Deep Learning Driven DAS Strain Conversion to Geophone Ground Motion

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Background

- Distributed Acoustic Sensing (DAS) has become a revolutionary observational technology.
- DAS, known for its high spatial resolution, environmental resilience, and ease of deployment.
- DAS inherently captures strain (or strain rate), in contrast to seismic instruments which record Ground Motion.
- Several physics-based methods have been proposed to convert DAS strain to ground motion response (displacement, velocity, or acceleration).
- Efficient conversion of strain to ground motion using physics-based methods relies on accurate estimation of phase velocity along the DAS cable which is challenging.
- To overcome this problem, we introduce a novel deep learning (DL) approach to convert high-resolution Distributed Acoustic Sensing (DAS) strain measurements into ground motion (GM) particle velocity.

Study area

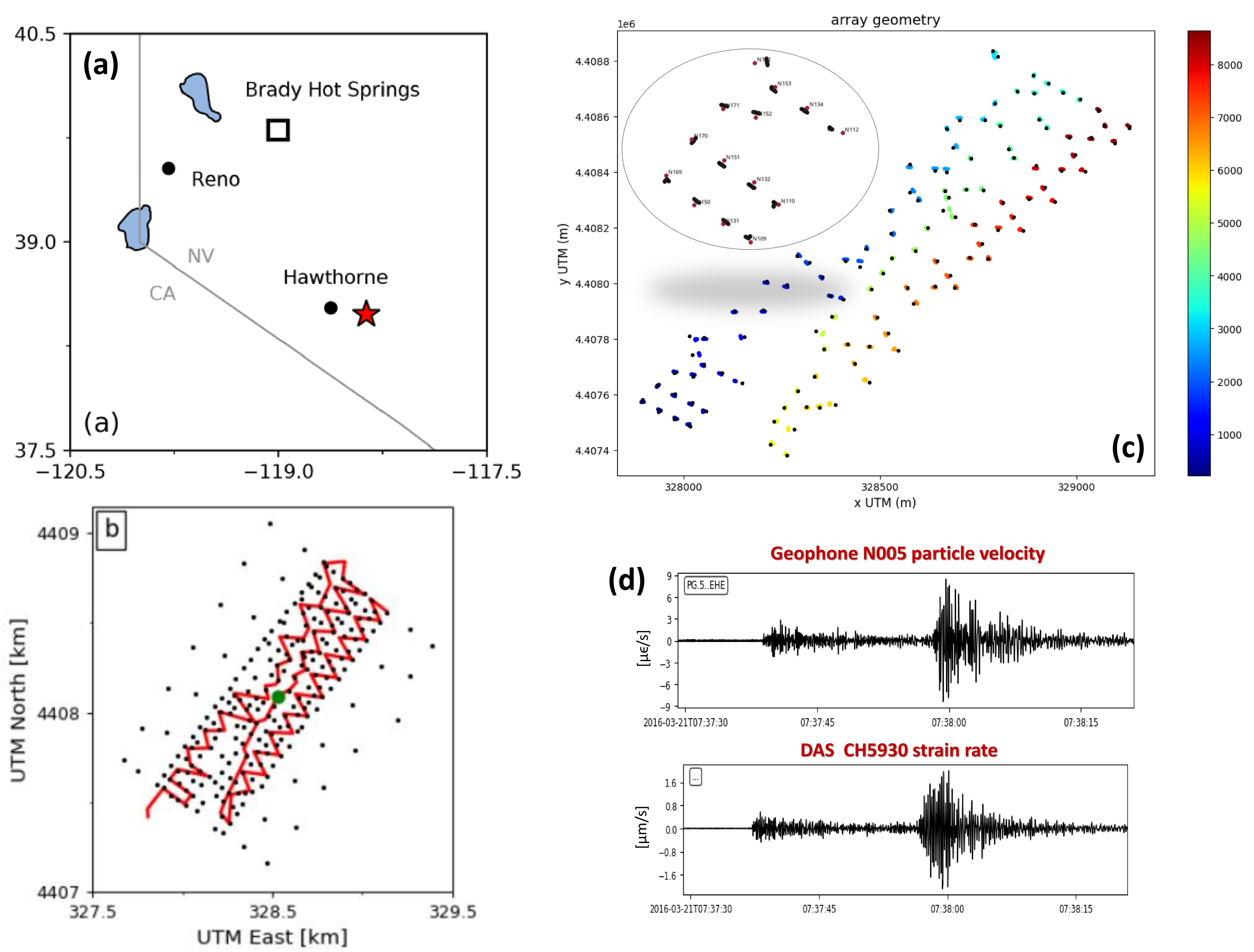

Figure 1: Location map for the Hawthorne earthquake and Brady Hot Springs (a) [2], DAS and geophones Array geometry (b) [2], selected co-located geophones with DAS channels (c), and example of co-located traces (d).

LSTM model used to convert high-resolution DAS strain to GM. The Predicted GM indicate comparable results with physics based conversion method in the frequency range 1 – 5 Hz.

Data analysis

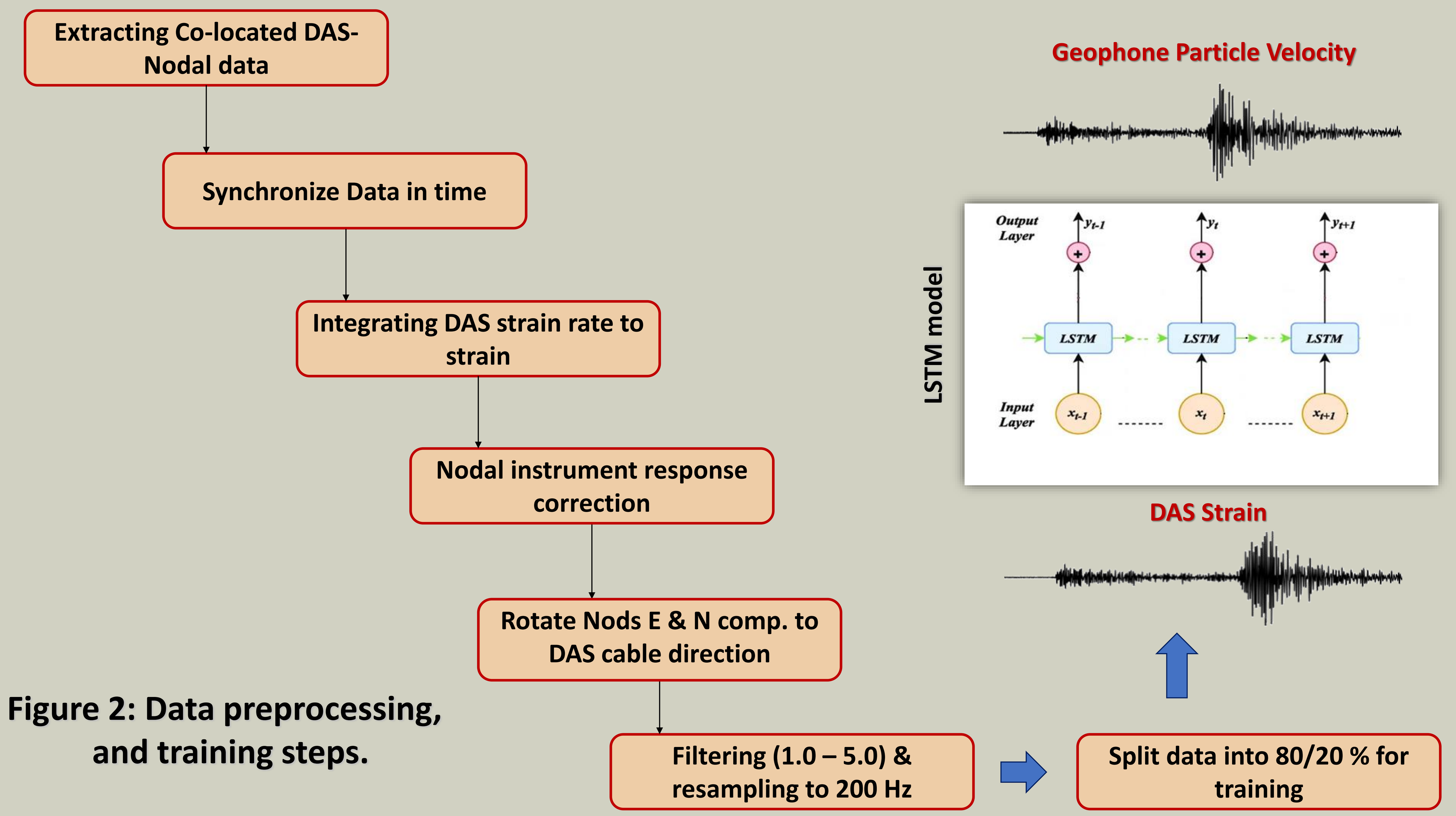

Figure 2: Data preprocessing, and training steps.

Table 1: The List of hyperparameters used in the training process.

Training set	Test set	Number of Layers	Learning Rate	Number of Epochs	Batch size
895	223	4	2.43e-05	5000	54

Results

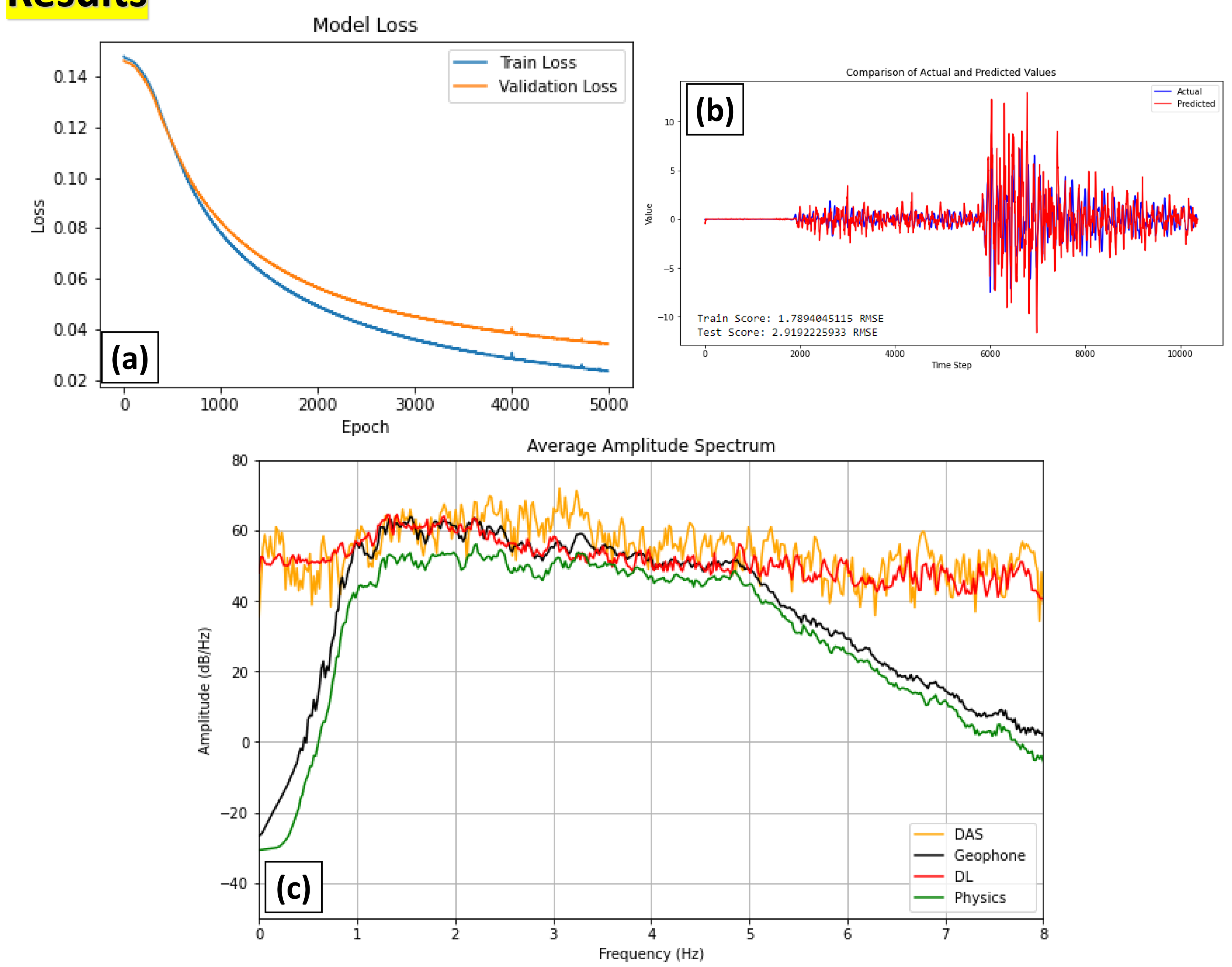

Figure 3: Training and validation Loss metric curves (a), a comparison between original and predicted geophone traces (b), and the average amplitude spectrum for DAS (orange), original (black) and predicted geophone using both physics (green) and DL (red) methods (c).

Conclusion

- Earthquake data recorded by co-located DAS-geophones at Brady Hot springs Geothermal Natural lab were used to train LSTM model.
- The model's performance is evaluated using RMSE metric, demonstrating an average values of 1.8 for training and 2.8 for testing, indicating the model's efficacy in transforming DAS strain to particle velocity.

References

1. Wang, H.F., Zeng, X., Miller, D.E., Fratta, D., Feigl, K.L., Thurber, C.H. and Mellors, R.J., 2018. Ground motion response to an ML 4.3 earthquake using co-located distributed acoustic sensing and seismometer arrays. Geophysical Journal International.
2. van den Ende, M.P. and Ampuero, J.P., 2021. Evaluating seismic beamforming capabilities of distributed acoustic sensing arrays. Solid Earth.
3. Feigl, K.L. and Parker, L.M., 2019. PoroTomo final technical report: poroelastic tomography by adjoint inverse modeling of data from seismology, geodesy, and hydrology (No. 3.1). Univ. of Wisconsin, Madison, WI (United States).