**Objectives**

- To detect sensor progressive degradation and predict sensor failures and reconstruct the degrading sensor readings

**State-of-the-Art**

- **Direct hardware redundancy method**: use two or more sensors to measure the same key variable and assess sensor performance by comparing the consistency between different sensors, simple to implement but potentially costly
- **Functional redundancy method**: use multiple sensors to measure related variables and validate sensor readings by employing sensor fusion techniques, more complex but cheaper approach

**Approaches**

- **Zero-lag correlation based direct hardware redundancy method**
  - By fitting Auto-Regressive Moving Average Vector (ARMAV) time series model to the data within an extending window, the dynamics of the plant and input/output sensor can be identified by finding the zeros and poles of the transfer function.

**Methods**

- **Future Work**
  - Evaluate both methods with real industrial data instead of simulation data
  - Develop algorithm for sensor data reconstruction
Detection of Intermittent Connections in An Industrial Network

Objectives

- Provide network performance and diagnostic information at the device level and network level.
- Develop novel network health monitoring tools for plant floor network systems.
- Minimize network diagnosing time due to intermittent connections on the network.

State-of-the-Art

- Intermittent Connection is difficult to identify.
- No tool available for Intermittent Connection detection

Approaches

- Network health monitoring framework

  - Error Source Detection

Accomplishments

- Developed Error Source Detection System

Future Work

- Conduct plant validations
- Construct intermittent connection model and estimate nodes bus-off time

Sponsors

- NSF I/UCRC for Intelligent Maintenance Systems

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu
**Objectives**

- Track 5-axis mill health under dynamically-varying, oblique loading conditions
- Improve tracking and prediction of process health for various machines through signal processing
- Propose a general method for tracking the health of a mill bit without adding sensors to the system
- Decrease the overall cost of milling compressor blades by using a condition-based method to change mill bits

**State-of-the-Art**

- Use only the load data (amount of current) from the spindle and 5 servo motor drives to track mill bit health
- Explore correlation between servo motor current and cutting force in an oblique cutting
- Employ Time Frequency Analysis and other recently-developed methods to extract features from load data.

**Approach**

- Filter raw load data using low-pass filter
- Partition filtered data to separate milling passes based on varying levels in servo-motor current
- Extract features from filtered data using TFA

**Accomplishments**

- Provided warning time (based on raw data) before unexpected shutdown happens
- Found method for properly partitioning data
- Determined predictive model for health of mill bit
- Produced CV degradation trends for load data

**Future Work**

- Finish characterization of mill health
- Install sensors and begin collecting data on grinder
- Integrate and process data from multiple sensors with various frequency ranges for the grinder project

**Sponsors**

- This research is supported by General Electric Aviation. My contact at GE is Roger Lindle.
Objectives

- Develop novel approach to realize “immune systems” functionalities in automated systems.
- Robustly detect abnormal behavior, isolate source, and compensate for negative effects to achieve desired performance in spite of the presence of an anomaly.

Problem Statement

- The goal of the proposed research will be to incorporate the natural immune system functionalities and uniqueness into automotive engine system. There are three primary parts for accomplishing this target:
  - Anomaly Detection Agents (ADA-s)
    - Identify the intrusion depicted in the degraded system
    - Isolate the intrusion source by reconfiguring, reconnecting and decomposing detection agents.
  - Diagnostic Agents (DA-s)
    - Recognize and describe the anomaly source character if input/output patterns have been observed in the past.
    - In case input/output patterns have not been seen in the past, create a new DA for recognizing the new anomaly next time.
  - Control Agents (CA-s)
    - Utilize fault characterization from DAs to postulate control laws for restoring the performance of the anomalous subsystem as much as possible.

Anomaly effects automated system like a virus effects human

Proposed Research Task and Time Table

**Tasks**

<table>
<thead>
<tr>
<th>Subtask</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtask 1.1: Multi-regime anomaly detection</td>
<td>0-6</td>
</tr>
<tr>
<td>Subtask 1.2: Isolation of the Anomaly Source</td>
<td>7-12</td>
</tr>
<tr>
<td>Subtask 1.3: Practical implementation of ADA-s</td>
<td>13-18</td>
</tr>
<tr>
<td>Subtask 2.1: Methods for realization of DA-s</td>
<td>19-24</td>
</tr>
<tr>
<td>Subtask 2.2: Development of identification methods</td>
<td>25-30</td>
</tr>
<tr>
<td>Subtask 2.3: Demonstration on an engine subsystem</td>
<td>31-36</td>
</tr>
<tr>
<td>Subtask 3.1: Design of CA-s for recovering performance</td>
<td></td>
</tr>
<tr>
<td>Subtask 3.2: Implementation on an engine subsystem</td>
<td></td>
</tr>
</tbody>
</table>

The research activity for over a three-year period

Project Leadership and Management

- PI: Dr. Dragan Djurdjanovic, University of Michigan
- Co-PI: Prof. Jun Ni, University of Michigan
- Kenneth Marko, ETAS Inc

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu