Friedrich-Alexander-Universität
Technische Fakultät

SIEMENS Healthineers

Pattern Recognition Lab

Speed-of-Sound Mapping for Pulse-Echo Ultrasound Raw Data using Linked-Autoencoders

Farnaz Khun Jush[1], Peter M. Dueppenbecker[2], Andreas Maier[1]

[1] Pattern Recognition Lab, Friedrich-Alexander-University, Erlangen, Germany

[2] Technology Excellence, Siemens Healthcare GmbH, Erlangen, Germany

Workshop on Machine Learning for Multimodal Healthcare Data (ML4MHD 2023), 29th of July, Honolulu

ICML International Conference On Machine Learning

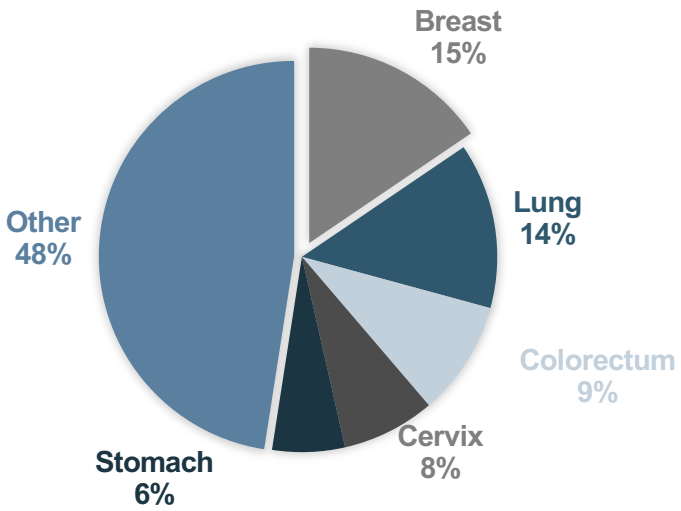
Motivation

Motivation

Breast Cancer Screening

Breast cancer is the leading cause of cancer-related death for women worlwide

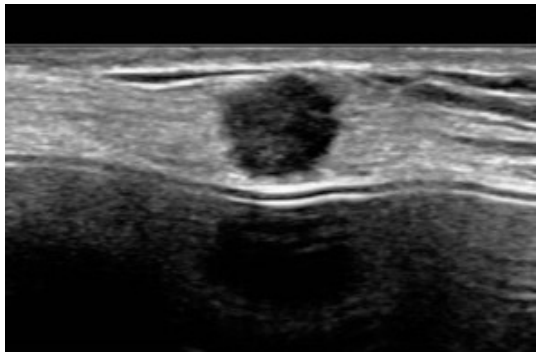
Mortality rates among cancers[1]



Gold-Standard: Xray mammography

Disadvantage: reduced sensitivity for dense breasts

(a) Digital mammogram image fails to reveal the mass (triangle denotes abnormality)[2]



(b) Handheld ultrasound easily depicts a mass due to invasive ductal carcinoma

[1] Sung, H., Ferlay, J., Siegel, R.L., Laversanne, M., Soerjomataram, I., Jemal, A. and Bray, F., 2021. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: a cancer journal for clinicians.

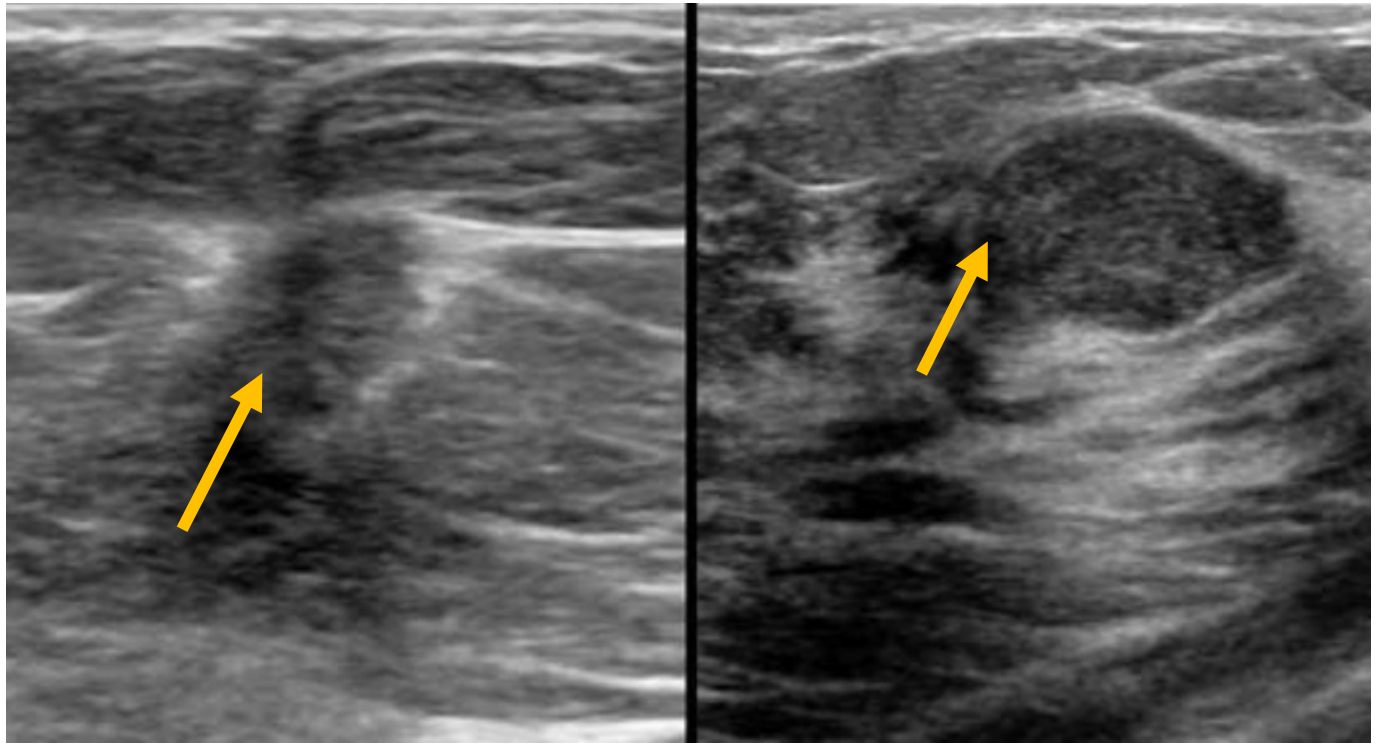
[2] Thigpen, D., Kappler, A. and Brem, R., 2018. The role of ultrasound in screening dense breasts—a review of the literature and practical solutions for implementation. Diagnostics, 8(1), p.20.

Motivation

Breast Cancer Screening

Ultrasound Shortcomings

- Dependent on operator's expertise
- Qualitative
- Similar tissue intrepretations



(a) Breast Carcinoma, Malignant and cancerous[3]

(b) Fibroadenoma, Benign and non-cancerous

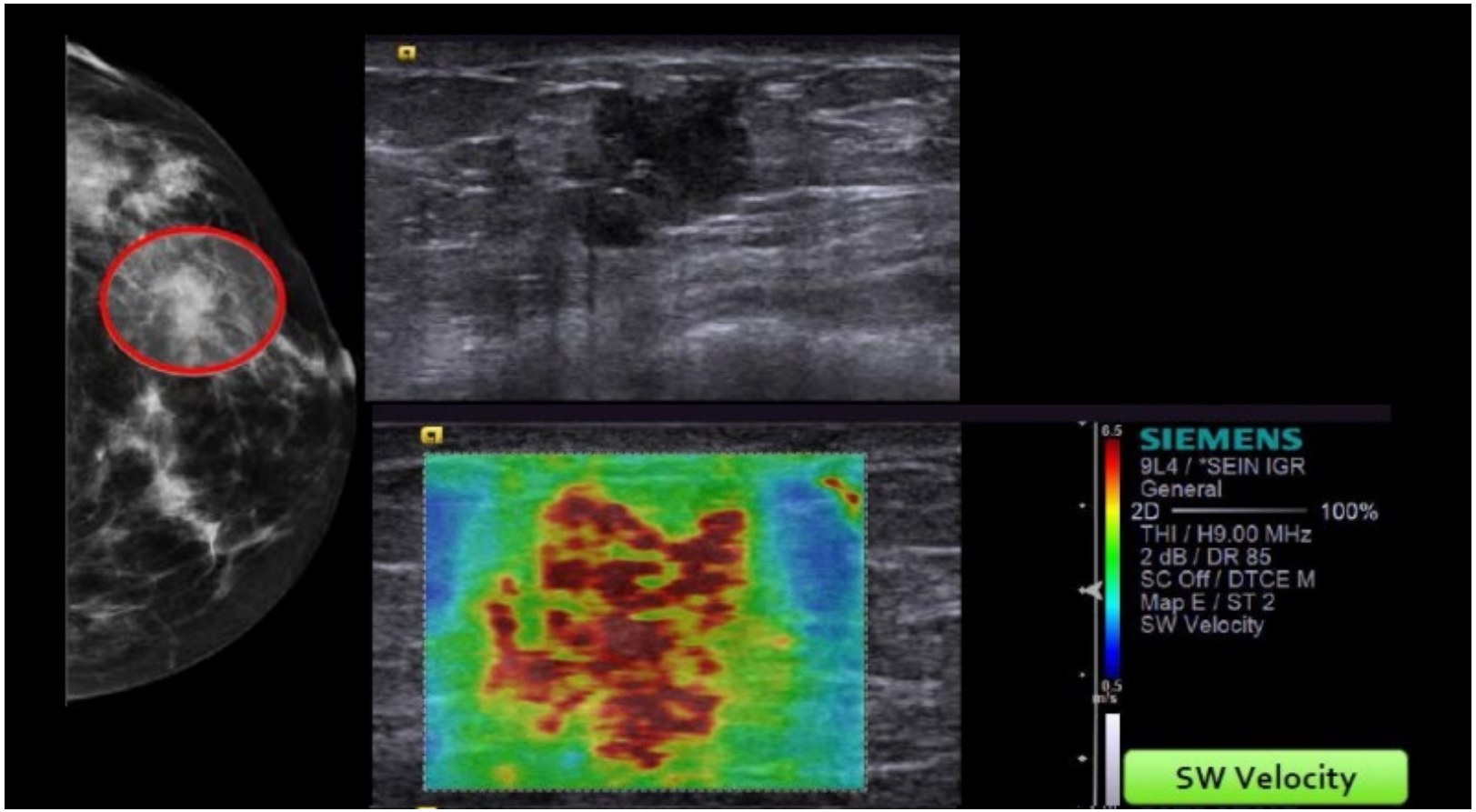
[3]Ultrasound of the Breast, Robin Smithuis, Lidy Wijers and Indra Dennert Alrijne, hospital in Leiderdorp - the Netherlands , https://radiologyassistant.nl/breast/ultrasound/ultrasound-of-the-breast

Motivation

Beyond B-mode imaging

Quantitative Information

- Density
- Speed-of-sound
- Attenuation

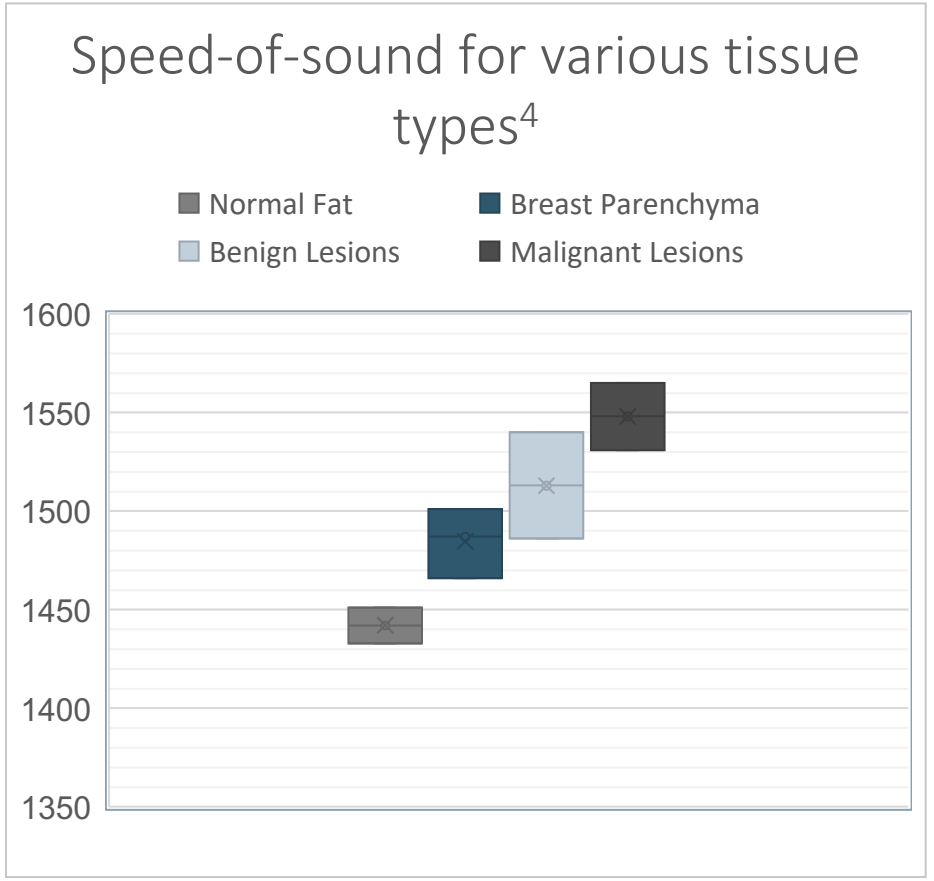


Motivation

Beyond B-mode imaging

Quantitative Information

- Density
- Speed-of-sound
- Attenuation

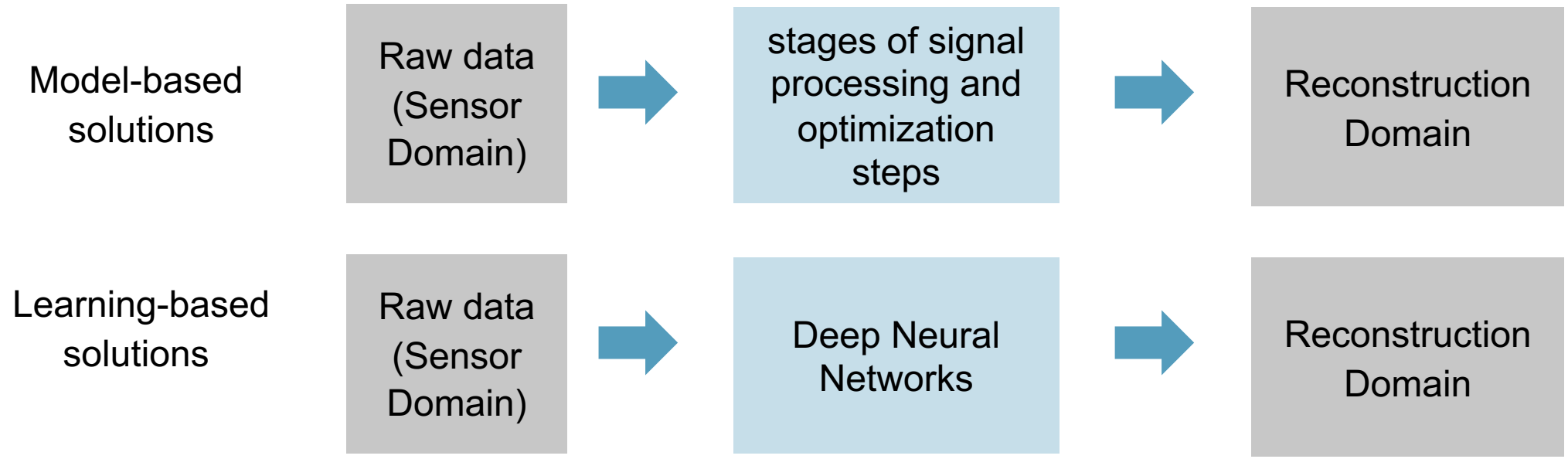


[4] Li, C., Duric, N., Littrup, P. and Huang, L., 2009. In vivo breast sound-speed imaging with ultrasound tomography. *Ultrasound in medicine & biology*, *35*(10), pp.1615-1628.

Prior Works

Prior works

- **Data Acquisition:** Transducer encodes an intermediate representation of the object under examination in the sensor domain.
- **Reconstruction:** Inversion of the corresponding encoding function:

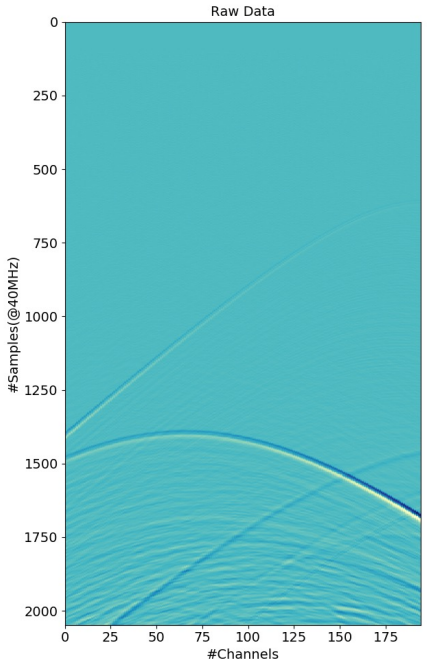


Prior works

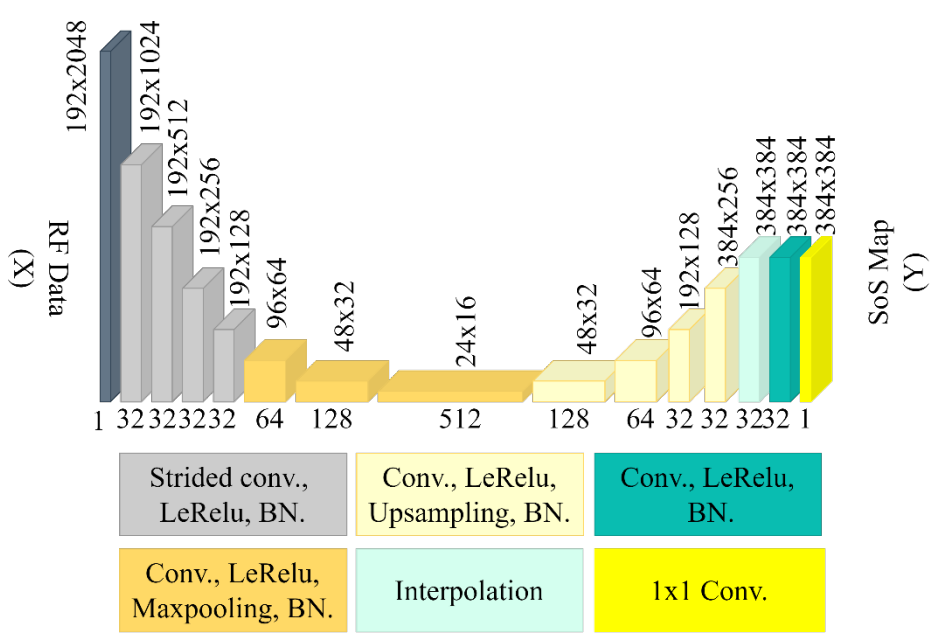
End-to-end trained networks

End-to-end Networks (domain transfer) trained on simulated data :

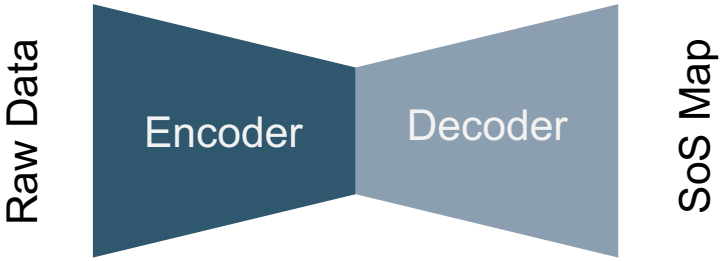
Take Raw data (RF data as input) and returns speed-of-sound map in the output

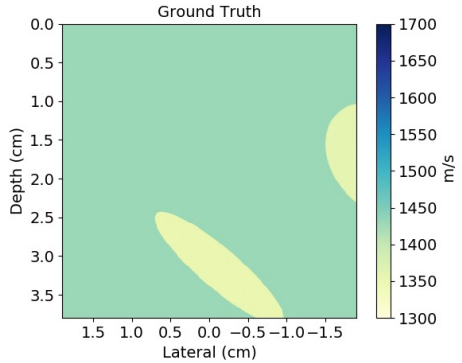


(a) Raw data



(b) Network architecture consists of encoding and decoding paths

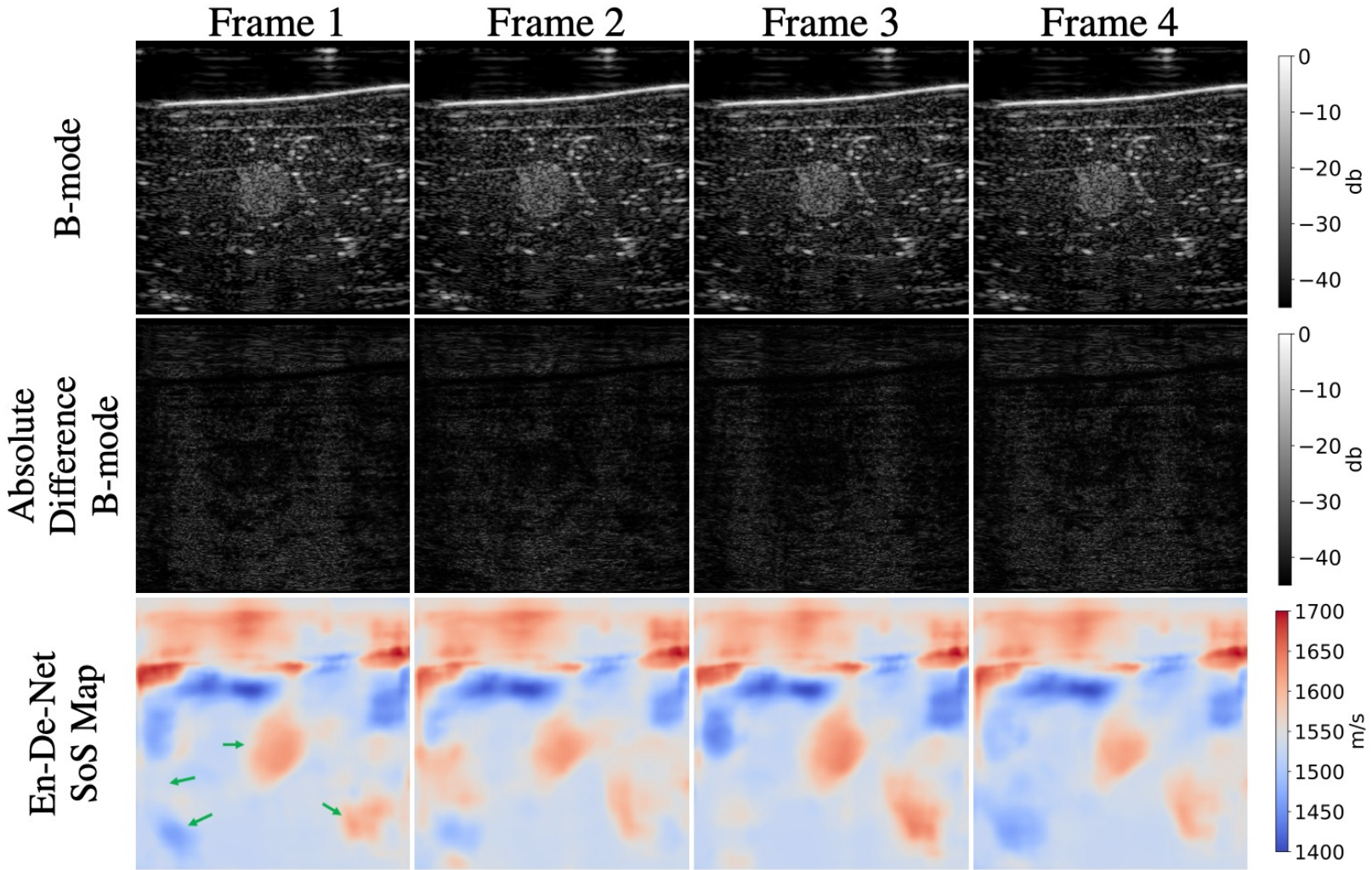




(c) Speed-of-sound ground truth

Prior works

Stability Challenges



Methods

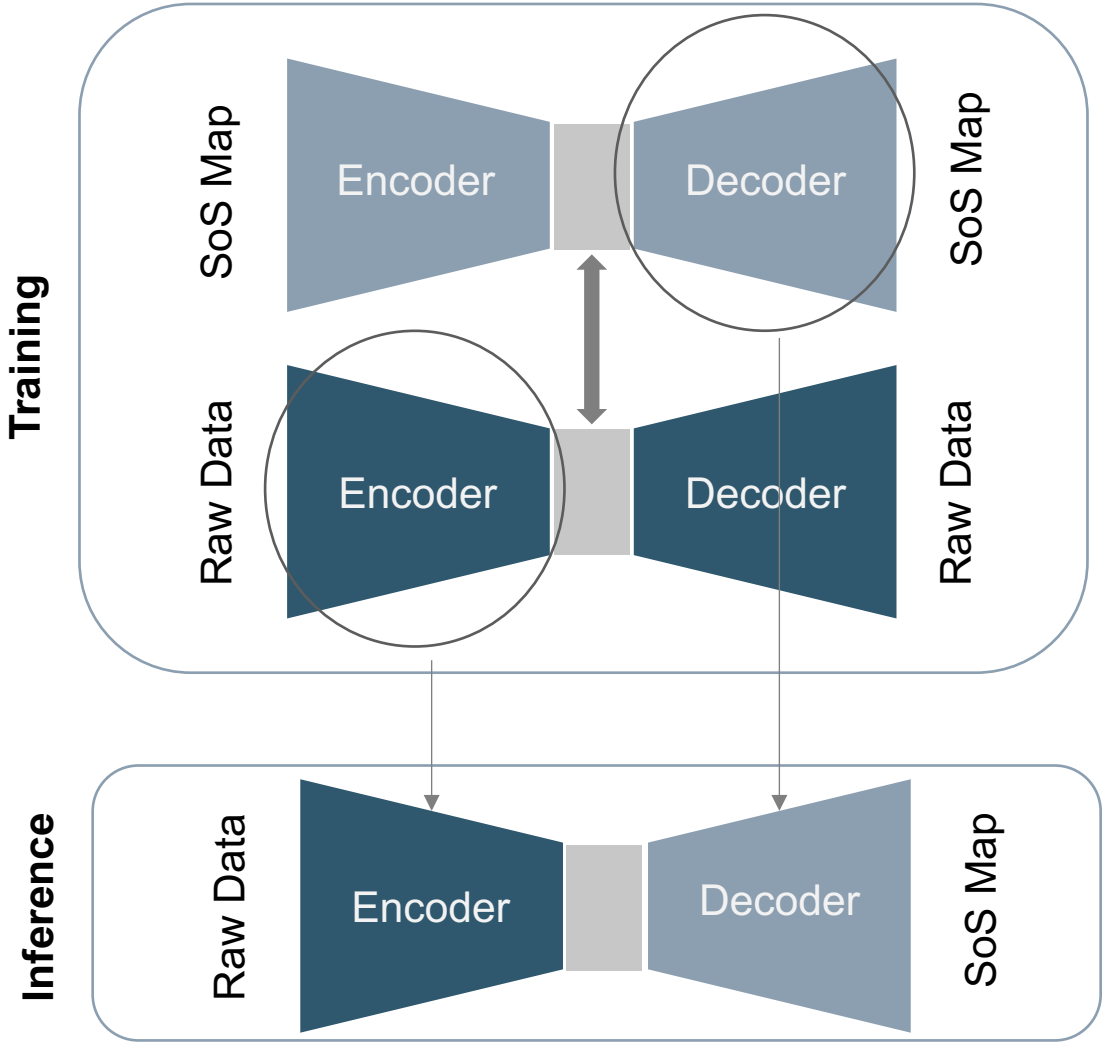
Methods

Autoencoder-based approach

Autoencoders:

I. Encode input data to an intermediate representation

II. From the intermediate representation reconstructs input in their outputs



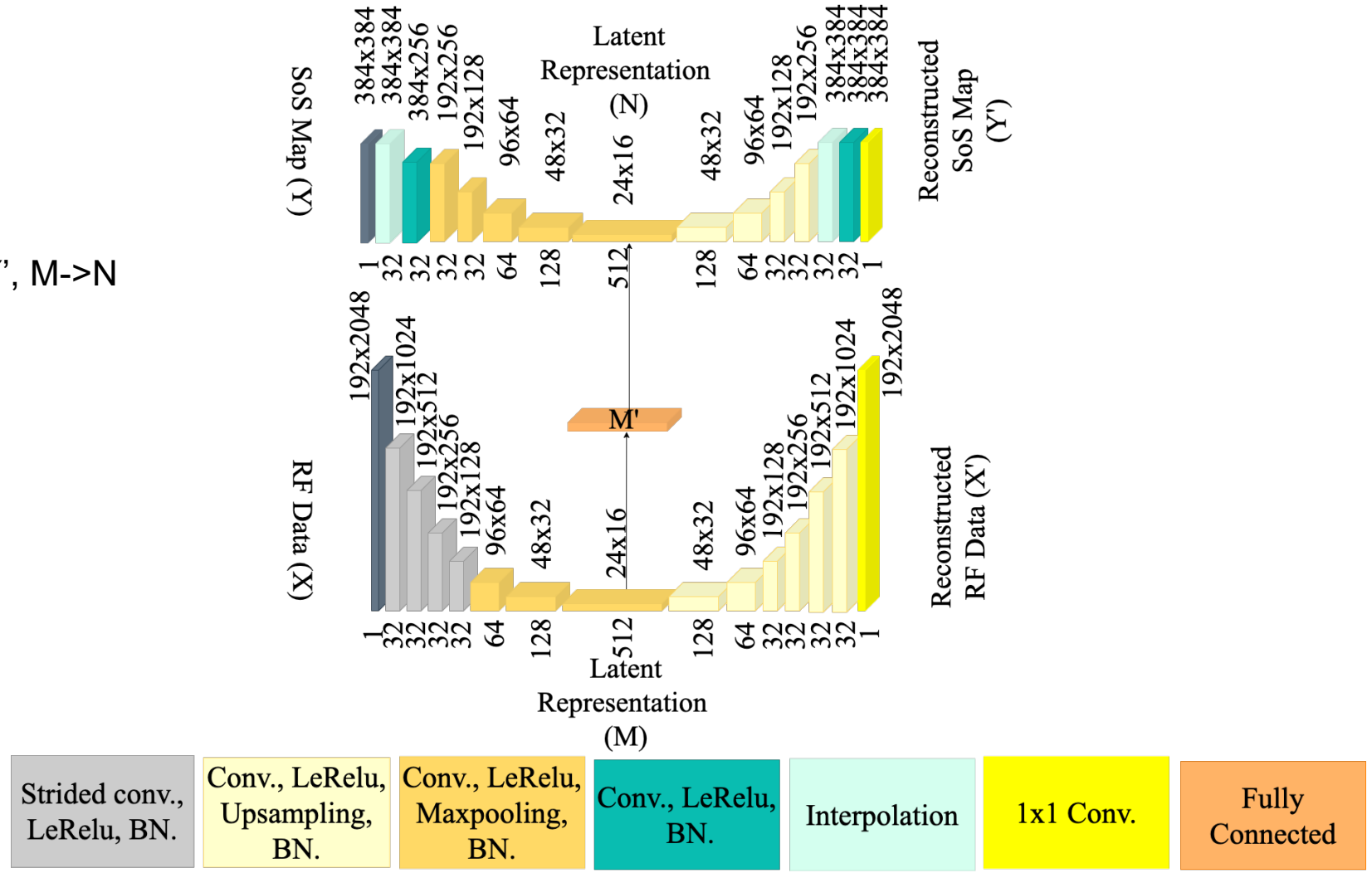
Methods

Training

Training

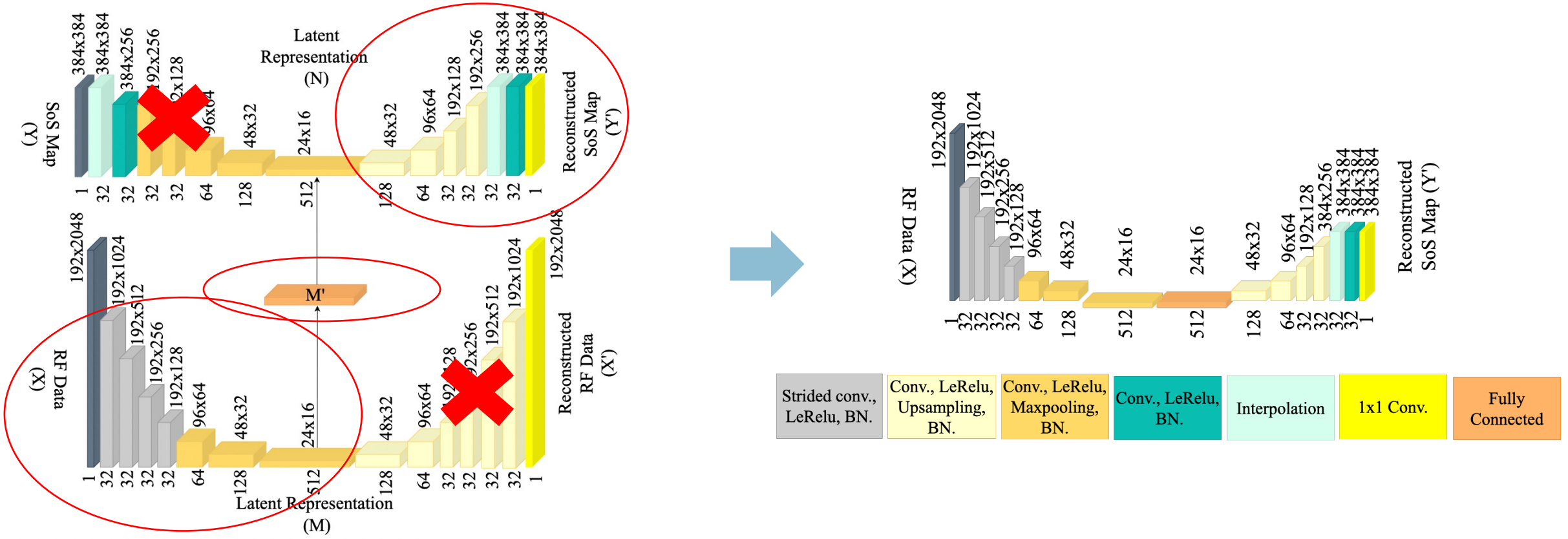
Optimizer: Adam

L2 loss: X->X' , Y->Y', M->N



Methods

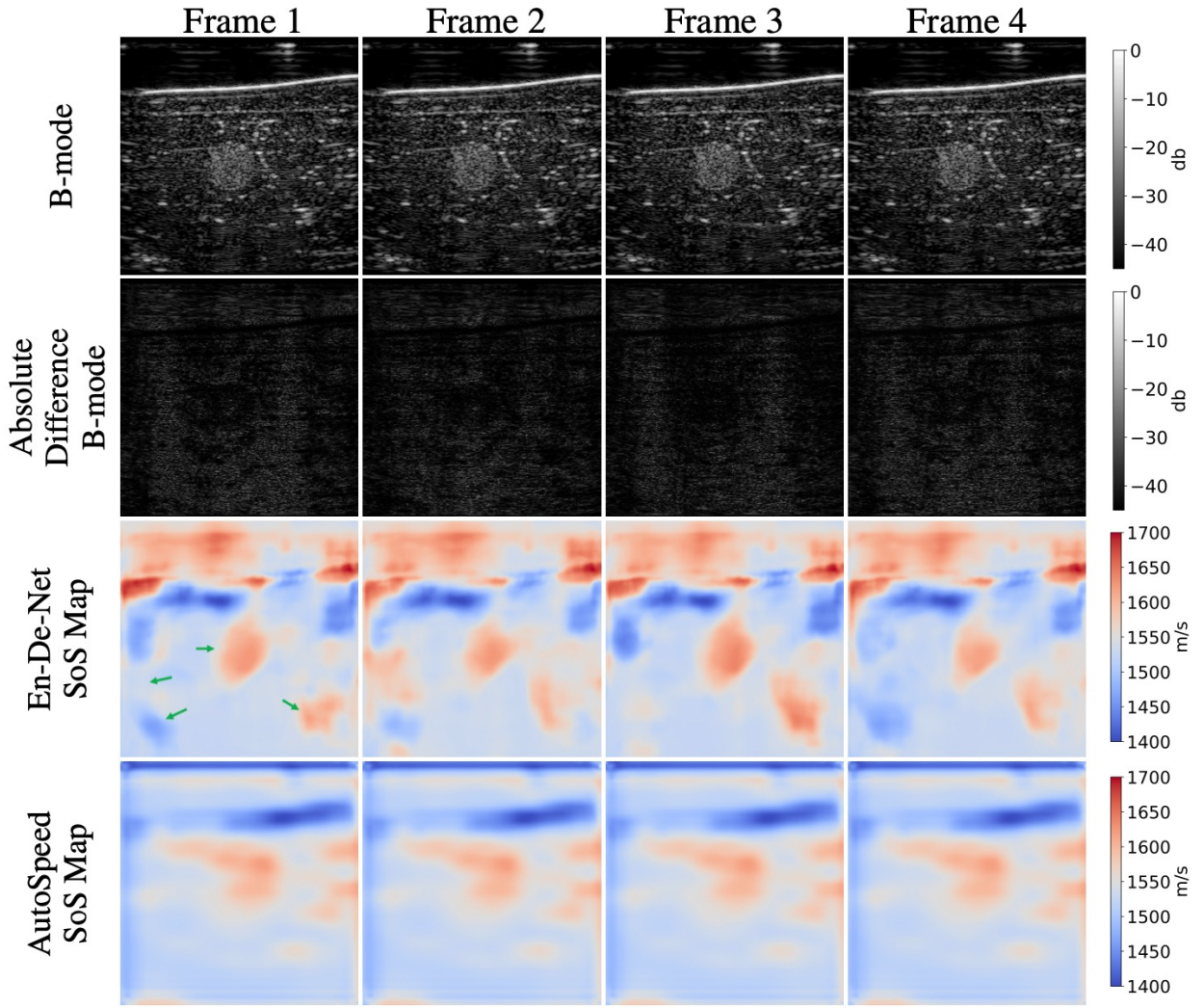
Inference



Results

Results

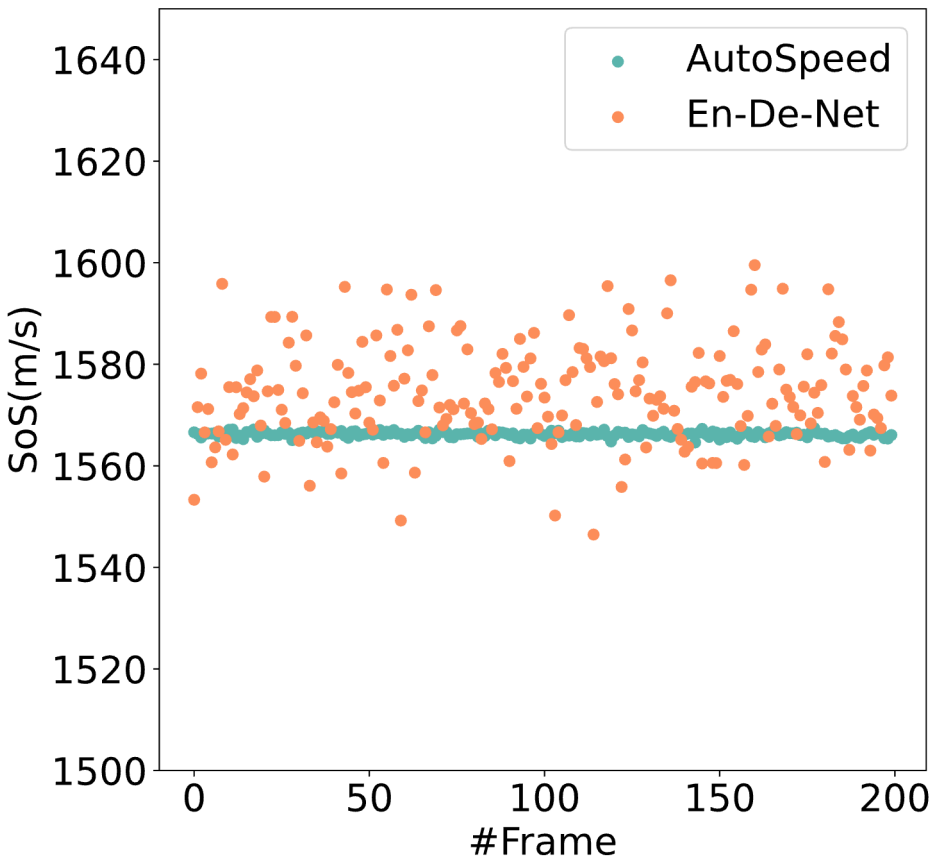
Over one frame, same field of view



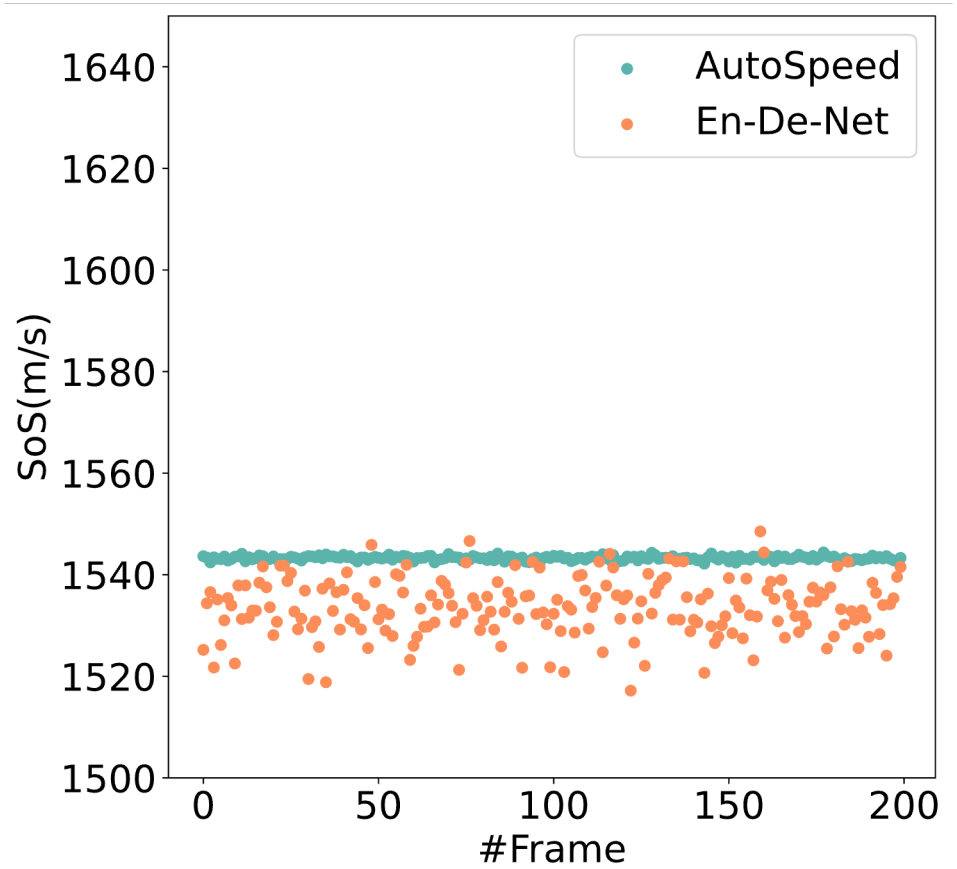
Results

Over one frame, same field of view

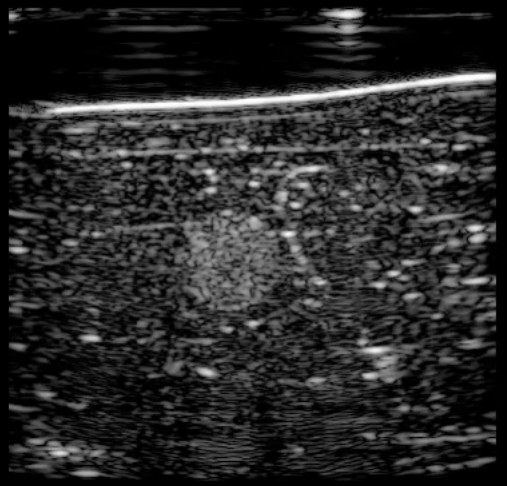
Mean SoS value inside the inclusion



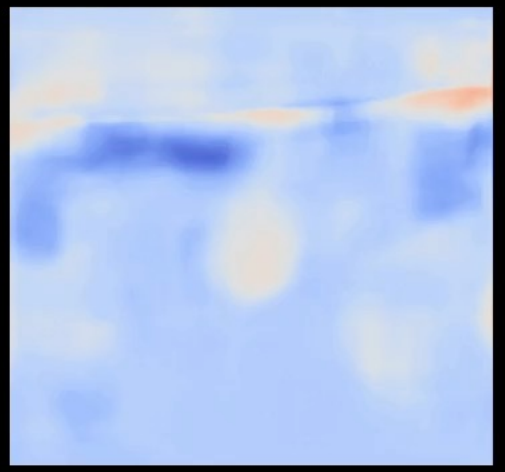
Mean SoS value in the background



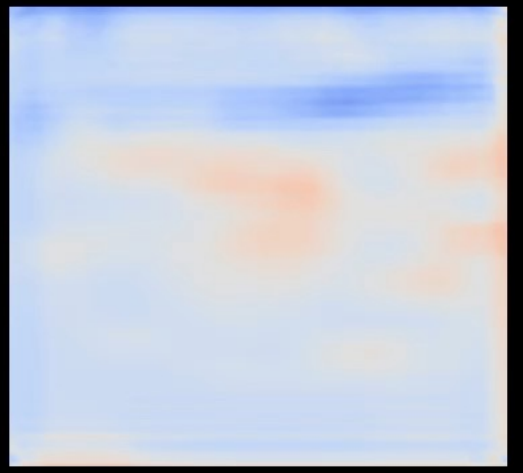
Stability comparison: AutoSpeed vs. En-De-Net



(a)



(b)



(c)

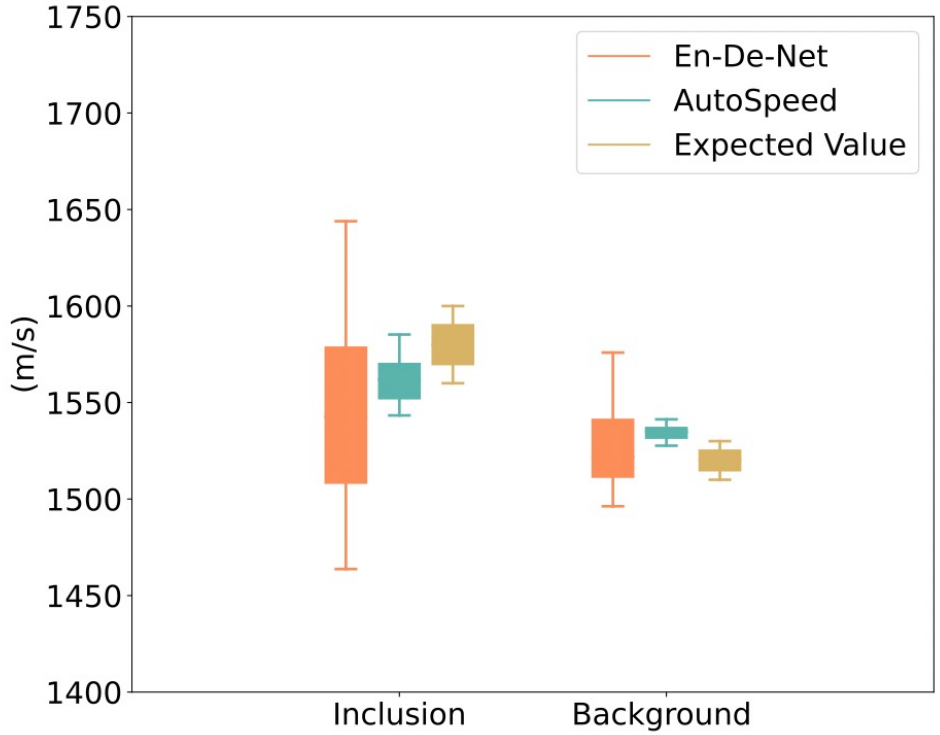
(a): 20 frames of same field of view from CIRS 073 breast mimicking phantom of size 3.8x3.8 cm in lateral and depth
(b): Corresponding reconstructed SoS maps using En-De-Net, (c): Corresponding reconstructed SoS maps using AutoSpeed
AutoSpeed shows more stability in comparison to the end-to-end trained network

Results

Multiple frames, dense inclusion in different locations

Networks Comparison:

	Background (m/s)	Inclusion (m/s)
Expected Value	1520 ± 10	1580 ± 20
AutoSpeed	1535 ± 6	1561 ± 11
En-De-Net	1527 ± 19	1545 ± 45



Conclusion and Outlook

Conclusion

- We showed that SoS mapping is possible by employing a Linked autoencoder setup
- We showed that the linked autoencoder approach is more stable compared to the end-to-end mapping solution previously being used
- Even though the network is trained using only simulated data, on the measured data setup, the predicted SoS maps are close to the expected range

Outlook

- More research is required to transfer and prove the efficiency of such methods in clinical setups

Thank you for your Attention!