DOCTORAL (PHD) THESIS

ADVANCEDIT-BASED INTEGRATION OF INDUSTRIAL SYSTEMS

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1. Introduction and objectives

My research motivation is based on the fact that the sensing and communication capabilities of IT applications in the field of manufacturing technology are increasingly enabling real-time data collection and analysis, thereby shortening the information flow and enhancing efficiency. The research focuses in part on the use of the resulting products collected by 3D scanners to identify welding defects, typically for density-based clustering of point clouds. Furthermore, it extends the detection of weld seams to Machine Learning technology. By integrating data from structured light scanners and edge detection algorithms, the research aims to enhance the quality control and monitoring of weld seams, thereby improving the efficiency of manufacturing processes.

2. Tools and methods

The dissertation presents a framework for the detection and identification of weld defects that uses advanced 3D scanning and image processing techniques. The point clouds are obtained from a 3D structured light scanner and serve as input for the point cloud processing matching processes. The top-view photographs, examined with image recognition algorithms to determine the weld width, are integrated with a digital interface (virtual robot), which is able to efficiently capture and visualise the data generated during the weld formation.

3. Practical application of results

The applied method effectively detects and classifies deviations according to standard welding defect classes, demonstrating that five of the six welding deviations defined in ISO 5817:2014 can be identified. The combined approach supports real-time analysis and optimisation, facilitating the identification of defects occurring during welding seams. The results highlight the potential of digital twin technology for real-time feedback and optimisation of welding parameters, which improves manufacturing efficiency and product quality.

4. Theses

1. **CAD-based point clouds of workpieces containing welding defects can be described and identified with the support of PFH histogram analysis, describing the points.**

I rely on four main publications in my research. My publications are related to the extension of welding defect analysis, the use of data recorded during weld formation, and the integration of data collected from 2D and 3D welds. The first related publication focuses on the differences obtained after matching the point clouds of welded workpieces using PFH analysis.

Related publication:

3D scanning and model error distribution - based characterisation of welding defects (HUNGARIAN JOURNAL OF INDUSTRY AND CHEMISTRY, Hegedűs-Kuti János, Szőlősi József, Varga Dániel, Farkas Gábor, Ruppert Tamás, Abonyi János és Andó Mátyás; DOI: 10.33927/hjic-2021-13

2. **Welding defects can be effectively identified based on the mass centres of defect clusters, cloud scores and cloud shape using the DBSCAN algorithm**

The second related publication describes a framework as a continuation of my first article, for the recognition of welding defects based on 3D scanner data and for the identification of deviations. The publication, therefore, describes a framework for the identification of welding defects based on 3D scanners. The study uses density-based clustering to compare the point cloud and identify deviations. Six welding deviations defined in ISO 5817:2014 were evaluated, and the method successfully identified four deviations.

Related publication:

3D Scanner Based Identification of Welding Defects - Clustering the Results of Point Cloud Alignment (Hegedűs-Kuti János, Szőlősi József, Varga Dániel, Abonyi János, Andó Mátyás és Ruppert Tamás; MDPI Sensors, Q1, **https://doi.org/10.3390/s23052503**)

3. The welding parameters which are the input to the formation of weld seams (Voltage, Current, Welding Speed, Wire Feed Rate), can be detected as an effect that influences the shape of the weld by consistently tracking the point clouds made from the welds during their alignment.

The publication deals with the extension of welding defect investigations. It shows how data collected during the welding process can be integrated with the results of image processing applications. The effect of electrical parameters can be traced on the aligned point clouds.

Related publication:

Extending the welding seams detection as preparation towards the Digital Twin technology (Hegedűs-Kuti János, Szőlősi József, Birosz Márton Tamás, Csobán Attila, Popa-Müller Izolda, és Andó Mátyás; IET Collaborative Intelligent Manufacturing, Q1, DOI:10.1049/cim2.70027)

4. With the support of Machine Learning technology, the geometric data characteristic of the weld seam can be estimated, based on previously performed welding experiments with other welding parameters

My third publication, mentioned in the previous thesis, also deals with the extension of welding defect investigations. It is about defect detection and identification, which shows how the data collected during the welding process can be integrated with the output products of 2D image processing applications, providing the missing data regarding the weld width with an estimate.

Related publication:

Extending the welding seams detection as preparation towards the Digital twin technology (Hegedűs-Kuti János, Szőlősi József, Birosz Márton Tamás, Csobán Attila, Popa-Müller Izolda, és Andó Mátyás; IET Collaborative Intelligent Manufacturing, Q1, DOI:10.1049/cim2.70027)

Other publications:

1. **Performance of Cell Phone Controlled Model Vehicle (**Mérnöki és Informatikai Megoldások, ELTE).
2. **Real-time data visualization of welding robot data and preparation for future of digital twin system** (Scientific Reports, D1)
3. **Lazy thermal annealing of material extrusion-based 3D-printed PLA specimens**, (Springer, Progress in Additive Manufacturing, Q1)