Parametric rate and cost estimation for laser-based additive manufacturing

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ABSTRACT

Additive manufacturing (AM) removes many traditional design constraints, as it can create complex internal geometries, enable multiple materials or structural gradients, significantly reduce lead times for small-batch production, and facilitate mass customization [1]. However, in order to utilize the expansive AM design and performance spaces, and to explore the full gamut of AM-enabled applications, we must advance our ability to optimize AM process parameters over manifold design considerations [2]. We propose that optimal use of AM in production contexts requires computational tools that enable rapid assessment of quantitative relationships between part design, manufacturability, and value.

To quantitatively assess the trade-offs between build rate, resolution and cost for AM processes, we present a parametric rate and cost estimator for scanning laser-based AM. The model takes a mesh representation of the part design as input, and uses a parametrized model of the rate-limiting physics of the build process to estimate the part-specific build time [3, 4]. From this build time estimate, per-part cost is calculated using a quantity-dependent activity-based model. The model thus enables analysis of large numbers of design alternatives for a single part, and parametric analysis of trade-offs between part quality (e.g., resolution), throughput, and cost. As such, the tool can be used for screening large libraries of components for AM suitability, and informing equipment design and selection as related to production objectives (e.g., total volume, required lead time, etc.).

Using a case study of 40 topology-optimized engine bracket designs, we demonstrate the accuracy of our build rate estimator for production with stereolithography (SLA) and selective laser melting (SLM), as well as its potential use case as a decision-making tool when selecting AM-suitable parts.

For industry, this work will enable faster, cost-effective product development cycles for engineering teams by co-optimizing design with economic and time constraints. In resource constrained settings, our work will enable new use cases for AM as an accessible means of production in contrast to the barriers of traditional manufacturing infrastructure. Our findings will also inform future research in machine design and material science for AM.

REFERENCES

[1] H. Quinlan, T. Hassan, J. Jaddou, A.J. Hart, “Industrial and Consumer Uses of Additive Manufacturing.” *Journal of Industrial Ecology*, Vol. 21(S1), S15-S20, (2017).

[2] M. K. Thompson, G. Moroni, T. Vaneker, G. Fadel, R. I. Campbell, I. Gibson, A. Bernard, J. Schulz, P. Graf, B. Ahuja, F. Martina, “Design for additive manufacturing: Trends, opportunities, considerations, and constraints.” *CIRP Annals*, Vol. 65(2), pp. 737-760, (2016).

[3] C. Chen and P. Sullivan, “Predicting total build-time and the resultant cure depth of the 3D SLA process.” *Rapid Prototyping Journal*, Vol. 2(4), pp. 27-40, (1996).

[4] M. van Elsen, F. Al-Bender, J. Kruth, "Application of dimensional analysis to selective laser melting," *Rapid Prototyping Journal*, Vol. 14(1), pp.15-22, (2018).