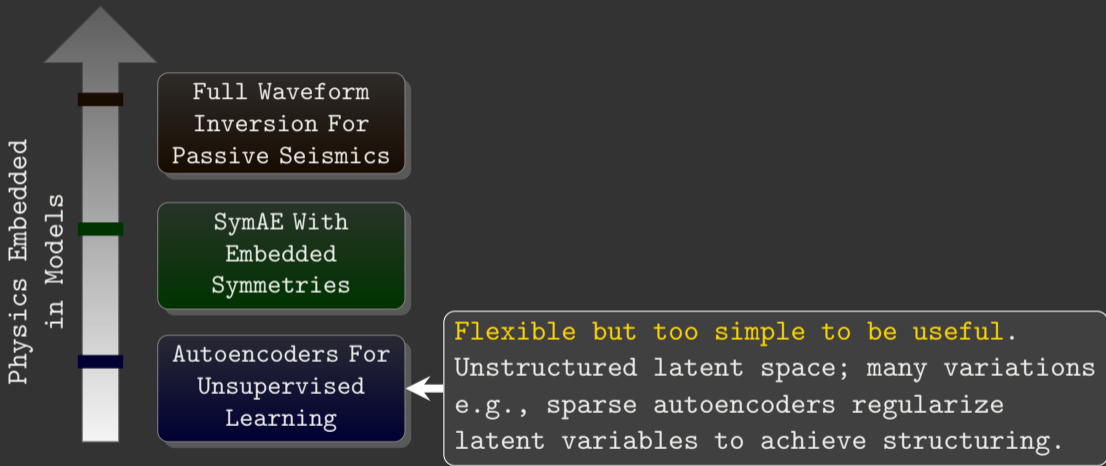




>>> Overview



See Sager et al., 2018, Towards Full Waveform Ambient Noise Inversion



>>> Autoencoder¹

Encoder

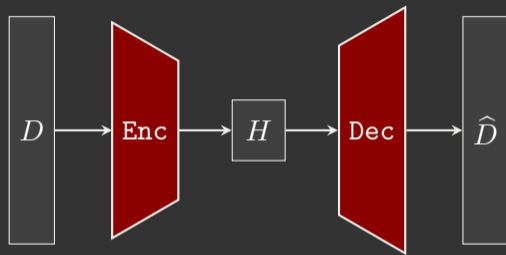
$$H_i = \text{Enc}(D_i)$$

Decoder

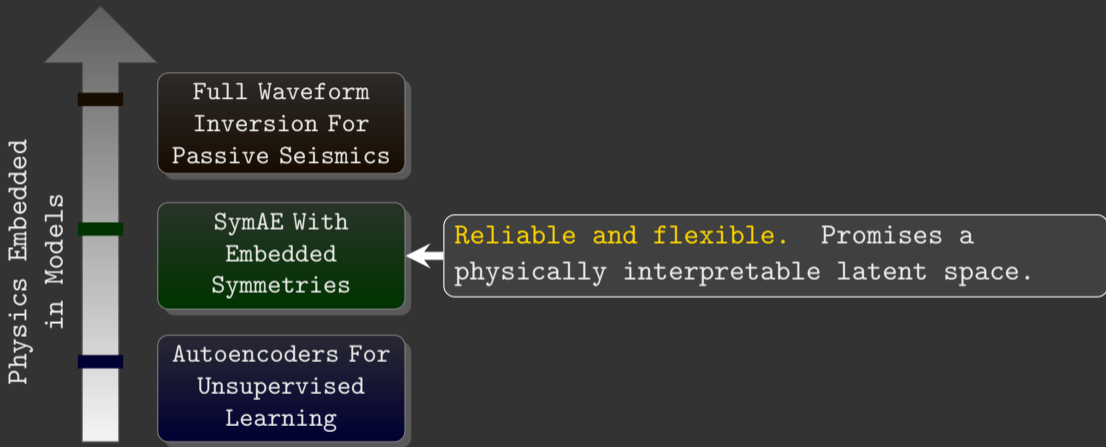
$$\widehat{D}_i = \text{Dec}(H_i)$$

Training

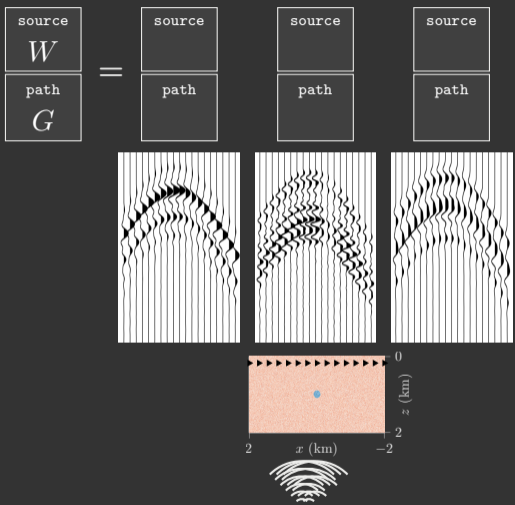
$$\text{Enc, Dec} = \arg \min_{\text{Enc, Dec}} \sum_i \|D_i - \text{Dec}(\text{Enc}(D_i))\|^2$$



¹Kramer, M. A., 1991, Nonlinear principal component analysis using autoassociative neural networks, AIChE Journal.



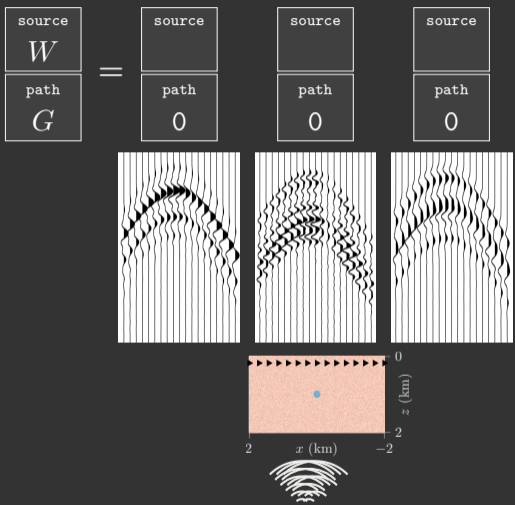
>>> Symmetries



Symmetry 1

The path-specific latent code G is symmetric w.r.t. the labeling of sources.

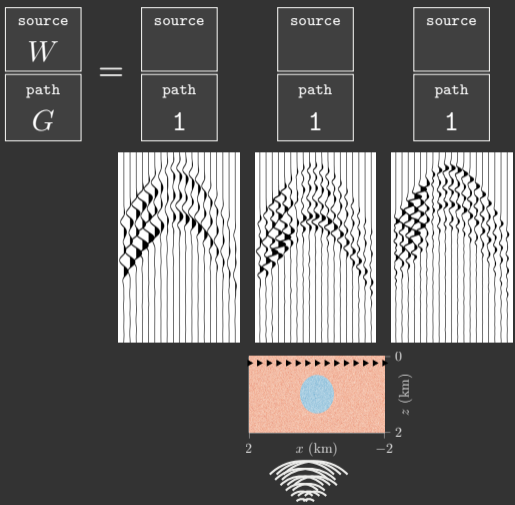
>>> Symmetries



Symmetry 1

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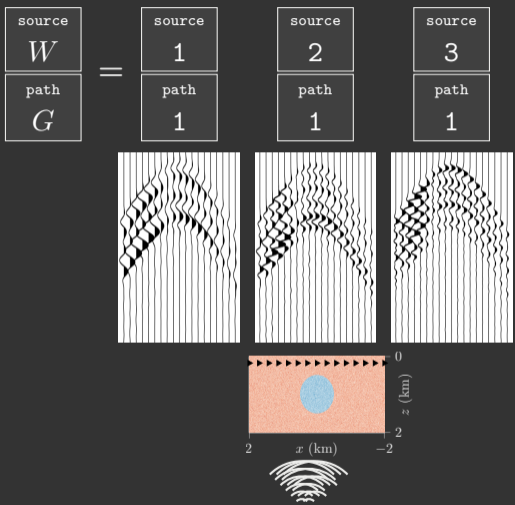
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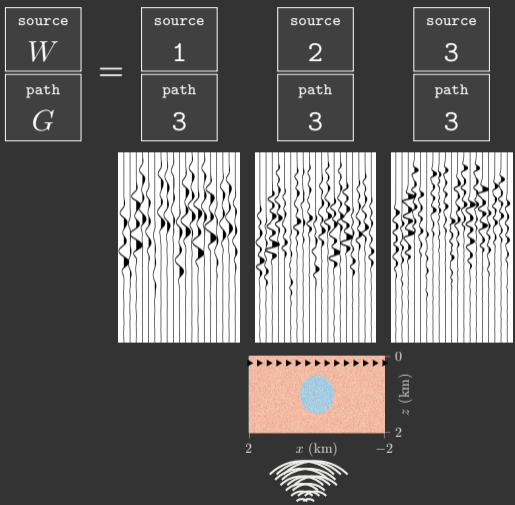
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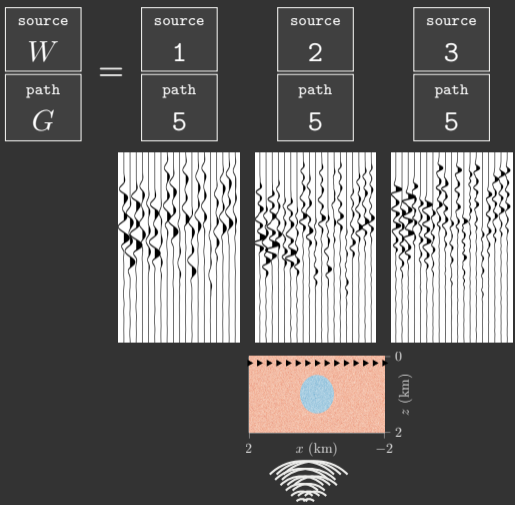
Symmetry 1

The path-specific latent code G is symmetric w.r.t. the labeling of sources.

Symmetry 2

The source-specific latent code W is symmetric w.r.t. the labeling of receivers.

>>> Symmetries



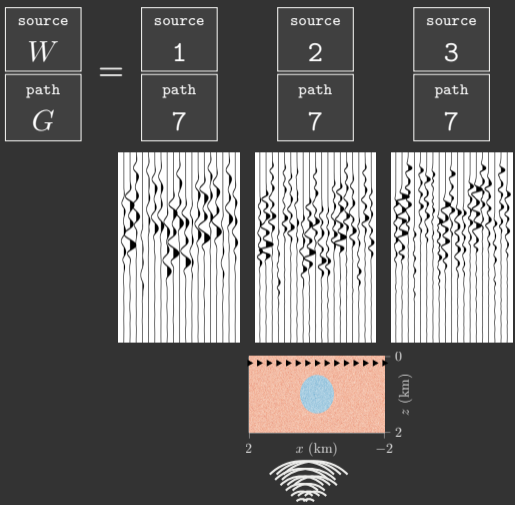
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>>> Symmetries



Symmetry 1

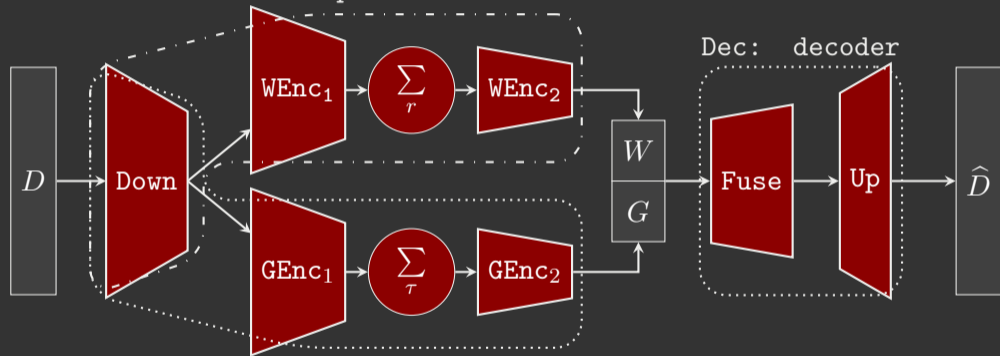
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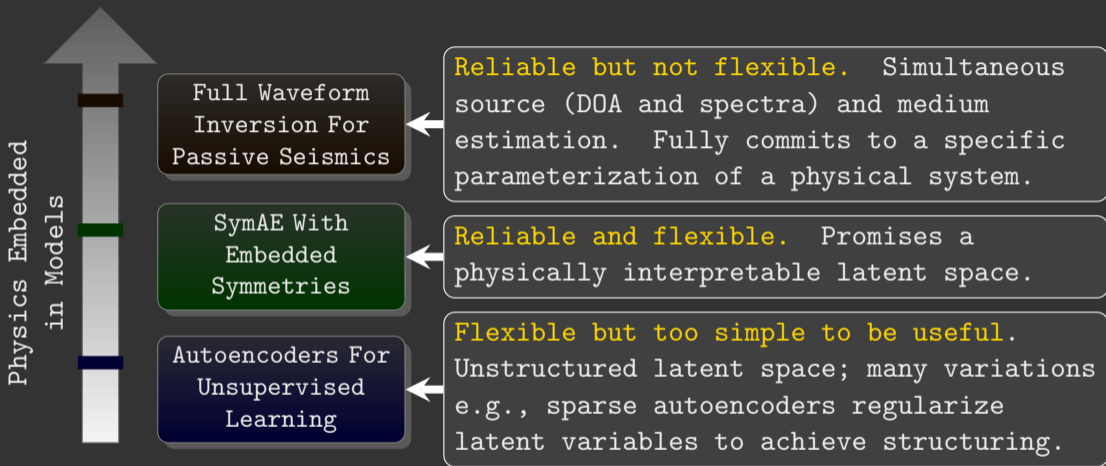
>>> SymAE's Network Architecture

WEnc: source encoder/ path-effect annihilator

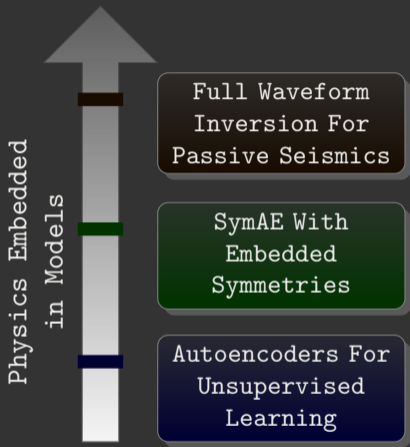


GEnc: path-effect encoder/ source annihilator

>>> Conclusions



>>> Conclusions



Thank you! Questions?!

Acknowledgements

Total S.A. for support.

Developers of deep learning packages in Julia and Python: Flux.jl, Tensorflow, Keras.