Research Papers on 'Aero'

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Paper 1:

Reduced order modeling of the unsteady pressure on turbine rotor blades using deep learning

Date: 2025-02-17

Time: 11:29:16

Authors:

Dominique Joachim, Salesses Lionel, Thomas Jean-François, Baert Lieven, Benamara Tariq, Mastrippolito Franck, Flament Theo

Summary:

- In transonic turbine stages, complex interactions between trailing edge shocks from nozzle guide vanes and rotor blades generate unsteady wall pressure fields, impacting rotor aerodynamic performance and structural integrity. While shock-related phenomena are prominent, unsteady pressure fluctuations can also arise in subsonic regimes from wake interactions. Traditional methods like Unsteady Reynolds-Averaged Navier-Stokes (URANS) simulations are accurate but computationally expensive. To address this, a novel deep learning-based Reduced Order Model (ROM) is proposed, built on a database of URANS simulations, to predict unsteady pressure fields on turbine rotor blades at a fraction of the cost. The model consists of a Variational Auto-Encoder (VAE) integrated with a Gated Recurrent Unit (GRU) to capture time-series data, overcoming the limitations of traditional linear ROMs in capturing nonlinear phenomena, such as moving shocks. The goal is to develop a ROM that accurately reproduces unsteady pressure fields from URANS simulations while reducing computational costs. The ROM is applied to the Turbine Aero-Thermal External Flows (TATEF2) project configuration, a representative test case in turbomachinery research. Model performance is evaluated using machine learning quality metrics and design-oriented criteria, including the accuracy of the first harmonic in the Fourier transform of the unsteady pressure field. The impact of the simulation database size on model accuracy is also analyzed, considering the number of training simulations required for task-specific accuracy as a key factor in industrial applicability.

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Paper 2:

Coupled hydro-aero-turbo dynamics of liquid-tank system for wave energy harvesting: Numerical modellings and scaled prototype tests

Date: 2025-02-15

Time: 13:43:41

Authors:

Chongwei Zhang, Xunhao Zhu, Cheng Zhang, Luofeng Huang, Dezhi Ning

Summary:

- An integrated numerical model is proposed for the first time to explore the coupled hydro-aero-turbo dynamics of wave-energy-harvesting (WEH) liquid tanks. A scaled prototype of the WEH liquid tank with an impulse air turbine system is made to experimentally validate the numerical model.Multi-layered impulse air turbine systems (MLATS) are creatively introduced into the liquid-tank system. The inherent mechanisms of the coupled hydro-aero-turbo dynamics of the WEH liquid tank with different turbine properties are systematically investigated.Compared with the experimental data, the numerical model can accurately reproduce the rotor speed, liquid motion, and air pressure of the WEH liquid tank. Upon analysing mechanical parameters of the turbine rotor, it is found that the rotor's moment of inertia mainly affects the rotor speed's variation range, while the damping coefficient significantly influences the averaged rotor speed. The optimal power take-off damping for the WEH liquid tank is identified. Considering the efficiency performances of three MLATSs, improving Turbine-L1 to Turbine-L2 or Turbine-L3 can increase the averaged power output by about 25% or 40%, respectively.Increasing the tank breadth can effectively boost the power output in a nonlinear way.Under the considered excitation conditions, if the tank breadth is doubled, the maximum averaged power output can be increased by around four times. Through a series of failure tests, Turbine-L3 shows greater reliability in extreme conditions compared to a conventional single-rotor turbine. Even if the most important rotor of Turbine-L3 fails to work, the maximum loss of the averaged power output is only 44%. The present WEH liquid with Turbine - L3 shows improved efficiency and reliability compared to the conventional liquid-tank system with a single-rotor turbine.

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Paper 3:

Aero-engines Anomaly Detection using an Unsupervised Fisher Autoencoder

Date: 2025-02-08

Time: 03:34:22

Authors:

Saba Sanami, Amir G. Aghdam

Summary:

- Reliable aero-engine anomaly detection is crucial for ensuring aircraft safety and operational efficiency. This research explores the application of the Fisher autoencoder as an unsupervised deep learning method for detecting anomalies in aero-engine multivariate sensor data, using a Gaussian mixture as the prior distribution of the latent space. The proposed method aims to minimize the Fisher divergence between the true and the modeled data distribution in order to train an autoencoder that can capture the normal patterns of aero-engine behavior. The Fisher divergence is robust to model uncertainty, meaning it can handle noisy or incomplete data. The Fisher autoencoder also has well-defined latent space regions, which makes it more generalizable and regularized for various types of aero-engines as well as facilitates diagnostic purposes. The proposed approach improves the accuracy of anomaly detection and reduces false alarms. Simulations using the CMAPSS dataset demonstrate the model's efficacy in achieving timely anomaly detection, even in the case of an unbalanced dataset.

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Paper 4:

Aero-LLM: A Distributed Framework for Secure UAV Communication and Intelligent Decision-Making

Date: 2025-02-05

Time: 15:46:27

Authors:

Balakrishnan Dharmalingam, Rajdeep Mukherjee, Brett Piggott, Guohuan Feng, Anyi Liu

Summary:

- Increased utilization of unmanned aerial vehicles (UAVs) in critical operations necessitates secure and reliable communication with Ground Control Stations (GCS). This paper introduces Aero-LLM, a framework integrating multiple Large Language Models (LLMs) to enhance UAV mission security and operational efficiency. Unlike conventional singular LLMs, Aero-LLM leverages multiple specialized LLMs for various tasks, such as inferencing, anomaly detection, and forecasting, deployed across onboard systems, edge, and cloud servers. This dynamic, distributed architecture reduces performance bottleneck and increases security capabilities. Aero-LLM's evaluation demonstrates outstanding task-specific metrics and robust defense against cyber threats, significantly enhancing UAV decision-making and operational capabilities and security resilience against cyber attacks, setting a new standard for secure, intelligent UAV operations.

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Paper 5:

Computational Modeling and Analysis of the Coupled Aero Structural Dynamics in Bat Inspired Wings

Date: 2025-01-03

Time: 09:54:11

Authors:

Sushrut Kumar, Jung-Hee Seo, Rajat Mittal

Summary:

- We employ a novel computational modeling framework to perform high-fidelity direct numerical simulations of aero-structural interactions in bat-inspired membrane wings. The wing of a bat consists of an elastic membrane supported by a highly articulated skeleton, enabling localized control over wing movement and deformation during flight. By modeling these complex deformations, along with realistic wing movements and interactions with the surrounding airflow, we expect to gain new insights into the performance of these unique wings. Our model achieves a high degree of realism by incorporating experimental measurements of the skeleton's joint movements to guide the fluid-structure interaction simulations. The simulations reveal that different segments of the wing undergo distinct aeroelastic deformations, impacting flow dynamics and aerodynamic loads. Specifically, the simulations show significant variations in the effectiveness of the wing in generating lift, drag, and thrust forces across different segments and regions of the wing. We employ a force partitioning method to analyze the causality of pressure loads over the wing, demonstrating that vortex-induced pressure forces are dominant while added mass contributions to aerodynamic loads are minimal. This approach also elucidates the role of various flow structures in shaping pressure distributions. Finally, we compare the fully articulated, flexible bat wing to equivalent stiff wings derived from the same kinematics, demonstrating the critical impact of wing articulation and deformation on aerodynamic efficiency.

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Paper 6:

AERO: Softmax-Only LLMs for Efficient Private Inference

Date: 2024-12-02

Time: 21:42:36

Authors:

Nandan Kumar Jha, Brandon Reagen

Summary:

- The pervasiveness of proprietary language models has raised privacy concerns for users' sensitive data, emphasizing the need for private inference (PI), where inference is performed directly on encrypted inputs. However, current PI methods face prohibitively higher communication and latency overheads, primarily due to nonlinear operations. In this paper, we present a comprehensive analysis to understand the role of nonlinearities in transformer-based decoder-only language models. We introduce AERO, a four-step architectural optimization framework that refines the existing LLM architecture for efficient PI by systematically removing nonlinearities such as LayerNorm and GELU and reducing FLOPs counts. For the first time, we propose a Softmax-only architecture with significantly fewer FLOPs tailored for efficient PI. Furthermore, we devise a novel entropy regularization technique to improve the performance of Softmax-only models. AERO achieves up to 4.23$\times$ communication and 1.94$\times$ latency reduction. We validate the effectiveness of AERO by benchmarking it against the state-of-the-art.

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Paper 7:

Turbofan Engine Remaining Useful Life (RUL) Prediction Based on Bi-Directional Long Short-Term Memory (BLSTM)

Date: 2024-11-25

Time: 14:27:07

Authors:

Abedin Sherifi

Summary:

- The aviation industry is rapidly evolving, driven by advancements in

technology. Turbofan engines used in commercial aerospace are very complex systems. The majority of turbofan engine components are susceptible to degradation over the life of their operation. Turbofan engine degradation has an impact to engine performance, operability, and reliability. Predicting accurate remaining useful life (RUL) of a commercial turbofan engine based on a variety of complex sensor data is of paramount importance for the safety of the passengers, safety of flight, and for cost effective operations. That is why it is essential for turbofan engines to be monitored, controlled, and maintained. RUL predictions can either come from model-based or data-based approaches. The model-based approach can be very expensive due to the complexity of the mathematical models and the deep expertise that is required in the domain of physical systems. The data-based approach is more frequently used nowadays thanks to the high computational complexity of computers, the advancements in Machine Learning (ML) models, and advancements in sensors. This paper is going to be focused on Bi-Directional Long Short-Term Memory (BLSTM) models but will also provide a benchmark of several RUL prediction databased models. The proposed RUL prediction models are going to be evaluated based on engine failure prediction benchmark dataset Commercial Modular Aero-Propulsion System Simulation (CMAPSS). The CMAPSS dataset is from NASA which contains turbofan engine run to failure events.

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