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Review

State of the art and taxonomy of prognostics approaches, trends of prognostics applications and open issues towards maturity at different technology readiness levels

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Integrating prognostics to a real application requires a certain maturity level and for this reason there is a lack of success stories about development of a complete Prognostics and Health Management system. In fact, the maturity of prognostics is closely linked to data and domain specific entities like modeling. Basically, prognostics task aims at predicting the degradation of engineering assets. However, practically it is not possible to precisely predict the impending failure, which requires a thorough understanding to encounter different sources of uncertainty that affect prognostics. Therefore, different aspects crucial to the prognostics framework, i.e., from monitoring data to remaining useful life of equipment need to be addressed. To this aim, the paper contributes to state of the art and taxonomy of prognostics approaches and their application perspectives. In addition, factors for prognostics approach selection are identified, and new case studies from component-system level are discussed. Moreover, open challenges toward maturity of the prognostics under uncertainty are highlighted and scheme for an efficient prognostics approach is presented. Finally, the existing challenges for verification and validation of prognostics at different technology readiness levels are discussed with respect to open challenges.

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1. Introduction

Availability and maintainability of critical engineering assets is of great concern for a modern industry to ensure proper operation and to prevent undesirable situations. The optimization of service and minimization of risks/life cycle costs demands continuous monitoring of degrading behavior, and accurate prediction of lifetime at which the equipment will be unable to perform required function. According to [1], the barriers of conventional Condition Based Maintenance (CBM) for a widespread application, identified at a workshop organized by National Institute of Standards and Technology (USA): (1) inability to continually monitor; (2) inability to reliably predict remaining useful life; (3) inability of maintenance systems to learn and identify impending failures and recommend actions. We can further define these barriers as deficiencies in sensing, prognostics and reasoning. In addition, over the last decade, CBM has evolved into a discipline Prognostics and Health Management (PHM), which links the studies of failure mechanisms (corrosion, fatigue, etc.,) and life cycle management [1,2]. Basically, PHM is acting on a higher level than CBM with a strong focus on prognostics for managing health of an equipment. Since, it aims at extending the service life of an equipment, while minimizing exploitation and maintenance costs. The details about commonalities and the difference between CBM and PHM are given in [3]. The acronym PHM has two elements [1,4].

1. Prognostics refers to prediction/extrapolation/forecasting of process behavior, based on current health state assessment and future operating conditions.
2. Health management is decision process to intelligently perform maintenance, logistics and system configuration activities on the basis of diagnostic/prognostics.

The overall aim of PHM is to produce actionable information to enable timely decisions. PHM is accepted by the engineering systems community in general, and the aerospace industry in particular, as the future direction [5]. Also it is a present-day strategy to benefit vendors, integrators and operators to dynamically maintain their equipment in different domains: manufacturing, aviation, automotive, energy, defense, health care, etc., Fig. 1.

PHM use past, present and future information of an equipment in order to assess its health, diagnose faults, predict and manage failures [4]. Considering such activities, PHM is described as the combination of 7 layers adapted from Open System