A REVISED UNDERSTANDING OF ENGINEERING PROGNOSTICS

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ABSTRACT

Much of the understanding of prognostics currently appeared is scattered among many publication. Actually, most researchers have developed their own understanding of prognostics, and there are some divergences in literature. Firstly, this work reviews the qualified publication that explained their understanding about prognostics in engineering application. Then, this paper has been prepared a revised understanding of engineering prognostics. However, it is hoped that this paper will provide the researchers with alternative prognostics's understanding in use, and will be convenient when prognostics problem have to be solved.

Keywords: prognostics, failure

1. Introduction

Prognostics is a quite new area of interest. It reveals to be a very promising maintenance activity. Industrials show a growing interest in this thematic which becomes a major research framework. Prognostics becomes an emerging research field, most of the published work has naturally been exploratory in nature, consisting mainly of proof-of-concepts and one-off applications.Being able to perform precise and reliable prognostics is the key of CBM for an engineering system, and it is also critical for improving safety, planning missions, scheduling maintenance, reducing maintenance costs, and down time.

The remaining parts of this paper are organized as follows. In Section 2, this paper reviews the qualified publication that explained their understanding about prognostics in engineering application. The proposed understanding of prognostics is discussed in Section3. Finally, the conclusions are presented in Section 4.

2. Discussion: Prognostics's Understanding Based On Various Publication

Prognostics or prognosis comes from the Greek *prognostikos* (of knowledge beforehand). It combines *pro* (before) and *gnosis* (a knowing). It can be translated as the ability to acquire knowledge about events before they actually occur [1].

Prognostics is traditionally related to fracture mechanics and fatigue [2]. It started to be brought up by the modal analysis community as a field of interest. In this "meaning", prognostics is called the prediction of a system's lifetime and corresponds to the last level of the classification of damage detection methods. Prognostics can also be defined as a probability measure: a way to quantify the chance that a machine operates without a fault or failure up to some future time. This "probabilistic prognostics value" is all the more an interesting indication as the fault or failure can have catastrophic consequences (e.g. nuclear power plant), and maintenance manager need to know if inspection intervals are appropriate. For instance, papers [3, 4] address this acceptation for prognostics.

Prognostics can be defined as recently proposed by the International Organization for Standardization: "prognostics is the estimation of time to failure and risk for one or more existing and future failure modes" [5]. In this acceptation, prognostics is also called the "prediction of a system's lifetime" as it is a process whose objective is to predict the remaining useful life (RUL) before a failure occurs given the current machine condition and past operation profile [6]. On the other hand, prognostics is the ability to predict accurately and precisely the remaining useful life of a failing component or subsystem [7].

For many years, prognostics methods have been successfully developed and utilized in medical applications. Medical prognostics is defined as the prediction of the future course and outcome of disease processes, which may either concern their natural course or their outcome after treatment [8]. Derived from the same concept as medical prognostics, a lot of prognostics methods and systems have been developed for machinery maintenance in the past twenty years. Vibration signature analysis and oil analysis, because of their excellent capability of describing machine performance, have been employed for prognostics for a long time. Today, many prognostics applications are still based on those classical methods.

It is very important to understand the relationship between diagnostics and prognostics capabilities. Envisioning an initial fault to failure progression timeline is one way of exploring this relationship [7]. Fig. 1 represents such a failure progression timeline. This timeline stars with a new component in proper working order, indicates a time when an early incipient fault develops, and depicts how, under continuing usage, the component reaches a component or system failure state and eventually, if under further operation, reaching state of secondary system damage and complete catastrophic failure.

Traditionally diagnostics capabilities have been applied at or between the initial detection of a system, component, or subcomponent failure and complete system catastrophic failure. More recent diagnostic technologies are enabling detection to be made at much earlier incipient fault stages.

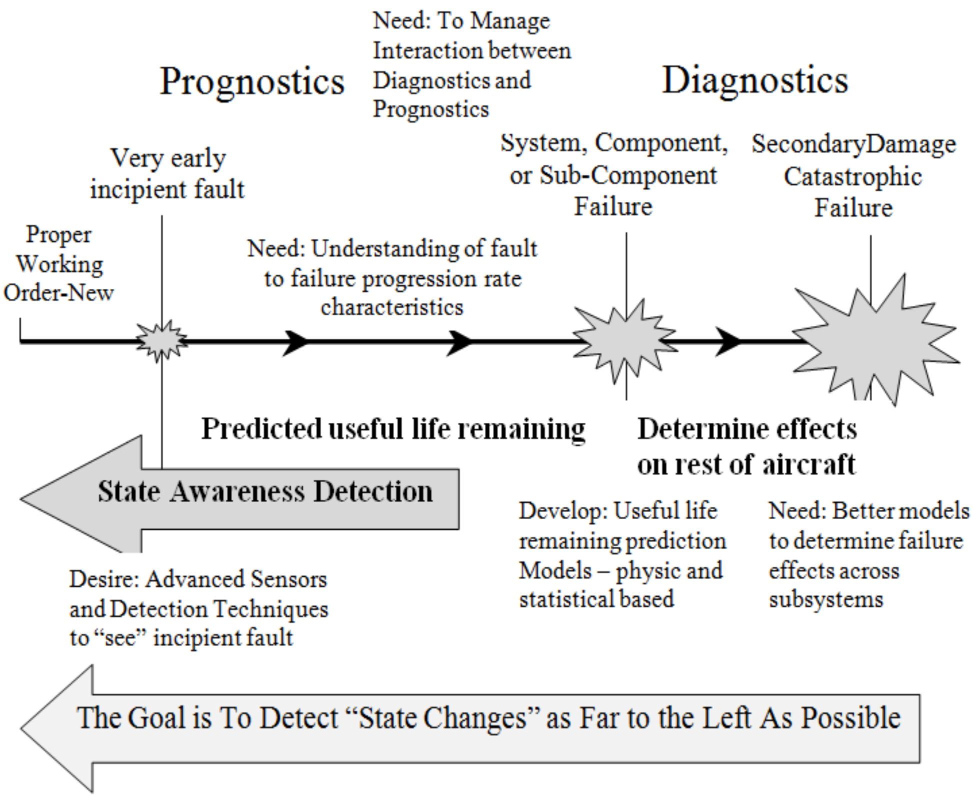

Fig. 1 Failure progression timeline [7]

Clarifying the relationship between diagnostics and prognostics will greatly help to understand the fundamentals of prognostics. In terms of the relationship between prognostics and diagnostics, diagnostics is when a failure mode is detected within a system or subsystem; prognostics occurs when a small incipient fault is detected, and a relatively accurate estimation of useful life remaining and/or performance life remaining until full failure is determined [9].

Fig. 2 presents that faults A, B, C, and D represent impending faults in a machine. After a long degradation stage where initial defects are developing, fault B finally caused the machine to break down. Diagnostics can be conceptualized as a vertical exploration of this problem to identify the leading cause after the failure has occurred, while prognostics is to investigate the problem both vertically and horizontally during the degradation period [10]. The key concept behind prognostics is to predict an event before its possible occurrence. Time is thus inherent to the concept of prognostics and distinguishes it from that of diagnosis, where the future plays a less important role. Prognostics does not only intend to discover the potential failure mode, but also to forecast the development pattern and tendency of that fault.

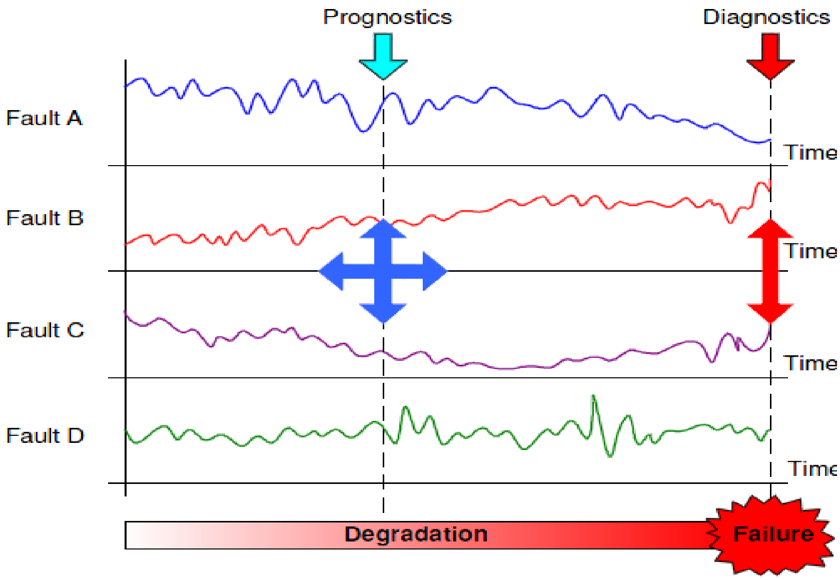

Fig. 2 Different perception of diagnostics and prognostics [10]

Some issues involved in failure prediction are shown in Fig.3. This figure shows the evolution of a fault feature of interest and introduces the notion of prescribed alarm bounds or fault tolerance limits outside of which a failure is declared. Also emphasized is the importance of confidence limits on the feature predicted values. When the confidence limits reach the tolerance limits, an alarm is declared.

Vachtsevanos and team as depicted in [7] explained about a case study of degradation prognostics. The analysis of the degradation requires the simulation to predict the range of conditions that might exist, given the measurement and modeling uncertainties. The result of this process is shown in Fig.4.

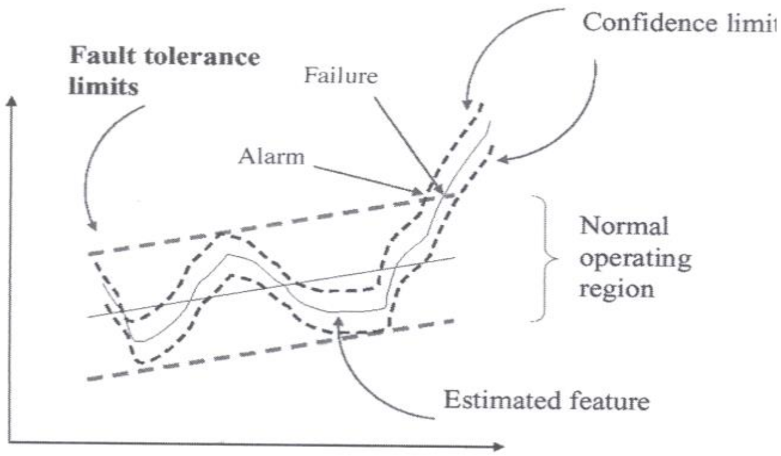

Fig. 3 Fault trend and failure prediction [7]

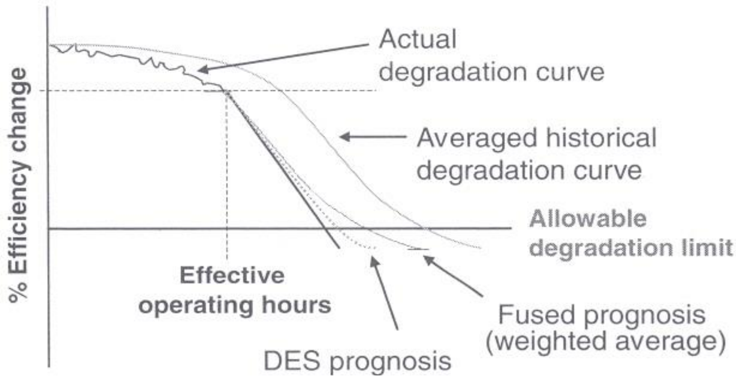

Fig. 4 Degradation curve as a prognostics model visualization [7]

Finally, a prognostics system architecture can be constructed as depicted in Fig. 5. The simplified system consists of the system confidence value calculation, which yields a overall system performance assessment [10]. It is designed to reveal the impending failure modes and the remaining useful life. In the confidence value domain, firstly, a signal relevance study will be conducted for the multiple sensor inputs. Signals will be clustered and weighed according to its relationship. Secondly, a performance assessment algorithm, which embeds the sensor fusion mechanism, will transform the signals into a system level confidence value that depicts the machine's overall health status. The calculation of confidence value should be calibrated by the historical failure analysis or physical life cycle model, which ensures that a reasonable threshold can be defined. Finally, confidence value can be tracked and predicted using time series analysis methods.

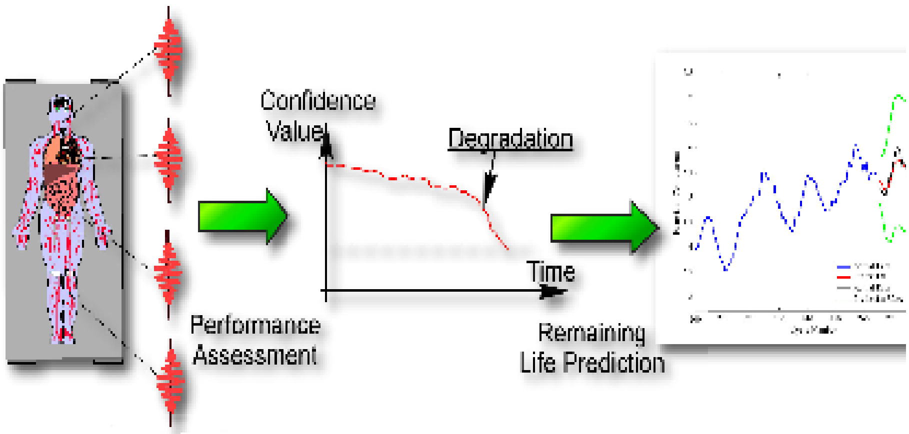

Fig. 5 The relationship among performance assessment, degradation curve, and remaining useful life [10]

3. The Proposed Understanding of Prognostics

In terms of the relationship between prognostics and diagnostics, diagnostics is when a failure mode is detected within a system or subsystem; prognostics occurs when a small incipient fault is detected, and a relatively accurate estimation of useful life remaining and/or performance life remaining until full failure is determined. The key concept behind prognostics is to predict an event before its possible occurrence. Time is thus inherent to the concept of prognostics and distinguishes it from that of diagnostics, where the future plays a less important role. Clarifying the relationship between diagnostics and prognostics will greatly help to understand the fundamentals of prognostics.

Prognostics is the ability to predict the remaining lifetime, futurehealth states, or reliability of machinery based on currenthealth assessment and historical trends.Thus, there are two mainfunctions of prognostics: failure prediction and remaining lifetimeestimation. Failure prediction allows the pending failures to beidentified before they come to a serious situation. Remaining lifetimeis the time left before a particular fault will occur or any partneeds to be replaced.

The proposed understanding of prognostics explained briefly in Fig. 6 as follows.

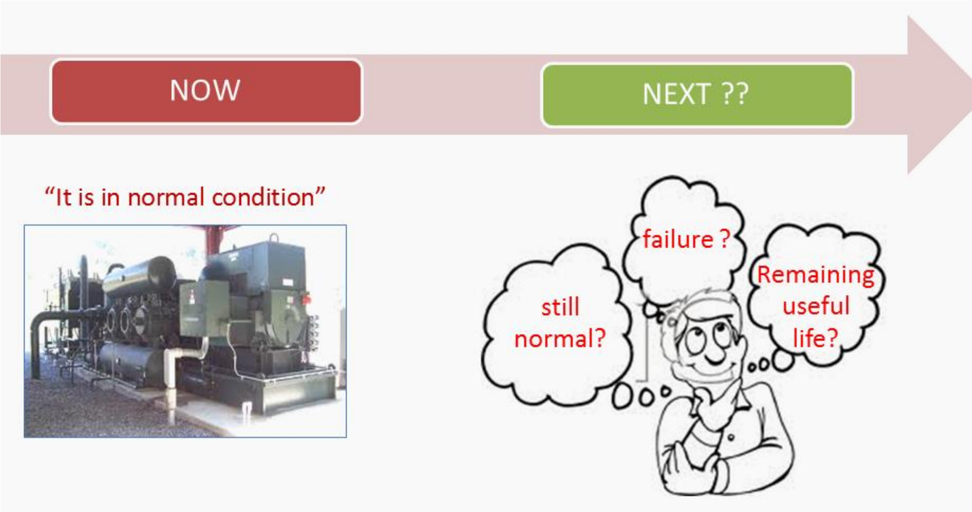

Fig. 6 A simple ilustration about the proposed understanding of engineering prognostics

4. Conclusion

A revised understanding of prognostics for engineering application has been proposed.Clarifying the relationship between diagnostics and prognostics will greatly help to understand the fundamentals of prognostics.Finally, this paper provides the researchers with a new prognostics's understanding, and will be helpful for engineering problem.

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