CAPSTONE PROJECT PROPOSAL

Project Title: Condition Based Maintenance of Naval Propulsion Plants

Problem: Availability, reliability and economic sustainability of naval propulsion plants are key elements to cope with since maintenance costs represent a large slice of total operational expenses.

Depending on the adopted strategy, impact of maintenance on overall expenses can remarkably vary; for example, letting an asset running up until breakdown can lead to unaffordable costs. As a matter of fact, a desideratum is to progress maintenance technology of ship propulsion systems from breakdown or preventive maintenance up to more effective condition-based maintenance approaches. The success of condition-based maintenance clearly hinges on the capability of developing effective predictive models.

In particular, we take into consideration an application of condition-based maintenance to gas turbines used for vessel propulsion, where the performance and advantages of exploiting statistical/machine learning method(s) in modeling the degradation of the propulsion plant over time are tested. Experiments, conducted on data generated from a sophisticated simulator of a gas turbine, mounted on a Frigate characterized by a COmbined Diesel eLectric And Gas propulsion plant type, will allow to show the effectiveness of the proposed statistical/machine learning approaches and to benchmark them in a realistic maritime application.

According to the British Standard, maintenance includes all actions necessary to retain a system or an item in, or restoring it to, a state in which it can perform its required functions. The most common way of inflecting such concepts in practice has been always deployed according to a "fix it when it breaks" approach. However, this has been becoming an unaffordable and gold-brick methodology since data gathering from the field is ever cheaper and costs related to a breakdown may overcome the asset value.

Indeed, in the last decades, going-smart technology and cross industry needs in maintenance, for example, ranging from manufacturing to the transportation domain, have engendered a pivotal change from a reactive to a proactive perspective, trespassing the original focus on repairing–replacing actions toward more sophisticated preventive and prescriptive activities. In particular, maintenance actions can be framed into a taxonomy, which includes three categories: corrective, preventive and condition-based.

a. Corrective Maintenance (CM)

In corrective maintenance (CM), the equipment or asset is run down to its breaking down point, and maintenance activities are carried out afterward with the purpose of restoring the system at earliest.

In this case, maintenance activities are triggered by an unscheduled event (e.g. failure), and no a priori strategies can be deployed. Consequently, costs related to such approach are usually high; they comprise direct costs, for example, due to potentially concatenated failures of other parts of the asset, and indirect costs, for example, related to potential losses in (environmental, worker, etc.) safety and integrity, and asset unavailability.

b. Preventive maintenance (PM)

Preventive maintenance (PM), instead, is carried out before breakdowns in order to avoid them and minimize the possibility of potential issues related to failures. Several variations exist, such as adjustments, replacements, renewals and inspections, which take place subject to a predetermined planning and schedule; this allows to establish time-slots of unavailability of an asset (or part of it), opposite to the unpredictability, which characterize random failure patterns in CM. With particular reference to systematic PM, parts are replaced independently of their actual status, as a safety-level lifetime is established for them; in such a way, the probability of failures for a system decreases, as popularly proved through adverting to the so-called bathtub curve.

c. Condition-based maintenance (CBM)

Condition-based maintenance (CBM) refers to triggering maintenance activities as they are necessitated by the condition of the target system. This approach enables determining the conditions of in-service assets to predict potential degradations and to plan, consequently, when maintenance activities will be needed and should be performed to minimize disruptions.

In other words, CBM switch maintenance view from pure diagnosis to high-valued prognosis of faults.

Who is our focus of interest:

The CBM approach to maintenance is very generic, depicting a horizontal view to a crosscut problem in different heterogeneous domains. When a more vertical view is taken into consideration, focusing on the maritime domain, repair maintenance expenses for conventional ships can amount up to about 20% of total operability costs, including manning expenses, insurance and administration costs.

For naval applications, maintenance optimization is a key task, focused to reduce operations costs while getting the optimal availability of the ship for the intended service; such optimization is the result of a trade-off between excessive maintenance and machinery downtime, where CBM helps opening the door toward best balancing costs and availability. In other words, CBM enables a just-in-time deployment of ship maintenance, by allowing to plan and execute maintenance activities only when needed.

Therefore our focus of interest is naval forces, naval dockyards and shipyards, ship owners.

Data: Data have been generated from a sophisticated simulator of a Gas Turbines (GT), mounted on a Frigate characterized by a Combined Diesel Electric And Gas (CODLAG) propulsion plant type.

The experiments have been carried out by means of a numerical simulator of a naval vessel (Frigate) characterized by a Gas Turbine (GT) propulsion plant. The different blocks forming the complete simulator (Propeller, Hull, GT, Gear Box and Controller) have been developed and fine tuned over the year on several similar real propulsion plants. In view of these observations the available data are in agreement with a possible real vessel.

In this release of the simulator it is also possible to take into account the performance decay over time of the GT components such as GT compressor and turbines.

The propulsion system behaviour has been described with this parameters:

- Ship speed (linear function of the lever position lp).
- Compressor degradation coefficient kMc.
- Turbine degradation coefficient kMt.

so that each possible degradation state can be described by a combination of this triple (lp,kMt,kMc).

Modeling approach: In this study, from the view of a regression problem we will mainly focus on the linear method, which is simple and interpretable. We will also build up some fancier machine learning models in order to compare their accuracy scores for prediction purposes.

Possible limitations:

Deliverables:

1. Codes
2. Capstone Project Report
3. Presentation on the Capstone Project