Application of Sparse Identification of Nonlinear Dynamics (SINDy) and Artificial Neural Network (ANN) algorithm for Magnetoelectric Sensor/Actuator Modelling.

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Understanding the nonlinear dynamics of Magnetoelectric (ME) heterostructures, due to having a diverse application route including sensors, energy harvesters, magnetoelectric random access memories etc., is of particular interest. The advances in machine learning encourages its utilization for the forecasting of dynamic systems across many domains of science. This work aims at analysing different aspects of the nonlinear dynamic behaviour of the ME heterostructure which is composed of magnetostrictive Cr-FeCoSiB and piezoelectric AlN thin films, having a natural frequency of 7.4kHz, by modelling its timeseries readout with a duffing equation via Sparse Identification of Nonlinear Dynamics (SINDy). Different driving frequencies of the periodic sinusoidal signal (7.4 kHz and 2.5 kHz) and different amplitudes of the magnetic excitation bias field by applying 100 mA and 449 mA (the saturation field)) currents to an embedded, spiral, parallel, copper micro-coil system, were considered while magnetic excitation was performed along the easy axis of the cantilever. The sensor was operated under linear conditions and the nonlinearity originating from the amplification (e.g., power, charge) systems were focused on modelling. The optimized model-equations, indicating a linear damped oscillator for the harmonic vibration case and self-excited nonlinear damped oscillator for the super harmonic vibration (i.e., 1/3 of the resonance frequency) case, were further analysed by performing local bifurcation analysis. The discovered equations suggested the existence of only the trivial fixed points, i.e., (0, 0) point in the phase space of the systems, for which the existence and stability of the trivial and non-trivial steady state amplitudes were examined via local bifurcation analysis by considering the magnitude and sign of the as-discovered linear and nonlinear damping coefficients and were verified with the phase portraits of the individual dynamic systems. Two time series predictive Artificial Neural Network (ANN) algorithms: Multi-Layer Perceptron (MLP) and Long-Short-Term-Memory (LSTM) were also employed to predict the sensor response and to compare (see **Figure 1**) the correlation of prediction with that of SINDy.

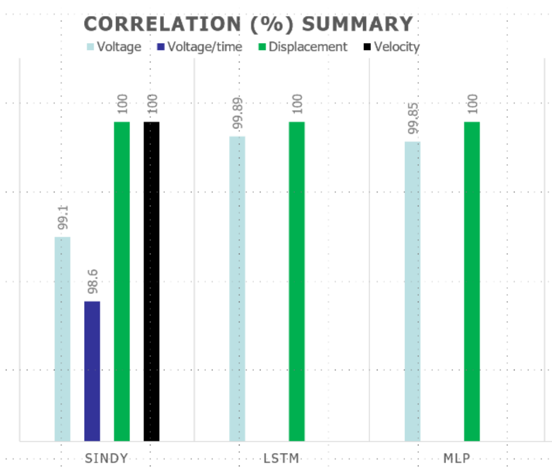

Figure 1: Correlations obtained for the utilized machine learning algorithms.