Prof. Dr. Holger Hoos
Chair for AI Methodology
RWTH Aachen University

Using automated machine learning to create optimized projection images within a minute for user-friendliness and accessibility of CAL volumetric 3D printing to the wider public

Collaborative research proposal with the University of California Berkeley (Prof. Hayden Taylor)

Type:
Bachelor Thesis ☐
Master Thesis ☒

Daily Supervisor:
Henning Duwe duwe@aim.rwth-aachen.de
Anna Münz muenz@aim.rwth-aachen.de
Theaterstrasse 35-39, 52062 Aachen, Room 303-304

Project Description

Computed Axial Lithography [1] (CAL) is a novel and ultra-fast Volumetric Additive Manufacturing (VAM) technique that was initiated and developed at the University of California Berkeley (Cal) in collaboration with the Lawrence Livermore National Laboratory since 2017. CAL enables the 3D printing of centimeter-scale objects with a resolution as low as 20 micrometers [2] within 30-120 seconds. Importantly, the CAL process involves the usage of pre-generated projection images, which require a costly optimization step. This step takes anywhere between a few minutes to hours depending on the size and complexity of the desired part geometry. Projection generation is currently a bottleneck with respect to the accessibility of CAL to the wider public such as hobbyists and researchers. The cost of projection optimization can be very high for users who do not have access to the right hardware that can be very expensive.
In order to bridge the accessibility gap, researchers at Cal are using generative AI and computer vision to create those projections within seconds to circumvent the costly optimization process. This project is transforming the complex software into a user-friendly tool that can be used by non-specialist users. Those users could input an STL file and would be able to get their projection video within a few minutes. As part of this master's thesis, techniques for automatic selection and configuration of machine learning methods (AutoML) will be applied to further enhance user-friendliness and accessibility.
Currently, Cal researchers have developed the computer vision architecture that was trained based on the VAMToolbox [3] (VTB) for a number of voxels of $512 \times 512 \times 512$. The current process of projection generation is open loop, has a quality that is comparable to what can be obtained with VTB, and is asymptotically as good as VTB. In order to supersede the VTB projection quality, a closed loop system needs to be developed. Hence, feedback is needed to improve the model and enable deeper understanding of the factors that affect the print quality beyond what has been integrated into the VTB. This is the starting point for the masters thesis.
Your task in the masters thesis would be to use the algorithms and projections to create physical prints and scan them. Once we scan those prints, we can generate STL files and feed them back into a ML model and close the loop. This would enable us to have better quality of prints and account for factors that affect the print quality such as scattering, oxygen or other inhibitor diffusion, and temperature distribution. This should help us to surpass the original projection toolbox (VAM toolbox), which we have used to train a preliminary model.

Timeline

July 2024	Onboarding Generating data/creating physical prints and scan them
August 2024	Generating data/data analysis Data cleaning
September 2024	Finding the right ML model: which algorithm is best suited for this (sample poor) machine learning task? Which ML model fulfills requirements with respect to explainability?
October 2024	Hyperparameter optimization: finding the best possible configuration Improving the 3D-printing with insights of the ML model by scattering, using oxygen or other inhibitor diffusion, and temperature distribution
November 2024	Improving the 3D-printing with insights of the ML model by scattering, using oxygen or other inhibitor diffusion, and temperature distribution
December 2024	Wrap-up Buffer

About Professor Holger Hoos

Holger H. Hoos is a distinguished figure in the field of artificial intelligence, holding key positions across Germany, the Netherlands, and Canada. He is an Alexander von Humboldt Professor of AI at RWTH Aachen University, a Professor of Machine Learning at Universiteit Leiden, and an Adjunct Professor of Computer Science at the University of British Columbia.

Recognized for his significant contributions, he is a Fellow of the Association for Computing Machinery (ACM), the Association for the Advancement of Artificial Intelligence (AAAI), and the European Association for Artificial Intelligence (EurAI). He holds leadership roles in various AI organizations, including chairman of the board of the Confederation of Laboratories of Artificial Intelligence Research in Europe (CLAIRE) and vice-president of EurAI.

Holger's research focuses on the intersection of machine learning, automated reasoning and optimisation, with an emphasis on automated performance modelling and optimisation and on promoting accessibility to cutting-edge AI methods. Notable among his contributions is the development and promotion of paradigms such as programming by optimization (PbO) and automated machine learning (AutoML).

In 2018, he co-founded CLAIRE, an initiative dedicated to enhancing European excellence in AI research and innovation, which won the German AI Innovation Prize in 2021. Holger's recent recognition with an Alexander von Humboldt Professorship further highlights his remarkable research record. He leads the RWTH AI Center (together with Prof. Sebastian Trimpe).

About Professor Hayden Taylor

Hayden Taylor is an Associate Professor in the Department of Mechanical Engineering at the University of California, Berkeley. His research spans the invention, modeling and simulation of manufacturing processes,

with the aim of reducing materials and energy usage to support industrial decarbonization. Current research activities have the following themes: (A) processing of materials for sustainable construction, (B) multi-scale volumetric additive manufacturing, and (C) contact mechanics in semiconductor manufacturing.
He was previously an Assistant Professor at Nanyang Technological University in Singapore, a Postdoctoral Research Fellow in the Biosystems and Micromechanics group at the Singapore-MIT Alliance for Research and Technology, and a Research Associate in the Microsystems Technology Laboratories at MIT.
Hayden was born in Bristol, United Kingdom. He attended Bristol Grammar School and Trinity College, Cambridge, receiving the B.A. and M.Eng. degrees in Electrical and Electronic Engineering. He was sponsored as an undergraduate by ST Microelectronics. He is a Senior Scholar of Trinity College, Cambridge, and received the Cambridge University Engineering Department's Baker Prize. Hayden received the Ph.D. in Electrical Engineering and Computer Science from MIT (with a minor in Sustainable Energy), working with Professor Duane Boning.
Hayden is a member of the IEEE and the Institution of Engineering and Technology. He was an Institution of Electrical Engineers Jubilee Scholar, and a Kennedy Scholar.

References

[1] Brett E. Kelly et al. "Volumetric additive manufacturing via tomographic reconstruction". In: *Science* 363.6431 (2019), pp. 1075–1079. DOI: 10.1126/science.aau7114.

[2] Joseph T. Toombs et al. "Volumetric additive manufacturing of silica glass with microscale computed axial lithography". In: *Science* 376.6590 (2022), pp. 308–312. DOI: 10.1126/science.abm6459.

[3] *Computed axial lithography*. https://github.com/computed-axial-lithography. GitHub. (n.d.)