RESEARCH

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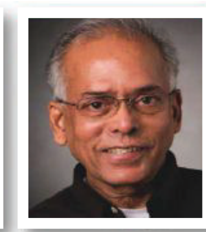
This month we highlight two articles from *IISE Transactions*. The first article provides a literature review on internet of things (IoT) in smart manufacturing systems. The paper discusses various aspects of IoT in manufacturing, including the evolution from hard-wired computer networks through human networks to the new era of smart and connected networks of manufacturing "things" that integrates cloud computing, virtual reality and big data analytics. A case study is also presented to illustrate the effectiveness of IoT to help manufacturing performance improvement. The second article studies how to predict the remaining useful life of a system with multiple sensing signals. The authors propose a new concept named as "failure surface" to define system failure, and further use a classification method to learn the failure surface. One advantage of the proposed method is its flexibility in considering complicated relationships among multiple sensors and also in handling asynchronous signals. These articles will appear in the November 2019 issue of *IISE Transactions* (Volume 51, No. 11).

Internet of things, analytics usher in new generation of smart manufacturing


Hui Yang


Soundar Kumara


Satish Bukkapatnam


Fugee Tsung

The manufacturing sector has a large footprint in the U.S. economy. To achieve competitive advantage in the global market, modern industries are investing in new technologies like the internet of things (IoT), big data analytics, cloud computing and cybersecurity. IoT helps a large number of entities in manufacturing, "things," to communicate and exchange data. Here, manufacturing "things" often refers to materials, sensors, actuators, controllers, robots, human operators, machines, products and material handling equipment, to name a few.

The internet-based IoT infrastructure provides an unprecedented opportunity to link manufacturing "things," services and applications so as to achieve effective digital integration of the entire manufacturing enterprise.

However, large-scale IoT sensing leads to the proliferation of big data from manufacturing systems in the physical world. The challenges facing manufacturing researchers are how to reflect physical manufacturing in cyberspace through data-driven information processing, knowledge representation and modeling, and how to exploit the useful information and knowledge extracted from data to improve the performance of manufacturing operations in the physical world. Indeed, smart manufacturing depends to a great extent on data-driven innovations to realize the seamless integration of cyber and physical spaces.

These issues are discussed in the paper "Internet of Things for Smart Manufacturing: A Review" by professors Hui Yang and Soundar Kumara of The Pennsylvania State University, Satish Bukkapatnam of Texas A&M University and Fugee Tsung of Hong Kong University of Science and Technology. This paper discusses the evolution from hard-wired computer networks through human networks (e.g., Facebook, LinkedIn, Twitter) to the new era of smart and connected networks of manufacturing "things." This trend is integrated with rapid advances in cloud computing, virtual reality and big data analytics to provide a new paradigm for smart manufacturing. This paradigm is a necessary foundation for building artificial intelligence-based futuristic manufacturing systems.

The team presented a case study in leveraging IoT and distributed computing to develop new network models for machine information processing and condition monitoring. Each machine is represented in cyberspace as a node of a large-scale network where node attributes are derived from machine signatures. Edges depend on the machine-to-machine interactions or, to be more specific, material, energy and information exchange between nodes. Dynamic network models help to extract useful information from machines (e.g., utilization, power use and degradation condition), thereby optimizing manufacturing planning, process control and maintenance decisions.

Further, this paper discusses the IoT cybersecurity issues that are of paramount importance to businesses and operations, as well as IoT and smart manufacturing policies by governments across the world. The team hopes this paper will help increase more in-depth investigations to usher in a new generation of smart manufacturing for strong business and economic growth.

CONTACT: Hui Yang; huy25@psu.edu; (814) 865-7397; Department of Industrial and Manufacturing Engineering, The Pennsylvania State University, 310 Leonhard Building, University Park, PA 16802

Predicting remaining useful life of engineering systems based on data analysis of multiple sensor signals

Degradation is inevitable in engineering systems and may lead to catastrophic failure. To monitor the degradation process, it is a common practice to deploy multiple sensors to collect heterogeneous signals from engineering systems.

For example, nowadays hundreds or even thousands of sensors are deployed in an aircraft engine to simultaneously monitor performance in real time. By analyzing the collected sensor signals, the remaining useful life of the systems can be predicted and then maintenance actions can be appropriately scheduled to improve the system performance and avoid sudden failure.

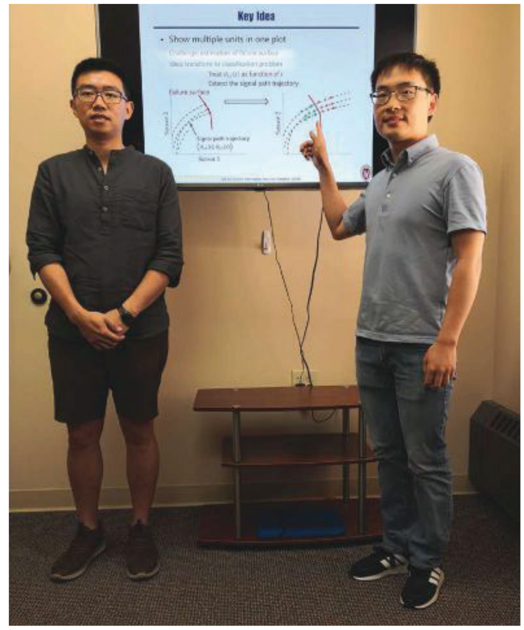
As each sensor signal only measures a certain characteristic of the system status, this leads to significant challenges such as heterogeneous data types, different signal-to-noise ratios, complex sensor relationships and distinct data acquisition rates. Therefore, the key problem of multisensor degradation modeling is how to develop a generic methodology that effectively identifies and fuses the useful information from multiple sensor signals to obtain a more accurate estimation of the degradation status.

In the paper "A Generic Framework for Multisensor Degradation Modeling based on Supervised Classification and Failure Surface," doctoral student Changyue Song and professor Kaibo Liu from the University of Wisconsin-Madison, along with professor Xi Zhang from Peking University, investigated the problem of remaining useful life prediction with multiple sensor signals.

They developed a new method that transformed the multisensor degradation modeling into a supervised classification problem, where a new concept called "failure surface" was proposed and a classifier was incorporated to estimate the probability of failure based on the underlying signal paths.

Comparing with existing literature, the proposed method has several unique advantages: it is flexible to consider complicated relations of the sensors, capable of handling asynchronous signals when different sensors have different sampling frequencies and can also automatically screen out noninformative sensors that are not related to the underlying degradation process.

As a result, the proposed method can be easily adopted in different applications in practice, leading to more effective predictive maintenance for industrial assets. Tests have shown that the proposed method can much improve the remaining useful life prediction based on the degradation datasets of aircraft engines.



Professor Kaibo Liu (left) and Changyue Song present the failure surface concept for multisensor degradation modeling.

CONTACT: Kaibo Liu; kliu8@wisc.edu; (608) 890-3546; Room 3017, Mechanical Engineering Building, University of Wisconsin-Madison, 1513 University Ave., Madison, WI 53706

Jianjun (Jan) Shi is the Carolyn J. Stewart Chair and professor in the H. Milton Stewart School of Industrial and Systems Engineering at the Georgia Institute of Technology. He is editor-in-chief of IISE Transactions*, an academician of the International Academy for Quality and a fellow of IISE, ASME and INFORMS.*

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