Paris Session 2022

Anomaly Detection in Regulation Ring from Bulb Turbines using Deep Learning

SC A1 – PS2

30 August 2022

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Summary

1. Introduction

2. Problem

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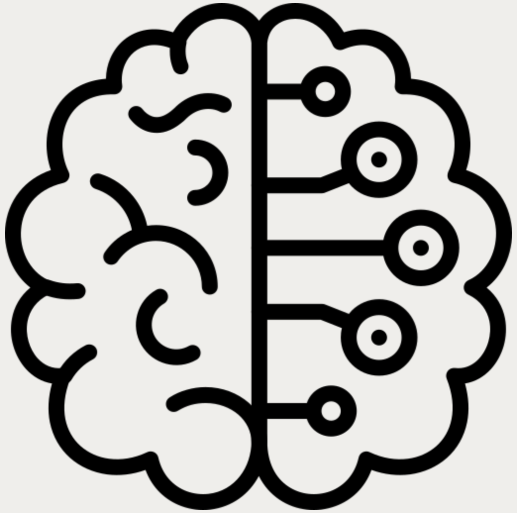
What is Deep Learning?

“Deep learning is a subset of machine learning, which is essentially a neural network with three or more layers. These neural networks attempt to simulate the behavior of the human brain—albeit far from matching its ability—allowing it to “learn” from large amounts of data.”



Hydroelectric Power

- Hydroelectric power is a renewable source that is ancient and widespread throughout the world.
- Recently, the demand in the energy market demands high reliability and availability from Operation and Maintenance (O&M).
- Extreme regimes in hydroelectric plants are concerned with the prevention of downtime and early detection of failures.

Anomalies in Regulation Ring

Figure 1 – Regulation ring

- The regulation ring is part of a system that moves the guide vanes from the wicket gate. With the movement of the regulation ring, more or less water passes through the turbine.
- As hydroelectric energy is acquired through the conversion of hydraulic energy provided by a flow of water into electric power.
- The contact of the flow with the turbine generates unwanted loads and vibrations of the whole generating

Proposed Methodology

Methodology - Data acquisition

- In this study, data was used from the signal registers of the regulation ring from the Generating Unit (GU) 38 in Santo Antônio HPP located in Porto Velho, RO, Brazil.
- The database has records collected between 2020 and 2021. In total, around 1400 samples were acquired.
- The regulation ring has 2 proximeters, radial at 120° (DAR-120) and 240° (DAR-240) that measure displacement, sampled at 20kHz.

Methodology - Feature Extraction

For each vibration signal features are extracted

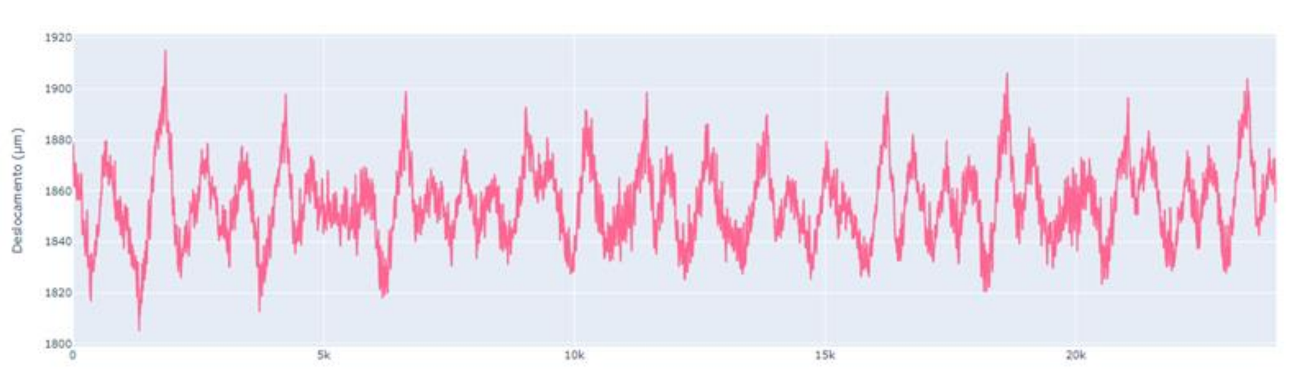


Figure 2 – Example vibration signal

N - Features	Features
1	Zero Crossing Rate
2	Energy
3	Entropy of Energy
4	Spectral Centroid
5	Spectral Spread
6	Spectral Entropy
7	Spectral Flux
8	Spectral Rolloff
9–21	MFCCs
22–33	Chroma Vector
34	Chroma Deviation

Methodology - Anomaly Detection (Deep Autoencoder)

Two mirrored artificial neural networks (Encoder and Decoder)

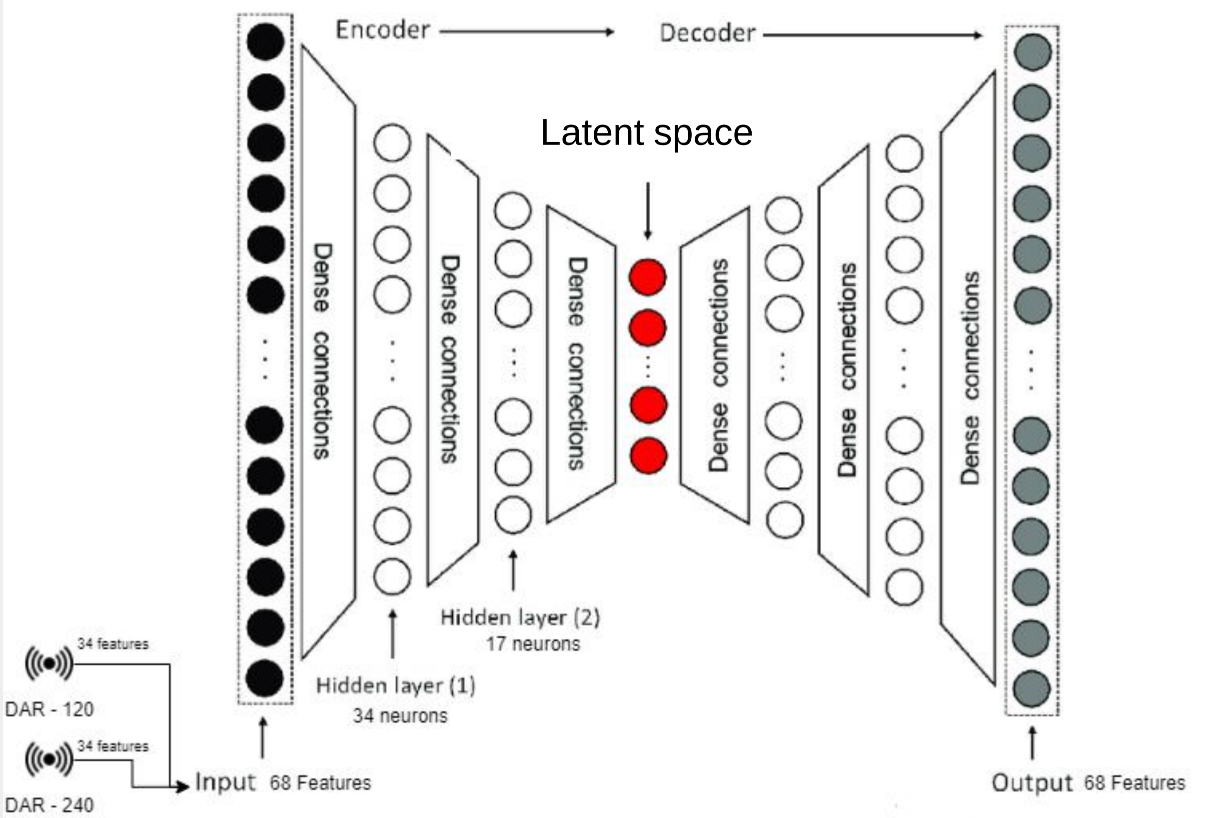


Figure 3 – Deep Autoencoder

Results - Learning Curve

The first step of the results was to analyze the learning curve throughout the training of the model.

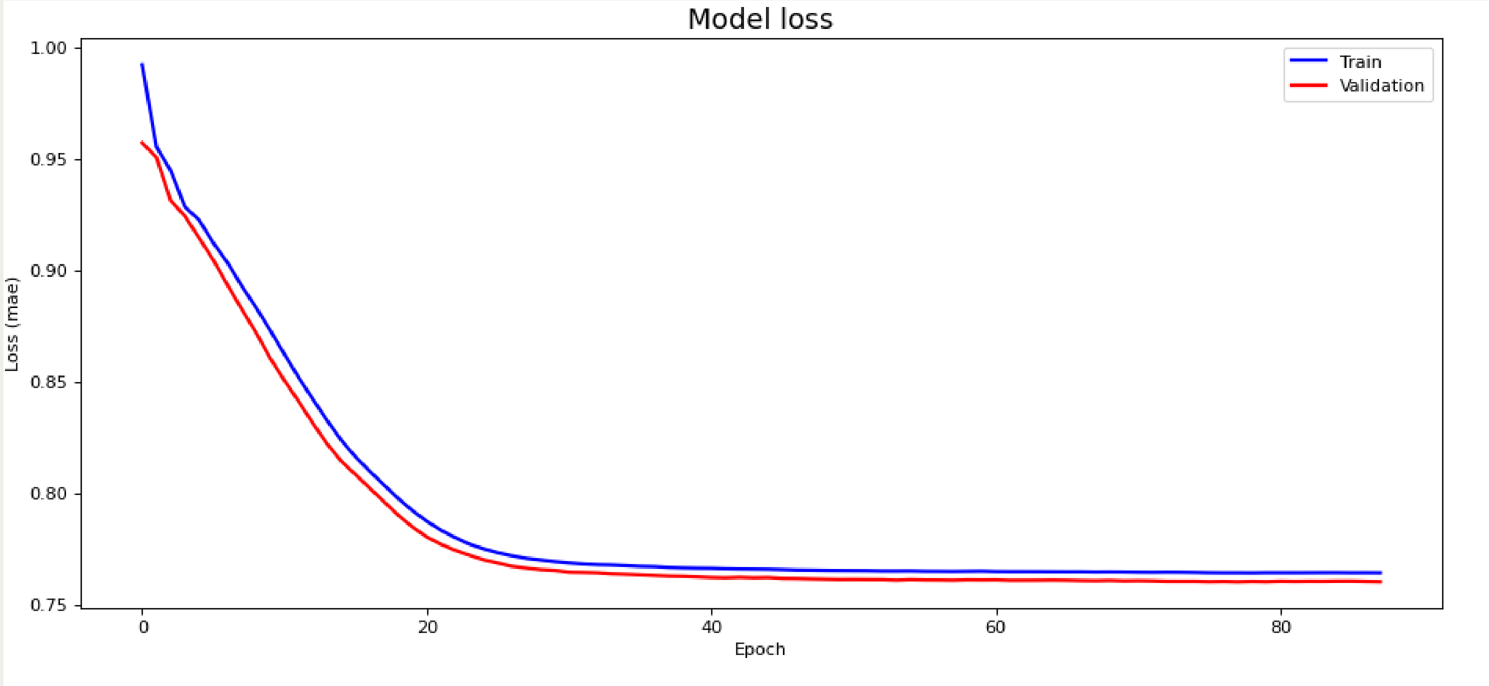


Figure 4 – Learning Curve

Results - Anomaly detection

For a better visualization, a sum of the anomalies over time (accumulation) was performed to compare with data obtained from the plant technicians.

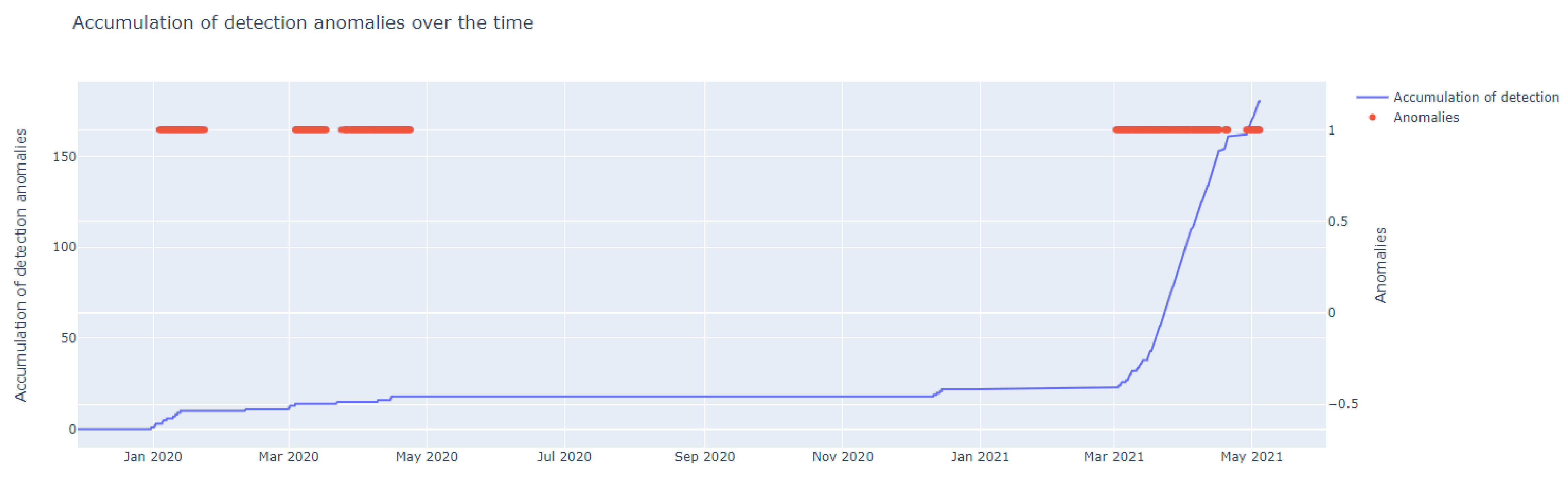


Figure 5 – A sum of the anomalies over time (accumulation)

Results - Evaluation Model

- Based on the equations that assess the quality of the model in detecting anomalies, it can be observed that the model obtained 87% accuracy and 92% precision in detecting anomalies, which can be considered good values.

$$\text{Accuracy} = \frac{\text{True Positive} + \text{True Negative}}{\text{All Samples}}$$

$$\text{Precision} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Positive}}$$

Conclusion

- The results of the detection performed by the model were validated with the technical field team, thus being able to say that the model was able to detect the anomalies in the regulation ring (for the specific generating unit).

- Based on the results obtained and metrics for detecting and accumulating anomalies over time, we can say that the model would be a tool to help those responsible for maintaining the regulation ring.

- Considering that the accumulation of anomalies can point out high loads and unwanted vibrations in the generating unit, mainly in the regulation ring, causing fatigue and defect.

- These accumulations can be indicative of possible preventive maintenance on the regulation ring.

This work is an integral part of the R&D project ANEEL PD-06683-0220/2020 entitled “Machine Learning System for analysis and diagnosis of failures in hydroelectric plants based on process, vibration and acoustic data”.

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For power system expertise

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