In [1]:

```
# storia più su nns convolutive, capsulenetwork, evoluzione, problemi di classificazione





# usare affnist



# prova minst su affnist e verificare risultati con paper
# testare su dataset normale + rotraslato*2
# clustering per training
# risultato si su db normale sia rototraslato
#
# + provare no shearing


# matrice di confusione normalizzata sia su righe che su colonne (tot 3 matrici)
```

Import statements

In [2]:

```
%%capture

import numpy as np
import tensorflow as tf

#mandatory for correct load and save of files
%cd /Users/paolobonomi/Work/Python/CapsNetwork

# for project class
import sys
sys.path.append("/Users/paolobonomi/Work/Python/CapsNetwork/src")

from setup import Setup # set up model and dataset
import perfu # performance function such as confusion matrix etc...
import printer
```

Retrieve model and dataset

In [3]:

```
train_dataset_type = Setup.d_k[1]
test_dataset_type = Setup.d_k[0]
```

In [8]:

```
setup = Setup(train_cfg=train_dataset_type, test_cfg=test_dataset_type, epochs=10)

model = setup.get_model()
epochs = model.get_epochs()

X_train, y_train = setup.get_train_images()
X_test, y_test = setup.get_test_images()
dataset = setup.get_dataset()
testing = setup.get_testing()
```

```
Found GPU at: /device:GPU:0
Load Custom affNIST train dataset _v1...
```

```
2022-10-21 09:16:38.718462: I tensorflow/core/common_runtime/pluggable_device/pluggable_
device_factory.cc:305] Could not identify NUMA node of platform GPU ID 0, defaulting to
0. Your kernel may not have been built with NUMA support.
2022-10-21 09:16:38.718516: I tensorflow/core/common_runtime/pluggable_device/pluggable_
```

```
device_factory.cc:271] Created TensorFlow device (/device:GPU:0 with 0 MB memory) -> phy
sical PluggableDevice (device: 0, name: METAL, pci bus id: <undefined>)
Load MINST test dataset from keras...
(10000, 28, 28)
Processing dataset...
Creating model...
Loading model...
2022-10-21 09:16:39.865816: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
2022-10-21 09:16:40.018468: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

In [9]:

```
printer.pretty_experiment_overview(setup)
```

```
The model was trained with 60000 Custom_affNIST images for 10 epochs.
It's going to be tested with 10000 MNIST images.
```

Perfomance data

In [10]:

```
should_create_matrix = True
```

In [11]:

```
if should_create_matrix:
    confusionmatrix_test = perfu.get_confusion_mat(model.predict, testing, "test")
    %store confusionmatrix_test

    confusionmatrix_train = perfu.get_confusion_mat(model.predict, dataset, "train")
    %store confusionmatrix_train
else:
    %store -r confusionmatrix_train
    %store -r confusionmatrix_test

acc_train = perfu.get_accuracy(perfu.normalize_matrix( confusionmatrix_train, X_train.sh
acc_test = perfu.get_accuracy(perfu.normalize_matrix( confusionmatrix_test, X_test.shape
```

```
Creating test confusion matrix:   0%|                    | 0/157 [00:00<?, ?it/s]2022-10-
21 09:16:49.328499: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registr
y.cc:113] Plugin optimizer for device_type GPU is enabled.
Creating test confusion matrix:  99%|█████████▉| 156/157 [08:02<00:03,  3.10s/it]2022-10-
21 09:24:52.075909: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registr
y.cc:113] Plugin optimizer for device_type GPU is enabled.
Creating test confusion matrix: 100%|██████████| 157/157 [08:04<00:00,  3.09s/it]
Stored 'confusionmatrix_test' (ndarray)
Creating train confusion matrix: 100%|█████████▉| 937/938 [48:06<00:03,  3.11s/it]2022-10-
21 10:13:00.584155: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registr
y.cc:113] Plugin optimizer for device_type GPU is enabled.
Creating train confusion matrix: 100%|██████████| 938/938 [48:09<00:00,  3.08s/it]
Stored 'confusionmatrix_train' (ndarray)
```

Testing Confusion Table

In [12]:

```
values, columns, index = perfu.get_confusion_table(confusionmatrix_test, X_test.shape[0]
printer.print_confusion_tables(values, columns, index)
```

Out[12]:

Digit	0	1	2	3	4	5	6	7	8	9
Condition Positive	984	1135	1044	998	993	877	962	1014	993	1000
Condition Negative	9016	8865	8956	9002	9007	9123	9038	8986	9007	9000
True Positive (TN)	971	1126	1023	991	963	865	948	997	959	981
False Negative (FN)	13	9	21	7	30	12	14	17	34	19
False Positive (FP)	9	9	9	19	19	27	10	31	15	28

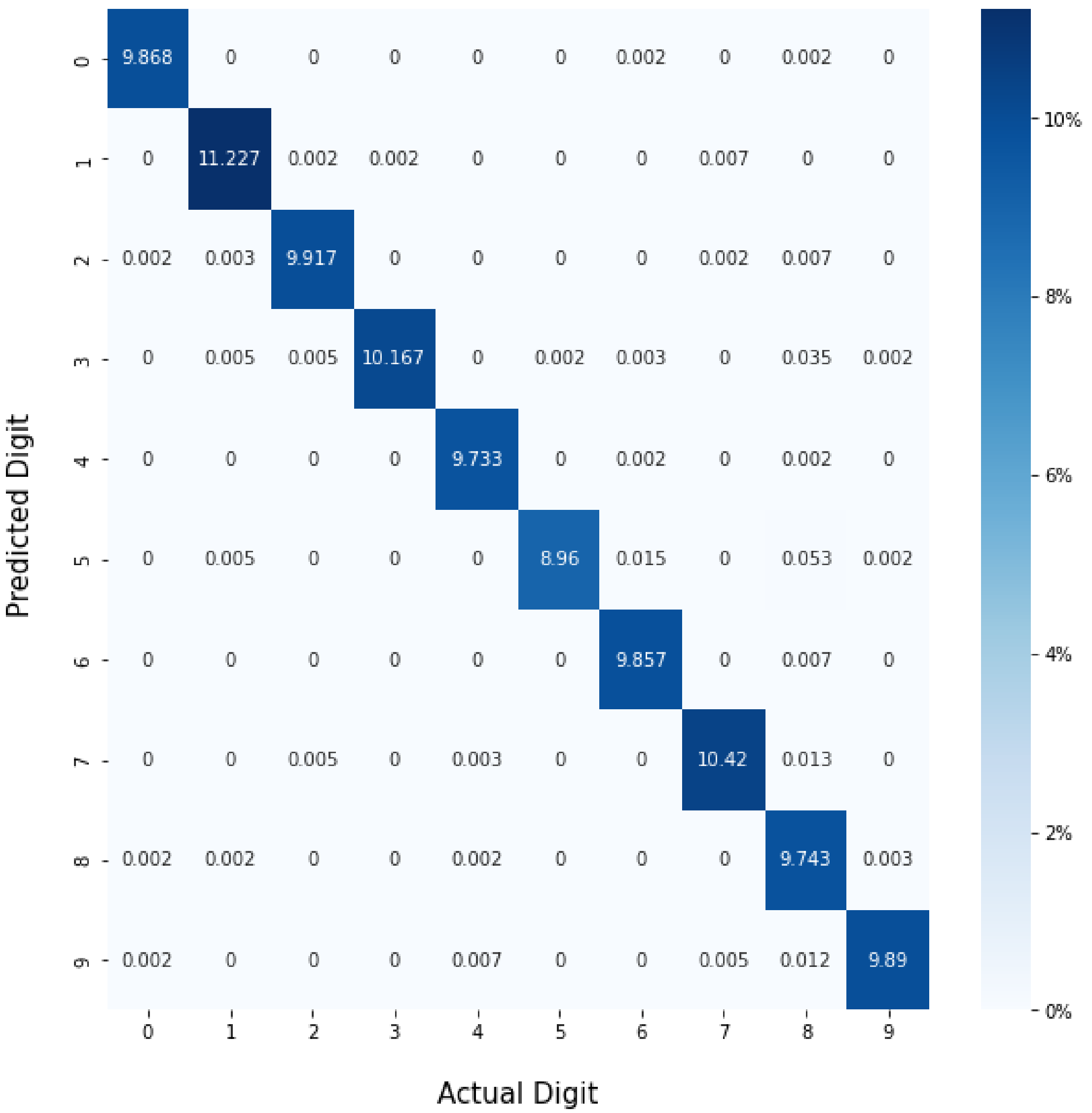
True Negative (TN)	9007	8856	8947	8983	8988	9096	9028	8955	8992	8972
Sensitivity (TPR)	0.987	0.992	0.98	0.993	0.97	0.986	0.985	0.983	0.966	0.981
Specificity (TNR)	0.999	0.999	0.999	0.998	0.998	0.997	0.999	0.997	0.998	0.997
Positive Predictive Value (PPV)	0.991	0.992	0.991	0.981	0.981	0.97	0.99	0.97	0.985	0.972
Negative Predictive Value (NPV)	0.999	0.999	0.998	0.999	0.997	0.999	0.998	0.998	0.996	0.998
False Negative Rate (FNR)	0.013	0.008	0.02	0.007	0.03	0.014	0.015	0.017	0.034	0.019
False Positive Rate (FPR)	0.001	0.001	0.001	0.002	0.002	0.003	0.001	0.003	0.002	0.003
False Discovery Rate (FDR)	0.009	0.008	0.009	0.019	0.019	0.03	0.01	0.03	0.015	0.028
False Omission Rate (FOR)	0.001	0.001	0.002	0.001	0.003	0.001	0.002	0.002	0.004	0.002
Positive Likelihood Ratio (LR+)	988	977	975	470	459	333	890	285	579	315
Negative Likelihood Ratio (LR-)	0.013	0.008	0.02	0.007	0.03	0.014	0.015	0.017	0.034	0.019
Prevalence Threshold (PT)	1.007	1.004	1.01	1.004	1.015	1.007	1.007	1.008	1.018	1.01
Threat Score	0.978	0.984	0.972	0.974	0.952	0.957	0.975	0.954	0.951	0.954
Prevalence	0.098	0.114	0.104	0.1	0.099	0.088	0.096	0.101	0.099	0.1
Accuracy (ACC)	0.998	0.998	0.997	0.997	0.995	0.996	0.998	0.995	0.995	0.995
Balanced Accuracy	0.493	0.496	0.489	0.495	0.484	0.492	0.492	0.49	0.482	0.489
F1 Score	0.989	0.992	0.986	0.987	0.975	0.978	0.988	0.976	0.975	0.977
Matthews Correlation Coefficient (MCC)	0.276	0.332	0.217	0.374	0.18	0.284	0.266	0.238	0.17	0.226
Fowlkes–Mallows Index (FM)	0.989	0.992	0.986	0.987	0.975	0.978	0.988	0.977	0.975	0.977
Bookmaker Informedness (BM)	0.986	0.991	0.979	0.991	0.968	0.983	0.984	0.98	0.964	0.978
Markedness (MK)	0.989	0.991	0.989	0.98	0.977	0.968	0.988	0.968	0.981	0.97
Diagnostic odds ratio (DOR)	74750	123109	48427	66933	15184	24284	61132	16941	16908	16544

Confusion Matrix -- change print statement

In [13]:

```
printer.print_matrix(
    np.around(perfu.normalize_matrix( confusionmatrix_train, X_train.shape[0]), decimals
    'CapsNet AFFNIST (10 epochs) Confusion Matrix on Training Set ('+str(int(X_train.sha
    'Actual Digit',
    'Predicted Digit',
    perfu.headers,
    perfu.headers)
```

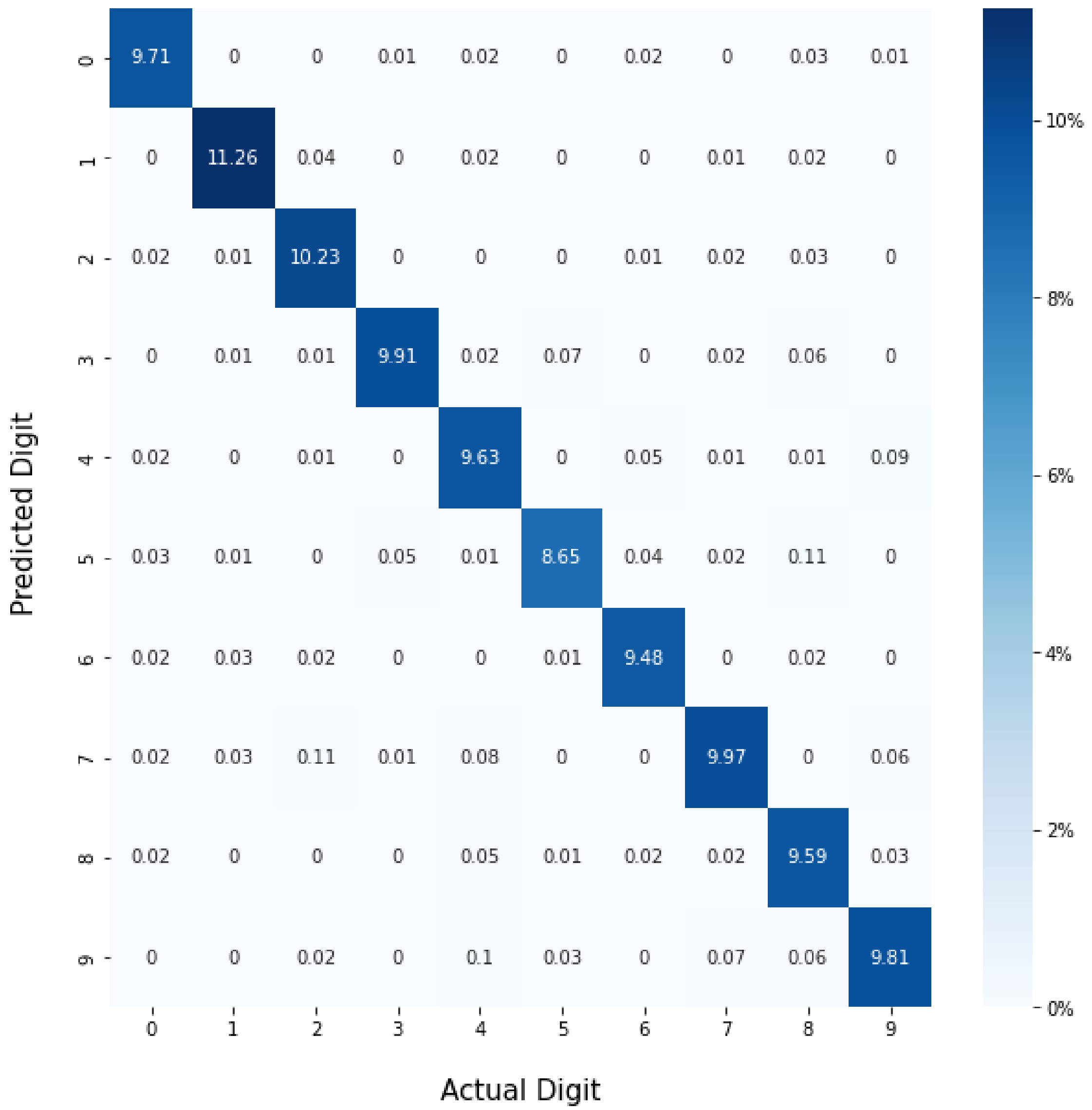
CapsNet AFFNIST (10 epochs) Confusion Matrix on Training Set (60k images)



	0	1	2	3	4	5	6	7	8	9
0	9.868	0	0	0	0	0	0.002	0	0.002	0
1	0	11.227	0.002	0.002	0	0	0	0.007	0	0
2	0.002	0.003	9.917	0	0	0	0	0.002	0.007	0
3	0	0.005	0.005	10.167	0	0.002	0.003	0	0.035	0.002
4	0	0	0	0	9.733	0	0.002	0	0.002	0
5	0	0.005	0	0	0	8.96	0.015	0	0.053	0.002
6	0	0	0	0	0	0	9.857	0	0.007	0
7	0	0	0.005	0	0.003	0	0	10.42	0.013	0
8	0.002	0.002	0	0	0.002	0	0	0	9.743	0.003
9	0.002	0	0	0	0.007	0	0	0.005	0.012	9.89

In [14]:
```
printer.print_matrix(
    np.around(perfu.normalize_matrix( confusionmatrix_test, X_test.shape[0]), decimals=3
    'CapsNet AFFNIST (10 epochs) Confusion Matrix on Testing Set ('+str(int(X_test.shape
    'Actual Digit',
    'Predicted Digit',
    perfu.headers,
    perfu.headers)
```

CapsNet AFFNIST (10 epochs) Confusion Matrix on Testing Set (10k images)



	0	1	2	3	4	5	6	7	8	9
0	9.71	0	0	0.01	0.02	0	0.02	0	0.03	0.01
1	0	11.26	0.04	0	0.02	0	0	0.01	0.02	0
2	0.02	0.01	10.23	0	0	0	0.01	0.02	0.03	0
3	0	0.01	0.01	9.91	0.02	0.07	0	0.02	0.06	0
4	0.02	0	0.01	0	9.63	0	0.05	0.01	0.01	0.09
5	0.03	0.01	0	0.05	0.01	8.65	0.04	0.02	0.11	0
6	0.02	0.03	0.02	0	0	0.01	9.48	0	0.02	0
7	0.02	0.03	0.11	0.01	0.08	0	0	9.97	0	0.06
8	0.02	0	0	0	0.05	0.01	0.02	0.02	9.59	0.03
9	0	0	0.02	0	0.1	0.03	0	0.07	0.06	9.81

Accuracy

In [15]:

```
printer.print_accuracy(acc_train, acc_test, X_train.shape[0], X_test.shape[0])
```

Out[15]:

	Accuracy	# Images	Epochs
Train	99.782	60000	10
Test	98.240	10000	10

Error cases

In [16]:

```
off = 44
n = 110
idx, pred = perfu.get_error_index(model, X_test[off:off+n], y_test[off:off+n], off)

print(idx)
print(pred)
```

```
2022-10-21 10:13:04.134657: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
[]
```

```
[]
```

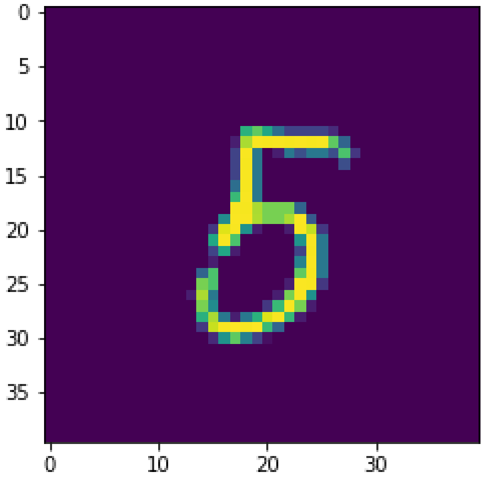
In [17]:

```
for i in range(len(idx)):
    img = idx[i]
    printer.print_image_and_prediction(X_test[img], y_test[img], pred[i], 40 )
```

Network Conv1/PrimaryCapsule Output

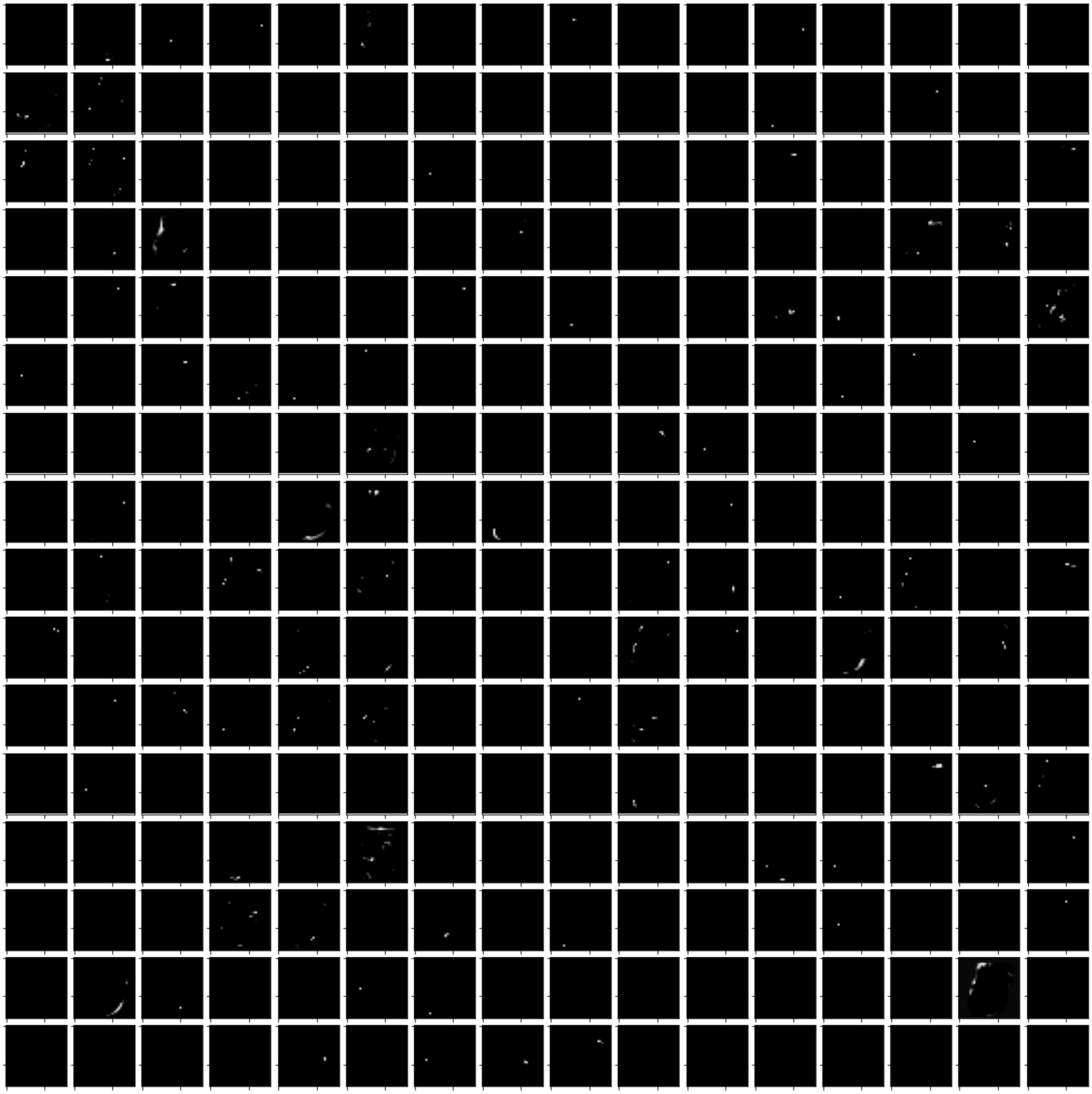
In [18]:

```
printer.print_network(model, X_test[45], y_test[45], 40)
```

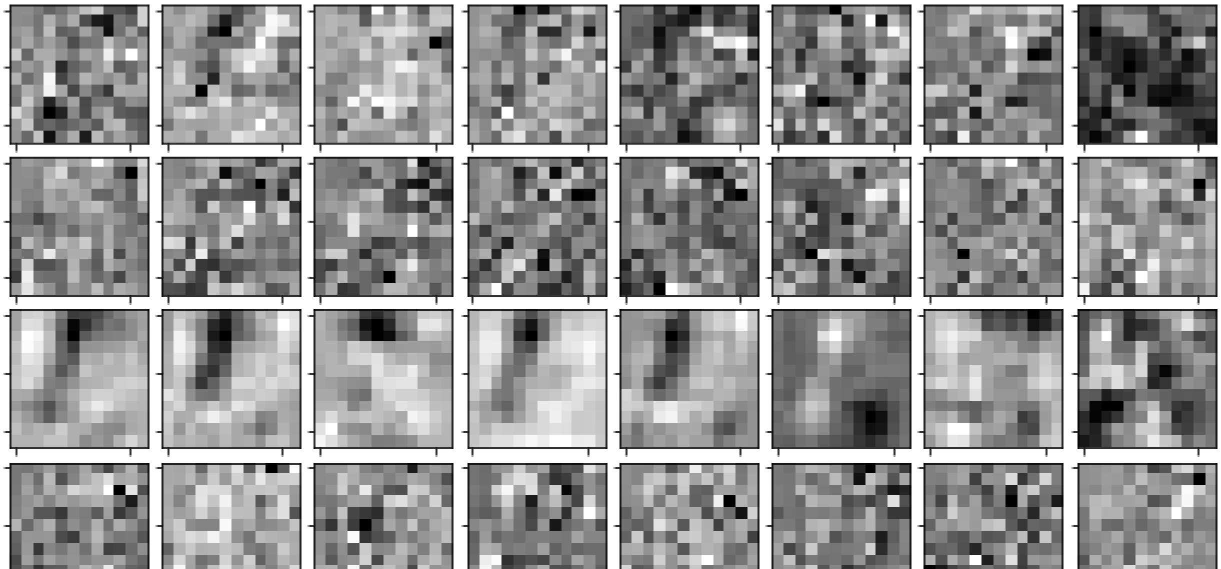


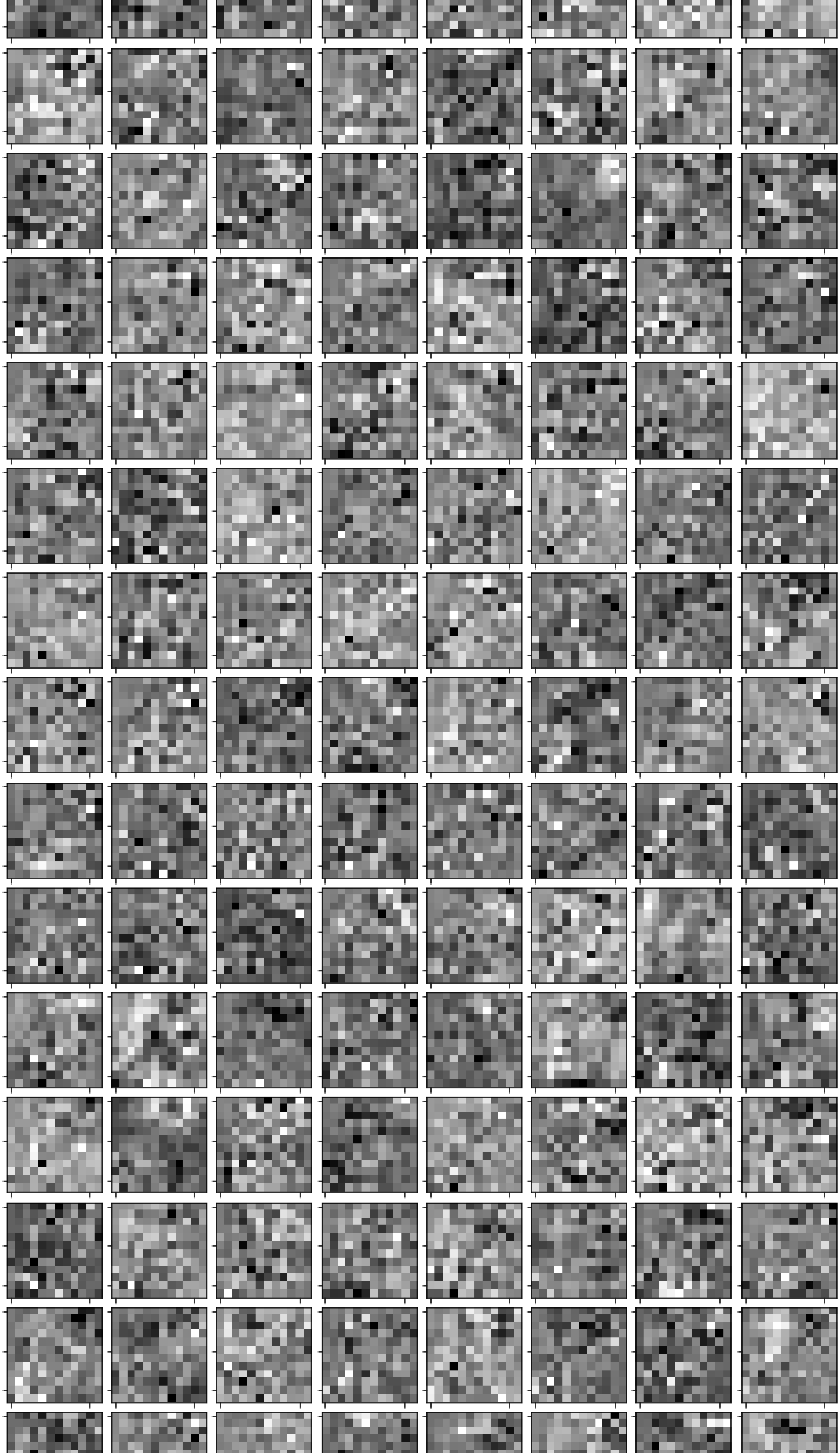
value: 5 - prediction: 5

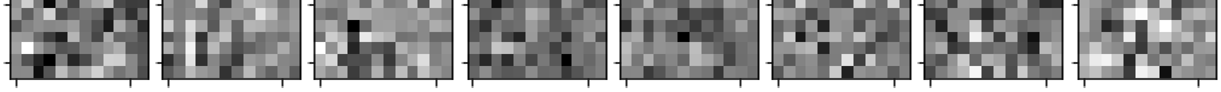
Conv1 256 output 32x32x256



Primary Capsule 12x12x8 output, each row is a channel (32 total)



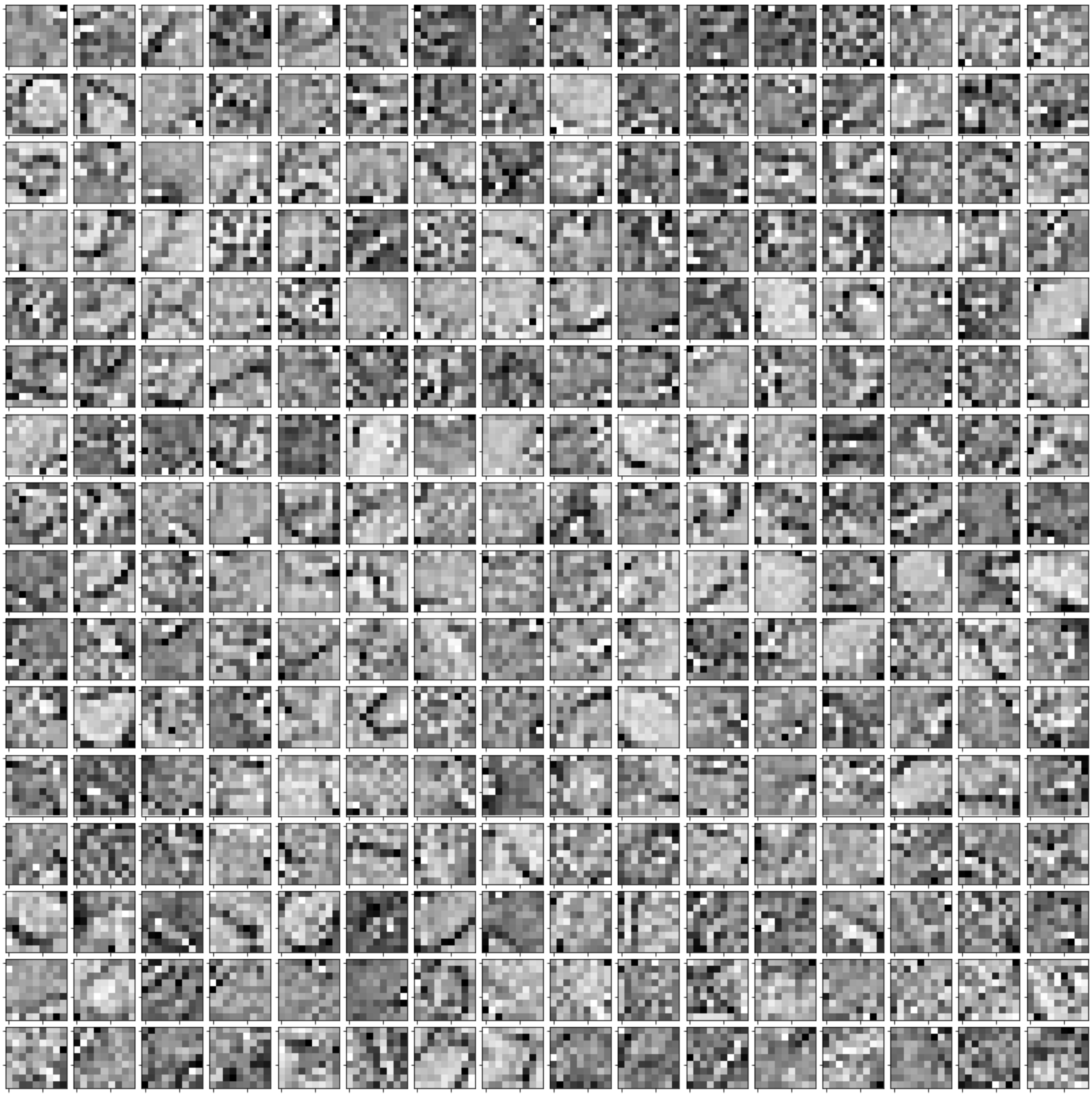




Network Kernels

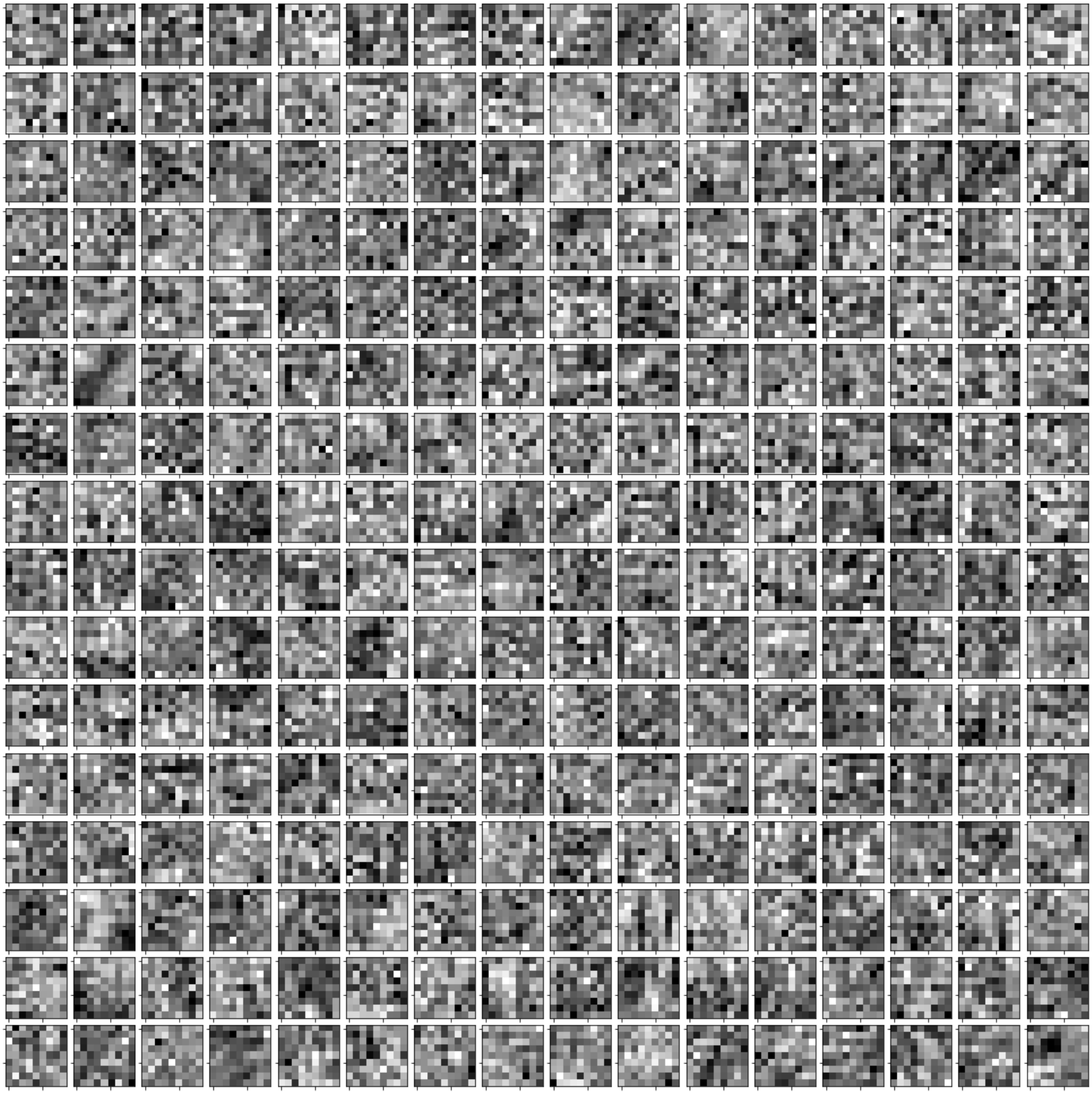
```
In [19]: printer.print_fixed_network_params(model)
```

Conv1 256 filters



Primary Capsule Filter 9x9x256 #1 of 32*8

Primary Capsule Filter 9x9x256 #2 of 32*8



Primary Capsule Filter 9x9x256 #3 of 32*8