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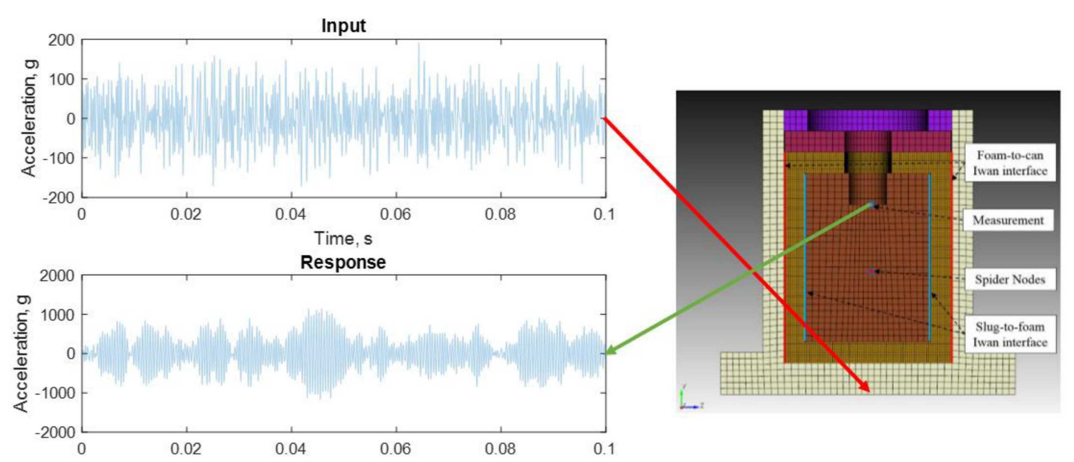
Recurrent Neural Networks for Efficient Modeling of Nonlinear Random Vibration Analysis

David A. Najera[1], Adam R. Brink[2]

MOTIVATION

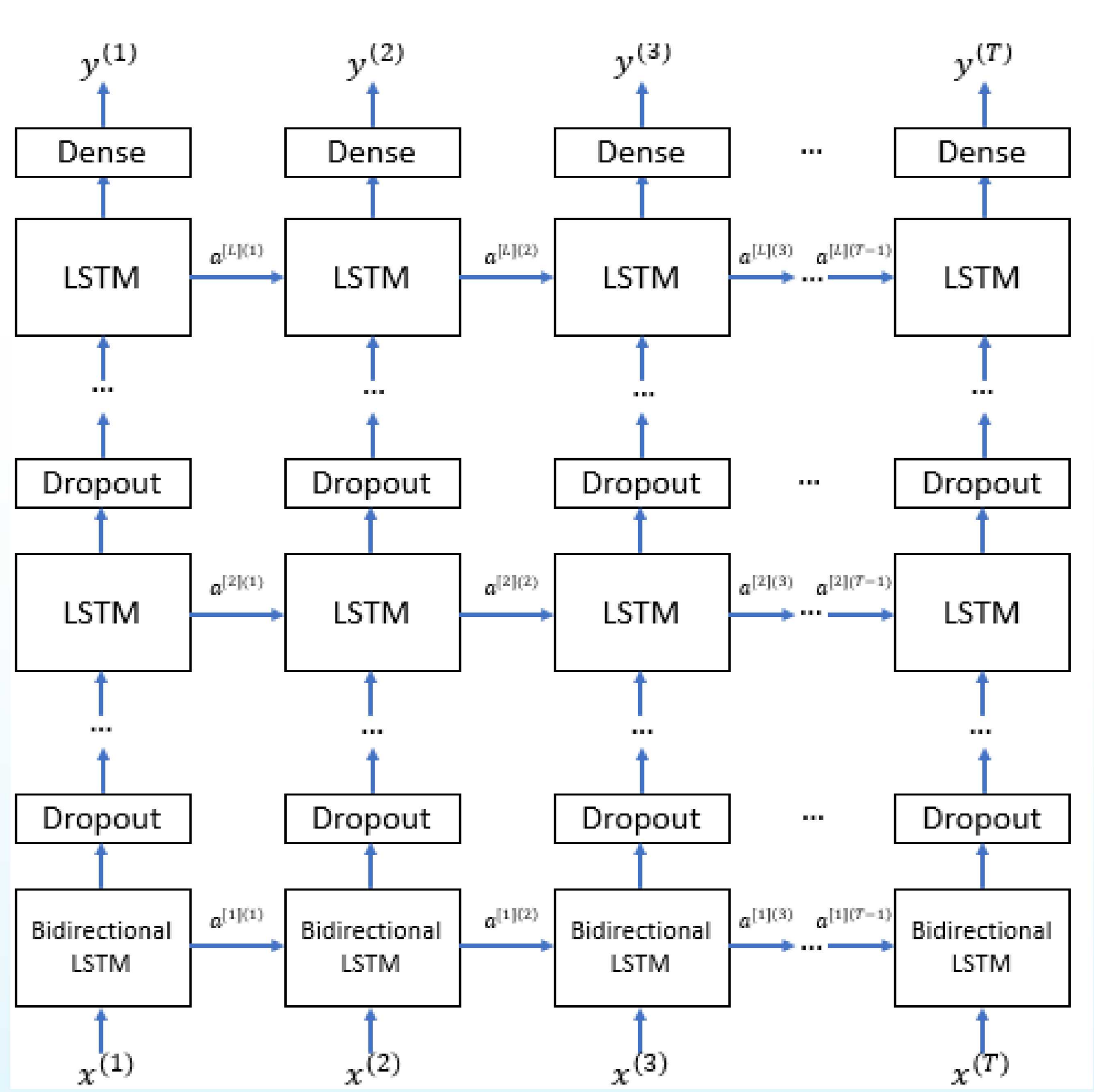
The work presented here is motivated by the need to develop an efficient method to calculate the structural response of nonlinear mechanical systems with a large number of degrees of freedom (DOF) subjected to any class of random vibration excitations.



Finite element simulations with nonlinear explicit solvers are too expensive

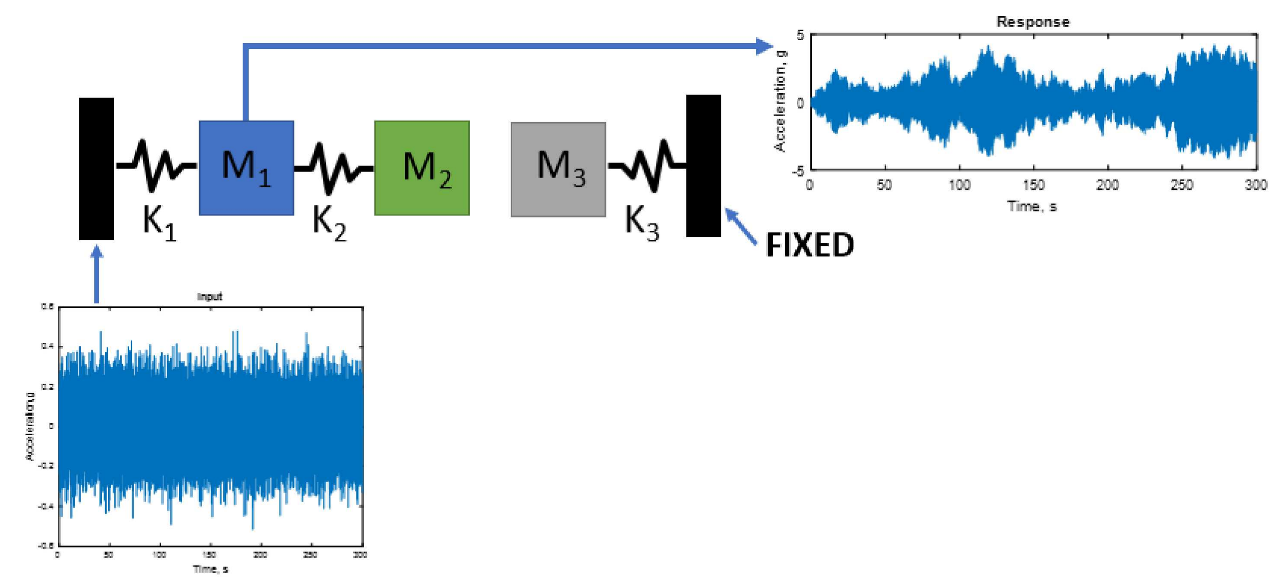
METHODOLOGY

This research proposes the use of a Long Short-Term Memory (LSTM) Network to model nonlinear structures subjected to random vibration excitations. The LSTM architecture shown has been implemented using the Python packages Tensorflow and Keras.



INTERMITTENT CONTACT

The case study considered was a three DOF problem with intermittent mechanical contact. A random vibration input was applied at one end, and accelerations were recovered at one of the masses.

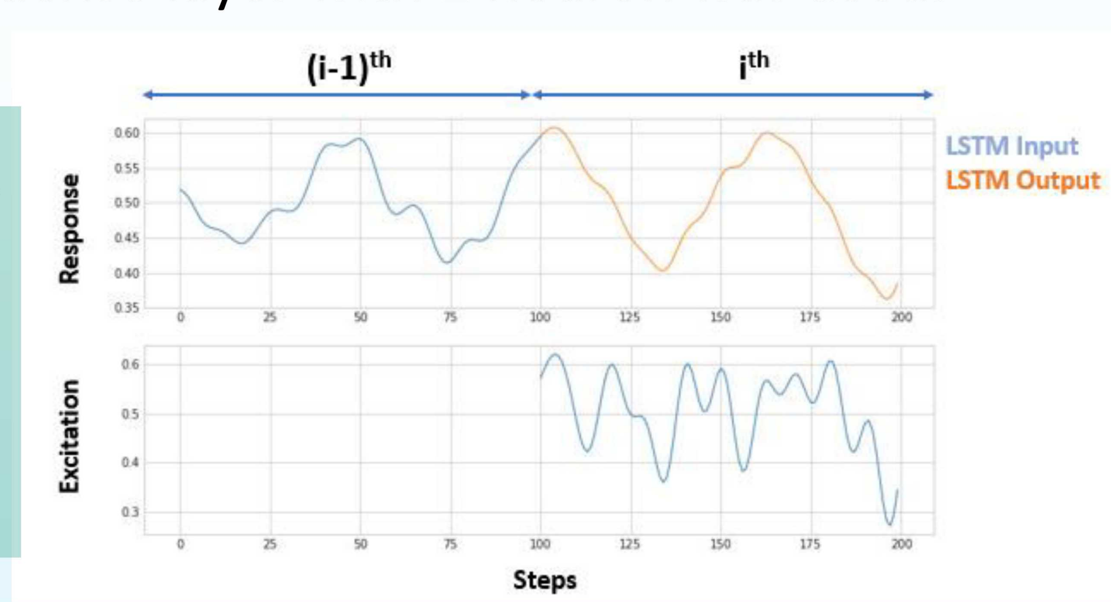


LSTM NETWORK

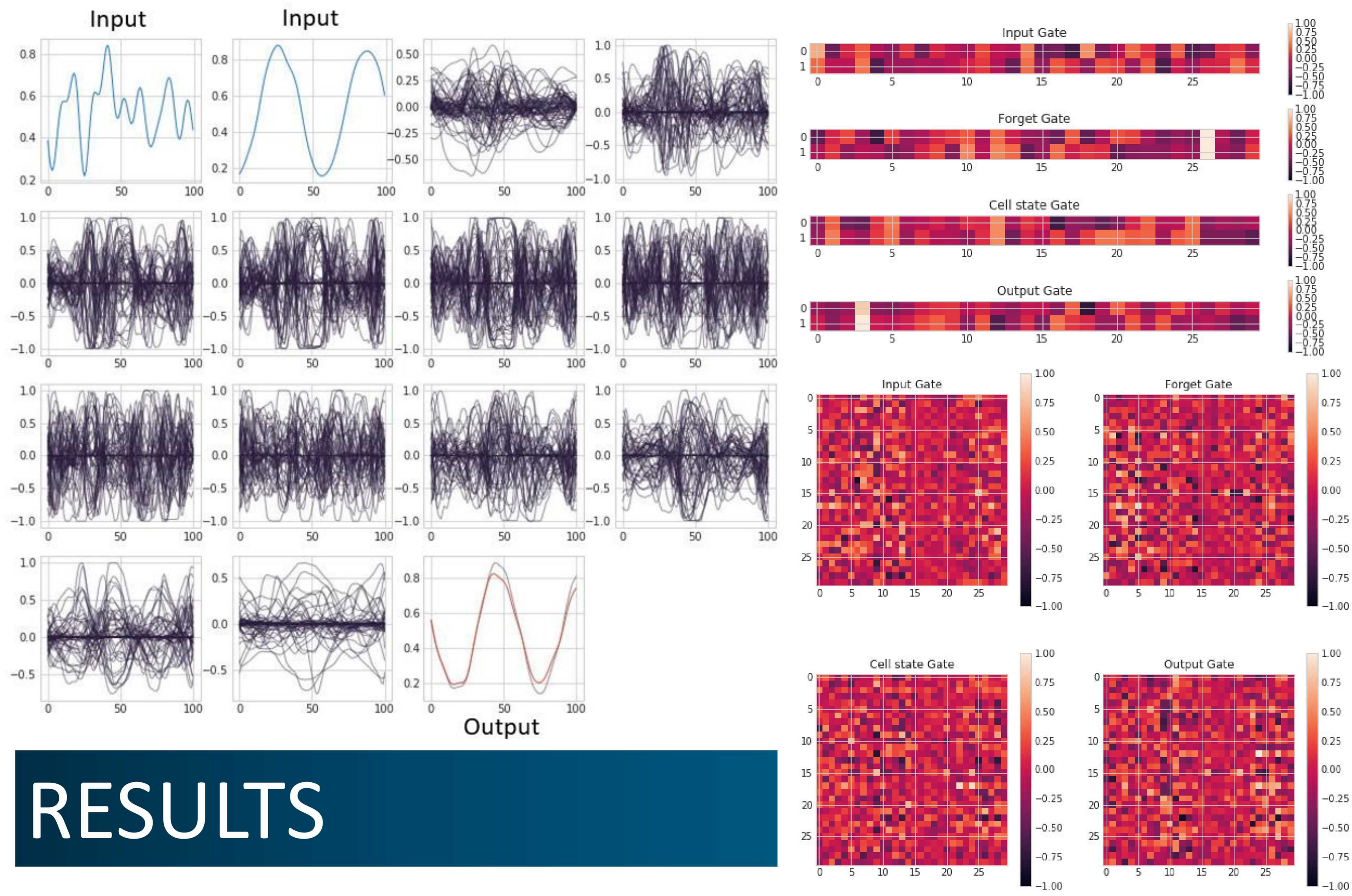
The LSTM network architecture was selected with an iterative process. It was found that the following features improved the network performance:

- Bidirectional layers: Preserving information about the "future" helped the network to anticipate contact events and it helped reduce bias.
- Dropout: Used for regularization, helped to decrease variance.
- Input layer: The input layer had 100 neurons.
- Hidden Layers: Each layer had 30 neurons; ReLu activation functions were used.
- Output Layer: A dense layer with 1 neuron was used.

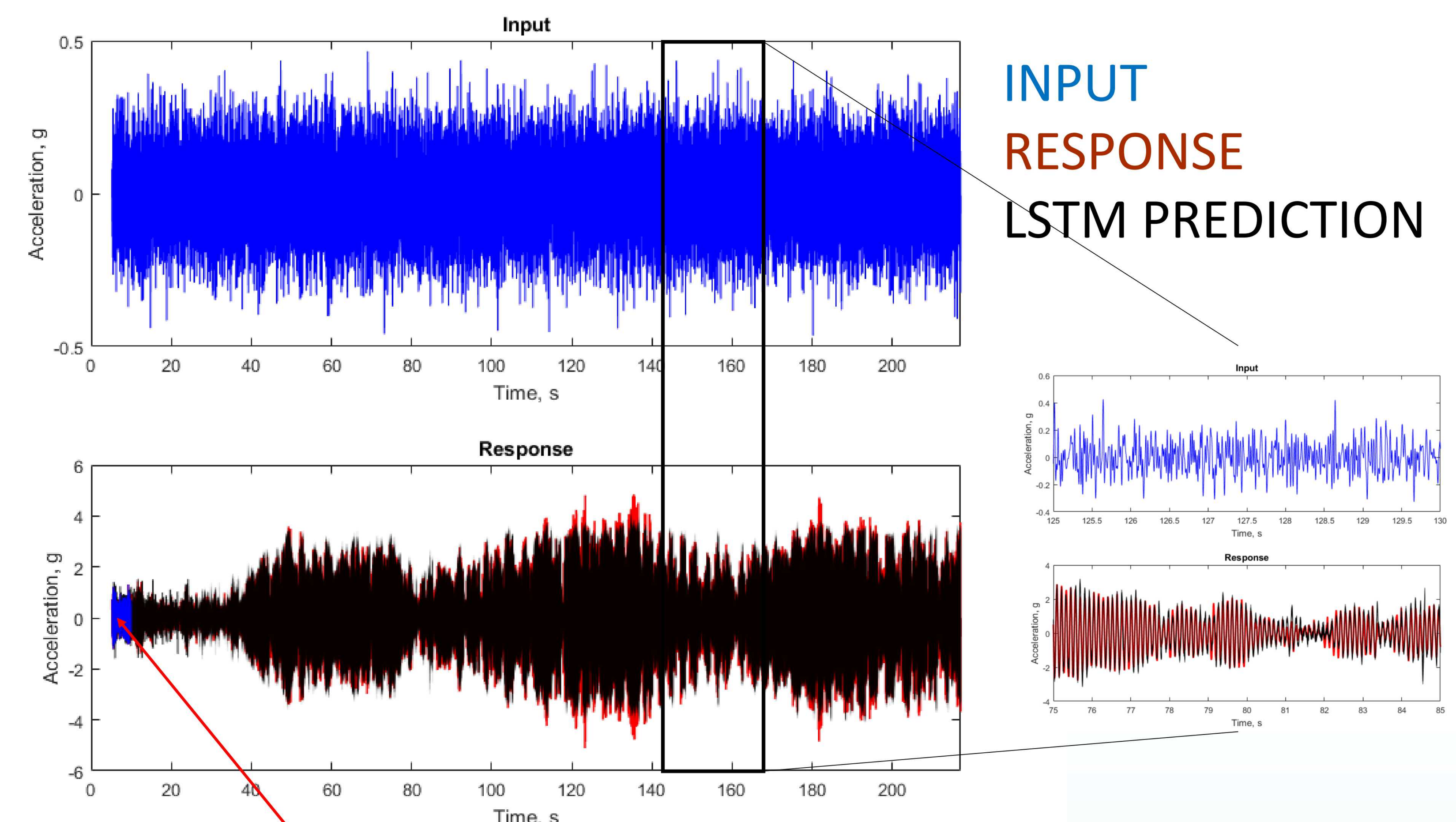
Trained on 180 samples with Adam optimizer. Tested on independent dataset. Training and test data shared statistical features.



VISUALIZING THE LSTM

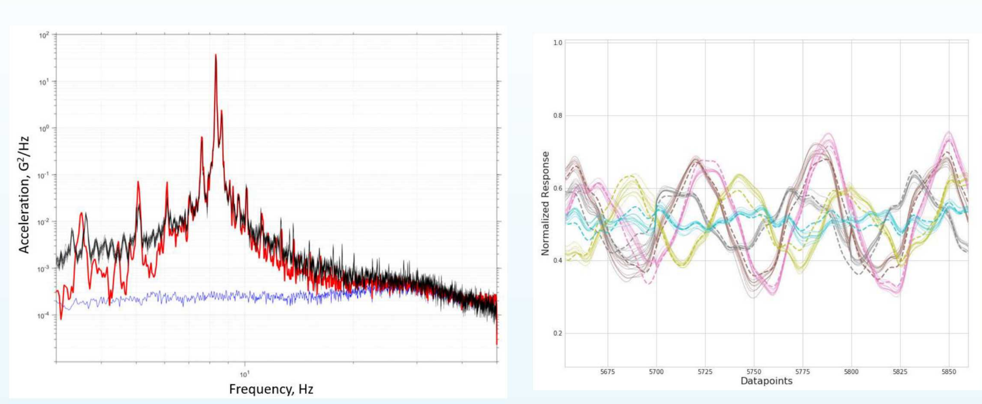


RESULTS



INPUT
RESPONSE
LSTM PREDICTION

10s of data used to predict >200s



LSTM captures parametric variability

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