Spectrogram Project - Train from Scratch

The data used for this project was obtained from the University of Iowa Electronic Music Studios.

The random seed is so the splitting between training, validation, and testing is consistent. If you are training on a GPU, your networks may not be the same if you train the same network multiple times.

```
rng(123)
```

Load and split data

The images are stored in the folder `Spectrograms`. The data for each instrument is separated in subfolders, labelled by the folder name.

Split the data so that 80% of the images are used for training, 10% are used for validation, and the rest are used for testing. If changing the image size, make augmented image datastores.

```
ids=imageDatastore("Projects\MusicProject\Spectrograms","IncludeSubfolders",true,"LabelSource",
[trig,vlig,tsig]=splitEachLabel(ids,0.8,0.1,0.1,"randomized");

trds=augmentedImageDatastore([100 100],trig);
vlds=augmentedImageDatastore([100 100], vlig);
tsds= augmentedImageDatastore([100 100], tsig);
```

Series architecture from the documentation

You can find the example that uses this architecture in the documentation here: Speech Recognition

The images are sized `[200 200 3]`.

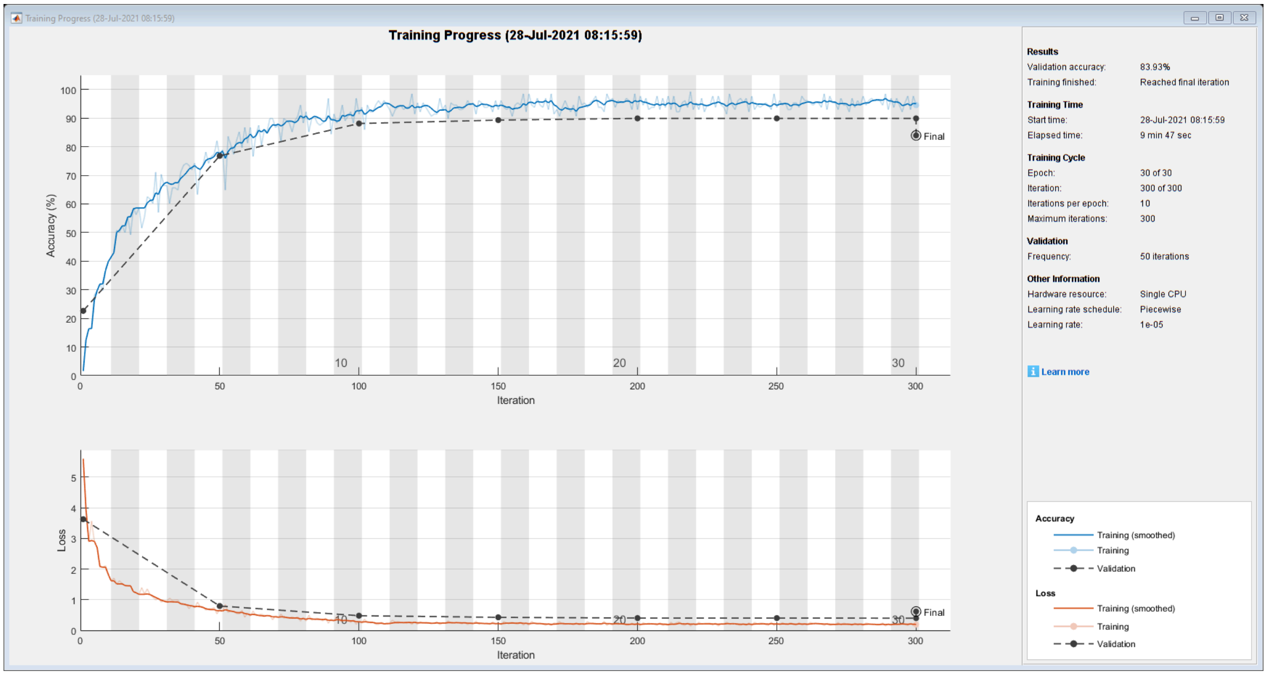
```
lbls=14;
drp = 0.2;
layers = [
    imageInputLayer([100 100 3])

    convolution2dLayer(3,16,"Padding","same")
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2,"Stride",2)

    convolution2dLayer(3,32,"Padding","same")
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2,"Stride",2,"Padding",[0,1])

    dropoutLayer(drp)
    convolution2dLayer(3,64,"Padding","same")
    batchNormalizationLayer
    reluLayer
    dropoutLayer(drp)
    convolution2dLayer(3,64,"Padding","same")
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2,"Stride",2,"Padding",[0,1])

    dropoutLayer(drp)
    convolution2dLayer(3,64,"Padding","same")
    batchNormalizationLayer
    reluLayer

    dropoutLayer(drp)
    convolution2dLayer(3,64,"Padding","same")
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer([1 13])

    fullyConnectedLayer(lbls)
    softmaxLayer
    classificationLayer];
```

Train the network

Set the training options and train the network.

```
opt=trainingOptions("adam","Plots","training-progress","Verbose",true,"LearnRateSchedule","piec
scrnet= trainNetwork(trds,layers,opt);
```

```
Training on single CPU.
Initializing input data normalization.
|===================================================================================================================
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Validation  |  Mini-batch  |  Validation  |  Base Learnin
|         |             |   (hh:mm:ss)   |   Accuracy   |   Accuracy   |     Loss     |     Loss     |      Rate
|===================================================================================================================
|       1 |           1 |       00:00:05 |        1.56% |       22.62% |       5.6014 |       3.6272 |          0.00
|       5 |          50 |       00:01:50 |       76.56% |       76.79% |       0.6757 |       0.7976 |          0.00
|      10 |         100 |       00:03:33 |       91.41% |       88.10% |       0.2912 |       0.4813 |          0.00
|      15 |         150 |       00:05:13 |       92.97% |       89.29% |       0.2334 |       0.4283 |          0.00
|      20 |         200 |       00:06:46 |       92.97% |       89.88% |       0.2513 |       0.4040 |          0.00
|      25 |         250 |       00:08:17 |       93.75% |       89.88% |       0.2181 |       0.4033 |      1.0000e-
|      30 |         300 |       00:09:46 |       94.53% |       89.88% |       0.1914 |       0.4004 |      1.0000e-
|===================================================================================================================
```



Results

Validation accuracy: 83.93%

Training finished: Reached final iteration

Training Time

Start time: 28-Jul-2021 08:15:59

Elapsed time: 9 min 47 sec

Training Cycle

Epoch: 30 of 30

Iteration: 300 of 300

Iterations per epoch: 10

Maximum iterations: 300

Validation

Frequency: 50 iterations

Other Information

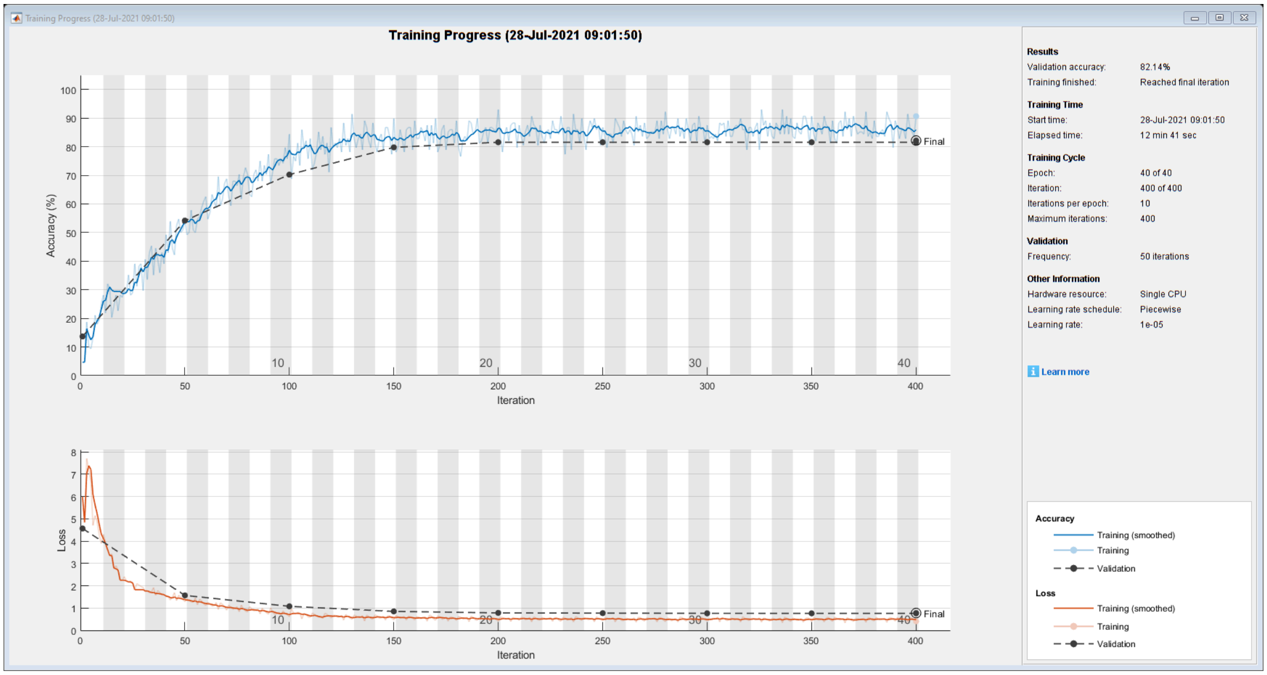
Hardware resource: Single CPU

Learning rate schedule: Piecewise

Learning rate: 1e-05

```
opt2=trainingOptions("adam","Plots","training-progress","Verbose",true,"LearnRateSchedule","pie
scrnet2= trainNetwork(trds,layers,opt2);
```

```
Training on single CPU.
Initializing input data normalization.
|==================================================================================================
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Validation  |  Mini-batch  |  Validation  |  Base Learnin
|         |             |   (hh:mm:ss)   |   Accuracy   |   Accuracy   |     Loss     |     Loss     |      Rate
|==================================================================================================
|       1 |           1 |       00:00:04 |        4.69% |       13.69% |       5.9819 |       4.5680 |          0.01
|       5 |          50 |       00:01:36 |       54.69% |       54.17% |       1.2881 |       1.5699 |          0.01
|      10 |         100 |       00:03:09 |       84.38% |       70.24% |       0.6160 |       1.0809 |          0.01
|      15 |         150 |       00:04:42 |       89.84% |       79.76% |       0.4717 |       0.8539 |          0.00
|      20 |         200 |       00:06:14 |       92.97% |       81.55% |       0.4105 |       0.7867 |          0.00
|      25 |         250 |       00:07:54 |       86.72% |       81.55% |       0.4382 |       0.7763 |      1.0000e-
|      30 |         300 |       00:09:36 |       87.50% |       81.55% |       0.4319 |       0.7670 |      1.0000e-
|      35 |         350 |       00:11:07 |       90.63% |       81.55% |       0.4041 |       0.7662 |      1.0000e-
|      40 |         400 |       00:12:40 |       90.63% |       81.55% |       0.4123 |       0.7659 |      1.0000e-
|==================================================================================================
```



Results

Validation accuracy: 82.14%
Training finished: Reached final iteration

Training Time

Start time: 28-Jul-2021 09:01:50
Elapsed time: 12 min 41 sec

Training Cycle

Epoch: 40 of 40
Iteration: 400 of 400
Iterations per epoch: 10
Maximum iterations: 400

Validation

Frequency: 50 iterations

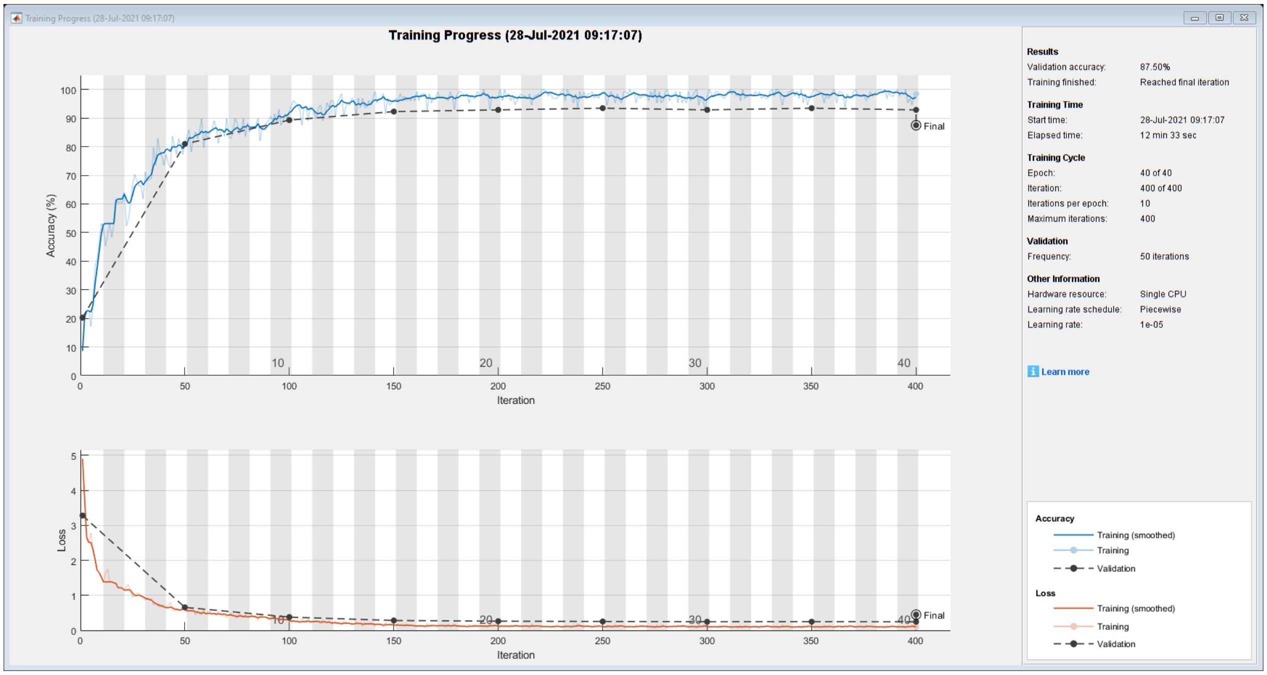
Other Information

Hardware resource: Single CPU
Learning rate schedule: Piecewise
Learning rate: 1e-05

Learn more

```
opt3=trainingOptions("adam","Plots","training-progress","Verbose",true,"LearnRateSchedule","pie
scrnet3= trainNetwork(trds,layers,opt3);
```

```
Training on single CPU.
Initializing input data normalization.
|=====================================================================================================
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Validation  |  Mini-batch  |  Validation  |  Base Learnin
|         |             |   (hh:mm:ss)   |   Accuracy   |   Accuracy   |     Loss     |     Loss     |      Rate
|=====================================================================================================
|       1 |           1 |       00:00:03 |        8.59% |       20.24% |       4.8994 |       3.2791 |          0.00
|       5 |          50 |       00:01:35 |       81.25% |       80.95% |       0.5430 |       0.6594 |          0.00
|      10 |         100 |       00:03:09 |       92.19% |       89.29% |       0.2668 |       0.3809 |          0.00
|      15 |         150 |       00:04:43 |       96.09% |       92.26% |       0.1566 |       0.2846 |          0.00
|      20 |         200 |       00:06:17 |       97.66% |       92.86% |       0.1069 |       0.2649 |          0.00
|      25 |         250 |       00:07:50 |       99.22% |       93.45% |       0.1063 |       0.2558 |          0.00
|      30 |         300 |       00:09:22 |       97.66% |       92.86% |       0.0923 |       0.2478 |          0.00
|      35 |         350 |       00:10:56 |       98.44% |       93.45% |       0.0854 |       0.2486 |      1.0000e-
|      40 |         400 |       00:12:33 |       98.44% |       92.86% |       0.0997 |       0.2471 |      1.0000e-
|=====================================================================================================
```



Results

Validation accuracy: 87.50%

Training finished: Reached final iteration

Training Time

Start time: 28-Jul-2021 09:17:07

Elapsed time: 12 min 33 sec

Training Cycle

Epoch: 40 of 40

Iteration: 400 of 400

Iterations per epoch: 10

Maximum iterations: 400

Validation

Frequency: 50 iterations

Other Information

Hardware resource: Single CPU

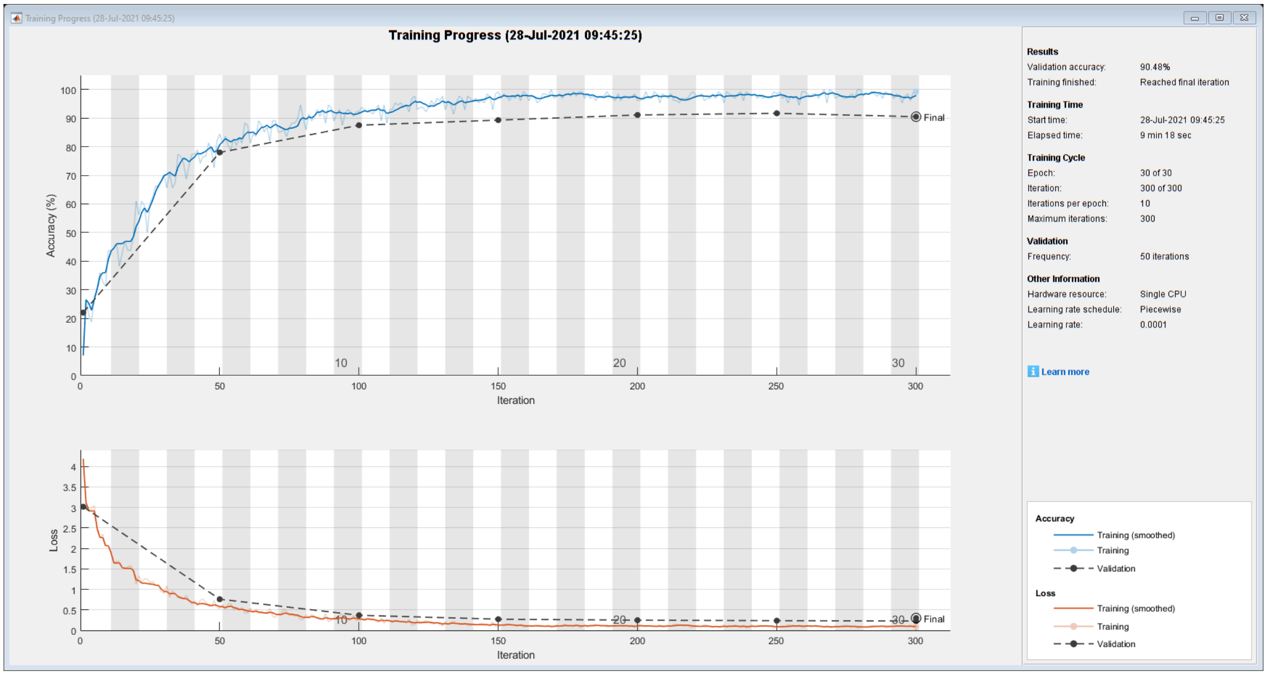
Learning rate schedule: Piecewise

Learning rate: 1e-05

Learn more

```
opt4=trainingOptions("adam","Plots","training-progress","Verbose",true,"LearnRateSchedule","pie
scrnet4= trainNetwork(trds,layers,opt4);
```

```
Training on single CPU.
Initializing input data normalization.
|==========================================================================================================
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Validation  |  Mini-batch  |  Validation  |  Base Learnin
|         |             |   (hh:mm:ss)   |   Accuracy   |   Accuracy   |     Loss     |     Loss     |      Rate
|==========================================================================================================
|       1 |           1 |       00:00:03 |        7.03% |       22.02% |       4.1875 |       3.0182 |          0.00
|       5 |          50 |       00:01:34 |       84.38% |       77.98% |       0.5283 |       0.7625 |          0.00
|      10 |         100 |       00:03:07 |       92.19% |       87.50% |       0.2535 |       0.3705 |          0.00
|      15 |         150 |       00:04:40 |       99.22% |       89.29% |       0.0968 |       0.2751 |          0.00
|      20 |         200 |       00:06:12 |       96.09% |       91.07% |       0.1210 |       0.2506 |          0.00
|      25 |         250 |       00:07:46 |       98.44% |       91.67% |       0.0779 |       0.2387 |          0.00
|      30 |         300 |       00:09:18 |       99.22% |       90.48% |       0.0861 |       0.2309 |          0.00
|==========================================================================================================
```



Results

Validation accuracy:	90.48%
Training finished:	Reached final iteration

Training Time

Start time:	28-Jul-2021 09:45:25
Elapsed time:	9 min 18 sec

Training Cycle

Epoch:	30 of 30
Iteration:	300 of 300
Iterations per epoch:	10
Maximum iterations:	300

Validation

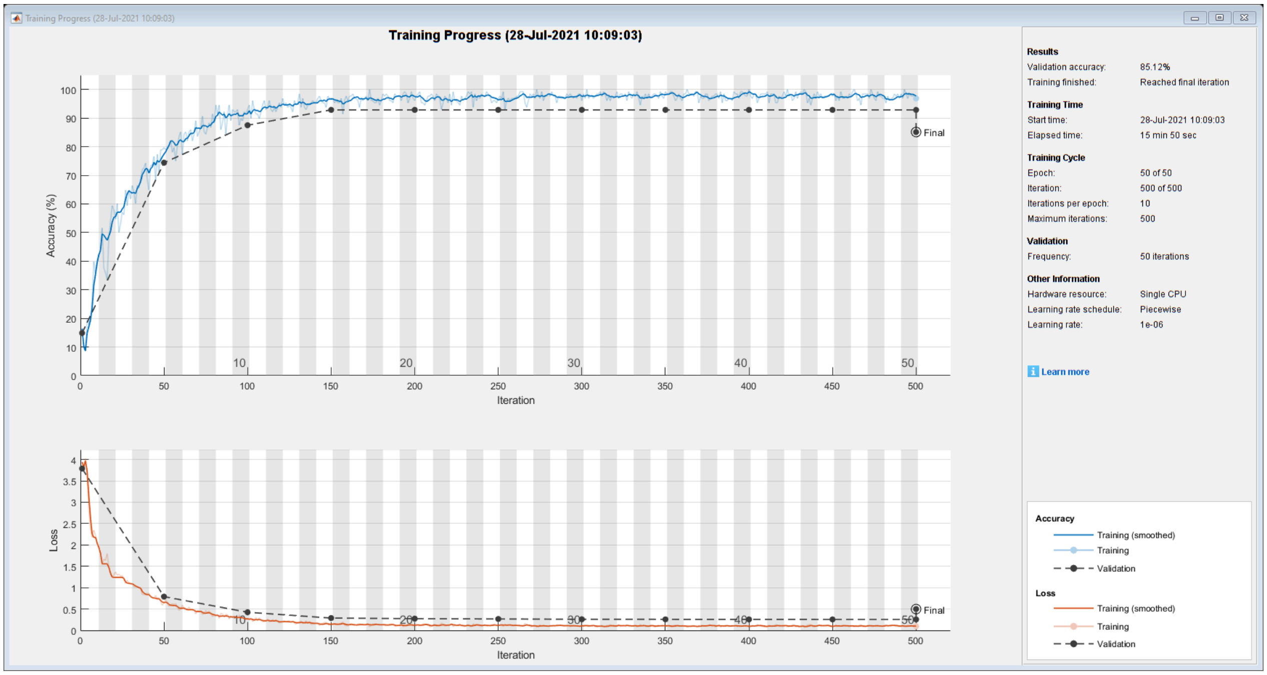
Frequency:	50 iterations

Other Information

Hardware resource:	Single CPU
Learning rate schedule:	Piecewise
Learning rate:	0.0001

```
opt5=trainingOptions("adam","Plots","training-progress","Verbose",true,"LearnRateSchedule","pie
scrnet5= trainNetwork(trds,layers,opt5);
```

```
Training on single CPU.
Initializing input data normalization.
|=========================================================================================================
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Validation  |  Mini-batch  |  Validation  |  Base Learnin
|         |             |   (hh:mm:ss)   |   Accuracy   |   Accuracy   |     Loss     |     Loss     |      Rate
|=========================================================================================================
|       1 |           1 |       00:00:03 |       16.41% |       14.88% |       3.9389 |       3.7883 |          0.00
|       5 |          50 |       00:01:35 |       79.69% |       74.40% |       0.6547 |       0.7913 |          0.00
|      10 |         100 |       00:03:08 |       92.97% |       87.50% |       0.2711 |       0.4260 |          0.00
|      15 |         150 |       00:04:43 |       96.88% |       92.86% |       0.1349 |       0.2900 |          0.00
|      20 |         200 |       00:06:16 |       96.09% |       92.86% |       0.1065 |       0.2761 |          0.00
|      25 |         250 |       00:07:49 |       96.88% |       92.86% |       0.1080 |       0.2693 |          0.00
|      30 |         300 |       00:09:24 |       96.09% |       92.86% |       0.1266 |       0.2615 |          0.00
|      35 |         350 |       00:11:01 |       99.22% |       92.86% |       0.0967 |       0.2605 |      1.0000e-
|      40 |         400 |       00:12:37 |      100.00% |       92.86% |       0.0770 |       0.2587 |      1.0000e-
|      45 |         450 |       00:14:13 |       97.66% |       92.86% |       0.0847 |       0.2584 |      1.0000e-
|      50 |         500 |       00:15:49 |       96.88% |       92.86% |       0.0983 |       0.2584 |      1.0000e-
|=========================================================================================================
```



Results

Validation accuracy:	85.12%
Training finished:	Reached final iteration

Training Time

Start time:	28-Jul-2021 10:09:03
Elapsed time:	15 min 50 sec

Training Cycle

Epoch:	50 of 50
Iteration:	500 of 500
Iterations per epoch:	10
Maximum iterations:	500

Validation

Frequency:	50 iterations

Other Information

Hardware resource:	Single CPU
Learning rate schedule:	Piecewise
Learning rate:	1e-06

Evaluate network

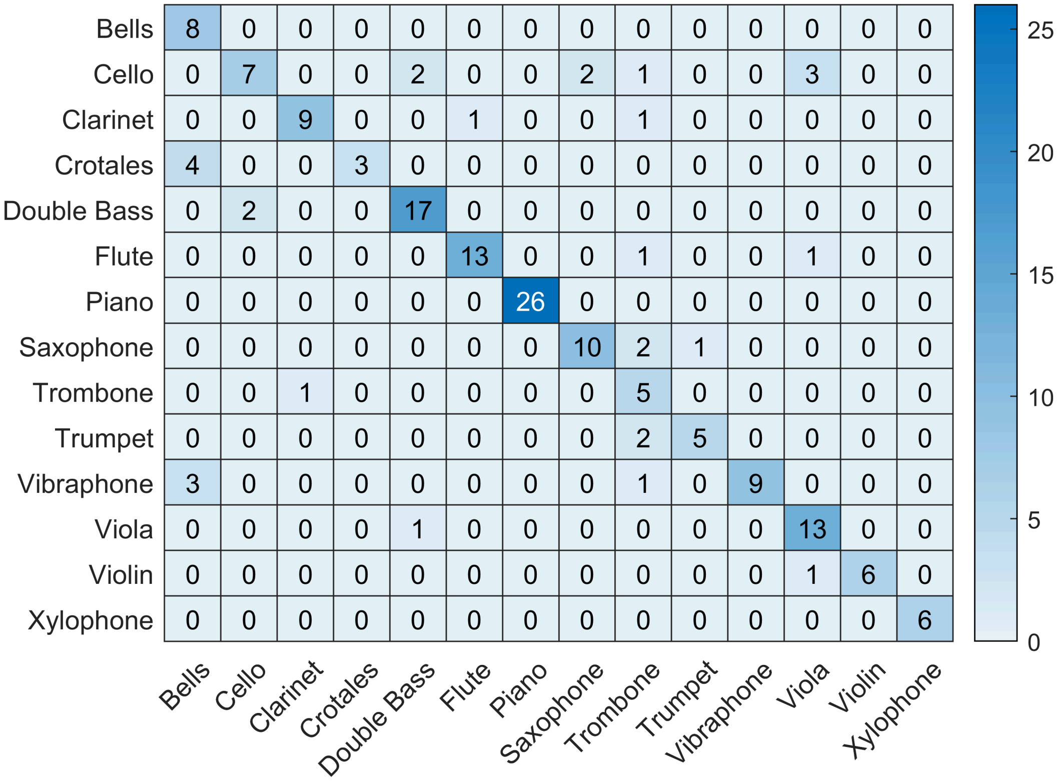
Calculate the accuracy on the test dataset.

```
pred1 = classify(scrnet,tsds);
nnz(pred1 == tsig.Labels)/numel(tsig.Labels)
```

```
ans = 0.8204
```

Plot confusion matrix

```
[cmap,clabel] = confusionmat(tsig.Labels,pred1);
heatmap(clabel,clabel,cmap)
```

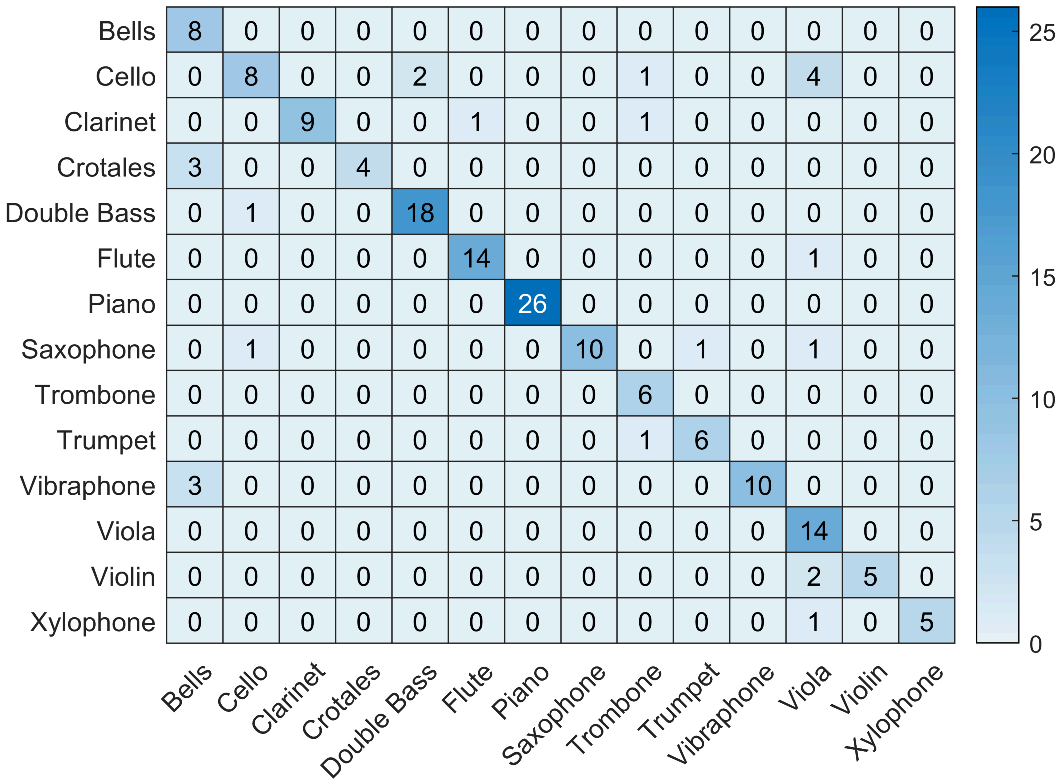


	Bells	Cello	Clarinet	Crotales	Double Bass	Flute	Piano	Saxophone	Trombone	Trumpet	Vibraphone	Viola	Violin	Xylophone
Bells	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Cello	0	7	0	0	2	0	0	2	1	0	0	3	0	0
Clarinet	0	0	9	0	0	1	0	0	1	0	0	0	0	0
Crotales	4	0	0	3	0	0	0	0	0	0	0	0	0	0
Double Bass	0	2	0	0	17	0	0	0	0	0	0	0	0	0
Flute	0	0	0	0	0	13	0	0	1	0	0	1	0	0
Piano	0	0	0	0	0	0	26	0	0	0	0	0	0	0
Saxophone	0	0	0	0	0	0	0	10	2	1	0	0	0	0
Trombone	0	0	1	0	0	0	0	0	5	0	0	0	0	0
Trumpet	0	0	0	0	0	0	0	0	2	5	0	0	0	0
Vibraphone	3	0	0	0	0	0	0	0	1	0	9	0	0	0
Viola	0	0	0	0	1	0	0	0	0	0	0	13	0	0
Violin	0	0	0	0	0	0	0	0	0	0	0	1	6	0
Xylophone	0	0	0	0	0	0	0	0	0	0	0	0	0	6

```
pred5 = classify(scrnet5,tsds);
nnz(pred5 == tsig.Labels)/numel(tsig.Labels)
```

```
ans = 0.8563
```

```
[cm,cl] = confusionmat(tsig.Labels,pred5);
heatmap(cl,cl,cm)
```



	Bells	Cello	Clarinet	Crotales	Double Bass	Flute	Piano	Saxophone	Trombone	Trumpet	Vibraphone	Viola	Violin	Xylophone
Bells	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Cello	0	8	0	0	2	0	0	0	1	0	0	4	0	0
Clarinet	0	0	9	0	0	1	0	0	1	0	0	0	0	0
Crotales	3	0	0	4	0	0	0	0	0	0	0	0	0	0
Double Bass	0	1	0	0	18	0	0	0	0	0	0	0	0	0
Flute	0	0	0	0	0	14	0	0	0	0	0	1	0	0
Piano	0	0	0	0	0	0	26	0	0	0	0	0	0	0
Saxophone	0	1	0	0	0	0	0	10	0	1	0	1	0	0
Trombone	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Trumpet	0	0	0	0	0	0	0	0	1	6	0	0	0	0
Vibraphone	3	0	0	0	0	0	0	0	0	0	10	0	0	0
Viola	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Violin	0	0	0	0	0	0	0	0	0	0	0	2	5	0
Xylophone	0	0	0	0	0	0	0	0	0	0	0	1	0	5