Precursor Detection of Spike Stall in Axial Compressor Systems using Machine Learning Fusion

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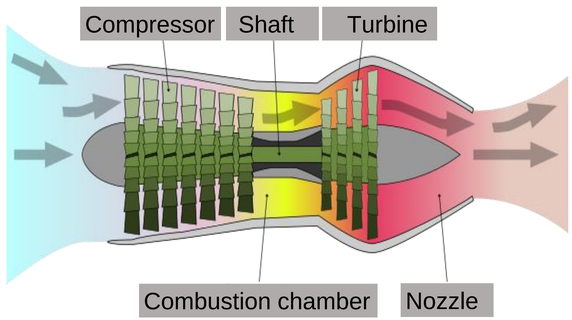
WHAT PROBLEM DOES IT SOLVE?

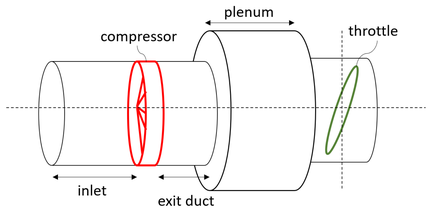
Commercial Jet engines, among others, use axial compressors. An axial compressor can experience spike stall events that lead to performance drops and engine damage that may even lead to a stalled jet engine during mid-flight. A stall event precursor detection system could prevent any incoming spike stall incident by applying active control measures. This study aims to develop a spike stall precursor detection system using deep learning on pressure data obtained from a single-stage compressor system.



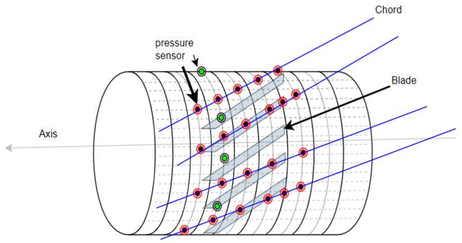
Compressor in action during jet engine operation

APPROACH

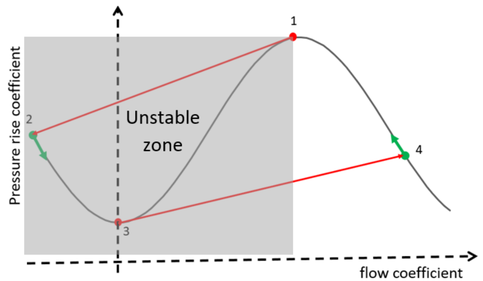
In the study, Recurrent Neural Networks such as Long Short Term Memory (LSTM) and Graphical Neural Network (GRU) are explored for binary classification of impending spikes. Spatiotemporal features are constructed and graphical networks are fused with the Recurrent Neural Networks (RNN) to gain insights into the nature of the precursor data. The method is validated using the data provided by the Chinese Academy of Science. In addition, the data augmentation is performed in order to increase the volume of the data for effective training and testing.



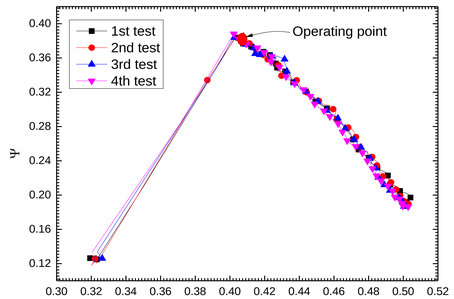
Single-stage compressor setup utilized in the study



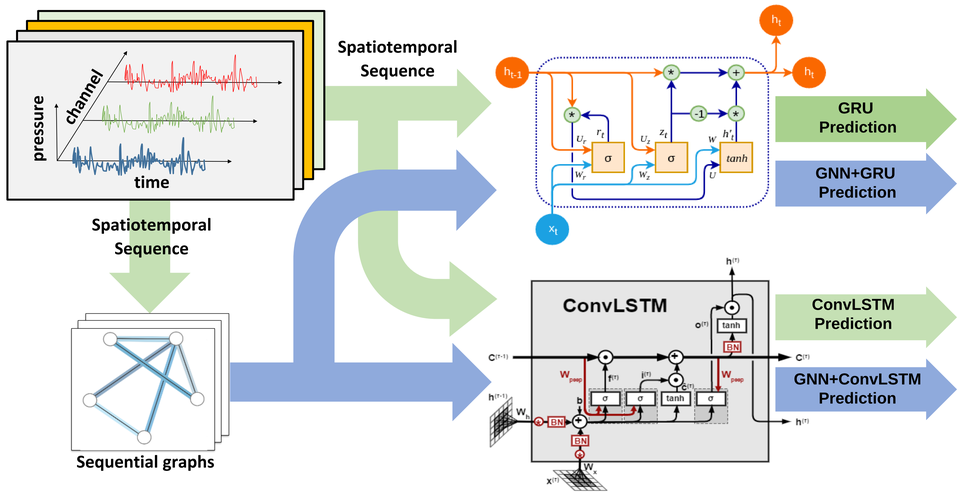
The pressure transducer chords around the compressors casing



The characteristics curve of a single-stage axial compressor



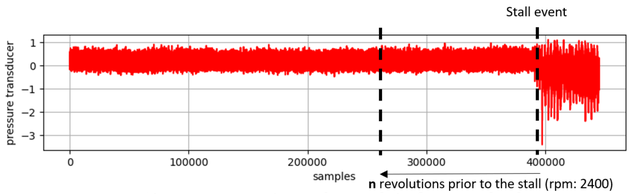
Compressor Characteristic Curve for Axial Compressor Undergoing Stall



Proposed hybrid and non-hybrid network architecture paths considered for the study

EXPERIMENTAL OUTCOME

Pressure readings from a 60-blade compressor experiments are used to develop a data-driven early warning system for spike stall events. Four hybrid neural network architectures achieve 93-100% accuracy in detecting spikes 30 revolutions prior. **This is a significant improvement relative to the existing research outcomes with maximum precursor detection distance less than 10 revolutions reported in the literature.**



Raw pressure transducer data from a single spike stall experiment

Summarized performance metrics

Precursor distances (Rev.)	Network	Accuracy (%)	F1-Score	False Negative Rate
10	GRU	100.00	1.00	0.00
	ConvLSTM	100.00	1.00	0.00
	GNN-GRU	87.50	0.86	0.25
	GNN-ConvLSTM	87.50	0.88	0.13
20	GRU	100.00	1.00	0.00
	ConvLSTM	100.00	1.00	0.00
	GNN-GRU	87.50	0.88	0.13
	GNN-ConvLSTM	87.50	0.88	0.13
30	GRU	100.00	1.00	0.00
	ConvLSTM	100.00	1.00	0.00
	GNN-GRU	100.00	1.00	0.00
	GNN-ConvLSTM	93.75	0.93	0.13
60	GRU	43.75	0.31	0.75
	ConvLSTM	56.25	0.63	0.25
	GNN-GRU	37.50	0.38	0.63
	GNN-ConvLSTM	31.25	0.15	0.88

CONCLUSION

The framework shows deep learning's capability for spike stall prediction in a single-stage compressor system from transient pressure data, enabling more efficient operation by avoiding instabilities. Further improvements in accuracy and robustness are possible by expanding the dataset size, model complexity, and evaluation metrics.

References