Computational Intelligence in Prognostics and Health Management (PHM)

Plenary Talk

Piero P. Bonissone

Computing and Decision Sciences Global Technology Office

GE Global Research

Niskayuna, NY 12309, USA

e-mail: bonissone@crd.ge.com

Prognostics and Health Management (PHM) is a multi-discipline field, as it includes facets of Electrical Engineering (reliability, design, service), Computer Science and Decision Sciences (Computational Intelligence, Artificial Intelligence, Soft Computing, Machine Learning, Statistics, OR), Mechanical Engineering (geometric models for fault propagation), Material Sciences, etc.

Within this talk we will focus on the role that Computational Intelligence (CI) plays in PHM for assets such as locomotives, medical scanners, aircraft engines, etc. functionalities. The main goal of PHM is to maintain these assets' operational performance over time, improving their utilization while minimizing their maintenance cost. This tradeoff is typical of long-term service agreements offered by OEM's to their valued customers. The main goal of PHM for assets such as locomotives, medical scanners, and aircraft engines is to maintain these assets' operational performance over time, improving their utilization while minimizing their maintenance cost. This tradeoff is critical for the proper execution of Contractual Service Agreements (CSA) offered by OEM's to their valued customers.

When addressing real-world PHM problems, we usually deal with systems that are difficult to model and possess large solution spaces. So we augment available physics-based models, which are usually more precise but difficult to construct, customize, and adapt, with approximate solutions derived from Computational Intelligence methodologies. In this process we leverage two types of resources: problem domain knowledge of the process (or product) and field data that characterize the system's behavior. The relevant available domain knowledge is typically a combination of first principles and empirical knowledge. This knowledge is often incomplete and sometimes erroneous. The available data are typically a collection of input-output measurements, representing instances of the system's behavior, and are generally incomplete and noisy. Computational Intelligence is a flexible framework in which we can find a broad spectrum of design choices to perform the integration of knowledge and data in the construction of approximate models.

To better understand PHM requirements, we introduce a decision-making framework in which we analyze PHM decisional tasks. This framework is the cross product of the decision's *time horizon* and the *domain knowledge* used by CI models. Within such a framework, we analyze the progression from simple to annotated lexicon, morphology, syntax, semantics, and pragmatics. We use this metaphor to monitor the leverage of domain knowledge in CI to perform anomaly detection, anomaly identification, failure mode analysis (diagnostics), estimation of remaining useful life (prognostics), on-board control, and off board logistics actions. This is shown in the following figure.

Time Horizon

	One Shoot	Tactical	Operational	Strategic	Lifecycle
Lexicon		Anomaly Detection			
Morphology		Anomaly Detection Anomaly Identification			
Marked-up Lexicon					
Syntax		Anomaly Id. Diagnostics	Scheduling		
Semantics	Transactional Decision	Anomaly Id. Diagnostics Prognostics Control	Scheduling Planning Readiness Assessment Asset Allocation Optimization DM	Long-Term Planning Contingency Planning Asset Management MOO, Tradeoffs, MCMD	
Pragmatics					Model Update & Maintenance

Domain Knowledge

We will illustrate this concept with a case study in anomaly detection, which is solved by the construction and fusion of an ensemble of diverse detectors, each of which is based on different CI technologies.