In-Line Root Cause Analysis of Assembly Systems using Artificial Intelligence – Industrial Demonstration

Digital Lifecycle Management (DLM) Research Group

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Digital Lifecycle Management (DLM)

Inline Root Cause Analysis for Sheet Metal Parts Assembly

Industry challenge:

- ***In-line root cause analysis*** **of defects using 3D surface scanners.**

Case study: 3D-Optical Robotic Scanner

Approach

Integrate the knowledge of first engineering principle based Digital Twins and Big Data provided by high dimensional Measurement Systems using Artificial Intelligence to Diagnose Assembly Systems

Key Benefits

- **Increased productivity due to rapid fault diagnosis based on artificial intelligence models**
- **Continuous quality improvement due to on-line learning and training**
- **Reduction of dependence on hit and trial based manual expertise**

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System Setup

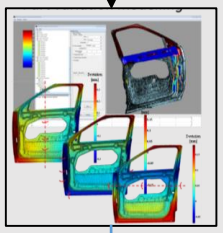
3D Optical Scanner

Measurement

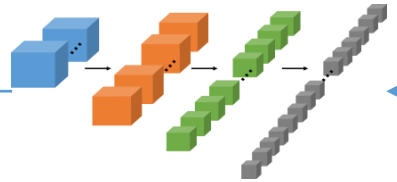
Data Transfer

Real System

Digital Twin

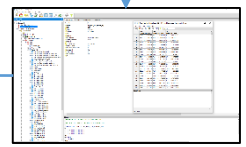


Root Cause Analysis



Artificial Intelligence Model

Integrated Learning and Training



Cloud Based Database System

System Simulation

Aim

Utilize artificial Intelligence techniques such as deep neural networks to diagnose multi-stage assembly systems

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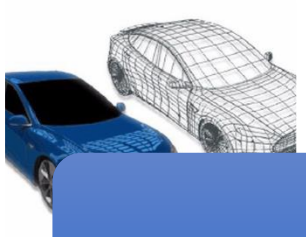
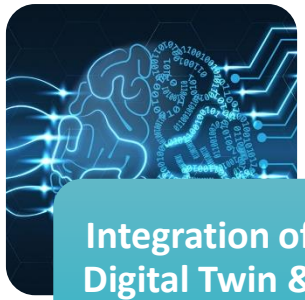
Demo Development Overview

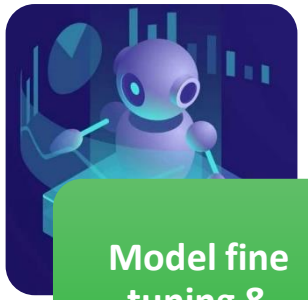


Digital Twin Validation

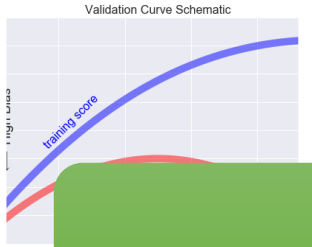


Integration of Digital Twin & Artificial Intelligence (AI) Model

Model Training in Simulation Space



Model fine tuning & transfer to physical space



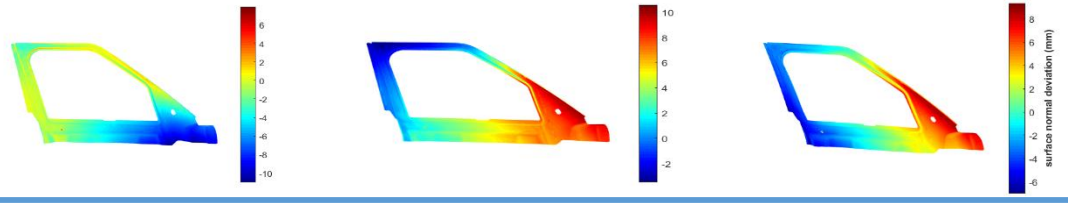
Model Benchmarking & Validation

Digital Lifecycle Management (DLM)

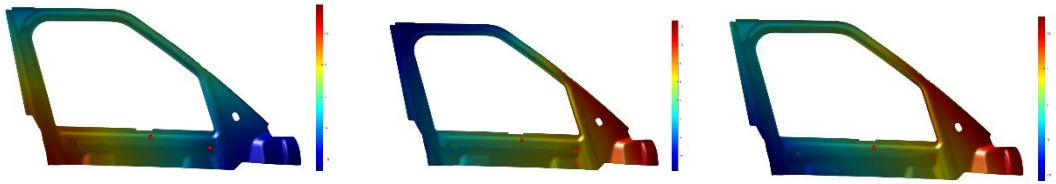
Digital Twin Validation

Index	Clamp_1	Clamp_2	Clamp_3	Clamp_4	Correlation Between Digital Twin and Actual System
1	0	0	0	0	1
2	-5	0	0	0	0.89
3	5	0	0	0	0.89
4	0	-5	0	0	0.92
5	0	5	0	0	0.88
6	0	0	-5	0	0.97
7	0	0	5	0	0.98
8	0	0	0	-5	0.97
9	0	0	0	5	0.99

Actual System Data



Digital Twin Data



Experiments were conducted between data obtained from the surface scanner and data simulated from the digital twin

After correcting for rigid rotation due alignment, compensating for non-ideal part nature and fine tuning digital twin parameters the correlations were calculated

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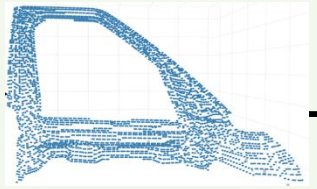
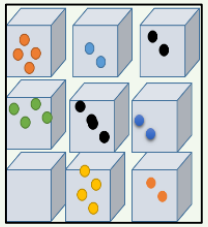
Integration of Digital Twin & Artificial Intelligence Model

In-line Root Cause Analysis (After off-line model training and Fine tuning)

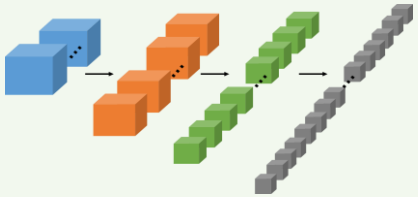
3D Optical Scanner



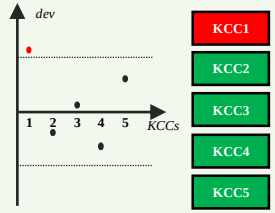
Cloud-of-point Measurement Data



Data-Pre-processing *(Voxelization)*



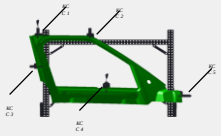
Artificial Intelligence Model *(3D Convolutional Neural Network)*



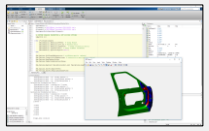
Root Cause Isolation

Model Training (Off-line)

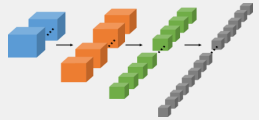
Sampling



Validated Digital Twin



Supervised model training



Model Validation

Is prediction accuracy above the required threshold ?

No

Generate more training data

Yes

Fine Tune Model using Real System Data

The 3D Convolutional Neural Network Model is trained using data generated from the validated digital twin until the required accuracy is obtained. The trained model is fine tuned using actual data obtained from the system to compensate for the difference between simulation and actual systems

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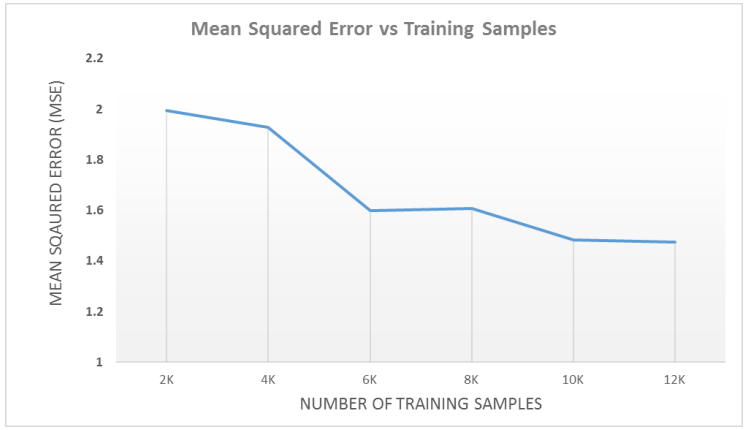
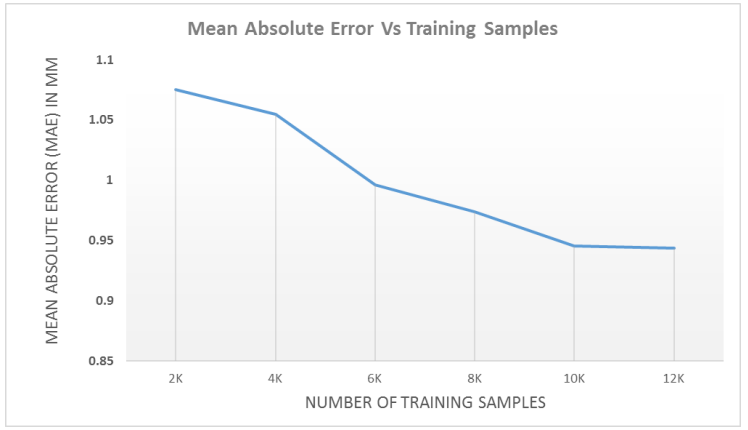
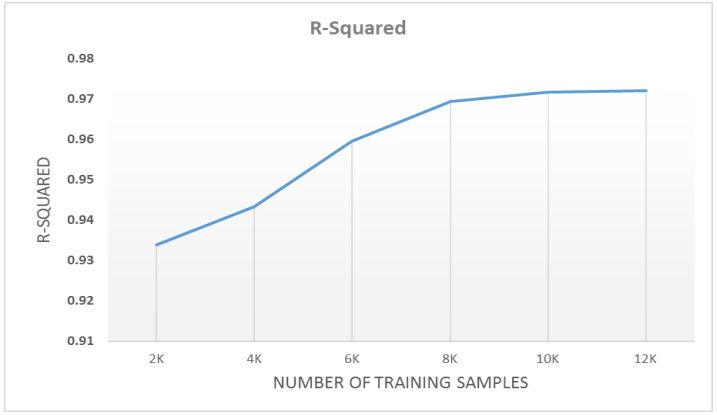
Artificial Intelligence Model Training in Simulation Space







The model converges after 10K training samples in terms of error metrics such as Mean Absolute Error (MAE) and Mean Squared Error (MSE) as well as Goodness of fit determined by R-Squared Value (R2)

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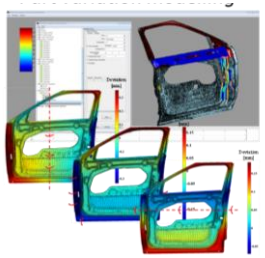
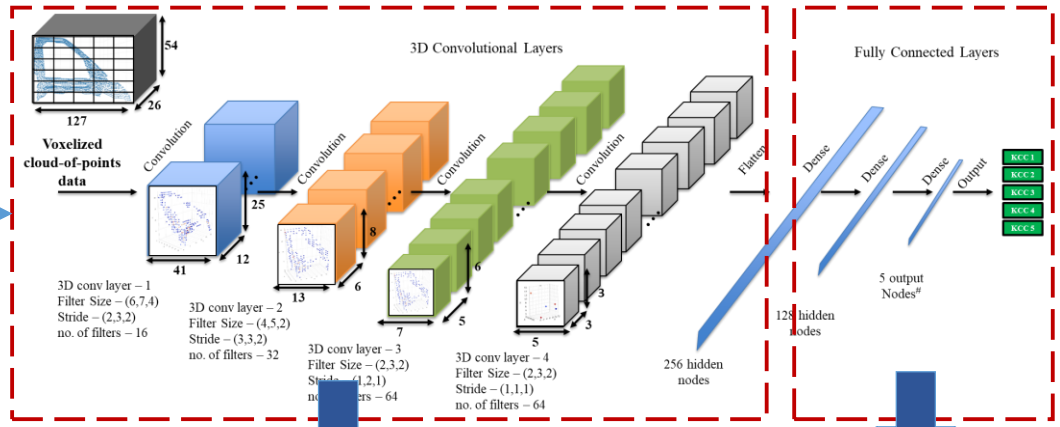
Artificial Intelligence Model Fine Tuning & Transfer to Actual System

Labelled actual system data

Model Trained and validated by Digital twin data





Freeze the initial convolutional layers as they are feature extractors already trained on large Digital Twin data

Fine Tune fully connected layers based on small sample of actual system data

The model is fine-tuned using the concept of transfer learning by freezing the weights of the convolutional layers and updating tuning the fully connected layers using a small sample of real data (~ 30 to 90 samples), this has significant improvement in model performance in the actual system

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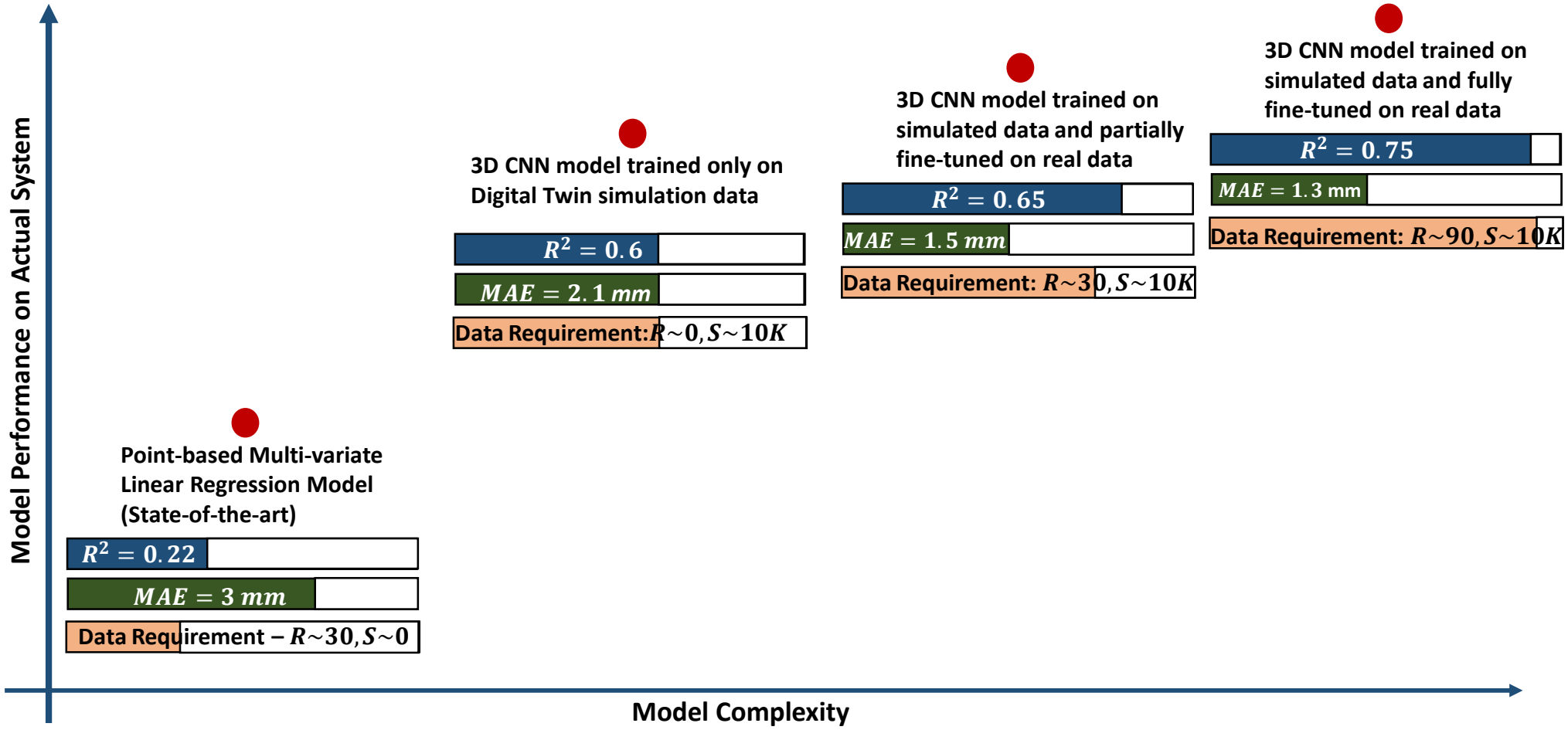
DIGITAL LIFECYCLE MANAGEMENT (DLM)

ARTIFICIAL INTELLIGENCE MODEL BENCHMARKING & VALIDATION



Benefits

- Enables to use a single model from design phase to full scale production phase by integrating small amount of actual system data obtained during operation
- Can be adapted to dynamic changes in the manufacturing system

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DIGITAL LIFECYCLE MANAGEMENT (DLM)

COMPATIBLE METROLOGY TECHNOLOGIES

NAME	TECHNIQUE	PURPOSE	VIEWPOINTS VS SCANNING
WLS400a (Hexagon)	Stereovision	Dimensional quality	Viewpoints
BLAZE 660A (Hexagon)	Stereovision	Dimensional quality	Viewpoints
RoboticScan (Artec3D)	Stereovision	Dimensional quality	Viewpoints
ATOS 5 (GOM)	Stereovision	Dimensional quality	Viewpoints
ATOS TRIPLE SCAN (GOM)	Stereovision	Dimensional quality	Viewpoints
Gocator (LMI Technologies)	Stereovision	Circuit board inspection	Viewpoints
ARIS (ARIS)	Laser	Dimensional quality	Viewpoints
Dimensional Gauging Perceptron (Perceptron),	Laser	Dimensional quality	Viewpoints
Laser Radar MV331/351 (Nikon Metrology),	Laser	Dimensional quality	Viewpoints
RAPID SCAN (API)	Structured light	Dimensional quality	Viewpoints
COMET Pro AE (Zeis)	Structured light	Dimensional quality	Viewpoints
FlexInspect (ABB),	Structured light	Dimensional quality	Viewpoints
MetraScan3D (Creaform),	Laser	Dimensional quality	Scanning
AirTrack (Kreon)	Laser	Dimensional quality	Scanning
ABIS II (Zeis),	Laser	Surface quality	Scanning

The proposed solutions for *partial measurements* are compatible with all technologies listed in the table above.
The proposed solutions for *coverage path planning and optimisation* as well as for *workpiece placement optimisation* are compatible with viewpoints-based technologies
The proposed solutions for *Root Cause Analysis* are compatible with all technologies that output high Dimensional Cloud of Point Data

Thank-you

Digital Lifecycle Management (DLM) Research Group

Please contact Sumit Sinha (email: sumit.sinha.1@warwick.ac.uk) in case of any doubts or colloboration

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