Hyper-parametric search using HPC infrastructures for Tensorflow.

Gonzalo Ferro - CESGA.

Fortissimo experiment 707: Cyber-Physical Laser Metal Deposition (CyPLAM)

Co-funded by the European Union

This project has received funding from the European Union's H2020 research and innovation programme under grant agreement No 680481

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Experiment Partners:

End User: EMO
Die and mould manufacturer (Slovenia)

Domain Expert & ISV: AIMEN
Expert in laser technologies (Vigo, Spain)

HPC Centre: CESGA
HPC expert and provider (Santiago de Compostela, Spain)

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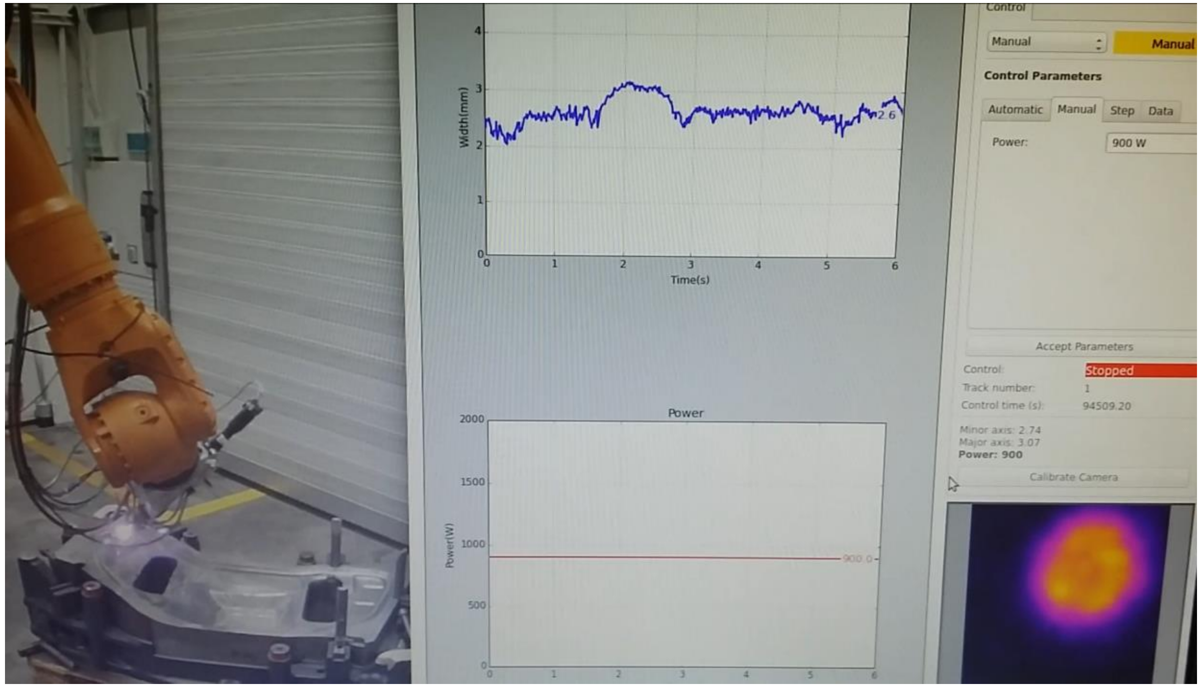
Experiment Description:

Laser Metal Deposition (**LMD**) for building and repairing large metal parts.

LMD process recorder by Medium Wavelength Infrared (**MWIR**) sensors attached to laser header.

Use Convolutional Neural Network model for monitoring the LMD process based on the MWIR images.



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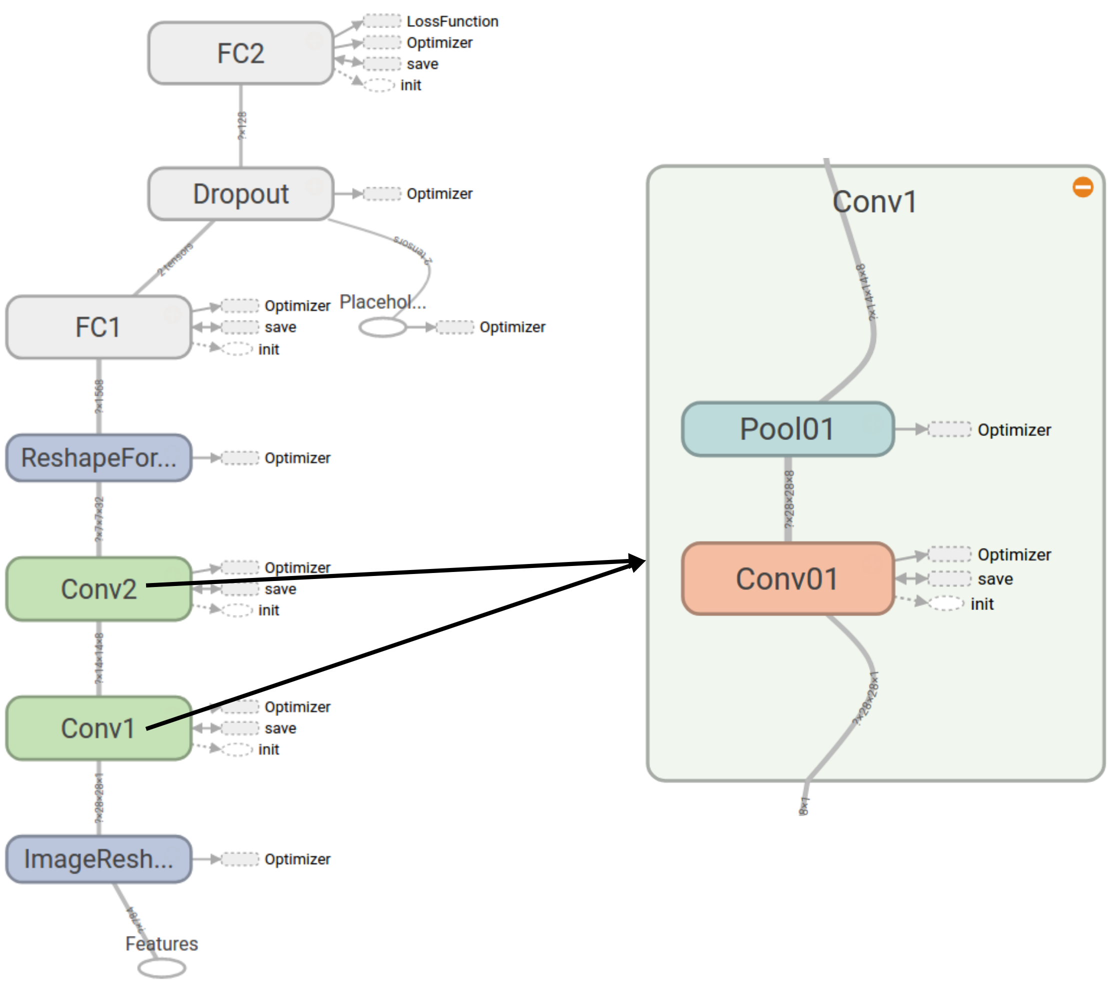
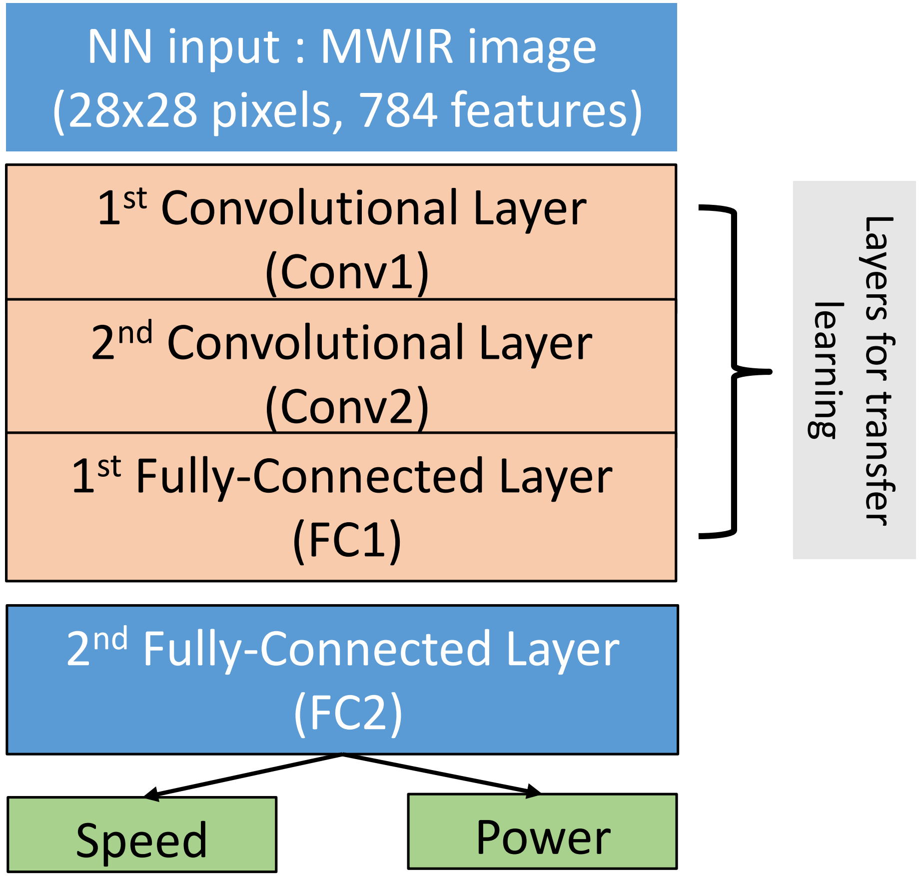
Model Description



NN Graph model (extracted from Tensorboard)



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Experiment Description: Loss Function

$$Loss = \frac{1}{2m}\sum_{i=1}^{m}\left[\left(h_{LP}\left(x^i\right) - y_{LP}^i\right)^2 + \left(h_{LS}\left(x^i\right) - y_{LS}^i\right)^2\right]$$

- x^i is the ith frame of the training dataset.
- $h_{LP}\left(x^i\right)$ is the prediction for Laser Power of the NN model for ith frame.
- y_{LP}^i : label for Laser Power of the ith frame.
- $h_{LS}\left(x^i\right)$ is the prediction for Laser Speed of the NN model for ith frame.
- y_{LS}^i : label for Laser Speed of the ith frame.
- m : total number of training frames

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Experiment Description: Metrics

$$Err^{i}(x^{i}, y_{LP}^{i}, y_{LS}^{i}) = Max\left(\frac{y_{LP}^{i}}{h_{LP}(x^{i})} - 1, \frac{y_{LS}^{i}}{h_{LS}(x^{i})} - 1\right)$$

$$Accuracy_{20\%} = \frac{1}{n}\sum_{i=1}^{n}\left(Err^{i}(x^{i}, y_{LP}^{i}, y_{LS}^{i}) < 20\%\right)$$

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Experiment Description: Dataset

414 LMD tracks stainless steel (316L), powder & base material.

324 tracks for training | **90** tracks for validation

Dataset	Number of frames	Pixels	Number of labels
Training	44,505	28 x 28 = 784	2
Validation	162,216	28 x 28 = 784	2

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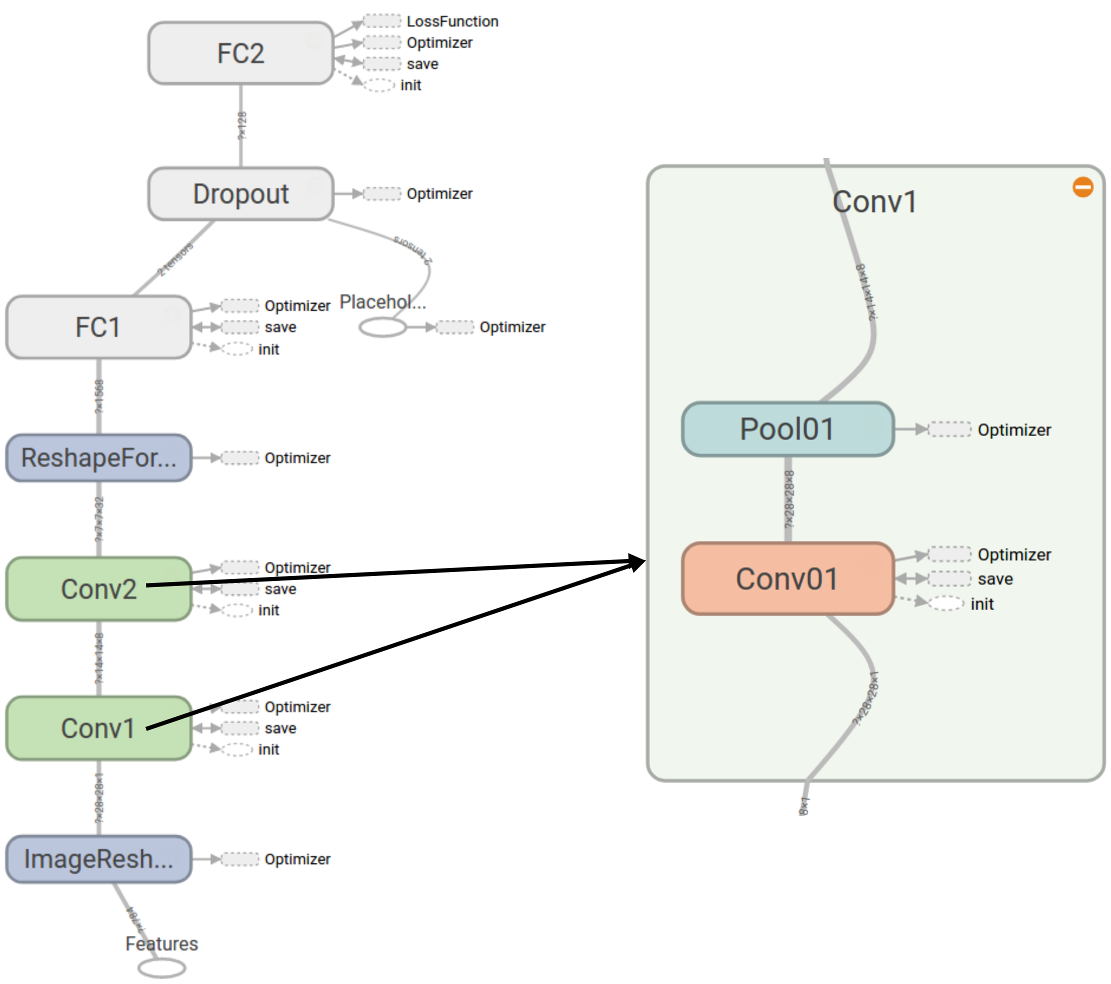
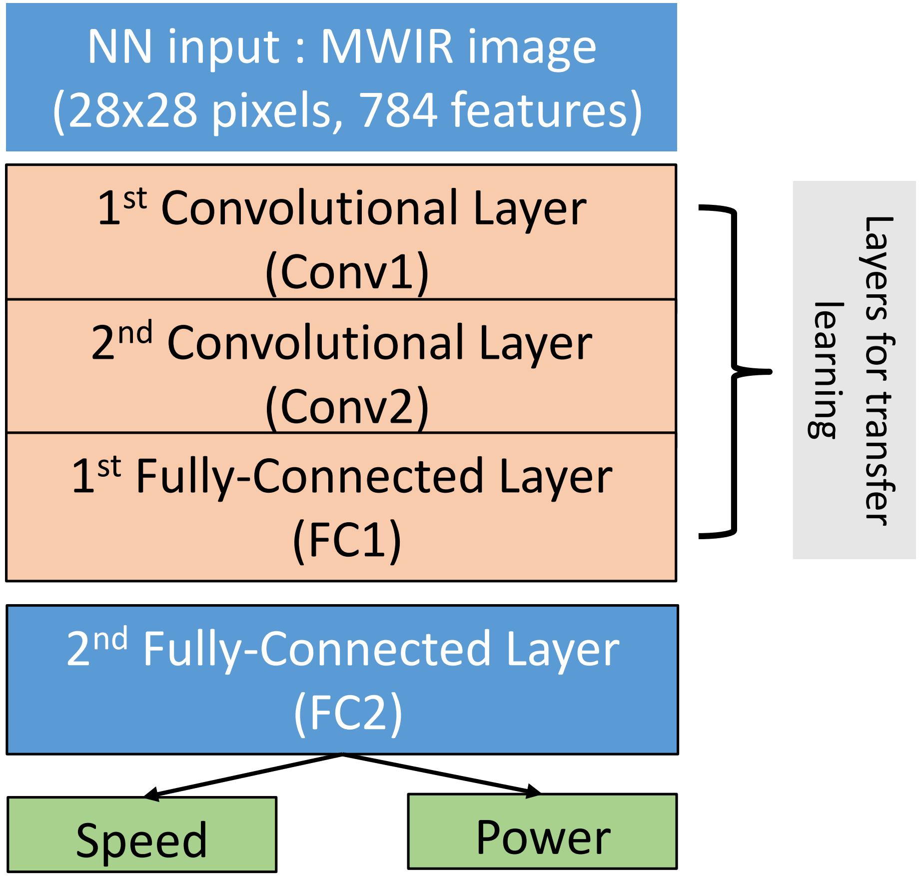
Model Description



NN Graph model (extracted from Tensorboard)



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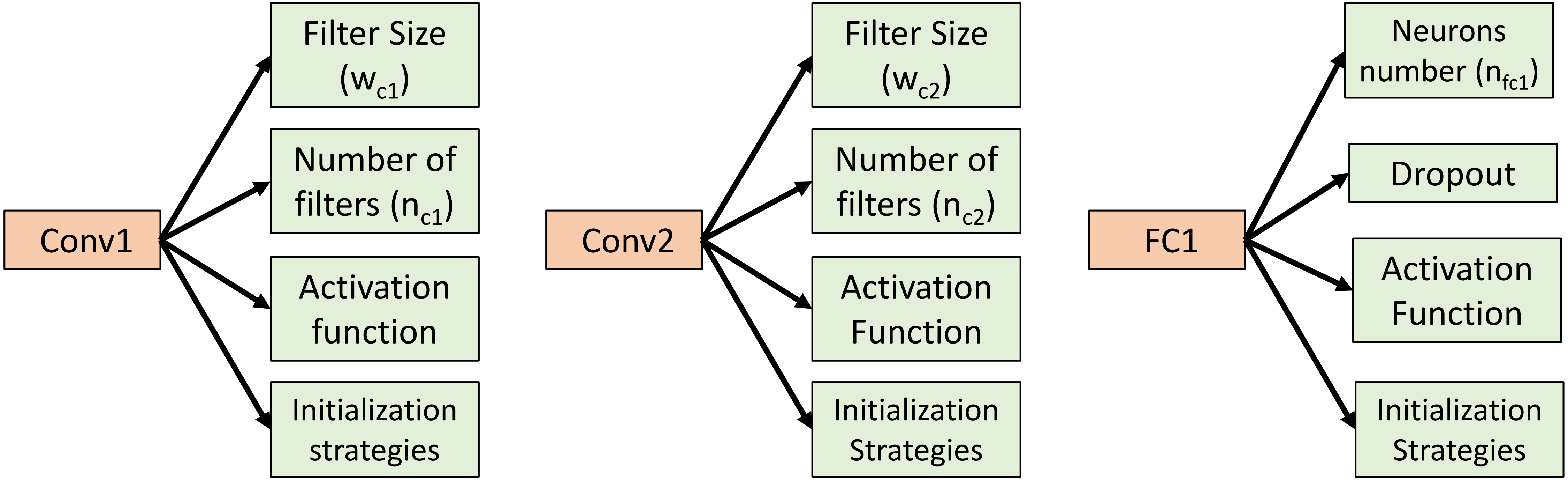
Hyper Parametric Search: Model Parameters



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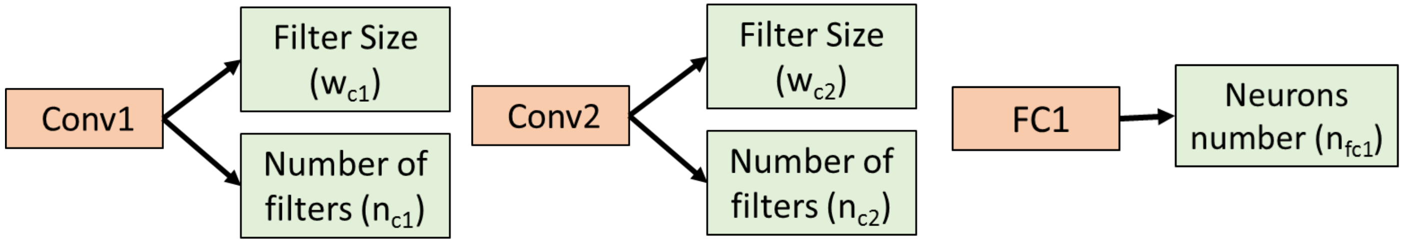
Hyper Parametric Search: Implementation



	Filter Size	Number of Filters
Convolutional Layer 01	w_{c1}=3,5	n_{cv1}= 8, 16, 32
Convolutional Layer 02	w_{c2}=3,5	n_{cv2}= 32, 64
	Number of Neurons	
Fully-connected Layer	n_{fc1}=128, 256, 384, 512, 640, 768, 896, 1024	

Hyper Parameter	Value
Learning Rate:	10^{-5}
Dropout:	0.75
Batch size:	128
Optimizer:	Adam
Regularizers:	None
Iterations	400k

Grid search strategy

192 possible models!!!

200k-3M free parameters

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Results: time performance

192 Models: 40 days

factor 13.7

70 hours

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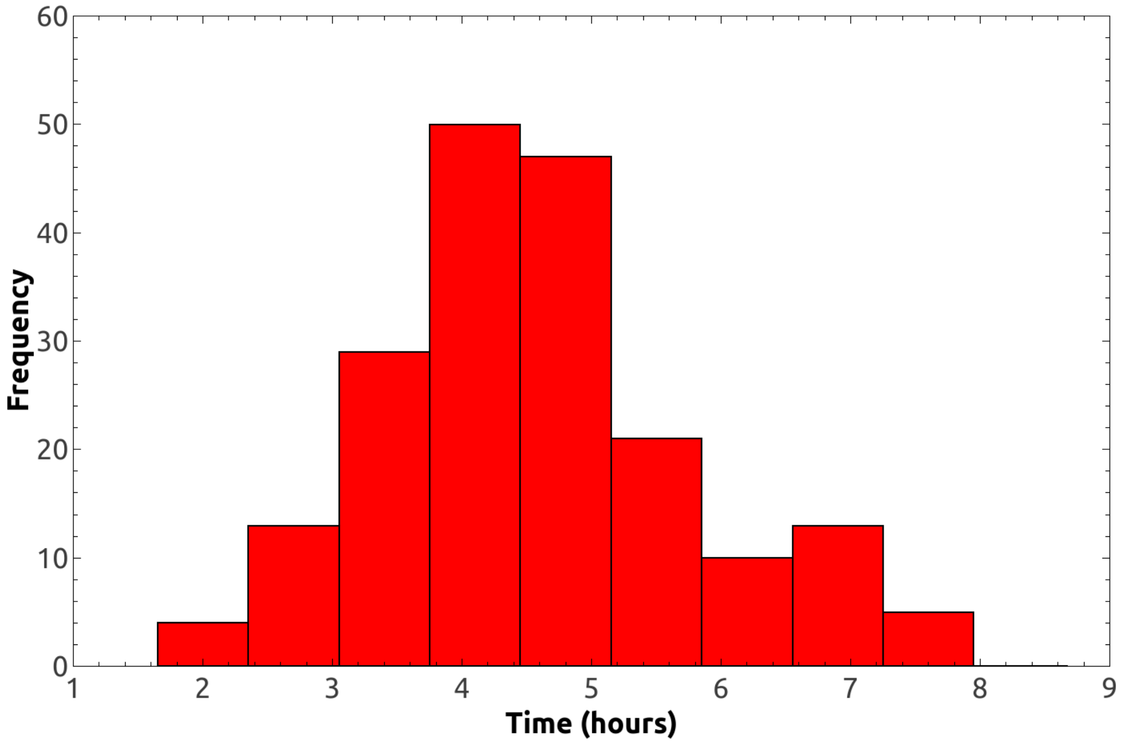
Results: time performance

192 Models: 40 days → 70 hours

Average trainings: 4-5 hours

Shortest training: 2.4 hours

Largest training: 8.2 hours



13.7 → 100 !!!!

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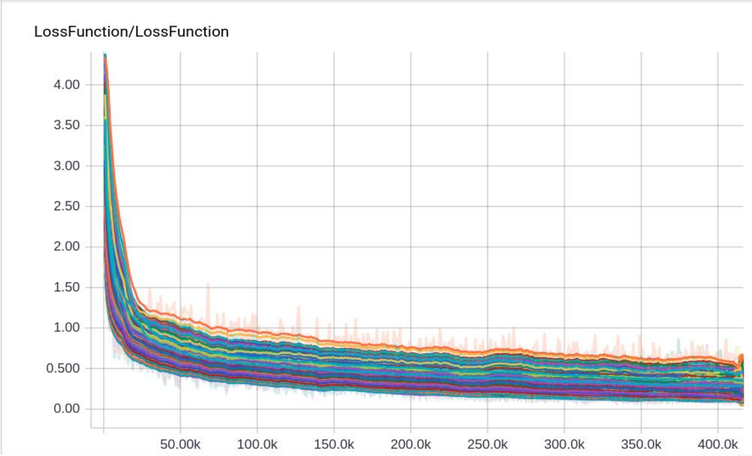
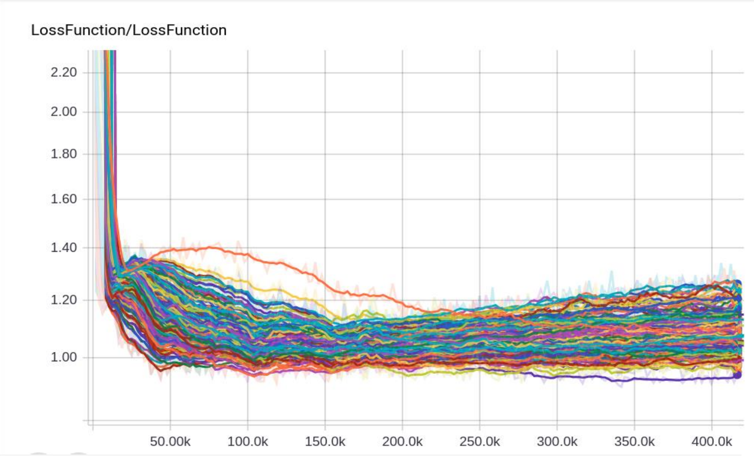
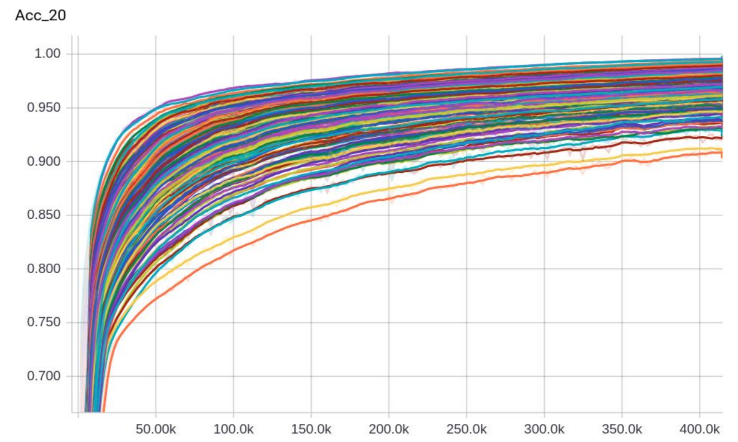
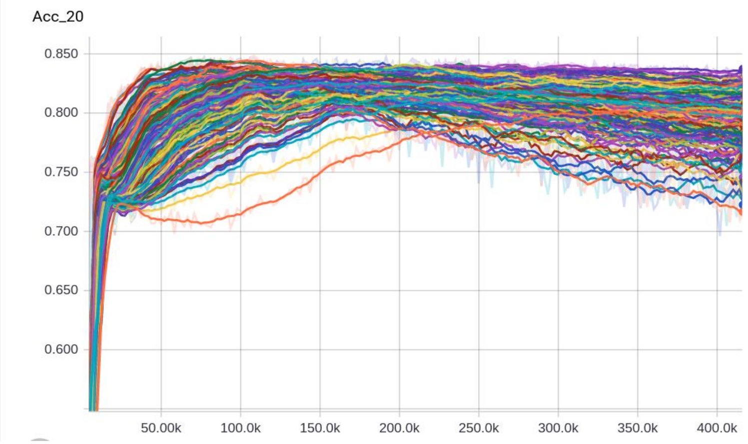
Results: Overall Performance

	Training dataset	Validation dataset
Loss function		
Accuracy$_{20\%}$		

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Results: Overall Performance

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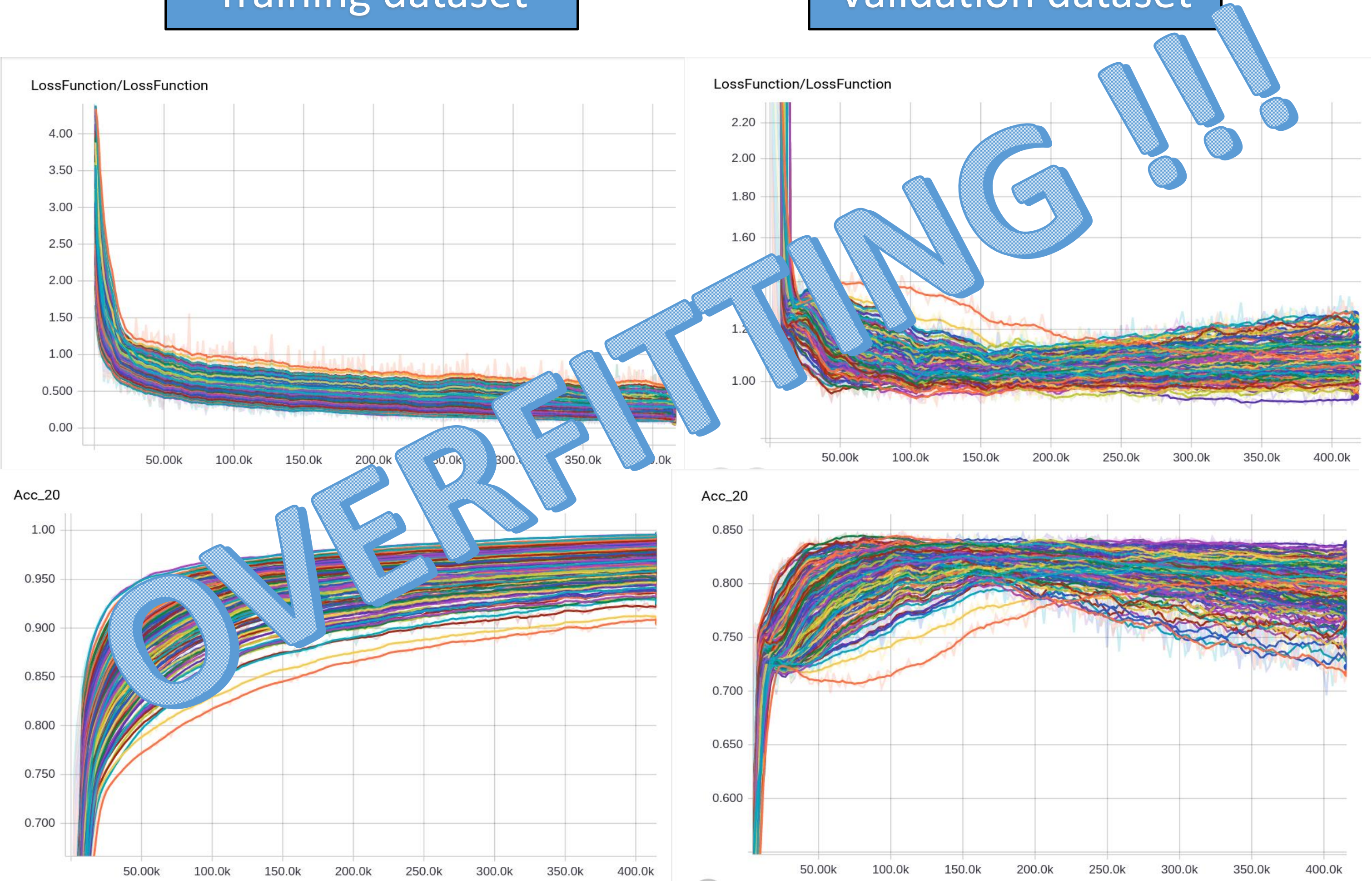
Training dataset

Validation dataset

Loss function

Accuracy$_{20\%}$



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Results: Overfitting solutions

- ✓ Increase size of training dataset.
- ✓ Change of activation functions.
- ✓ User of Regularization techniques.
- ✓ Early Stopping.

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Results: Overfitting solutions

- ✓ Increase size of training dataset.
- ✓ Change of activation functions.
- ✓ User of Regularization techniques.
- ✓ Early Stopping.

EARLY STOPPING !!!

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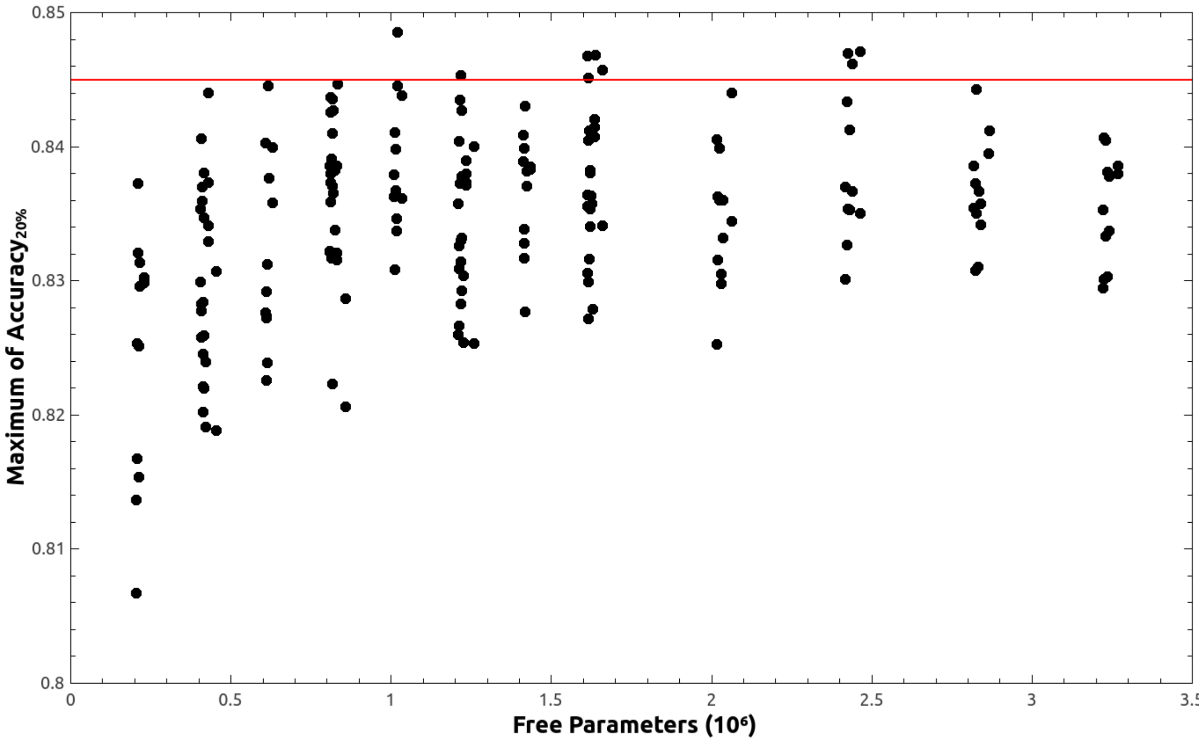
Results: Early Stopping



Top 10 models

	w_{c1}	n_{c1}	w_{c2}	n_{c2}	n_{fc1}	Max Accuracy$_{20\%}$	Iteration Step	Free Parameters
Model-108	5	16	5	32	640	0.8485	108,264	1,018,690
Model-189	5	32	5	64	768	0.8471	68,706	2,462,850
Model-061	5	8	5	64	768	0.847	106,182	2,423,826
Model-175	5	32	5	32	1024	0.8469	68,706	1,635,170
Model-039	5	8	3	32	1024	0.8468	191,544	1,611,250
Model-125	5	16	5	64	768	0.8462	68,706	2,436,834
Model-187	5	32	5	64	512	0.8457	83,280	1,659,266
Model-114	5	16	3	64	384	0.8453	158,232	1,215,074
Model-047	5	8	5	32	1024	0.8452	77,034	1,615,346
Model-171	5	32	5	32	512	0.8447	104,100	830,818

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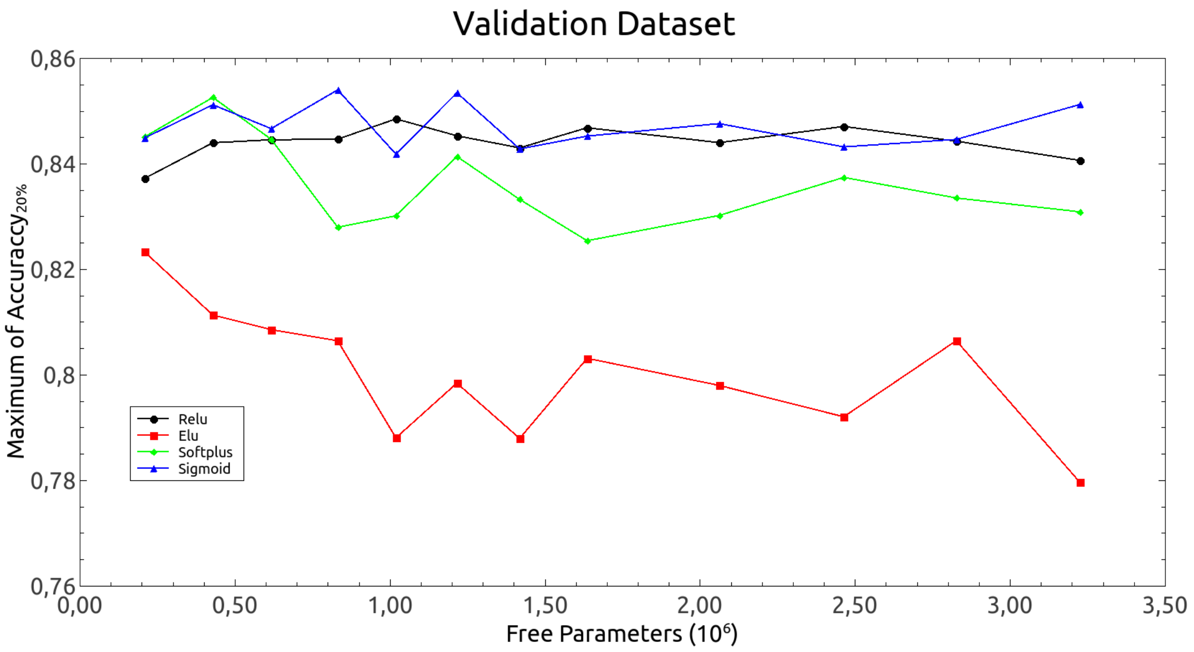
Results: Activation Function

	wc1	nc1	wc2	nc2	nfc1	Free Parameters
Model-040	5	8	5	32	128	207730
Model-137	3	32	5	32	256	428130
Model-074	3	16	5	32	384	616258
Model-171	5	32	5	32	512	830818
Model-108	5	16	5	32	640	1018690
Model-114	5	16	3	64	384	1215074
Model-166	5	32	3	32	896	1417698
Model-175	5	32	5	32	1024	1635170
Model-188	5	32	5	64	640	2061058
Model-189	5	32	5	64	768	2462850
Model-062	5	8	5	64	896	2825618
Model-119	5	16	3	64	1024	3224034



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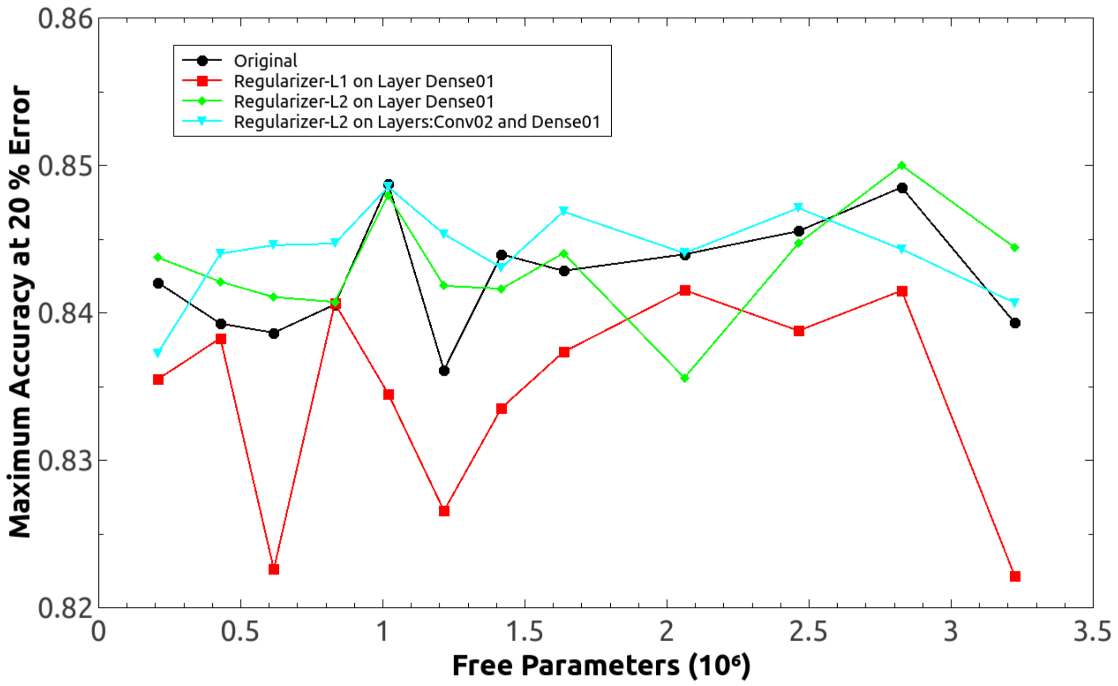
Results: Regularization

	wc1	nc1	wc2	nc2	nfc1	Free Parameters
Model-040	5	8	5	32	128	207730
Model-137	3	32	5	32	256	428130
Model-074	3	16	5	32	384	616258
Model-171	5	32	5	32	512	830818
Model-108	5	16	5	32	640	1018690
Model-114	5	16	3	64	384	1215074
Model-166	5	32	3	32	896	1417698
Model-175	5	32	5	32	1024	1635170
Model-188	5	32	5	64	640	2061058
Model-189	5	32	5	64	768	2462850
Model-062	5	8	5	64	896	2825618
Model-119	5	16	3	64	1024	3224034



$$L1 = \lambda \sum_{i=1}^{k} |w_i|$$

$$L2 = \lambda \sum_{i=1}^{k} w_i^2$$

$$\lambda(L1) = 0.001$$

$$\lambda(L2) = 0.01$$

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Summary and Conclusions

An hyper-parametric search (# filters, filter size and #neurons) was conducted to obtain best model for monitoring LMD process based on MWIR images.

Thanks to Finis Terrae II HPC CESGA infrastructure the time-to –solution was reduced from 40 days to 70 hours.

Time factor decrease of 14 but could increase to more that 100!!.

Additional approximations like changing activation functions or using regularizers can improve model performance.

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THANKS FOR YOUR ATTENTION !!!

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