Integrated Information for Improved Quality

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Data and Information Systems; Metrology & NDT

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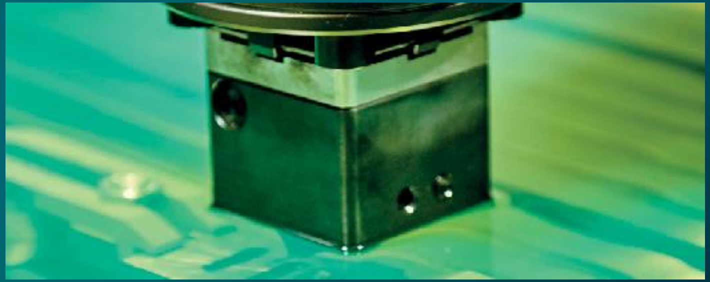
MANUFACTRUING INNOVATION

Component Manufacturing

Additive Manufacturing



Non-Conventional Machining

High Integrity Fabrication

Assembly Systems

Advanced Tooling and Fixturing

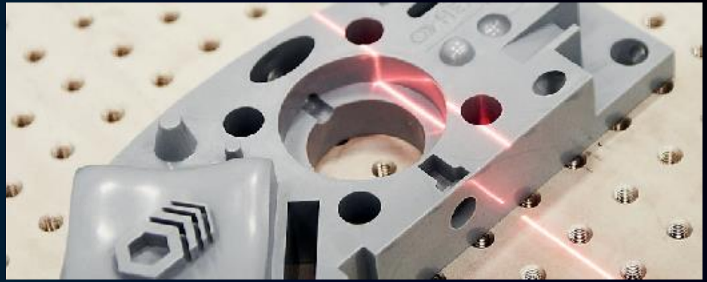
Electronics Manufacturing

Robotics and Autonomous Systems

Data Systems

Design and Simulation

Manufacturing Informatics



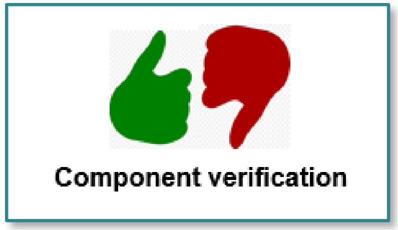
Metrology and NDT

CONTENTS

Background

Trends in Manufacturing

- Final part verification is often thought of as being the sole purpose of Metrology:
  - Design and manufacturing produce components and metrology check they meet specification;
  - PASS / FAIL results are stored and occasionally used for statistical reporting.



- The demand for high quality and efficient production has never been higher:
  - Competitive markets and demanding consumers;
  - Lean, 6 sigma, etc.

- Manufacturing processes are being digitalised to meet this demand:
  - Industry 4.0, Smart manufacturing, Industrial Internet of Things, Digital Thread;
  - **All designed to give more information, to make better decisions, to improve quality & productivity.**

The intelligent use of data is the key.

Background

Quality data throughout the product lifecycle

Metrology and NDT are critical to providing quality data **throughout the product lifecycle**.

In-line
- Inspection between processes.
- What is the current state of the component?

In-process
- Inspection during processes.
- How is the current process performing?

End-of-line
- Final part quality
- What is the 'as built' state?

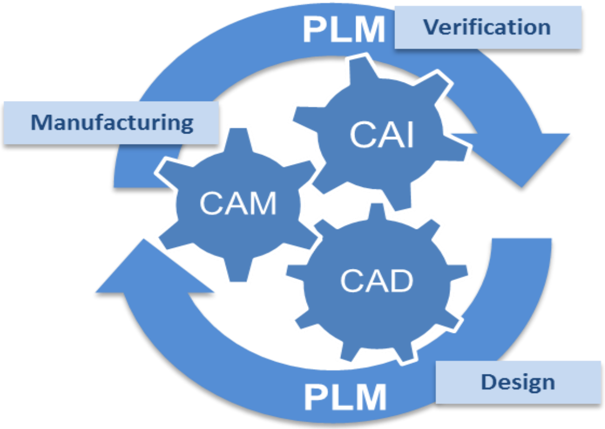
Through life
- Service inspection.
- What has happened to the quality through use?

A Selection of equipment and inspection capabilities at the MTC

Background

Integrated Information for Improved Quality

- In isolation, quality data is not enough.
- Advanced manufacturing methods require domain expertise and knowledge from all disciplines working together to make better decisions and realise benefits;
- Data capture and integration from design, manufacturing and quality are all required.
- All sorts of advanced Industry 4.0 empowered principles can be achieved by integrating quality data with design characteristics and manufacturing process data.



Intelligent Process Control	Adaptive Inspection Planning	Root Cause Analysis
Optimisation of production quality by feeding back knowledge to manufacturing. Increase component quality, reducing scrap and rework.	Increase efficiency by filtering out features within process capability. Reduce cycle times and reduce load on measurement equipment.	Maintain traceability of all data associated to a product from Design, Manufacturing and Quality. Quickly trace through the data to see why something failed and prescribe corrective action.

A selection of key manufacturing benefits, targeted by projects at the MTC

Integrated Information for Improved Quality

Challenges to implementation

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What Benefits?
- Decision support
- Adaptive inspection planning
- Intelligent process control

What Systems?
- Manufacturing processes
- Hardware & software
- How to demonstrate?

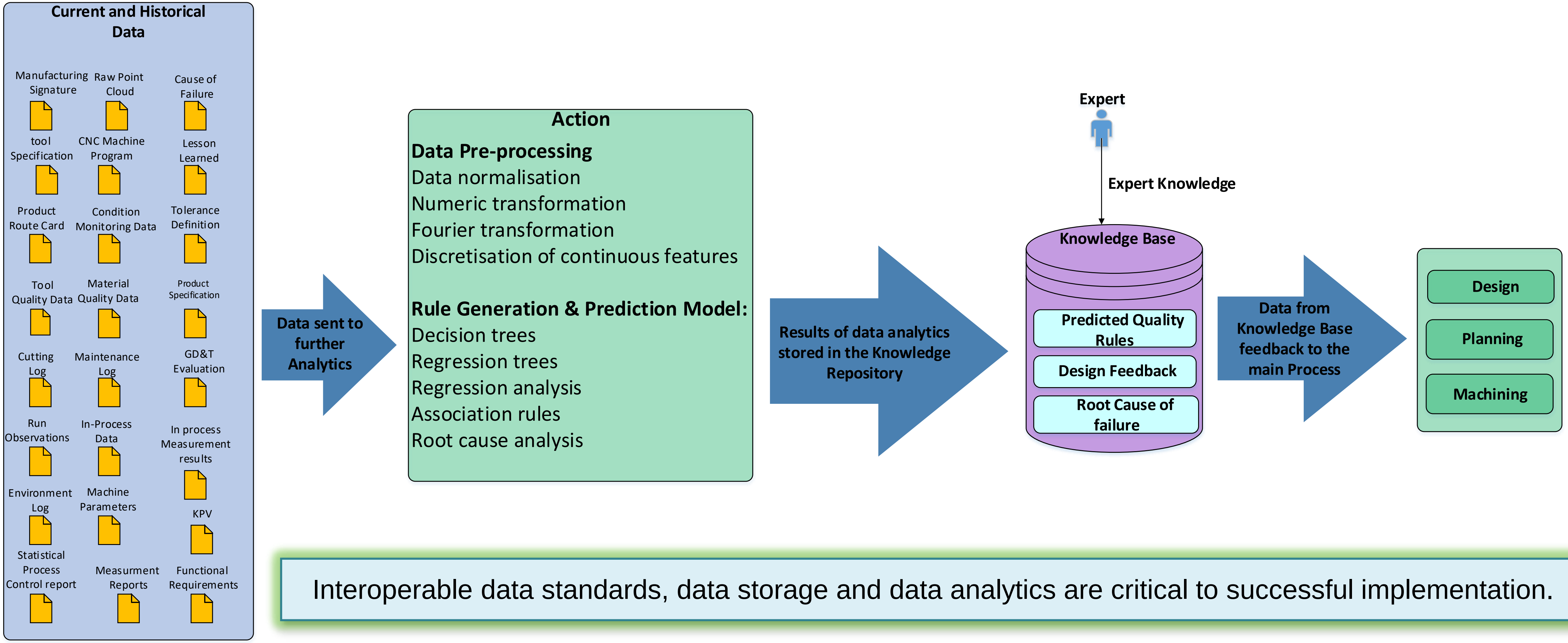
What Data?
- Which parameters?
- Unutilised dark data
- Formats and standards

What Analytics?
- Data Integration & mapping
- Techniques – big data, cloud, IoT
- Algorithms

What Skills?
- Data driven mind-set
- Cross domain expertise
- Support for technology

Data Analytics for Manufacturing

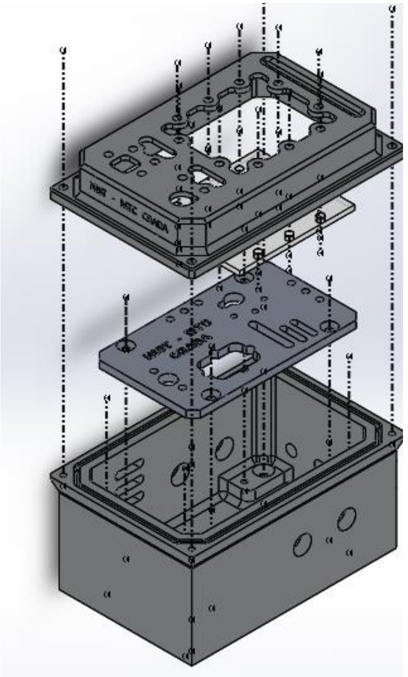
Improve Quality: What data? What techniques? What feedback?



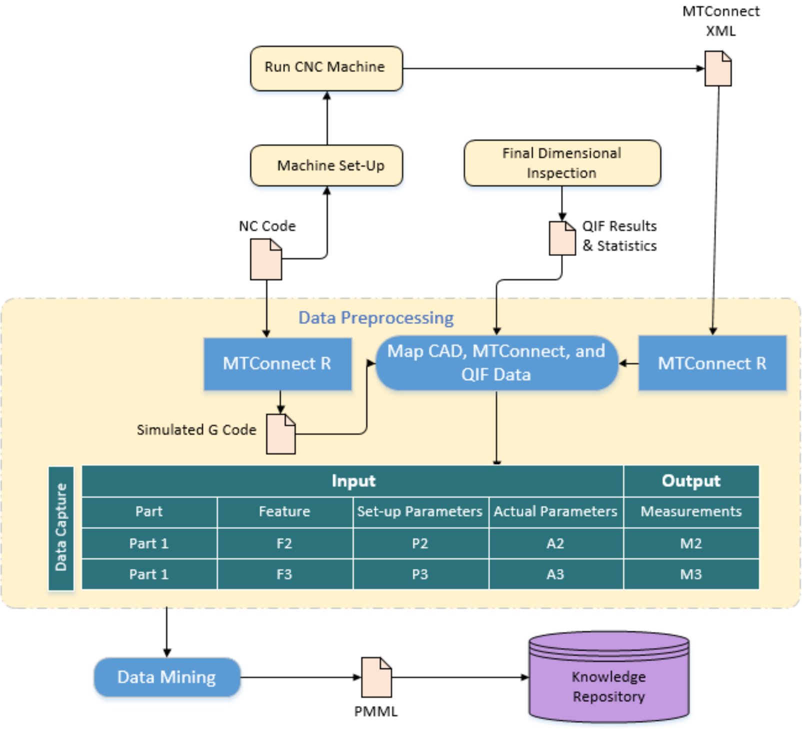
Interoperable data standards, data storage and data analytics are critical to successful implementation.

CASE STUDY 1

Data Integration Experiment



Test assembly produced for data integration experiment.



Experiment data flow illustrating how manufacturing and inspection data must be mapped using feature ID as a reference.

Objectives

- Investigate data standards for manufacturing process control;
- Investigate techniques for manipulation of data standards;
- Identify capabilities and gaps of integrated data interoperability.

Outcomes

- Data interoperability between processes is critical for automation.
- Persistent IDs are required that make all data traceable to the authority CAD model through all process steps.
- Tool path data can be used to map quality to machining which could form the basis for visualisation of root causes.
- Standards such as STEP AP242, QIF and MTConnect contain the required structure and content to facilitate machine readable data interoperability.
- The software landscape is changing rapidly but adoption of the standards has been slow. Software providers require end user pull for implementation.

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CASE STUDY 1 Cont.

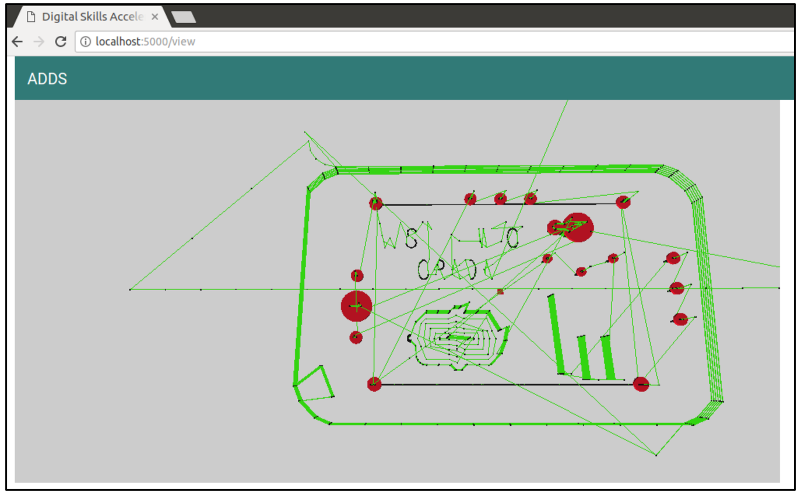
Data Integration Experiment

Objectives

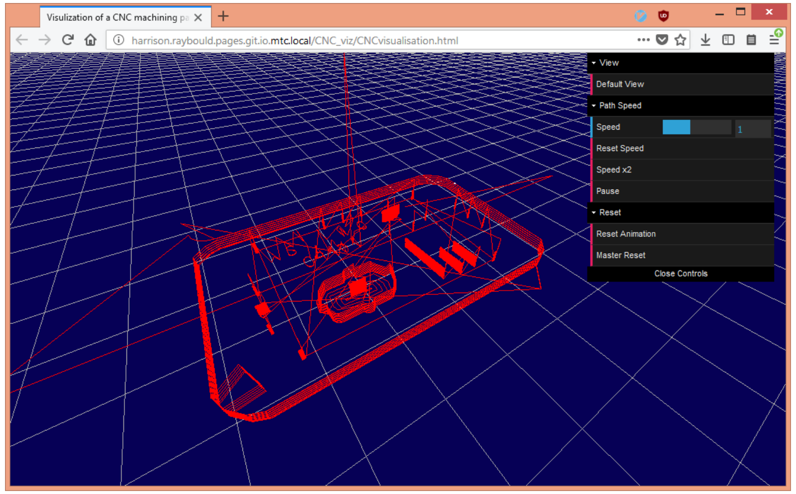
- Link data collected from machining with inspection data;
- Visualise the data collected;

Outcomes

- Data collected from the process was matched with the MBD features;
    - This linking can be used to monitor parameters during the process, and flag up problems when they occur saving process time;
- Visualisations were created to:
    - Match machine tool path and feature locations, and
    - Replay the machining process with playback controls.



Browser-based visualisation tool showing the tool path in green, with MBD features in red.



Browser-based visualisation tool replaying the machining process in real-time. A white sphere traces the machining tool around the path defined in red.

CASE STUDY 2

Intelligent Process Control

Objectives

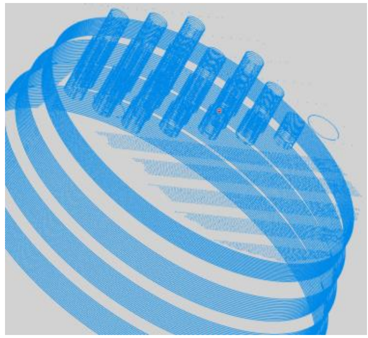
- To use **data mining** algorithms to create rules linking **final part quality** of a test batch **to machining parameters** of production.
- To demonstrate **intelligent process control** by using the rules to improve quality in subsequent parts.

Process

- 30 test pieces: 540 holes.
- Varied manufacturing control parameters.
- High resolution and high precision inspection.
- Classification of feature quality for form and size.
- Regression tree and decision tree analysis for rule creation.
- Selection of most accurate rules.
- Production of a subsequent batch using quality rules.
- Inspection and results comparison.

Outcomes

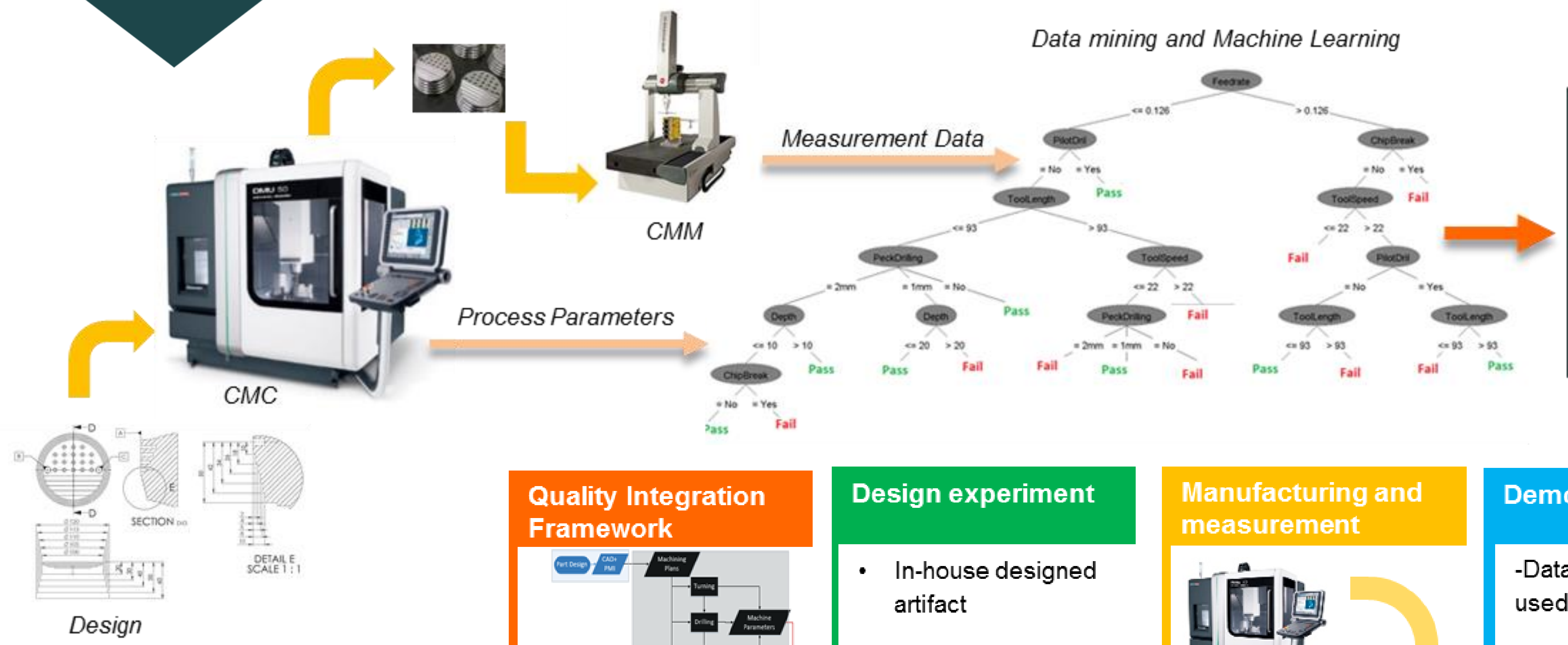
- Successful creation of quality rules with both decision tree and regression tree for size, position and form characteristics of holes.
- Successful demonstration of intelligent process control through combination of manufacturing and inspection data.
- Improved quality and repeatability of subsequent production batch using the quality rules.



R.J. Mason, M. Mostafizur Rahman, T.M.M. Maw, Analysis of the manufacturing signature using data mining, Precision Eng., 47, 292-302, (2017)

CASE STUDY 2 Cont.

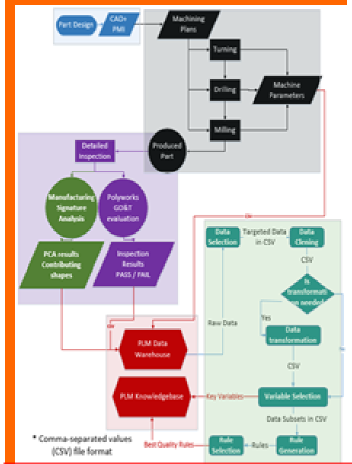
Intelligent Process Control



Rule1:

IF	Feedrate	is	[High]
AND	PilotDrill	is	[Done]
AND	Depth	is	[Low]
AND	ToolSpeed	is	[Low]
THEN	Quality	is	[PASS]

Quality Integration Framework



Design experiment

- In-house designed artifact
- Part design
- Machining procedure document
- CNC programs
- Measurement planning
- Data capture

Manufacturing and measurement

Demonstration of the framework

-Data mining and machine learning algorithms used for :

- quality rule generation and
- discovery of key process variables

-Unsupervised learning (clustering) methods used to group different quality types

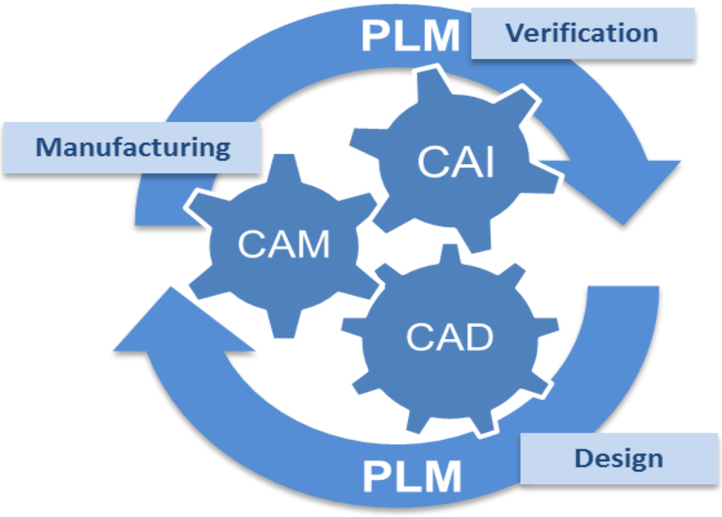
-Class balancing technique used to manage unbalance quality data

-Development of part quality prediction model

Conclusions

Integrated Information for Improved Quality

- There are **significant benefits** to be gained by integrating information throughout manufacturing.
- There are also **challenges** faced by industry in generating knowledge that can be used to drive positive change within manufacturing organisations.
- The research done at the **MTC** has shown how integration of **quality and manufacturing data** play key roles in advanced manufacturing techniques.
- **MTC** remain active to further demonstrate the possibilities and benefits that can be gained by **implementation of systems** built from commercially available technologies.



Intelligent Process Control	Adaptive Inspection Planning	Root Cause Analysis
Increase component quality, reducing scrap and rework.	Reduce cycle times and reduce load on measurement equipment.	Quickly trace through the data to see why something failed and prescribe corrective action.

Thank you for listening!

Any questions?

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