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Continuous3D, an end-to-end solution for robotic additive manufacturing

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Abstract: Additive manufacturing (AM) using robots with 6+ degrees of freedom is an emerging technology whereby a manipulator arm controls a deposition head, sometimes in combination with other mechanisms such as rotary-tilt tables, linear tracks and mobile platforms. Unlike commonly known gantry 3D printers, robots are not constrained by a fixed build volume and are able to build on nonplanar or multi-faceted surfaces. Metals can be deposited using processes such as laser metal deposition (LMD), wire arc additive manufacturing (WAAM) and supersonic cold spray deposition. Other materials such as polymers, ceramics and concrete have been robotically printed. Along with manufacturing of new components, automated repair of worn and damaged metallic components is a particularly attractive proposition with rising labor costs, supply shortages and a shift toward the circular economy.

Programming of robotic deposition systems is complex and often a barrier to entry for many would be users. There is a need for digital tools, particularly for repair of damaged or worn components or for printing large-scale topology optimized parts. These cases usually have geometric complexity such as, compound curves, surface irregularity, and overhangs.

Instabilities in metal deposition processes can cause defects, which once started, tend to grow in subsequent layers. In such instances the deposition process must be stopped before the part is milled or ground back to specifications after which the toolpath is adjusted, and deposition resumed. This requires an operator to closely monitor the system. Large defects can also result in significant machine downtime or scrapping of the component. There is a need for automated tools to help monitor the process and resolve defects before they become problematic.

CSIRO is developing a software called Continuous3D which offers a suite of tools for toolpath planning, simulation, sensing, and control of robotic AM systems.

Within Continuous3D, multiple toolpath strategies are available to cater to a wide range of jobs and processes. Revolved slicing enables utilization of an external rotator when printing revolute parts. Non-planar toolpaths conform to irregular geometries and substrates and are ideal for repair operations or for 3D printing organic shapes. There are multiple planar toolpath options including continuous paths suitable for processes where deposition cannot easily be stopped such as cold spray (Australian Patent Application No. 2020322728). Custom delay sequences can be set to allow for cooling between layers as required by directed energy deposition (DED) processes such as LMD and WAAM.

The integrated ecosystem allows multiple robot deposition systems to be simulated simultaneously in a time synchronous manner. Forward and inverse kinematics models are computed with the QuIK algorithm (Lloyd et al 2022). A voxel-based virtual material deposition model enables the user to rapidly check their toolpaths prior to sending a program to the robot. Simulated deposition profiles can be customized either by inserting a CAD file or parametrically.

Continuous3D interfaces directly with a robot-driven 3D scanner system and can generate point clouds in real time. Path planning can be carried out directly from scanner data even in cases with no preexisting CAD file. Real time scanning and reconstruction during deposition enables rapid comparison between expected geometry and actual geometry.

REFERENCES

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