Soft Computing in Prognostics and Health Management (PHM) Applications:
A Case Study in Anomaly Detection

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Soft Computing (SC) is a term that has evolved, since its inception in 1991, to represent a methodology and a set of techniques covering the aspects of data-driven models design, domain knowledge integration, model generation, and model tuning. We distinguish between offline Meta-heuristics (MH's), used for model design and tuning, and online MH's, used for models selection or aggregation. This view suggests the use of hybrid SC at each MH's level as well as at the object level. We manage model complexity by finding the best model architecture to support problem decomposition, generate local models with high-performance in focused applicability regions, provide smooth interpolations among local models, and increase robustness to imperfect data by aggregating diverse models.

Within the broad spectrum of Soft Computing (SC) applications, we will focus on Prognostics & Health Management (PHM) for assets such as locomotives, medical scanners, aircraft engines, etc. 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. Typical PHM functions range from anomaly detection, to anomaly identification, failure mode analysis (diagnostics), estimation of remaining useful life (prognostics), on-board control, and off board logistics actions.

We illustrate this concept with a case study in anomaly detection for a fleet of physical assets (such as an aircraft engines or a gas turbines.) Anomaly detection typically uses unsupervised learning techniques to extract the underlying structural information from the data, define normal structures and regions, and identify departures from such regions. We focus on one of the most common causes for anomalies: the inadequate accuracy of the anomaly detection models, which are prone to create false alarms. To address this issue, we propose a hybrid approach based on a fuzzy supervisory system and an ensemble of locally trained auto associative neural networks (AANN's.) The design and tuning of this hierarchical model is performed using evolutionary algorithms. In our approach we interpolate among the outputs of the local models (AANN's) to assure smoothness in operating regime transition and provide continuous condition monitoring to the system. Experiments on simulated data from a high bypass, turbofan aircraft engine model demonstrated promising results.