# Anomaly detection is nonlinear vibrational structures using variational auto-encoders

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**Abstract**. We propose the use of a Variational Auto-encoder (VAE) with Long Short-Term Memory Neural Networks (LSTM) for the unsupervised learning of the dynamics of a nonlinear vibrational structure. We then show our model has learned the parameters of the structure by passing unit impulses through the encoder and decoder networks to obtain pseudo-impulse responses that mimic the true impulse responses of the structure. Our model is validated on a two-story shear frame with hysteric links to shown that our method generalises to nonlinear dynamics. Furthermore, we show that the inferred latent features can be used for auxiliary tasks, such as anomaly detection. In the case of the two-story shear frame, we introduce different types of structural damage through shifts in the elastic and hysteretic system properties. These damages prove easily identifiable when looking at the latent features learned by the VAE.

## Introduction

Structural monitoring of engineered systems experiencing nonlinearities, e.g. geometric [1] or material [2], is non-trivial. While advances in Internet of Things (IoT) technologies have allowed for gathering of massive amounts of heterogeneous data, nonlinearity remains challenging to characterize, especially since most of the collected data is not labeled. This hardens the application of off-the-shelf machine learning tools, which rely on supervised learning paradigms. For accomplishing the task of anomaly detection on nonlinear systems, we here turn to unsupervised machine learning methods, such as VAEs to extract the intrinsic physical properties of a nonlinear structure.

From the latent representation learned in an unsupervised manner, we seek to solve two inverse problems: the recovery of the original excitation of the system and the geometry of the structure expressed in its modes. Once we have shown that our model has indeed encoded both these properties, we use the reduced features for discriminant tasks, such as anomaly detection. We validate the proposed scheme on a simulated two-story benchmark frame comprising multiple hysteric joints [3]. The bottom links are excited with a parameterized synthetic ground motion database [4]. Once the features are learned by the VAE, different types of anomalies are classified, which arise from structural damage.

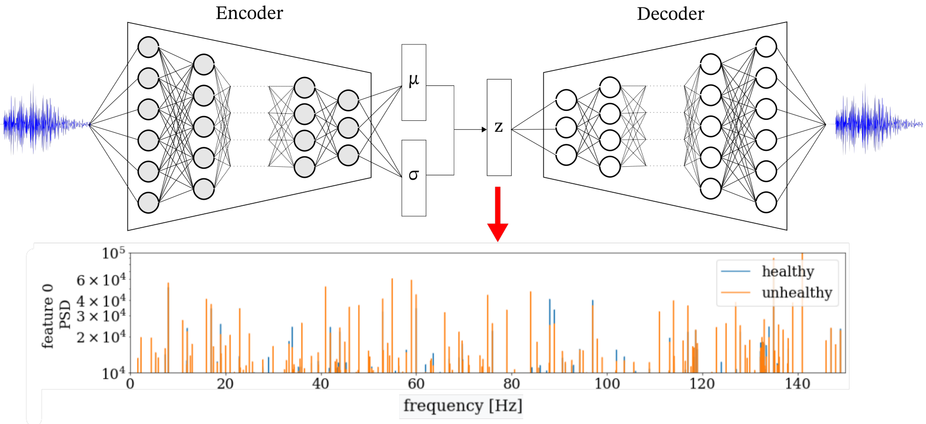


Figure 1: The autoencoder is trained to reconstruct the earthquake excitation acceleration histories of the system. Its latent features allow us to distinguish healthy from unhealthy structures.

## Results and discussion

Once our model has been fully trained on the target dataset, we trigger the encoder and decoder networks to obtain pseudo-impulse responses of the VAE. The outputs under the trigger show close resemblance to the impulse response of the system. Future work will include the use of domain-adaptation techniques to reuse the features that were learned for real datasets, comprising too few samples to directly train a neural network.

## References

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