DEMONSTRATOR: Inline Quality Monitoring with Root-Cause Diagnosis

THE UNIVERSITY OF WARWICK

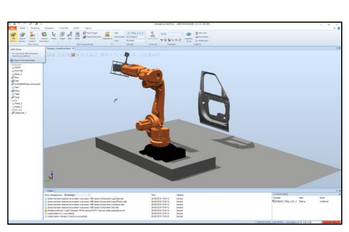
INTRODUCTION:

Achieving resilient performance in terms of quality improvement within production systems is nowadays a key goal for manufacturing industry to be able to predict behaviour of process machinery, to optimise existing equipment for increased quality or to introduce new equipment into an existing assembly line with minimum disruption. Within this context, there is a high need for inline quality monitoring capabilities that allow to rapidly diagnose faults. On top of that, data alone is often insufficient to reveal underlying interdependent relationships between system configuration, process faults and quality defects. It is therefore necessary to enhance data-analysis using multi-disciplinary simulation.

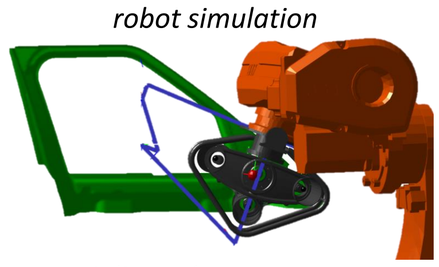
OBJECTIVES:

The objectives for this demonstrator are to showcase inline quality monitoring with root cause diagnosis for a case study of a sheet metal assembly. The incorporated digital methodologies use multi-physics simulation combined with data analytics, statistical modelling, optimisation and machine learning to minimise inspection cycle-time while maintaining fault diagnosis capabilities. This capability is a crucial element for systematic quality improvement within manufacturing systems found for example in automotive or aerospace industry.

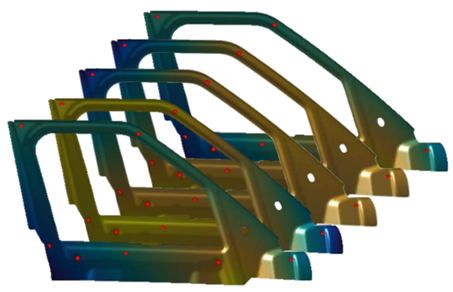
APPROACH:

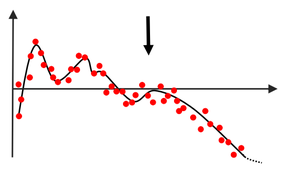


robot simulation

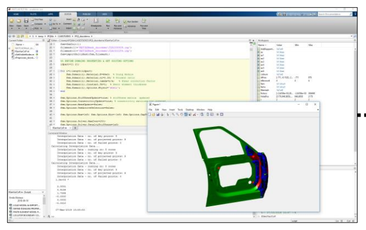


inline robot coverage path planning



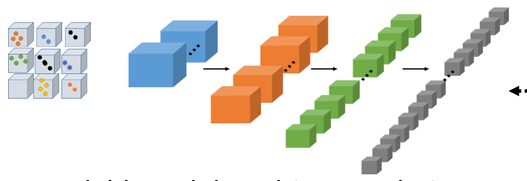


spatiotemporal predictions statistical modelling

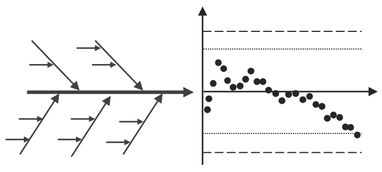


multi-physics simulation

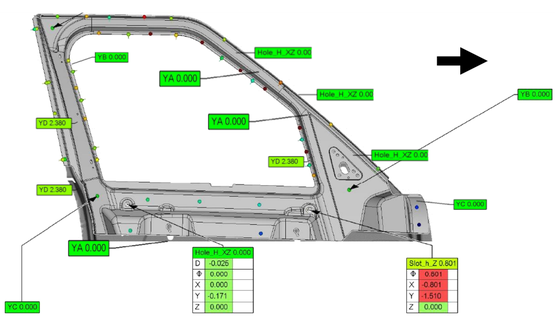
machine learning model training



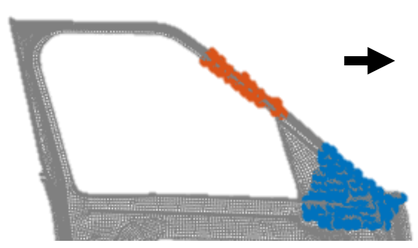
model-based data driven analysis *(3D Convolutional Neural Network)*



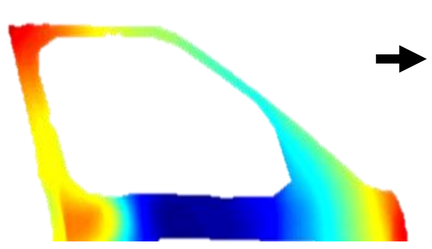
fault isolation



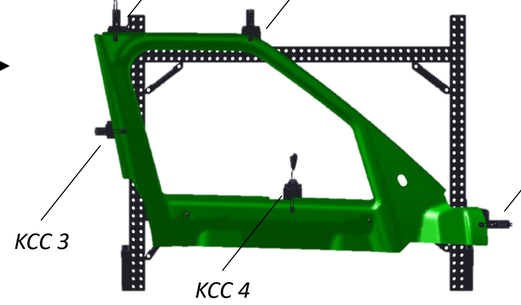
Geometric dimensioning and tolerancing (GD&T)



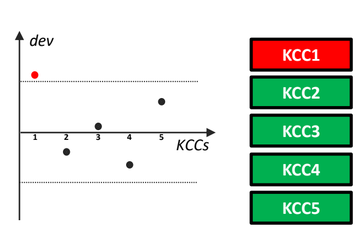
Measurement Data Cloud-of-Point (CoP)



CoP Estimation



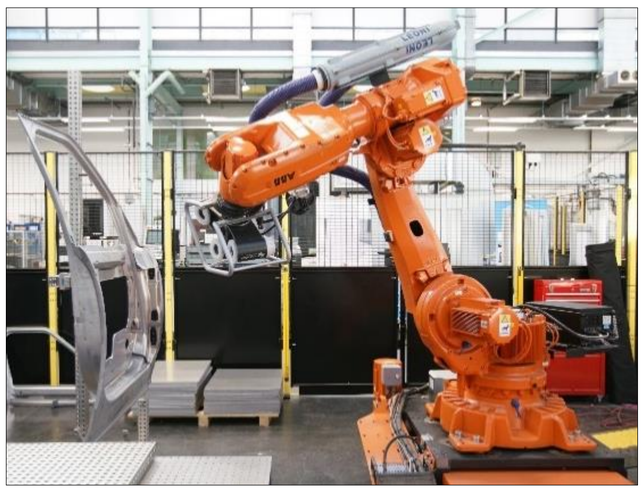
Key Control Characteristics (KCCs) estimation



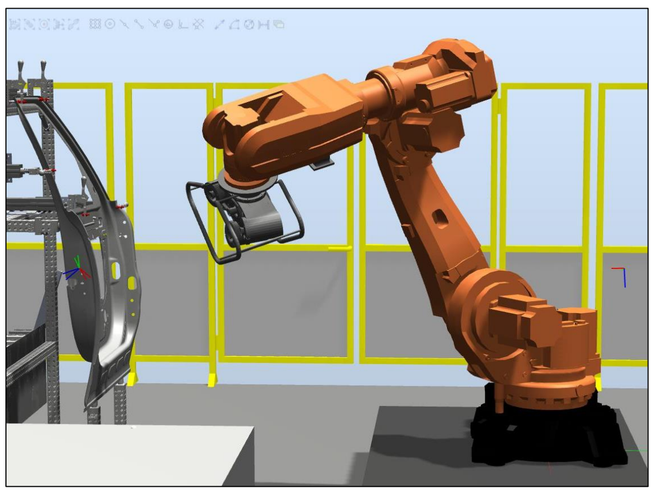
fault diagnostics report

DIGITAL TWIN:

This demonstrator, utilising Industry 4.0 technologies, showcases a precise ***digital twin*** for inline quality monitoring with root cause diagnosis to achieve ***resilience performance*** in manufacturing systems. It incorporates novel digital methods combining ***multi-physics simulation*** with ***data analytics*** are deployed to systematically monitor and improve product quality.



physical



digital

METHODOLOGY:

The overall approach for fault diagnosis includes four different steps, therefore the following four sets of methodologies have been developed:

1. **Inline robot coverage path planning** – self-programming robot for positioning metrology gauge to optimised viewpoints for inspecting targeted areas on workpiece
2. **Spatiotemporal predictions** – statistical modelling to predict the entire component deviation pattern from nominal from partial measurement data in real-time
3. **Model-based data driven analysis** – 3D Convolutional Neural Networks analysing cloud-of-point data for process parameter estimation trained on multi-physics simulation data
4. **Fault isolation** – identifying the key control characteristic (KCC) that lies at the root cause of the detected fault

These are integrated following a specialised architecture in order to work in tandem as well as to be connected. The system hardware is equipped with state-of-the-art software for cloud-based data-storage, machine learning, metrology configuration and robot simulation.

OUTCOME:

(1) adaptive robotic inline quality inspection, (2) partial measurements with spatiotemporal predictions, (3) extract functional information from high volume measurement data, (4) real-time isolation of process faults

IMPACT:

utilising dimensional measurement systems inline for dimensional quality to optimally control quality in sheet metal assembly processes. This demonstrator show how these technologies can help to eliminate, reduce and correct defects rapidly. This will lead to increased productivity and product quality.

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