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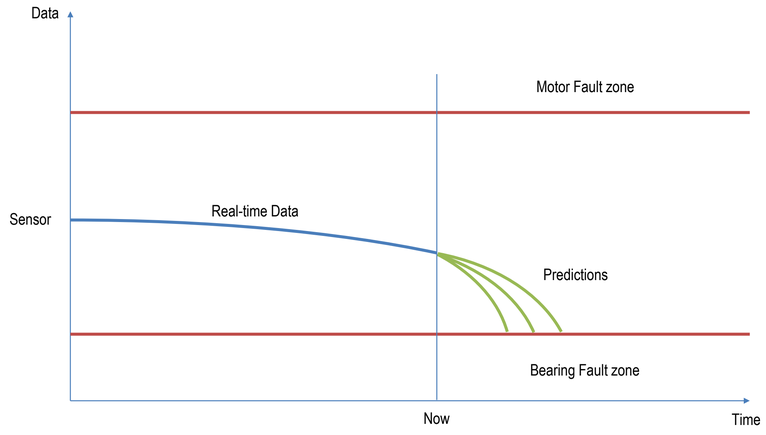
Real-time Novelty Detection framework in the Predictive Maintenance context

Umberto Albertin

Supervisor: Prof. Marcello Chiaberge

Research context and motivation

- In recent years, **Predictive Maintenance (PM)** has become increasingly popular and important for companies. PM is a branch of maintenance **able to recognize anomalies of the system under study in advance**, estimating when it should break down in the future (Remaining Useful Life - RUL estimation).
- It is possible to recognize and prevent failures by monitoring the machine's status using **real-time sensors**; a classification is performed to relate the real-time data to a known behavior. **A RUL prediction is performed by monitoring how the behavior changes over time.**

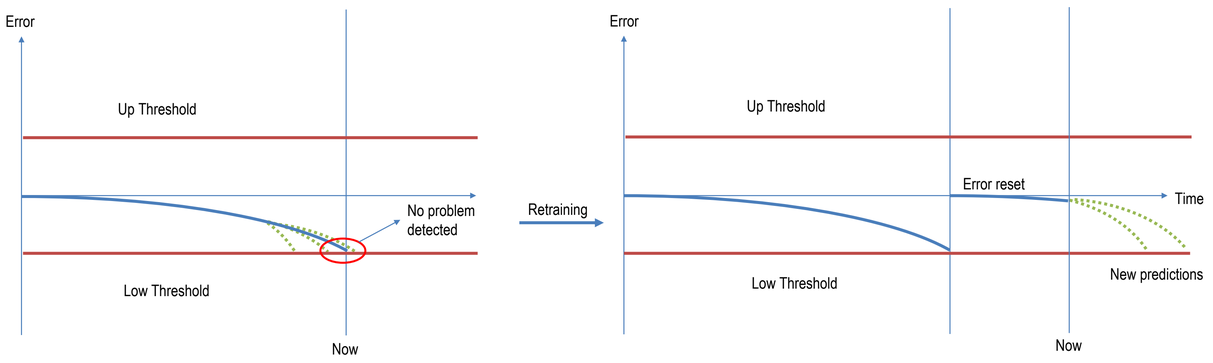


Addressed research questions/problems

- Often, a **Predictive Maintenance framework cannot be applied easily due to the absence of past failure data**. Without these data, the relationship between real-time data and known behavior is hard to recognize. This problem is common, **especially when the machine is new or very old**.
- Another common problem related to a predictive maintenance framework is the high computational effort required from the framework. **Some algorithms are too complex, and a low-power CPU cannot process data well**.

Novel contributions

- The **Novelty Detection** tries to overcome the above-cited problems, helping the user to develop a preliminary Predictive Maintenance framework **without any past failure data collected**. Indeed, Novelty Detection **can detect changes over time**, warning the maintainer when this change becomes too big.



- **The change is measured by computing an error between real-time and normal data**. When this **change/error** becomes **too big**, **the maintainer is alerted** and can decide if the change is a problem.
- If the change is not a problem, **the maintainer can "reset" the error** by retraining the framework.
- The **Novelty Detection framework** developed **is based on a simple Machine Learning approach** that is very light from the computational point of view and easily implementable on embedded devices.

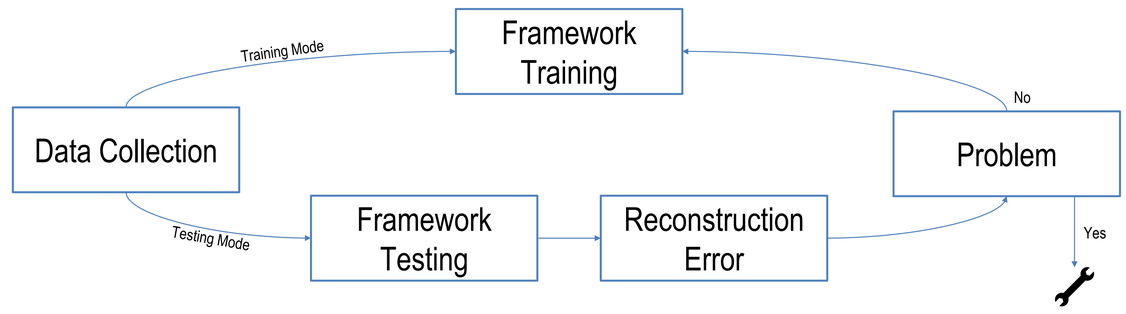
Collaborations

ETEL — PhD – The partner company of the PNRR PhD project

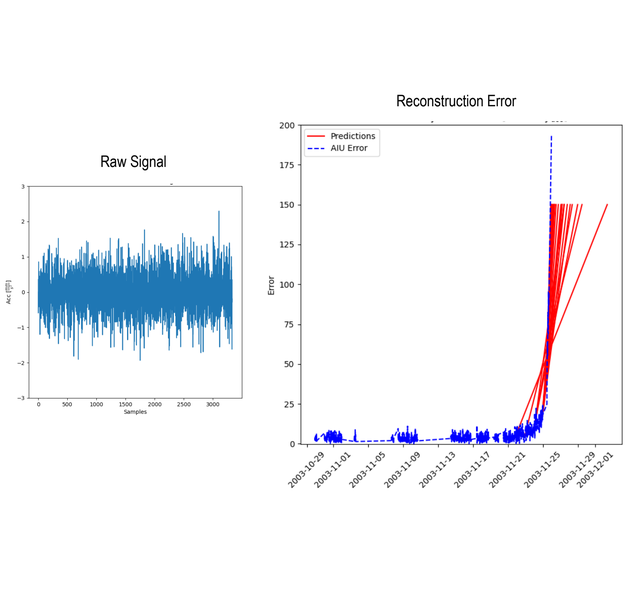
SPEA — Archimede Project – a Predictive Maintenance framework applied to the company's systems

Adopted methodologies

- The adopted methodology uses a Machine Learning model to measure the change variation in real-time.



- The idea behind this approach concerns **training the model with only normal data** (similar to an overfit). The **data collected must represent the normal behavior of the machine**.
- After the training, the maintainer switches into Testing Mode after a reasonable time (i.e., two weeks of data).
- The **testing mode no longer trains the model** but tests each coming sample, predicting the related label. **Many detectors are created as a function of the features number**. The i^{th} feature is the label for the i^{th} detector. Each detector is trained to predict the corresponding label based on all the other features.
- **The reconstruction error measures the difference between real data and normal data. If the machine's behavior starts to change, the reconstruction error of the model starts to diverge.**
- A big error deviation is related to a big machine change that could be related to a possible problem. **The maintainer should decide if the change is a problem or not**. If it is a problem, the maintainer works to solve it; otherwise, the model must be updated by retraining the framework with last data to reduce the reconstruction error.
- This methodology could be applied to raw signals coming from industrial machine's sensors or to raw images to detect differences from normal data.



Future work

- **Further enhancements** and tests should be tried directly **on an embedded platform** to verify the low computational effort required by the framework.
- **Further studies** should be performed **to enhance novelty detection** in the **vision domain**. This domain could be useful for robotics applications and not only for industrial ones. Neural Networks such as **Autoencoders** and **GANs** are interesting choices for this application.
- Studies using **Neuromorphic Computing** should be explored in the future to understand if this new research area could contribute to the Novelty Detection topic. This technique could be very useful to reduce the energy the network consumes.

Publications

- Published works: 1 journals, 0 conferences
- Submitted works: 0 journals, 0 conferences
- Albertin, Umberto, Giuseppe Pedone, Matilde Brossa, Giovanni Squillero, and Marcello Chiaberge. 2023. "*A Real-Time Novelty Recognition Framework Based on Machine Learning for Fault Detection*" Algorithms 16, no. 2: 61. https://doi.org/10.3390/a16020061

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