**Title**: A deep learning-based dual latent space model for physical flow parameter estimation using fiber-optic sensing data.

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**Keywords**: fiber optics sensing, deep learning, dimensionality reduction, real-time predictions

**Introduction:**

**Conclusion**:

We present a novel deep learning-based architecture for the prediction of injection points and relative rates based on fiber-optic sensing measurements. The proposed methodology exploits the spatiotemporal latent space from time-lapse DAS and DTS measurements through a double-U-Net architecture. Measurements from controlled flow-loop experiments with three-phase flow are used to train the network and extract acoustic and temperature latent spaces. These are combined in order to accurately predict the points of injection along the flow-loop as well as the relative rates of each phase passing through the perforations.

The double-U-Net architecture is designed modularly, with one convolutional AutoEncoder for the time-lapse DAS data and a separate convolutional AutoEncoder for the time-lapse DTS data. However, both AutoEncoders are exactly the same in terms of architecture but trained separately due to the difference in sampling rate of the two signals. The AutoEncoders are designed with four convolutional blocks encoding the data into a latent space and four transpose convolutional blocks, which are concatenated to the original encoder blocks using residual blocks, onto the decoded time-lapse signal. The parameters are trained to minimize the difference between the original and reconstructed signals. The Encoder portion of the architectures is extracted and used to generate the acoustic and temperature latent spaces, respectively. A third network is designed to receive the combined latent space and predict a mask containing the injection locations and relative rates. The entire training process required approximately 27 minutes on a single NVIDIA Quadro M6000 GPU. Training is done with one experimental dataset, and testing is performed with different experimental data. Errors are consistently below and signal similarity is over 98.9%. When training with only half of the DAS and DTS data, we are still able to obtain predictions with less than error and over 95.6% similarity. After the training is done, predictions are obtained in under seconds.

Therefore, this model can be used for real-time predictions and evaluation of subsurface energy systems in applications such as oil and gas production, hydraulic fracturing monitoring, geologic carbon storage, and geothermal energy production. To our knowledge, our work is the first to develop a methodology for reduced-dimensional modeling of fiber-optic distributed sensing data, and the prediction of injection locations and relative rates through the enhanced latent space for accurate and real-time multiphase fluid flow characterization.