First DNN for COSINE

Seungmok Lee

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DL Study - Status

- We are making results

2020 Deep Learning Study Progress										
Month	Jan			Feb.				Mar.		
Week	3	4	5	6	7	**8**	9	10	11	12
Orientation										
Survey & Study										
Environment Construction										
DNN for COSINE										
CNN for COSINE										
DNN for GBAR										
CNN for GBAR										
Abstract	TMVA & Keras chosen.			Uproot, h5py tested. DNN started.				DNN optimization. Trial CNN. (plan)		

DNN Cosine - Best Result

- I'm concentrating on Dense layer. (basic DNN)
- For the best result, I got accuracy of 80%!
  - for crystal 3.

Event Selection

- Signal waveform is obtained from calibration run.
  - Run number 1765, 1601.
  - Coincidence (with LS or other crystals) events with basic pre-cut are considered as signal.
- Background waveform is obtained from physics run.
  - Run number 1858.
  - Events without coincidence, with basic pre-cut are considered as background.

※ No lpar used.

Data Statistics

Run number	1	2	3	4	6	7
1601 (Sig)	1834	3771	5619	2612	7782	7300
1765 (Sig)	1864	3478	5531	2640	7261	8049
1858 (Bkg)	1151944	891598	1219143	1342570	1047218	1184431
Ratio [%] (Sig/Total)	0.320	0.806	0.906	0.390	1.416	1.279

Layer

Layer (type)	Output Shape	Param #
reshape_1 (Reshape)	(None, 8160)	0
dense_1 (Dense)	(None, 768)	6267648
activation_1 (Activation)	(None, 768)	0
dropout_1 (Dropout)	(None, 768)	0
dense_2 (Dense)	(None, 768)	590592
activation_2 (Activation)	(None, 768)	0
dropout_2 (Dropout)	(None, 768)	0
dense_3 (Dense)	(None, 512)	393728
activation_3 (Activation)	(None, 512)	0
dropout_3 (Dropout)	(None, 512)	0
dense_4 (Dense)	(None, 512)	262656
activation_4 (Activation)	(None, 512)	0
dropout_4 (Dropout)	(None, 512)	0
dense_5 (Dense)	(None, 512)	262656
activation_5 (Activation)	(None, 512)	0
dropout_5 (Dropout)	(None, 512)	0
dense_6 (Dense)	(None, 2)	1026
activation_6 (Activation)	(None, 2)	0

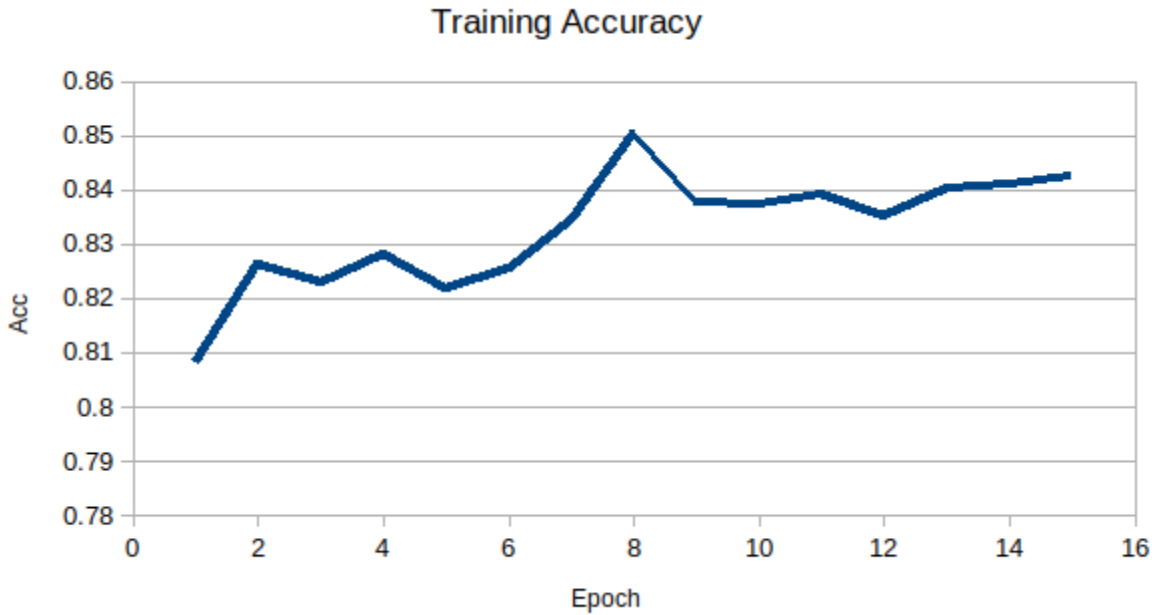
Total params: 7,778,306

- Fully connected layers
- Dropout 0.25~0.3
- ReLU activation

Training

- Optimizer: Adam
- Epochs: 15
- Batch_size: 2048
- class_weights was set.
  - We have poor statistics of signal events. Setting high weight to signal samples, we can make signal as important as background.

Training Result



Test Result

Energy	Signal 0.000	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950	: Efficiency (%)
0.0	1	0	0	0	0	0	0	0	1	0	3	4	6	1	1	2	3	4	5	2	: eff 93.94
0.5	5	0	0	0	0	0	1	0	8	5	8	6	13	20	19	18	12	13	15	25	: eff 88.69
1.0	3	0	0	0	0	1	0	0	29	9	11	9	14	17	20	14	13	9	13	37	: eff 78.89
1.5	5	0	0	0	0	0	0	1	30	15	10	12	8	12	15	10	11	6	4	36	: eff 70.86
2.0	7	0	0	0	0	1	0	0	27	21	14	12	11	10	6	9	11	8	4	35	: eff 68.18
2.5	1	0	0	0	0	0	0	0	23	14	8	9	5	8	12	9	5	5	5	41	: eff 73.79
3.0	4	0	0	0	0	0	0	0	17	2	5	6	10	9	5	8	3	11	4	53	: eff 83.21
3.5	2	0	0	0	0	0	0	0	12	8	4	1	5	7	2	7	3	4	5	43	: eff 78.64
4.0	2	0	0	0	0	0	0	0	14	1	6	2	1	6	5	2	5	3	6	36	: eff 80.90
4.5	1	0	0	0	0	0	0	0	20	2	5	5	5	1	1	3	0	7	1	35	: eff 73.26
5.0	2	0	0	0	0	0	0	0	9	2	1	3	5	2	3	1	3	4	2	41	: eff 83.33
5.5	0	0	0	0	0	0	0	0	4	3	0	3	1	1	4	3	2	0	3	39	: eff 88.89
6.0	0	0	0	0	0	0	0	0	6	1	2	2	4	1	3	3	3	2	5	42	: eff 90.54
6.5	1	0	0	0	0	0	0	0	10	2	4	1	2	1	0	1	0	1	5	29	: eff 77.19
7.0	0	0	0	0	0	0	0	0	5	1	1	1	4	1	3	1	4	1	3	34	: eff 89.83
7.5	0	0	0	0	0	0	0	0	5	0	3	1	0	1	3	1	1	0	2	62	: eff 93.67
8.0	1	0	0	0	0	0	0	0	5	2	3	2	1	3	3	1	0	2	4	48	: eff 89.33
8.5	0	0	0	0	0	0	0	0	2	1	0	1	2	2	1	3	4	0	3	48	: eff 95.52
9.0	0	0	0	0	0	0	0	0	4	2	0	1	1	2	2	1	1	2	5	53	: eff 91.89
9.5	0	0	0	0	0	0	0	0	4	0	1	1	2	2	0	0	1	0	0	52	: eff 93.65

Test Result

Background

Energy	0.000	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950	: Efficiency (%)
0.0	364	2	0	1	0	2	0	1	23	3	2	3	1	1	0	0	0	0	0	0	: eff 98.26
0.5	541	2	4	1	2	2	1	1	96	12	6	7	5	5	2	1	4	1	0	0	: eff 95.53
1.0	298	0	0	0	0	1	0	1	71	8	6	5	8	5	4	1	1	1	0	0	: eff 92.44
1.5	64	0	0	1	0	0	0	0	59	6	1	5	4	2	0	1	3	0	0	1	: eff 88.44
2.0	21	0	0	0	0	0	0	0	34	6	1	3	1	1	0	0	1	0	0	1	: eff 88.41
2.5	11	0	0	0	0	0	0	0	22	2	7	3	0	5	2	0	0	1	1	1	: eff 63.64
3.0	5	0	0	0	0	0	0	0	27	6	4	3	3	0	1	1	1	1	0	0	: eff 73.08
3.5	1	0	0	0	0	0	0	0	12	1	3	0	1	3	1	1	0	1	1	0	: eff 56.00
4.0	4	0	0	0	0	0	0	0	15	1	5	4	1	0	0	0	0	2	0	2	: eff 58.82
4.5	0	0	0	0	0	0	0	0	11	6	2	0	0	0	1	1	0	1	0	0	: eff 77.27
5.0	0	0	0	0	0	0	0	0	9	0	1	3	1	1	0	0	0	1	0	0	: eff 56.25
5.5	0	0	0	0	0	0	0	0	8	1	2	0	0	0	0	0	0	0	0	1	: eff 75.00
6.0	0	0	0	0	0	0	0	0	6	0	0	1	0	1	0	1	1	0	0	2	: eff 50.00
6.5	0	0	0	0	0	0	0	0	4	3	1	1	1	0	1	0	0	0	0	1	: eff 58.33
7.0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	2	0	1	0	1	: eff 55.56
7.5	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	1	2	: eff 14.29
8.0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	2	: eff 60.00
8.5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	: eff 100.00
9.0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	4	: eff 37.50
9.5	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	3	: eff 42.86

Test Result

Signal

Energy	0.000	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950	: Efficiency (%)
0.0	1	0	0	0	0	0	0	0	1	0	3	4	6	1	1	2	3	4	5	2	: eff 93.94
0.5	5	0	0	0	0	0	1	0	8	5	8	6	13	20	19	18	12	13	15	25	: eff 88.69
1.0	3	0	0	0	0	1	0	0	29	9	11	9	14	17	20	14	13	9	13	37	: eff 78.89
1.5	5	0	0	0	0	0	0	1	30	15	10	12	8	12	15	10	11	6	4	36	: eff 70.86
2.0	7	0	0	0	0	1	0	0	27	21	14	12	11	10	6	9	11	8	4	35	: eff 68.18
2.5	1	0	0	0	0	0	0	0	23	14	8	9	5	8	12	9	5	5	5	41	: eff 73.79
3.0	4	0	0	0	0	0	0	0	17	2	5	6	10	9	5	8	3	11	4	53	: eff 83.21
3.5	2	0	0	0	0	0	0	0	12	8	4	1	5	7	2	7	3	4	5	43	: eff 78.64
4.0	2	0	0	0	0	0	0	0	14	1	6	2	1	6	5	2	5	3	6	36	: eff 80.90
4.5	1	0	0	0	0	0	0	0	20	2	5	5	5	1	1	3	0	7	1	35	: eff 73.26
5.0	2	0	0	0	0	0	0	0	9	2	1	3	5	2	3	1	3	4	2	41	: eff 83.33
5.5	0	0	0	0	0	0	0	0	4	3	0	3	1	1	4	3	2	0	3	39	: eff 88.89
6.0	0	0	0	0	0	0	0	0	6	1	2	2	4	1	3	3	3	2	5	42	: eff 90.54
6.5	1	0	0	0	0	0	0	0	10	2	4	1	2	1	0	1	0	1	5	29	: eff 77.19
7.0	0	0	0	0	0	0	0	0	5	1	1	1	4	1	3	1	4	1	3	34	: eff 89.83
7.5	0	0	0	0	0	0	0	0	5	0	3	1	0	1	3	1	1	0	2	62	: eff 93.67
8.0	1	0	0	0	0	0	0	0	5	2	3	2	1	3	3	1	0	2	4	48	: eff 89.33
8.5	0	0	0	0	0	0	0	0	2	1	0	1	2	2	1	3	4	0	3	48	: eff 95.52
9.0	0	0	0	0	0	0	0	0	4	2	0	1	1	2	2	1	1	2	5	53	: eff 91.89
9.5	0	0	0	0	0	0	0	0	4	0	1	1	2	2	0	0	1	0	0	52	: eff 93.65

Background

Energy	0.000	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950	: Efficiency (%)
0.0	364	2	0	1	0	2	0	1	23	3	2	3	1	1	0	0	0	0	0	0	: eff 98.26
0.5	541	2	4	1	2	2	1	1	96	12	6	7	5	5	2	1	4	1	0	0	: eff 95.53
1.0	298	0	0	0	0	1	0	1	71	8	6	5	8	5	4	1	1	1	0	0	: eff 92.44
1.5	64	0	0	1	0	0	0	0	59	6	1	5	4	2	0	1	3	0	0	1	: eff 88.44
2.0	21	0	0	0	0	0	0	0	34	6	1	3	1	1	0	0	1	0	0	1	: eff 88.41
2.5	11	0	0	0	0	0	0	0	22	2	7	3	0	5	2	0	0	1	1	1	: eff 63.64
3.0	5	0	0	0	0	0	0	0	27	6	4	3	3	0	1	1	1	1	0	0	: eff 73.08
3.5	1	0	0	0	0	0	0	0	12	1	3	0	1	3	1	1	0	1	1	0	: eff 56.00
4.0	4	0	0	0	0	0	0	0	15	1	5	4	1	0	0	0	0	2	0	2	: eff 58.82
4.5	0	0	0	0	0	0	0	0	11	6	2	0	0	0	1	1	0	1	0	0	: eff 77.27
5.0	0	0	0	0	0	0	0	0	9	0	1	3	1	1	0	0	0	1	0	0	: eff 56.25
5.5	0	0	0	0	0	0	0	0	8	1	2	0	0	0	0	0	0	0	0	1	: eff 75.00
6.0	0	0	0	0	0	0	0	0	6	0	0	1	0	1	0	1	1	0	0	2	: eff 50.00
6.5	0	0	0	0	0	0	0	0	4	3	1	1	1	0	1	0	0	0	0	1	: eff 58.33
7.0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	2	0	1	0	1	: eff 55.56
7.5	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	1	2	: eff 14.29
8.0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	2	: eff 60.00
8.5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	: eff 100.00
9.0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	4	: eff 37.50
9.5	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	3	: eff 42.86

Plan

- Try lots of hyper parameters.
  - First, I will focus on Dense layer only.
- Try dropout, batch normalization.
  - Batch normalization: normalize input data. It prohibits over-fitting, initialization problem, and accelerates learning speed.
- Observe accuracy distribution in energy.
  - Observe waveform case-by-case, if needed.