

Toolpath-Aware Planning and Analysis in Wire Arc Additive Manufacturing

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Introduction

- Cold Metal Transfer Wire Arc Additive Manufacturing (CMT-WAAM) enables high-rate fabrication of large metal components with reduced heat input and spatter.
- However, build quality remains highly dependent on toolpath strategy, particularly in geometries containing sharp corners, thin walls, and overhangs.
- Systematic benchmarking is needed to evaluate and optimize deposition performance prior to large-scale fabrication.

Methods

GUI Toolkit

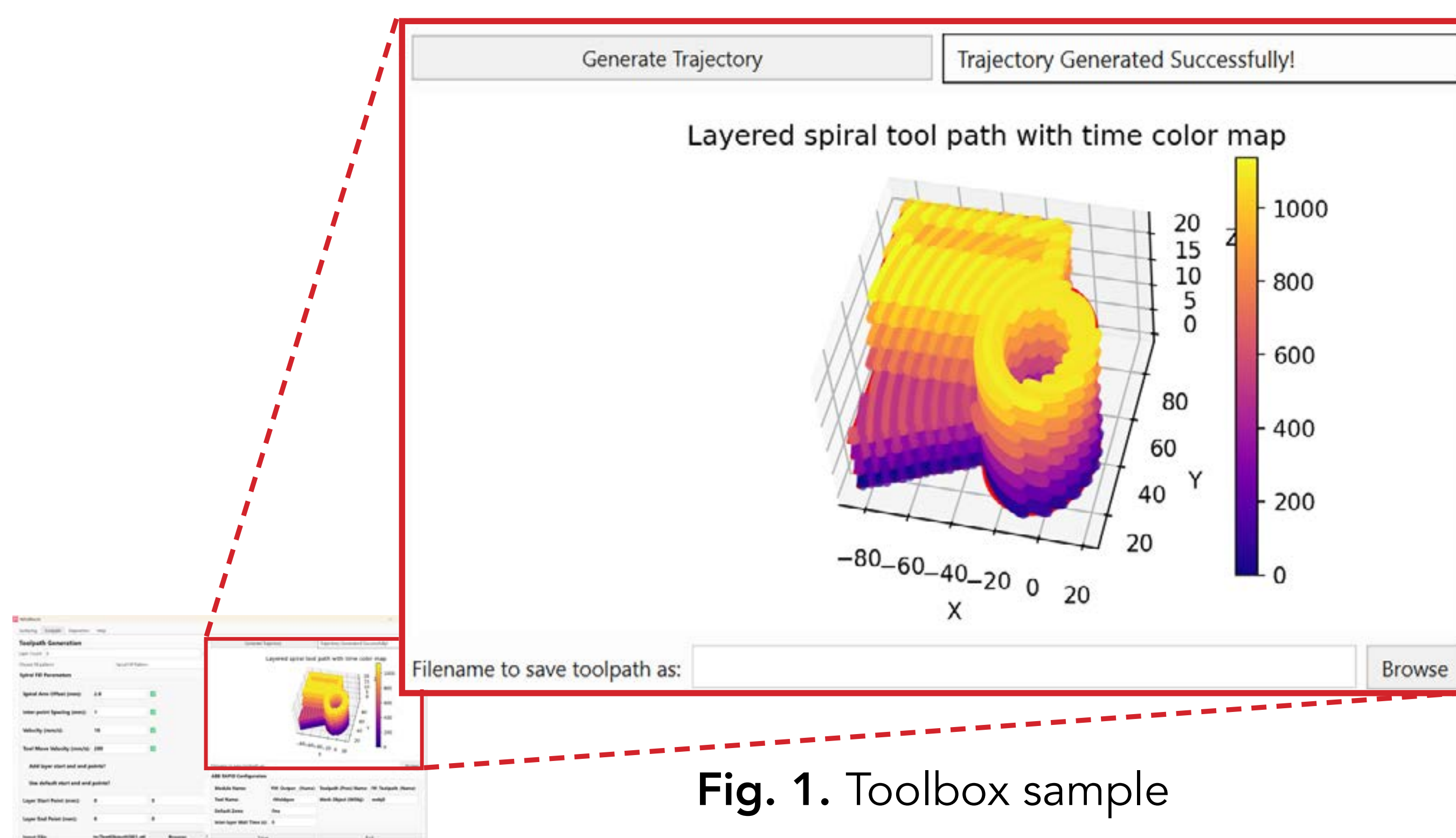


Fig. 1. Toolbox sample

Experimental Setup

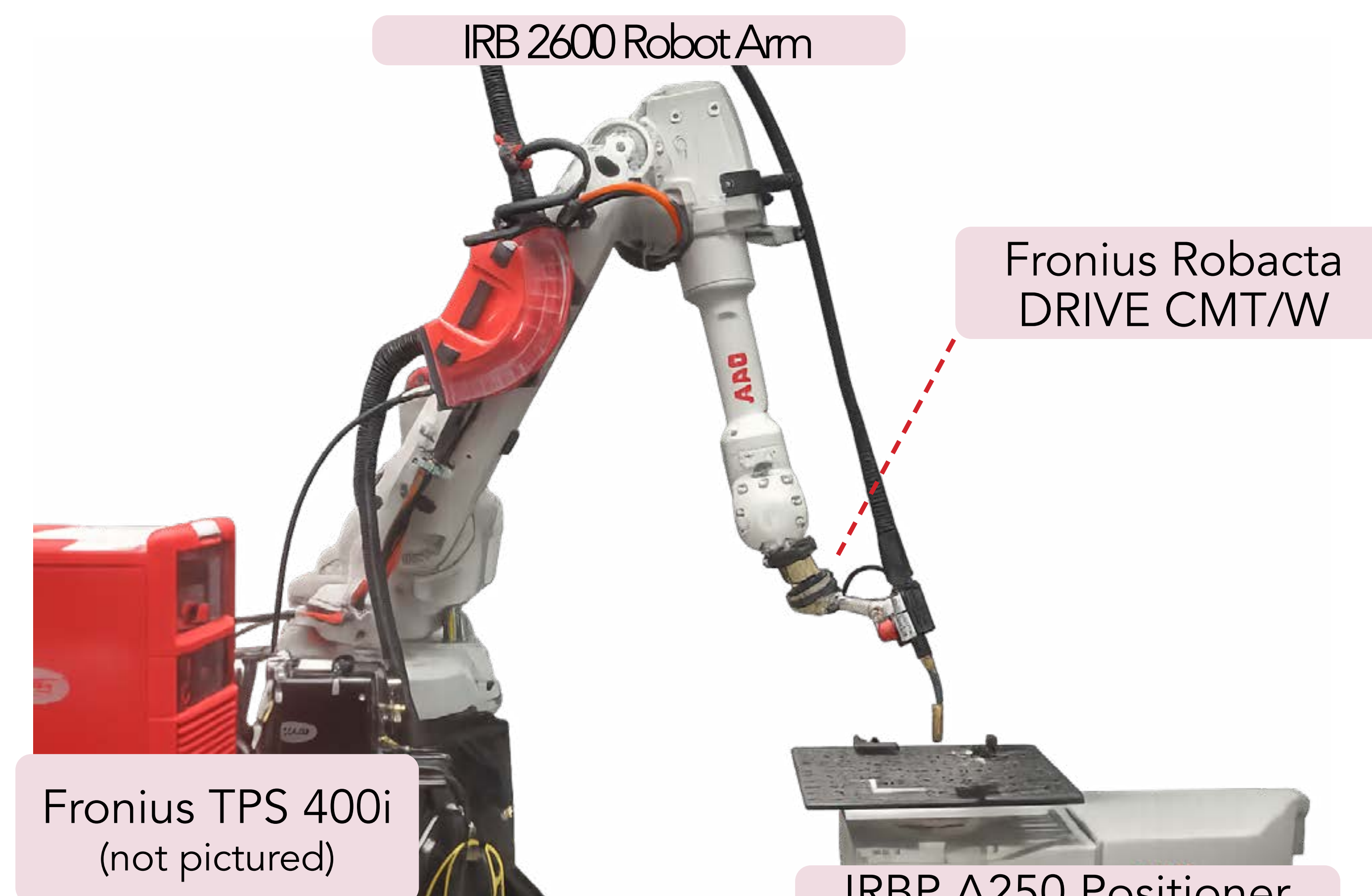


Fig. 2. Robot

Workflow

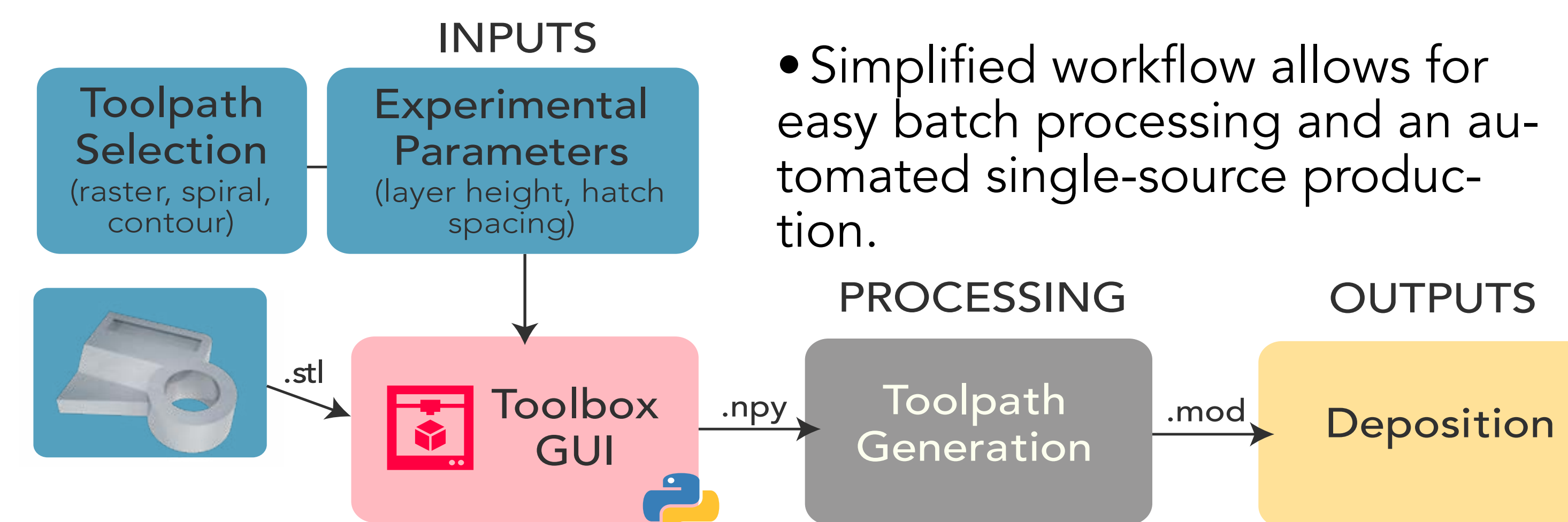


Fig. 3. Simplified toolbox flowchart

Benchmarking Artifact



Fig. 4. Test Geometry Render

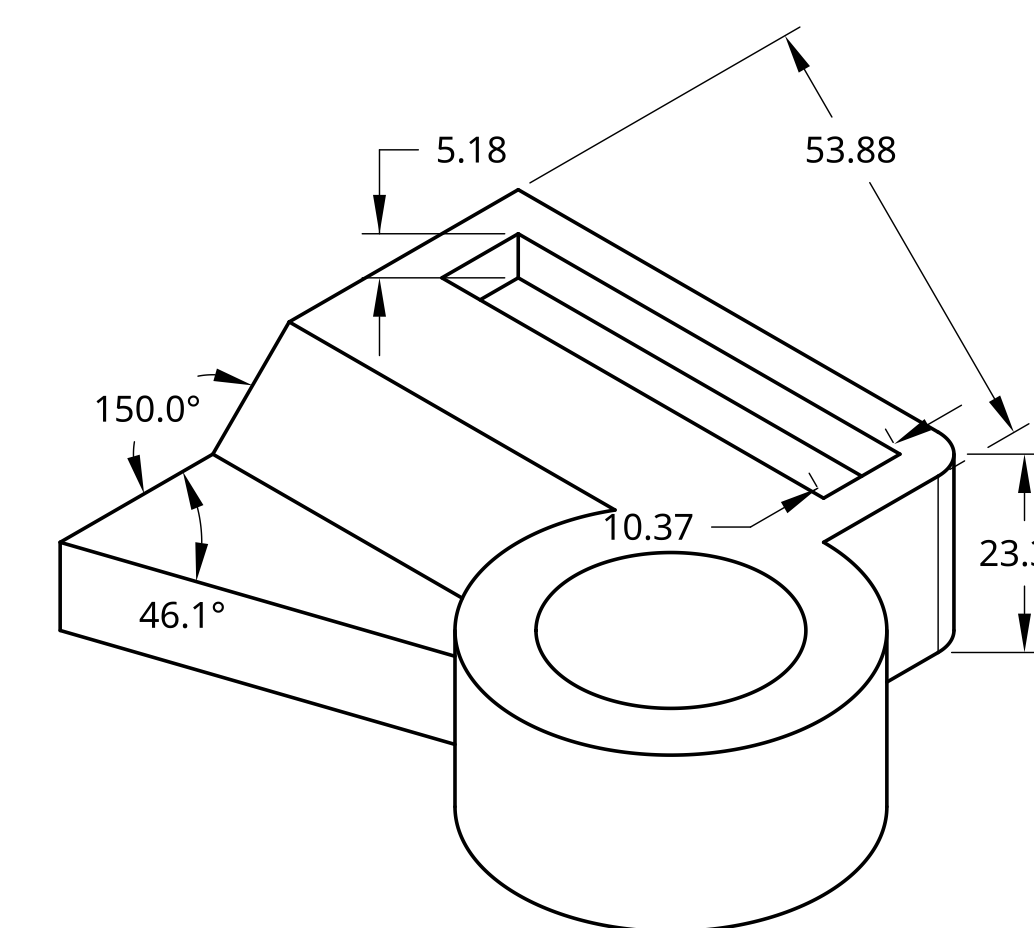


Fig. 5. Key measurements (mm)

- Designed a CMT-WAAM test artifact inspired by the methodologies described in de Pastre, Toguem Tagne, and Anwer (2020).¹

Results

Sample Layer Toolpaths

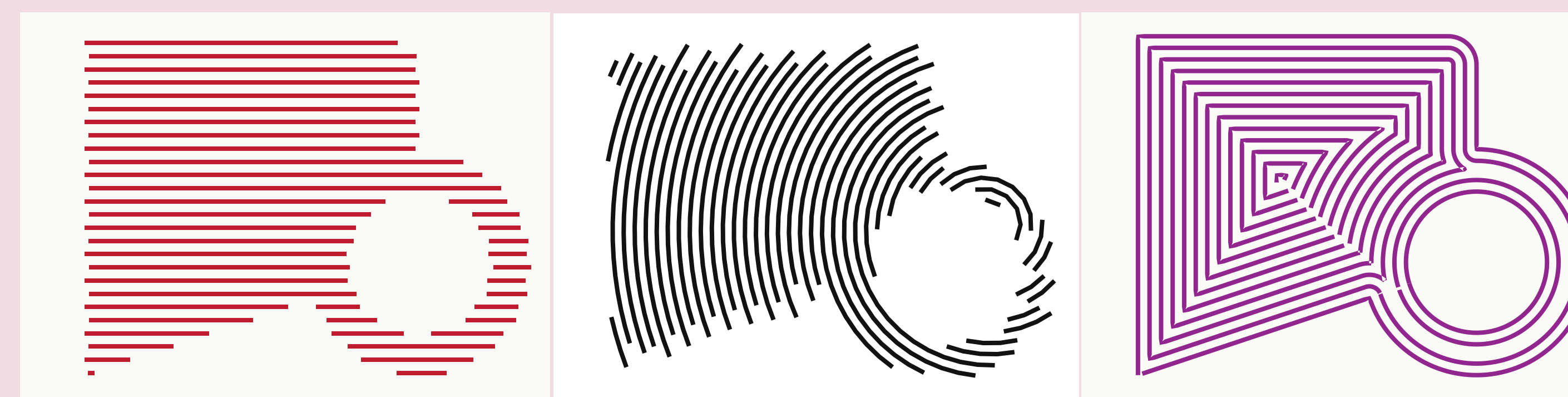


Fig. 6. Base layer SVG toolpaths

Depositions



Fig. 7. Sample depositions

Deposition Parameters	Value	Note
Wire feed speed	350 ipm	.045" steel wire
Torch speed	20 mm/s	welddata/seamdata
Torch orientation	q=[0,0,1,0]	fixed torch orientation

Iterative Build Data

Toolpath	Weld Distance	Motion Time	Relative Time
Raster	12.41 m	20.68 min	1.000x
Spiral	12.43 m	20.71 min	1.001x
Contour	14.17 m	23.61 min	1.141x

Discussions

Takeaways

- Toolbox allows for integrated end-to-end planning and iterative optimization of builds.
- Raster, contour, and spiral strategies show different tradeoffs in coverage, continuity, and boundary fidelity.
- Features smaller than steady-state bead dimensions are difficult to deposit using generalized toolpath methods.

Impact on Large Scale CMT-WAAM

- Difficult features can be systematically benchmarked before committing to expensive large-scale builds.
- Provides a standardized framework for comparing deposition strategies before fabrication.

Ongoing and Future Work

- Quantitative comparisons of dimensional accuracy and bead morphology across toolpath types.
- Implementation of multi-toolpath strategies that balance deposition efficiency and dimensional accuracy.
- Integration of thermal simulations and instrumentation data to predict heat accumulation for toolpath refinement.
- Development of advanced toolpaths such as space filling curves.

Acknowledgments

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References

- 1) de Pastre, Toguem Tagne SaintClair, and Nabil Anwer, "Test Artefacts for Additive Manufacturing: A Design Methodology Review," CIRP Journal of Manufacturing Science and Technology 31 (2020): 14–24, <https://doi.org/10.1016/j.cirpj.2020.09.008>.