Data Infrastructure and Management for the Digital Thread in Manufacturing

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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
Information sharing across the digital thread can improve the overall performance of the product design and manufacturing process.
Life cycle Information Framework

Product Lifecycle Data

- Design
- Analysis
- Manufacturing
- Quality Assurance
- Customer & Product Support

Data Certification and Traceability
Root of Trust, Key Distribution, Cryptographic Services, Data Quality Services

Design and implement reference solutions to collect rich data to support technology development and transfer

Domain-Specific Knowledge
Decision Support
Requirements Management

Diagnosis, Prognosis, and Control

Current Challenge

- PLM solutions:
  - CAx: CAD, CAE, CAM, etc.
  - PDM
  - V&V

- Operations solutions:
  - Devices, SCADA, PLC
  - MES, MOM
  - ERP

Integration of heterogeneous solutions across the product lifecycle for SMEs and larger organizations
NIST Smart Mfg. Systems Test Bed

Goals:
- Reference architecture and implementation
- Rich source of data for fundamental research
- Physical infrastructure for standards and technology development
- Demonstration test cases for education
Data Collection and Aggregation

Design → Fabrication → Inspection

CAx → CAM/NC Code → MTConnect

ECR → OIF

As Designed → As Planned → As Executed → As Measured

Monitoring + Diagnosis + Prognosis
Manufacturing Data Architecture

- Designed as a four-tier architecture
- Implemented across three networks
- Provides segregated access to internal and external clients
Tier #1: Services

- Shop-floor IT and OT systems
- External sensors and equipment
- Any additional sources of data
Tier #2: Aggregation

- Aggregates and contextualizes service data
- Provides data protocol translation
- Supplies data and information structure for underlying services
Tier #3: Delivery

- Processes and contextualizes data for delivery to client
- Caches content for efficient performance
- Enables further development through data analytics
Tier #4: Client

- Responsible for data delivery
- Consists of web applications and clients

VDS at: https://smstestbed.nist.gov
Requirements and Specifications

- **General description:**
  - Product functions
  - User characteristics
  - Operating environments

- **Interfaces:**
  - User
  - Hardware
  - Software
  - Communications

- **Features:**
  - VDS and QDR
  - Data curation
  - System administration

- **Others:**
  - Performance
  - Reliability
  - Availability
  - Security
  - Maintainability
Simulated cycle time for one feature was 15 seconds, but measured results show actual cycle time was 80 seconds.

Feed rate mismatch affects production schedule.

Need a solution to overcome impact to scheduling.

In collaboration with: System Insights

Retrieve models and data at: https://smstestbed.nist.gov/tdp/d2mi
Questions to Correct Mismatch

- **[Design]** Can we redesign geometry to avoid the need for toolpaths with high feed discrepancies?
- **[Planning]** Can we redesign toolpath to minimize impact of machine dynamics?
- **[Machining]** Can we enable operator to make informed decisions?
- **[Inspection]** Can we use information to identify areas for more detailed measurement?

What is the correct question to answer?
How to determine correct solution?

- **Goal**: Determine the best course of action to remedy production scheduling issues
- **Need**: Root cause of feed mismatch
- **Solution**: Integrate multiple data sources from systems across the product lifecycle to determine causation using data analytics
Available Data

- Design model data in native and STEP standard format (*as designed*)
- Milling program as NC code in ISO 6983 standard format (*as planned*)
- Manufacturing execution data in MTConnect standard format (*as executed*)
- Inspection data in QIF standard format (*as inspected*)
Step 1: Present and Represent Activities

Design Data

Manufacturing Data

#131=DIRECTION(' ',(1.,0.,0.));
#136=AXIS2_PLACEMENT_3D(' ',#126,#121,#131);
#141=PLANE('',#136);
#146=CARTESIAN_POINT(' ',(-8.361367154208E-16...)
#151=DIRECTION(' ',(1.087705058168E-16,1.,0.));
#156=VECTOR(' ',#151,1.);
#161=LINE(' ',#146,#156);
#166=CARTESIAN_POINT(' ',(-8.361367154208E-16...)
#167=VERTEX_POINT(' ',#166);

2016-05-09T11:46:51.456188Z|path_pos|15.0998...
2016-05-09T11:46:51.608005Z|path_pos|15.0998...
2016-05-09T11:46:51.752206Z|path_pos|15.0998...
2016-05-09T11:46:52.040056Z|path_pos|15.0998...
2016-05-09T11:46:52.040278Z|Cposition|359.9848
2016-05-09T11:46:52.184104Z|Cposition|359.9847
2016-05-09T11:46:52.616003Z|path_pos|15.0998...
2016-05-09T11:46:52.616184Z|Yposition|-37.80295
2016-05-09T11:46:52.760205Z|path_pos|15.0998...

... ...
Step 2: Apply Data Analytics

- Overlay the as designed, as planned, and as executed data
- Investigate the relationship of each “feature” across the linked data
- Determine causations and correlations of issues
Step 3: Generate Results

Step 4: Build Knowledge

- **Cause:** Machine never reached planned feed rate
  - Height of the design feature (i.e., chamfers) is small
  - Machine cannot complete acceleration to planned feed rate before completing the fabrication of the design feature
  - Design based on legacy concept and design feature not needed in this design

- **Correlation:** Design, Planning, and Program defects
Step 5: Affect Change

- **Short-term (program):** Enable operator to make educated decisions to override the planned program to speed machining

- **Mid-term (planning):** Rework production schedule and routing to compensate for longer than expected fabrication time

- **Long-term (design):** Redesign part to remove legacy design artifacts and optimize the design for manufacturing
Digital thread has potential to improve overall performance of product design and manufacture

Substantial implementation effort needed to achieve promise of digital thread

NIST Smart Manufacturing Systems Test Bed enables development of digital thread:
  - Data available @ https://smstestbed.nist.gov/
  - Documentation to be released
  - Data-driven applications forthcoming

Grand Opening:
MFG Day, Oct 7th
Thank you for your kind attention!

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More information at: https://smstestbed.nist.gov/

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