



**ASME® 2020 IDETC-CIE**

International Design Engineering Technical Conferences  
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VIRTUAL CONFERENCE  
AUG 17–19, 2020

# Melt Pool Prediction and Process Control

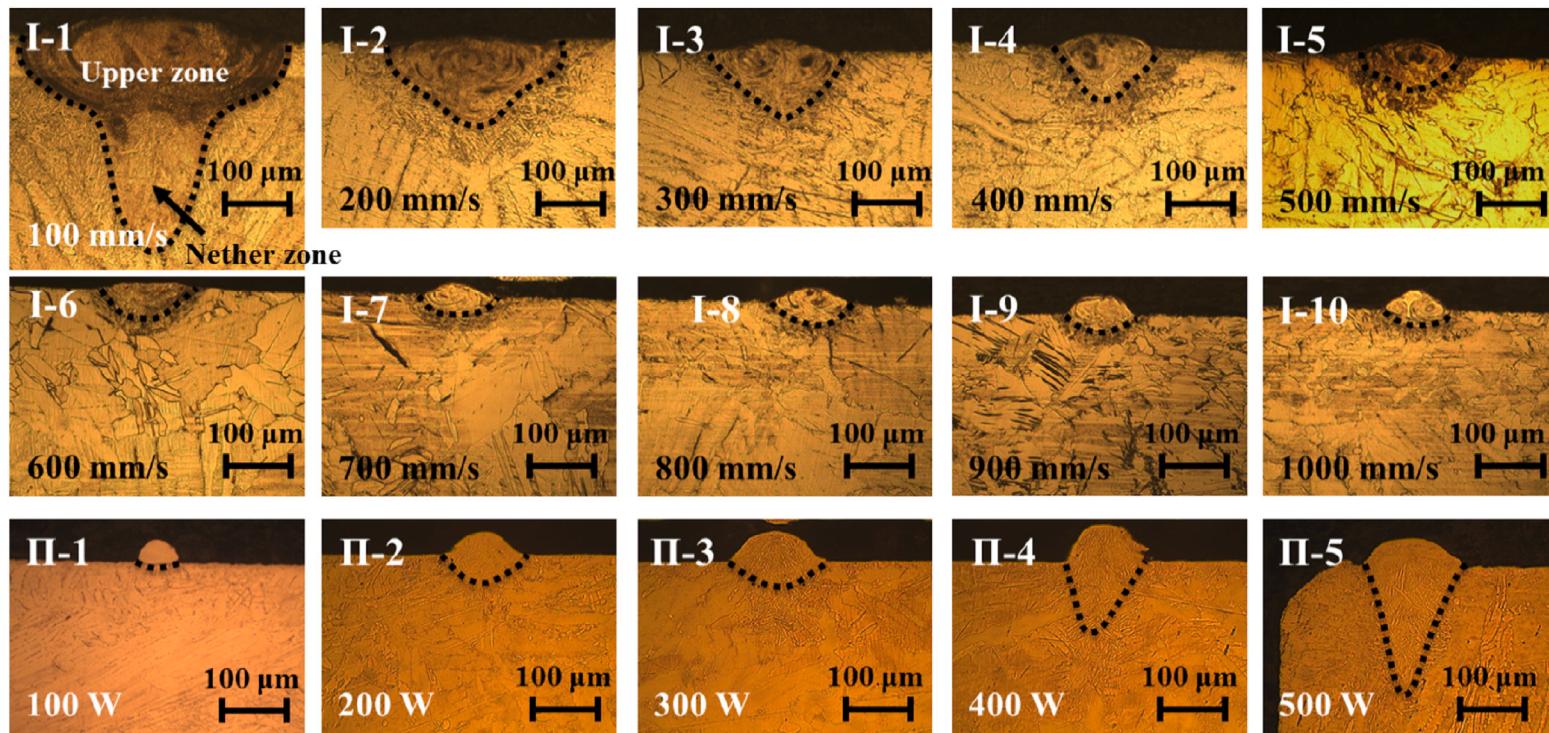
Problem #2

Charge On!

**Ziyang Zhang & Junchuan Shi, Qingyang Liu**



## Background

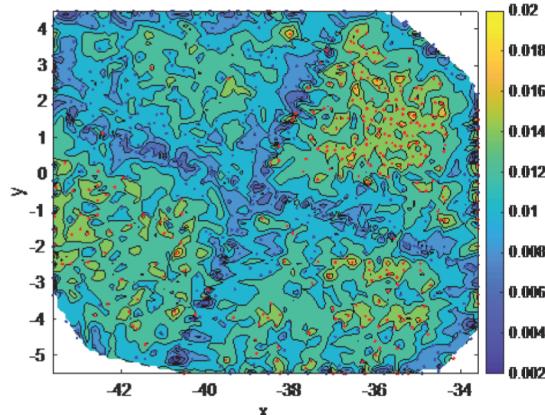
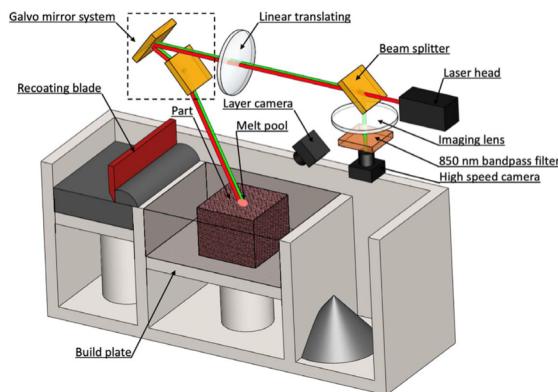


- Melt pool geometry monitoring is important as it is highly correlated to part quality.
- Estimating the melt pool geometry based on scan strategy, laser power and scan speed before printing can generally improve the overall printing quality.
- In-situ process control and optimization is essential for adaptively updating printing parameters for each layer.

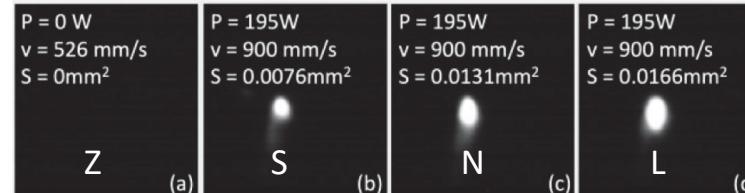
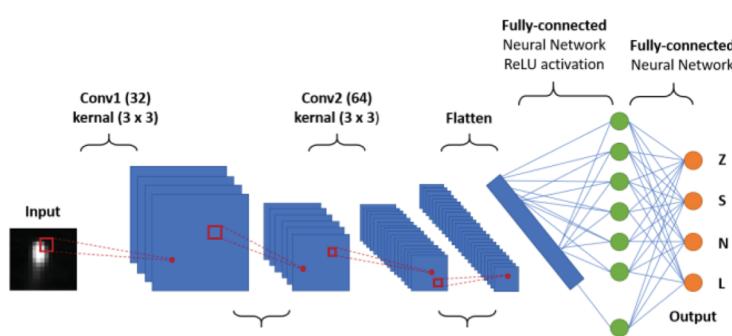
Image from: Yang, Jingjing, et al. "Role of molten pool mode on formability, microstructure and mechanical properties of selective laser melted Ti-6Al-4V alloy." *Materials & Design* 110 (2016): 558-570.



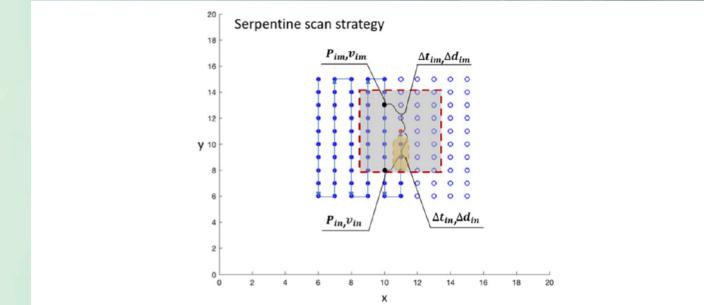
## Literature review



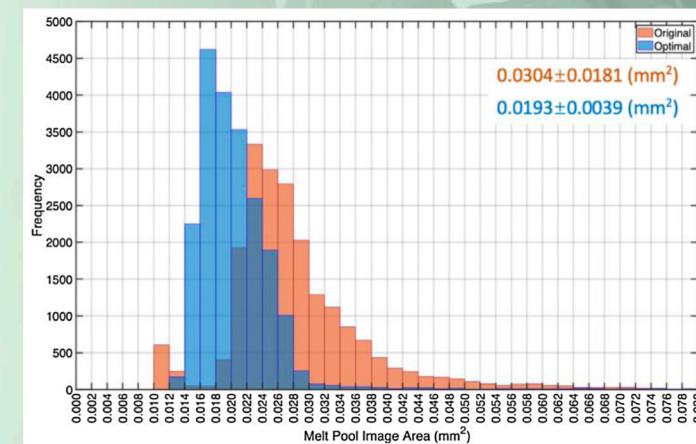
Yang, Zhuo, et al. "Investigation of Deep Learning for Real-Time Melt Pool Classification in Additive Manufacturing." 2019 IEEE 15th International Conference on Automation Science and Engineering (CASE). IEEE, 2019.



Size	Training time (s)	Total processing time per image (s)	Predictive accuracy
64x60	602.03	7.18 (0.00245)	88.62 %
32x30	94.69	0.99 (0.00034)	90.84 %
16x15	27.28	0.35 (0.00012)	89.47 %
8x8	9.14	0.15 (0.00005)	90.77 %



$$S_i = c_1 + c_2 P_i + c_3 v_i + c_4 P_i v_i + c_5 P_i^2 + c_6 v_i^2$$



Yeung, H., Z. Yang, and L. Yan. "A Melt pool Prediction Based Scan Strategy for Powder Bed Fusion Additive Manufacturing." *Additive Manufacturing* (2020)

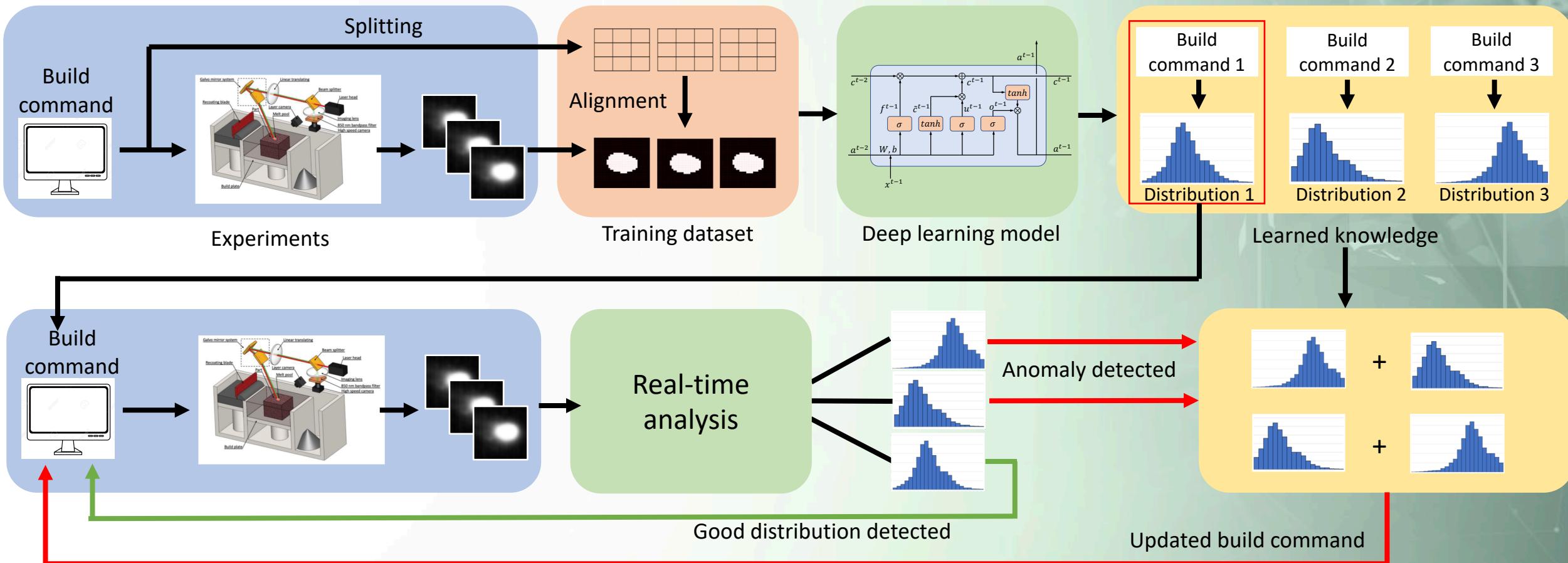


## Research question & challenges

- How to accurately predict melt pool sizes based on process parameters?
  - Data selection, preprocessing & alignment
  - Selection of suitable algorithms
- How to update process parameters layer by layer using in-situ monitored melt pool information?
  - Computational speed
  - Updating strategy

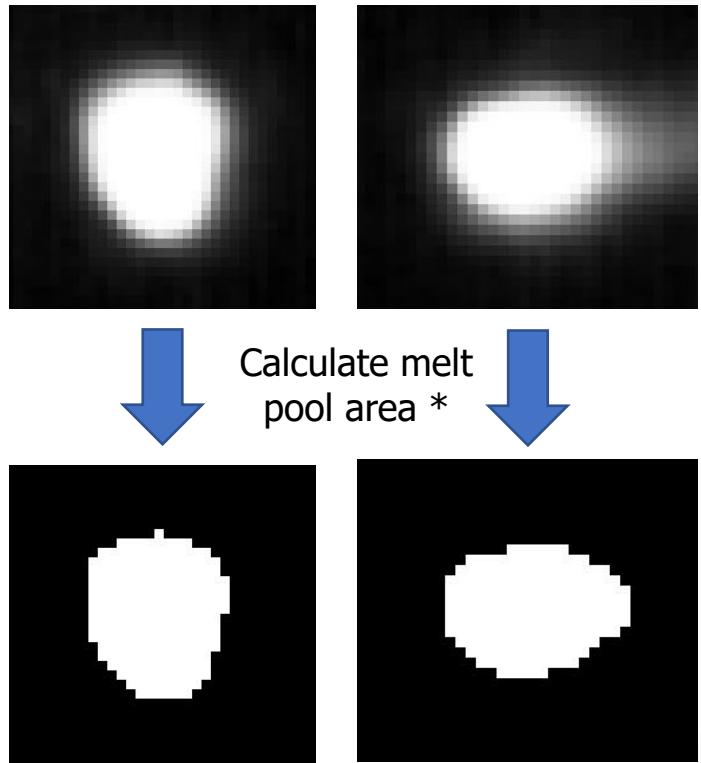


## Proposed frame work

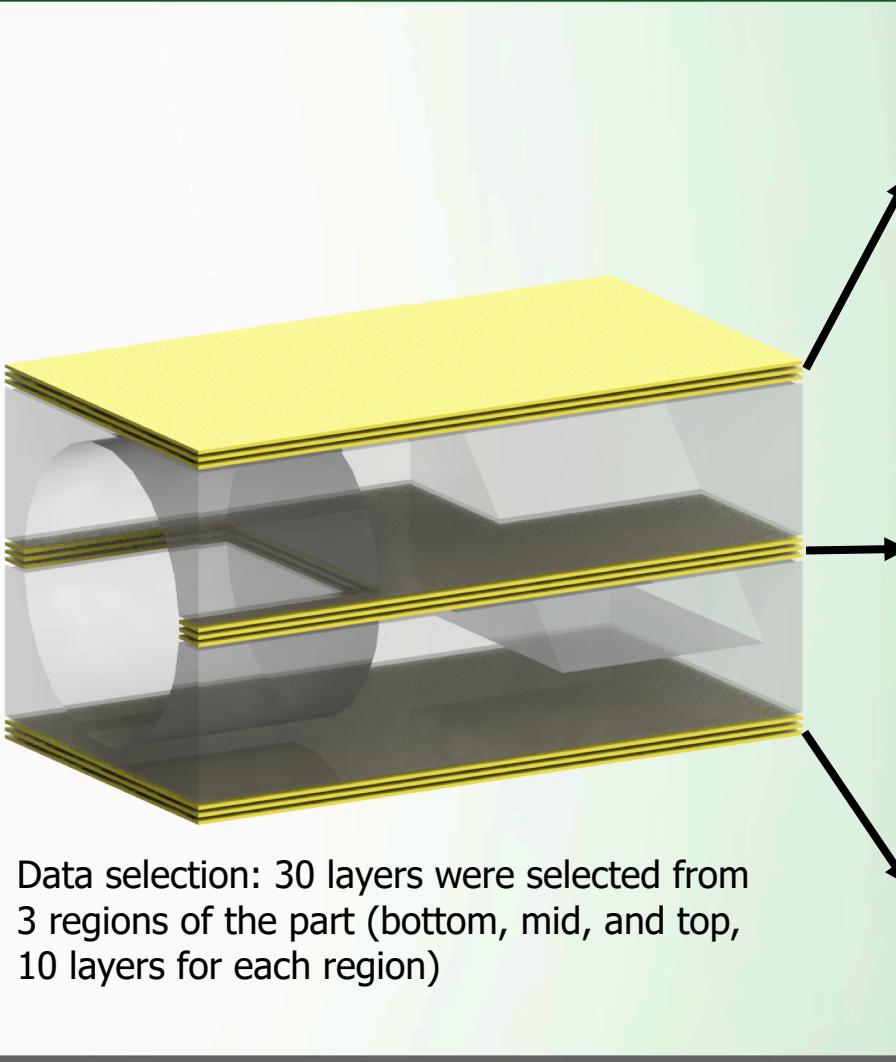




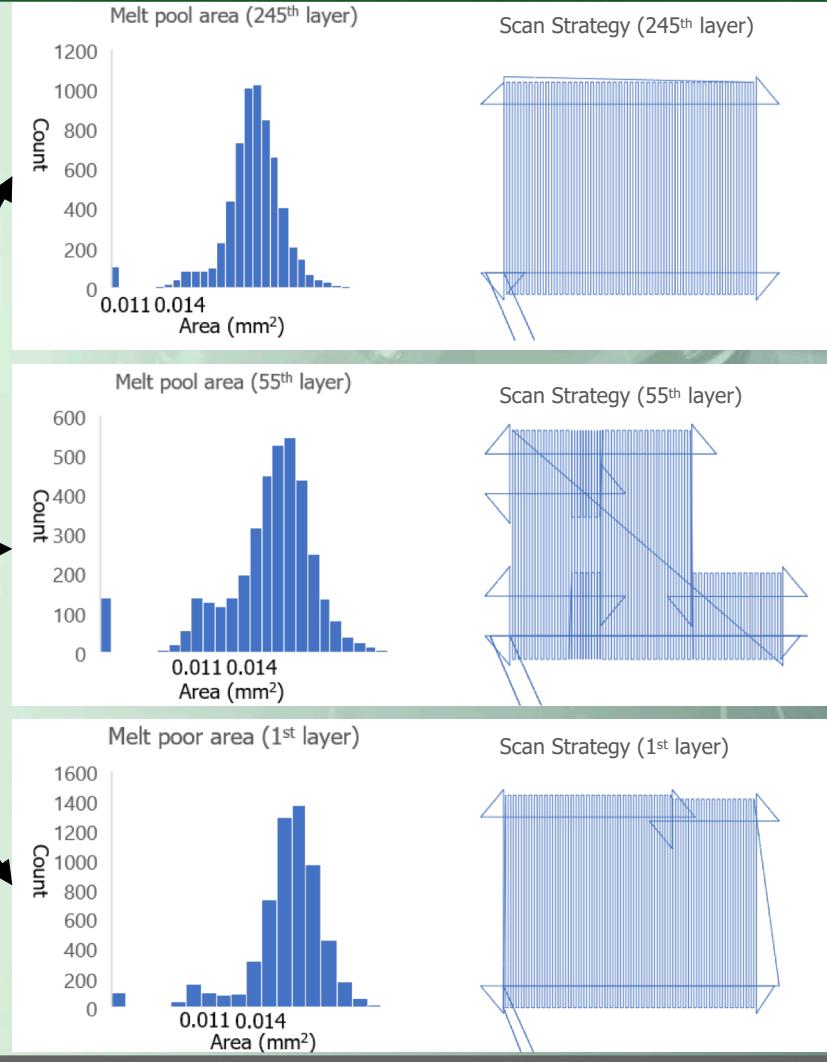
## Data preprocess



\* Schindelin, Johannes, et al. "Fiji: an open-source platform for biological-image analysis." *Nature methods* 9.7 (2012): 676-682.



Data selection: 30 layers were selected from 3 regions of the part (bottom, mid, and top, 10 layers for each region)

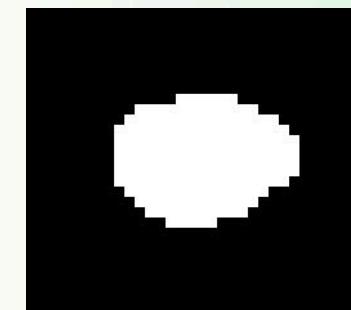




## Data description & alignment

X	Y	Laser power	Layer index	Trigger
-4.9149	9.0107	200	1	0
-4.9159	9.0125	200	1	0
-4.9169	9.0142	200	1	0
-4.9178	9.016	200	1	0
-4.9188	9.0177	200	1	0
-4.9197	9.0195	200	1	0
-4.9207	9.0213	200	1	0
-4.9216	9.023	200	1	0
-4.9226	9.0248	200	1	0
-4.9236	9.0265	200	1	2

Input features



Output: melt pool size

- Training data: 24 layers
- Test data: 6 layers

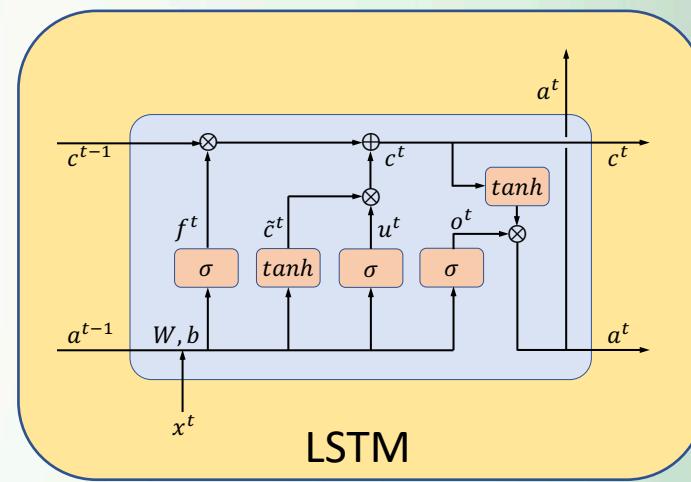


## Deep learning model: LSTM

X	Y	Laser power	Layer index
-4.9149	9.0107	200	1
-4.9159	9.0125	200	1
-4.9169	9.0142	200	1
-4.9178	9.016	200	1
-4.9188	9.0177	200	1
-4.9197	9.0195	200	1
-4.9207	9.0213	200	1
-4.9216	9.023	200	1
-4.9226	9.0248	200	1
-4.9236	9.0265	200	1

Average →

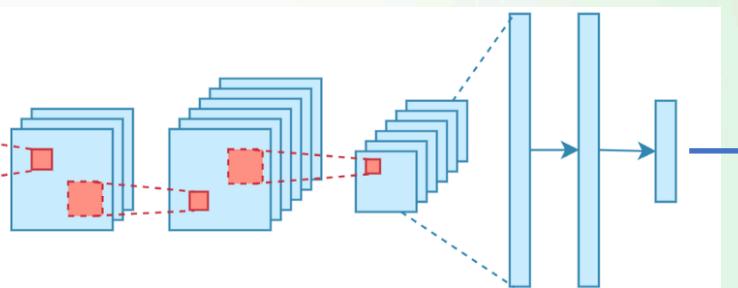
X	Y	Laser power	Layer index
-4.9149	9.0107	200	1



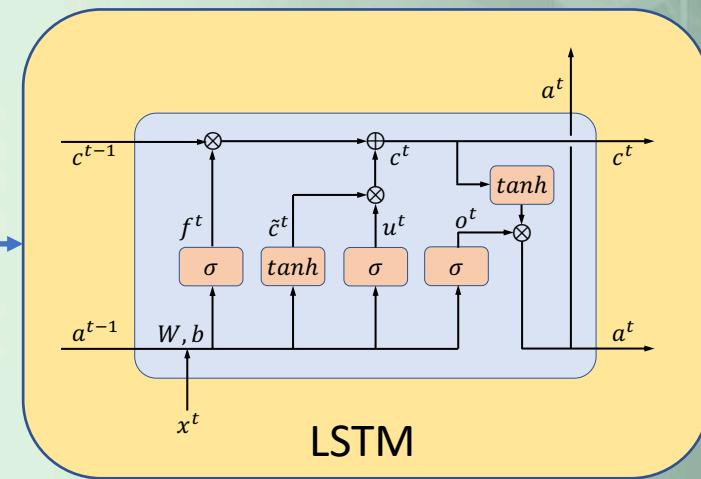


## Deep learning model: CNN-LSTM

X	Y	Laser power	Layer index
-4.9149	9.0107	200	1
-4.9159	9.0125	200	1
-4.9169	9.0142	200	1
-4.9178	9.016	200	1
-4.9188	9.0177	200	1
-4.9197	9.0195	200	1
-4.9207	9.0213	200	1
-4.9216	9.023	200	1
-4.9226	9.0248	200	1
-4.9236	9.0265	200	1



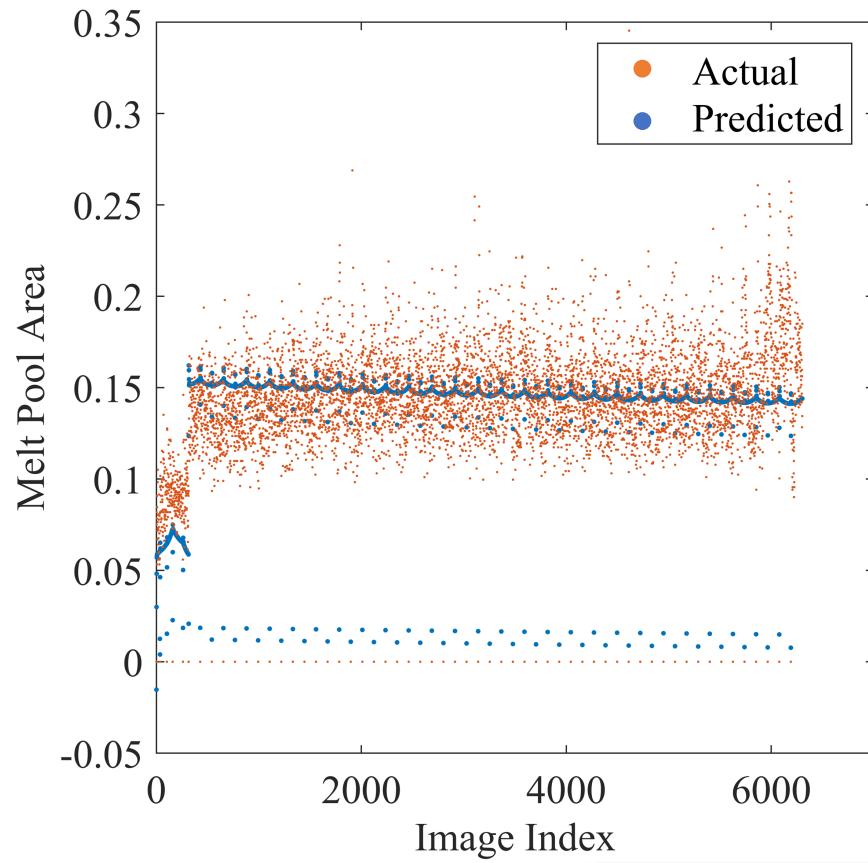
CNN



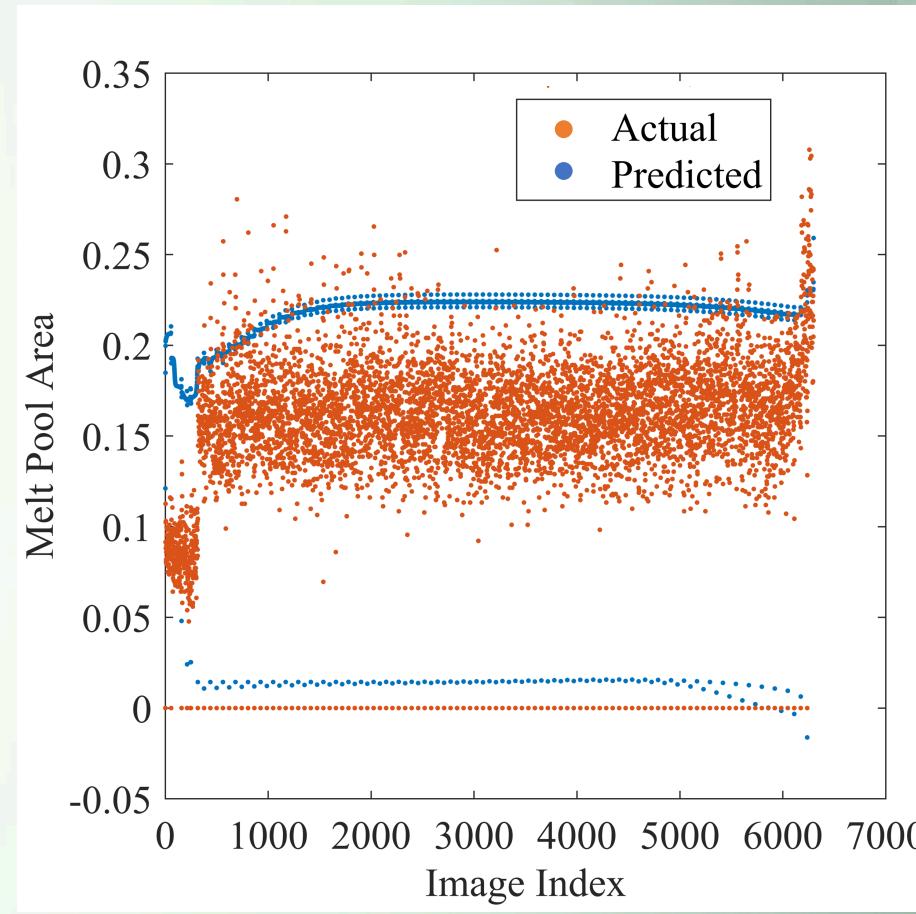
LSTM



## Prediction results



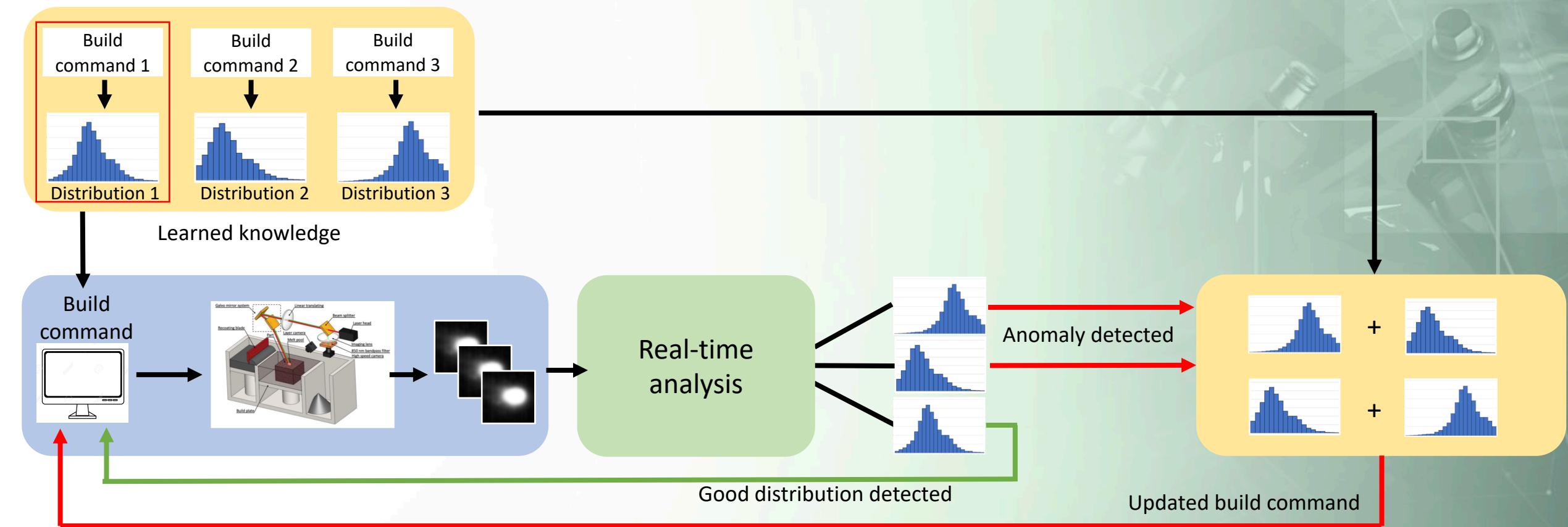
LSTM prediction result (relative error: 12.08%)



CNN+LSTM prediction result (relative error: 31.10%)



## Layerwise process control





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## Conclusion and future work

- Proposed deep learning model can predict the melt pool size with high accuracy.
- A layerwise real-time process control and optimization is proposed.
- More work needs to be done on model tuning and real-time analysis.