

# model\_comparison

April 29, 2018

```
In [1]: # allow the notebook to access the parent directory so we can import the other modules
# https://stackoverflow.com/a/35273613
import os
import sys
nb_dir = os.path.split(os.getcwd())[0]
if nb_dir not in sys.path:
    sys.path.append(nb_dir)
```

## 0.1 # Data Preparation

### 0.1.1 Constants and Folder Paths

```
In [2]: import os
dataset_folder_path = os.path.join("../", "files", "dataset")
NUM_SAMPLES = 50
```

### 0.1.2 Load Data and Split into *Test, Train/Valid*

```
In [3]: from data.DataSet import DataSet
dataset = DataSet()
# dataset.load(dataset_folder_path, test_set_percentage=0.3333, validation_set_percentage=0.3333)
dataset.load(dataset_folder_path, test_set_percentage=0, validation_set_percentage=0)
```

```
In [4]: print(len(dataset.train_data))
print(len(dataset.test_data))
```

```
3600
0
```

### 0.1.3 Data Preprocessing

```
In [5]: from utils.preprocessing import *
from functools import partial
dataset.apply(apply_mean_centering)
dataset.apply(apply_unit_distance_normalization)
#dataset.apply(partial(normalize_pressure_value, max_pressure_val=512))
dataset.apply(partial(spline_interpolate_and_resample, num_samples=NUM_SAMPLES))
```

```

dataset.expand(reverse_digit_sequence)
# dataset.apply(lambda digit: convert_xy_to_derivative(digit, normalize=False))
# dataset.apply(partial(convert_xy_to_derivative, normalize=True))

In [6]: print(len(dataset.train_data))
        print(len(dataset.test_data))

7200
0

```

#### 0.1.4 Setup Dataset, don't split, don't onehot encode, since we will perform cross validation

```

In [7]: import numpy as np
        from sklearn.model_selection import train_test_split

X_train = np.array(dataset.train_data)
# X_valid = np.array(dataset.valid_data)
# X_test = np.array(dataset.test_data)

Y_train = np.array(dataset.train_labels)
# Convert labels to numpy array and OneHot encode them
# encoder, Y_train, Y_valid, Y_test = dataset.onehot_encode_labels()
# Y_train = Y_train.astype('float32').todense()
# Y_valid = Y_valid.astype('float32').todense()
# Y_test = Y_test.astype('float32').todense()

In [8]: Y_train.shape

Out[8]: (7200,)

```

## 1 Test Constants

```
In [9]: RANDOM_STATE = 42
```

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### # Regularized Deep GRU

---

#### Batch Size 300

```

In [11]: PARAM_NUM_EPOCHS = 40
        PARAM_BATCH_SIZE = 300

        from models.regularized_deep_gru import RegularizedDeepGRU
        from utils.evaluation import cross_validate_model

        mymodel = RegularizedDeepGRU(X_train.shape[1:])
        mymodel.batch_size = PARAM_BATCH_SIZE

```

```

        mymodel.num_epochs = PARAM_NUM_EPOCHS

        cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)

Using TensorFlow backend.

...
Cross validation fold [1]
...

Train on 4800 samples, validate on 2400 samples
Epoch 1/40
4800/4800 [=====] - 4s 897us/step - loss: 2.1520 - categorical_accuracy
Epoch 2/40
4800/4800 [=====] - 3s 677us/step - loss: 1.7538 - categorical_accuracy
Epoch 3/40
4800/4800 [=====] - 3s 679us/step - loss: 1.2495 - categorical_accuracy
Epoch 4/40
4800/4800 [=====] - 3s 678us/step - loss: 0.8755 - categorical_accuracy
Epoch 5/40
4800/4800 [=====] - 3s 680us/step - loss: 0.5751 - categorical_accuracy
Epoch 6/40
4800/4800 [=====] - 3s 683us/step - loss: 0.4613 - categorical_accuracy
Epoch 7/40
4800/4800 [=====] - 3s 701us/step - loss: 0.3206 - categorical_accuracy
Epoch 8/40
4800/4800 [=====] - 3s 685us/step - loss: 0.2788 - categorical_accuracy
Epoch 9/40
4800/4800 [=====] - 3s 687us/step - loss: 0.2150 - categorical_accuracy
Epoch 10/40
4800/4800 [=====] - 3s 705us/step - loss: 0.1751 - categorical_accuracy
Epoch 11/40
4800/4800 [=====] - 3s 689us/step - loss: 0.1516 - categorical_accuracy
Epoch 12/40
4800/4800 [=====] - 3s 703us/step - loss: 0.1394 - categorical_accuracy
Epoch 13/40
4800/4800 [=====] - 3s 699us/step - loss: 0.1133 - categorical_accuracy
Epoch 14/40
4800/4800 [=====] - 3s 689us/step - loss: 0.0984 - categorical_accuracy
Epoch 15/40
4800/4800 [=====] - 3s 669us/step - loss: 0.1010 - categorical_accuracy
Epoch 16/40
4800/4800 [=====] - 3s 668us/step - loss: 0.0901 - categorical_accuracy
Epoch 17/40
4800/4800 [=====] - 3s 680us/step - loss: 0.0857 - categorical_accuracy
Epoch 18/40

```

```

4800/4800 [=====] - 3s 718us/step - loss: 0.0680 - categorical_accuracy
Epoch 19/40
4800/4800 [=====] - 3s 687us/step - loss: 0.0646 - categorical_accuracy
Epoch 20/40
4800/4800 [=====] - 3s 672us/step - loss: 0.0546 - categorical_accuracy
Epoch 21/40
4800/4800 [=====] - 3s 670us/step - loss: 0.0568 - categorical_accuracy
Epoch 22/40
4800/4800 [=====] - 3s 674us/step - loss: 0.0548 - categorical_accuracy
Epoch 23/40
4800/4800 [=====] - 3s 668us/step - loss: 0.0378 - categorical_accuracy
Epoch 24/40
4800/4800 [=====] - 3s 669us/step - loss: 0.0368 - categorical_accuracy
Epoch 25/40
4800/4800 [=====] - 3s 678us/step - loss: 0.0566 - categorical_accuracy
Epoch 26/40
4800/4800 [=====] - 3s 669us/step - loss: 0.0478 - categorical_accuracy
Epoch 27/40
4800/4800 [=====] - 3s 669us/step - loss: 0.0352 - categorical_accuracy
Epoch 28/40
4800/4800 [=====] - 3s 668us/step - loss: 0.0339 - categorical_accuracy
Epoch 29/40
4800/4800 [=====] - 3s 684us/step - loss: 0.0273 - categorical_accuracy
Epoch 30/40
4800/4800 [=====] - 3s 679us/step - loss: 0.0324 - categorical_accuracy
Epoch 31/40
4800/4800 [=====] - 3s 703us/step - loss: 0.0289 - categorical_accuracy
Epoch 32/40
4800/4800 [=====] - 4s 733us/step - loss: 0.0346 - categorical_accuracy
Epoch 33/40
4800/4800 [=====] - 3s 709us/step - loss: 0.0329 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 3s 685us/step - loss: 0.0274 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 3s 729us/step - loss: 0.0198 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 3s 698us/step - loss: 0.0340 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 3s 704us/step - loss: 0.0218 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 3s 707us/step - loss: 0.0237 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 3s 691us/step - loss: 0.0209 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 3s 689us/step - loss: 0.0167 - categorical_accuracy
2400/2400 [=====] - 1s 513us/step
categorical_accuracy: 95.00%

```

...

Cross validation fold [2]

...

Train on 4800 samples, validate on 2400 samples

Epoch 1/40

4800/4800 [=====] - 4s 849us/step - loss: 2.1597 - categorical\_accuracy

Epoch 2/40

4800/4800 [=====] - 3s 717us/step - loss: 1.7440 - categorical\_accuracy

Epoch 3/40

4800/4800 [=====] - 3s 694us/step - loss: 1.3214 - categorical\_accuracy

Epoch 4/40

4800/4800 [=====] - 3s 692us/step - loss: 0.9615 - categorical\_accuracy

Epoch 5/40

4800/4800 [=====] - 3s 692us/step - loss: 0.7089 - categorical\_accuracy

Epoch 6/40

4800/4800 [=====] - 3s 690us/step - loss: 0.4931 - categorical\_accuracy

Epoch 7/40

4800/4800 [=====] - 3s 683us/step - loss: 0.3555 - categorical\_accuracy

Epoch 8/40

4800/4800 [=====] - 3s 687us/step - loss: 0.2780 - categorical\_accuracy

Epoch 9/40

4800/4800 [=====] - 3s 688us/step - loss: 0.2108 - categorical\_accuracy

Epoch 10/40

4800/4800 [=====] - 3s 687us/step - loss: 0.1749 - categorical\_accuracy

Epoch 11/40

4800/4800 [=====] - 3s 689us/step - loss: 0.1432 - categorical\_accuracy

Epoch 12/40

4800/4800 [=====] - 3s 691us/step - loss: 0.1326 - categorical\_accuracy

Epoch 13/40

4800/4800 [=====] - 3s 692us/step - loss: 0.1153 - categorical\_accuracy

Epoch 14/40

4800/4800 [=====] - 4s 732us/step - loss: 0.0911 - categorical\_accuracy

Epoch 15/40

4800/4800 [=====] - 3s 692us/step - loss: 0.0877 - categorical\_accuracy

Epoch 16/40

4800/4800 [=====] - 3s 695us/step - loss: 0.0747 - categorical\_accuracy

Epoch 17/40

4800/4800 [=====] - 3s 692us/step - loss: 0.0692 - categorical\_accuracy

Epoch 18/40

4800/4800 [=====] - 3s 698us/step - loss: 0.0649 - categorical\_accuracy

Epoch 19/40

4800/4800 [=====] - 3s 699us/step - loss: 0.0575 - categorical\_accuracy

Epoch 20/40

4800/4800 [=====] - 3s 698us/step - loss: 0.0488 - categorical\_accuracy

Epoch 21/40

4800/4800 [=====] - 3s 701us/step - loss: 0.0454 - categorical\_accuracy

Epoch 22/40

```

4800/4800 [=====] - 3s 711us/step - loss: 0.0416 - categorical_accuracy
Epoch 23/40
4800/4800 [=====] - 3s 705us/step - loss: 0.0333 - categorical_accuracy
Epoch 24/40
4800/4800 [=====] - 3s 702us/step - loss: 0.0347 - categorical_accuracy
Epoch 25/40
4800/4800 [=====] - 3s 702us/step - loss: 0.0336 - categorical_accuracy
Epoch 26/40
4800/4800 [=====] - 3s 714us/step - loss: 0.0279 - categorical_accuracy
Epoch 27/40
4800/4800 [=====] - 3s 703us/step - loss: 0.0316 - categorical_accuracy
Epoch 28/40
4800/4800 [=====] - 3s 706us/step - loss: 0.0265 - categorical_accuracy
Epoch 29/40
4800/4800 [=====] - 3s 705us/step - loss: 0.0269 - categorical_accuracy
Epoch 30/40
4800/4800 [=====] - 3s 714us/step - loss: 0.0218 - categorical_accuracy
Epoch 31/40
4800/4800 [=====] - 3s 701us/step - loss: 0.0184 - categorical_accuracy
Epoch 32/40
4800/4800 [=====] - 3s 703us/step - loss: 0.0182 - categorical_accuracy
Epoch 33/40
4800/4800 [=====] - 3s 702us/step - loss: 0.0147 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 3s 701us/step - loss: 0.0165 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 3s 695us/step - loss: 0.0122 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 3s 690us/step - loss: 0.0226 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 3s 688us/step - loss: 0.0186 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 3s 692us/step - loss: 0.0142 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 3s 693us/step - loss: 0.0178 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 3s 690us/step - loss: 0.0100 - categorical_accuracy
2400/2400 [=====] - 1s 506us/step
categorical_accuracy: 95.25%

```

```

...
Cross validation fold [3]
...

```

Train on 4800 samples, validate on 2400 samples

```

Epoch 1/40
4800/4800 [=====] - 4s 871us/step - loss: 2.1338 - categorical_accuracy
Epoch 2/40

```

4800/4800 [=====] - 3s 687us/step - loss: 1.7123 - categorical\_accuracy  
 Epoch 3/40  
 4800/4800 [=====] - 3s 680us/step - loss: 1.2808 - categorical\_accuracy  
 Epoch 4/40  
 4800/4800 [=====] - 3s 679us/step - loss: 0.9269 - categorical\_accuracy  
 Epoch 5/40  
 4800/4800 [=====] - 3s 680us/step - loss: 0.6091 - categorical\_accuracy  
 Epoch 6/40  
 4800/4800 [=====] - 3s 680us/step - loss: 0.4455 - categorical\_accuracy  
 Epoch 7/40  
 4800/4800 [=====] - 3s 681us/step - loss: 0.3032 - categorical\_accuracy  
 Epoch 8/40  
 4800/4800 [=====] - 3s 680us/step - loss: 0.2279 - categorical\_accuracy  
 Epoch 9/40  
 4800/4800 [=====] - 3s 681us/step - loss: 0.1864 - categorical\_accuracy  
 Epoch 10/40  
 4800/4800 [=====] - 3s 681us/step - loss: 0.1423 - categorical\_accuracy  
 Epoch 11/40  
 4800/4800 [=====] - 3s 682us/step - loss: 0.1227 - categorical\_accuracy  
 Epoch 12/40  
 4800/4800 [=====] - 3s 681us/step - loss: 0.1100 - categorical\_accuracy  
 Epoch 13/40  
 4800/4800 [=====] - 3s 682us/step - loss: 0.0910 - categorical\_accuracy  
 Epoch 14/40  
 4800/4800 [=====] - 3s 673us/step - loss: 0.0802 - categorical\_accuracy  
 Epoch 15/40  
 4800/4800 [=====] - 3s 670us/step - loss: 0.0784 - categorical\_accuracy  
 Epoch 16/40  
 4800/4800 [=====] - 3s 671us/step - loss: 0.0638 - categorical\_accuracy  
 Epoch 17/40  
 4800/4800 [=====] - 3s 671us/step - loss: 0.0681 - categorical\_accuracy  
 Epoch 18/40  
 4800/4800 [=====] - 3s 673us/step - loss: 0.0632 - categorical\_accuracy  
 Epoch 19/40  
 4800/4800 [=====] - 3s 697us/step - loss: 0.0526 - categorical\_accuracy  
 Epoch 20/40  
 4800/4800 [=====] - 3s 700us/step - loss: 0.0478 - categorical\_accuracy  
 Epoch 21/40  
 4800/4800 [=====] - 3s 703us/step - loss: 0.0412 - categorical\_accuracy  
 Epoch 22/40  
 4800/4800 [=====] - 3s 687us/step - loss: 0.0393 - categorical\_accuracy  
 Epoch 23/40  
 4800/4800 [=====] - 3s 683us/step - loss: 0.0368 - categorical\_accuracy  
 Epoch 24/40  
 4800/4800 [=====] - 3s 685us/step - loss: 0.0345 - categorical\_accuracy  
 Epoch 25/40  
 4800/4800 [=====] - 3s 687us/step - loss: 0.0427 - categorical\_accuracy  
 Epoch 26/40

```

4800/4800 [=====] - 3s 706us/step - loss: 0.0324 - categorical_accuracy
Epoch 27/40
4800/4800 [=====] - 3s 697us/step - loss: 0.0329 - categorical_accuracy
Epoch 28/40
4800/4800 [=====] - 3s 693us/step - loss: 0.0261 - categorical_accuracy
Epoch 29/40
4800/4800 [=====] - 3s 693us/step - loss: 0.0216 - categorical_accuracy
Epoch 30/40
4800/4800 [=====] - 3s 694us/step - loss: 0.0235 - categorical_accuracy
Epoch 31/40
4800/4800 [=====] - 3s 696us/step - loss: 0.0198 - categorical_accuracy
Epoch 32/40
4800/4800 [=====] - 3s 691us/step - loss: 0.0149 - categorical_accuracy
Epoch 33/40
4800/4800 [=====] - 3s 681us/step - loss: 0.0165 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 3s 681us/step - loss: 0.0207 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 3s 682us/step - loss: 0.0132 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 3s 682us/step - loss: 0.0158 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 3s 714us/step - loss: 0.0302 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 3s 699us/step - loss: 0.0294 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 3s 700us/step - loss: 0.0155 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 3s 715us/step - loss: 0.0156 - categorical_accuracy
2400/2400 [=====] - 1s 507us/step
categorical_accuracy: 91.25%
93.83% (+/- 1.83%)

```

```
Out[11]: [95.0, 95.25, 91.25]
```

```
In [12]: PARAM_NUM_EPOCHS = 80
PARAM_BATCH_SIZE = 300
```

```
from models.regularized_deep_gru import RegularizedDeepGRU
from utils.evaluation import cross_validate_model
```

```
mymodel = RegularizedDeepGRU(X_train.shape[1:])
mymodel.batch_size = PARAM_BATCH_SIZE
mymodel.num_epochs = PARAM_NUM_EPOCHS
```

```
cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)
```



...

Cross validation fold [1]

...

Train on 4800 samples, validate on 2400 samples

Epoch 1/80

4800/4800 [=====] - 6s 1ms/step - loss: 2.1299 - categorical\_accuracy:

Epoch 2/80

4800/4800 [=====] - 3s 682us/step - loss: 1.6836 - categorical\_accuracy

Epoch 3/80

4800/4800 [=====] - 3s 681us/step - loss: 1.2066 - categorical\_accuracy

Epoch 4/80

4800/4800 [=====] - 3s 681us/step - loss: 0.9093 - categorical\_accuracy

Epoch 5/80

4800/4800 [=====] - 3s 699us/step - loss: 0.5985 - categorical\_accuracy

Epoch 6/80

4800/4800 [=====] - 3s 709us/step - loss: 0.4132 - categorical\_accuracy

Epoch 7/80

4800/4800 [=====] - 4s 737us/step - loss: 0.3169 - categorical\_accuracy

Epoch 8/80

4800/4800 [=====] - 3s 683us/step - loss: 0.2568 - categorical\_accuracy

Epoch 9/80

4800/4800 [=====] - 3s 682us/step - loss: 0.2032 - categorical\_accuracy

Epoch 10/80

4800/4800 [=====] - 3s 701us/step - loss: 0.1723 - categorical\_accuracy

Epoch 11/80

4800/4800 [=====] - 3s 681us/step - loss: 0.1468 - categorical\_accuracy

Epoch 12/80

4800/4800 [=====] - 4s 750us/step - loss: 0.1147 - categorical\_accuracy

Epoch 13/80

4800/4800 [=====] - 4s 744us/step - loss: 0.1033 - categorical\_accuracy

Epoch 14/80

4800/4800 [=====] - 3s 713us/step - loss: 0.0909 - categorical\_accuracy

Epoch 15/80

4800/4800 [=====] - 3s 713us/step - loss: 0.0745 - categorical\_accuracy

Epoch 16/80

4800/4800 [=====] - 4s 732us/step - loss: 0.0698 - categorical\_accuracy

Epoch 17/80

4800/4800 [=====] - 3s 728us/step - loss: 0.0668 - categorical\_accuracy

Epoch 18/80

4800/4800 [=====] - 4s 739us/step - loss: 0.0576 - categorical\_accuracy

Epoch 19/80

4800/4800 [=====] - 3s 699us/step - loss: 0.0529 - categorical\_accuracy

Epoch 20/80

4800/4800 [=====] - 3s 695us/step - loss: 0.0442 - categorical\_accuracy

Epoch 21/80

4800/4800 [=====] - 3s 686us/step - loss: 0.0402 - categorical\_accuracy

Epoch 22/80

4800/4800 [=====] - 3s 688us/step - loss: 0.0393 - categorical\_accuracy  
Epoch 23/80  
4800/4800 [=====] - 3s 697us/step - loss: 0.0355 - categorical\_accuracy  
Epoch 24/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0450 - categorical\_accuracy  
Epoch 25/80  
4800/4800 [=====] - 3s 690us/step - loss: 0.0329 - categorical\_accuracy  
Epoch 26/80  
4800/4800 [=====] - 3s 721us/step - loss: 0.0319 - categorical\_accuracy  
Epoch 27/80  
4800/4800 [=====] - 3s 701us/step - loss: 0.0307 - categorical\_accuracy  
Epoch 28/80  
4800/4800 [=====] - 3s 703us/step - loss: 0.0305 - categorical\_accuracy  
Epoch 29/80  
4800/4800 [=====] - 3s 714us/step - loss: 0.0306 - categorical\_accuracy  
Epoch 30/80  
4800/4800 [=====] - 3s 712us/step - loss: 0.0255 - categorical\_accuracy  
Epoch 31/80  
4800/4800 [=====] - 3s 677us/step - loss: 0.0198 - categorical\_accuracy  
Epoch 32/80  
4800/4800 [=====] - 3s 679us/step - loss: 0.0255 - categorical\_accuracy  
Epoch 33/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0250 - categorical\_accuracy  
Epoch 34/80  
4800/4800 [=====] - 3s 674us/step - loss: 0.0214 - categorical\_accuracy  
Epoch 35/80  
4800/4800 [=====] - 3s 715us/step - loss: 0.0174 - categorical\_accuracy  
Epoch 36/80  
4800/4800 [=====] - 3s 692us/step - loss: 0.0145 - categorical\_accuracy  
Epoch 37/80  
4800/4800 [=====] - 3s 716us/step - loss: 0.0160 - categorical\_accuracy  
Epoch 38/80  
4800/4800 [=====] - 3s 674us/step - loss: 0.0149 - categorical\_accuracy  
Epoch 39/80  
4800/4800 [=====] - 3s 683us/step - loss: 0.0168 - categorical\_accuracy  
Epoch 40/80  
4800/4800 [=====] - 3s 696us/step - loss: 0.0131 - categorical\_accuracy  
Epoch 41/80  
4800/4800 [=====] - 3s 686us/step - loss: 0.0133 - categorical\_accuracy  
Epoch 42/80  
4800/4800 [=====] - 3s 691us/step - loss: 0.0128 - categorical\_accuracy  
Epoch 43/80  
4800/4800 [=====] - 3s 707us/step - loss: 0.0115 - categorical\_accuracy  
Epoch 44/80  
4800/4800 [=====] - 3s 712us/step - loss: 0.0077 - categorical\_accuracy  
Epoch 45/80  
4800/4800 [=====] - 3s 672us/step - loss: 0.0162 - categorical\_accuracy  
Epoch 46/80

4800/4800 [=====] - 3s 676us/step - loss: 0.0202 - categorical\_accuracy  
Epoch 47/80  
4800/4800 [=====] - 3s 673us/step - loss: 0.0626 - categorical\_accuracy  
Epoch 48/80  
4800/4800 [=====] - 3s 674us/step - loss: 0.0279 - categorical\_accuracy  
Epoch 49/80  
4800/4800 [=====] - 3s 676us/step - loss: 0.0273 - categorical\_accuracy  
Epoch 50/80  
4800/4800 [=====] - 3s 676us/step - loss: 0.0142 - categorical\_accuracy  
Epoch 51/80  
4800/4800 [=====] - 3s 700us/step - loss: 0.0106 - categorical\_accuracy  
Epoch 52/80  
4800/4800 [=====] - 3s 675us/step - loss: 0.0070 - categorical\_accuracy  
Epoch 53/80  
4800/4800 [=====] - 3s 675us/step - loss: 0.0095 - categorical\_accuracy  
Epoch 54/80  
4800/4800 [=====] - 3s 674us/step - loss: 0.0225 - categorical\_accuracy  
Epoch 55/80  
4800/4800 [=====] - 3s 674us/step - loss: 0.0197 - categorical\_accuracy  
Epoch 56/80  
4800/4800 [=====] - 3s 675us/step - loss: 0.0180 - categorical\_accuracy  
Epoch 57/80  
4800/4800 [=====] - 3s 714us/step - loss: 0.0143 - categorical\_accuracy  
Epoch 58/80  
4800/4800 [=====] - 3s 693us/step - loss: 0.0094 - categorical\_accuracy  
Epoch 59/80  
4800/4800 [=====] - 3s 694us/step - loss: 0.0099 - categorical\_accuracy  
Epoch 60/80  
4800/4800 [=====] - 3s 674us/step - loss: 0.0078 - categorical\_accuracy  
Epoch 61/80  
4800/4800 [=====] - 3s 674us/step - loss: 0.0057 - categorical\_accuracy  
Epoch 62/80  
4800/4800 [=====] - 3s 675us/step - loss: 0.0100 - categorical\_accuracy  
Epoch 63/80  
4800/4800 [=====] - 3s 675us/step - loss: 0.0059 - categorical\_accuracy  
Epoch 64/80  
4800/4800 [=====] - 3s 674us/step - loss: 0.0080 - categorical\_accuracy  
Epoch 65/80  
4800/4800 [=====] - 3s 692us/step - loss: 0.0061 - categorical\_accuracy  
Epoch 66/80  
4800/4800 [=====] - 3s 683us/step - loss: 0.0043 - categorical\_accuracy  
Epoch 67/80  
4800/4800 [=====] - 3s 696us/step - loss: 0.0047 - categorical\_accuracy  
Epoch 68/80  
4800/4800 [=====] - 3s 678us/step - loss: 0.0028 - categorical\_accuracy  
Epoch 69/80  
4800/4800 [=====] - 3s 684us/step - loss: 0.0017 - categorical\_accuracy  
Epoch 70/80

```

4800/4800 [=====] - 3s 707us/step - loss: 0.0016 - categorical_accuracy
Epoch 71/80
4800/4800 [=====] - 3s 684us/step - loss: 0.0022 - categorical_accuracy
Epoch 72/80
4800/4800 [=====] - 3s 677us/step - loss: 0.0031 - categorical_accuracy
Epoch 73/80
4800/4800 [=====] - 3s 688us/step - loss: 0.0040 - categorical_accuracy
Epoch 74/80
4800/4800 [=====] - 3s 712us/step - loss: 0.0053 - categorical_accuracy
Epoch 75/80
4800/4800 [=====] - 4s 734us/step - loss: 0.0108 - categorical_accuracy
Epoch 76/80
4800/4800 [=====] - 3s 704us/step - loss: 0.0173 - categorical_accuracy
Epoch 77/80
4800/4800 [=====] - 3s 727us/step - loss: 0.0242 - categorical_accuracy
Epoch 78/80
4800/4800 [=====] - 3s 725us/step - loss: 0.0235 - categorical_accuracy
Epoch 79/80
4800/4800 [=====] - 3s 696us/step - loss: 0.0114 - categorical_accuracy
Epoch 80/80
4800/4800 [=====] - 4s 738us/step - loss: 0.0123 - categorical_accuracy
2400/2400 [=====] - 1s 519us/step
categorical_accuracy: 93.42%

```

```

...
Cross validation fold [2]
...

```

```

Train on 4800 samples, validate on 2400 samples
Epoch 1/80
4800/4800 [=====] - 6s 1ms/step - loss: 2.1683 - categorical_accuracy:
Epoch 2/80
4800/4800 [=====] - 4s 755us/step - loss: 1.7651 - categorical_accuracy
Epoch 3/80
4800/4800 [=====] - 3s 714us/step - loss: 1.3302 - categorical_accuracy
Epoch 4/80
4800/4800 [=====] - 3s 694us/step - loss: 0.9385 - categorical_accuracy
Epoch 5/80
4800/4800 [=====] - 4s 756us/step - loss: 0.6417 - categorical_accuracy
Epoch 6/80
4800/4800 [=====] - 3s 722us/step - loss: 0.4490 - categorical_accuracy
Epoch 7/80
4800/4800 [=====] - 4s 765us/step - loss: 0.3350 - categorical_accuracy
Epoch 8/80
4800/4800 [=====] - 4s 749us/step - loss: 0.2559 - categorical_accuracy
Epoch 9/80
4800/4800 [=====] - 4s 730us/step - loss: 0.2077 - categorical_accuracy
Epoch 10/80

```

4800/4800 [=====] - 3s 729us/step - loss: 0.1673 - categorical\_accuracy  
 Epoch 11/80  
 4800/4800 [=====] - 4s 755us/step - loss: 0.1587 - categorical\_accuracy  
 Epoch 12/80  
 4800/4800 [=====] - 3s 716us/step - loss: 0.1243 - categorical\_accuracy  
 Epoch 13/80  
 4800/4800 [=====] - 4s 740us/step - loss: 0.1084 - categorical\_accuracy  
 Epoch 14/80  
 4800/4800 [=====] - 4s 734us/step - loss: 0.0943 - categorical\_accuracy  
 Epoch 15/80  
 4800/4800 [=====] - 3s 693us/step - loss: 0.0845 - categorical\_accuracy  
 Epoch 16/80  
 4800/4800 [=====] - 3s 688us/step - loss: 0.0697 - categorical\_accuracy  
 Epoch 17/80  
 4800/4800 [=====] - 3s 692us/step - loss: 0.0682 - categorical\_accuracy  
 Epoch 18/80  
 4800/4800 [=====] - 3s 684us/step - loss: 0.0561 - categorical\_accuracy  
 Epoch 19/80  
 4800/4800 [=====] - 3s 684us/step - loss: 0.0498 - categorical\_accuracy  
 Epoch 20/80  
 4800/4800 [=====] - 3s 686us/step - loss: 0.0503 - categorical\_accuracy  
 Epoch 21/80  
 4800/4800 [=====] - 3s 684us/step - loss: 0.0449 - categorical\_accuracy  
 Epoch 22/80  
 4800/4800 [=====] - 3s 685us/step - loss: 0.0415 - categorical\_accuracy  
 Epoch 23/80  
 4800/4800 [=====] - 3s 685us/step - loss: 0.0329 - categorical\_accuracy  
 Epoch 24/80  
 4800/4800 [=====] - 3s 685us/step - loss: 0.0318 - categorical\_accuracy  
 Epoch 25/80  
 4800/4800 [=====] - 3s 683us/step - loss: 0.0311 - categorical\_accuracy  
 Epoch 26/80  
 4800/4800 [=====] - 3s 686us/step - loss: 0.0225 - categorical\_accuracy  
 Epoch 27/80  
 4800/4800 [=====] - 3s 683us/step - loss: 0.0193 - categorical\_accuracy  
 Epoch 28/80  
 4800/4800 [=====] - 3s 684us/step - loss: 0.0209 - categorical\_accuracy  
 Epoch 29/80  
 4800/4800 [=====] - 3s 685us/step - loss: 0.0367 - categorical\_accuracy  
 Epoch 30/80  
 4800/4800 [=====] - 3s 684us/step - loss: 0.0331 - categorical\_accuracy  
 Epoch 31/80  
 4800/4800 [=====] - 3s 685us/step - loss: 0.0251 - categorical\_accuracy  
 Epoch 32/80  
 4800/4800 [=====] - 3s 685us/step - loss: 0.0244 - categorical\_accuracy  
 Epoch 33/80  
 4800/4800 [=====] - 3s 686us/step - loss: 0.0314 - categorical\_accuracy  
 Epoch 34/80

4800/4800 [=====] - 3s 686us/step - loss: 0.0255 - categorical\_accuracy  
Epoch 35/80  
4800/4800 [=====] - 3s 685us/step - loss: 0.0235 - categorical\_accuracy  
Epoch 36/80  
4800/4800 [=====] - 3s 686us/step - loss: 0.0176 - categorical\_accuracy  
Epoch 37/80  
4800/4800 [=====] - 3s 685us/step - loss: 0.0183 - categorical\_accuracy  
Epoch 38/80  
4800/4800 [=====] - 3s 724us/step - loss: 0.0192 - categorical\_accuracy  
Epoch 39/80  
4800/4800 [=====] - 3s 707us/step - loss: 0.0165 - categorical\_accuracy  
Epoch 40/80  
4800/4800 [=====] - 3s 707us/step - loss: 0.0132 - categorical\_accuracy  
Epoch 41/80  
4800/4800 [=====] - 3s 704us/step - loss: 0.0099 - categorical\_accuracy  
Epoch 42/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0088 - categorical\_accuracy  
Epoch 43/80  
4800/4800 [=====] - 3s 693us/step - loss: 0.0118 - categorical\_accuracy  
Epoch 44/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0093 - categorical\_accuracy  
Epoch 45/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0120 - categorical\_accuracy  
Epoch 46/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0132 - categorical\_accuracy  
Epoch 47/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0131 - categorical\_accuracy  
Epoch 48/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0091 - categorical\_accuracy  
Epoch 49/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0161 - categorical\_accuracy  
Epoch 50/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0364 - categorical\_accuracy  
Epoch 51/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0229 - categorical\_accuracy  
Epoch 52/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0178 - categorical\_accuracy  
Epoch 53/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0079 - categorical\_accuracy  
Epoch 54/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0090 - categorical\_accuracy  
Epoch 55/80  
4800/4800 [=====] - 3s 720us/step - loss: 0.0091 - categorical\_accuracy  
Epoch 56/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0086 - categorical\_accuracy  
Epoch 57/80  
4800/4800 [=====] - 3s 693us/step - loss: 0.0057 - categorical\_accuracy  
Epoch 58/80

4800/4800 [=====] - 3s 700us/step - loss: 0.0042 - categorical\_accuracy  
Epoch 59/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0046 - categorical\_accuracy  
Epoch 60/80  
4800/4800 [=====] - 3s 701us/step - loss: 0.0021 - categorical\_accuracy  
Epoch 61/80  
4800/4800 [=====] - 3s 698us/step - loss: 0.0042 - categorical\_accuracy  
Epoch 62/80  
4800/4800 [=====] - 3s 696us/step - loss: 0.0030 - categorical\_accuracy  
Epoch 63/80  
4800/4800 [=====] - 3s 681us/step - loss: 0.0043 - categorical\_accuracy  
Epoch 64/80  
4800/4800 [=====] - 3s 681us/step - loss: 0.0039 - categorical\_accuracy  
Epoch 65/80  
4800/4800 [=====] - 3s 692us/step - loss: 0.0026 - categorical\_accuracy  
Epoch 66/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0025 - categorical\_accuracy  
Epoch 67/80  
4800/4800 [=====] - 3s 683us/step - loss: 0.0026 - categorical\_accuracy  
Epoch 68/80  
4800/4800 [=====] - 3s 679us/step - loss: 0.0032 - categorical\_accuracy  
Epoch 69/80  
4800/4800 [=====] - 3s 678us/step - loss: 0.0049 - categorical\_accuracy  
Epoch 70/80  
4800/4800 [=====] - 3s 680us/step - loss: 0.0092 - categorical\_accuracy  
Epoch 71/80  
4800/4800 [=====] - 3s 678us/step - loss: 0.0103 - categorical\_accuracy  
Epoch 72/80  
4800/4800 [=====] - 3s 678us/step - loss: 0.0140 - categorical\_accuracy  
Epoch 73/80  
4800/4800 [=====] - 3s 678us/step - loss: 0.0224 - categorical\_accuracy  
Epoch 74/80  
4800/4800 [=====] - 3s 678us/step - loss: 0.0149 - categorical\_accuracy  
Epoch 75/80  
4800/4800 [=====] - 3s 678us/step - loss: 0.0155 - categorical\_accuracy  
Epoch 76/80  
4800/4800 [=====] - 3s 679us/step - loss: 0.0171 - categorical\_accuracy  
Epoch 77/80  
4800/4800 [=====] - 3s 681us/step - loss: 0.0181 - categorical\_accuracy  
Epoch 78/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0105 - categorical\_accuracy  
Epoch 79/80  
4800/4800 [=====] - 3s 721us/step - loss: 0.0137 - categorical\_accuracy  
Epoch 80/80  
4800/4800 [=====] - 3s 710us/step - loss: 0.0182 - categorical\_accuracy  
2400/2400 [=====] - 1s 500us/step  
categorical\_accuracy: 95.38%

...

Cross validation fold [3]

...

Train on 4800 samples, validate on 2400 samples

Epoch 1/80

4800/4800 [=====] - 6s 1ms/step - loss: 2.1442 - categorical\_accuracy:

Epoch 2/80

4800/4800 [=====] - 3s 706us/step - loss: 1.7014 - categorical\_accuracy

Epoch 3/80

4800/4800 [=====] - 3s 705us/step - loss: 1.2860 - categorical\_accuracy

Epoch 4/80

4800/4800 [=====] - 3s 687us/step - loss: 0.9011 - categorical\_accuracy

Epoch 5/80

4800/4800 [=====] - 3s 688us/step - loss: 0.6469 - categorical\_accuracy

Epoch 6/80

4800/4800 [=====] - 3s 688us/step - loss: 0.4484 - categorical\_accuracy

Epoch 7/80

4800/4800 [=====] - 3s 688us/step - loss: 0.3493 - categorical\_accuracy

Epoch 8/80

4800/4800 [=====] - 3s 689us/step - loss: 0.2714 - categorical\_accuracy

Epoch 9/80

4800/4800 [=====] - 3s 688us/step - loss: 0.2857 - categorical\_accuracy

Epoch 10/80

4800/4800 [=====] - 3s 704us/step - loss: 0.1809 - categorical\_accuracy

Epoch 11/80

4800/4800 [=====] - 3s 703us/step - loss: 0.1498 - categorical\_accuracy

Epoch 12/80

4800/4800 [=====] - 3s 700us/step - loss: 0.1351 - categorical\_accuracy

Epoch 13/80

4800/4800 [=====] - 3s 691us/step - loss: 0.1205 - categorical\_accuracy

Epoch 14/80

4800/4800 [=====] - 3s 689us/step - loss: 0.1116 - categorical\_accuracy

Epoch 15/80

4800/4800 [=====] - 3s 690us/step - loss: 0.1017 - categorical\_accuracy

Epoch 16/80

4800/4800 [=====] - 3s 687us/step - loss: 0.0934 - categorical\_accuracy

Epoch 17/80

4800/4800 [=====] - 3s 689us/step - loss: 0.0833 - categorical\_accuracy

Epoch 18/80

4800/4800 [=====] - 3s 690us/step - loss: 0.0742 - categorical\_accuracy

Epoch 19/80

4800/4800 [=====] - 3s 689us/step - loss: 0.0680 - categorical\_accuracy

Epoch 20/80

4800/4800 [=====] - 3s 690us/step - loss: 0.0686 - categorical\_accuracy

Epoch 21/80

4800/4800 [=====] - 3s 691us/step - loss: 0.0690 - categorical\_accuracy

Epoch 22/80



4800/4800 [=====] - 3s 706us/step - loss: 0.0567 - categorical\_accuracy  
Epoch 23/80  
4800/4800 [=====] - 4s 740us/step - loss: 0.0531 - categorical\_accuracy  
Epoch 24/80  
4800/4800 [=====] - 3s 705us/step - loss: 0.0481 - categorical\_accuracy  
Epoch 25/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0424 - categorical\_accuracy  
Epoch 26/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0359 - categorical\_accuracy  
Epoch 27/80  
4800/4800 [=====] - 3s 690us/step - loss: 0.0304 - categorical\_accuracy  
Epoch 28/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0339 - categorical\_accuracy  
Epoch 29/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0344 - categorical\_accuracy  
Epoch 30/80  
4800/4800 [=====] - 3s 680us/step - loss: 0.0285 - categorical\_accuracy  
Epoch 31/80  
4800/4800 [=====] - 3s 681us/step - loss: 0.0264 - categorical\_accuracy  
Epoch 32/80  
4800/4800 [=====] - 3s 680us/step - loss: 0.0214 - categorical\_accuracy  
Epoch 33/80  
4800/4800 [=====] - 4s 736us/step - loss: 0.0232 - categorical\_accuracy  
Epoch 34/80  
4800/4800 [=====] - 3s 707us/step - loss: 0.0309 - categorical\_accuracy  
Epoch 35/80  
4800/4800 [=====] - 3s 686us/step - loss: 0.0281 - categorical\_accuracy  
Epoch 36/80  
4800/4800 [=====] - 3s 691us/step - loss: 0.0197 - categorical\_accuracy  
Epoch 37/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0237 - categorical\_accuracy  
Epoch 38/80  
4800/4800 [=====] - 3s 691us/step - loss: 0.0271 - categorical\_accuracy  
Epoch 39/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0261 - categorical\_accuracy  
Epoch 40/80  
4800/4800 [=====] - 3s 685us/step - loss: 0.0284 - categorical\_accuracy  
Epoch 41/80  
4800/4800 [=====] - 3s 683us/step - loss: 0.0215 - categorical\_accuracy  
Epoch 42/80  
4800/4800 [=====] - 3s 686us/step - loss: 0.0252 - categorical\_accuracy  
Epoch 43/80  
4800/4800 [=====] - 3s 685us/step - loss: 0.0152 - categorical\_accuracy  
Epoch 44/80  
4800/4800 [=====] - 3s 684us/step - loss: 0.0241 - categorical\_accuracy  
Epoch 45/80  
4800/4800 [=====] - 3s 684us/step - loss: 0.0203 - categorical\_accuracy  
Epoch 46/80

4800/4800 [=====] - 3s 686us/step - loss: 0.0166 - categorical\_accuracy  
Epoch 47/80  
4800/4800 [=====] - 3s 685us/step - loss: 0.0124 - categorical\_accuracy  
Epoch 48/80  
4800/4800 [=====] - 3s 719us/step - loss: 0.0112 - categorical\_accuracy  
Epoch 49/80  
4800/4800 [=====] - 3s 703us/step - loss: 0.0091 - categorical\_accuracy  
Epoch 50/80  
4800/4800 [=====] - 3s 697us/step - loss: 0.0078 - categorical\_accuracy  
Epoch 51/80  
4800/4800 [=====] - 3s 697us/step - loss: 0.0062 - categorical\_accuracy  
Epoch 52/80  
4800/4800 [=====] - 3s 701us/step - loss: 0.0074 - categorical\_accuracy  
Epoch 53/80  
4800/4800 [=====] - 3s 701us/step - loss: 0.0056 - categorical\_accuracy  
Epoch 54/80  
4800/4800 [=====] - 3s 696us/step - loss: 0.0044 - categorical\_accuracy  
Epoch 55/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0043 - categorical\_accuracy  
Epoch 56/80  
4800/4800 [=====] - 3s 691us/step - loss: 0.0034 - categorical\_accuracy  
Epoch 57/80  
4800/4800 [=====] - 3s 695us/step - loss: 0.0039 - categorical\_accuracy  
Epoch 58/80  
4800/4800 [=====] - 3s 694us/step - loss: 0.0075 - categorical\_accuracy  
Epoch 59/80  
4800/4800 [=====] - 3s 694us/step - loss: 0.0074 - categorical\_accuracy  
Epoch 60/80  
4800/4800 [=====] - 3s 693us/step - loss: 0.0191 - categorical\_accuracy  
Epoch 61/80  
4800/4800 [=====] - 3s 694us/step - loss: 0.0163 - categorical\_accuracy  
Epoch 62/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0092 - categorical\_accuracy  
Epoch 63/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0073 - categorical\_accuracy  
Epoch 64/80  
4800/4800 [=====] - 3s 686us/step - loss: 0.0140 - categorical\_accuracy  
Epoch 65/80  
4800/4800 [=====] - 3s 687us/step - loss: 0.0124 - categorical\_accuracy  
Epoch 66/80  
4800/4800 [=====] - 3s 688us/step - loss: 0.0270 - categorical\_accuracy  
Epoch 67/80  
4800/4800 [=====] - 3s 685us/step - loss: 0.0184 - categorical\_accuracy  
Epoch 68/80  
4800/4800 [=====] - 3s 686us/step - loss: 0.0113 - categorical\_accuracy  
Epoch 69/80  
4800/4800 [=====] - 3s 689us/step - loss: 0.0079 - categorical\_accuracy  
Epoch 70/80

```

4800/4800 [=====] - 3s 689us/step - loss: 0.0123 - categorical_accuracy
Epoch 71/80
4800/4800 [=====] - 3s 688us/step - loss: 0.0056 - categorical_accuracy
Epoch 72/80
4800/4800 [=====] - 3s 687us/step - loss: 0.0035 - categorical_accuracy
Epoch 73/80
4800/4800 [=====] - 3s 702us/step - loss: 0.0050 - categorical_accuracy
Epoch 74/80
4800/4800 [=====] - 3s 693us/step - loss: 0.0139 - categorical_accuracy
Epoch 75/80
4800/4800 [=====] - 3s 695us/step - loss: 0.0085 - categorical_accuracy
Epoch 76/80
4800/4800 [=====] - 3s 686us/step - loss: 0.0049 - categorical_accuracy
Epoch 77/80
4800/4800 [=====] - 3s 686us/step - loss: 0.0054 - categorical_accuracy
Epoch 78/80
4800/4800 [=====] - 3s 678us/step - loss: 0.0072 - categorical_accuracy
Epoch 79/80
4800/4800 [=====] - 3s 680us/step - loss: 0.0119 - categorical_accuracy
Epoch 80/80
4800/4800 [=====] - 3s 680us/step - loss: 0.0268 - categorical_accuracy
2400/2400 [=====] - 1s 495us/step
categorical_accuracy: 94.92%
94.57% (+/- 0.84%)

```

```
Out[12]: [93.41666666666667, 95.375, 94.91666666666667]
```

## Batch Size 600

```

In [12]: PARAM_NUM_EPOCHS = 40
        PARAM_BATCH_SIZE = 600

        from models.regularized_deep_gru import RegularizedDeepGRU
        from utils.evaluation import cross_validate_model

        mymodel = RegularizedDeepGRU(X_train.shape[1:])
        mymodel.batch_size = PARAM_BATCH_SIZE
        mymodel.num_epochs = PARAM_NUM_EPOCHS

        cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)

...
Cross validation fold [1]
...

Train on 4800 samples, validate on 2400 samples

```

Epoch 1/40  
4800/4800 [=====] - 4s 766us/step - loss: 2.2194 - categorical\_accuracy  
Epoch 2/40  
4800/4800 [=====] - 3s 582us/step - loss: 2.0138 - categorical\_accuracy  
Epoch 3/40  
4800/4800 [=====] - 3s 563us/step - loss: 1.6939 - categorical\_accuracy  
Epoch 4/40  
4800/4800 [=====] - 3s 615us/step - loss: 1.4508 - categorical\_accuracy  
Epoch 5/40  
4800/4800 [=====] - 3s 571us/step - loss: 1.1906 - categorical\_accuracy  
Epoch 6/40  
4800/4800 [=====] - 3s 570us/step - loss: 1.0385 - categorical\_accuracy  
Epoch 7/40  
4800/4800 [=====] - 3s 569us/step - loss: 0.8065 - categorical\_accuracy  
Epoch 8/40  
4800/4800 [=====] - 3s 595us/step - loss: 0.6718 - categorical\_accuracy  
Epoch 9/40  
4800/4800 [=====] - 3s 574us/step - loss: 0.5490 - categorical\_accuracy  
Epoch 10/40  
4800/4800 [=====] - 3s 574us/step - loss: 0.5206 - categorical\_accuracy  
Epoch 11/40  
4800/4800 [=====] - 3s 575us/step - loss: 0.3921 - categorical\_accuracy  
Epoch 12/40  
4800/4800 [=====] - 3s 608us/step - loss: 0.3249 - categorical\_accuracy  
Epoch 13/40  
4800/4800 [=====] - 3s 578us/step - loss: 0.3107 - categorical\_accuracy  
Epoch 14/40  
4800/4800 [=====] - 3s 578us/step - loss: 0.2756 - categorical\_accuracy  
Epoch 15/40  
4800/4800 [=====] - 3s 602us/step - loss: 0.2396 - categorical\_accuracy  
Epoch 16/40  
4800/4800 [=====] - 3s 583us/step - loss: 0.2945 - categorical\_accuracy  
Epoch 17/40  
4800/4800 [=====] - 3s 586us/step - loss: 0.2066 - categorical\_accuracy  
Epoch 18/40  
4800/4800 [=====] - 3s 578us/step - loss: 0.1818 - categorical\_accuracy  
Epoch 19/40  
4800/4800 [=====] - 3s 599us/step - loss: 0.1676 - categorical\_accuracy  
Epoch 20/40  
4800/4800 [=====] - 3s 581us/step - loss: 0.1544 - categorical\_accuracy  
Epoch 21/40  
4800/4800 [=====] - 3s 580us/step - loss: 0.1484 - categorical\_accuracy  
Epoch 22/40  
4800/4800 [=====] - 3s 603us/step - loss: 0.1292 - categorical\_accuracy  
Epoch 23/40  
4800/4800 [=====] - 3s 593us/step - loss: 0.1201 - categorical\_accuracy  
Epoch 24/40  
4800/4800 [=====] - 3s 589us/step - loss: 0.1093 - categorical\_accuracy

```

Epoch 25/40
4800/4800 [=====] - 3s 639us/step - loss: 0.1141 - categorical_accuracy
Epoch 26/40
4800/4800 [=====] - 3s 583us/step - loss: 0.0919 - categorical_accuracy
Epoch 27/40
4800/4800 [=====] - 3s 582us/step - loss: 0.0935 - categorical_accuracy
Epoch 28/40
4800/4800 [=====] - 3s 595us/step - loss: 0.0816 - categorical_accuracy
Epoch 29/40
4800/4800 [=====] - 3s 581us/step - loss: 0.0814 - categorical_accuracy
Epoch 30/40
4800/4800 [=====] - 3s 597us/step - loss: 0.0744 - categorical_accuracy
Epoch 31/40
4800/4800 [=====] - 3s 589us/step - loss: 0.0668 - categorical_accuracy
Epoch 32/40
4800/4800 [=====] - 3s 577us/step - loss: 0.0629 - categorical_accuracy
Epoch 33/40
4800/4800 [=====] - 3s 585us/step - loss: 0.0557 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 3s 573us/step - loss: 0.0530 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 3s 572us/step - loss: 0.0512 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 3s 570us/step - loss: 0.0477 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 3s 572us/step - loss: 0.0454 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 3s 576us/step - loss: 0.0423 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 3s 581us/step - loss: 0.0632 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 3s 575us/step - loss: 0.0415 - categorical_accuracy
2400/2400 [=====] - 1s 493us/step
categorical_accuracy: 93.21%

```

```

...
Cross validation fold [2]
...

```

Train on 4800 samples, validate on 2400 samples

```

Epoch 1/40
4800/4800 [=====] - 4s 809us/step - loss: 2.2142 - categorical_accuracy
Epoch 2/40
4800/4800 [=====] - 3s 573us/step - loss: 2.0143 - categorical_accuracy
Epoch 3/40
4800/4800 [=====] - 3s 576us/step - loss: 1.7508 - categorical_accuracy
Epoch 4/40
4800/4800 [=====] - 3s 592us/step - loss: 1.4755 - categorical_accuracy

```

Epoch 5/40  
4800/4800 [=====] - 3s 578us/step - loss: 1.3128 - categorical\_accuracy  
Epoch 6/40  
4800/4800 [=====] - 3s 579us/step - loss: 1.1456 - categorical\_accuracy  
Epoch 7/40  
4800/4800 [=====] - 3s 575us/step - loss: 0.8573 - categorical\_accuracy  
Epoch 8/40  
4800/4800 [=====] - 3s 623us/step - loss: 0.6766 - categorical\_accuracy  
Epoch 9/40  
4800/4800 [=====] - 3s 632us/step - loss: 0.6929 - categorical\_accuracy  
Epoch 10/40  
4800/4800 [=====] - 3s 601us/step - loss: 0.4106 - categorical\_accuracy  
Epoch 11/40  
4800/4800 [=====] - 3s 590us/step - loss: 0.3580 - categorical\_accuracy  
Epoch 12/40  
4800/4800 [=====] - 3s 574us/step - loss: 0.2671 - categorical\_accuracy  
Epoch 13/40  
4800/4800 [=====] - 3s 578us/step - loss: 0.2138 - categorical\_accuracy  
Epoch 14/40  
4800/4800 [=====] - 3s 578us/step - loss: 0.1969 - categorical\_accuracy  
Epoch 15/40  
4800/4800 [=====] - 3s 575us/step - loss: 0.1944 - categorical\_accuracy  
Epoch 16/40  
4800/4800 [=====] - 3s 581us/step - loss: 0.1502 - categorical\_accuracy  
Epoch 17/40  
4800/4800 [=====] - 3s 579us/step - loss: 0.1531 - categorical\_accuracy  
Epoch 18/40  
4800/4800 [=====] - 3s 592us/step - loss: 0.1226 - categorical\_accuracy  
Epoch 19/40  
4800/4800 [=====] - 3s 580us/step - loss: 0.1154 - categorical\_accuracy  
Epoch 20/40  
4800/4800 [=====] - 3s 581us/step - loss: 0.1088 - categorical\_accuracy  
Epoch 21/40  
4800/4800 [=====] - 3s 585us/step - loss: 0.1005 - categorical\_accuracy  
Epoch 22/40  
4800/4800 [=====] - 3s 584us/step - loss: 0.0903 - categorical\_accuracy  
Epoch 23/40  
4800/4800 [=====] - 3s 594us/step - loss: 0.0857 - categorical\_accuracy  
Epoch 24/40  
4800/4800 [=====] - 3s 583us/step - loss: 0.0795 - categorical\_accuracy  
Epoch 25/40  
4800/4800 [=====] - 3s 586us/step - loss: 0.0761 - categorical\_accuracy  
Epoch 26/40  
4800/4800 [=====] - 3s 587us/step - loss: 0.0811 - categorical\_accuracy  
Epoch 27/40  
4800/4800 [=====] - 3s 587us/step - loss: 0.0769 - categorical\_accuracy  
Epoch 28/40  
4800/4800 [=====] - 3s 584us/step - loss: 0.0638 - categorical\_accuracy

```

Epoch 29/40
4800/4800 [=====] - 3s 587us/step - loss: 0.0587 - categorical_accuracy
Epoch 30/40
4800/4800 [=====] - 3s 588us/step - loss: 0.0521 - categorical_accuracy
Epoch 31/40
4800/4800 [=====] - 3s 586us/step - loss: 0.0482 - categorical_accuracy
Epoch 32/40
4800/4800 [=====] - 3s 593us/step - loss: 0.0534 - categorical_accuracy
Epoch 33/40
4800/4800 [=====] - 3s 587us/step - loss: 0.0468 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 3s 580us/step - loss: 0.0458 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 3s 590us/step - loss: 0.0391 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 3s 580us/step - loss: 0.0328 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 3s 580us/step - loss: 0.0341 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 3s 578us/step - loss: 0.0374 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 3s 587us/step - loss: 0.0359 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 3s 578us/step - loss: 0.0284 - categorical_accuracy
2400/2400 [=====] - 1s 507us/step
categorical_accuracy: 91.71%

```

```

...
Cross validation fold [3]
...

```

Train on 4800 samples, validate on 2400 samples

```

Epoch 1/40
4800/4800 [=====] - 4s 827us/step - loss: 2.2177 - categorical_accuracy
Epoch 2/40
4800/4800 [=====] - 3s 587us/step - loss: 2.0299 - categorical_accuracy
Epoch 3/40
4800/4800 [=====] - 3s 608us/step - loss: 1.7929 - categorical_accuracy
Epoch 4/40
4800/4800 [=====] - 3s 566us/step - loss: 1.5211 - categorical_accuracy
Epoch 5/40
4800/4800 [=====] - 3s 580us/step - loss: 1.3092 - categorical_accuracy
Epoch 6/40
4800/4800 [=====] - 3s 565us/step - loss: 1.1079 - categorical_accuracy
Epoch 7/40
4800/4800 [=====] - 3s 566us/step - loss: 0.9318 - categorical_accuracy
Epoch 8/40
4800/4800 [=====] - 3s 584us/step - loss: 0.6657 - categorical_accuracy

```

Epoch 9/40  
4800/4800 [=====] - 3s 574us/step - loss: 0.6339 - categorical\_accuracy  
Epoch 10/40  
4800/4800 [=====] - 3s 571us/step - loss: 0.4886 - categorical\_accuracy  
Epoch 11/40  
4800/4800 [=====] - 3s 605us/step - loss: 0.3728 - categorical\_accuracy  
Epoch 12/40  
4800/4800 [=====] - 3s 562us/step - loss: 0.2961 - categorical\_accuracy  
Epoch 13/40  
4800/4800 [=====] - 3s 572us/step - loss: 0.2610 - categorical\_accuracy  
Epoch 14/40  
4800/4800 [=====] - 3s 575us/step - loss: 0.2537 - categorical\_accuracy  
Epoch 15/40  
4800/4800 [=====] - 3s 601us/step - loss: 0.1846 - categorical\_accuracy  
Epoch 16/40  
4800/4800 [=====] - 3s 571us/step - loss: 0.1661 - categorical\_accuracy  
Epoch 17/40  
4800/4800 [=====] - 3s 623us/step - loss: 0.1723 - categorical\_accuracy  
Epoch 18/40  
4800/4800 [=====] - 3s 579us/step - loss: 0.1392 - categorical\_accuracy  
Epoch 19/40  
4800/4800 [=====] - 3s 575us/step - loss: 0.1249 - categorical\_accuracy  
Epoch 20/40  
4800/4800 [=====] - 3s 578us/step - loss: 0.1154 - categorical\_accuracy  
Epoch 21/40  
4800/4800 [=====] - 3s 579us/step - loss: 0.1001 - categorical\_accuracy  
Epoch 22/40  
4800/4800 [=====] - 3s 577us/step - loss: 0.0801 - categorical\_accuracy  
Epoch 23/40  
4800/4800 [=====] - 3s 581us/step - loss: 0.0744 - categorical\_accuracy  
Epoch 24/40  
4800/4800 [=====] - 3s 582us/step - loss: 0.0693 - categorical\_accuracy  
Epoch 25/40  
4800/4800 [=====] - 3s 582us/step - loss: 0.0675 - categorical\_accuracy  
Epoch 26/40  
4800/4800 [=====] - 3s 578us/step - loss: 0.0609 - categorical\_accuracy  
Epoch 27/40  
4800/4800 [=====] - 3s 580us/step - loss: 0.0537 - categorical\_accuracy  
Epoch 28/40  
4800/4800 [=====] - 3s 590us/step - loss: 0.0696 - categorical\_accuracy  
Epoch 29/40  
4800/4800 [=====] - 3s 592us/step - loss: 0.0573 - categorical\_accuracy  
Epoch 30/40  
4800/4800 [=====] - 3s 591us/step - loss: 0.0476 - categorical\_accuracy  
Epoch 31/40  
4800/4800 [=====] - 3s 576us/step - loss: 0.0415 - categorical\_accuracy  
Epoch 32/40  
4800/4800 [=====] - 3s 570us/step - loss: 0.0382 - categorical\_accuracy



```

Epoch 33/40
4800/4800 [=====] - 3s 572us/step - loss: 0.0355 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 3s 572us/step - loss: 0.0309 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 3s 570us/step - loss: 0.0295 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 3s 574us/step - loss: 0.0262 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 3s 580us/step - loss: 0.0271 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 3s 578us/step - loss: 0.0217 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 3s 571us/step - loss: 0.0268 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 3s 573us/step - loss: 0.0221 - categorical_accuracy
2400/2400 [=====] - 1s 489us/step
categorical_accuracy: 94.21%
93.04% (+/- 1.03%)

```

```
Out[12]: [93.20833333333334, 91.70833333333334, 94.20833333333334]
```

### # Regularized Deep LSTM

#### 40 epochs

```

In [14]: PARAM_NUM_EPOCHS = 40
        PARAM_BATCH_SIZE = 300

        from models.regularized_deep_lstm import RegularizedDeepLSTM
        from utils.evaluation import cross_validate_model

        mymodel = RegularizedDeepLSTM(X_train.shape[1:])
        mymodel.batch_size = PARAM_BATCH_SIZE
        mymodel.num_epochs = PARAM_NUM_EPOCHS

        cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)

        ...
        Cross validation fold [1]
        ...

        Train on 4800 samples, validate on 2400 samples
        Epoch 1/40
        4800/4800 [=====] - 6s 1ms/step - loss: 2.2044 - categorical_accuracy:

```

Epoch 2/40  
4800/4800 [=====] - 4s 932us/step - loss: 1.9835 - categorical\_accuracy  
Epoch 3/40  
4800/4800 [=====] - 4s 930us/step - loss: 1.8053 - categorical\_accuracy  
Epoch 4/40  
4800/4800 [=====] - 5s 950us/step - loss: 1.6462 - categorical\_accuracy  
Epoch 5/40  
4800/4800 [=====] - 5s 939us/step - loss: 1.5111 - categorical\_accuracy  
Epoch 6/40  
4800/4800 [=====] - 5s 938us/step - loss: 1.3580 - categorical\_accuracy  
Epoch 7/40  
4800/4800 [=====] - 5s 939us/step - loss: 1.2558 - categorical\_accuracy  
Epoch 8/40  
4800/4800 [=====] - 5s 939us/step - loss: 1.1646 - categorical\_accuracy  
Epoch 9/40  
4800/4800 [=====] - 5s 954us/step - loss: 1.0808 - categorical\_accuracy  
Epoch 10/40  
4800/4800 [=====] - 5s 948us/step - loss: 1.0424 - categorical\_accuracy  
Epoch 11/40  
4800/4800 [=====] - 5s 947us/step - loss: 0.9708 - categorical\_accuracy  
Epoch 12/40  
4800/4800 [=====] - 5s 960us/step - loss: 0.8687 - categorical\_accuracy  
Epoch 13/40  
4800/4800 [=====] - 5s 949us/step - loss: 0.8352 - categorical\_accuracy  
Epoch 14/40  
4800/4800 [=====] - 5s 951us/step - loss: 0.7472 - categorical\_accuracy  
Epoch 15/40  
4800/4800 [=====] - 5s 966us/step - loss: 0.7191 - categorical\_accuracy  
Epoch 16/40  
4800/4800 [=====] - 5s 963us/step - loss: 0.6278 - categorical\_accuracy  
Epoch 17/40  
4800/4800 [=====] - 5s 950us/step - loss: 0.5678 - categorical\_accuracy  
Epoch 18/40  
4800/4800 [=====] - 5s 950us/step - loss: 0.5254 - categorical\_accuracy  
Epoch 19/40  
4800/4800 [=====] - 5s 951us/step - loss: 0.5033 - categorical\_accuracy  
Epoch 20/40  
4800/4800 [=====] - 5s 958us/step - loss: 0.4674 - categorical\_accuracy  
Epoch 21/40  
4800/4800 [=====] - 5s 960us/step - loss: 0.4381 - categorical\_accuracy  
Epoch 22/40  
4800/4800 [=====] - 5s 952us/step - loss: 0.3916 - categorical\_accuracy  
Epoch 23/40  
4800/4800 [=====] - 5s 951us/step - loss: 0.3583 - categorical\_accuracy  
Epoch 24/40  
4800/4800 [=====] - 5s 949us/step - loss: 0.3442 - categorical\_accuracy  
Epoch 25/40  
4800/4800 [=====] - 5s 949us/step - loss: 0.3133 - categorical\_accuracy

```

Epoch 26/40
4800/4800 [=====] - 5s 959us/step - loss: 0.3082 - categorical_accuracy:
Epoch 27/40
4800/4800 [=====] - 5s 959us/step - loss: 0.2999 - categorical_accuracy:
Epoch 28/40
4800/4800 [=====] - 5s 947us/step - loss: 0.2788 - categorical_accuracy:
Epoch 29/40
4800/4800 [=====] - 5s 948us/step - loss: 0.2869 - categorical_accuracy:
Epoch 30/40
4800/4800 [=====] - 5s 955us/step - loss: 0.2555 - categorical_accuracy:
Epoch 31/40
4800/4800 [=====] - 5s 950us/step - loss: 0.2579 - categorical_accuracy:
Epoch 32/40
4800/4800 [=====] - 5s 949us/step - loss: 0.2421 - categorical_accuracy:
Epoch 33/40
4800/4800 [=====] - 5s 944us/step - loss: 0.2253 - categorical_accuracy:
Epoch 34/40
4800/4800 [=====] - 5s 947us/step - loss: 0.2300 - categorical_accuracy:
Epoch 35/40
4800/4800 [=====] - 5s 947us/step - loss: 0.2086 - categorical_accuracy:
Epoch 36/40
4800/4800 [=====] - 5s 955us/step - loss: 0.2151 - categorical_accuracy:
Epoch 37/40
4800/4800 [=====] - 5s 955us/step - loss: 0.2111 - categorical_accuracy:
Epoch 38/40
4800/4800 [=====] - 5s 954us/step - loss: 0.2108 - categorical_accuracy:
Epoch 39/40
4800/4800 [=====] - 5s 970us/step - loss: 0.1983 - categorical_accuracy:
Epoch 40/40
4800/4800 [=====] - 5s 1ms/step - loss: 0.2028 - categorical_accuracy:
2400/2400 [=====] - 2s 730us/step
categorical_accuracy: 95.75%

```

```

...
Cross validation fold [2]
...

```

```

Train on 4800 samples, validate on 2400 samples
Epoch 1/40
4800/4800 [=====] - 7s 1ms/step - loss: 2.1935 - categorical_accuracy:
Epoch 2/40
4800/4800 [=====] - 5s 985us/step - loss: 1.9849 - categorical_accuracy:
Epoch 3/40
4800/4800 [=====] - 5s 946us/step - loss: 1.8290 - categorical_accuracy:
Epoch 4/40
4800/4800 [=====] - 4s 923us/step - loss: 1.6661 - categorical_accuracy:
Epoch 5/40
4800/4800 [=====] - 5s 947us/step - loss: 1.4744 - categorical_accuracy:

```

Epoch 6/40  
4800/4800 [=====] - 5s 946us/step - loss: 1.3407 - categorical\_accuracy:  
Epoch 7/40  
4800/4800 [=====] - 5s 985us/step - loss: 1.2566 - categorical\_accuracy:  
Epoch 8/40  
4800/4800 [=====] - 5s 951us/step - loss: 1.1295 - categorical\_accuracy:  
Epoch 9/40  
4800/4800 [=====] - 5s 958us/step - loss: 1.0807 - categorical\_accuracy:  
Epoch 10/40  
4800/4800 [=====] - 5s 1ms/step - loss: 1.0110 - categorical\_accuracy:  
Epoch 11/40  
4800/4800 [=====] - 4s 924us/step - loss: 0.9604 - categorical\_accuracy:  
Epoch 12/40  
4800/4800 [=====] - 4s 929us/step - loss: 0.9193 - categorical\_accuracy:  
Epoch 13/40  
4800/4800 [=====] - 5s 963us/step - loss: 0.8143 - categorical\_accuracy:  
Epoch 14/40  
4800/4800 [=====] - 5s 976us/step - loss: 0.7471 - categorical\_accuracy:  
Epoch 15/40  
4800/4800 [=====] - 5s 951us/step - loss: 0.6737 - categorical\_accuracy:  
Epoch 16/40  
4800/4800 [=====] - 5s 980us/step - loss: 0.6116 - categorical\_accuracy:  
Epoch 17/40  
4800/4800 [=====] - 5s 950us/step - loss: 0.5107 - categorical\_accuracy:  
Epoch 18/40  
4800/4800 [=====] - 5s 952us/step - loss: 0.5134 - categorical\_accuracy:  
Epoch 19/40  
4800/4800 [=====] - 5s 954us/step - loss: 0.4494 - categorical\_accuracy:  
Epoch 20/40  
4800/4800 [=====] - 5s 957us/step - loss: 0.4066 - categorical\_accuracy:  
Epoch 21/40  
4800/4800 [=====] - 5s 963us/step - loss: 0.4052 - categorical\_accuracy:  
Epoch 22/40  
4800/4800 [=====] - 5s 959us/step - loss: 0.3490 - categorical\_accuracy:  
Epoch 23/40  
4800/4800 [=====] - 5s 959us/step - loss: 0.3345 - categorical\_accuracy:  
Epoch 24/40  
4800/4800 [=====] - 5s 956us/step - loss: 0.3095 - categorical\_accuracy:  
Epoch 25/40  
4800/4800 [=====] - 5s 957us/step - loss: 0.2750 - categorical\_accuracy:  
Epoch 26/40  
4800/4800 [=====] - 5s 948us/step - loss: 0.2810 - categorical\_accuracy:  
Epoch 27/40  
4800/4800 [=====] - 5s 942us/step - loss: 0.2731 - categorical\_accuracy:  
Epoch 28/40  
4800/4800 [=====] - 5s 942us/step - loss: 0.2576 - categorical\_accuracy:  
Epoch 29/40  
4800/4800 [=====] - 5s 941us/step - loss: 0.2479 - categorical\_accuracy:

```

Epoch 30/40
4800/4800 [=====] - 5s 942us/step - loss: 0.2455 - categorical_accuracy:
Epoch 31/40
4800/4800 [=====] - 5s 942us/step - loss: 0.2182 - categorical_accuracy:
Epoch 32/40
4800/4800 [=====] - 5s 945us/step - loss: 0.2175 - categorical_accuracy:
Epoch 33/40
4800/4800 [=====] - 5s 940us/step - loss: 0.2130 - categorical_accuracy:
Epoch 34/40
4800/4800 [=====] - 5s 943us/step - loss: 0.2120 - categorical_accuracy:
Epoch 35/40
4800/4800 [=====] - 5s 981us/step - loss: 0.1780 - categorical_accuracy:
Epoch 36/40
4800/4800 [=====] - 5s 956us/step - loss: 0.2146 - categorical_accuracy:
Epoch 37/40
4800/4800 [=====] - 5s 952us/step - loss: 0.1850 - categorical_accuracy:
Epoch 38/40
4800/4800 [=====] - 5s 950us/step - loss: 0.1966 - categorical_accuracy:
Epoch 39/40
4800/4800 [=====] - 5s 960us/step - loss: 0.1848 - categorical_accuracy:
Epoch 40/40
4800/4800 [=====] - 5s 947us/step - loss: 0.1740 - categorical_accuracy:
2400/2400 [=====] - 2s 730us/step
categorical_accuracy: 95.46%

```

```

...
Cross validation fold [3]
...

```

Train on 4800 samples, validate on 2400 samples

```

Epoch 1/40
4800/4800 [=====] - 7s 1ms/step - loss: 2.2005 - categorical_accuracy:
Epoch 2/40
4800/4800 [=====] - 5s 950us/step - loss: 1.9545 - categorical_accuracy:
Epoch 3/40
4800/4800 [=====] - 5s 943us/step - loss: 1.7977 - categorical_accuracy:
Epoch 4/40
4800/4800 [=====] - 5s 940us/step - loss: 1.6168 - categorical_accuracy:
Epoch 5/40
4800/4800 [=====] - 5s 941us/step - loss: 1.5042 - categorical_accuracy:
Epoch 6/40
4800/4800 [=====] - 5s 950us/step - loss: 1.3750 - categorical_accuracy:
Epoch 7/40
4800/4800 [=====] - 5s 952us/step - loss: 1.2217 - categorical_accuracy:
Epoch 8/40
4800/4800 [=====] - 5s 940us/step - loss: 1.0800 - categorical_accuracy:
Epoch 9/40
4800/4800 [=====] - 5s 939us/step - loss: 0.9624 - categorical_accuracy:

```

Epoch 10/40  
4800/4800 [=====] - 5s 941us/step - loss: 0.9017 - categorical\_accuracy  
Epoch 11/40  
4800/4800 [=====] - 5s 941us/step - loss: 0.8103 - categorical\_accuracy  
Epoch 12/40  
4800/4800 [=====] - 5s 940us/step - loss: 0.6998 - categorical\_accuracy  
Epoch 13/40  
4800/4800 [=====] - 5s 942us/step - loss: 0.5998 - categorical\_accuracy  
Epoch 14/40  
4800/4800 [=====] - 4s 928us/step - loss: 0.5595 - categorical\_accuracy  
Epoch 15/40  
4800/4800 [=====] - 4s 927us/step - loss: 0.4965 - categorical\_accuracy  
Epoch 16/40  
4800/4800 [=====] - 4s 926us/step - loss: 0.4551 - categorical\_accuracy  
Epoch 17/40  
4800/4800 [=====] - 4s 932us/step - loss: 0.4572 - categorical\_accuracy  
Epoch 18/40  
4800/4800 [=====] - 4s 927us/step - loss: 0.3808 - categorical\_accuracy  
Epoch 19/40  
4800/4800 [=====] - 4s 929us/step - loss: 0.3583 - categorical\_accuracy  
Epoch 20/40  
4800/4800 [=====] - 5s 961us/step - loss: 0.3454 - categorical\_accuracy  
Epoch 21/40  
4800/4800 [=====] - 5s 949us/step - loss: 0.3023 - categorical\_accuracy  
Epoch 22/40  
4800/4800 [=====] - 5s 950us/step - loss: 0.2962 - categorical\_accuracy  
Epoch 23/40  
4800/4800 [=====] - 5s 953us/step - loss: 0.2733 - categorical\_accuracy  
Epoch 24/40  
4800/4800 [=====] - 5s 953us/step - loss: 0.2706 - categorical\_accuracy  
Epoch 25/40  
4800/4800 [=====] - 5s 953us/step - loss: 0.2517 - categorical\_accuracy  
Epoch 26/40  
4800/4800 [=====] - 5s 949us/step - loss: 0.2387 - categorical\_accuracy  
Epoch 27/40  
4800/4800 [=====] - 5s 951us/step - loss: 0.2448 - categorical\_accuracy  
Epoch 28/40  
4800/4800 [=====] - 5s 952us/step - loss: 0.2208 - categorical\_accuracy  
Epoch 29/40  
4800/4800 [=====] - 5s 946us/step - loss: 0.2020 - categorical\_accuracy  
Epoch 30/40  
4800/4800 [=====] - 5s 942us/step - loss: 0.2193 - categorical\_accuracy  
Epoch 31/40  
4800/4800 [=====] - 5s 942us/step - loss: 0.2163 - categorical\_accuracy  
Epoch 32/40  
4800/4800 [=====] - 5s 971us/step - loss: 0.1995 - categorical\_accuracy  
Epoch 33/40  
4800/4800 [=====] - 5s 985us/step - loss: 0.2024 - categorical\_accuracy

```

Epoch 34/40
4800/4800 [=====] - 5s 964us/step - loss: 0.1839 - categorical_accuracy:
Epoch 35/40
4800/4800 [=====] - 5s 964us/step - loss: 0.1870 - categorical_accuracy:
Epoch 36/40
4800/4800 [=====] - 5s 965us/step - loss: 0.1660 - categorical_accuracy:
Epoch 37/40
4800/4800 [=====] - 5s 964us/step - loss: 0.1680 - categorical_accuracy:
Epoch 38/40
4800/4800 [=====] - 5s 963us/step - loss: 0.1649 - categorical_accuracy:
Epoch 39/40
4800/4800 [=====] - 5s 964us/step - loss: 0.1656 - categorical_accuracy:
Epoch 40/40
4800/4800 [=====] - 5s 963us/step - loss: 0.1585 - categorical_accuracy:
2400/2400 [=====] - 2s 725us/step
categorical_accuracy: 92.96%
94.72% (+/- 1.25%)

```

```

Out[14]: [95.75, 95.45833333333329, 92.95833333333329]

```

## 80 epochs

```

In [11]: PARAM_NUM_EPOCHS = 80
        PARAM_BATCH_SIZE = 300

        from models.regularized_deep_lstm import RegularizedDeepLSTM
        from utils.evaluation import cross_validate_model

        mymodel = RegularizedDeepLSTM(X_train.shape[1:])
        mymodel.batch_size = PARAM_BATCH_SIZE
        mymodel.num_epochs = PARAM_NUM_EPOCHS

        cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)

...
Cross validation fold [1]
...

Train on 4800 samples, validate on 2400 samples
Epoch 1/80
4800/4800 [=====] - 7s 1ms/step - loss: 2.2126 - categorical_accuracy:
Epoch 2/80
4800/4800 [=====] - 5s 947us/step - loss: 1.9922 - categorical_accuracy:
Epoch 3/80
4800/4800 [=====] - 5s 945us/step - loss: 1.8640 - categorical_accuracy:
Epoch 4/80

```

4800/4800 [=====] - 5s 942us/step - loss: 1.7202 - categorical\_accuracy  
Epoch 5/80  
4800/4800 [=====] - 5s 942us/step - loss: 1.5587 - categorical\_accuracy  
Epoch 6/80  
4800/4800 [=====] - 5s 947us/step - loss: 1.4762 - categorical\_accuracy  
Epoch 7/80  
4800/4800 [=====] - 5s 963us/step - loss: 1.3021 - categorical\_accuracy  
Epoch 8/80  
4800/4800 [=====] - 5s 948us/step - loss: 1.1848 - categorical\_accuracy  
Epoch 9/80  
4800/4800 [=====] - 5s 949us/step - loss: 1.1033 - categorical\_accuracy  
Epoch 10/80  
4800/4800 [=====] - 5s 951us/step - loss: 1.0545 - categorical\_accuracy  
Epoch 11/80  
4800/4800 [=====] - 5s 953us/step - loss: 0.9972 - categorical\_accuracy  
Epoch 12/80  
4800/4800 [=====] - 5s 951us/step - loss: 0.8940 - categorical\_accuracy  
Epoch 13/80  
4800/4800 [=====] - 5s 948us/step - loss: 0.7850 - categorical\_accuracy  
Epoch 14/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.7126 - categorical\_accuracy  
Epoch 15/80  
4800/4800 [=====] - 5s 958us/step - loss: 0.6365 - categorical\_accuracy  
Epoch 16/80  
4800/4800 [=====] - 5s 953us/step - loss: 0.6063 - categorical\_accuracy  
Epoch 17/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.5862 - categorical\_accuracy  
Epoch 18/80  
4800/4800 [=====] - 5s 958us/step - loss: 0.5114 - categorical\_accuracy  
Epoch 19/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.4693 - categorical\_accuracy  
Epoch 20/80  
4800/4800 [=====] - 5s 953us/step - loss: 0.4305 - categorical\_accuracy  
Epoch 21/80  
4800/4800 [=====] - 5s 957us/step - loss: 0.4393 - categorical\_accuracy  
Epoch 22/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.4191 - categorical\_accuracy  
Epoch 23/80  
4800/4800 [=====] - 5s 953us/step - loss: 0.3363 - categorical\_accuracy  
Epoch 24/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.3163 - categorical\_accuracy  
Epoch 25/80  
4800/4800 [=====] - 5s 951us/step - loss: 0.2935 - categorical\_accuracy  
Epoch 26/80  
4800/4800 [=====] - 5s 955us/step - loss: 0.2932 - categorical\_accuracy  
Epoch 27/80  
4800/4800 [=====] - 5s 953us/step - loss: 0.2759 - categorical\_accuracy  
Epoch 28/80



4800/4800 [=====] - 5s 953us/step - loss: 0.2461 - categorical\_accuracy  
Epoch 29/80  
4800/4800 [=====] - 5s 954us/step - loss: 0.2347 - categorical\_accuracy  
Epoch 30/80  
4800/4800 [=====] - 5s 953us/step - loss: 0.2437 - categorical\_accuracy  
Epoch 31/80  
4800/4800 [=====] - 5s 953us/step - loss: 0.2329 - categorical\_accuracy  
Epoch 32/80  
4800/4800 [=====] - 5s 954us/step - loss: 0.2242 - categorical\_accuracy  
Epoch 33/80  
4800/4800 [=====] - 5s 954us/step - loss: 0.2069 - categorical\_accuracy  
Epoch 34/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.2082 - categorical\_accuracy  
Epoch 35/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.2010 - categorical\_accuracy  
Epoch 36/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.2048 - categorical\_accuracy  
Epoch 37/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.1976 - categorical\_accuracy  
Epoch 38/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.2005 - categorical\_accuracy  
Epoch 39/80  
4800/4800 [=====] - 5s 951us/step - loss: 0.1649 - categorical\_accuracy  
Epoch 40/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.1870 - categorical\_accuracy  
Epoch 41/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.1819 - categorical\_accuracy  
Epoch 42/80  
4800/4800 [=====] - 5s 951us/step - loss: 0.1691 - categorical\_accuracy  
Epoch 43/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.1465 - categorical\_accuracy  
Epoch 44/80  
4800/4800 [=====] - 5s 951us/step - loss: 0.1626 - categorical\_accuracy  
Epoch 45/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.1567 - categorical\_accuracy  
Epoch 46/80  
4800/4800 [=====] - 5s 956us/step - loss: 0.1490 - categorical\_accuracy  
Epoch 47/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.1353 - categorical\_accuracy  
Epoch 48/80  
4800/4800 [=====] - 5s 940us/step - loss: 0.1407 - categorical\_accuracy  
Epoch 49/80  
4800/4800 [=====] - 5s 942us/step - loss: 0.1502 - categorical\_accuracy  
Epoch 50/80  
4800/4800 [=====] - 5s 993us/step - loss: 0.1387 - categorical\_accuracy  
Epoch 51/80  
4800/4800 [=====] - 5s 976us/step - loss: 0.1349 - categorical\_accuracy  
Epoch 52/80

4800/4800 [=====] - 5s 963us/step - loss: 0.1335 - categorical\_accuracy  
Epoch 53/80  
4800/4800 [=====] - 5s 947us/step - loss: 0.1292 - categorical\_accuracy  
Epoch 54/80  
4800/4800 [=====] - 5s 960us/step - loss: 0.1199 - categorical\_accuracy  
Epoch 55/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.1217 - categorical\_accuracy  
Epoch 56/80  
4800/4800 [=====] - 5s 956us/step - loss: 0.1124 - categorical\_accuracy  
Epoch 57/80  
4800/4800 [=====] - 5s 954us/step - loss: 0.1260 - categorical\_accuracy  
Epoch 58/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.1157 - categorical\_accuracy  
Epoch 59/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.1162 - categorical\_accuracy  
Epoch 60/80  
4800/4800 [=====] - 5s 948us/step - loss: 0.1172 - categorical\_accuracy  
Epoch 61/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.1197 - categorical\_accuracy  
Epoch 62/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.1121 - categorical\_accuracy  
Epoch 63/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.1032 - categorical\_accuracy  
Epoch 64/80  
4800/4800 [=====] - 5s 996us/step - loss: 0.1087 - categorical\_accuracy  
Epoch 65/80  
4800/4800 [=====] - 5s 967us/step - loss: 0.1072 - categorical\_accuracy  
Epoch 66/80  
4800/4800 [=====] - 5s 973us/step - loss: 0.1145 - categorical\_accuracy  
Epoch 67/80  
4800/4800 [=====] - 5s 977us/step - loss: 0.1059 - categorical\_accuracy  
Epoch 68/80  
4800/4800 [=====] - 5s 984us/step - loss: 0.1187 - categorical\_accuracy  
Epoch 69/80  
4800/4800 [=====] - 5s 978us/step - loss: 0.1069 - categorical\_accuracy  
Epoch 70/80  
4800/4800 [=====] - 5s 975us/step - loss: 0.0973 - categorical\_accuracy  
Epoch 71/80  
4800/4800 [=====] - 5s 980us/step - loss: 0.1002 - categorical\_accuracy  
Epoch 72/80  
4800/4800 [=====] - 5s 979us/step - loss: 0.0917 - categorical\_accuracy  
Epoch 73/80  
4800/4800 [=====] - 5s 974us/step - loss: 0.0912 - categorical\_accuracy  
Epoch 74/80  
4800/4800 [=====] - 5s 971us/step - loss: 0.0946 - categorical\_accuracy  
Epoch 75/80  
4800/4800 [=====] - 5s 970us/step - loss: 0.0953 - categorical\_accuracy  
Epoch 76/80

```

4800/4800 [=====] - 5s 968us/step - loss: 0.1043 - categorical_accuracy
Epoch 77/80
4800/4800 [=====] - 5s 967us/step - loss: 0.0985 - categorical_accuracy
Epoch 78/80
4800/4800 [=====] - 5s 956us/step - loss: 0.1074 - categorical_accuracy
Epoch 79/80
4800/4800 [=====] - 5s 949us/step - loss: 0.0875 - categorical_accuracy
Epoch 80/80
4800/4800 [=====] - 5s 952us/step - loss: 0.1028 - categorical_accuracy
2400/2400 [=====] - 2s 725us/step
categorical_accuracy: 93.79%

```

```

...
Cross validation fold [2]
...

```

Train on 4800 samples, validate on 2400 samples

```

Epoch 1/80
4800/4800 [=====] - 7s 1ms/step - loss: 2.2040 - categorical_accuracy:
Epoch 2/80
4800/4800 [=====] - 5s 951us/step - loss: 1.9681 - categorical_accuracy
Epoch 3/80
4800/4800 [=====] - 5s 951us/step - loss: 1.7988 - categorical_accuracy
Epoch 4/80
4800/4800 [=====] - 5s 952us/step - loss: 1.6182 - categorical_accuracy
Epoch 5/80
4800/4800 [=====] - 5s 952us/step - loss: 1.4808 - categorical_accuracy
Epoch 6/80
4800/4800 [=====] - 5s 954us/step - loss: 1.3682 - categorical_accuracy
Epoch 7/80
4800/4800 [=====] - 5s 953us/step - loss: 1.2289 - categorical_accuracy
Epoch 8/80
4800/4800 [=====] - 5s 950us/step - loss: 1.1194 - categorical_accuracy
Epoch 9/80
4800/4800 [=====] - 5s 952us/step - loss: 1.0453 - categorical_accuracy
Epoch 10/80
4800/4800 [=====] - 5s 952us/step - loss: 0.9756 - categorical_accuracy
Epoch 11/80
4800/4800 [=====] - 5s 953us/step - loss: 0.9267 - categorical_accuracy
Epoch 12/80
4800/4800 [=====] - 5s 951us/step - loss: 0.7891 - categorical_accuracy
Epoch 13/80
4800/4800 [=====] - 5s 952us/step - loss: 0.7168 - categorical_accuracy
Epoch 14/80
4800/4800 [=====] - 5s 957us/step - loss: 0.6430 - categorical_accuracy
Epoch 15/80
4800/4800 [=====] - 5s 965us/step - loss: 0.5814 - categorical_accuracy
Epoch 16/80

```

4800/4800 [=====] - 5s 981us/step - loss: 0.5449 - categorical\_accuracy:  
 Epoch 17/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.5332 - categorical\_accuracy:  
 Epoch 18/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.4733 - categorical\_accuracy:  
 Epoch 19/80  
 4800/4800 [=====] - 5s 980us/step - loss: 0.4276 - categorical\_accuracy:  
 Epoch 20/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.4115 - categorical\_accuracy:  
 Epoch 21/80  
 4800/4800 [=====] - 5s 958us/step - loss: 0.3667 - categorical\_accuracy:  
 Epoch 22/80  
 4800/4800 [=====] - 5s 969us/step - loss: 0.3711 - categorical\_accuracy:  
 Epoch 23/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.3318 - categorical\_accuracy:  
 Epoch 24/80  
 4800/4800 [=====] - 5s 951us/step - loss: 0.3132 - categorical\_accuracy:  
 Epoch 25/80  
 4800/4800 [=====] - 5s 956us/step - loss: 0.2948 - categorical\_accuracy:  
 Epoch 26/80  
 4800/4800 [=====] - 5s 953us/step - loss: 0.2871 - categorical\_accuracy:  
 Epoch 27/80  
 4800/4800 [=====] - 5s 948us/step - loss: 0.2546 - categorical\_accuracy:  
 Epoch 28/80  
 4800/4800 [=====] - 5s 950us/step - loss: 0.2589 - categorical\_accuracy:  
 Epoch 29/80  
 4800/4800 [=====] - 5s 948us/step - loss: 0.2337 - categorical\_accuracy:  
 Epoch 30/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.2301 - categorical\_accuracy:  
 Epoch 31/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.2487 - categorical\_accuracy:  
 Epoch 32/80  
 4800/4800 [=====] - 5s 948us/step - loss: 0.2341 - categorical\_accuracy:  
 Epoch 33/80  
 4800/4800 [=====] - 5s 947us/step - loss: 0.2292 - categorical\_accuracy:  
 Epoch 34/80  
 4800/4800 [=====] - 5s 950us/step - loss: 0.2115 - categorical\_accuracy:  
 Epoch 35/80  
 4800/4800 [=====] - 5s 953us/step - loss: 0.1964 - categorical\_accuracy:  
 Epoch 36/80  
 4800/4800 [=====] - 5s 980us/step - loss: 0.1772 - categorical\_accuracy:  
 Epoch 37/80  
 4800/4800 [=====] - 5s 976us/step - loss: 0.1856 - categorical\_accuracy:  
 Epoch 38/80  
 4800/4800 [=====] - 5s 967us/step - loss: 0.1897 - categorical\_accuracy:  
 Epoch 39/80  
 4800/4800 [=====] - 5s 953us/step - loss: 0.1778 - categorical\_accuracy:  
 Epoch 40/80

4800/4800 [=====] - 5s 952us/step - loss: 0.1699 - categorical\_accuracy:  
 Epoch 41/80  
 4800/4800 [=====] - 5s 953us/step - loss: 0.1758 - categorical\_accuracy:  
 Epoch 42/80  
 4800/4800 [=====] - 5s 946us/step - loss: 0.1866 - categorical\_accuracy:  
 Epoch 43/80  
 4800/4800 [=====] - 5s 952us/step - loss: 0.1709 - categorical\_accuracy:  
 Epoch 44/80  
 4800/4800 [=====] - 5s 952us/step - loss: 0.1523 - categorical\_accuracy:  
 Epoch 45/80  
 4800/4800 [=====] - 5s 955us/step - loss: 0.1476 - categorical\_accuracy:  
 Epoch 46/80  
 4800/4800 [=====] - 5s 954us/step - loss: 0.1615 - categorical\_accuracy:  
 Epoch 47/80  
 4800/4800 [=====] - 5s 952us/step - loss: 0.1564 - categorical\_accuracy:  
 Epoch 48/80  
 4800/4800 [=====] - 5s 961us/step - loss: 0.1397 - categorical\_accuracy:  
 Epoch 49/80  
 4800/4800 [=====] - 5s 952us/step - loss: 0.1397 - categorical\_accuracy:  
 Epoch 50/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.1250 - categorical\_accuracy:  
 Epoch 51/80  
 4800/4800 [=====] - 5s 961us/step - loss: 0.1365 - categorical\_accuracy:  
 Epoch 52/80  
 4800/4800 [=====] - 5s 977us/step - loss: 0.1336 - categorical\_accuracy:  
 Epoch 53/80  
 4800/4800 [=====] - 5s 946us/step - loss: 0.1332 - categorical\_accuracy:  
 Epoch 54/80  
 4800/4800 [=====] - 5s 948us/step - loss: 0.1455 - categorical\_accuracy:  
 Epoch 55/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.1383 - categorical\_accuracy:  
 Epoch 56/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.1398 - categorical\_accuracy:  
 Epoch 57/80  
 4800/4800 [=====] - 5s 948us/step - loss: 0.1270 - categorical\_accuracy:  
 Epoch 58/80  
 4800/4800 [=====] - 5s 951us/step - loss: 0.1325 - categorical\_accuracy:  
 Epoch 59/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.1188 - categorical\_accuracy:  
 Epoch 60/80  
 4800/4800 [=====] - 5s 950us/step - loss: 0.1256 - categorical\_accuracy:  
 Epoch 61/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.1151 - categorical\_accuracy:  
 Epoch 62/80  
 4800/4800 [=====] - 5s 951us/step - loss: 0.1068 - categorical\_accuracy:  
 Epoch 63/80  
 4800/4800 [=====] - 4s 936us/step - loss: 0.1133 - categorical\_accuracy:  
 Epoch 64/80

```

4800/4800 [=====] - 5s 960us/step - loss: 0.1156 - categorical_accuracy:
Epoch 65/80
4800/4800 [=====] - 5s 1ms/step - loss: 0.1153 - categorical_accuracy:
Epoch 66/80
4800/4800 [=====] - 5s 945us/step - loss: 0.1338 - categorical_accuracy:
Epoch 67/80
4800/4800 [=====] - 5s 947us/step - loss: 0.1147 - categorical_accuracy:
Epoch 68/80
4800/4800 [=====] - 5s 951us/step - loss: 0.1008 - categorical_accuracy:
Epoch 69/80
4800/4800 [=====] - 5s 945us/step - loss: 0.1029 - categorical_accuracy:
Epoch 70/80
4800/4800 [=====] - 5s 941us/step - loss: 0.1141 - categorical_accuracy:
Epoch 71/80
4800/4800 [=====] - 5s 942us/step - loss: 0.1092 - categorical_accuracy:
Epoch 72/80
4800/4800 [=====] - 5s 944us/step - loss: 0.1205 - categorical_accuracy:
Epoch 73/80
4800/4800 [=====] - 5s 941us/step - loss: 0.1041 - categorical_accuracy:
Epoch 74/80
4800/4800 [=====] - 5s 942us/step - loss: 0.0936 - categorical_accuracy:
Epoch 75/80
4800/4800 [=====] - 5s 942us/step - loss: 0.1060 - categorical_accuracy:
Epoch 76/80
4800/4800 [=====] - 5s 989us/step - loss: 0.1036 - categorical_accuracy:
Epoch 77/80
4800/4800 [=====] - 5s 977us/step - loss: 0.1031 - categorical_accuracy:
Epoch 78/80
4800/4800 [=====] - 5s 962us/step - loss: 0.1230 - categorical_accuracy:
Epoch 79/80
4800/4800 [=====] - 5s 953us/step - loss: 0.0948 - categorical_accuracy:
Epoch 80/80
4800/4800 [=====] - 5s 954us/step - loss: 0.0962 - categorical_accuracy:
2400/2400 [=====] - 2s 713us/step
categorical_accuracy: 96.17%

```

...

Cross validation fold [3]

...

Train on 4800 samples, validate on 2400 samples

```

Epoch 1/80
4800/4800 [=====] - 7s 1ms/step - loss: 2.1830 - categorical_accuracy:
Epoch 2/80
4800/4800 [=====] - 5s 949us/step - loss: 1.9579 - categorical_accuracy:
Epoch 3/80
4800/4800 [=====] - 5s 953us/step - loss: 1.8085 - categorical_accuracy:
Epoch 4/80

```

4800/4800 [=====] - 5s 951us/step - loss: 1.6135 - categorical\_accuracy:  
 Epoch 5/80  
 4800/4800 [=====] - 5s 948us/step - loss: 1.4452 - categorical\_accuracy:  
 Epoch 6/80  
 4800/4800 [=====] - 5s 982us/step - loss: 1.3393 - categorical\_accuracy:  
 Epoch 7/80  
 4800/4800 [=====] - 5s 969us/step - loss: 1.1629 - categorical\_accuracy:  
 Epoch 8/80  
 4800/4800 [=====] - 5s 986us/step - loss: 1.1794 - categorical\_accuracy:  
 Epoch 9/80  
 4800/4800 [=====] - 5s 958us/step - loss: 1.0612 - categorical\_accuracy:  
 Epoch 10/80  
 4800/4800 [=====] - 5s 967us/step - loss: 0.9590 - categorical\_accuracy:  
 Epoch 11/80  
 4800/4800 [=====] - 5s 957us/step - loss: 0.8717 - categorical\_accuracy:  
 Epoch 12/80  
 4800/4800 [=====] - 5s 978us/step - loss: 0.7534 - categorical\_accuracy:  
 Epoch 13/80  
 4800/4800 [=====] - 5s 946us/step - loss: 0.7141 - categorical\_accuracy:  
 Epoch 14/80  
 4800/4800 [=====] - 5s 951us/step - loss: 0.6481 - categorical\_accuracy:  
 Epoch 15/80  
 4800/4800 [=====] - 5s 976us/step - loss: 0.5777 - categorical\_accuracy:  
 Epoch 16/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.5325 - categorical\_accuracy:  
 Epoch 17/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.5051 - categorical\_accuracy:  
 Epoch 18/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.4521 - categorical\_accuracy:  
 Epoch 19/80  
 4800/4800 [=====] - 5s 984us/step - loss: 0.4160 - categorical\_accuracy:  
 Epoch 20/80  
 4800/4800 [=====] - 5s 962us/step - loss: 0.4229 - categorical\_accuracy:  
 Epoch 21/80  
 4800/4800 [=====] - 5s 954us/step - loss: 0.3686 - categorical\_accuracy:  
 Epoch 22/80  
 4800/4800 [=====] - 5s 965us/step - loss: 0.3520 - categorical\_accuracy:  
 Epoch 23/80  
 4800/4800 [=====] - 5s 947us/step - loss: 0.3163 - categorical\_accuracy:  
 Epoch 24/80  
 4800/4800 [=====] - 5s 966us/step - loss: 0.3054 - categorical\_accuracy:  
 Epoch 25/80  
 4800/4800 [=====] - 5s 979us/step - loss: 0.3002 - categorical\_accuracy:  
 Epoch 26/80  
 4800/4800 [=====] - 5s 959us/step - loss: 0.3036 - categorical\_accuracy:  
 Epoch 27/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.2799 - categorical\_accuracy:  
 Epoch 28/80

4800/4800 [=====] - 5s 972us/step - loss: 0.2632 - categorical\_accuracy:  
 Epoch 29/80  
 4800/4800 [=====] - 5s 979us/step - loss: 0.2460 - categorical\_accuracy:  
 Epoch 30/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.2226 - categorical\_accuracy:  
 Epoch 31/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.2293 - categorical\_accuracy:  
 Epoch 32/80  
 4800/4800 [=====] - 5s 941us/step - loss: 0.2055 - categorical\_accuracy:  
 Epoch 33/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.2287 - categorical\_accuracy:  
 Epoch 34/80  
 4800/4800 [=====] - 5s 1ms/step - loss: 0.2179 - categorical\_accuracy:  
 Epoch 35/80  
 4800/4800 [=====] - 5s 953us/step - loss: 0.2085 - categorical\_accuracy:  
 Epoch 36/80  
 4800/4800 [=====] - 5s 938us/step - loss: 0.1810 - categorical\_accuracy:  
 Epoch 37/80  
 4800/4800 [=====] - 5s 947us/step - loss: 0.2002 - categorical\_accuracy:  
 Epoch 38/80  
 4800/4800 [=====] - 5s 967us/step - loss: 0.1890 - categorical\_accuracy:  
 Epoch 39/80  
 4800/4800 [=====] - 5s 990us/step - loss: 0.1913 - categorical\_accuracy:  
 Epoch 40/80  
 4800/4800 [=====] - 5s 956us/step - loss: 0.1911 - categorical\_accuracy:  
 Epoch 41/80  
 4800/4800 [=====] - 5s 977us/step - loss: 0.1857 - categorical\_accuracy:  
 Epoch 42/80  
 4800/4800 [=====] - 5s 982us/step - loss: 0.1885 - categorical\_accuracy:  
 Epoch 43/80  
 4800/4800 [=====] - 5s 954us/step - loss: 0.1620 - categorical\_accuracy:  
 Epoch 44/80  
 4800/4800 [=====] - 5s 958us/step - loss: 0.1708 - categorical\_accuracy:  
 Epoch 45/80  
 4800/4800 [=====] - 5s 958us/step - loss: 0.1632 - categorical\_accuracy:  
 Epoch 46/80  
 4800/4800 [=====] - 5s 958us/step - loss: 0.1586 - categorical\_accuracy:  
 Epoch 47/80  
 4800/4800 [=====] - 5s 947us/step - loss: 0.1751 - categorical\_accuracy:  
 Epoch 48/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.1641 - categorical\_accuracy:  
 Epoch 49/80  
 4800/4800 [=====] - 5s 949us/step - loss: 0.1607 - categorical\_accuracy:  
 Epoch 50/80  
 4800/4800 [=====] - 5s 966us/step - loss: 0.1361 - categorical\_accuracy:  
 Epoch 51/80  
 4800/4800 [=====] - 5s 962us/step - loss: 0.1480 - categorical\_accuracy:  
 Epoch 52/80



4800/4800 [=====] - 5s 975us/step - loss: 0.1531 - categorical\_accuracy:  
Epoch 53/80  
4800/4800 [=====] - 5s 955us/step - loss: 0.1411 - categorical\_accuracy:  
Epoch 54/80  
4800/4800 [=====] - 5s 958us/step - loss: 0.1506 - categorical\_accuracy:  
Epoch 55/80  
4800/4800 [=====] - 5s 979us/step - loss: 0.1459 - categorical\_accuracy:  
Epoch 56/80  
4800/4800 [=====] - 5s 1ms/step - loss: 0.1376 - categorical\_accuracy:  
Epoch 57/80  
4800/4800 [=====] - 5s 1ms/step - loss: 0.1448 - categorical\_accuracy:  
Epoch 58/80  
4800/4800 [=====] - 5s 992us/step - loss: 0.1297 - categorical\_accuracy:  
Epoch 59/80  
4800/4800 [=====] - 5s 979us/step - loss: 0.1426 - categorical\_accuracy:  
Epoch 60/80  
4800/4800 [=====] - 5s 1ms/step - loss: 0.1380 - categorical\_accuracy:  
Epoch 61/80  
4800/4800 [=====] - 5s 1ms/step - loss: 0.1396 - categorical\_accuracy:  
Epoch 62/80  
4800/4800 [=====] - 5s 956us/step - loss: 0.1268 - categorical\_accuracy:  
Epoch 63/80  
4800/4800 [=====] - 5s 948us/step - loss: 0.1188 - categorical\_accuracy:  
Epoch 64/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.1218 - categorical\_accuracy:  
Epoch 65/80  
4800/4800 [=====] - 5s 947us/step - loss: 0.1384 - categorical\_accuracy:  
Epoch 66/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.1143 - categorical\_accuracy:  
Epoch 67/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.1268 - categorical\_accuracy:  
Epoch 68/80  
4800/4800 [=====] - 5s 952us/step - loss: 0.1228 - categorical\_accuracy:  
Epoch 69/80  
4800/4800 [=====] - 5s 951us/step - loss: 0.1139 - categorical\_accuracy:  
Epoch 70/80  
4800/4800 [=====] - 5s 959us/step - loss: 0.1154 - categorical\_accuracy:  
Epoch 71/80  
4800/4800 [=====] - 5s 977us/step - loss: 0.1019 - categorical\_accuracy:  
Epoch 72/80  
4800/4800 [=====] - 5s 948us/step - loss: 0.1079 - categorical\_accuracy:  
Epoch 73/80  
4800/4800 [=====] - 5s 949us/step - loss: 0.1102 - categorical\_accuracy:  
Epoch 74/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.1013 - categorical\_accuracy:  
Epoch 75/80  
4800/4800 [=====] - 5s 950us/step - loss: 0.1202 - categorical\_accuracy:  
Epoch 76/80

```

4800/4800 [=====] - 5s 948us/step - loss: 0.1155 - categorical_accuracy:
Epoch 77/80
4800/4800 [=====] - 5s 948us/step - loss: 0.1180 - categorical_accuracy:
Epoch 78/80
4800/4800 [=====] - 4s 935us/step - loss: 0.1041 - categorical_accuracy:
Epoch 79/80
4800/4800 [=====] - 4s 936us/step - loss: 0.1076 - categorical_accuracy:
Epoch 80/80
4800/4800 [=====] - 4s 934us/step - loss: 0.1099 - categorical_accuracy:
2400/2400 [=====] - 2s 712us/step
categorical_accuracy: 92.46%
94.14% (+/- 1.53%)

```

```

Out[11]: [93.791666666666657, 96.166666666666671, 92.458333333333329]

```

### # Regularized Deep Bidirectional LSTM

```

In [10]: PARAM_NUM_EPOCHS = 40
        PARAM_BATCH_SIZE = 300

        from models.regularized_deep_bidirectional_lstm import RegularizedDeepBidirectionalLSTM
        from utils.evaluation import cross_validate_model

        mymodel = RegularizedDeepBidirectionalLSTM(X_train.shape[1:])
        mymodel.batch_size = PARAM_BATCH_SIZE
        mymodel.num_epochs = PARAM_NUM_EPOCHS

        cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)

Using TensorFlow backend.

...
Cross validation fold [1]
...

Train on 4800 samples, validate on 2400 samples
Epoch 1/40
4800/4800 [=====] - 13s 3ms/step - loss: 2.0170 - categorical_accuracy:
Epoch 2/40
4800/4800 [=====] - 11s 2ms/step - loss: 1.4302 - categorical_accuracy:
Epoch 3/40
4800/4800 [=====] - 11s 2ms/step - loss: 1.1046 - categorical_accuracy:
Epoch 4/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.8992 - categorical_accuracy:

```

Epoch 5/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.8101 - categorical\_accuracy:  
Epoch 6/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.6622 - categorical\_accuracy:  
Epoch 7/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.6000 - categorical\_accuracy:  
Epoch 8/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.5330 - categorical\_accuracy:  
Epoch 9/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.5193 - categorical\_accuracy:  
Epoch 10/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.4888 - categorical\_accuracy:  
Epoch 11/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.4285 - categorical\_accuracy:  
Epoch 12/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.3879 - categorical\_accuracy:  
Epoch 13/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.3184 - categorical\_accuracy:  
Epoch 14/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2721 - categorical\_accuracy:  
Epoch 15/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2595 - categorical\_accuracy:  
Epoch 16/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2002 - categorical\_accuracy:  
Epoch 17/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1791 - categorical\_accuracy:  
Epoch 18/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1673 - categorical\_accuracy:  
Epoch 19/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1652 - categorical\_accuracy:  
Epoch 20/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1408 - categorical\_accuracy:  
Epoch 21/40  
4800/4800 [=====] - 12s 2ms/step - loss: 0.1260 - categorical\_accuracy:  
Epoch 22/40  
4800/4800 [=====] - 12s 2ms/step - loss: 0.1180 - categorical\_accuracy:  
Epoch 23/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1144 - categorical\_accuracy:  
Epoch 24/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1072 - categorical\_accuracy:  
Epoch 25/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1072 - categorical\_accuracy:  
Epoch 26/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0886 - categorical\_accuracy:  
Epoch 27/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0822 - categorical\_accuracy:  
Epoch 28/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0861 - categorical\_accuracy:

```

Epoch 29/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0880 - categorical_accuracy:
Epoch 30/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0831 - categorical_accuracy:
Epoch 31/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0780 - categorical_accuracy:
Epoch 32/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0674 - categorical_accuracy:
Epoch 33/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0720 - categorical_accuracy:
Epoch 34/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0637 - categorical_accuracy:
Epoch 35/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0712 - categorical_accuracy:
Epoch 36/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0579 - categorical_accuracy:
Epoch 37/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0656 - categorical_accuracy:
Epoch 38/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0632 - categorical_accuracy:
Epoch 39/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0450 - categorical_accuracy:
Epoch 40/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0465 - categorical_accuracy:
2400/2400 [=====] - 3s 1ms/step
categorical_accuracy: 93.92%

```

```

...
Cross validation fold [2]
...

```

```

Train on 4800 samples, validate on 2400 samples
Epoch 1/40
4800/4800 [=====] - 13s 3ms/step - loss: 2.0206 - categorical_accuracy:
Epoch 2/40
4800/4800 [=====] - 12s 2ms/step - loss: 1.4606 - categorical_accuracy:
Epoch 3/40
4800/4800 [=====] - 11s 2ms/step - loss: 1.1110 - categorical_accuracy:
Epoch 4/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.9440 - categorical_accuracy:
Epoch 5/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.8061 - categorical_accuracy:
Epoch 6/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.6951 - categorical_accuracy:
Epoch 7/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.6634 - categorical_accuracy:
Epoch 8/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.5516 - categorical_accuracy:

```

Epoch 9/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.5350 - categorical\_accuracy:  
Epoch 10/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.4867 - categorical\_accuracy:  
Epoch 11/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.4387 - categorical\_accuracy:  
Epoch 12/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.3949 - categorical\_accuracy:  
Epoch 13/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.3486 - categorical\_accuracy:  
Epoch 14/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2920 - categorical\_accuracy:  
Epoch 15/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2446 - categorical\_accuracy:  
Epoch 16/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2209 - categorical\_accuracy:  
Epoch 17/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2074 - categorical\_accuracy:  
Epoch 18/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1865 - categorical\_accuracy:  
Epoch 19/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1612 - categorical\_accuracy:  
Epoch 20/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1409 - categorical\_accuracy:  
Epoch 21/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1365 - categorical\_accuracy:  
Epoch 22/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1351 - categorical\_accuracy:  
Epoch 23/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1167 - categorical\_accuracy:  
Epoch 24/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1200 - categorical\_accuracy:  
Epoch 25/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1084 - categorical\_accuracy:  
Epoch 26/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0938 - categorical\_accuracy:  
Epoch 27/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0926 - categorical\_accuracy:  
Epoch 28/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1041 - categorical\_accuracy:  
Epoch 29/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0829 - categorical\_accuracy:  
Epoch 30/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0882 - categorical\_accuracy:  
Epoch 31/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0708 - categorical\_accuracy:  
Epoch 32/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0780 - categorical\_accuracy:

```

Epoch 33/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0680 - categorical_accuracy:
Epoch 34/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0762 - categorical_accuracy:
Epoch 35/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0776 - categorical_accuracy:
Epoch 36/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0669 - categorical_accuracy:
Epoch 37/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0637 - categorical_accuracy:
Epoch 38/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0681 - categorical_accuracy:
Epoch 39/40
4800/4800 [=====] - 12s 2ms/step - loss: 0.0726 - categorical_accuracy:
Epoch 40/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0574 - categorical_accuracy:
2400/2400 [=====] - 3s 1ms/step
categorical_accuracy: 96.50%

```

```

...
Cross validation fold [3]
...

```

```

Train on 4800 samples, validate on 2400 samples
Epoch 1/40
4800/4800 [=====] - 14s 3ms/step - loss: 1.9929 - categorical_accuracy:
Epoch 2/40
4800/4800 [=====] - 11s 2ms/step - loss: 1.4009 - categorical_accuracy:
Epoch 3/40
4800/4800 [=====] - 11s 2ms/step - loss: 1.0756 - categorical_accuracy:
Epoch 4/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.9023 - categorical_accuracy:
Epoch 5/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.7794 - categorical_accuracy:
Epoch 6/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.6902 - categorical_accuracy:
Epoch 7/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.5844 - categorical_accuracy:
Epoch 8/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.5503 - categorical_accuracy:
Epoch 9/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.4954 - categorical_accuracy:
Epoch 10/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.4274 - categorical_accuracy:
Epoch 11/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.3723 - categorical_accuracy:
Epoch 12/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.3634 - categorical_accuracy:

```

Epoch 13/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.3053 - categorical\_accuracy:  
Epoch 14/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2544 - categorical\_accuracy:  
Epoch 15/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2085 - categorical\_accuracy:  
Epoch 16/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.2006 - categorical\_accuracy:  
Epoch 17/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1797 - categorical\_accuracy:  
Epoch 18/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1571 - categorical\_accuracy:  
Epoch 19/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1499 - categorical\_accuracy:  
Epoch 20/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1433 - categorical\_accuracy:  
Epoch 21/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1312 - categorical\_accuracy:  
Epoch 22/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1206 - categorical\_accuracy:  
Epoch 23/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1105 - categorical\_accuracy:  
Epoch 24/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1143 - categorical\_accuracy:  
Epoch 25/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1036 - categorical\_accuracy:  
Epoch 26/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.1101 - categorical\_accuracy:  
Epoch 27/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0972 - categorical\_accuracy:  
Epoch 28/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0816 - categorical\_accuracy:  
Epoch 29/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0867 - categorical\_accuracy:  
Epoch 30/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0723 - categorical\_accuracy:  
Epoch 31/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0805 - categorical\_accuracy:  
Epoch 32/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0786 - categorical\_accuracy:  
Epoch 33/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0788 - categorical\_accuracy:  
Epoch 34/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0809 - categorical\_accuracy:  
Epoch 35/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0752 - categorical\_accuracy:  
Epoch 36/40  
4800/4800 [=====] - 11s 2ms/step - loss: 0.0675 - categorical\_accuracy:

```

Epoch 37/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0583 - categorical_accuracy:
Epoch 38/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0715 - categorical_accuracy:
Epoch 39/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0707 - categorical_accuracy:
Epoch 40/40
4800/4800 [=====] - 11s 2ms/step - loss: 0.0671 - categorical_accuracy:
2400/2400 [=====] - 3s 1ms/step
categorical_accuracy: 93.75%
94.72% (+/- 1.26%)

```

```

Out[10]: [93.916666666666671, 96.5, 93.75]

```

### # Regularized 1024 GRU

```

In [14]: PARAM_NUM_EPOCHS = 20
        PARAM_BATCH_SIZE = 300

        from models.regularized_1024_gru import Regularized1024GRU
        from utils.evaluation import cross_validate_model

        mymodel = Regularized1024GRU(X_train.shape[1:])
        mymodel.batch_size = PARAM_BATCH_SIZE
        mymodel.num_epochs = PARAM_NUM_EPOCHS

        cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)

...
Cross validation fold [1]
...

Train on 4800 samples, validate on 2400 samples
Epoch 1/20
4800/4800 [=====] - 13s 3ms/step - loss: 2.0314 - categorical_accuracy:
Epoch 2/20
4800/4800 [=====] - 10s 2ms/step - loss: 1.5816 - categorical_accuracy:
Epoch 3/20
4800/4800 [=====] - 10s 2ms/step - loss: 1.1800 - categorical_accuracy:
Epoch 4/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.8433 - categorical_accuracy:
Epoch 5/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.5726 - categorical_accuracy:
Epoch 6/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.4468 - categorical_accuracy:

```



```

Epoch 7/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.2480 - categorical_accuracy:
Epoch 8/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.1555 - categorical_accuracy:
Epoch 9/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.1169 - categorical_accuracy:
Epoch 10/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0993 - categorical_accuracy:
Epoch 11/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0934 - categorical_accuracy:
Epoch 12/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0585 - categorical_accuracy:
Epoch 13/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0578 - categorical_accuracy:
Epoch 14/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0415 - categorical_accuracy:
Epoch 15/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0362 - categorical_accuracy:
Epoch 16/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0300 - categorical_accuracy:
Epoch 17/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0247 - categorical_accuracy:
Epoch 18/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0298 - categorical_accuracy:
Epoch 19/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0221 - categorical_accuracy:
Epoch 20/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0215 - categorical_accuracy:
2400/2400 [=====] - 2s 926us/step
categorical_accuracy: 94.08%

```

```

...
Cross validation fold [2]
...

```

```

Train on 4800 samples, validate on 2400 samples
Epoch 1/20
4800/4800 [=====] - 13s 3ms/step - loss: 2.0475 - categorical_accuracy:
Epoch 2/20
4800/4800 [=====] - 10s 2ms/step - loss: 1.6984 - categorical_accuracy:
Epoch 3/20
4800/4800 [=====] - 10s 2ms/step - loss: 1.3379 - categorical_accuracy:
Epoch 4/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.9131 - categorical_accuracy:
Epoch 5/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.5871 - categorical_accuracy:
Epoch 6/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.4153 - categorical_accuracy:

```

```

Epoch 7/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.2591 - categorical_accuracy:
Epoch 8/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.1811 - categorical_accuracy:
Epoch 9/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.1428 - categorical_accuracy:
Epoch 10/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.1243 - categorical_accuracy:
Epoch 11/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0911 - categorical_accuracy:
Epoch 12/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0734 - categorical_accuracy:
Epoch 13/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0665 - categorical_accuracy:
Epoch 14/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0728 - categorical_accuracy:
Epoch 15/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0505 - categorical_accuracy:
Epoch 16/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0383 - categorical_accuracy:
Epoch 17/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0258 - categorical_accuracy:
Epoch 18/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0245 - categorical_accuracy:
Epoch 19/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0163 - categorical_accuracy:
Epoch 20/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0155 - categorical_accuracy:
2400/2400 [=====] - 2s 919us/step
categorical_accuracy: 95.12%

```

```

...
Cross validation fold [3]
...

```

```

Train on 4800 samples, validate on 2400 samples
Epoch 1/20
4800/4800 [=====] - 13s 3ms/step - loss: 2.0211 - categorical_accuracy:
Epoch 2/20
4800/4800 [=====] - 10s 2ms/step - loss: 1.5902 - categorical_accuracy:
Epoch 3/20
4800/4800 [=====] - 10s 2ms/step - loss: 1.2645 - categorical_accuracy:
Epoch 4/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.8347 - categorical_accuracy:
Epoch 5/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.7516 - categorical_accuracy:
Epoch 6/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.4835 - categorical_accuracy:

```

```

Epoch 7/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.3262 - categorical_accuracy:
Epoch 8/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.2089 - categorical_accuracy:
Epoch 9/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.1691 - categorical_accuracy:
Epoch 10/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.1204 - categorical_accuracy:
Epoch 11/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.1058 - categorical_accuracy:
Epoch 12/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0893 - categorical_accuracy:
Epoch 13/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0683 - categorical_accuracy:
Epoch 14/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0616 - categorical_accuracy:
Epoch 15/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0505 - categorical_accuracy:
Epoch 16/20
4800/4800 [=====] - 11s 2ms/step - loss: 0.0458 - categorical_accuracy:
Epoch 17/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0494 - categorical_accuracy:
Epoch 18/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0499 - categorical_accuracy:
Epoch 19/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0314 - categorical_accuracy:
Epoch 20/20
4800/4800 [=====] - 10s 2ms/step - loss: 0.0269 - categorical_accuracy:
2400/2400 [=====] - 2s 913us/step
categorical_accuracy: 93.83%
94.35% (+/- 0.56%)

```

```
Out[14]: [94.083333333333329, 95.125, 93.833333333333329]
```

### # Regularized 64 GRU

```

In [10]: PARAM_NUM_EPOCHS = 80
        PARAM_BATCH_SIZE = 300

        from models.regularized_64_gru import Regularized64GRU
        from utils.evaluation import cross_validate_model

        mymodel = Regularized64GRU(X_train.shape[1:])
        mymodel.batch_size = PARAM_BATCH_SIZE
        mymodel.num_epochs = PARAM_NUM_EPOCHS

```

```
cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)
```

Using TensorFlow backend.

...

Cross validation fold [1]

...

Train on 4800 samples, validate on 2400 samples

Epoch 1/80

4800/4800 [=====] - 2s 482us/step - loss: 2.2321 - categorical\_accuracy

Epoch 2/80

4800/4800 [=====] - 1s 255us/step - loss: 2.0600 - categorical\_accuracy

Epoch 3/80

4800/4800 [=====] - 1s 254us/step - loss: 1.8150 - categorical\_accuracy

Epoch 4/80

4800/4800 [=====] - 1s 256us/step - loss: 1.5284 - categorical\_accuracy

Epoch 5/80

4800/4800 [=====] - 1s 257us/step - loss: 1.2856 - categorical\_accuracy

Epoch 6/80

4800/4800 [=====] - 1s 260us/step - loss: 1.0693 - categorical\_accuracy

Epoch 7/80

4800/4800 [=====] - 1s 260us/step - loss: 0.8738 - categorical\_accuracy

Epoch 8/80

4800/4800 [=====] - 1s 261us/step - loss: 0.6847 - categorical\_accuracy

Epoch 9/80

4800/4800 [=====] - 1s 258us/step - loss: 0.5887 - categorical\_accuracy

Epoch 10/80

4800/4800 [=====] - 1s 259us/step - loss: 0.4553 - categorical\_accuracy

Epoch 11/80

4800/4800 [=====] - 1s 259us/step - loss: 0.3746 - categorical\_accuracy

Epoch 12/80

4800/4800 [=====] - 1s 261us/step - loss: 0.3526 - categorical\_accuracy

Epoch 13/80

4800/4800 [=====] - 1s 260us/step - loss: 0.2925 - categorical\_accuracy

Epoch 14/80

4800/4800 [=====] - 1s 258us/step - loss: 0.2644 - categorical\_accuracy

Epoch 15/80

4800/4800 [=====] - 1s 266us/step - loss: 0.2429 - categorical\_accuracy

Epoch 16/80

4800/4800 [=====] - 1s 258us/step - loss: 0.2120 - categorical\_accuracy

Epoch 17/80

4800/4800 [=====] - 1s 262us/step - loss: 0.2046 - categorical\_accuracy

Epoch 18/80

4800/4800 [=====] - 1s 263us/step - loss: 0.1844 - categorical\_accuracy

Epoch 19/80

4800/4800 [=====] - 1s 262us/step - loss: 0.1745 - categorical\_accuracy  
 Epoch 20/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.1710 - categorical\_accuracy  
 Epoch 21/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.1602 - categorical\_accuracy  
 Epoch 22/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.1528 - categorical\_accuracy  
 Epoch 23/80  
 4800/4800 [=====] - 1s 264us/step - loss: 0.1486 - categorical\_accuracy  
 Epoch 24/80  
 4800/4800 [=====] - 1s 263us/step - loss: 0.1418 - categorical\_accuracy  
 Epoch 25/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.1314 - categorical\_accuracy  
 Epoch 26/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.1324 - categorical\_accuracy  
 Epoch 27/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.1167 - categorical\_accuracy  
 Epoch 28/80  
 4800/4800 [=====] - 1s 258us/step - loss: 0.1173 - categorical\_accuracy  
 Epoch 29/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.1112 - categorical\_accuracy  
 Epoch 30/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.1165 - categorical\_accuracy  
 Epoch 31/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.1049 - categorical\_accuracy  
 Epoch 32/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.1139 - categorical\_accuracy  
 Epoch 33/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.0910 - categorical\_accuracy  
 Epoch 34/80  
 4800/4800 [=====] - 1s 265us/step - loss: 0.0865 - categorical\_accuracy  
 Epoch 35/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.0931 - categorical\_accuracy  
 Epoch 36/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.0915 - categorical\_accuracy  
 Epoch 37/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.0821 - categorical\_accuracy  
 Epoch 38/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.0819 - categorical\_accuracy  
 Epoch 39/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.0786 - categorical\_accuracy  
 Epoch 40/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.0714 - categorical\_accuracy  
 Epoch 41/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.0735 - categorical\_accuracy  
 Epoch 42/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.0732 - categorical\_accuracy  
 Epoch 43/80

4800/4800 [=====] - 1s 262us/step - loss: 0.0676 - categorical\_accuracy  
Epoch 44/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0641 - categorical\_accuracy  
Epoch 45/80  
4800/4800 [=====] - 1s 258us/step - loss: 0.0673 - categorical\_accuracy  
Epoch 46/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0715 - categorical\_accuracy  
Epoch 47/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0722 - categorical\_accuracy  
Epoch 48/80  
4800/4800 [=====] - 1s 257us/step - loss: 0.0692 - categorical\_accuracy  
Epoch 49/80  
4800/4800 [=====] - 1s 255us/step - loss: 0.0664 - categorical\_accuracy  
Epoch 50/80  
4800/4800 [=====] - 1s 256us/step - loss: 0.0625 - categorical\_accuracy  
Epoch 51/80  
4800/4800 [=====] - 1s 258us/step - loss: 0.0580 - categorical\_accuracy  
Epoch 52/80  
4800/4800 [=====] - 1s 258us/step - loss: 0.0572 - categorical\_accuracy  
Epoch 53/80  
4800/4800 [=====] - 1s 256us/step - loss: 0.0540 - categorical\_accuracy  
Epoch 54/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0526 - categorical\_accuracy  
Epoch 55/80  
4800/4800 [=====] - 1s 256us/step - loss: 0.0515 - categorical\_accuracy  
Epoch 56/80  
4800/4800 [=====] - 1s 258us/step - loss: 0.0483 - categorical\_accuracy  
Epoch 57/80  
4800/4800 [=====] - 1s 256us/step - loss: 0.0572 - categorical\_accuracy  
Epoch 58/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0554 - categorical\_accuracy  
Epoch 59/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0625 - categorical\_accuracy  
Epoch 60/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0506 - categorical\_accuracy  
Epoch 61/80  
4800/4800 [=====] - 1s 261us/step - loss: 0.0535 - categorical\_accuracy  
Epoch 62/80  
4800/4800 [=====] - 1s 261us/step - loss: 0.0513 - categorical\_accuracy  
Epoch 63/80  
4800/4800 [=====] - 1s 258us/step - loss: 0.0436 - categorical\_accuracy  
Epoch 64/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0415 - categorical\_accuracy  
Epoch 65/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.0376 - categorical\_accuracy  
Epoch 66/80  
4800/4800 [=====] - 1s 258us/step - loss: 0.0566 - categorical\_accuracy  
Epoch 67/80

```

4800/4800 [=====] - 1s 259us/step - loss: 0.0449 - categorical_accuracy
Epoch 68/80
4800/4800 [=====] - 1s 261us/step - loss: 0.0446 - categorical_accuracy
Epoch 69/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0559 - categorical_accuracy
Epoch 70/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0590 - categorical_accuracy
Epoch 71/80
4800/4800 [=====] - 1s 260us/step - loss: 0.0541 - categorical_accuracy
Epoch 72/80
4800/4800 [=====] - 1s 262us/step - loss: 0.0569 - categorical_accuracy
Epoch 73/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0507 - categorical_accuracy
Epoch 74/80
4800/4800 [=====] - 1s 258us/step - loss: 0.0435 - categorical_accuracy
Epoch 75/80
4800/4800 [=====] - 1s 262us/step - loss: 0.0487 - categorical_accuracy
Epoch 76/80
4800/4800 [=====] - 1s 256us/step - loss: 0.0345 - categorical_accuracy
Epoch 77/80
4800/4800 [=====] - 1s 257us/step - loss: 0.0341 - categorical_accuracy
Epoch 78/80
4800/4800 [=====] - 1s 262us/step - loss: 0.0467 - categorical_accuracy
Epoch 79/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0457 - categorical_accuracy
Epoch 80/80
4800/4800 [=====] - 1s 261us/step - loss: 0.0355 - categorical_accuracy
2400/2400 [=====] - 1s 496us/step
categorical_accuracy: 94.08%

```

```

...
Cross validation fold [2]
...

```

```

Train on 4800 samples, validate on 2400 samples
Epoch 1/80
4800/4800 [=====] - 2s 419us/step - loss: 2.2232 - categorical_accuracy
Epoch 2/80
4800/4800 [=====] - 1s 265us/step - loss: 2.0744 - categorical_accuracy
Epoch 3/80
4800/4800 [=====] - 1s 260us/step - loss: 1.7908 - categorical_accuracy
Epoch 4/80
4800/4800 [=====] - 1s 263us/step - loss: 1.5146 - categorical_accuracy
Epoch 5/80
4800/4800 [=====] - 1s 266us/step - loss: 1.2715 - categorical_accuracy
Epoch 6/80
4800/4800 [=====] - 1s 257us/step - loss: 1.0812 - categorical_accuracy
Epoch 7/80

```

4800/4800 [=====] - 1s 262us/step - loss: 0.9353 - categorical\_accuracy  
 Epoch 8/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.7959 - categorical\_accuracy  
 Epoch 9/80  
 4800/4800 [=====] - 1s 265us/step - loss: 0.6560 - categorical\_accuracy  
 Epoch 10/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.6021 - categorical\_accuracy  
 Epoch 11/80  
 4800/4800 [=====] - 1s 265us/step - loss: 0.4838 - categorical\_accuracy  
 Epoch 12/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.4341 - categorical\_accuracy  
 Epoch 13/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.3549 - categorical\_accuracy  
 Epoch 14/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.3161 - categorical\_accuracy  
 Epoch 15/80  
 4800/4800 [=====] - 1s 269us/step - loss: 0.2851 - categorical\_accuracy  
 Epoch 16/80  
 4800/4800 [=====] - 1s 258us/step - loss: 0.2470 - categorical\_accuracy  
 Epoch 17/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.2459 - categorical\_accuracy  
 Epoch 18/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.2250 - categorical\_accuracy  
 Epoch 19/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.1984 - categorical\_accuracy  
 Epoch 20/80  
 4800/4800 [=====] - 1s 257us/step - loss: 0.2105 - categorical\_accuracy  
 Epoch 21/80  
 4800/4800 [=====] - 1s 257us/step - loss: 0.1856 - categorical\_accuracy  
 Epoch 22/80  
 4800/4800 [=====] - 1s 257us/step - loss: 0.1796 - categorical\_accuracy  
 Epoch 23/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.1700 - categorical\_accuracy  
 Epoch 24/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.1496 - categorical\_accuracy  
 Epoch 25/80  
 4800/4800 [=====] - 1s 264us/step - loss: 0.1434 - categorical\_accuracy  
 Epoch 26/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.1360 - categorical\_accuracy  
 Epoch 27/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.1296 - categorical\_accuracy  
 Epoch 28/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.1254 - categorical\_accuracy  
 Epoch 29/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.1233 - categorical\_accuracy  
 Epoch 30/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.1133 - categorical\_accuracy  
 Epoch 31/80



4800/4800 [=====] - 1s 263us/step - loss: 0.1112 - categorical\_accuracy  
Epoch 32/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.1076 - categorical\_accuracy  
Epoch 33/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.0992 - categorical\_accuracy  
Epoch 34/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.1012 - categorical\_accuracy  
Epoch 35/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0928 - categorical\_accuracy  
Epoch 36/80  
4800/4800 [=====] - 1s 269us/step - loss: 0.0861 - categorical\_accuracy  
Epoch 37/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0985 - categorical\_accuracy  
Epoch 38/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0765 - categorical\_accuracy  
Epoch 39/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0919 - categorical\_accuracy  
Epoch 40/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0876 - categorical\_accuracy  
Epoch 41/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0905 - categorical\_accuracy  
Epoch 42/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.0774 - categorical\_accuracy  
Epoch 43/80  
4800/4800 [=====] - 1s 265us/step - loss: 0.0869 - categorical\_accuracy  
Epoch 44/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0816 - categorical\_accuracy  
Epoch 45/80  
4800/4800 [=====] - 1s 264us/step - loss: 0.0709 - categorical\_accuracy  
Epoch 46/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0745 - categorical\_accuracy  
Epoch 47/80  
4800/4800 [=====] - 1s 263us/step - loss: 0.0622 - categorical\_accuracy  
Epoch 48/80  
4800/4800 [=====] - 1s 258us/step - loss: 0.0649 - categorical\_accuracy  
Epoch 49/80  
4800/4800 [=====] - 1s 261us/step - loss: 0.0612 - categorical\_accuracy  
Epoch 50/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0544 - categorical\_accuracy  
Epoch 51/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0628 - categorical\_accuracy  
Epoch 52/80  
4800/4800 [=====] - 1s 263us/step - loss: 0.0575 - categorical\_accuracy  
Epoch 53/80  
4800/4800 [=====] - 1s 264us/step - loss: 0.0630 - categorical\_accuracy  
Epoch 54/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0676 - categorical\_accuracy  
Epoch 55/80

4800/4800 [=====] - 1s 259us/step - loss: 0.0577 - categorical\_accuracy  
 Epoch 56/80  
 4800/4800 [=====] - 1s 258us/step - loss: 0.0583 - categorical\_accuracy  
 Epoch 57/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.0643 - categorical\_accuracy  
 Epoch 58/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.0585 - categorical\_accuracy  
 Epoch 59/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.0721 - categorical\_accuracy  
 Epoch 60/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.0613 - categorical\_accuracy  
 Epoch 61/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.0508 - categorical\_accuracy  
 Epoch 62/80  
 4800/4800 [=====] - 1s 258us/step - loss: 0.0444 - categorical\_accuracy  
 Epoch 63/80  
 4800/4800 [=====] - 1s 257us/step - loss: 0.0427 - categorical\_accuracy  
 Epoch 64/80  
 4800/4800 [=====] - 1s 258us/step - loss: 0.0395 - categorical\_accuracy  
 Epoch 65/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.0407 - categorical\_accuracy  
 Epoch 66/80  
 4800/4800 [=====] - 1s 264us/step - loss: 0.0307 - categorical\_accuracy  
 Epoch 67/80  
 4800/4800 [=====] - 1s 257us/step - loss: 0.0326 - categorical\_accuracy  
 Epoch 68/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.0350 - categorical\_accuracy  
 Epoch 69/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.0351 - categorical\_accuracy  
 Epoch 70/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.0413 - categorical\_accuracy  
 Epoch 71/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.0420 - categorical\_accuracy  
 Epoch 72/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.0508 - categorical\_accuracy  
 Epoch 73/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.0460 - categorical\_accuracy  
 Epoch 74/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.0449 - categorical\_accuracy  
 Epoch 75/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.0358 - categorical\_accuracy  
 Epoch 76/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.0474 - categorical\_accuracy  
 Epoch 77/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.0347 - categorical\_accuracy  
 Epoch 78/80  
 4800/4800 [=====] - 1s 266us/step - loss: 0.0375 - categorical\_accuracy  
 Epoch 79/80

```
4800/4800 [=====] - 1s 262us/step - loss: 0.0461 - categorical_accuracy
Epoch 80/80
4800/4800 [=====] - 1s 267us/step - loss: 0.0503 - categorical_accuracy
2400/2400 [=====] - 1s 515us/step
categorical_accuracy: 93.21%
```

```
...
Cross validation fold [3]
...
```

Train on 4800 samples, validate on 2400 samples

```
Epoch 1/80
4800/4800 [=====] - 2s 459us/step - loss: 2.2285 - categorical_accuracy
Epoch 2/80
4800/4800 [=====] - 1s 269us/step - loss: 2.0482 - categorical_accuracy
Epoch 3/80
4800/4800 [=====] - 1s 270us/step - loss: 1.8181 - categorical_accuracy
Epoch 4/80
4800/4800 [=====] - 1s 269us/step - loss: 1.5914 - categorical_accuracy
Epoch 5/80
4800/4800 [=====] - 1s 273us/step - loss: 1.3553 - categorical_accuracy
Epoch 6/80
4800/4800 [=====] - 1s 270us/step - loss: 1.1142 - categorical_accuracy
Epoch 7/80
4800/4800 [=====] - 1s 262us/step - loss: 0.9014 - categorical_accuracy
Epoch 8/80
4800/4800 [=====] - 1s 259us/step - loss: 0.7643 - categorical_accuracy
Epoch 9/80
4800/4800 [=====] - 1s 261us/step - loss: 0.6411 - categorical_accuracy
Epoch 10/80
4800/4800 [=====] - 1s 260us/step - loss: 0.5658 - categorical_accuracy
Epoch 11/80
4800/4800 [=====] - 1s 261us/step - loss: 0.4734 - categorical_accuracy
Epoch 12/80
4800/4800 [=====] - 1s 260us/step - loss: 0.4217 - categorical_accuracy
Epoch 13/80
4800/4800 [=====] - 1s 262us/step - loss: 0.3798 - categorical_accuracy
Epoch 14/80
4800/4800 [=====] - 1s 261us/step - loss: 0.3298 - categorical_accuracy
Epoch 15/80
4800/4800 [=====] - 1s 260us/step - loss: 0.3032 - categorical_accuracy
Epoch 16/80
4800/4800 [=====] - 1s 261us/step - loss: 0.3033 - categorical_accuracy
Epoch 17/80
4800/4800 [=====] - 1s 260us/step - loss: 0.2609 - categorical_accuracy
Epoch 18/80
4800/4800 [=====] - 1s 268us/step - loss: 0.2321 - categorical_accuracy
Epoch 19/80
```

4800/4800 [=====] - 1s 267us/step - loss: 0.2126 - categorical\_accuracy  
 Epoch 20/80  
 4800/4800 [=====] - 1s 263us/step - loss: 0.2012 - categorical\_accuracy  
 Epoch 21/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.2003 - categorical\_accuracy  
 Epoch 22/80  
 4800/4800 [=====] - 1s 264us/step - loss: 0.1703 - categorical\_accuracy  
 Epoch 23/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.1545 - categorical\_accuracy  
 Epoch 24/80  
 4800/4800 [=====] - 1s 264us/step - loss: 0.1499 - categorical\_accuracy  
 Epoch 25/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.1531 - categorical\_accuracy  
 Epoch 26/80  
 4800/4800 [=====] - 1s 260us/step - loss: 0.1478 - categorical\_accuracy  
 Epoch 27/80  
 4800/4800 [=====] - 1s 262us/step - loss: 0.1405 - categorical\_accuracy  
 Epoch 28/80  
 4800/4800 [=====] - 1s 261us/step - loss: 0.1341 - categorical\_accuracy  
 Epoch 29/80  
 4800/4800 [=====] - 1s 259us/step - loss: 0.1225 - categorical\_accuracy  
 Epoch 30/80  
 4800/4800 [=====] - 1s 257us/step - loss: 0.1159 - categorical\_accuracy  
 Epoch 31/80  
 4800/4800 [=====] - 1s 254us/step - loss: 0.1197 - categorical\_accuracy  
 Epoch 32/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.1149 - categorical\_accuracy  
 Epoch 33/80  
 4800/4800 [=====] - 1s 257us/step - loss: 0.1145 - categorical\_accuracy  
 Epoch 34/80  
 4800/4800 [=====] - 1s 255us/step - loss: 0.1069 - categorical\_accuracy  
 Epoch 35/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.0896 - categorical\_accuracy  
 Epoch 36/80  
 4800/4800 [=====] - 1s 255us/step - loss: 0.0966 - categorical\_accuracy  
 Epoch 37/80  
 4800/4800 [=====] - 1s 257us/step - loss: 0.0957 - categorical\_accuracy  
 Epoch 38/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.1010 - categorical\_accuracy  
 Epoch 39/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.0929 - categorical\_accuracy  
 Epoch 40/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.0926 - categorical\_accuracy  
 Epoch 41/80  
 4800/4800 [=====] - 1s 258us/step - loss: 0.0796 - categorical\_accuracy  
 Epoch 42/80  
 4800/4800 [=====] - 1s 256us/step - loss: 0.0770 - categorical\_accuracy  
 Epoch 43/80

4800/4800 [=====] - 1s 255us/step - loss: 0.0897 - categorical\_accuracy  
Epoch 44/80  
4800/4800 [=====] - 1s 255us/step - loss: 0.0864 - categorical\_accuracy  
Epoch 45/80  
4800/4800 [=====] - 1s 256us/step - loss: 0.1152 - categorical\_accuracy  
Epoch 46/80  
4800/4800 [=====] - 1s 255us/step - loss: 0.0827 - categorical\_accuracy  
Epoch 47/80  
4800/4800 [=====] - 1s 254us/step - loss: 0.0869 - categorical\_accuracy  
Epoch 48/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0720 - categorical\_accuracy  
Epoch 49/80  
4800/4800 [=====] - 1s 263us/step - loss: 0.0832 - categorical\_accuracy  
Epoch 50/80  
4800/4800 [=====] - 1s 269us/step - loss: 0.0624 - categorical\_accuracy  
Epoch 51/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0684 - categorical\_accuracy  
Epoch 52/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.0760 - categorical\_accuracy  
Epoch 53/80  
4800/4800 [=====] - 1s 258us/step - loss: 0.0684 - categorical\_accuracy  
Epoch 54/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.0565 - categorical\_accuracy  
Epoch 55/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0602 - categorical\_accuracy  
Epoch 56/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.0546 - categorical\_accuracy  
Epoch 57/80  
4800/4800 [=====] - 1s 264us/step - loss: 0.0535 - categorical\_accuracy  
Epoch 58/80  
4800/4800 [=====] - 1s 265us/step - loss: 0.0588 - categorical\_accuracy  
Epoch 59/80  
4800/4800 [=====] - 1s 259us/step - loss: 0.0497 - categorical\_accuracy  
Epoch 60/80  
4800/4800 [=====] - 1s 256us/step - loss: 0.0535 - categorical\_accuracy  
Epoch 61/80  
4800/4800 [=====] - 1s 260us/step - loss: 0.0593 - categorical\_accuracy  
Epoch 62/80  
4800/4800 [=====] - 1s 261us/step - loss: 0.0555 - categorical\_accuracy  
Epoch 63/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.0518 - categorical\_accuracy  
Epoch 64/80  
4800/4800 [=====] - 1s 262us/step - loss: 0.0442 - categorical\_accuracy  
Epoch 65/80  
4800/4800 [=====] - 1s 261us/step - loss: 0.0413 - categorical\_accuracy  
Epoch 66/80  
4800/4800 [=====] - 1s 268us/step - loss: 0.0519 - categorical\_accuracy  
Epoch 67/80

```

4800/4800 [=====] - 1s 260us/step - loss: 0.0413 - categorical_accuracy
Epoch 68/80
4800/4800 [=====] - 1s 257us/step - loss: 0.0434 - categorical_accuracy
Epoch 69/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0552 - categorical_accuracy
Epoch 70/80
4800/4800 [=====] - 1s 258us/step - loss: 0.0504 - categorical_accuracy
Epoch 71/80
4800/4800 [=====] - 1s 262us/step - loss: 0.0401 - categorical_accuracy
Epoch 72/80
4800/4800 [=====] - 1s 263us/step - loss: 0.0421 - categorical_accuracy
Epoch 73/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0344 - categorical_accuracy
Epoch 74/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0579 - categorical_accuracy
Epoch 75/80
4800/4800 [=====] - 1s 260us/step - loss: 0.0497 - categorical_accuracy
Epoch 76/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0387 - categorical_accuracy
Epoch 77/80
4800/4800 [=====] - 1s 266us/step - loss: 0.0415 - categorical_accuracy
Epoch 78/80
4800/4800 [=====] - 1s 258us/step - loss: 0.0445 - categorical_accuracy
Epoch 79/80
4800/4800 [=====] - 1s 257us/step - loss: 0.0380 - categorical_accuracy
Epoch 80/80
4800/4800 [=====] - 1s 259us/step - loss: 0.0444 - categorical_accuracy
2400/2400 [=====] - 1s 487us/step
categorical_accuracy: 95.29%
94.19% (+/- 0.85%)

```

```
Out[10]: [94.08333333333329, 93.20833333333343, 95.29166666666657]
```

---

### # Regularized 4x64 GRU

---

```

In [11]: PARAM_NUM_EPOCHS = 40
        PARAM_BATCH_SIZE = 300

        from models.regularized_4x64_gru import Regularized4x64GRU
        from utils.evaluation import cross_validate_model

        mymodel = Regularized4x64GRU(X_train.shape[1:])
        mymodel.batch_size = PARAM_BATCH_SIZE
        mymodel.num_epochs = PARAM_NUM_EPOCHS

        cross_validate_model(X_train, Y_train, mymodel, 3, RANDOM_STATE)

```

...

Cross validation fold [1]

...

Train on 4800 samples, validate on 2400 samples

Epoch 1/40

4800/4800 [=====] - 4s 821us/step - loss: 2.2662 - categorical\_accuracy

Epoch 2/40

4800/4800 [=====] - 2s 512us/step - loss: 2.1847 - categorical\_accuracy

Epoch 3/40

4800/4800 [=====] - 2s 502us/step - loss: 1.9920 - categorical\_accuracy

Epoch 4/40

4800/4800 [=====] - 2s 499us/step - loss: 1.6808 - categorical\_accuracy

Epoch 5/40

4800/4800 [=====] - 2s 508us/step - loss: 1.4076 - categorical\_accuracy

Epoch 6/40

4800/4800 [=====] - 2s 500us/step - loss: 1.2057 - categorical\_accuracy

Epoch 7/40

4800/4800 [=====] - 2s 502us/step - loss: 1.0510 - categorical\_accuracy

Epoch 8/40

4800/4800 [=====] - 2s 511us/step - loss: 0.8658 - categorical\_accuracy

Epoch 9/40

4800/4800 [=====] - 2s 509us/step - loss: 0.7238 - categorical\_accuracy

Epoch 10/40

4800/4800 [=====] - 2s 507us/step - loss: 0.5893 - categorical\_accuracy

Epoch 11/40

4800/4800 [=====] - 2s 502us/step - loss: 0.5049 - categorical\_accuracy

Epoch 12/40

4800/4800 [=====] - 2s 502us/step - loss: 0.4418 - categorical\_accuracy

Epoch 13/40

4800/4800 [=====] - 2s 508us/step - loss: 0.3819 - categorical\_accuracy

Epoch 14/40

4800/4800 [=====] - 2s 503us/step - loss: 0.3314 - categorical\_accuracy

Epoch 15/40

4800/4800 [=====] - 2s 502us/step - loss: 0.2886 - categorical\_accuracy

Epoch 16/40

4800/4800 [=====] - 2s 504us/step - loss: 0.2612 - categorical\_accuracy

Epoch 17/40

4800/4800 [=====] - 2s 501us/step - loss: 0.2508 - categorical\_accuracy

Epoch 18/40

4800/4800 [=====] - 2s 504us/step - loss: 0.2216 - categorical\_accuracy

Epoch 19/40

4800/4800 [=====] - 2s 504us/step - loss: 0.2002 - categorical\_accuracy

Epoch 20/40

4800/4800 [=====] - 2s 502us/step - loss: 0.1822 - categorical\_accuracy

Epoch 21/40

4800/4800 [=====] - 2s 501us/step - loss: 0.1842 - categorical\_accuracy

```

Epoch 22/40
4800/4800 [=====] - 2s 505us/step - loss: 0.1662 - categorical_accuracy
Epoch 23/40
4800/4800 [=====] - 2s 506us/step - loss: 0.1619 - categorical_accuracy
Epoch 24/40
4800/4800 [=====] - 2s 505us/step - loss: 0.1503 - categorical_accuracy
Epoch 25/40
4800/4800 [=====] - 2s 506us/step - loss: 0.1516 - categorical_accuracy
Epoch 26/40
4800/4800 [=====] - 2s 506us/step - loss: 0.1387 - categorical_accuracy
Epoch 27/40
4800/4800 [=====] - 2s 504us/step - loss: 0.1297 - categorical_accuracy
Epoch 28/40
4800/4800 [=====] - 2s 519us/step - loss: 0.1200 - categorical_accuracy
Epoch 29/40
4800/4800 [=====] - 2s 512us/step - loss: 0.1198 - categorical_accuracy
Epoch 30/40
4800/4800 [=====] - 2s 510us/step - loss: 0.1072 - categorical_accuracy
Epoch 31/40
4800/4800 [=====] - 2s 509us/step - loss: 0.1097 - categorical_accuracy
Epoch 32/40
4800/4800 [=====] - 2s 506us/step - loss: 0.1052 - categorical_accuracy
Epoch 33/40
4800/4800 [=====] - 3s 523us/step - loss: 0.0901 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 3s 522us/step - loss: 0.0910 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 2s 508us/step - loss: 0.0938 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 2s 507us/step - loss: 0.0847 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 2s 512us/step - loss: 0.0819 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 2s 512us/step - loss: 0.0764 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 2s 510us/step - loss: 0.0846 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 2s 513us/step - loss: 0.0877 - categorical_accuracy
2400/2400 [=====] - 2s 961us/step
categorical_accuracy: 94.33%

```

```

...
Cross validation fold [2]
...

```

Train on 4800 samples, validate on 2400 samples

```

Epoch 1/40
4800/4800 [=====] - 4s 869us/step - loss: 2.2599 - categorical_accuracy

```



Epoch 2/40  
4800/4800 [=====] - 2s 504us/step - loss: 2.0953 - categorical\_accuracy  
Epoch 3/40  
4800/4800 [=====] - 2s 501us/step - loss: 1.8910 - categorical\_accuracy  
Epoch 4/40  
4800/4800 [=====] - 2s 504us/step - loss: 1.6596 - categorical\_accuracy  
Epoch 5/40  
4800/4800 [=====] - 2s 502us/step - loss: 1.4087 - categorical\_accuracy  
Epoch 6/40  
4800/4800 [=====] - 2s 512us/step - loss: 1.1886 - categorical\_accuracy  
Epoch 7/40  
4800/4800 [=====] - 2s 508us/step - loss: 1.0201 - categorical\_accuracy  
Epoch 8/40  
4800/4800 [=====] - 2s 508us/step - loss: 0.8960 - categorical\_accuracy  
Epoch 9/40  
4800/4800 [=====] - 2s 502us/step - loss: 0.7566 - categorical\_accuracy  
Epoch 10/40  
4800/4800 [=====] - 2s 513us/step - loss: 0.6420 - categorical\_accuracy  
Epoch 11/40  
4800/4800 [=====] - 2s 509us/step - loss: 0.5529 - categorical\_accuracy  
Epoch 12/40  
4800/4800 [=====] - 2s 514us/step - loss: 0.4646 - categorical\_accuracy  
Epoch 13/40  
4800/4800 [=====] - 2s 509us/step - loss: 0.4069 - categorical\_accuracy  
Epoch 14/40  
4800/4800 [=====] - 2s 508us/step - loss: 0.3606 - categorical\_accuracy  
Epoch 15/40  
4800/4800 [=====] - 2s 520us/step - loss: 0.3127 - categorical\_accuracy  
Epoch 16/40  
4800/4800 [=====] - 2s 506us/step - loss: 0.2798 - categorical\_accuracy  
Epoch 17/40  
4800/4800 [=====] - 3s 522us/step - loss: 0.2558 - categorical\_accuracy  
Epoch 18/40  
4800/4800 [=====] - 3s 531us/step - loss: 0.2371 - categorical\_accuracy  
Epoch 19/40  
4800/4800 [=====] - 2s 520us/step - loss: 0.2118 - categorical\_accuracy  
Epoch 20/40  
4800/4800 [=====] - 3s 526us/step - loss: 0.2040 - categorical\_accuracy  
Epoch 21/40  
4800/4800 [=====] - 2s 518us/step - loss: 0.1795 - categorical\_accuracy  
Epoch 22/40  
4800/4800 [=====] - 2s 515us/step - loss: 0.1645 - categorical\_accuracy  
Epoch 23/40  
4800/4800 [=====] - 2s 507us/step - loss: 0.1592 - categorical\_accuracy  
Epoch 24/40  
4800/4800 [=====] - 2s 505us/step - loss: 0.1505 - categorical\_accuracy  
Epoch 25/40  
4800/4800 [=====] - 2s 503us/step - loss: 0.1399 - categorical\_accuracy

```

Epoch 26/40
4800/4800 [=====] - 2s 508us/step - loss: 0.1337 - categorical_accuracy
Epoch 27/40
4800/4800 [=====] - 2s 507us/step - loss: 0.1276 - categorical_accuracy
Epoch 28/40
4800/4800 [=====] - 2s 508us/step - loss: 0.1300 - categorical_accuracy
Epoch 29/40
4800/4800 [=====] - 2s 505us/step - loss: 0.1199 - categorical_accuracy
Epoch 30/40
4800/4800 [=====] - 2s 506us/step - loss: 0.1127 - categorical_accuracy
Epoch 31/40
4800/4800 [=====] - 2s 506us/step - loss: 0.1077 - categorical_accuracy
Epoch 32/40
4800/4800 [=====] - 2s 509us/step - loss: 0.1041 - categorical_accuracy
Epoch 33/40
4800/4800 [=====] - 2s 512us/step - loss: 0.1033 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 2s 511us/step - loss: 0.0958 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 2s 508us/step - loss: 0.1001 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 2s 510us/step - loss: 0.0883 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 2s 509us/step - loss: 0.0863 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 2s 508us/step - loss: 0.0890 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 2s 516us/step - loss: 0.0822 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 2s 511us/step - loss: 0.0810 - categorical_accuracy
2400/2400 [=====] - 2s 945us/step
categorical_accuracy: 94.25%

```

```

...
Cross validation fold [3]
...

```

```

Train on 4800 samples, validate on 2400 samples
Epoch 1/40
4800/4800 [=====] - 4s 915us/step - loss: 2.2675 - categorical_accuracy
Epoch 2/40
4800/4800 [=====] - 2s 505us/step - loss: 2.1679 - categorical_accuracy
Epoch 3/40
4800/4800 [=====] - 2s 504us/step - loss: 2.0176 - categorical_accuracy
Epoch 4/40
4800/4800 [=====] - 2s 504us/step - loss: 1.7466 - categorical_accuracy
Epoch 5/40
4800/4800 [=====] - 2s 510us/step - loss: 1.5157 - categorical_accuracy

```

Epoch 6/40  
4800/4800 [=====] - 2s 505us/step - loss: 1.3056 - categorical\_accuracy  
Epoch 7/40  
4800/4800 [=====] - 2s 504us/step - loss: 1.1314 - categorical\_accuracy  
Epoch 8/40  
4800/4800 [=====] - 2s 505us/step - loss: 1.0021 - categorical\_accuracy  
Epoch 9/40  
4800/4800 [=====] - 2s 506us/step - loss: 0.8587 - categorical\_accuracy  
Epoch 10/40  
4800/4800 [=====] - 2s 503us/step - loss: 0.7323 - categorical\_accuracy  
Epoch 11/40  
4800/4800 [=====] - 2s 501us/step - loss: 0.6230 - categorical\_accuracy  
Epoch 12/40  
4800/4800 [=====] - 2s 502us/step - loss: 0.5255 - categorical\_accuracy  
Epoch 13/40  
4800/4800 [=====] - 2s 504us/step - loss: 0.4514 - categorical\_accuracy  
Epoch 14/40  
4800/4800 [=====] - 2s 514us/step - loss: 0.3932 - categorical\_accuracy  
Epoch 15/40  
4800/4800 [=====] - 2s 501us/step - loss: 0.3339 - categorical\_accuracy  
Epoch 16/40  
4800/4800 [=====] - 2s 501us/step - loss: 0.2952 - categorical\_accuracy  
Epoch 17/40  
4800/4800 [=====] - 2s 503us/step - loss: 0.2596 - categorical\_accuracy  
Epoch 18/40  
4800/4800 [=====] - 2s 501us/step - loss: 0.2317 - categorical\_accuracy  
Epoch 19/40  
4800/4800 [=====] - 2s 498us/step - loss: 0.2104 - categorical\_accuracy  
Epoch 20/40  
4800/4800 [=====] - 2s 498us/step - loss: 0.2075 - categorical\_accuracy  
Epoch 21/40  
4800/4800 [=====] - 2s 499us/step - loss: 0.1864 - categorical\_accuracy  
Epoch 22/40  
4800/4800 [=====] - 2s 500us/step - loss: 0.1731 - categorical\_accuracy  
Epoch 23/40  
4800/4800 [=====] - 2s 504us/step - loss: 0.1679 - categorical\_accuracy  
Epoch 24/40  
4800/4800 [=====] - 2s 500us/step - loss: 0.1534 - categorical\_accuracy  
Epoch 25/40  
4800/4800 [=====] - 2s 500us/step - loss: 0.1374 - categorical\_accuracy  
Epoch 26/40  
4800/4800 [=====] - 2s 505us/step - loss: 0.1303 - categorical\_accuracy  
Epoch 27/40  
4800/4800 [=====] - 2s 504us/step - loss: 0.1276 - categorical\_accuracy  
Epoch 28/40  
4800/4800 [=====] - 2s 501us/step - loss: 0.1131 - categorical\_accuracy  
Epoch 29/40  
4800/4800 [=====] - 2s 517us/step - loss: 0.1195 - categorical\_accuracy

```

Epoch 30/40
4800/4800 [=====] - 2s 506us/step - loss: 0.1120 - categorical_accuracy
Epoch 31/40
4800/4800 [=====] - 2s 502us/step - loss: 0.1060 - categorical_accuracy
Epoch 32/40
4800/4800 [=====] - 2s 506us/step - loss: 0.0942 - categorical_accuracy
Epoch 33/40
4800/4800 [=====] - 2s 505us/step - loss: 0.0942 - categorical_accuracy
Epoch 34/40
4800/4800 [=====] - 2s 509us/step - loss: 0.0929 - categorical_accuracy
Epoch 35/40
4800/4800 [=====] - 2s 505us/step - loss: 0.0945 - categorical_accuracy
Epoch 36/40
4800/4800 [=====] - 2s 505us/step - loss: 0.0863 - categorical_accuracy
Epoch 37/40
4800/4800 [=====] - 2s 508us/step - loss: 0.0799 - categorical_accuracy
Epoch 38/40
4800/4800 [=====] - 2s 507us/step - loss: 0.0768 - categorical_accuracy
Epoch 39/40
4800/4800 [=====] - 2s 508us/step - loss: 0.0772 - categorical_accuracy
Epoch 40/40
4800/4800 [=====] - 2s 507us/step - loss: 0.0808 - categorical_accuracy
2400/2400 [=====] - 2s 945us/step
categorical_accuracy: 93.25%
93.94% (+/- 0.49%)

```

```

Out[11]: [94.33333333333343, 94.25, 93.25]

```