MSc thesis proposal

Dynamic RUL Estimates Based on Time Transformation Methods

- ## Context of the research

Predictive maintenance aims to anticipate failures and optimize maintenance by estimating the Remaining Useful Life (RUL) of assets. Many standard RUL models assume that operating conditions and degradation dynamics are stationary. In practice, assets such as batteries, mechanical components, and civil infrastructure experience changing usage, environment, and control strategies, which can accelerate or slow down degradation over time. Time transformation methods address this by mapping calendar time $t$to an *effective degradation time* $g(t)$. This enables the model to represent non-stationary aging within a coherent reliability framework and to provide uncertainty-aware RUL estimates. Recent work shows that dynamic estimation of $g(t)$and aging parameters is key to making these methods operational in real monitoring settings. This thesis contributes to more robust, deployable predictive maintenance approaches; supporting safer operation, fewer unexpected failures, and better planning of inspections and interventions.

- ## Objective of the research

The goal is to implement and validate a dynamic RUL estimation approach based on time transformation, focusing on the dynamic estimation of (i) the time transformation function $g(t;k)$, and (ii) the aging rate parameter constant or time-varying $k(t)$.
To achieve this, the student will:

- implement one or more dynamic estimation approaches, e.g., recurrent neural networks (RNNs) or physics-informed neural networks (PINNs), or time-dependent covariate survival models where covariates influence $R(t)$;
- design an evaluation protocol for accuracy and uncertainty, e.g., prediction quality, calibration, robustness under regime shifts;
- validate the methods on a practical case study, with a primary application example being battery degradation and lifetime prediction.

- ## Data and Resources

Battery degradation / lifetime datasets (open datasets and/or partner-provided datasets when available) or other equipment degradation data; Simulated degradation trajectories for controlled validation and stress testing; Python coding environment.

- ## Duration

The student will work on the implementation path over **8** to **10 months.**

- ## International Collaborations

SUPSI (Switzerland); Luleå (Sweden), Polimi/LASAR (Italy).

- ## Scientific references and background

Analysis of RUL dynamics and uncertainty via time transformation , P.Dersin, R.Rocchetta, Reliability Engineering & System Safety, Volume 266, Part B, February 2026, 111730 available in Science Direct.

For further information, please contact:

Prof. Enrico Zio, enrico.zio@polimi.it