Smart Prediction to Prevent Downtime

A smart watchdog system sounds an alert before serious problems arise in the manufacturing process.

by Jay LEE and Jun NI

Is there any way to prevent the breakdown of a piece of machinery – especially an expensive and sophisticated piece of equipment – so that the manufacturing operation can run like the well-oiled process it is intended to be? Manufacturers' wish lists would certainly include the ability to predict and troubleshoot trouble before it happens; smart systems known as Watchdog Agents are about to grant their wishes.

Developed by the Center for Intelligent Maintenance Systems (IMS) in the US, the software employs prognostic technologies to transform product and manufacturing systems from the traditional fail-and-fix to predict-and-prevent. These transformational technologies will enable smart products and systems with embedded and remote intelligence to predict and forecast their performance proactively as well as to synchronise their service needs with business support systems.

The IMS Center – a cooperative National Science Foundation Industry/University Cooperative Research Center established by the University of Wisconsin at Milwaukee and the University of Michigan at Ann Arbor – gets its support from over 45 company members and sponsors including General Motors, Intel, DaimlerChrysler, United Technologies, Harley Davidson, Rockwell Automation, Hitachi, Mitsubishi Heavy Industry, Omron, and Toyota. The centre focuses on infotronics technologies for prognostic and smart-service systems. Infotronics comprises the fields of industrial automation, integrated systems, and information technology.

Most machine maintenance today is either reactive – fixing or replacing equipment after it fails – or blindly proactive – assuming a certain level of performance degradation, with no input from the machinery itself, and equipment servicing on a routine schedule whether service is actually needed. Both scenarios are extremely wasteful.

Although machines often seem to fail suddenly, in reality they usually go through a measurable process of degradation before they breakdown. When technicians network and remotely monitor smart machines, and when sophisticated embedded systems model and continually analyse their data, they can go beyond mere predictive maintenance to intelligent prognostics – pinpointing exactly which and when machine components are likely to fail and autonomously trigger service and order spare parts.

The existing condition-based maintenance approach estimates a machine's current condition by watching for indications of failure. The IMS Center has developed a toolbox of algorithms for multisensor performance assessment and prediction. These tools enable quantitative assessment and then performance-degradation prediction of key product components, thus closing the loop in product-life-cycle monitoring and management. The centre and the Technical University of Berlin jointly pursue this line of research. The centre is also currently establishing a partnership with the Singapore Institute of Manufacturing Technology (SIMTech) to develop the technology in Singapore.

Figure 1 shows an IMS that comprises (1) components to transform data into information into knowledge and synchronise decisions with remote systems, (2) intelligent embedded prognostics algorithms for performance-degradation assessment and prediction, (3) an infotronics software and hardware platform enabling products to think, link, reconfigure, and sustain themselves within a networked and tether-free environment, and (4) embedded product service and life-cycle information for closed-loop product design.

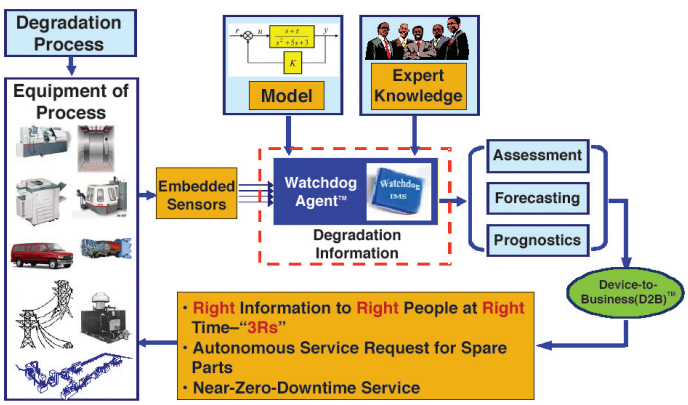

Figure 1: Infotronics structure of an intelligent maintenance system.

Smart Prognostics

A Watchdog Agent, created by IMS Center, bases its degradation assessment on readings from multiple sensors that measure critical properties of the process or machine under consideration. Alteration of the sensor readings fed into the Watchdog Agent by the degradation process enables it to assess and quantify that degradation by quantitatively describing the corresponding change of sensor signatures. In addition, looking at the trend and performing statistical modelling of the observed process-performance signatures and/or model parameters allow prediction of future behaviour of these patterns and thus the forecast of process/machinery performance.

The Watchdog Agent also memorises significant signature patterns, allowing it to answer these questions:

- When is the observed process or equipment going to fail or degrade to the point when its performance becomes unacceptable?
- Why is the performance of the observed process or equipment degrading?

The Watchdog Agent feeds prognostic and diagnostic output mounted on all processes and machines of interest into the Decision Support Tool that addresses the question what is the most critical object or process in the system with respect to maintenance or repair? The answer lies in taking into account the risks of taking, or not taking, maintenance action at a given time, and then optimising the cost if the decision to perform maintenance is made or the cost of downtime and repair if maintenance is omitted and the process or machine fails.

The software achieves assessment of performance degradation via several modules, including carrying out processing of multiple sensory inputs and extraction of features relevant to description of a product's performance and sensor fusion (Figure 2).

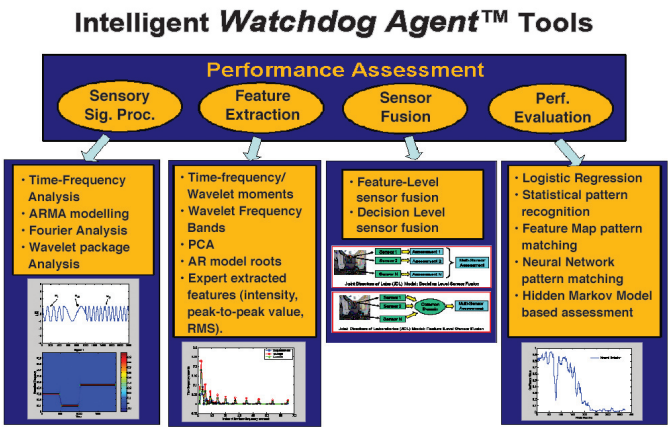

Figure 2: Performance assessment modules.

Researchers have already developed and implemented several Watchdog Agents for online performance assessment as standalone applications in a number of industrial and service facilities. A typical mechatronics system such as an elevator door system has successfully validated an IMS remote monitoring and maintenance platform. Figure 3 shows the system architecture of the test bed. A data-acquisition system collects data from the elevator door controller, switches, encoder, and some vibration sensors. The Watchdog Agent processes and then transforms raw data into a system performance index.

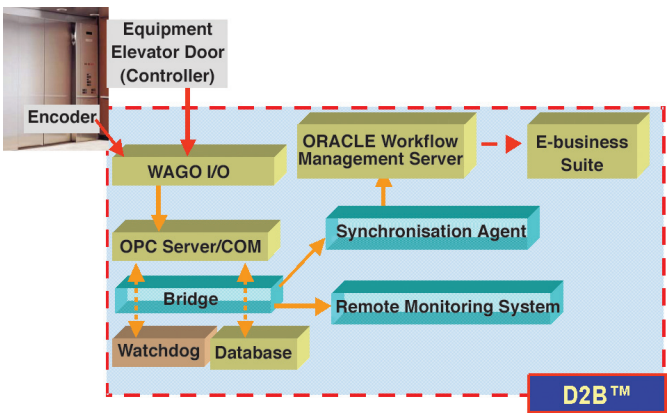

Figure 3: Remote monitoring and predictive maintenance of an elevator system.

Figure 4 shows a time-frequency-based Watchdog Agent installed for performance assessment of a gearbox in automated-storage-and-retrieve-system material handling. Four vibration-sensor readings have been fused to evaluate its performance autonomously and online. Processing the vibration signals into joint time-frequency energy distributions allows extraction of a set of time-shift invariant time-frequency moments. Using statistical reasoning allows evaluation of the overlap between signatures describing the normal process behaviour (used for training) and those describing the most recent process behaviour.

Figure 4: Material-handling device for staging.

IMS Center researchers have designed a wide range of Watchdog Agents to address various applications of different levels of complexity and criticality. They will be studying performance forecasting (knowing when something will happen) more in depth. They are also establishing a link with a decision-making module that will enable optimal maintenance action in a timely manner to achieve complete functionality for scalable applications.

Finally, to assess and to predict product performance requires an embedded infotronics agent to enable assessment of a product's reusability, as well as its proactive maintenance based on that prediction. The research challenge will be to accomplish sophisticated performance evaluation and to achieve prediction capabilities imposed by embedding under severe power consumption, processing power, and data storage limitations.

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