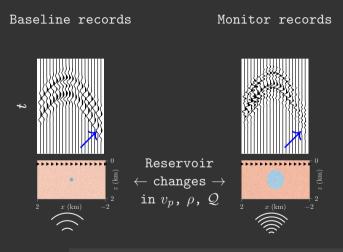
>>> SymAE: An Autoencoder With Embedded Physical Symmetries
>>> Applications To Passive Time-Lapse Monitoring

Pawan Bharadwaj

Earth Resources Laboratory Annual Meeting, 20 May 2020

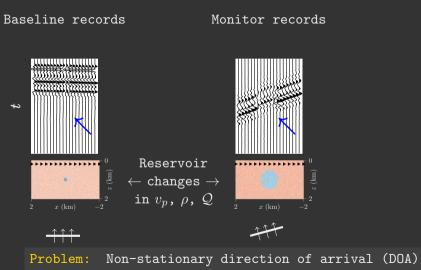
Massachusetts Institute of Technology

Thanks to my collaborators Matt Li and Laurent Demanet

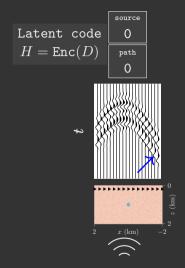


Problem: Non-stationary source signature

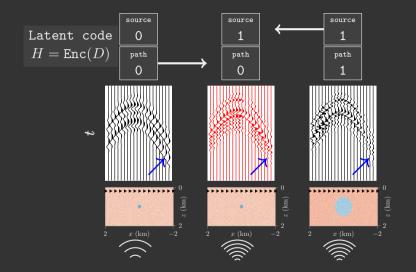
[pavbz/SymAE]\$ _ [2/9]



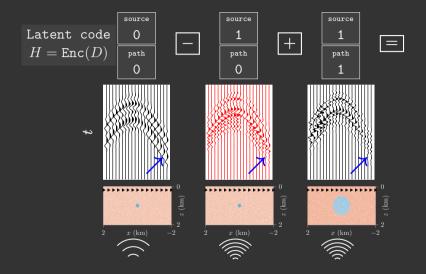
[pawbz/SymAE] \$ _

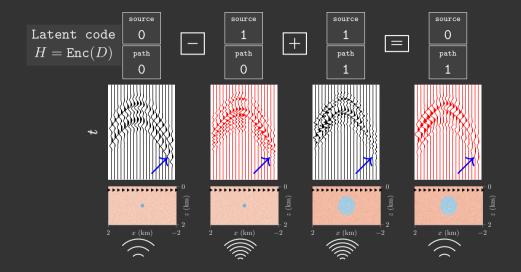




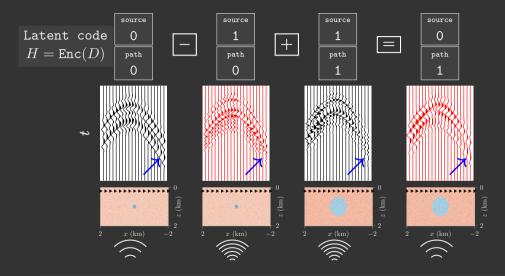


[pawbz/SymAE]\$ _ [2/9]



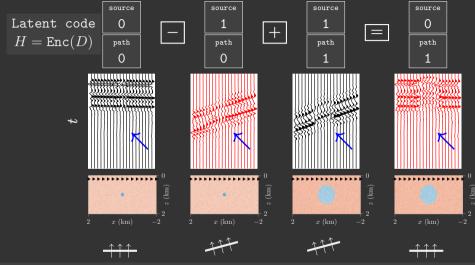


[pavbz/SymAE]\$ _ [2/9]



Solution: SymAE's hybrid records have identical source signature

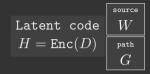
[pawbz/SymAE]\$_

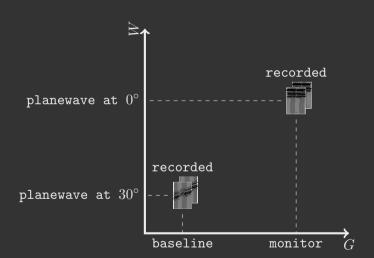


Solution: SymAE's hybrid records have identical direction of arrival (DOA)

[pawbz/SymAE]\$ _ [2/9]

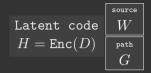
>>> SymAE's Latent-space Structure

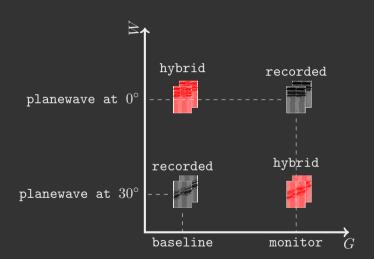




[pawbz/SymAE]\$ _ [3/9

>>> SymAE's Latent-space Structure





[paubz/Sym#E]\$ _ [3/9]



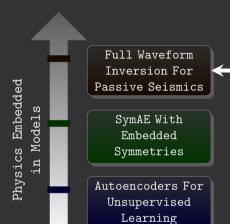
Full Waveform
Inversion For
Passive Seismics

SymAE With Embedded Symmetries

Autoencoders For Unsupervised Learning

[pawbz/SymAE]\$ _ [4/9]





Reliable but not flexible. Simultaneous source (DOA and spectra) and medium estimation. Fully commits to a specific parameterization of a physical system.

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

Physics Embedded in Models Full Waveform
Inversion For
Passive Seismics

SymAE With Embedded Symmetries

Autoencoders For Unsupervised Learning Flexible but too simple to be useful.
Unstructured latent space; many variations e.g., sparse autoencoders regularize latent variables to achieve structuring.

>>> Autoencoder¹

Encoder

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

Decoder

$$\widehat{D_i} = \mathtt{Dec}(H_i)$$

$D \longrightarrow Enc \longrightarrow H \longrightarrow \widehat{D}$

Training

Enc,
$$\operatorname{Dec} = \underset{\operatorname{Enc, Dec}}{\operatorname{arg\,min}} \sum_{i} \|D_i - \operatorname{Dec}(\operatorname{Enc}(D_i))\|^2$$

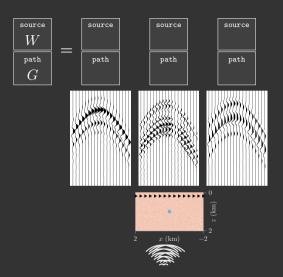
¹Kramer, M. A., 1991, Nonlinear principal component analysis using autoassociative neural networks, AIChE Journal.



Full Waveform
Inversion For
Passive Seismics

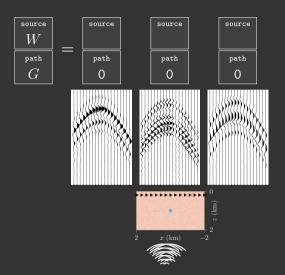
SymAE With Embedded Symmetries

Autoencoders For Unsupervised Learning Reliable and flexible. Promises a physically interpretable latent space.



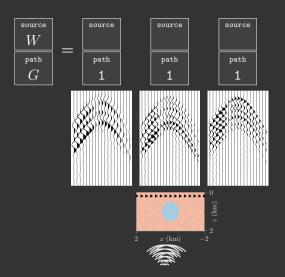
Symmetry 1

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



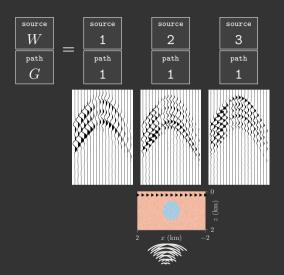
Symmetry 1

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



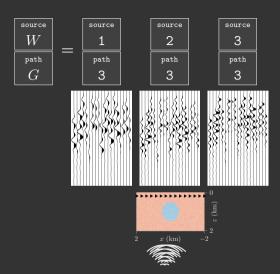
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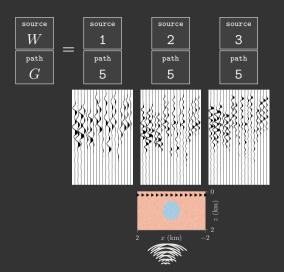


Symmetry 1

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.

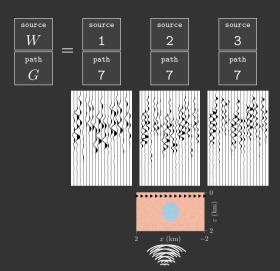


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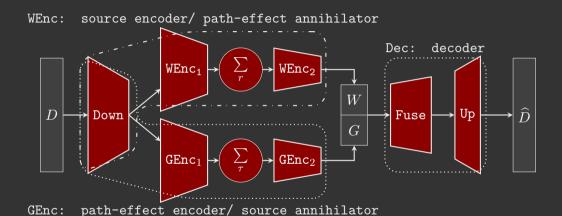


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[pavbz/SymAE]\$ _ [8/9]

Physics Embedded in Models Full Waveform
Inversion For
Passive Seismics

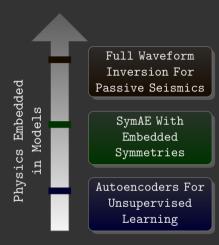
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[pavbz/SymAE]\$ - [9/9]



Thank you! Questions?!

Acknowledgements

Total S.A. for support.

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