PHM FOR SMART MANUFACTURING SYSTEMS

CASE STUDIES & LESSONS LEARNED

XIAONING JIN
ASSISTANT PROFESSOR
DEPT. OF MECHANICAL & INDUSTRIAL ENGINEERING
NORTHEASTERN UNIVERSITY
COMPELLING NEEDS OF NEXT GENERATION MANUFACTURING

Next Gen. Manufacturing
- Machine level
- Process level
- Factory level

Connect & Data Collection
- Sensor data
- Content (images, videos, manuals, etc.)
- Historian data
- Machine data

Advanced Analytics
- Assess & Analyze
- Predict
- Consolidate
- Optimize

- Self-aware and predictive of equipment condition
- Resilient to uncertainties and disruptions
- Near-zero defect and downtime factory performance

- Massive and complex data
- Imperfect/missing data
- Multi-stream/multi-source data

- Greater asset reliability
- Lower operating costs
- Increased factory visibility
- Worry-free production
Current Data Analytics capabilities are stronger in the areas of monitoring and connecting equipment than in predicting issues and optimizing operations.

UNOBSERVABLE PERFORMANCE DEGRADATION

- Model-based methods
  - Physics-based, empirical
- Data-driven methods
  - Statistical, AI
- Hybrid methods
  - Various fusion interface
CHALLENGES & OPPORTUNITIES

• Rich Data / Sparse Data environment
• Sensor selection & allocation
• Lack of understanding degradation mechanism
• Sampling Strategy (static, dynamic, event-driven)
• Nominal condition (baseline) identification
• Variability & uncertainty quantification & control
• Physics-based or Data-driven methods fusion and interface design
• Applications: (1) discrete manufacturing (2) continuous manufacturing
MULTISTAGE DISCRETE MANUFACTURING SYSTEMS

Data from Sensors
- Force (N)
  - Tonnage waveform signal

Data from Controllers
- Speed (RPM)
  - Spindle rotation command

Process
- Stage 1
- Stage 2
- Stage 3

Products
- Quality Control
- Inspection

Data from Metrology
- 2D surface features
- 3D high definition image

**Physical World**
- Real implementation
- Real component
- Real machine
- Real system
- Real ……

**Cyber Space**
- Virtual synthesis
- Virtual component
- Virtual machine
- Virtual system
- Virtual ……

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**Physical knowledge**

**Monitoring data**

**Degradation model**

**Risk analysis**

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**Methodology**

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FUSION OF PHYSICAL MODELS AND DATA ANALYTICS

- An integrated physics-based and data-driven prognostics for degradation modeling of vehicle sub-systems under different environments, each dynamic.

Physical modeling + Data analytics

- Fast system dynamics
  - System Dynamics Model
  - Future System Behavior
- Slow degradation dynamics
  - Degradation Model
  - Failure Mode/Remaining Useful Life
- Resilience Control & Decision Making

Inputs/Outputs
Dynamic Operation Conditions
Incomplete Multiple/unknown Failure Modes
PHM FOR SMART CONNECTED SYSTEMS

- Networked Machines
- Connected IoT Devices
- Remote Monitoring
- Fleet Health Management of Connected Assets
- ...

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