Data-driven Prognosis, Health Monitoring, and Control for Smart Manufacturing

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Data Can Improve Production Control

• Complex system, sub-system, and component interactions/relationships within manufacturing systems make it challenging to determine the specific influences on performance

• Increasing interest and ability to leverage data and analysis to generate actionable intelligence about system interactions/relationships for control

• No uniform process exists that guides sensing, monitoring, and control at all levels from the component to the system to the enterprise
Dynamic Control of Production Cell

Materials, Resources → Control Volume → Finished Part

Control Volume

Linear Axes  Process & Equipment  Robotics
Research Focus

• Identify data and information needed to make an informed decision with respect to setting and updating control points
• Define data collection requirements to minimize the collection of "big data."
• Determine appropriate structure, organization, and analysis of data to gain actionable intelligence
• Enable feedback of intelligence through the system to update control for optimal production

**Expected Impact:** Improved decision-making support and automation with a focus on vendor-neutral approaches and plug-and-play solutions
Research Thrust: Manufacturing Process and Equipment Monitoring

- **GOAL**: Identify high-value data sources and most appropriate opportunities to collect data to avoid the big data challenge to improve monitoring and control?

- **Infrastructure**: How can we collect data from manufacturing systems across multiple sensing and control levels?

- **Data**: What is the right way to collect the best data available?

- **Actionable Intelligence and Control**: How can I apply machine learning to diagnosis and predict system performance and use this knowledge for control?
Research Thrust: Machine Tool Linear Axes Diagnostics & Prognostics

- **Goal:** Develop sensor-based method with inertial measurement unit (IMU) for quick and accurate tracking of machine tool linear axis errors
- Test bed was constructed with laser-based system for V&V
- Initial data sets collected with positive preliminary results
- Method will be applied in Summer 2016 on multi-axis machine tool

1. Linear Slide
2. DC Motor with Encoder
3. Sensor Box
4. Laser
5. Laser Sensor Boxes
Research Thrust: PHM for Robotics

- **Goal**: Develop the measurement science to enable the determination of what, where, and when faults/failures will materialize within a robot system.

- **Robot System**: A robot along with end-effector(s), sensors, controller(s), automation, user interface, etc.

- **Approach**: Develop a PHM for Robotics Test bed that will include:

  - Supporting the development test methods and implementation of use case scenarios
  - Producing reference data from a range of sensors and activities

**Possible actions**

1. PHM remedy module
   - Accuracy related PHM remedy module, e.g., recalibration
   - Human related PHM remedy module, e.g., controller setting errors
   - Performance related remedy module, e.g., joint failure

2. Possible action module
   - Possible action 1
   - Possible action 2
   - Possible action 3

3. Issue alarm of Health condition
   - Yes
   - No

4. Detected abnormal situation?
   - Yes
   - No

**Implementation**

- Hardware - sensing
- Advanced sensing suite
  - Advanced sensing cloud, Design embedded or add-on sensing module for PHM
- Data collection module
  - Data collection, classification, correlation, filtering & analysis
- Cost function module
  - Cost function 1
  - Cost function 2
  - Cost function 3
- Degradation module
  - Assessment of system health condition
- Prognostic model
  - Prognostic analysis for health/safety condition
- Visualization Tools
  - Visualizing data & cost functions related to prognostic model
- Auto correction procedures

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2016 MBE Summit
Some Next Steps

- Use Case Development
- Reference Datasets
- Standards
- Guidelines