BENCHMARK
NNTO MODEL MNIST

On this Benchmark, NNTO was applied over a MNIST model (« State Of the Art ») from a kaggle champion (99,457% on Kaggle site). This base model on our test rules reached 99,01 % efficiency.

We achieve a **99,50% efficiency after 10 generation of mutants** (implying an error decrease of 8%) over performing the base model..

We also achieve a **76% parameter reduction** to 175K with another mutant.

Here after you will find all information you may need to reproduce our results.

kaggle

ORIGINAL BASED ON THE TOPOLOGY OF KAGGLE AND BASED ON KERAS MNIST DATASET

BASED ON A 20 EPOCH PER LEARNING FOLLOWED BY ENHANCEMENT.

LINK TO KAGGLE >>

```
60000/60000 [==============================] - 88s 1ms/step - loss: 0.0320 - acc: 0.9895 - val_loss: 0.0322 -
val_acc: 0.9901
Baseline Error: 0.99%
Metrics: [0.032208847535658426, 0.9901]

ORIGINAL MODEL SUMMARY:
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         (None, 28, 28, 1)         0
_________________________________________________________________
conv2d (Conv2D)              (None, 26, 26, 32)        320
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 24, 24, 32)        9248
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 12, 12, 32)        0
_________________________________________________________________
dropout (Dropout)            (None, 12, 12, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 12, 12, 64)        18496
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 12, 12, 64)        36928
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 6, 6, 64)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 6, 6, 64)          0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 6, 6, 128)         73856
_________________________________________________________________
dropout_2 (Dropout)          (None, 6, 6, 128)         0
_________________________________________________________________
flatten (Flatten)            (None, 4608)              0
_________________________________________________________________
dense (Dense)                (None, 128)               589952
_________________________________________________________________
batch_normalization (BatchNo (None, 128)               512
_________________________________________________________________
dropout_3 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_1 (Dense)              (None, 10)                1290
=================================================================
Total params: 730,602
Trainable params: 730,346
Non-trainable params: 256
_________________________________________________________________
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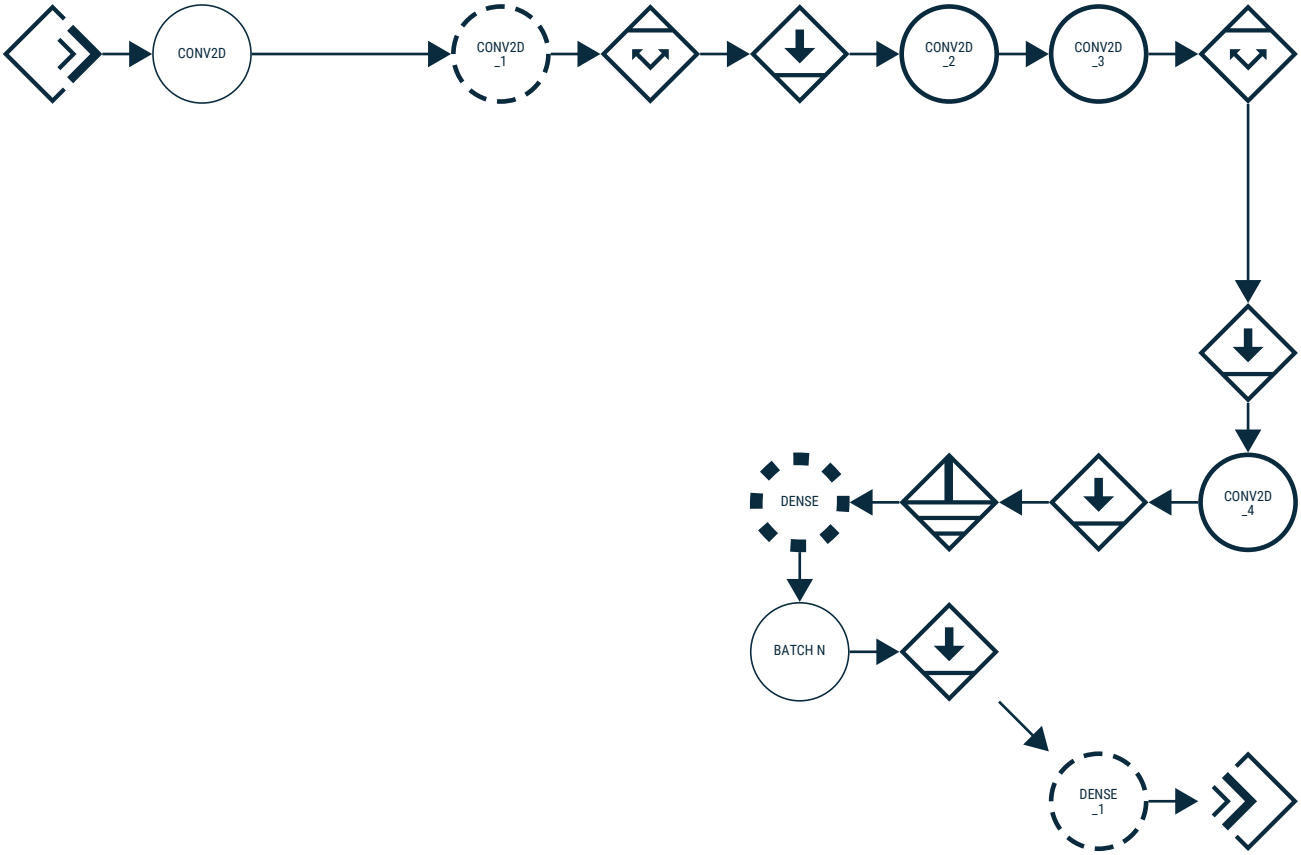
BENCHMARK
NNTO MODEL MNIST



BENCHMARK
NNTO MODEL MNIST

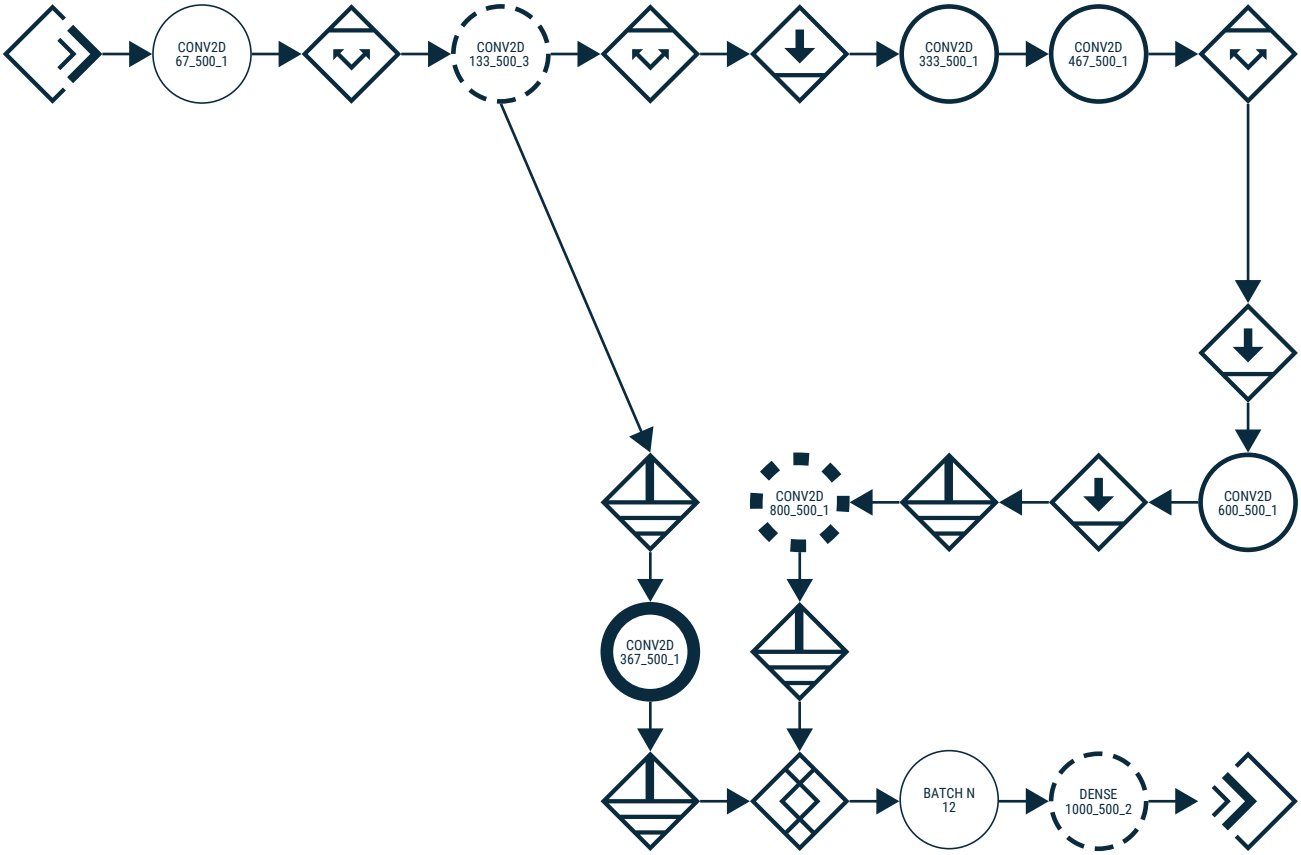
BEST MUTANT AFTER ONLY THE 9TH GENERATION

NNTO CREATED A NEW CONNECTION LIKE IN THE INCEPTION NETWORK.

Accurracy from 0,9901 (Kaggle champion) to **0,9950 (NNTO Champion)**

```
60000/60000 [==============================] - 2499s 42ms/step - loss: 0.0113 - acc: 0.9963 - val_loss: 0.0146 -
val_acc: 0.9950
save_Agent(Agent):
Evaluating agent
_________________________________________________________________________________________________
Layer (type)                 Output Shape              Param #     Connected to
=================================================================================================
0_500_1 (InputLayer)         (None, 28, 28, 1)         0
_________________________________________________________________________________________________
67_500_1 (Conv2D)            (None, 26, 26, 32)        320         0_500_1[0][0]
_________________________________________________________________________________________________
100_500_1 (MaxPooling2D)     (None, 26, 26, 32)        0           67_500_1[0][0]
_________________________________________________________________________________________________
133_500_3 (Conv2D)           (None, 24, 24, 32)        9248        100_500_1[0][0]
_________________________________________________________________________________________________
200_500_1 (MaxPooling2D)     (None, 12, 12, 32)        0           133_500_3[0][0]
_________________________________________________________________________________________________
dropout_37 (Dropout)         (None, 12, 12, 32)        0           200_500_1[0][0]
_________________________________________________________________________________________________
333_500_1 (Conv2D)           (None, 12, 12, 64)        18496       dropout_37[0][0]
_________________________________________________________________________________________________
400_500_1 (Conv2D)           (None, 12, 12, 64)        36928       333_500_1[0][0]
_________________________________________________________________________________________________
467_500_1 (MaxPooling2D)     (None, 6, 6, 64)          0           400_500_1[0][0]
_________________________________________________________________________________________________
dropout_38 (Dropout)         (None, 6, 6, 64)          0           467_500_1[0][0]
_________________________________________________________________________________________________
600_500_1 (Conv2D)           (None, 6, 6, 128)         73856       dropout_38[0][0]
_________________________________________________________________________________________________
dropout_39 (Dropout)         (None, 6, 6, 128)         0           600_500_1[0][0]
_________________________________________________________________________________________________
800_500_1_F (Flatten)        (None, 4608)              0           dropout_39[0][0]
_________________________________________________________________________________________________
367_500_1_F (Flatten)        (None, 18432)             0           133_500_3[0][0]
_________________________________________________________________________________________________
800_500_1 (Dense)            (None, 128)               589952      800_500_1_F[0][0]
_________________________________________________________________________________________________
367_500_1 (Dense)            (None, 66)                1216512     367_500_1_F[0][0]
_________________________________________________________________________________________________
flatten_3 (Flatten)          (None, 128)               0           800_500_1[0][0]
_________________________________________________________________________________________________
flatten_4 (Flatten)          (None, 66)                0           367_500_1[0][0]
_________________________________________________________________________________________________
1000_500_2_C (Concatenate)   (None, 194)               0           flatten_3[0][0]
                                                                 flatten_4[0][0]
_________________________________________________________________________________________________
batch_normalization_12 (BatchNo (None, 194)            776         1000_500_2_C[0][0]
_________________________________________________________________________________________________
1000_500_2 (Dense)           (None, 10)                1950        batch_normalization_12[0][0]
=================================================================================================
Total params: 1,948,038
Trainable params: 1,947,650
Non-trainable params: 388
_________________________________________________________________________________________________
None
SignalShape_Dimension: 3
Metrics(Test loss & Test Accuracy):
[0.01455551053226518, 0.995]
###################### FITNESS PROGRESSION::(Fitness,Mutant_Index,Agent_Id) ######################
[(0.9941, 'InitAgent_1548063195245435904')]
ITERATION: 9 THIS MUTANT: 0.995 BEST MUTANT FOUND: 0.9941
################################################################################################
```

BENCHMARK
NNTO MODEL MNIST



A MUTANT WITH GOOD EFFICIENCIES WITH PARAMETER REDUCTION

56% PARAMETER REDUCTION (From 730 602 to 321 698 parameters) with same accuracy as Kaggle champion

```
60000/60000 [==============================] - 84s 1ms/step - loss: 0.0153 - acc: 0.9951 - val_loss: 0.0195 -
val_acc: 0.9940
Evaluating agent
_________________________________________________________________________________________________
Layer (type)                 Output Shape              Param #     Connected to
=================================================================================================
0_500_1 (InputLayer)         (None, 28, 28, 1)         0
_________________________________________________________________________________________________
67_500_1 (Conv2D)            (None, 26, 26, 32)        320         0_500_1[0][0]
_________________________________________________________________________________________________
133_500_1 (Conv2D)           (None, 24, 24, 32)        9248        67_500_1[0][0]
_________________________________________________________________________________________________
200_500_1 (MaxPooling2D)     (None, 12, 12, 32)        0           133_500_1[0][0]
_________________________________________________________________________________________________
dropout_257 (Dropout)        (None, 12, 12, 32)        0           200_500_1[0][0]
_________________________________________________________________________________________________
333_500_1 (Conv2D)           (None, 12, 12, 64)        18496       dropout_257[0][0]
_________________________________________________________________________________________________
367_500_1 (AveragePooling2D) (None, 4, 4, 64)          0           333_500_1[0][0]
_________________________________________________________________________________________________
400_500_3 (Conv2D)           (None, 4, 4, 64)          36928       367_500_1[0][0]
_________________________________________________________________________________________________
467_500_1 (MaxPooling2D)     (None, 2, 2, 64)          0           400_500_3[0][0]
_________________________________________________________________________________________________
batch_normalization_104 (BatchN (None, 28, 28, 1)      4           0_500_1[0][0]
_________________________________________________________________________________________________
dropout_258 (Dropout)        (None, 2, 2, 64)          0           467_500_1[0][0]
_________________________________________________________________________________________________
67_250_1 (MaxPooling2D)      (None, 28, 28, 1)         0           batch_normalization_104[0][0]
_________________________________________________________________________________________________
600_500_1 (Conv2D)           (None, 2, 2, 128)         73856       dropout_258[0][0]
_________________________________________________________________________________________________
dropout_256 (Dropout)        (None, 28, 28, 1)         0           67_250_1[0][0]
_________________________________________________________________________________________________
dropout_259 (Dropout)        (None, 2, 2, 128)         0           600_500_1[0][0]
_________________________________________________________________________________________________
flatten_130 (Flatten)        (None, 18432)             0           133_500_1[0][0]
_________________________________________________________________________________________________
flatten_131 (Flatten)        (None, 784)               0           dropout_256[0][0]
_________________________________________________________________________________________________
800_500_1_F (Flatten)        (None, 512)               0           dropout_259[0][0]
_________________________________________________________________________________________________
467_250_2_C (Concatenate)    (None, 19216)             0           flatten_130[0][0]
                                                                   flatten_131[0][0]
_________________________________________________________________________________________________
800_500_1 (Dense)            (None, 128)               65664       800_500_1_F[0][0]
_________________________________________________________________________________________________
467_250_2 (Dense)            (None, 6)                 115296      467_250_2_C[0][0]
_________________________________________________________________________________________________
flatten_132 (Flatten)        (None, 128)               0           800_500_1[0][0]
_________________________________________________________________________________________________
flatten_133 (Flatten)        (None, 6)                 0           467_250_2[0][0]
_________________________________________________________________________________________________
1000_500_2_C (Concatenate)   (None, 134)               0           flatten_132[0][0]
                                                                   flatten_133[0][0]
_________________________________________________________________________________________________
batch_normalization_105 (BatchN (None, 134)            536         1000_500_2_C[0][0]
_________________________________________________________________________________________________
1000_500_2 (Dense)           (None, 10)                1350        batch_normalization_105[0][0]
=================================================================================================
Total params: 321,698
Trainable params: 321,428
Non-trainable params: 270
_________________________________________________________________________________________________
None
SignalShape_Dimension: 3
Metrics(Test loss & Test Accuracy):
[0.019499899024692423, 0.994]
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```

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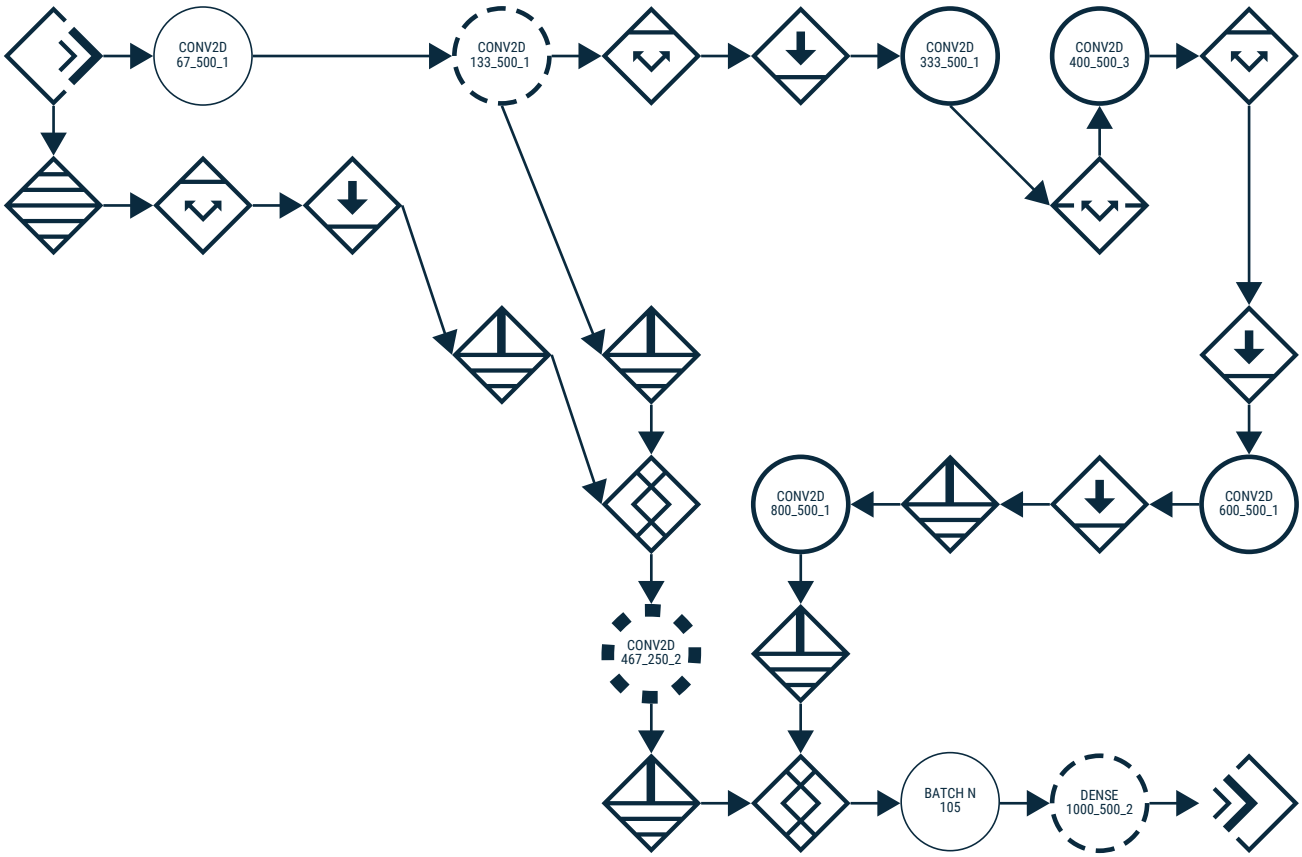

ANOTHER MUTANT WITH GOOD EFFICIENCIES WITH PARAMETER REDUCTION

76% PARAMETER REDUCTION (From 730 602 to 175 180 parameters) with little reduction of the accuracy of the Kaggle champion

```
60000/60000 [==============================] - 26s 437us/step - loss: 0.0172 - acc: 0.9944 - val_loss: 0.0199 -
val_acc: 0.9932
Epoch 20/20
60000/60000 [==============================] - 26s 433us/step - loss: 0.0145 - acc: 0.9955 - val_loss: 0.0216 -
val_acc: 0.9928
Evaluating agent
_________________________________________________________________________________________________
Layer (type)                 Output Shape              Param #     Connected to
=================================================================================================
0_500_1 (InputLayer)         (None, 28, 28, 1)         0
_________________________________________________________________________________________________
67_500_1 (Conv2D)            (None, 26, 26, 32)        320         0_500_1[0][0]
_________________________________________________________________________________________________
100_500_1 (AveragePooling2D) (None, 13, 13, 32)        0           67_500_1[0][0]
_________________________________________________________________________________________________
133_500_3 (Conv2D)           (None, 11, 11, 32)        9248        100_500_1[0][0]
_________________________________________________________________________________________________
200_500_1 (MaxPooling2D)     (None, 5, 5, 32)          0           133_500_3[0][0]
_________________________________________________________________________________________________
333_500_1 (Conv2D)           (None, 5, 5, 64)          18496       200_500_1[0][0]
_________________________________________________________________________________________________
400_500_1 (Conv2D)           (None, 5, 5, 64)          36928       333_500_1[0][0]
_________________________________________________________________________________________________
467_500_1 (MaxPooling2D)     (None, 2, 2, 64)          0           400_500_1[0][0]
_________________________________________________________________________________________________
dropout_293 (Dropout)        (None, 2, 2, 64)          0           467_500_1[0][0]
_________________________________________________________________________________________________
600_500_2 (Conv2D)           (None, 2, 2, 78)          45006       dropout_293[0][0]
_________________________________________________________________________________________________
dropout_294 (Dropout)        (None, 2, 2, 78)          0           600_500_2[0][0]
_________________________________________________________________________________________________
800_500_1_F (Flatten)        (None, 312)               0           dropout_294[0][0]
_________________________________________________________________________________________________
467_250_1_F (Flatten)        (None, 3872)              0           133_500_3[0][0]
_________________________________________________________________________________________________
800_500_1 (Dense)            (None, 128)               40064       800_500_1_F[0][0]
_________________________________________________________________________________________________
467_250_1 (Dense)            (None, 6)                 23232       467_250_1_F[0][0]
_________________________________________________________________________________________________
flatten_165 (Flatten)        (None, 128)               0           800_500_1[0][0]
_________________________________________________________________________________________________
flatten_166 (Flatten)        (None, 6)                 0           467_250_1[0][0]
_________________________________________________________________________________________________
1000_500_2_C (Concatenate)   (None, 134)               0           flatten_165[0][0]
                                                                 flatten_166[0][0]
_________________________________________________________________________________________________
batch_normalization_123 (BatchN (None, 134)            536         1000_500_2_C[0][0]
_________________________________________________________________________________________________
1000_500_2 (Dense)           (None, 10)                1350        batch_normalization_123[0][0]
=================================================================================================
Total params: 175,180
Trainable params: 174,912
Non-trainable params: 268
_________________________________________________________________________________________________
None
SignalShape_Dimension: 3
Metrics(Test loss & Test Accuracy):
[0.021634296982052912, 0.9928]
##################################################################################################
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NNTO MODEL MNIST