Task 4.3 – Defect-free metal additive manufacturing

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CoE RAISE All-Hands Meeting

August 28-30, 2023 Hveragerði, Iceland

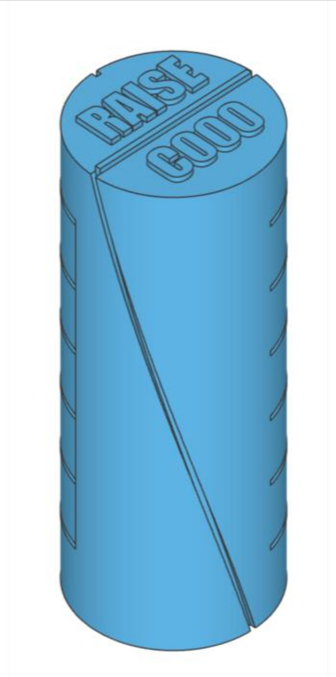
Task 4.3 – Defect-free metal additive manufacturing

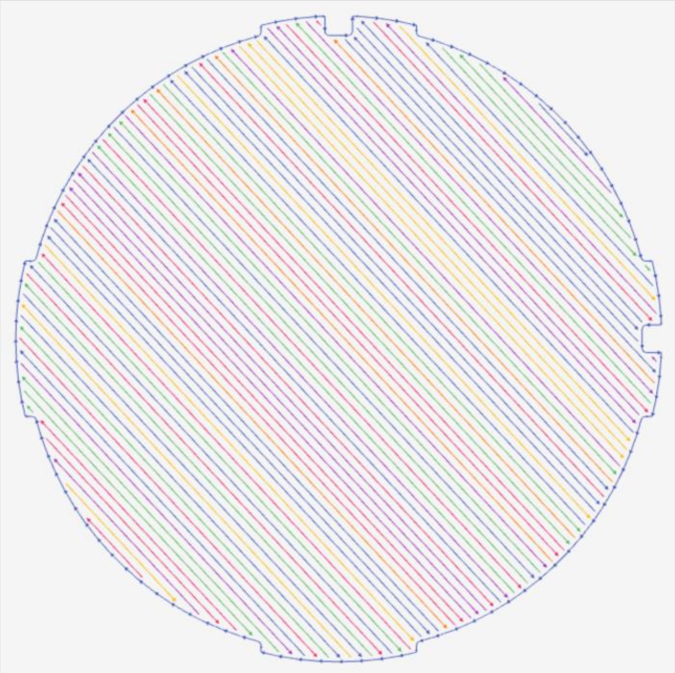
Laser powder bed fusion (LPBF)
is the main industrial 3D printing process for
metal parts

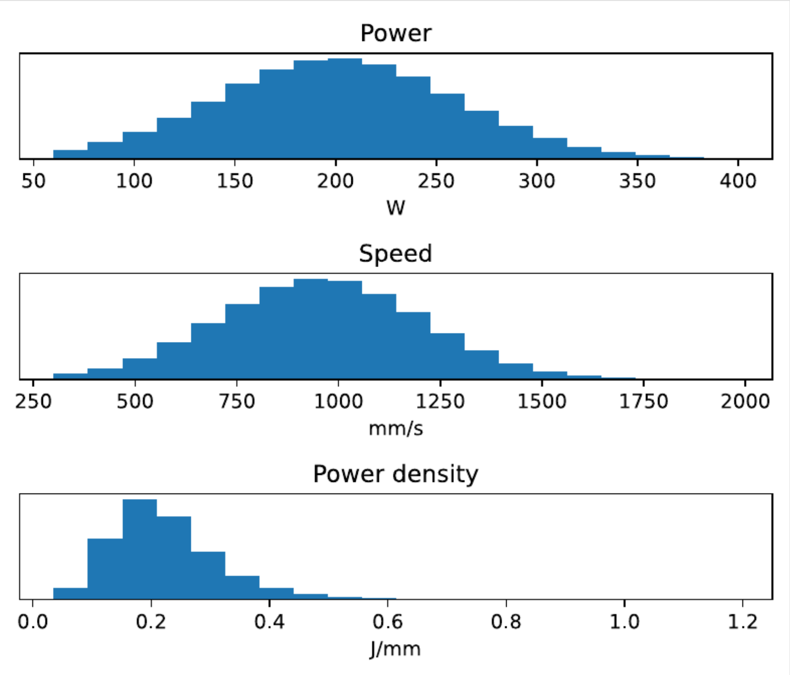
Major bottleneck: quality control

Dataset

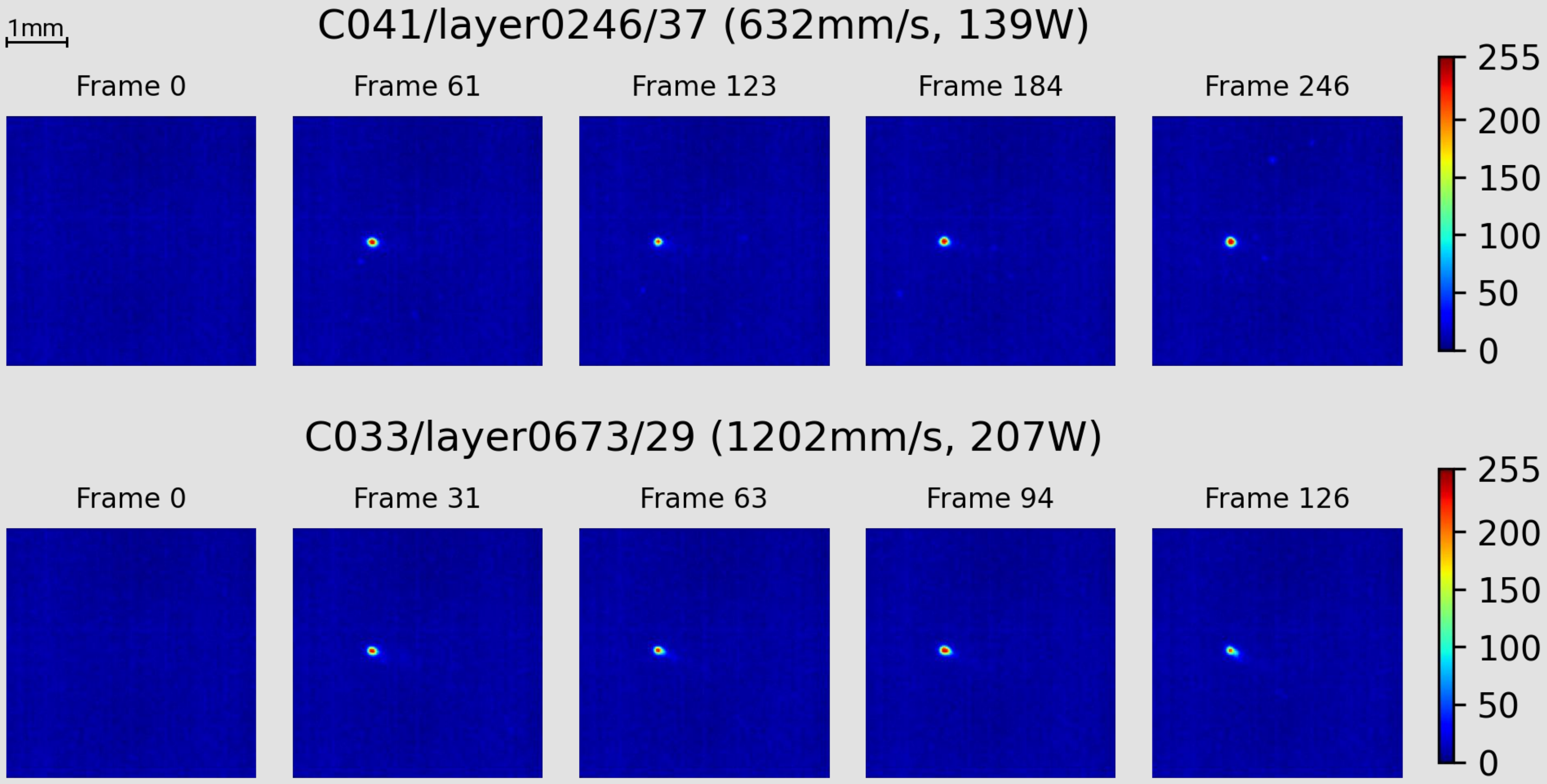
Fuse powder using randomized laser parameters







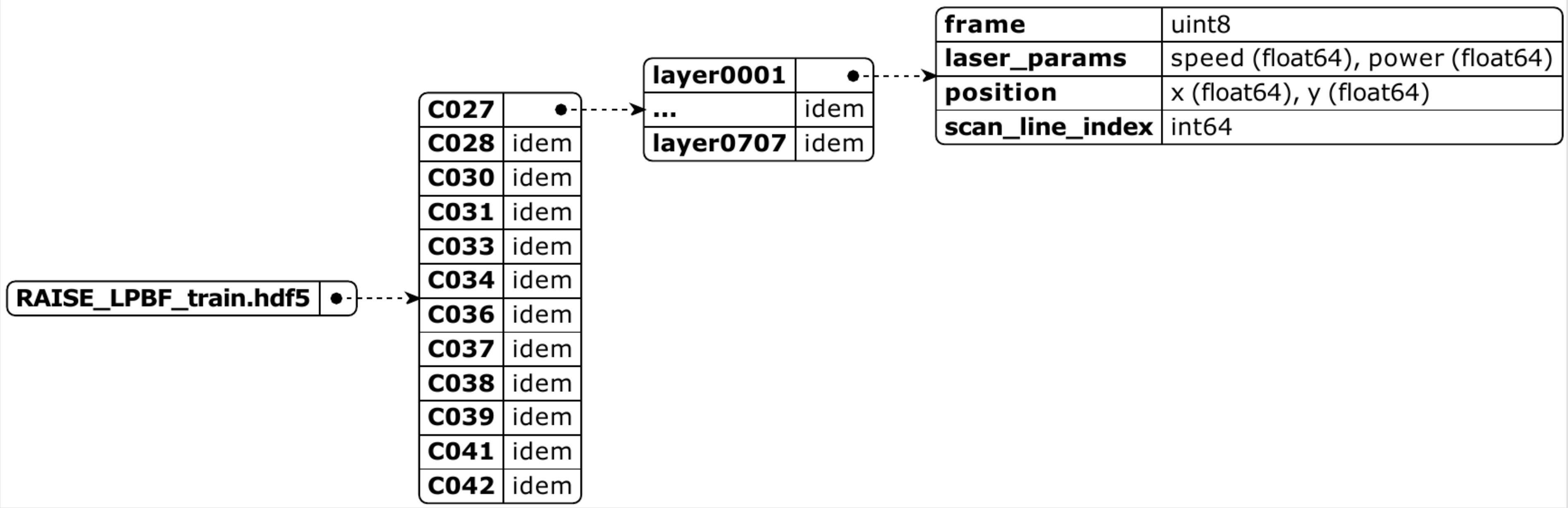
Dataset


1mm
C041/layer0246/37 (632mm/s, 139W)
Frame 0
Frame 61
Frame 123
Frame 184
Frame 246
255
200
150
100
50
0
C033/layer0673/29 (1202mm/s, 207W)
Frame 0
Frame 31
Frame 63
Frame 94
Frame 126
255
200
150
100
50
0

Dataset

Compiled to a simple HDF5 structure

1TB



Baseline models

KISS principle!

Baseline models simplified as much as possible:

- Only essential preprocessing
  - No cropping
  - No camera calibration
- Default hyperparameters
- Using only a few (equidistant) frames

Results: baselines

Model	Frames used	RMSE Speed	RMSE Power	RMSE Energy density
SlowFast	32	67.6	11.1	0.0290
3D ResNet	8	157.8	19.5	0.0520
MViT	16	191.9	24.9	0.0623
Swin3D	16	205.0	25.3	0.0568

Results: short journal paper

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Additive Manufacturing Letters 7 (2023) 100161

Contents lists available at ScienceDirect

Additive Manufacturing Letters

journal homepage: www.elsevier.com/locate/addlet

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Short Communication

Reference dataset and benchmark for reconstructing laser parameters from on-axis video in powder bed fusion of bulk stainless steel

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ARTICLE INFO

Keywords:
Selective laser melting
Stainless steel
On-axis camera
Dataset
Machine learning
Monitoring

ABSTRACT

We present RAISE-LPBF, a large dataset on the effect of laser power and laser dot speed in powder bed fusion (LPBF) of 316L stainless steel bulk material, monitored by on-axis 20k FPS video. Both process parameters are independently sampled for each scan line from a continuous distribution, so interactions of different parameter choices can be investigated. The data can be used to derive statistical properties of LPBF, as well as to build anomaly detectors. We provide example source code for loading the data, baseline machine learning models and results, and a public benchmark to evaluate predictive models.

1. Introduction

Powder Bed Fusion (PBF) is the most common Additive Manufacturing (AM) method where the powder of the chosen material (e.g., nylon, or various types of metal powder) is heated to construct the product.

solution, the monitoring system observes the meltpool and monitors a set of print parameters to predict whether the current trajectory of the printing is expected to end up in generating pores. Consequently, the control unit may generate corrective control measures to prevent the generation of defects in the first place, or compensate for it by remelting the faulty region.

The very fast movements of the melting laser, i.e., laser dot speeds

Side result: AIAI conference paper

Check for updates

Accelerated Monitoring of Powder Bed Fusion Additive Manufacturing via High-Throughput Imaging and Low-Latency Machine Learning

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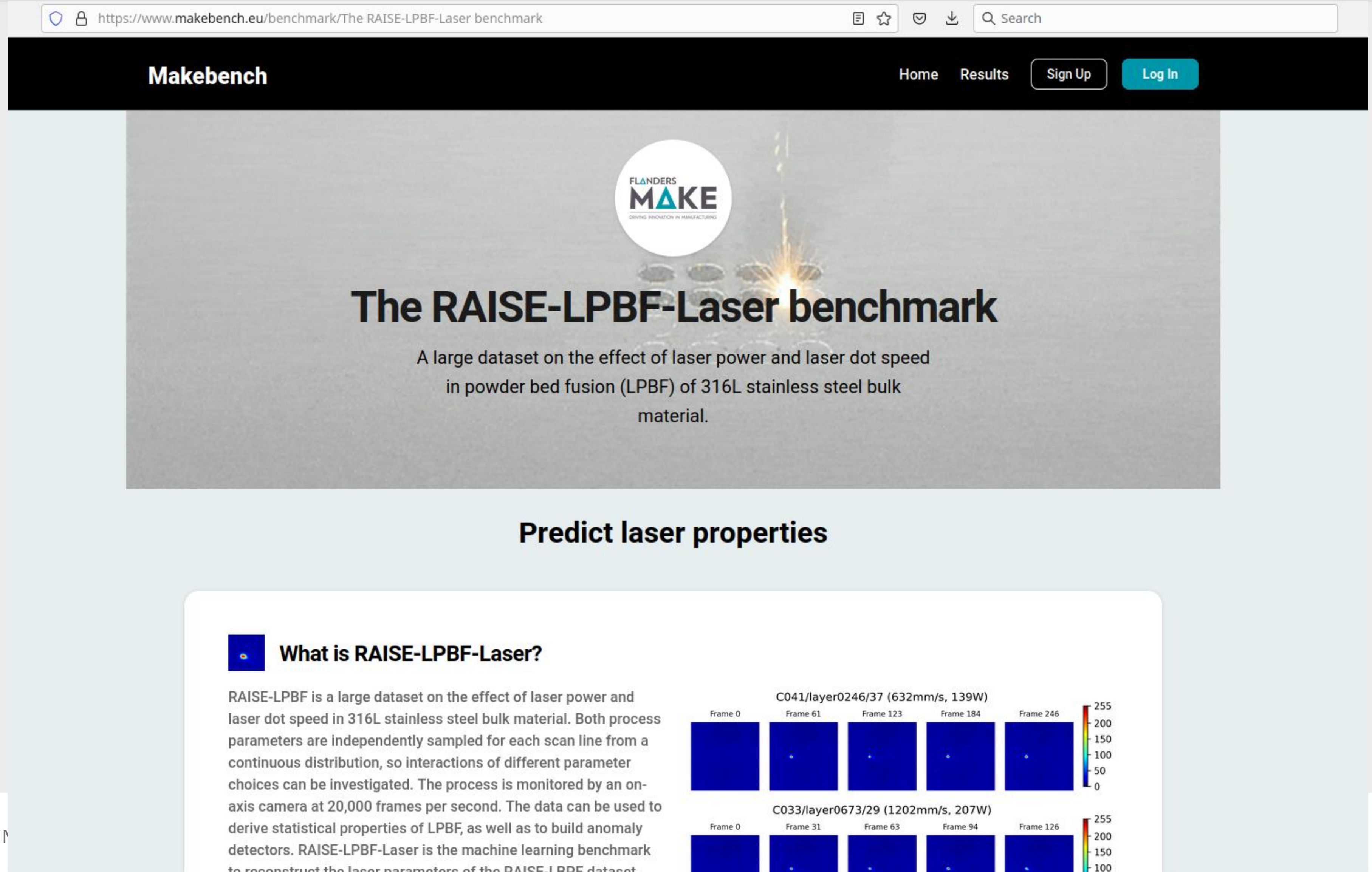
Abstract. Metal 3D printing in particular laser powder bed fusion is in the forefront of product manufacturing with complex geometries. However, these printed products are susceptible to several printing defects mainly due to complexities of utilizing high-power, ultra-fast laser for melting the metal powder. Accurate defect prediction methods to monitor the printing process are of high demand. More critically, such solutions must maintain a very low computational cost to enable feedback control signals for future low-latency laser parameter correction loops, preventing creation of defects in the first place. In this research, first we design an experiment to explore impact of several laser settings on creation of the most common defect called "keyhole porosity". We print an object while recording the laser meltpool with an externally installed high-speed visual camera. After extracting keyhole pore densities, we annotate the meltpool recordings and use it to evaluate performance of a simple but fast CNN model as a low-latency defect detector.

Keywords: pore density · melt-pool monitoring · keyhole pores · defect detection · additive manufacturing · laser powder bed fusion

1 Introduction

Layer by layer 3D printing of objects with high-complex geometries has been possible in a process called Additive Manufacturing (AM) [12]. Its advantages over other traditional manufacturing methods among others are: on-demand production of uniquely designed objects in limited quantities, substantial cost reduction via shorter supply chain and less storage [3], reduced parts counts, faster and less complicated assembling and decreased time and complexity for ... parts [10]. Various printing materials like polymers and metals ... called laser powder bed fusion (LPBF) ... with a moving laser

Results: makebench.eu



Results: makebench.eu (ctd.)

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Makebench — Home | Results | Sign Up | Log In

Download dataset

The training data comprises 12 cylinders, the test set 4. Each cylinder has 669 fully randomized layers, each with about 84 scan lines. To each line corresponds a pair of laser parameters: speed in mm/s and power in W.

See results

Check out the results and leaderboard for this dataset.

Example code

Example code to load the data in PyTorch, and a few baseline AI models.

How to submit

After you have built a predictive model on the training set, you can submit predictions for the test set to get listed on the leaderboard. Instructions on how to submit your model's predictions. (Requires login/signup.)

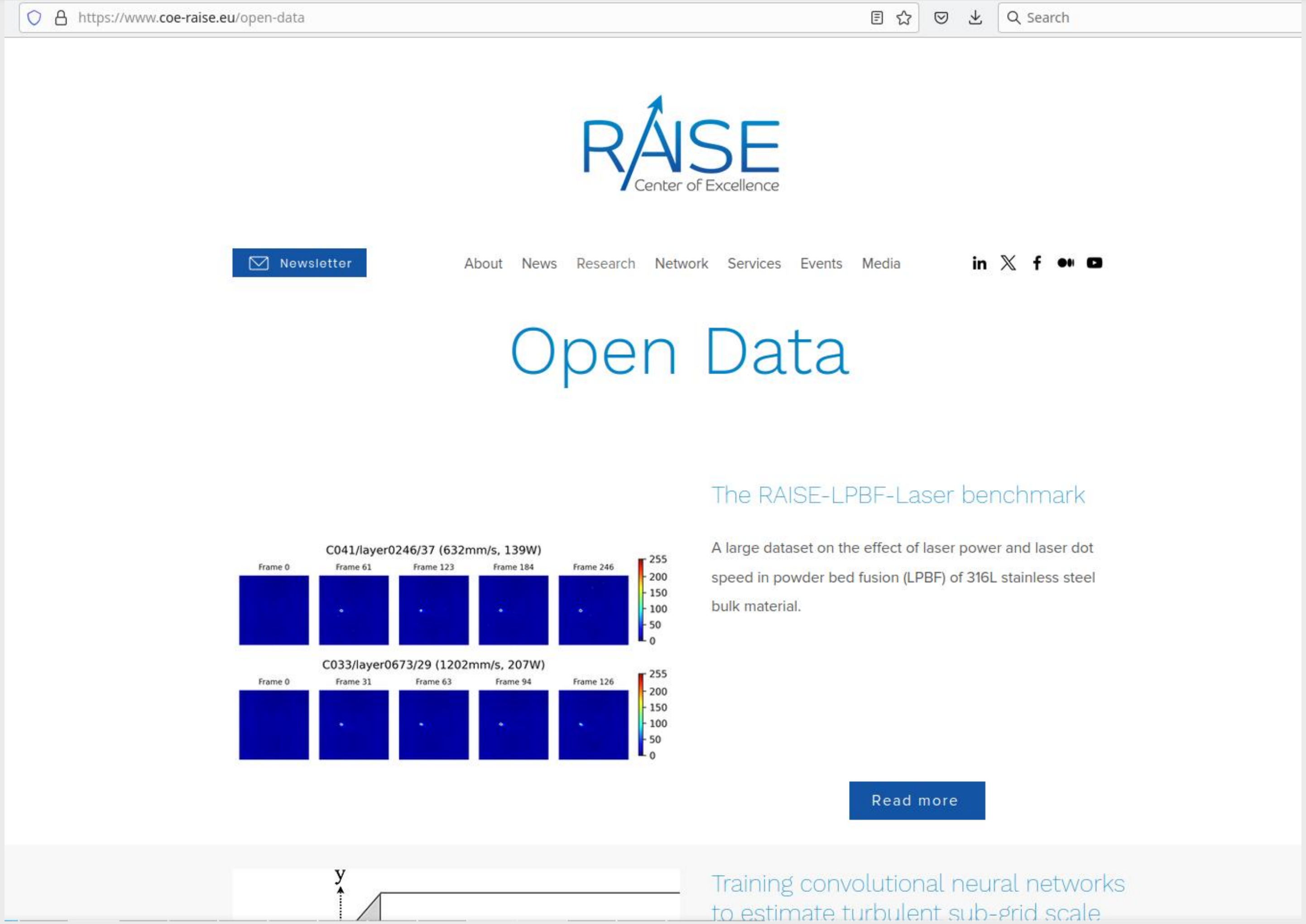
The paper

C. Blanc, A. Ahar, and K. De Grave. "Reference dataset and benchmark for reconstructing laser parameters from on-axis video in powder bed fusion of bulk stainless steel." Additive Manufacturing Letters (2023): 100161.

Acknowledgements

The CoE RAISE project has received funding from the European Union's Horizon 2020 – Research and Innovation Framework Programme H2020-INFRAEDI-2019-1 under grant agreement no. 951733.

Open data


https://www.coe-raise.eu/open-data
Search
RAISE
Center of Excellence
Newsletter
About
News
Research
Network
Services
Events
Media
Open Data
C041/layer0246/37 (632mm/s, 139W)
Frame 0
Frame 61
Frame 123
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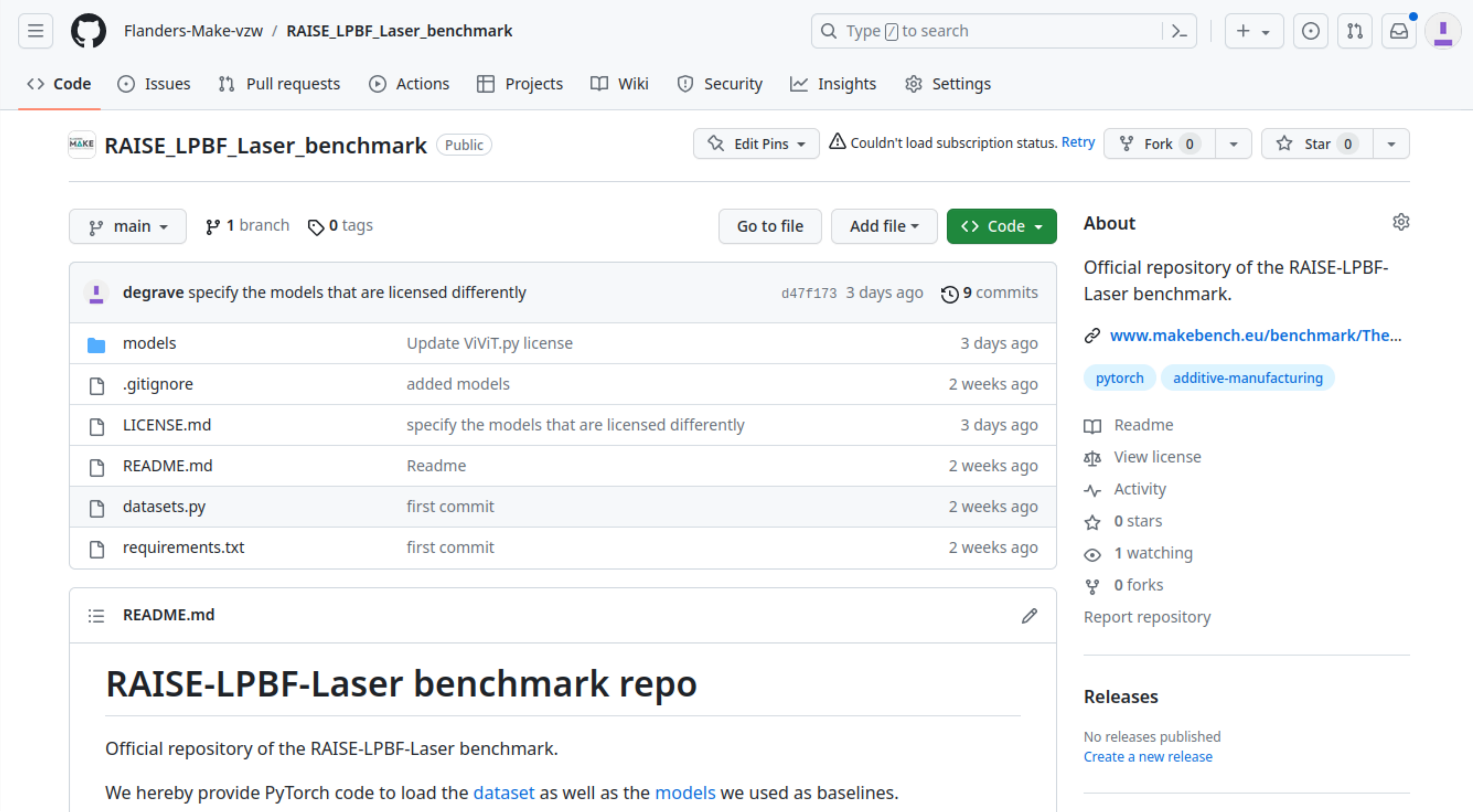
Frame 0
Frame 31
Frame 63
Frame 94
Frame 126
255
200
150
100
50
0
The RAISE-LPBF-Laser benchmark
A large dataset on the effect of laser power and laser dot speed in powder bed fusion (LPBF) of 316L stainless steel bulk material.
Read more
y
Training convolutional neural networks to estimate turbulent sub-grid scale

Supporting public repo



Misc.

- Master Thesis postponed to H2 2023.
- Experimented with ClearML Agent in VSC cloud
  - Read-only git access (granted in advance)
  - Job isolation: OpenStack VM + Docker + non-privileged container
    - Various caches are necessary for performance but break isolation
  - Still GPU-accelerated
  - Data access still TBD

Next Steps

- Beating the baseline
- Helping others beat the baseline
- Bigger Transformers and other foundational models
  - However, industry prefers small models and cheap sensors
- Mass density model

drive. enable. innovate.

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