Machine Learning for the Offshore Wind Industry

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BIG DATA ANALYTICS

UK Research and Innovation

Introduction

- PhD Student at the Aura CDT – based at the University of Hull
- Part of the Big Data Analytics (BDA) Research Group.
- Research Areas:
  - Machine Learning (ML)
  - Image Anomaly Detection (AD)
  - Natural Language Processing (NLP)
- Completed an Internship with Toshiba Cambridge Research Lab.

Structural Health Monitoring

- **Challenge**: Inspection of turbines is costly due to access to wind farms and scale of turbines.
- **Solution**: Leveraging pre-trained object detectors to locate and classify damage in UAV-gathered images.
  - Defects are located and classified in near real-time.
  - Our experiments have been competitive with state-of-the-art benchmarks. [1]
- **Complication:** annotated data is still required to train a model, which is labour intensive.

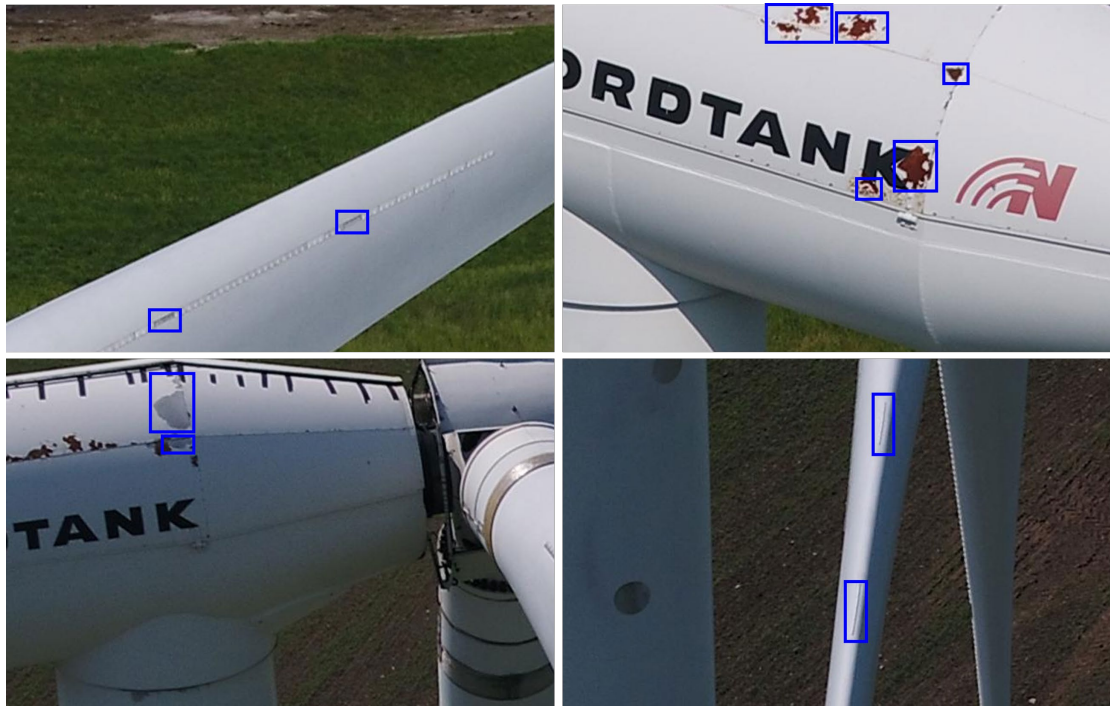

Image: Predicted Instances of anomaly on UAV gathered images (Adapted from Nordtank DTU Dataset. [2])

References:
[1] C. Rothon, N. Dethlefs. 2023. Applying Machine Learning Methods to Damage Detection on Offshore Wind Turbines. WESC 2023
[2] A. Shihavuddin, X. Chen. 2018. Dtu-drone inspection images of wind turbine. DOI 10.17632/hd96prn3nc.2

Interactive Learning with NLP

- **Challenge:** Annotated data for training is costly to obtain and prepare.
- **Solution**: Apply NLP and Interactive learning to integrate prior knowledge into training.
  - Multimodal information gathering via a novel Human-in-the Loop interface based on a purpose built conversational agent [1].
  - Interactive Learning queries a human on the most valuable examples for training, reducing data requirements and integrating expertise.
- **Next Steps**: Physics-informed ML for prognosis and predicted time-to-failure using Transformers.

Image: Example annotated image and conversation from [1]

References:
[1] C. Rothon, S. Keizer, R. Doddipatla, N. Dethlefs. 2024. Towards Interactive Anomaly Detection using Natural Language. WESC 2023

Operations and Maintenance

- **Challenges**: Alarms and repair actions are difficult to predict before failures occur. Black Box models are hard to interpret, and are prone to invalid and unsafe responses.
- **Solution:** Apply NLP techniques for long-term relationships and explainability.
  - LSTM Networks for repair action prediction before failure occurs. [1]
  - Generative AI for repair actions, and filtering for unsafe and hallucinated outputs – **SafeLLM.** [2]
- **Next Steps:** OSW-specific decision support from a purpose trained AI – **Chat OSW.** [3]

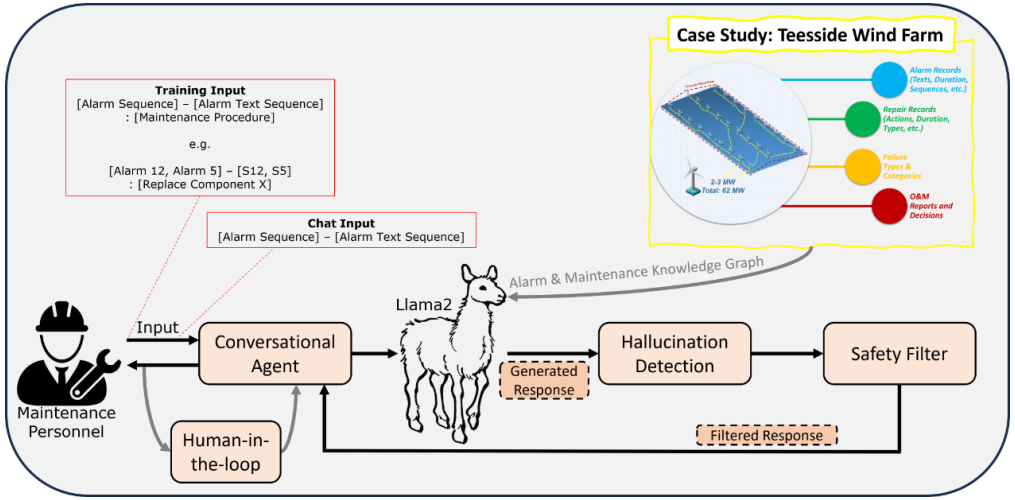

Image: Overview of SafeLLM, as proposed in [2].

References:
[1] C. Walker, C. Rothon, K. Aslansefat, Y. Papadopoulos, N. Dethlefs. 2022. A Deep Learning Framework for Wind Turbine Repair Action Prediction Using Alarm Sequences and Long Short Term Memory Algorithms. IMBSA 2022
[2] C. Walker, C. Rothon, K. Aslansefat, Y. Papadopoulos, N. Dethlefs. 2024. Using Large Language Models to Recommend Repair Actions for Offshore Wind Maintenance. DeepWind 2024
[3] J. Chatterjee and N. Dethlefs. 2022. Automated Question-Answering for Interactive Decision Support in Operations & Maintenance of Wind Turbines. in IEEE Access