Industry Forum

NIST Research on Monitoring, Diagnostics, and Prognostics for Manufacturing Workcells

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Disclaimer

• Identification of commercial systems does not imply recommendation or endorsement by NIST

• Identified commercial systems are not necessarily the best available for the purpose
The Most Critical Piece of the Project...
Research Objective and Deliverables

The PHMC project will deliver *Measurement Science Products* for robust sensing, diagnostics, prognostics, and control that enable manufacturers to respond to planned and un-planned performance changes thereby enhancing the efficiency of smart manufacturing systems.
How do we know this is Important?

- Measurement Science Roadmapping Workshop
- Manufacturing Standards Requirements Gathering Workshop
- Collaborator studies with university and industry partners
- Interactions with various technical organizations

www.nist.gov/el/isd/ks/phmc.cfm
Research Levels

Manufacturing Process and Equipment Monitoring
- System-Level Research
- Smart Manufacturing Systems Testbed

Health and Control Management for Robot Workcells
- Work Cell-Level Research
- PHM for Robot Systems Lab/Testbed

Machine Tool Linear Axes Diagnostics and Prognostics
- Component-Level Research
- Linear Axis Test bed & ‘Shops’ Machine Tools
Manufacturing Workcells

Potential Fault/Failure Sources
- Human
- Control/Software
- Mechanical
- Electrical
- Environmental
Robotic Workcell

• **Goal:** Develop the necessary measurement science to enable the V&V of monitoring, diagnostic, and prognostic technologies within a manufacturing robot work cell

• **Impact:** Increase equipment and process health intelligence through advanced monitoring, diagnostic, prognostic, and control strategies to optimize planned maintenance and minimize unplanned maintenance of manufacturing workcells
Robotic Workcell – Use Case
Identifying Process Repeatability Degradation via Position

**Goal:** To develop a low cost in situ method to identify source of process repeatability degradation within industrial robot enabled workcells with minimal process disruption.

**Method:** Workcells self-inspect at select points along kinematic chains to provide insight on if repeatability is degrading and where the degradation is occurring.

**Challenges:**
1. Identifying the points that should be measured / monitored along the kinematic chain
2. Choosing / developing sensing technology
Selection of Measurement Points – Material Handling Use Case

- Measurement Points chosen at specific locations along the kinematic chain to enhance information gained during inspection.
Work Cell Level Research – Quick Health Assessment Methodology

- **Research Objective:** Develop a quick health assessment methodology to provide manufacturers with robot health intelligence to enhance maintenance and control decisions.

- **Key Output to Date:**
  - Advance sensing - 7-D measurement system
  - Innovative target – smart target
  - Algorithms and test method for quick robot position and orientation accuracy assessment

- **Impact:**
  - Reference test methods will educate and guide manufacturers in deploying PHM to quickly assess robot health promoting greater employment of predictive maintenance strategies (e.g. robot system calibration, joint and gear box replacement etc.) that will increase efficiency and productivity while decreasing downtime.
Test Method Development and Reference Data Collection

Real-time controller data collection
Robot – Reference Data Sets

Reference data set URL: https://www.nist.gov/el/intelligent-systems-division-73500/cognition-and-collaboration-systems/degradation-measurement

TCP deviations: 7-D system measured vs. calculated deviations from controller actual joint positions minus target joint positions.
What is the ripple effect in the physical, functional, and informational hierarchies when a process/product degrades?
Is there a cost-effective, methodical approach to guide manufacturers through the PHM design and deployment process when you don’t know all of the failure modes?

How do you **verify** and **validate** such an approach?
Questions to Answer During PHM Design & Deployment

• What physical or task degradation has the potential to impact the metrics I care about most in my process?
  *What health degradations can impact my quality, productivity, scrap, etc.?*

• What data, leading to intelligence, do I need about my process to determine where and when health degradation will occur?
  *What can be monitored and how?*

• How do I prioritize the risk of faults and failures in my system and process?
  *Where should I deploy PHM since I can’t put it everywhere?*

• How does the health of my physical system, and its constituent elements, influence the health of my process?
  *How can I map the relationships between the physical and functional to better understand my process?*
Physical and Task Decomposition, Process and Task Metric ID with Relationships

Steps 1, 2, 3

Risk Identification

Step 4

Risk Reduction

Steps 7, 8

START

END

Physical Element Metric ID, Relationship Mapping and Quantification

Data to Collect and Collection Method

Physical Element Metric ID,
Relationship Mapping and Quantification

Steps 7, 8

Elimination of faults/failures

Substitution of lesser faults/failures

‘Automated’ Proactive Maintenance

‘Manual’ Predictive Maintenance

Preventative/Reactive Maintenance

Most Preferred

Least Preferred

Impact

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Steps 4, 5, 6

Prognostics, Health Management, & Control
Next Steps...

• Updating our research efforts to better reflect changing needs of industry
• Further development of test methods and performance metrics
• Strategic collaborations with industry to pilot test methods to get and give feedback
• Greater understanding of common configurations
• ATTEND Friday’s ASME’s Standards Meeting
Prognostics, Health Management, and Control

www.nist.gov/el/isd/ks/phmc.cfm