Application of Multi-task Learning at the Injector of European XFEL

Intelligent Process Control Seminar

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Large-scale Multi-task Learning in Production



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Benefits and Challenges of Multi-task Learning

Benefits:

- Improve data efficiency
- Reduce overfitting through shared representation
- Accelerate learning by leveraging auxiliary information
- Speed up test and inference

Challenges:

- Neural network architecture design
- Training strategy
 - Loss weighting
 - Regularization
 - Task scheduling
- Task relationship learning

Surrogate model at the injector of European XFEL

ASTRA simulation:

- 20 k particles
- The following highlighted parameters were randomly sampled within the given range.

Parameters	Sample range
Charge (pC)	250
Laser pulse duration (ps)	3
Laser spot size (mm)	0.2 ~ 0.3
Gun solenoid (T)	0.2 ~ 0.25
Gun phase (degree)	-10 ~ 10
Gun gradient (MV/m)	50 ~ 60
A1 phase (degree)	-10 ~ 10
A1 gradient (MV/m)	30 ~ 40
AH1 phase (degree)	170 ~ 190
AH1 gradient (MV/m)	0 ~ 20
Q37 gradient (T/m)	-0.2 ~ 0.2
Q38 gradient (T/m)	-0.2 ~ 0.2



In a sense, this surrogate model is an example of multitask learning.

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Surrogate model at the injector of European XFEL



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Longitudinal Phase Space Prediction

ASTRA + ELEGANT simulation:

- 20 k particles _
- The following highlighted parameters were _ randomly sampled within the given range.

Parameters	Sample range
Charge (pC)	250
Laser pulse duration (ps)	3
Laser spot size (mm)	0.25
Gun solenoid (T)	0.216
Gun phase (degree)	-6 ~ 6
Gun gradient (MV/m)	56.3
A1 phase (degree)	-6 ~ 6
A1 gradient (MV/m)	33.3
AH1 phase (degree)	182 ~ 188
AH1 gradient (MV/m)	14
Q37 gradient (T/m)	-1.156
Q38 gradient (T/m)	1.093



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AH1 - 3.9 GHz laser TDS dipole A1 - 1.3 GHz heater **Beam parameters** gun Shared screen 130 backbone 6.5 dump beam Image on the screen MeV MeV 2000 data points gamma (r2 = 0.9931) _{1e-7} emitx (r2 = 0.9855) _{1e-7} emity (r2 = 0.9856) Predicted (-0.38, -0.93, 184.61) Ground truth Sx(r2 = 0.9882)254.5D 0.000325 85 8.5 254.25 5.D 5.D · 0.000300 ti so ŧ 254.0D 팤 0.000275 25 25 -E 253.75 P 7.5 1 7.5 7.0 0.000250 O.D O.D 10 10 10 10 Z53.50 0.000725 -2.5 -2.5 Ū 253.25 0.000200 65 -5.0 -5.0 253.0D 0.000175 254.0 7.D 7.5 8.D 7.D 7.5 8.D 8.5 1e-7 0.00020 0.00025 0.00030 253.0 253.5 254.5 6.5 8.5 6.5 -7.5 -7.5 Predicted Predicted le-7 Predicted Predicted -10.0 -10.0 -Sy (r2 = 0.9784) alphax (r2 = 0.9743) alphay (r2 = 0.8615) betax (r2 = 0.9806)-12.5 -12.5 · 0.00014 -1.6 Ground truth N N N -io ÷s. Ó 5 18 -io ÷. Ó ÷. fi 0.00013 y (mm) y (mm) -1.8 0.00012 2 -2.0 y projection x projection 0.00011 -376 -2.2 — ground truth ground truth 0.00010 predicted predicted -498 -377

-378

-379

-381

-382

-383

-3**R**/

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18D

20D

30D

y (pixel)

401

SÖD.

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Surrogate Model with Longitudinal Phase Space Prediction



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-500

-502

-504

-506

-508

-510

-512

Ó 50 10D 150 230 250 300 350 400

x (pixel)

"HydraNets" for the Injector



Thank you for your attention!