Computer Aided Inspection and Quality

MBE Summit 2018
National Institute for Standards and Technology (NIST)
Gaithersburg, MD, USA

Toby Maw, David Ross-Pinnock,
James Whicker
02/04/2018 – 06/04/2018
Computer Aided Inspection and Quality

Overview

- Introduction
- Project Background
- Digital Measurement Planning Use Cases
- Conclusions
- Future Work
Who are we?

INSPIRING

Great British Manufacturing
INDUSTRY CHALLENGES

You want to make something
at a lower cost
better quality
quicker
in higher volume
you’ve never made before

You want to assemble something to
minimise reject rate
improve reliability
improve consistency
reduce waste
reduce errors

You want to use data more effectively for
improved design
better quality
efficient logistics
new business models
Digital Measurement Planning Project Background

Project Aim

- To improve the state of current manual measurement planning processes through the use of digital tools, standards and software, paving the way for a Digital Twin for design and metrology;
- To highlight current capabilities and gaps to standards agencies, software vendors and industrial end users.

Project Objectives

1. Investigate the standards that enable model based definition (MBD) and digital measurement planning, including QIF and STEP AP242;
2. Investigate Product Manufacturing Information (PMI) as a fundamental component of digital measurement planning, focussing on ‘difficult to define’ dimensional characteristics;
3. Develop use cases to test out the capabilities and gaps of the standards and software in this field;
4. Scope routes to implementation through work with industrial end users to understand their current systems, with which digital measurement planning must integrate.
Opportunities for innovation identified in site visits

The following opportunities were identified based on the challenges faced by several industrial end users during site visits for further investigation in Digital Measurement Planning:

- **Traceability**
  - Validation of derivative MBD;
  - Traceable statistical process control;

- **Reproducibility**
  - Rule-based automatic measurement programming;
  - Digital measurement planning with modular fixturing;
  - Reproducible measurement result reporting;

- **Communicability**
  - Human-readable measurement planning
  - Interactive model-based measurement reporting;
Three use cases were selected for demonstration of potential workflows based upon the site visits:

1. Model Based Definition-linked Statistical Process Control for Adaptive Inspection Planning
2. Rule Based Automatic Programming from Model Based Definition
3. Traceable, Reproducible, and Interactive Measurement Reporting
Use Case 1

Model Based Definition - Linked Statistical Process Control for Adaptive Inspection Planning
Volume of data generated in production is vast, but underutilised.

There is a desire to use SPC to improve quality.

Model Based Definition (MBD) with semantically linked features can provide traceability of useful information throughout production.

SPC can result in higher conformance, but could potentially reduce the overall time for inspection.

Could knowledge of process capability drive the digital measurement plan through required demand?
A workflow has been developed which demonstrates the addition of **SPC data to CAD models within the QIF framework** and shows the potential for adaptive inspection program changing based on these results. Achievable, but currently requires bespoke scripting.
MBDVidia can display measurement data of features on the CAD.

Inspection report templates can be generated (in Microsoft Excel format), and entered data is interactively linked to the model.

Cpk and Ppk can be calculated without the need for additional statistical software.

Moving range charts allowing visualisation of the part variation across production runs can be generated.
Addition of measurement data to MBD - MBDVidia

Demonstration of measurement data addition to MBD

Empty bill of characteristics awaiting measurement results

Measurement results added updated live real time to the QIF model.

Demonstration of the addition of measurement data to an MBD and calculation of Cpk.
QIF Rules can alter inspection parameters using Boolean IF rules:
- Number of measurement points
- Measurement point density
- Point sampling strategy (taken from ISO-14406:2010)
- Feature fitting algorithm to use.

Rules can be called within QIF Plan.

Rules currently only take arguments related to the model itself – taking measurement data as arguments not currently supported by QIF Rules.

Extending the scope of QIF Rules to include results may allow process-lead measurement plans.

Examples include:
- More rigorous inspection for more variable features.
- Removal of measurement instructions when process confidence is high.
Use Case 2

Rule Based Automatic Programming from Model Based Definition
Rule based automatic CMM programming from MBD

• In the development and new product introduction (NPI) phase, new inspection programs have to be produced **frequently**.
• Programmers draw on **knowledge and experience** to assign measurement strategies with similar characteristics to **previously qualified** parts and features.
• Programs are often written online, from scratch, when the first component is produced.
• MBD allows for the **automatic generation** of the bill of characteristics (BOC).
• For simple components it has been demonstrated that it is possible to **automate inspection programming**, resulting in dramatic process **time savings**.
• Measurement strategies employed for these components are held in templates and routines can be called according to simple **rules related to feature characteristics**.
Rule based automatic CMM programming from MBD

The following workflow was used for this use case:

1. Investigation into functional requirements to understand tolerances
2. Addition of supplemental geometry:
   - Theoretical datum planes
   - Constructed gauge points
   - Predefined scan paths
3. PMI added and associated to surfaces and supplemental geometry
4. Bill of characteristics generated in BCT inspector giving PMI balloon numbers
5. NX CMM
Rules architectures exist to support strategy selection based on **single feature characteristics**.

Automation of programming, point cloud evaluation or strategy validation can be achieved.

Capvidia Pundit CMM, Origin Checkmate, Siemens NX CMM and Kotem SmartProfile were all trialed in this project - each supported aspects of this.

No automatic rule based strategy selection exists to combine multiple constructed features.

This project workflow has shown that tools are available to assist this **multi-feature strategy** selection process.

Once defined, PMI can be created to assist CMM programmers to implement strategies containing, gauge points; constructed features and iterative alignments, whilst retaining traceability to the model. However, this does reduce the level of automation in the process.

---

**Key Points**

**MBD Assisted Programming**

- **Assign Characteristics**
  - NX - PMI
  - Define PMIs to specify design intent including functional datums, tolerances, gauge points and key reference geometry.
  - Apply ID/naming to functional features.

- **Validate Characteristics**
  - TcVis VSA; NX Checkmate
  - Verify that all functional features DoFs are controlled.
  - Simulate to confirm that the functional characteristics are capable of achieving the design requirements.
  - Validate PMI syntax and semantics.

- **Plan Inspection**
  - BCT Inspector; Teamcenter Mfg
  - Apply IDs to functional characteristics generate matrix.
  - Review design characteristics and select inspection processes. Assign characteristics to inspection operations including in-process and final inspections.

- **Plan Metrology**
  - NX CMM
  - Filter features and characteristics for inspection operation.
  - Define measurement strategies (methods) including alignments, scan curves and sampling points.
  - Define analysis modes.

- **Generate Program**
  - NX CMM; CMM IE
  - Select inspection hardware.
  - Generate and optimise inspection paths.
  - Simulate program and check for and avoid collisions.
  - Post process to selected execution system. Validate program code.

**Summary of the Siemens workflow for model based quality**
Use Case 3

Traceable, Reproducible, and Interactive Measurement Reporting
Ad-hoc measurement requires documentation of the measurement setup;
A measurement report prefaced by a retrospective measurement plan is produced;
Users of the report often have to spend time making sure they understand the procedure, and have enough evidence upon which to sentence parts appropriately.
Static representations of results can be unclear downstream.
3D PDF is one example in which 3D objects can be viewed without the need for CAD software.

Can we use 3D PDF to visualise measurement result data, to extend and augment the Human Readable Measurement Plan?
Workflow
Traceable, Reproducible, and Interactive Measurement Reporting

Report Template Creation
CMM Fixturing Scene Creation
Physical Measurement
Inspection Results Output
3D PDF Report Generation

Export 2D PDF
Export STEP and assembly instructions
Export Point Cloud with Deviations CSV
3D PDF
Traceable, Reproducible, and Interactive Measurement Reporting

Key Points

• Measurement plan and report generation can be achieved using a familiar, straightforward workflow.

• Report templates can be created using readily available software.

• 3D PDFs require only Adobe Acrobat Reader, meaning that expensive CAD software not required.

• Interactive elements can complement existing documentation.

• Traceability can be further improved with increased support for use of QIF in 3D PDF tools.
The Digital Measurement Planning project has investigated a wide range of technologies, tools and standards to highlight to industry the current capabilities and challenges when moving towards digitalisation.

Potential benefits demonstrated to the end users through use cases include:
- Reduction of manual processes in measurement planning;
- Shorter inspection lead times;
- Standardisation of measurement planning;
- Traceability of results and reports.

End user demand for data standards would increase support amongst software vendors.

The benefits to traceability and interoperability need to continue to be demonstrated to drive this demand.
### Thank You

**Consortium Members**

<table>
<thead>
<tr>
<th>End Users</th>
<th>Standards Agencies</th>
<th>Software Providers</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWE</td>
<td>GKN Aerospace</td>
<td>Parker Aerospace</td>
</tr>
<tr>
<td>BAE Systems</td>
<td>Hexagon MI</td>
<td>Renishaw</td>
</tr>
<tr>
<td>Capvidia</td>
<td>IPI Solutions</td>
<td>Rolls-Royce</td>
</tr>
<tr>
<td>CDS</td>
<td>Kotem</td>
<td>Sandvik</td>
</tr>
<tr>
<td>Doncasters</td>
<td>Origin</td>
<td>Siemens PLM</td>
</tr>
</tbody>
</table>

**Collaborators**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NIST</td>
<td>DMSC</td>
<td>NCC</td>
</tr>
</tbody>
</table>
Thank you for your attention – any questions?
### Version Control

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Author</th>
<th>Status</th>
<th>Change Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td></td>
<td>David Ross-Pinnock</td>
<td>Issued</td>
<td></td>
</tr>
</tbody>
</table>

### Key Project Contacts

<table>
<thead>
<tr>
<th>Customer</th>
<th>Principal Customer Contact</th>
<th>Principal MTC Contact</th>
</tr>
</thead>
</table>

### MTC Endorsement

<table>
<thead>
<tr>
<th>Reviewed By</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrew Clough</td>
<td><img src="signature.png" alt="" /></td>
<td>02/03/2018</td>
</tr>
</tbody>
</table>