2ARMY

AUTOMATED ADDITIVE REPAIR AND MANUFACTURING SYSTEM

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Continuously emerging additive manufacturing technologies, especially developments within the last decade, offer new opportunities for producing metallic parts. The project 2ARMY addresses the growing needs regarding the on-demand production of spare parts and repairing worn metallic components. The maintenance units can use mobile deployable workshops for additive manufacturing and significantly improve the availability of critically important weapon systems and equipment on the battlefield. The possibility of producing the old and eventually unavailable parts in sufficient quality and maintaining existing worn parts is expected to have a positive economic impact on the lifetime of related systems and their short-time availability. It can be especially relevant for military use.

Three vital system components of such a mobile and partially autonomous robotic cell for wire and arc additive manufacturing and repair of metallic parts were investigated during the project.

Optical 3D acquisition of the part's actual shape and computation of the difference to the expected part's geometry is desirable for process automation. An appropriate 3D-scanning system has been found and integrated with available robotic welding cell. Algorithms were developed for automatically detecting the damaged regions on the part and for path generation according to the suitable manufacturing strategy.

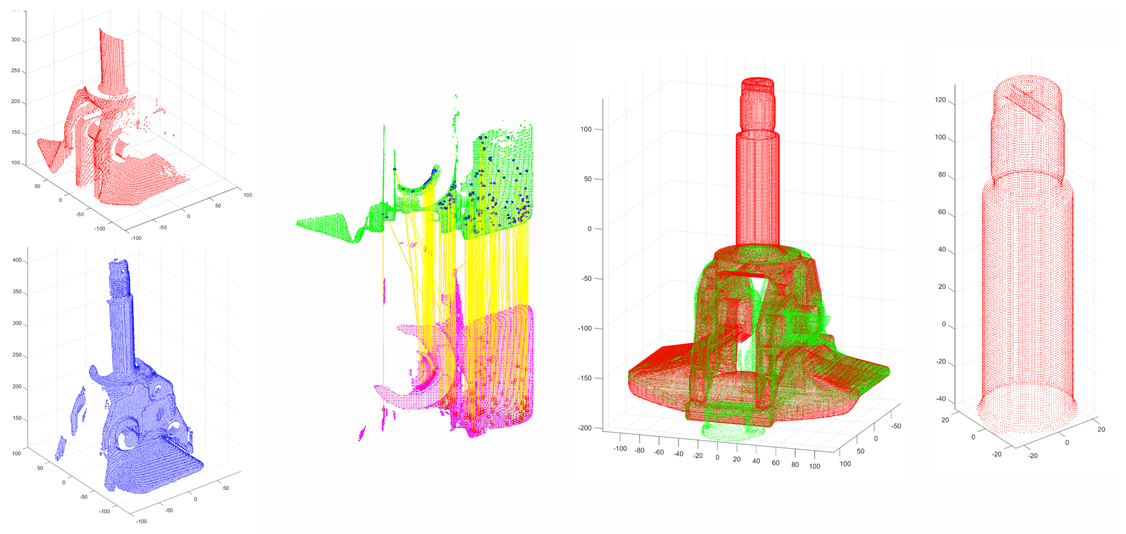
Furthermore, the current challenges regarding the quality assurance of additively manufactured parts were addressed. A digital signal acquisition chain was developed to monitor dynamic GMAW process variants. The designed database allows more in-depth analysis of the manufacturing process and optimisation of the non-destructive testing methods.

A damaged part has been repaired, and a spare part has been produced to illustrate the capability of the methods, algorithms and system components developed during the project 2ARMY.

3D GEOMETRY ACQUISITION

The welding robot has been equipped with an optical 3D geometry acquisition device wenglor MLBS201, to become capable of detecting the actual workpiece geometry and retrieving its damaged regions.

An agnostic algorithmic approach has been developed to locate the part inside the machine's working envelope and compute damaged regions. The complete process of 3D geometry acquisition can be carried out automatically. Either entire dataset matching or matching between keypoints with fast point feature histogram descriptor (FPFH) can be considered for performance reasons for exceptionally large parts.



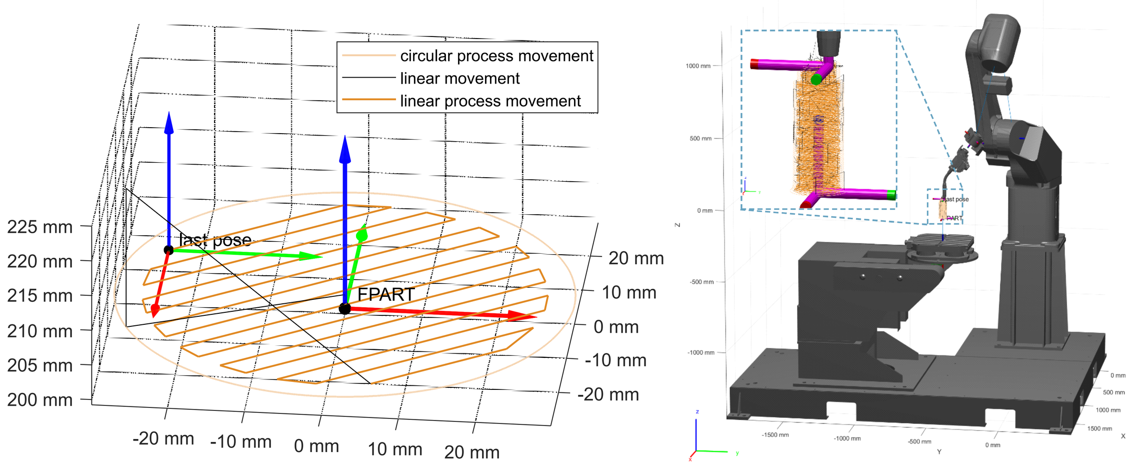
„Missing material" volume information along with the surface, which separates missing volume from actual part geometry, is used as input for the toolpath generation step.

3D geometry acquisition after additive manufacturing operation may be helpful for path planning optimisation of further cutting operations. A toolpath can be generated to remove only physically present material, minimising the wasted machine time due to air cuts.

TOOLPATH GENERATION

In a general case, a part may require certainly ordered manufacturing or repair of its geometric features. A state-of-the-art layer-wise representation of the part's geometry through „slicing" it with a plane may result in „overhanging" areas, which can not be manufactured in a WAAM process.

A 5D slicing approach has been developed to cope with these limitations. If seen as a graph, the skeleton axis provides information about the hierarchy of the part's geometry and allows one to automatically select regions which must be manufactured or repaired at first. This axis, being also a three-dimensional line in cartesian space, may be used to specify workpiece orientation.



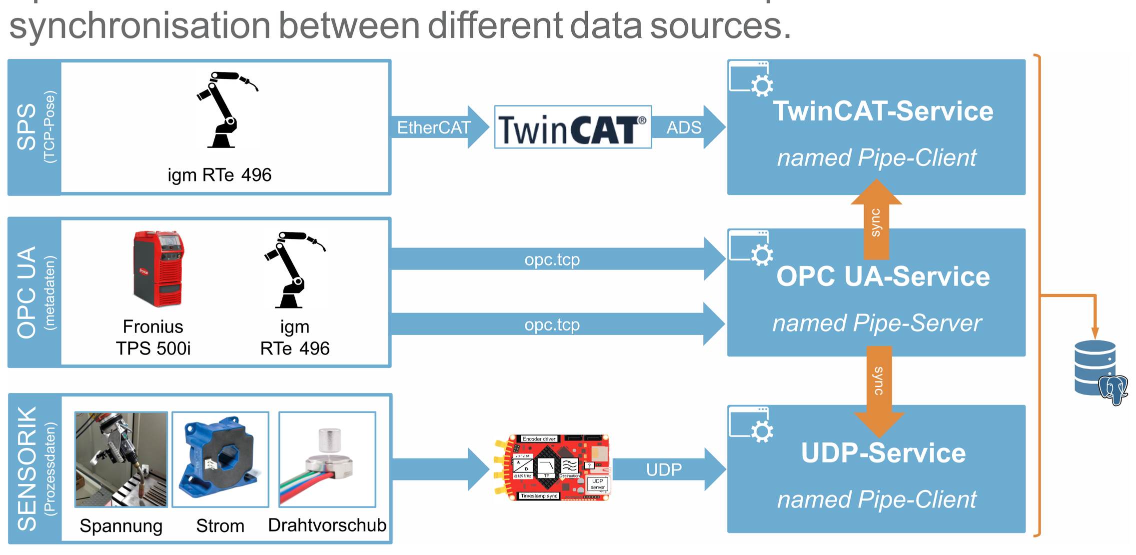
The downhand flat welding position (ISO PA) was mainly suitable for the WAAM manufacturing process.

Since the workpiece orientation is defined globally in an environmental reference frame and the tool orientation is defined in the workpiece reference frame, the complete manufacturing process may be described in a machine-independent generic matter. Generic representation of the additive manufacturing process requires the calculation of inverse kinematics for every tool pose to provide a machine-specific program. Respective object-oriented implementations have been developed with MATLAB.

QUALITY ASSURANCE

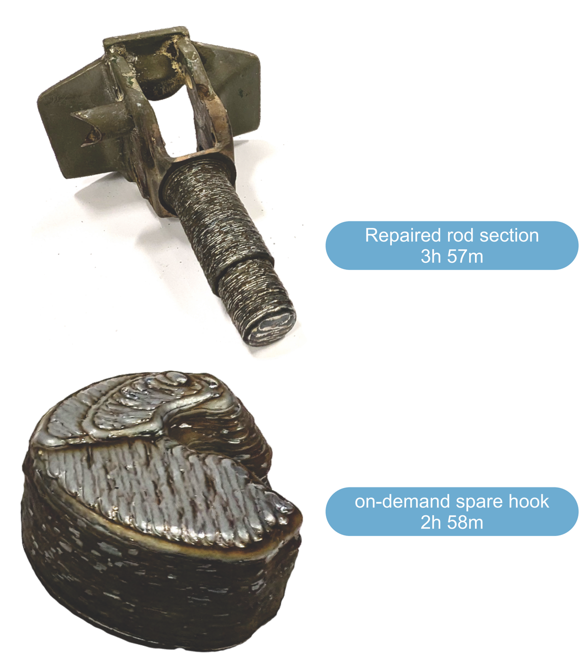
Every additively produced part should be considered unique due to unavoidable deviations [1] during the manufacturing process. Even the same program will yield different results if executed on different machines [2]. Thus more advanced quality assurance approach than sample-based destructive testing methods is necessary. Most recent industrial standards require manufacturers to provide „a detailed process qualification" and „ensure reproducibility of the process" [3, p. 7].

For instance, Cold Metal Transfer (CMT) was found to be a dynamic GMAW process variant. A base frequency of about 80 kHz [4] makes the data acquisition (DAQ) a challenging task by means of hardware specification of the DAQ chain components and time synchronisation between different data sources.



An effort was made to sample the process-related data (current, voltage and wire feed speed) externally and possibly near the arc to ensure the data reliability and comparability with other systems.

Data samples are spatially localised in the workpiece reference coordinate frame, which allows focusing non-destructive testing efforts primarily on the areas where instabilities or failures occurred during the process.



WHAT IS NEXT

Techniques and algorithms for 3D geometry acquisition, toolpath generation and quality assurance have been developed and evaluated during project 2ARMY. The proof-of-concept took place on a stationary robotic welding cell.

Examples of repair and on-demand spare part manufacturing have been documented.

The follow-up project 2ARMY II aims to manufacture a working prototype with a form factor and configuration appropriate for actual use. Further work is necessary to ensure the overall stability and reliability of the algorithms and system components. A possible influence of impacts due to the transportation on the robot's accuracy performance will be evaluated during the project.

Benefits

- Deployable workshop in a standard 20ft container
- Suitable for civil and military use
- Material- and energy-efficient manufacturing process
- A short lead time for the produced parts

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