PROJECT 1

Miscellaneous

Adding the path to the `functions` and `data` folder. In `functions` you can find the functions used in this project. In `data` you can find the datasets used.

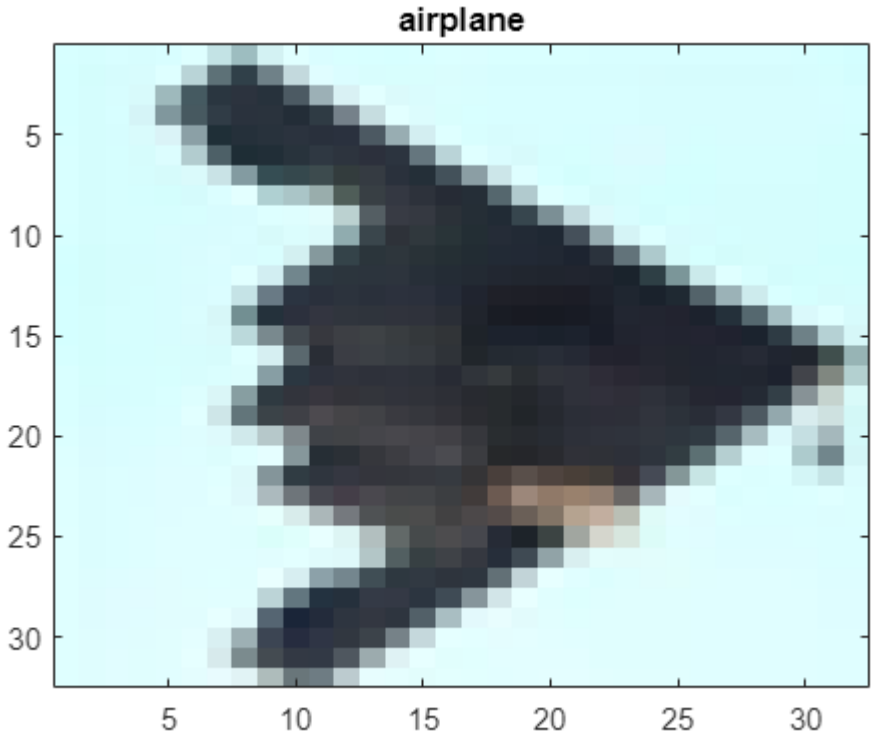
```
addpath('./functions');
addpath('./data');
```

Created a function `load_data` that takes as input the location of the CIFAR10 dataset. The function looks for the "cifar-10-batches-mat" folder and creates a training and test set. Additionally, the function carries out the some permutation on the data such as: reshape, converts labels to categorical, flips the images by 90deg.

```
[XTrain, YTrain, XTest, YTest] = load_data('data');
```

This code samples randomly from the training set and displays the image with its label.

```
idx = randi(size(XTrain,4));

imagesc(XTrain(:,:,:,idx))
title(YTrain(idx))
```



Base Model

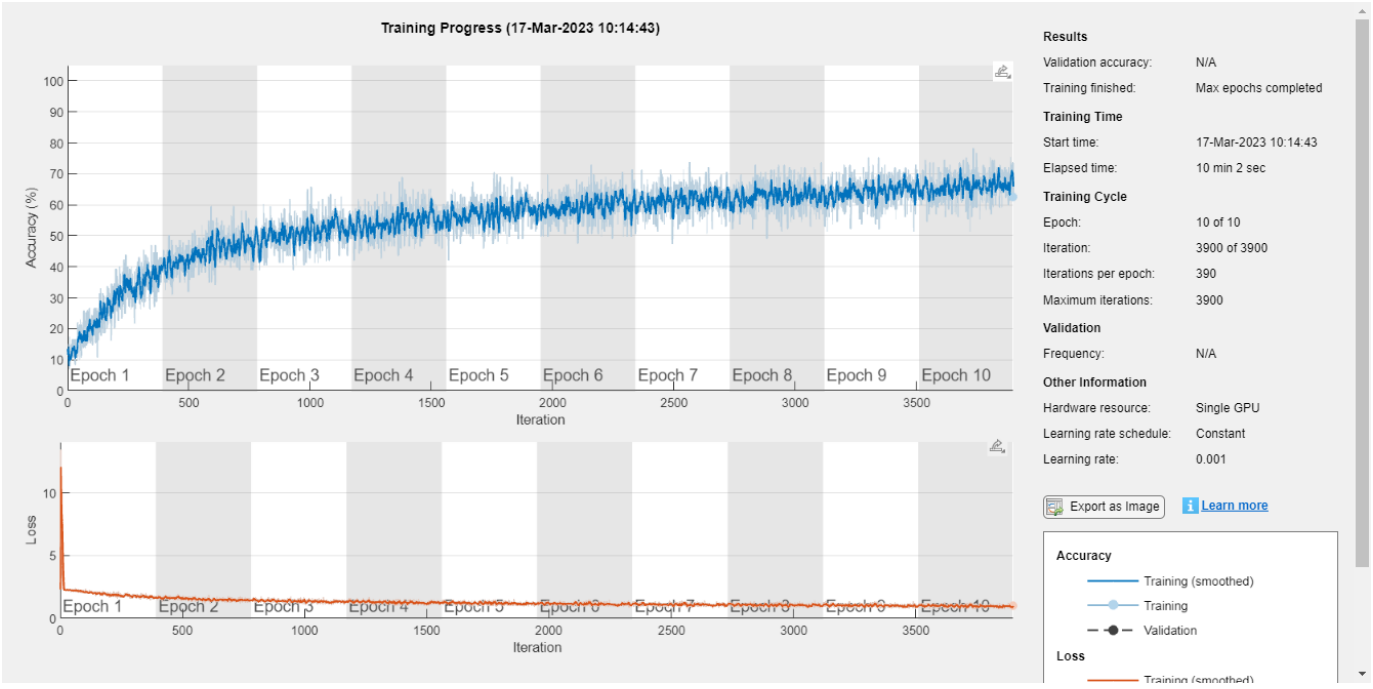
Here I defined a first basic classifier and perfomed its training.

```
layers = basic_cnn_classifier_v2();

opts = trainingOptions('sgdm', ...
    'Momentum', 0.9, ...
    'InitialLearnRate', 0.001, ...
    'MaxEpochs', 10, ...
    'MiniBatchSize', 128, ...
    'Verbose', true,...
    'Plots','training-progress',...
    'ExecutionEnvironment','gpu');

basic_net = trainNetwork(XTrain, YTrain, layers, opts);
```

```
Initializing input data normalization.
|=========================================================================================|
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Mini-batch  |  Base Learning  |
|         |             |   (hh:mm:ss)   |   Accuracy   |     Loss     |      Rate       |
|=========================================================================================|
|       1 |           1 |       00:00:04 |       13.28% |       2.3054 |          0.0010 |
|       1 |          50 |       00:00:13 |       10.16% |       2.3038 |          0.0010 |
|       1 |         100 |       00:00:22 |       21.09% |       2.1012 |          0.0010 |
|       1 |         150 |       00:00:29 |       27.34% |       2.0246 |          0.0010 |
|       1 |         200 |       00:00:35 |       28.91% |       1.9084 |          0.0010 |
|       1 |         250 |       00:00:44 |       31.25% |       1.7814 |          0.0010 |
|       1 |         300 |       00:00:52 |       31.25% |       1.8145 |          0.0010 |
|       1 |         350 |       00:01:00 |       33.59% |       1.7769 |          0.0010 |
|       2 |         400 |       00:01:10 |       39.84% |       1.6022 |          0.0010 |
|       2 |         450 |       00:01:20 |       42.97% |       1.6119 |          0.0010 |
|       2 |         500 |       00:01:31 |       43.75% |       1.5007 |          0.0010 |
|       2 |         550 |       00:01:36 |       40.62% |       1.5714 |          0.0010 |
|       2 |         600 |       00:01:40 |       54.69% |       1.4029 |          0.0010 |
|       2 |         650 |       00:01:46 |       40.62% |       1.4598 |          0.0010 |
|       2 |         700 |       00:01:52 |       48.44% |       1.4097 |          0.0010 |
|       2 |         750 |       00:01:55 |       47.66% |       1.5252 |          0.0010 |
|       3 |         800 |       00:02:03 |       48.44% |       1.4048 |          0.0010 |
|       3 |         850 |       00:02:13 |       53.12% |       1.3706 |          0.0010 |
|       3 |         900 |       00:02:21 |       48.44% |       1.3780 |          0.0010 |
|       3 |         950 |       00:02:24 |       53.12% |       1.3198 |          0.0010 |
|       3 |        1000 |       00:02:32 |       60.16% |       1.1748 |          0.0010 |
|       3 |        1050 |       00:02:41 |       45.31% |       1.4849 |          0.0010 |
|       3 |        1100 |       00:02:50 |       58.59% |       1.1705 |          0.0010 |
|       3 |        1150 |       00:03:02 |       51.56% |       1.3697 |          0.0010 |
|       4 |        1200 |       00:03:31 |       60.94% |       1.2650 |          0.0010 |
|       4 |        1250 |       00:03:34 |       50.00% |       1.4018 |          0.0010 |
|       4 |        1300 |       00:03:39 |       48.44% |       1.3429 |          0.0010 |
|       4 |        1350 |       00:03:44 |       51.56% |       1.2732 |          0.0010 |
|       4 |        1400 |       00:03:54 |       53.91% |       1.2466 |          0.0010 |
|       4 |        1450 |       00:04:02 |       57.81% |       1.1993 |          0.0010 |
|       4 |        1500 |       00:04:07 |       60.16% |       1.0504 |          0.0010 |
|       4 |        1550 |       00:04:12 |       60.16% |       1.2055 |          0.0010 |
|       5 |        1600 |       00:04:19 |       60.16% |       1.1629 |          0.0010 |
|       5 |        1650 |       00:04:28 |       54.69% |       1.3604 |          0.0010 |
|       5 |        1700 |       00:04:37 |       59.38% |       1.2608 |          0.0010 |
|       5 |        1750 |       00:04:47 |       61.72% |       1.0777 |          0.0010 |
|       5 |        1800 |       00:04:57 |       58.59% |       1.2184 |          0.0010 |
|       5 |        1850 |       00:05:06 |       64.84% |       1.1465 |          0.0010 |
|       5 |        1900 |       00:05:08 |       53.12% |       1.2623 |          0.0010 |
|       5 |        1950 |       00:05:15 |       56.25% |       1.1685 |          0.0010 |
|       6 |        2000 |       00:05:18 |       59.38% |       1.1693 |          0.0010 |
|       6 |        2050 |       00:05:26 |       60.16% |       1.1278 |          0.0010 |
```

6	2100	00:05:35	53.91%	1.2602	0.0010
6	2150	00:05:46	56.25%	1.1980	0.0010
6	2200	00:05:48	64.06%	1.0543	0.0010
6	2250	00:05:54	61.72%	1.1105	0.0010
6	2300	00:06:00	60.16%	1.0996	0.0010
7	2350	00:06:07	60.16%	1.1377	0.0010
7	2400	00:06:13	57.81%	1.1862	0.0010
7	2450	00:06:18	69.53%	1.0062	0.0010
7	2500	00:06:27	61.72%	1.0567	0.0010
7	2550	00:06:37	67.19%	1.0424	0.0010
7	2600	00:06:47	62.50%	1.0346	0.0010
7	2650	00:06:50	63.28%	1.0563	0.0010
7	2700	00:06:55	61.72%	1.1040	0.0010
8	2750	00:07:01	62.50%	1.0353	0.0010
8	2800	00:07:04	66.41%	1.0239	0.0010
8	2850	00:07:13	65.62%	1.0603	0.0010
8	2900	00:07:23	68.75%	0.9643	0.0010
8	2950	00:07:31	66.41%	0.9600	0.0010
8	3000	00:07:37	60.16%	1.1336	0.0010
8	3050	00:07:45	68.75%	0.9379	0.0010
8	3100	00:07:54	59.38%	1.0801	0.0010
9	3150	00:08:03	61.72%	1.0775	0.0010
9	3200	00:08:13	63.28%	1.0813	0.0010
9	3250	00:08:23	64.84%	1.0505	0.0010
9	3300	00:08:34	61.72%	0.9652	0.0010
9	3350	00:08:36	64.06%	1.1092	0.0010
9	3400	00:08:43	65.62%	1.0297	0.0010
9	3450	00:08:53	68.75%	0.8434	0.0010
9	3500	00:08:59	67.19%	0.8890	0.0010
10	3550	00:09:04	66.41%	0.9941	0.0010
10	3600	00:09:09	64.84%	1.1145	0.0010
10	3650	00:09:17	66.41%	0.9309	0.0010
10	3700	00:09:26	67.97%	0.9787	0.0010
10	3750	00:09:35	64.06%	1.0298	0.0010
10	3800	00:09:46	67.97%	1.0207	0.0010
10	3850	00:09:57	64.06%	0.8537	0.0010
10	3900	00:10:02	62.50%	1.0181	0.0010

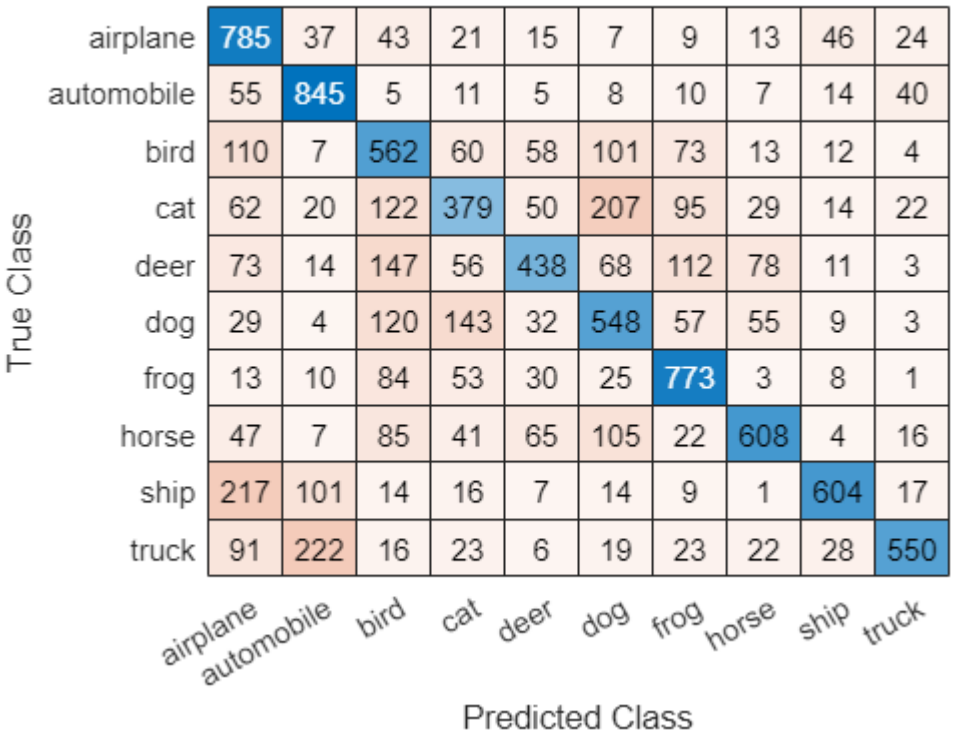
Training finished: Max epochs completed.



```
preds = basic_net.classify(XTest);
tp = nnz(preds == YTest);
accuracy = tp / length(YTest);
disp(['The network achieved an accuracy of: ', num2str((accuracy)*100), '%'])
```

```
The network achieved an accuracy of: 60.92%
```

```
confusionchart(YTest,preds)
```




```
indeces = find(preds ~= YTest);
idx = datasample(indeces,2);
subplot(1,2,1);
imshow(XTest(:,:,:,idx(1)));
title([YTest(idx(1)), "mistaken as ", preds(idx(1))])
subplot(1,2,2);
imshow(XTest(:,:,:,idx(2)));
title([YTest(idx(2)), "mistaken as ", preds(idx(2))])
```

Improved Model

Here I improved the model and trained it.

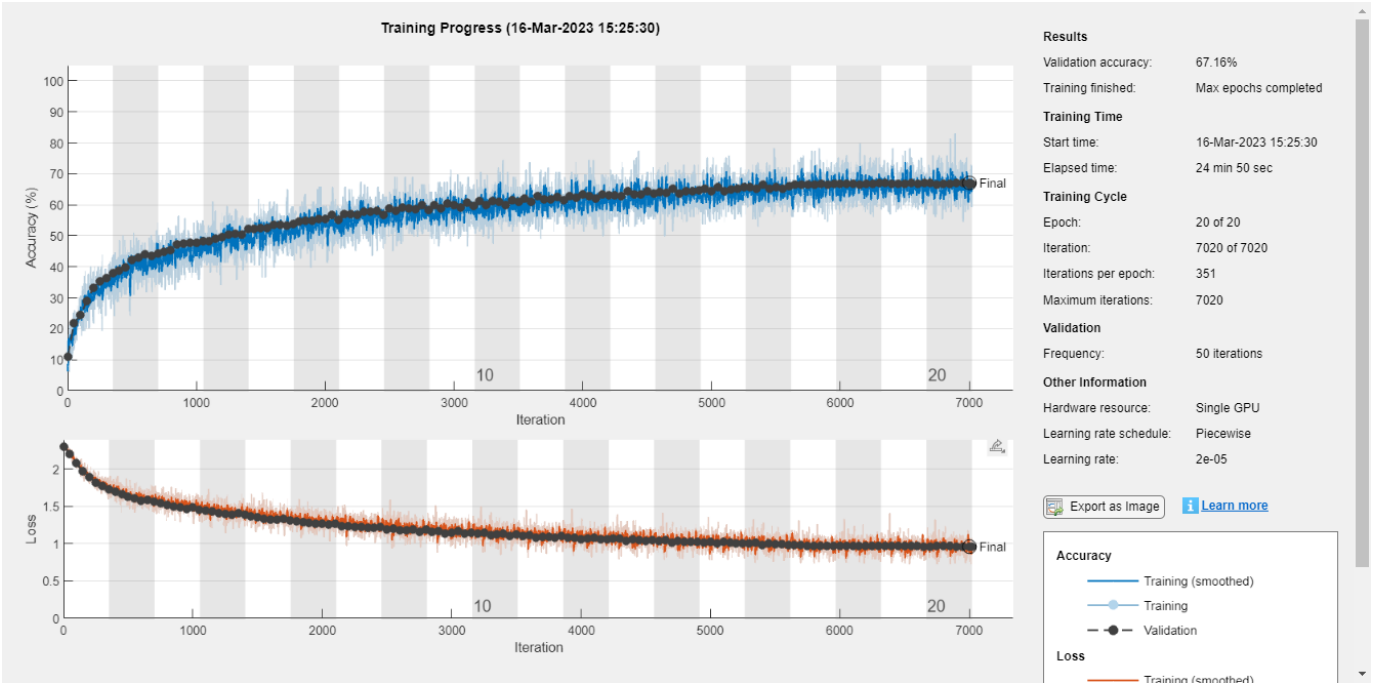
```
layers = improved_cnn_classifier_v2();
[X_train, X_val, Y_train, Y_val] = train_test_split(XTrain,YTrain,0.1);
opts = trainingOptions('sgdm', ...
    'Momentum', 0.9, ...
    'InitialLearnRate', 0.0002, ...
    'LearnRateSchedule', 'piecewise', ...
    'LearnRateDropFactor', 0.1, ...
    'LearnRateDropPeriod', 16, ...
    'L2Regularization', 0.004, ...
    'ValidationData',{X_val, Y_val}, ...
    'OutputNetwork','best-validation-loss', ...
    'MaxEpochs', 20, ...
    'MiniBatchSize', 128, ...
    'Verbose', true,...
    'Plots','training-progress',...
    'ExecutionEnvironment','gpu');

improved_net = trainNetwork(X_train, Y_train, layers, opts);
```

```
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 |        6.25% |       10.94% |       2.3035 |       2.3017 |          0.00
|       1 |          50 |       00:00:18 |       21.09% |       21.94% |       2.2050 |       2.2018 |          0.00
|       1 |         100 |       00:00:30 |       21.09% |       24.34% |       2.1074 |       2.0737 |          0.00
|       1 |         150 |       00:00:39 |       31.25% |       29.06% |       1.9105 |       1.9642 |          0.00
|       1 |         200 |       00:00:50 |       35.94% |       33.28% |       1.8049 |       1.8869 |          0.00
|       1 |         250 |       00:01:02 |       32.81% |       35.18% |       1.8095 |       1.8148 |          0.00
|       1 |         300 |       00:01:14 |       32.03% |       36.30% |       1.9003 |       1.7752 |          0.00
|       1 |         350 |       00:01:24 |       39.84% |       38.04% |       1.7714 |       1.7271 |          0.00
|       2 |         400 |       00:01:28 |       45.31% |       38.76% |       1.5744 |       1.6919 |          0.00
|       2 |         450 |       00:01:39 |       42.19% |       39.82% |       1.6695 |       1.6568 |          0.00
|       2 |         500 |       00:01:50 |       41.41% |       42.30% |       1.5622 |       1.6233 |          0.00
|       2 |         550 |       00:02:01 |       43.75% |       43.06% |       1.5212 |       1.6053 |          0.00
|       2 |         600 |       00:02:13 |       40.62% |       43.92% |       1.5378 |       1.5716 |          0.00
|       2 |         650 |       00:02:26 |       50.00% |       43.50% |       1.5144 |       1.5841 |          0.00
|       2 |         700 |       00:02:34 |       42.97% |       44.18% |       1.5707 |       1.5580 |          0.00
|       3 |         750 |       00:02:40 |       38.28% |       44.78% |       1.5868 |       1.5364 |          0.00
|       3 |         800 |       00:02:51 |       46.09% |       45.24% |       1.6421 |       1.5216 |          0.00
|       3 |         850 |       00:03:03 |       41.41% |       47.20% |       1.5529 |       1.4961 |          0.00
|       3 |         900 |       00:03:15 |       45.31% |       47.42% |       1.4558 |       1.4886 |          0.00
|       3 |         950 |       00:03:23 |       45.31% |       47.72% |       1.5404 |       1.4693 |          0.00
|       3 |        1000 |       00:03:30 |       49.22% |       47.70% |       1.3670 |       1.4846 |          0.00
|       3 |        1050 |       00:03:41 |       54.69% |       48.34% |       1.3027 |       1.4584 |          0.00
|       4 |        1100 |       00:03:52 |       46.88% |       48.36% |       1.5793 |       1.4413 |          0.00
|       4 |        1150 |       00:04:05 |       44.53% |       49.04% |       1.5236 |       1.4336 |          0.00
|       4 |        1200 |       00:04:15 |       57.03% |       49.70% |       1.3011 |       1.4077 |          0.00
|       4 |        1250 |       00:04:21 |       42.97% |       50.40% |       1.5224 |       1.4018 |          0.00
|       4 |        1300 |       00:04:31 |       49.22% |       50.76% |       1.4680 |       1.3884 |          0.00
|       4 |        1350 |       00:04:43 |       42.19% |       50.46% |       1.4894 |       1.4103 |          0.00
|       4 |        1400 |       00:04:55 |       47.66% |       52.16% |       1.3590 |       1.3835 |          0.00
|       5 |        1450 |       00:05:06 |       50.78% |       52.24% |       1.3617 |       1.3627 |          0.00
|       5 |        1500 |       00:05:19 |       58.59% |       52.42% |       1.2224 |       1.3583 |          0.00
```

5	1550	00:05:28	43.75%	52.42%	1.5818	1.3371	0.00
5	1600	00:05:36	58.59%	53.68%	1.3005	1.3264	0.00
5	1650	00:05:47	50.78%	53.64%	1.4058	1.3215	0.00
5	1700	00:05:59	60.94%	53.36%	1.2973	1.3299	0.00
5	1750	00:06:11	57.03%	53.70%	1.3485	1.3128	0.00
6	1800	00:06:24	46.88%	54.64%	1.4167	1.2978	0.00
6	1850	00:06:28	56.25%	54.88%	1.2222	1.2931	0.00
6	1900	00:06:39	50.00%	54.80%	1.4593	1.2822	0.00
6	1950	00:06:51	50.00%	55.54%	1.3213	1.2692	0.00
6	2000	00:07:03	56.25%	55.36%	1.3495	1.2687	0.00
6	2050	00:07:10	57.81%	56.74%	1.2672	1.2588	0.00
6	2100	00:07:20	59.38%	55.12%	1.2048	1.2666	0.00
7	2150	00:07:31	52.34%	57.10%	1.3370	1.2388	0.00
7	2200	00:07:43	60.16%	56.92%	1.1142	1.2370	0.00
7	2250	00:07:56	57.03%	56.82%	1.2601	1.2269	0.00
7	2300	00:08:06	51.56%	57.68%	1.4118	1.2204	0.00
7	2350	00:08:18	54.69%	57.70%	1.2562	1.2165	0.00
7	2400	00:08:30	50.00%	58.08%	1.2598	1.2082	0.00
7	2450	00:08:43	49.22%	56.70%	1.3048	1.2270	0.00
8	2500	00:08:53	54.69%	58.86%	1.1773	1.1951	0.00
8	2550	00:09:00	62.50%	57.94%	1.2034	1.2054	0.00
8	2600	00:09:12	55.47%	59.00%	1.2767	1.1802	0.00
8	2650	00:09:35	50.78%	58.80%	1.3293	1.1818	0.00
8	2700	00:09:45	52.34%	58.46%	1.3285	1.1893	0.00
8	2750	00:09:53	58.59%	59.86%	1.1733	1.1607	0.00
8	2800	00:10:04	51.56%	58.36%	1.2034	1.1864	0.00
9	2850	00:10:16	57.81%	59.80%	1.2661	1.1623	0.00
9	2900	00:10:29	60.16%	58.82%	1.0845	1.1733	0.00
9	2950	00:10:36	61.72%	60.56%	1.0606	1.1394	0.00
9	3000	00:10:42	66.41%	60.00%	1.0379	1.1444	0.00
9	3050	00:10:50	67.19%	59.06%	1.0661	1.1640	0.00
9	3100	00:11:01	63.28%	60.74%	1.0835	1.1305	0.00
9	3150	00:11:14	60.16%	59.64%	1.0668	1.1505	0.00
10	3200	00:11:24	58.59%	61.18%	1.1968	1.1329	0.00
10	3250	00:11:30	53.12%	59.90%	1.1705	1.1502	0.00
10	3300	00:11:42	57.03%	61.32%	1.2692	1.1118	0.00
10	3350	00:11:53	53.12%	60.86%	1.0731	1.1192	0.00
10	3400	00:12:06	63.28%	60.00%	1.0347	1.1349	0.00
10	3450	00:12:19	57.03%	61.52%	1.1351	1.0998	0.00
10	3500	00:12:24	63.28%	60.94%	1.1037	1.1198	0.00
11	3550	00:12:35	58.59%	62.06%	1.1263	1.1059	0.00
11	3600	00:12:47	63.28%	61.06%	1.1450	1.1173	0.00
11	3650	00:13:00	58.59%	62.84%	1.0958	1.0814	0.00
11	3700	00:13:08	62.50%	61.80%	1.0988	1.0898	0.00
11	3750	00:13:16	59.38%	61.72%	1.1538	1.0937	0.00
11	3800	00:13:24	53.91%	62.44%	1.1538	1.0785	0.00
11	3850	00:13:36	63.28%	61.60%	1.0751	1.0972	0.00
12	3900	00:13:49	53.91%	62.94%	1.1317	1.0844	0.00
12	3950	00:14:02	67.97%	62.34%	1.0170	1.0844	0.00
12	4000	00:14:06	67.19%	63.40%	0.9667	1.0636	0.00
12	4050	00:14:17	57.03%	62.70%	1.1804	1.0724	0.00
12	4100	00:14:29	60.94%	62.00%	1.0994	1.0817	0.00
12	4150	00:14:42	58.59%	63.28%	1.0673	1.0583	0.00
12	4200	00:14:49	64.84%	63.18%	1.0320	1.0627	0.00
13	4250	00:14:57	61.72%	63.18%	1.0410	1.0657	0.00
13	4300	00:15:08	64.06%	62.80%	1.0458	1.0677	0.00
13	4350	00:15:20	64.06%	64.44%	0.9380	1.0374	0.00
13	4400	00:15:33	57.81%	63.46%	1.1354	1.0572	0.00
13	4450	00:15:43	63.28%	63.34%	0.9953	1.0493	0.00
13	4500	00:15:48	64.84%	64.28%	1.0136	1.0366	0.00
13	4550	00:15:59	63.28%	63.60%	0.9919	1.0516	0.00
14	4600	00:16:11	60.16%	64.20%	1.0755	1.0372	0.00
14	4650	00:16:24	60.16%	63.90%	1.0533	1.0426	0.00
14	4700	00:16:33	62.50%	65.20%	0.9757	1.0179	0.00

14	4750	00:16:41	59.38%	63.60%	1.1545	1.0392	0.00
14	4800	00:16:52	61.72%	64.30%	1.0488	1.0303	0.00
14	4850	00:17:05	64.06%	64.42%	1.1326	1.0222	0.00
14	4900	00:17:18	62.50%	64.74%	1.1621	1.0242	0.00
15	4950	00:17:28	61.72%	65.18%	1.0395	1.0134	0.00
15	5000	00:17:35	71.09%	64.40%	0.9494	1.0252	0.00
15	5050	00:17:46	63.28%	65.66%	1.0904	0.9983	0.00
15	5100	00:17:59	73.44%	64.36%	0.8204	1.0232	0.00
15	5150	00:18:12	60.94%	65.00%	1.0294	1.0100	0.00
15	5200	00:18:18	66.41%	65.10%	0.8921	1.0062	0.00
15	5250	00:18:29	60.94%	65.84%	1.0795	1.0057	0.00
16	5300	00:18:40	64.06%	65.62%	1.0293	1.0002	0.00
16	5350	00:18:53	61.72%	65.20%	1.0850	1.0132	0.00
16	5400	00:19:05	64.84%	66.48%	1.0246	0.9871	0.00
16	5450	00:19:10	68.75%	65.28%	0.8660	1.0021	0.00
16	5500	00:19:21	64.84%	65.68%	0.9914	0.9968	0.00
16	5550	00:19:32	64.06%	65.18%	1.0336	0.9969	0.00
16	5600	00:19:45	64.84%	66.04%	0.9235	0.9844	0.00
17	5650	00:19:55	60.94%	66.46%	1.0468	0.9832	2.0000e-
17	5700	00:20:00	71.09%	66.46%	0.9271	0.9765	2.0000e-
17	5750	00:20:10	70.31%	66.62%	0.9325	0.9751	2.0000e-
17	5800	00:20:21	69.53%	66.62%	0.8262	0.9727	2.0000e-
17	5850	00:20:33	59.38%	66.82%	0.9930	0.9697	2.0000e-
17	5900	00:20:46	54.69%	66.64%	1.0875	0.9713	2.0000e-
17	5950	00:20:51	67.97%	66.78%	0.9357	0.9706	2.0000e-
18	6000	00:21:00	64.06%	66.70%	1.0265	0.9700	2.0000e-
18	6050	00:21:11	66.41%	66.72%	0.8632	0.9689	2.0000e-
18	6100	00:21:23	65.62%	66.76%	0.9602	0.9725	2.0000e-
18	6150	00:21:36	75.00%	66.58%	0.8211	0.9701	2.0000e-
18	6200	00:21:46	65.62%	66.76%	1.0399	0.9665	2.0000e-
18	6250	00:21:56	66.41%	66.72%	0.9947	0.9698	2.0000e-
18	6300	00:22:08	75.00%	66.92%	0.7944	0.9660	2.0000e-
19	6350	00:22:21	63.28%	66.96%	1.1165	0.9672	2.0000e-
19	6400	00:22:31	71.09%	66.66%	0.7454	0.9684	2.0000e-
19	6450	00:22:36	60.16%	66.70%	1.1316	0.9699	2.0000e-
19	6500	00:22:46	64.06%	66.90%	1.0067	0.9683	2.0000e-
19	6550	00:22:58	68.75%	66.94%	0.9216	0.9657	2.0000e-
19	6600	00:23:10	67.97%	66.80%	0.9403	0.9686	2.0000e-
19	6650	00:23:23	62.50%	66.96%	1.0177	0.9650	2.0000e-
20	6700	00:23:28	66.41%	67.00%	0.8552	0.9651	2.0000e-
20	6750	00:23:39	72.66%	66.60%	0.7896	0.9673	2.0000e-
20	6800	00:23:50	64.06%	66.74%	0.9226	0.9674	2.0000e-
20	6850	00:24:03	67.97%	66.86%	0.9085	0.9666	2.0000e-
20	6900	00:24:14	68.75%	66.96%	0.8893	0.9629	2.0000e-
20	6950	00:24:32	73.44%	67.00%	0.9094	0.9638	2.0000e-
20	7000	00:24:43	63.28%	66.60%	0.8573	0.9629	2.0000e-
20	7020	00:24:49	66.41%	66.76%	0.9401	0.9629	2.0000e-

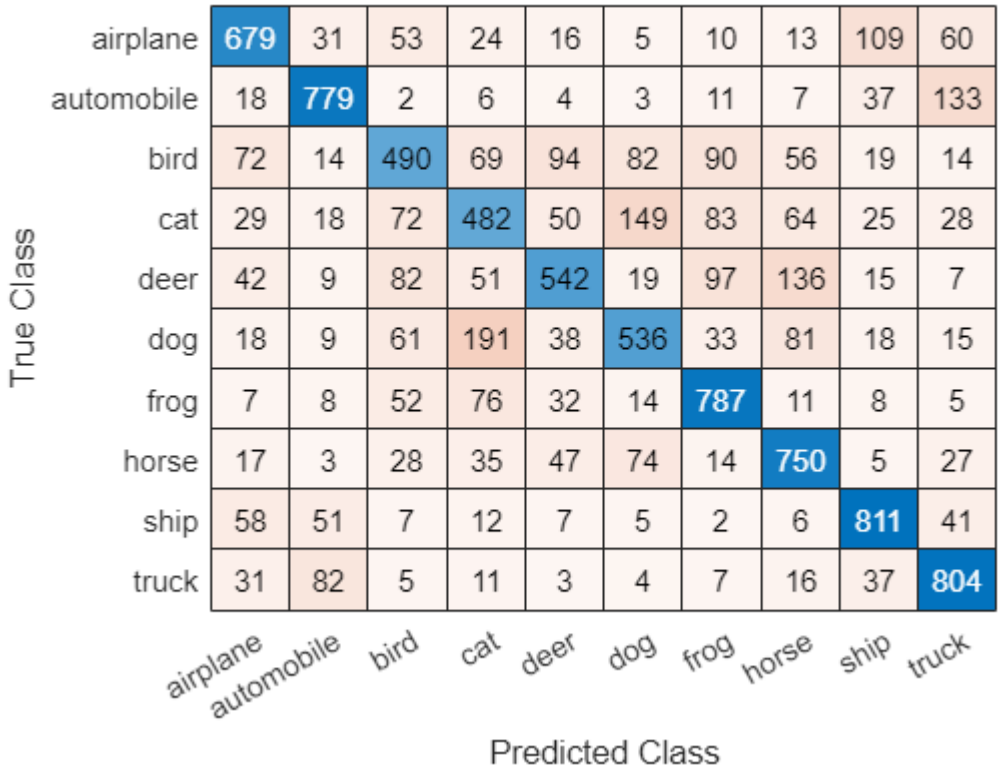
Training finished: Max epochs completed.




```
preds = improved_net.classify(XTest);
tp = nnz(preds == YTest);
accuracy = tp / length(YTest);
disp(['The network achieved an accuracy of: ', num2str((accuracy)*100), '%'])
```

```
The network achieved an accuracy of: 66.6%
```

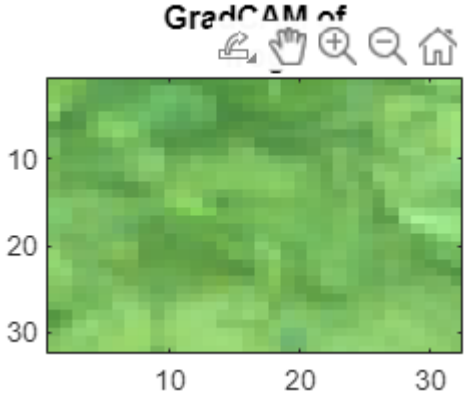
```
confusionchart(YTest,preds)
```



Visualizing incorrectely classified images. Additionally, added a gradCAM visualization to se which parts of an image are important to the classification decision of a network.

```
indeces = find(preds ~= YTest);
idx = datasample(indeces,4);
subplot(2,2,1);
imshow(XTest(:,:,:,idx(1)));
title([YTest(idx(1)), "mistaken as ", preds(idx(1))])
subplot(2,2,2);
imshow(XTest(:,:,:,idx(2)));
title([YTest(idx(2)), "mistaken as ", preds(idx(2))])
subplot(2,2,3);
imshow(XTest(:,:,:,idx(3)));
title([YTest(idx(3)), "mistaken as ", preds(idx(3))])
subplot(2,2,4);
imshow(XTest(:,:,:,idx(4)));
title([YTest(idx(4)), "mistaken as ", preds(idx(4))])
sgtitle('Wrongly predicted images')
```

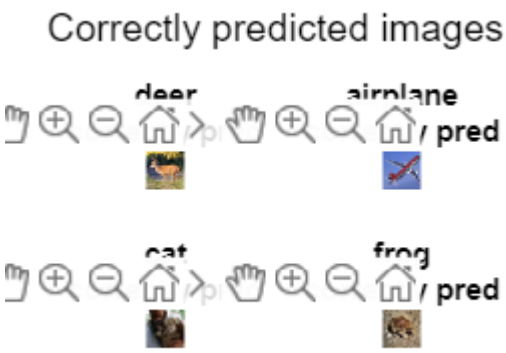

```
scoreMap = gradCAM(improved_net,XTest(:,:,:,idx(1)),YTest(idx(1)));
figure
imagesc(XTest(:,:,:,idx(1)))
hold on
imagesc(scoreMap,'AlphaData',0.5)
colormap jet
title(["GradCAM of", YTest(idx(1))])
hold off
```



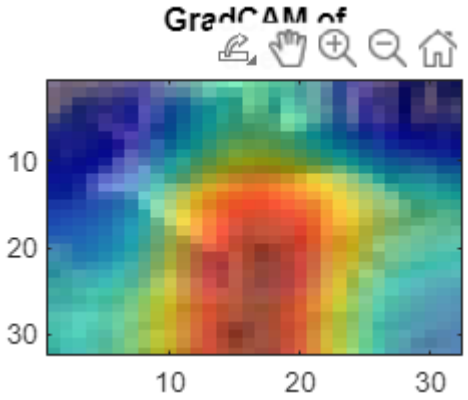
Visualizing correctely classified images. Additionally, added a gradCAM visualization to se which parts of an image are important to the classification decision of a network.

```
indeces = find(preds == YTest);
idx = datasample(indeces,4);
subplot(2,2,1);
imshow(XTest(:,:,:,idx(1)));
title([YTest(idx(1)), "correctly pred"])
subplot(2,2,2);
imshow(XTest(:,:,:,idx(2)));
title([YTest(idx(2)), "correctly pred"])
subplot(2,2,3);
imshow(XTest(:,:,:,idx(3)));
title([YTest(idx(3)), "correctly pred"])
subplot(2,2,4);
imshow(XTest(:,:,:,idx(4)));
```

```
title([YTest(idx(4)), "correctly pred"])
sgtitle('Correctly predicted images')
```




```
scoreMap = gradCAM(improved_net,XTest(:,:,:,idx(1)),YTest(idx(1)));
figure
imagesc(XTest(:,:,:,idx(1)))
hold on
imagesc(scoreMap,'AlphaData',0.5)
colormap jet
title(["GradCAM of", YTest(idx(1))])
hold off
```



Ablation Study

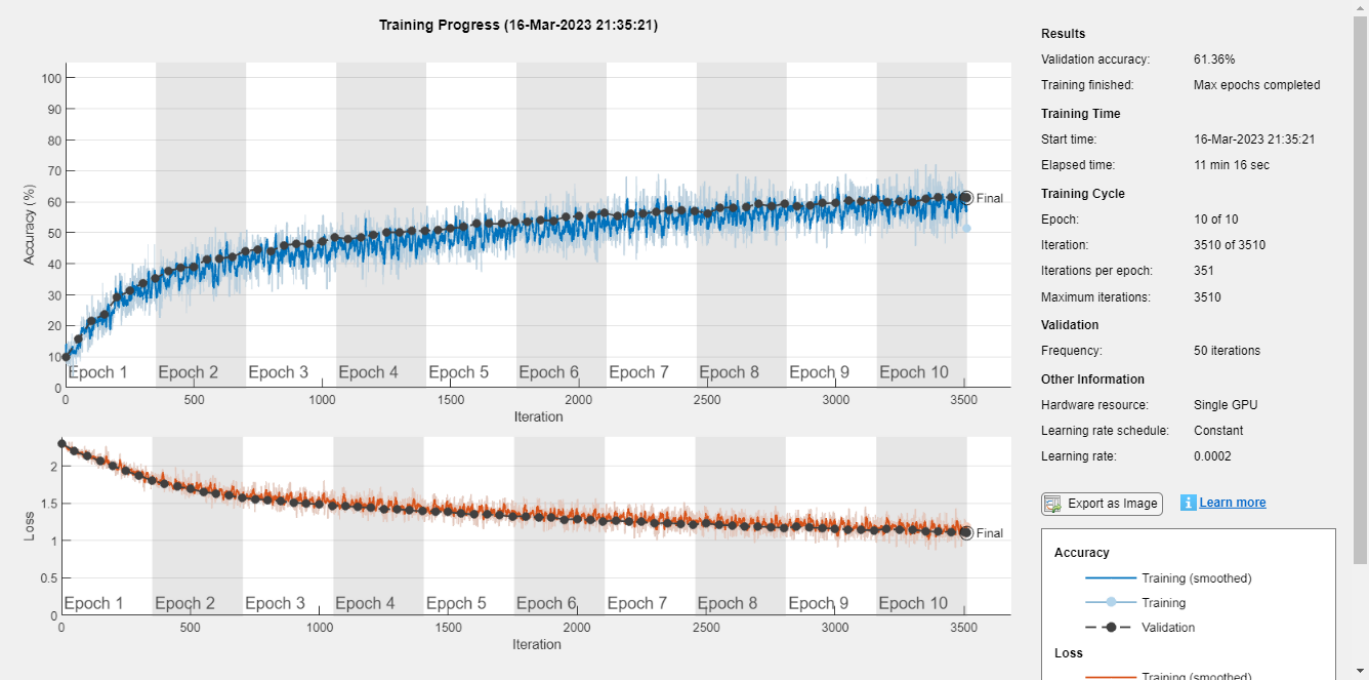
Improved Model (no scheduler)

```
layers = improved_cnn_classifier_v2();
[X_train, X_val, Y_train, Y_val] = train_test_split(XTrain,YTrain,0.1);
opts = trainingOptions('sgdm', ...
    'Momentum', 0.9, ...
    'InitialLearnRate', 0.0002, ...
    'LearnRateDropFactor', 0.1, ...
    'LearnRateDropPeriod', 16, ...
    'L2Regularization', 0.004, ...
    'ValidationData',{X_val, Y_val}, ...
    'OutputNetwork','best-validation-loss', ...
    'MaxEpochs', 10, ...
```

```
    'MiniBatchSize', 128, ...
    'Verbose', true,...
    'Plots','training-progress',...
    'ExecutionEnvironment','gpu');

improved_net = trainNetwork(X_train, Y_train, layers, opts);
```

```
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 |       00:00:02 |       10.16% |        9.88% |       2.3029 |       2.2995 |          0.00
|       1 |          50 |       00:00:04 |       15.62% |       15.64% |       2.2066 |       2.1967 |          0.00
|       1 |         100 |       00:00:07 |       18.75% |       21.54% |       2.1512 |       2.1287 |          0.00
|       1 |         150 |       00:00:09 |       22.66% |       23.72% |       2.0048 |       2.0665 |          0.00
|       1 |         200 |       00:00:11 |       27.34% |       29.26% |       1.9710 |       1.9983 |          0.00
|       1 |         250 |       00:00:14 |       28.12% |       31.26% |       2.0090 |       1.9310 |          0.00
|       1 |         300 |       00:00:16 |       27.34% |       33.82% |       1.8685 |       1.8692 |          0.00
|       1 |         350 |       00:00:18 |       31.25% |       35.38% |       1.8216 |       1.8069 |          0.00
|       2 |         400 |       00:00:21 |       33.59% |       37.58% |       1.8849 |       1.7559 |          0.00
|       2 |         450 |       00:00:32 |       33.59% |       38.76% |       1.7164 |       1.7208 |          0.00
|       2 |         500 |       00:00:44 |       37.50% |       38.98% |       1.7128 |       1.6907 |          0.00
|       2 |         550 |       00:00:57 |       39.06% |       41.50% |       1.6177 |       1.6502 |          0.00
|       2 |         600 |       00:01:09 |       44.53% |       41.70% |       1.5522 |       1.6286 |          0.00
|       2 |         650 |       00:01:22 |       39.06% |       42.26% |       1.6993 |       1.6004 |          0.00
|       2 |         700 |       00:01:34 |       41.41% |       44.08% |       1.5923 |       1.5729 |          0.00
|       3 |         750 |       00:01:47 |       39.84% |       44.66% |       1.6830 |       1.5546 |          0.00
|       3 |         800 |       00:01:59 |       43.75% |       44.14% |       1.6612 |       1.5440 |          0.00
|       3 |         850 |       00:02:07 |       42.97% |       45.90% |       1.6999 |       1.5290 |          0.00
|       3 |         900 |       00:02:19 |       46.88% |       46.50% |       1.4982 |       1.5054 |          0.00
|       3 |         950 |       00:02:28 |       46.09% |       46.36% |       1.4018 |       1.4974 |          0.00
|       3 |        1000 |       00:02:34 |       46.88% |       47.10% |       1.4164 |       1.4832 |          0.00
|       3 |        1050 |       00:02:45 |       37.50% |       48.56% |       1.6796 |       1.4681 |          0.00
|       4 |        1100 |       00:02:56 |       42.19% |       48.02% |       1.3809 |       1.4598 |          0.00
|       4 |        1150 |       00:03:07 |       43.75% |       48.46% |       1.4445 |       1.4494 |          0.00
|       4 |        1200 |       00:03:20 |       54.69% |       49.44% |       1.3390 |       1.4378 |          0.00
|       4 |        1250 |       00:03:30 |       43.75% |       50.18% |       1.5242 |       1.4178 |          0.00
|       4 |        1300 |       00:03:35 |       39.06% |       50.10% |       1.6340 |       1.4218 |          0.00
|       4 |        1350 |       00:03:46 |       49.22% |       50.60% |       1.4814 |       1.4029 |          0.00
|       4 |        1400 |       00:03:57 |       55.47% |       50.68% |       1.2978 |       1.3930 |          0.00
|       5 |        1450 |       00:04:10 |       43.75% |       50.82% |       1.4908 |       1.3894 |          0.00
|       5 |        1500 |       00:04:20 |       50.78% |       51.40% |       1.3381 |       1.3813 |          0.00
|       5 |        1550 |       00:04:25 |       49.22% |       51.86% |       1.4804 |       1.3624 |          0.00
|       5 |        1600 |       00:04:36 |       55.47% |       52.90% |       1.3527 |       1.3490 |          0.00
|       5 |        1650 |       00:04:47 |       45.31% |       52.90% |       1.5926 |       1.3513 |          0.00
|       5 |        1700 |       00:05:00 |       47.66% |       52.90% |       1.5307 |       1.3373 |          0.00
|       5 |        1750 |       00:05:12 |       50.78% |       53.54% |       1.3210 |       1.3226 |          0.00
|       6 |        1800 |       00:05:29 |       54.69% |       53.56% |       1.2105 |       1.3253 |          0.00
|       6 |        1850 |       00:05:42 |       51.56% |       54.06% |       1.4496 |       1.3097 |          0.00
|       6 |        1900 |       00:05:46 |       58.59% |       53.92% |       1.1564 |       1.3122 |          0.00
|       6 |        1950 |       00:05:55 |       63.28% |       55.20% |       1.1233 |       1.2822 |          0.00
|       6 |        2000 |       00:06:05 |       57.81% |       55.30% |       1.2360 |       1.2887 |          0.00
|       6 |        2050 |       00:06:16 |       49.22% |       55.70% |       1.4211 |       1.2718 |          0.00
|       6 |        2100 |       00:06:28 |       58.59% |       56.40% |       1.2263 |       1.2569 |          0.00
|       7 |        2150 |       00:06:41 |       53.91% |       55.38% |       1.2807 |       1.2713 |          0.00
|       7 |        2200 |       00:06:53 |       54.69% |       56.26% |       1.2934 |       1.2516 |          0.00
|       7 |        2250 |       00:06:57 |       55.47% |       56.18% |       1.1564 |       1.2516 |          0.00
|       7 |        2300 |       00:07:07 |       51.56% |       56.78% |       1.3398 |       1.2297 |          0.00
|       7 |        2350 |       00:07:19 |       63.28% |       57.28% |       1.1068 |       1.2373 |          0.00
|       7 |        2400 |       00:07:32 |       54.69% |       57.22% |       1.2760 |       1.2229 |          0.00
|       7 |        2450 |       00:07:37 |       49.22% |       57.10% |       1.3548 |       1.2148 |          0.00
|       8 |        2500 |       00:07:45 |       51.56% |       56.32% |       1.2887 |       1.2322 |          0.00
```

```
|       8 |        2550 |        00:07:56 |        54.69% |        58.08% |        1.2588 |        1.2087 |          0.00
|       8 |        2600 |        00:08:08 |        57.03% |        58.18% |        1.1149 |        1.2046 |          0.00
|       8 |        2650 |        00:08:20 |        67.97% |        58.36% |        1.0364 |        1.1907 |          0.00
|       8 |        2700 |        00:08:29 |        51.56% |        59.34% |        1.3918 |        1.1859 |          0.00
|       8 |        2750 |        00:08:36 |        60.16% |        58.46% |        1.0756 |        1.1835 |          0.00
|       8 |        2800 |        00:08:47 |        56.25% |        59.42% |        1.3123 |        1.1676 |          0.00
|       9 |        2850 |        00:08:58 |        53.12% |        58.46% |        1.3258 |        1.1874 |          0.00
|       9 |        2900 |        00:09:11 |        50.00% |        58.96% |        1.3275 |        1.1766 |          0.00
|       9 |        2950 |        00:09:21 |        53.91% |        59.52% |        1.3655 |        1.1670 |          0.00
|       9 |        3000 |        00:09:25 |        57.03% |        59.62% |        1.1656 |        1.1616 |          0.00
|       9 |        3050 |        00:09:35 |        60.94% |        60.50% |        1.1793 |        1.1499 |          0.00
|       9 |        3100 |        00:09:46 |        59.38% |        60.24% |        1.1877 |        1.1460 |          0.00
|       9 |        3150 |        00:09:59 |        57.81% |        60.68% |        1.1013 |        1.1354 |          0.00
|      10 |        3200 |        00:10:12 |        50.00% |        59.98% |        1.3266 |        1.1592 |          0.00
|      10 |        3250 |        00:10:20 |        52.34% |        60.14% |        1.3075 |        1.1430 |          0.00
|      10 |        3300 |        00:10:31 |        60.16% |        59.94% |        1.1337 |        1.1454 |          0.00
|      10 |        3350 |        00:10:43 |        55.47% |        60.84% |        1.1251 |        1.1256 |          0.00
|      10 |        3400 |        00:10:56 |        54.69% |        61.38% |        1.2932 |        1.1202 |          0.00
|      10 |        3450 |        00:11:03 |        58.59% |        61.50% |        1.1281 |        1.1141 |          0.00
|      10 |        3500 |        00:11:11 |        60.94% |        61.50% |        1.0964 |        1.1091 |          0.00
|      10 |        3510 |        00:11:14 |        51.56% |        61.46% |        1.1848 |        1.1075 |          0.00
|=========================================================================================================================
Training finished: Max epochs completed.
```




```
preds = improved_net.classify(XTest);
tp = nnz(preds == YTest);
accuracy = tp / length(YTest);
disp(['The network achieved an accuracy of: ', num2str((accuracy)*100), '%'])
```

```
The network achieved an accuracy of: 60.51%
```

```
confusionchart(YTest,preds)
```

True Class \ Predicted Class	airplane	automobile	bird	cat	deer	dog	frog	horse	ship	truck
airplane	663	42	73	18	37	10	14	10	80	53
automobile	36	768	8	10	12	4	15	8	27	112
bird	70	10	422	61	180	89	106	32	14	16
cat	19	18	85	363	105	206	131	32	17	24
deer	38	9	74	50	582	41	97	85	12	12
dog	12	7	72	158	90	523	57	58	16	7
frog	5	6	43	56	77	27	769	7	6	4
horse	19	8	34	37	134	98	15	620	4	31
ship	141	70	23	24	8	7	11	2	637	77
truck	29	149	9	20	19	5	17	14	34	704

```
indeces = find(preds ~= YTest);
idx = datasample(indeces,2);
subplot(1,2,1);
imshow(XTest(:,:,:,idx(1)));
title([YTest(idx(1)), "mistaken as ", preds(idx(1))])
subplot(1,2,2);
imshow(XTest(:,:,:,idx(2)));
title([YTest(idx(2)), "mistaken as ", preds(idx(2))])
```

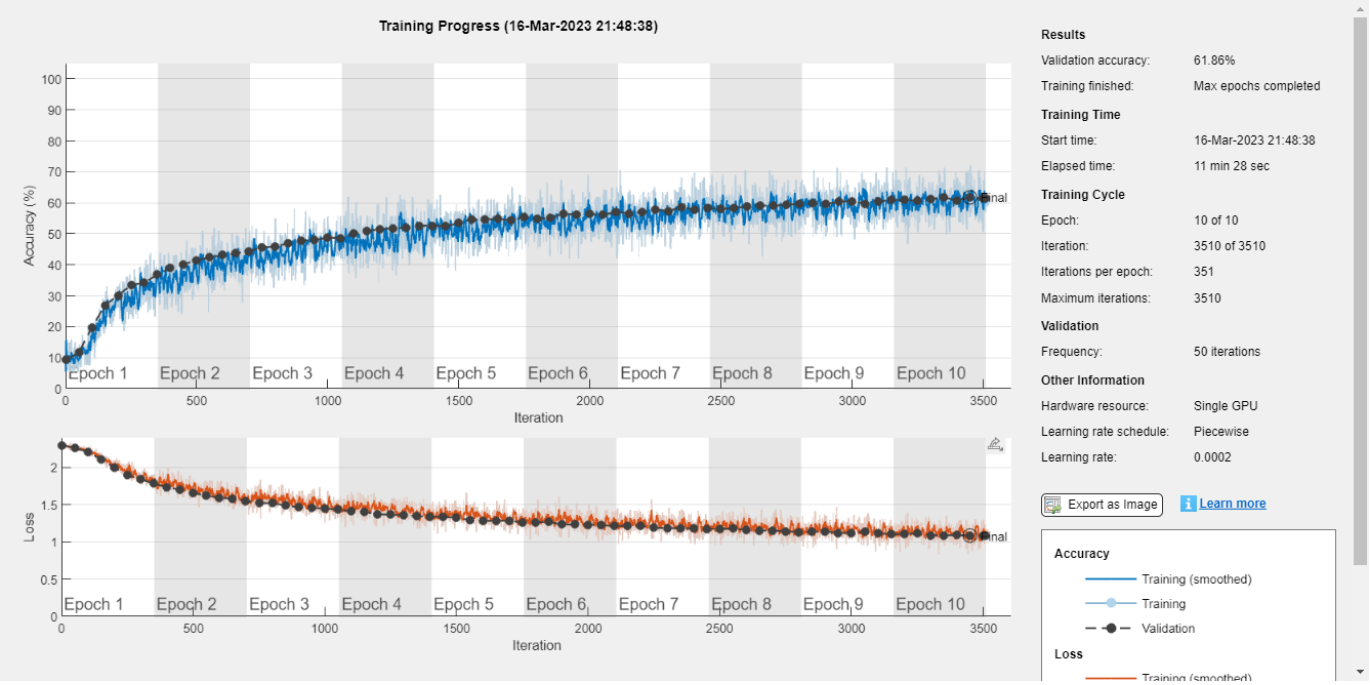
Improved Model (no learn drop factor)

```
layers = improved_cnn_classifier_v2();
[X_train, X_val, Y_train, Y_val] = train_test_split(XTrain,YTrain,0.1);
opts = trainingOptions('sgdm', ...
    'Momentum', 0.9, ...
    'InitialLearnRate', 0.0002, ...
```

```
    'LearnRateSchedule', 'piecewise', ...
    'L2Regularization', 0.004, ...
    'ValidationData',{X_val, Y_val}, ...
    'OutputNetwork','best-validation-loss', ...
    'MaxEpochs', 10, ...
    'MiniBatchSize', 128, ...
    'Verbose', true,...
    'Plots','training-progress',...
    'ExecutionEnvironment','gpu');

improved_net = trainNetwork(X_train, Y_train, layers, opts);
```

```
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 |       00:00:01 |        5.47% |        9.30% |       2.3046 |       2.3010 |          0.00
|       1 |          50 |       00:00:04 |       11.72% |       11.68% |       2.2648 |       2.2652 |          0.00
|       1 |         100 |       00:00:06 |       15.62% |       19.70% |       2.1902 |       2.2086 |          0.00
|       1 |         150 |       00:00:08 |       21.88% |       26.88% |       2.1346 |       2.1125 |          0.00
|       1 |         200 |       00:00:10 |       30.47% |       30.14% |       2.0314 |       2.0017 |          0.00
|       1 |         250 |       00:00:12 |       28.91% |       33.44% |       1.9836 |       1.9005 |          0.00
|       1 |         300 |       00:00:14 |       35.16% |       34.22% |       1.8816 |       1.8437 |          0.00
|       1 |         350 |       00:00:16 |       36.72% |       36.80% |       1.8632 |       1.7841 |          0.00
|       2 |         400 |       00:00:19 |       32.03% |       38.98% |       1.7880 |       1.7347 |          0.00
|       2 |         450 |       00:00:31 |       39.84% |       40.14% |       1.7234 |       1.7014 |          0.00
|       2 |         500 |       00:00:44 |       34.38% |       41.52% |       1.8204 |       1.6584 |          0.00
|       2 |         550 |       00:00:57 |       44.53% |       42.40% |       1.6165 |       1.6219 |          0.00
|       2 |         600 |       00:01:11 |       33.59% |       43.16% |       1.7913 |       1.5937 |          0.00
|       2 |         650 |       00:01:24 |       49.22% |       43.66% |       1.4407 |       1.5827 |          0.00
|       2 |         700 |       00:01:36 |       38.28% |       44.36% |       1.6472 |       1.5520 |          0.00
|       3 |         750 |       00:01:49 |       37.50% |       45.72% |       1.7627 |       1.5257 |          0.00
|       3 |         800 |       00:01:54 |       54.69% |       45.78% |       1.5343 |       1.5203 |          0.00
|       3 |         850 |       00:02:03 |       46.88% |       47.04% |       1.4858 |       1.4910 |          0.00
|       3 |         900 |       00:02:15 |       37.50% |       47.86% |       1.6260 |       1.4679 |          0.00
|       3 |         950 |       00:02:26 |       41.41% |       47.88% |       1.5693 |       1.4611 |          0.00
|       3 |        1000 |       00:02:30 |       47.66% |       48.86% |       1.4482 |       1.4469 |          0.00
|       3 |        1050 |       00:02:41 |       42.97% |       48.48% |       1.5309 |       1.4364 |          0.00
|       4 |        1100 |       00:02:52 |       51.56% |       50.02% |       1.3590 |       1.4124 |          0.00
|       4 |        1150 |       00:03:04 |       47.66% |       50.88% |       1.4281 |       1.4042 |          0.00
|       4 |        1200 |       00:03:16 |       40.62% |       51.52% |       1.5319 |       1.3735 |          0.00
|       4 |        1250 |       00:03:27 |       45.31% |       51.80% |       1.4253 |       1.3654 |          0.00
|       4 |        1300 |       00:03:31 |       50.78% |       51.92% |       1.3332 |       1.3587 |          0.00
|       4 |        1350 |       00:03:41 |       50.00% |       52.62% |       1.4151 |       1.3482 |          0.00
|       4 |        1400 |       00:03:53 |       51.56% |       52.62% |       1.3399 |       1.3372 |          0.00
|       5 |        1450 |       00:04:05 |       57.03% |       52.38% |       1.2348 |       1.3406 |          0.00
|       5 |        1500 |       00:04:18 |       49.22% |       53.52% |       1.4667 |       1.3232 |          0.00
|       5 |        1550 |       00:04:22 |       56.25% |       54.58% |       1.3136 |       1.2959 |          0.00
|       5 |        1600 |       00:04:33 |       46.88% |       54.60% |       1.3205 |       1.2832 |          0.00
|       5 |        1650 |       00:04:44 |       50.00% |       54.92% |       1.3731 |       1.2859 |          0.00
|       5 |        1700 |       00:04:57 |       51.56% |       54.24% |       1.2684 |       1.2843 |          0.00
|       5 |        1750 |       00:05:08 |       60.16% |       55.48% |       1.2204 |       1.2608 |          0.00
|       6 |        1800 |       00:05:12 |       45.31% |       54.86% |       1.4445 |       1.2656 |          0.00
|       6 |        1850 |       00:05:23 |       55.47% |       55.16% |       1.2591 |       1.2682 |          0.00
|       6 |        1900 |       00:05:34 |       55.47% |       56.44% |       1.2618 |       1.2345 |          0.00
|       6 |        1950 |       00:05:47 |       52.34% |       56.18% |       1.2672 |       1.2334 |          0.00
|       6 |        2000 |       00:05:59 |       55.47% |       56.34% |       1.2474 |       1.2302 |          0.00
|       6 |        2050 |       00:06:04 |       50.78% |       56.10% |       1.2946 |       1.2259 |          0.00
|       6 |        2100 |       00:06:15 |       57.81% |       57.04% |       1.2398 |       1.2123 |          0.00
|       7 |        2150 |       00:06:24 |       53.91% |       56.56% |       1.2002 |       1.2162 |          0.00
```

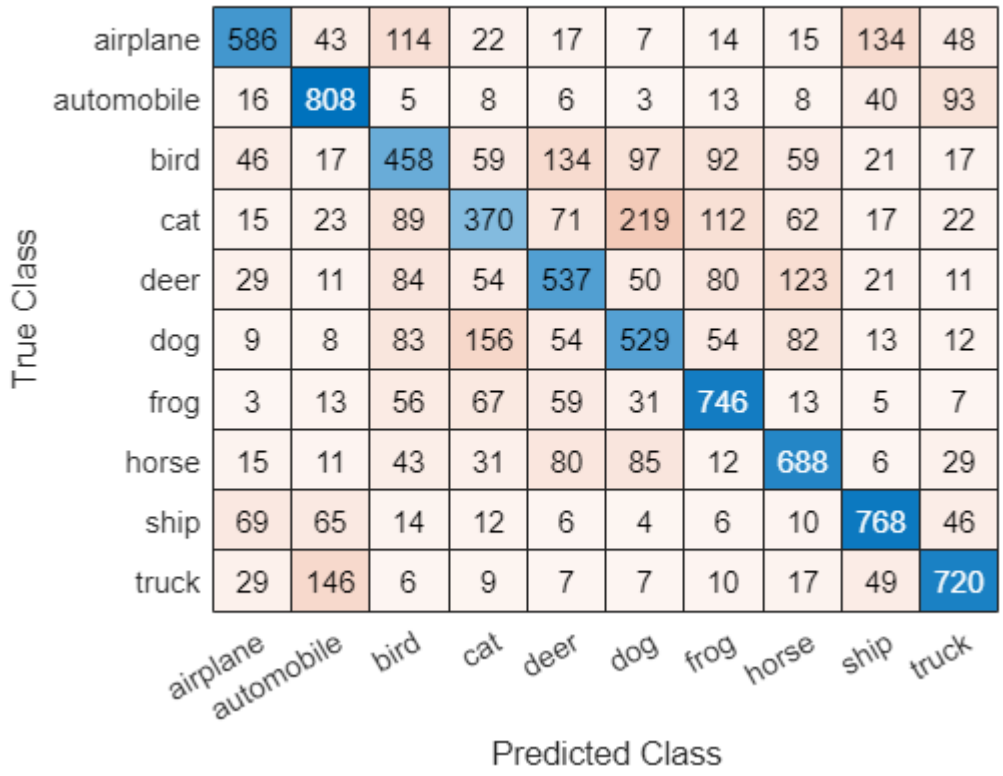
```
|       7 |        2200 |       00:06:29 |       56.25% |       56.98% |       1.1907 |       1.2195 |          0.00
|       7 |        2250 |       00:06:40 |       63.28% |       57.76% |       1.1765 |       1.1892 |          0.00
|       7 |        2300 |       00:06:52 |       58.59% |       57.38% |       1.1153 |       1.1875 |          0.00
|       7 |        2350 |       00:07:16 |       62.50% |       58.62% |       1.1658 |       1.1825 |          0.00
|       7 |        2400 |       00:07:28 |       69.53% |       57.76% |       1.0743 |       1.1827 |          0.00
|       7 |        2450 |       00:07:37 |       63.28% |       58.40% |       1.1288 |       1.1768 |          0.00
|       8 |        2500 |       00:07:48 |       53.91% |       58.04% |       1.3579 |       1.1736 |          0.00
|       8 |        2550 |       00:08:00 |       51.56% |       58.24% |       1.3414 |       1.1810 |          0.00
|       8 |        2600 |       00:08:13 |       56.25% |       58.80% |       1.1395 |       1.1596 |          0.00
|       8 |        2650 |       00:08:23 |       55.47% |       59.18% |       1.1116 |       1.1543 |          0.00
|       8 |        2700 |       00:08:34 |       67.19% |       59.00% |       1.0677 |       1.1517 |          0.00
|       8 |        2750 |       00:08:45 |       59.38% |       59.46% |       1.1239 |       1.1430 |          0.00
|       8 |        2800 |       00:08:58 |       60.16% |       59.58% |       1.1631 |       1.1340 |          0.00
|       9 |        2850 |       00:09:11 |       63.28% |       59.80% |       1.0554 |       1.1366 |          0.00
|       9 |        2900 |       00:09:16 |       49.22% |       59.52% |       1.3414 |       1.1447 |          0.00
|       9 |        2950 |       00:09:25 |       64.06% |       60.36% |       1.0590 |       1.1199 |          0.00
|       9 |        3000 |       00:09:35 |       57.81% |       60.56% |       1.2427 |       1.1213 |          0.00
|       9 |        3050 |       00:09:47 |       60.94% |       59.68% |       1.0922 |       1.1383 |          0.00
|       9 |        3100 |       00:10:00 |       58.59% |       60.48% |       1.0939 |       1.1151 |          0.00
|       9 |        3150 |       00:10:09 |       60.94% |       60.92% |       1.1390 |       1.1047 |          0.00
|      10 |        3200 |       00:10:20 |       60.16% |       60.86% |       1.0939 |       1.1072 |          0.00
|      10 |        3250 |       00:10:31 |       57.03% |       60.68% |       1.1785 |       1.1125 |          0.00
|      10 |        3300 |       00:10:44 |       56.25% |       61.16% |       1.2843 |       1.0893 |          0.00
|      10 |        3350 |       00:10:56 |       60.16% |       61.80% |       1.1766 |       1.0883 |          0.00
|      10 |        3400 |       00:11:04 |       58.59% |       60.76% |       1.2199 |       1.0930 |          0.00
|      10 |        3450 |       00:11:12 |       55.47% |       61.74% |       1.1429 |       1.0831 |          0.00
|      10 |        3500 |       00:11:24 |       50.78% |       61.38% |       1.2923 |       1.0832 |          0.00
|      10 |        3510 |       00:11:28 |       60.16% |       61.56% |       1.1202 |       1.0857 |          0.00
|=========|=============|================|==============|==============|==============|==============|==============
Training finished: Max epochs completed.
```




```
preds = improved_net.classify(XTest);
tp = nnz(preds == YTest);
accuracy = tp / length(YTest);
disp(['The network achieved an accuracy of: ', num2str((accuracy)*100), '%'])
```

```
The network achieved an accuracy of: 62.1%
```

```
confusionchart(YTest,preds)
```




```
indeces = find(preds ~= YTest);
idx = datasample(indeces,2);
subplot(1,2,1);
imshow(XTest(:,:,:,idx(1)));
title([YTest(idx(1)), "mistaken as ", preds(idx(1))])
subplot(1,2,2);
imshow(XTest(:,:,:,idx(2)));
title([YTest(idx(2)), "mistaken as ", preds(idx(2))])
```

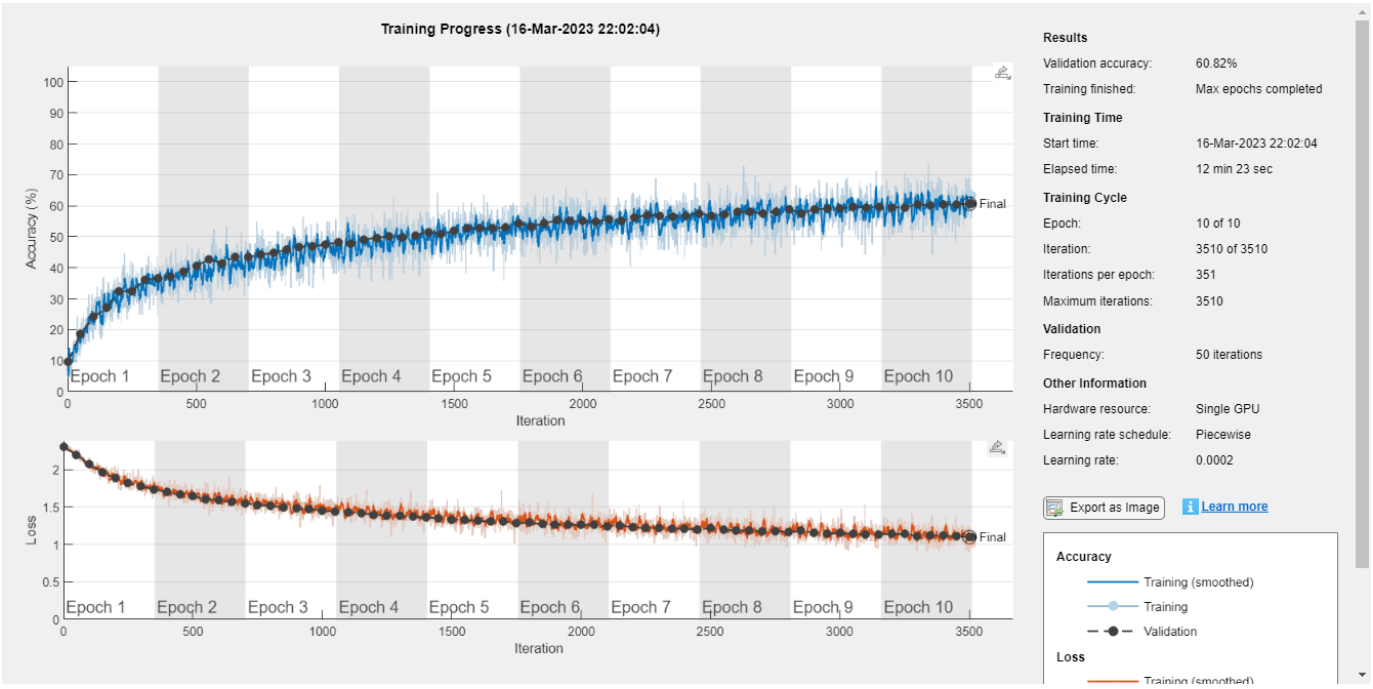
Improved Model (no l2 regularization)

```
layers = improved_cnn_classifier_v2();
[X_train, X_val, Y_train, Y_val] = train_test_split(XTrain,YTrain,0.1);
opts = trainingOptions('sgdm', ...
    'Momentum', 0.9, ...
```

```
    'InitialLearnRate', 0.0002, ...
    'LearnRateSchedule', 'piecewise', ...
    'LearnRateDropFactor', 0.1, ...
    'LearnRateDropPeriod', 16, ...
    'ValidationData',{X_val, Y_val}, ...
    'OutputNetwork','best-validation-loss', ...
    'MaxEpochs', 10, ...
    'MiniBatchSize', 128, ...
    'Verbose', true,...
    'Plots','training-progress',...
    'ExecutionEnvironment','gpu');

improved_net = trainNetwork(X_train, Y_train, layers, opts);
```

```
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 |        7.81% |        9.58% |       2.3030 |       2.3009 |          0.00
|       1 |          50 |       00:00:16 |       21.88% |       18.68% |       2.1780 |       2.1987 |          0.00
|       1 |         100 |       00:00:29 |       21.88% |       24.12% |       2.0851 |       2.0689 |          0.00
|       1 |         150 |       00:00:41 |       32.03% |       26.98% |       1.9193 |       1.9670 |          0.00
|       1 |         200 |       00:00:53 |       28.12% |       32.44% |       1.8580 |       1.8839 |          0.00
|       1 |         250 |       00:01:06 |       32.81% |       32.48% |       1.8603 |       1.8273 |          0.00
|       1 |         300 |       00:01:18 |       34.38% |       35.98% |       1.8293 |       1.7736 |          0.00
|       1 |         350 |       00:01:28 |       24.22% |       36.70% |       1.8598 |       1.7393 |          0.00
|       2 |         400 |       00:01:34 |       33.59% |       37.20% |       1.7967 |       1.6977 |          0.00
|       2 |         450 |       00:01:45 |       35.94% |       38.84% |       1.7677 |       1.6648 |          0.00
|       2 |         500 |       00:01:58 |       41.41% |       40.68% |       1.6095 |       1.6463 |          0.00
|       2 |         550 |       00:02:05 |       35.16% |       42.66% |       1.6101 |       1.6023 |          0.00
|       2 |         600 |       00:02:13 |       42.19% |       41.46% |       1.5807 |       1.5965 |          0.00
|       2 |         650 |       00:02:24 |       34.38% |       43.62% |       1.6952 |       1.5655 |          0.00
|       2 |         700 |       00:02:35 |       42.97% |       43.44% |       1.5581 |       1.5540 |          0.00
|       3 |         750 |       00:02:48 |       50.00% |       44.28% |       1.4229 |       1.5265 |          0.00
|       3 |         800 |       00:03:00 |       40.62% |       44.78% |       1.5972 |       1.5172 |          0.00
|       3 |         850 |       00:03:09 |       42.19% |       45.94% |       1.5467 |       1.4975 |          0.00
|       3 |         900 |       00:03:20 |       34.38% |       46.72% |       1.7033 |       1.4782 |          0.00
|       3 |         950 |       00:03:32 |       42.19% |       46.88% |       1.6788 |       1.4725 |          0.00
|       3 |        1000 |       00:03:44 |       45.31% |       47.46% |       1.4612 |       1.4552 |          0.00
|       3 |        1050 |       00:03:48 |       42.19% |       48.24% |       1.5250 |       1.4378 |          0.00
|       4 |        1100 |       00:03:59 |       45.31% |       47.80% |       1.4605 |       1.4329 |          0.00
|       4 |        1150 |       00:04:09 |       48.44% |       49.18% |       1.4604 |       1.4185 |          0.00
|       4 |        1200 |       00:04:21 |       42.97% |       49.64% |       1.5428 |       1.3993 |          0.00
|       4 |        1250 |       00:04:33 |       47.66% |       50.22% |       1.5722 |       1.3882 |          0.00
|       4 |        1300 |       00:04:41 |       52.34% |       49.76% |       1.5553 |       1.3820 |          0.00
|       4 |        1350 |       00:04:49 |       50.00% |       50.48% |       1.4848 |       1.3702 |          0.00
|       4 |        1400 |       00:05:02 |       46.09% |       51.56% |       1.3961 |       1.3578 |          0.00
|       5 |        1450 |       00:05:11 |       42.97% |       50.84% |       1.5020 |       1.3549 |          0.00
|       5 |        1500 |       00:05:21 |       47.66% |       51.96% |       1.4143 |       1.3342 |          0.00
|       5 |        1550 |       00:05:32 |       51.56% |       52.84% |       1.2701 |       1.3244 |          0.00
|       5 |        1600 |       00:05:43 |       57.81% |       52.68% |       1.2365 |       1.3152 |          0.00
|       5 |        1650 |       00:05:56 |       55.47% |       52.78% |       1.3370 |       1.3109 |          0.00
|       5 |        1700 |       00:06:08 |       42.19% |       52.92% |       1.4641 |       1.3123 |          0.00
|       5 |        1750 |       00:06:14 |       51.56% |       54.26% |       1.3720 |       1.2828 |          0.00
|       6 |        1800 |       00:06:23 |       53.91% |       53.34% |       1.3344 |       1.2932 |          0.00
|       6 |        1850 |       00:06:33 |       56.25% |       54.32% |       1.2652 |       1.2709 |          0.00
|       6 |        1900 |       00:06:44 |       48.44% |       55.34% |       1.4240 |       1.2663 |          0.00
|       6 |        1950 |       00:06:57 |       50.78% |       55.04% |       1.3767 |       1.2665 |          0.00
|       6 |        2000 |       00:07:09 |       49.22% |       55.12% |       1.3105 |       1.2591 |          0.00
|       6 |        2050 |       00:07:13 |       59.38% |       54.76% |       1.1977 |       1.2651 |          0.00
```

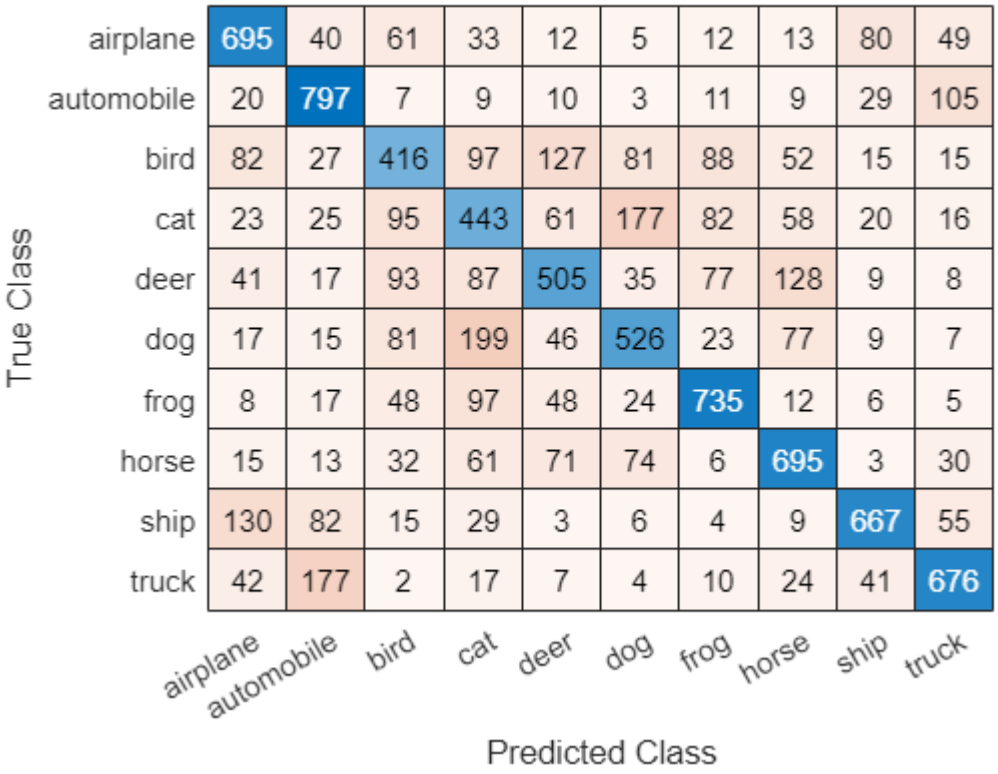
```
|       6 |        2100 |       00:07:23 |       51.56% |       55.80% |       1.3038 |       1.2377 |          0.00
|       7 |        2150 |       00:07:34 |       47.66% |       55.18% |       1.2990 |       1.2560 |          0.00
|       7 |        2200 |       00:07:47 |       53.91% |       56.26% |       1.1875 |       1.2298 |          0.00
|       7 |        2250 |       00:07:57 |       57.81% |       56.98% |       1.2901 |       1.2177 |          0.00
|       7 |        2300 |       00:08:08 |       53.91% |       56.84% |       1.2804 |       1.2242 |          0.00
|       7 |        2350 |       00:08:18 |       49.22% |       56.50% |       1.3217 |       1.2110 |          0.00
|       7 |        2400 |       00:08:40 |       57.81% |       56.82% |       1.1468 |       1.2129 |          0.00
|       7 |        2450 |       00:08:51 |       57.03% |       57.50% |       1.1522 |       1.2013 |          0.00
|       8 |        2500 |       00:08:59 |       60.16% |       56.82% |       1.1402 |       1.2200 |          0.00
|       8 |        2550 |       00:09:10 |       55.47% |       57.26% |       1.2748 |       1.1980 |          0.00
|       8 |        2600 |       00:09:22 |       54.69% |       57.94% |       1.3399 |       1.1827 |          0.00
|       8 |        2650 |       00:09:34 |       54.69% |       58.14% |       1.1989 |       1.1900 |          0.00
|       8 |        2700 |       00:09:41 |       57.03% |       57.54% |       1.2778 |       1.1772 |          0.00
|       8 |        2750 |       00:09:47 |       59.38% |       58.16% |       1.1414 |       1.1814 |          0.00
|       8 |        2800 |       00:09:53 |       57.03% |       58.86% |       1.2965 |       1.1641 |          0.00
|       9 |        2850 |       00:09:59 |       57.03% |       57.64% |       1.2931 |       1.1842 |          0.00
|       9 |        2900 |       00:10:11 |       65.62% |       58.78% |       1.1451 |       1.1580 |          0.00
|       9 |        2950 |       00:10:24 |       60.94% |       59.14% |       1.1793 |       1.1474 |          0.00
|       9 |        3000 |       00:10:33 |       60.94% |       59.06% |       1.1929 |       1.1498 |          0.00
|       9 |        3050 |       00:10:40 |       60.94% |       59.70% |       1.2063 |       1.1393 |          0.00
|       9 |        3100 |       00:10:51 |       59.38% |       59.42% |       1.2418 |       1.1377 |          0.00
|       9 |        3150 |       00:11:02 |       60.94% |       59.70% |       1.0703 |       1.1382 |          0.00
|      10 |        3200 |       00:11:15 |       57.03% |       59.50% |       1.2923 |       1.1406 |          0.00
|      10 |        3250 |       00:11:28 |       59.38% |       59.48% |       1.1407 |       1.1397 |          0.00
|      10 |        3300 |       00:11:32 |       62.50% |       60.50% |       1.2098 |       1.1138 |          0.00
|      10 |        3350 |       00:11:43 |       64.06% |       60.12% |       1.1273 |       1.1243 |          0.00
|      10 |        3400 |       00:11:54 |       57.81% |       60.42% |       1.1289 |       1.1166 |          0.00
|      10 |        3450 |       00:12:07 |       64.06% |       60.52% |       1.1046 |       1.1060 |          0.00
|      10 |        3500 |       00:12:19 |       58.59% |       60.62% |       1.1213 |       1.1026 |          0.00
|      10 |        3510 |       00:12:22 |       63.28% |       60.62% |       1.0075 |       1.1043 |          0.00
|=======================================================================================================================
Training finished: Max epochs completed.
```




```
preds = improved_net.classify(XTest);
tp = nnz(preds == YTest);
accuracy = tp / length(YTest);
disp(['The network achieved an accuracy of: ', num2str((accuracy)*100), '%'])
```

```
The network achieved an accuracy of: 61.55%
```

```
confusionchart(YTest,preds)
```




```
indeces = find(preds ~= YTest);
idx = datasample(indeces,2);
subplot(1,2,1);
imshow(XTest(:,:,:,idx(1)));
title([YTest(idx(1)), "mistaken as ", preds(idx(1))])
subplot(1,2,2);
imshow(XTest(:,:,:,idx(2)));
title([YTest(idx(2)), "mistaken as ", preds(idx(2))])
```

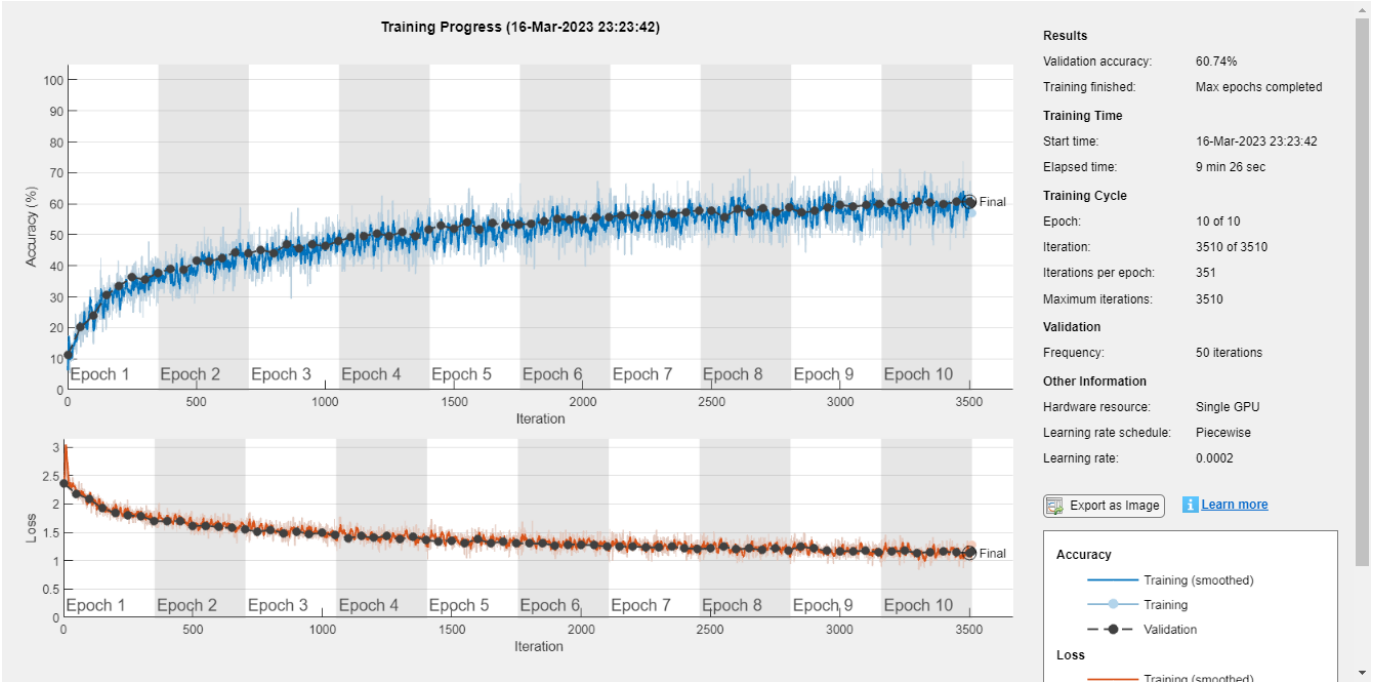
Improved Model (no batch norm)

```
layers = improved_cnn_classifier_v2();
[X_train, X_val, Y_train, Y_val] = train_test_split(XTrain,YTrain,0.1);
```

```
opts = trainingOptions('sgdm', ...
    'Momentum', 0.9, ...
    'InitialLearnRate', 0.0002, ...
    'LearnRateSchedule', 'piecewise', ...
    'LearnRateDropFactor', 0.1, ...
    'LearnRateDropPeriod', 16, ...
    'L2Regularization', 0.004, ...
    'ValidationData',{X_val, Y_val}, ...
    'OutputNetwork','best-validation-loss', ...
    'MaxEpochs', 10, ...
    'MiniBatchSize', 128, ...
    'Verbose', true,...
    'Plots','training-progress',...
    'ExecutionEnvironment','gpu');

improved_net = trainNetwork(X_train, Y_train, layers, opts);
```

```
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 |       00:00:01 |        6.25% |       11.16% |       2.3075 |       2.3557 |          0.00
|       1 |          50 |       00:00:04 |       18.75% |       20.14% |       2.2579 |       2.1762 |          0.00
|       1 |         100 |       00:00:06 |       14.84% |       23.94% |       2.1735 |       2.0796 |          0.00
|       1 |         150 |       00:00:08 |       19.53% |       30.46% |       2.0732 |       1.9230 |          0.00
|       1 |         200 |       00:00:10 |       26.56% |       33.46% |       1.9690 |       1.8398 |          0.00
|       1 |         250 |       00:00:12 |       32.81% |       36.32% |       1.8535 |       1.7897 |          0.00
|       1 |         300 |       00:00:13 |       33.59% |       35.54% |       1.9281 |       1.7872 |          0.00
|       1 |         350 |       00:00:15 |       35.94% |       37.80% |       1.6470 |       1.6953 |          0.00
|       2 |         400 |       00:00:17 |       35.16% |       38.90% |       1.9126 |       1.6918 |          0.00
|       2 |         450 |       00:00:19 |       36.72% |       38.76% |       1.6476 |       1.6988 |          0.00
|       2 |         500 |       00:00:21 |       35.94% |       41.64% |       1.6485 |       1.6113 |          0.00
|       2 |         550 |       00:00:23 |       38.28% |       41.42% |       1.6813 |       1.6163 |          0.00
|       2 |         600 |       00:00:24 |       39.84% |       42.54% |       1.6528 |       1.5883 |          0.00
|       2 |         650 |       00:00:26 |       47.66% |       44.34% |       1.5899 |       1.5737 |          0.00
|       2 |         700 |       00:00:28 |       43.75% |       43.94% |       1.5567 |       1.5504 |          0.00
|       3 |         750 |       00:00:30 |       44.53% |       45.16% |       1.4013 |       1.5062 |          0.00
|       3 |         800 |       00:00:32 |       41.41% |       44.16% |       1.5716 |       1.5433 |          0.00
|       3 |         850 |       00:00:37 |       39.06% |       46.84% |       1.5624 |       1.4862 |          0.00
|       3 |         900 |       00:00:48 |       44.53% |       45.66% |       1.5801 |       1.5145 |          0.00
|       3 |         950 |       00:00:59 |       50.00% |       46.88% |       1.4357 |       1.4681 |          0.00
|       3 |        1000 |       00:01:11 |       47.66% |       46.40% |       1.4426 |       1.4883 |          0.00
|       3 |        1050 |       00:01:22 |       53.91% |       47.88% |       1.3613 |       1.4458 |          0.00
|       4 |        1100 |       00:01:34 |       42.97% |       49.28% |       1.5337 |       1.3996 |          0.00
|       4 |        1150 |       00:01:46 |       42.97% |       49.60% |       1.6072 |       1.4314 |          0.00
|       4 |        1200 |       00:02:05 |       42.97% |       50.50% |       1.4771 |       1.4011 |          0.00
|       4 |        1250 |       00:02:17 |       42.97% |       49.56% |       1.4667 |       1.4333 |          0.00
|       4 |        1300 |       00:02:28 |       49.22% |       51.00% |       1.4852 |       1.3758 |          0.00
|       4 |        1350 |       00:02:40 |       37.50% |       49.56% |       1.5204 |       1.4272 |          0.00
|       4 |        1400 |       00:02:51 |       52.34% |       51.68% |       1.3499 |       1.3600 |          0.00
|       5 |        1450 |       00:02:58 |       57.03% |       53.08% |       1.2940 |       1.3367 |          0.00
|       5 |        1500 |       00:03:05 |       50.00% |       51.84% |       1.4825 |       1.3562 |          0.00
|       5 |        1550 |       00:03:16 |       60.16% |       53.96% |       1.1128 |       1.3087 |          0.00
|       5 |        1600 |       00:03:27 |       54.69% |       51.62% |       1.3066 |       1.3793 |          0.00
|       5 |        1650 |       00:03:30 |       46.09% |       53.78% |       1.4496 |       1.3066 |          0.00
|       5 |        1700 |       00:03:40 |       54.69% |       53.06% |       1.2523 |       1.3348 |          0.00
|       5 |        1750 |       00:03:50 |       57.81% |       53.38% |       1.1403 |       1.3062 |          0.00
|       6 |        1800 |       00:04:01 |       50.78% |       53.48% |       1.2838 |       1.3031 |          0.00
|       6 |        1850 |       00:04:12 |       50.78% |       54.36% |       1.3883 |       1.3002 |          0.00
```

```
|       6 |        1900 |       00:04:24 |       54.69% |       55.08% |       1.1897 |       1.2684 |          0.00
|       6 |        1950 |       00:04:29 |       52.34% |       54.90% |       1.2787 |       1.2841 |          0.00
|       6 |        2000 |       00:04:37 |       52.34% |       54.92% |       1.3593 |       1.2809 |          0.00
|       6 |        2050 |       00:04:48 |       48.44% |       55.56% |       1.4300 |       1.2706 |          0.00
|       6 |        2100 |       00:04:59 |       46.88% |       55.72% |       1.3767 |       1.2449 |          0.00
|       7 |        2150 |       00:05:11 |       52.34% |       56.30% |       1.2569 |       1.2470 |          0.00
|       7 |        2200 |       00:05:19 |       60.94% |       56.32% |       1.1628 |       1.2477 |          0.00
|       7 |        2250 |       00:05:23 |       59.38% |       56.34% |       1.1481 |       1.2325 |          0.00
|       7 |        2300 |       00:05:33 |       50.78% |       56.54% |       1.3606 |       1.2333 |          0.00
|       7 |        2350 |       00:05:44 |       56.25% |       56.82% |       1.2481 |       1.2432 |          0.00
|       7 |        2400 |       00:05:55 |       53.12% |       57.30% |       1.3501 |       1.2230 |          0.00
|       7 |        2450 |       00:06:07 |       57.03% |       57.90% |       1.1319 |       1.2009 |          0.00
|       8 |        2500 |       00:06:13 |       48.44% |       57.90% |       1.3248 |       1.2172 |          0.00
|       8 |        2550 |       00:06:20 |       52.34% |       55.66% |       1.2946 |       1.2461 |          0.00
|       8 |        2600 |       00:06:31 |       54.69% |       58.26% |       1.2391 |       1.1985 |          0.00
|       8 |        2650 |       00:06:42 |       53.12% |       57.34% |       1.1843 |       1.2153 |          0.00
|       8 |        2700 |       00:06:53 |       57.03% |       58.46% |       1.0874 |       1.1869 |          0.00
|       8 |        2750 |       00:06:57 |       53.12% |       57.14% |       1.2639 |       1.2189 |          0.00
|       8 |        2800 |       00:07:07 |       58.59% |       58.72% |       1.1838 |       1.1813 |          0.00
|       9 |        2850 |       00:07:17 |       59.38% |       57.18% |       1.1184 |       1.2475 |          0.00
|       9 |        2900 |       00:07:28 |       62.50% |       57.66% |       1.1482 |       1.2133 |          0.00
|       9 |        2950 |       00:07:40 |       58.59% |       58.90% |       1.1259 |       1.1693 |          0.00
|       9 |        3000 |       00:07:51 |       59.38% |       59.66% |       1.0206 |       1.1660 |          0.00
|       9 |        3050 |       00:07:57 |       56.25% |       59.08% |       1.2536 |       1.1661 |          0.00
|       9 |        3100 |       00:08:00 |       57.03% |       59.58% |       1.2822 |       1.1696 |          0.00
|       9 |        3150 |       00:08:10 |       56.25% |       59.80% |       1.2216 |       1.1544 |          0.00
|      10 |        3200 |       00:08:22 |       53.91% |       60.38% |       1.2771 |       1.1587 |          0.00
|      10 |        3250 |       00:08:34 |       56.25% |       59.38% |       1.1594 |       1.1731 |          0.00
|      10 |        3300 |       00:08:40 |       64.06% |       60.78% |       1.0391 |       1.1387 |          0.00
|      10 |        3350 |       00:08:48 |       68.75% |       60.46% |       1.0628 |       1.1477 |          0.00
|      10 |        3400 |       00:08:58 |       63.28% |       59.94% |       1.0988 |       1.1585 |          0.00
|      10 |        3450 |       00:09:09 |       64.06% |       60.60% |       1.1733 |       1.1425 |          0.00
|      10 |        3500 |       00:09:21 |       60.94% |       60.74% |       1.0634 |       1.1355 |          0.00
|      10 |        3510 |       00:09:24 |       57.03% |       60.10% |       1.2757 |       1.1571 |          0.00
|=========================================================================================================================================
Training finished: Max epochs completed.
```

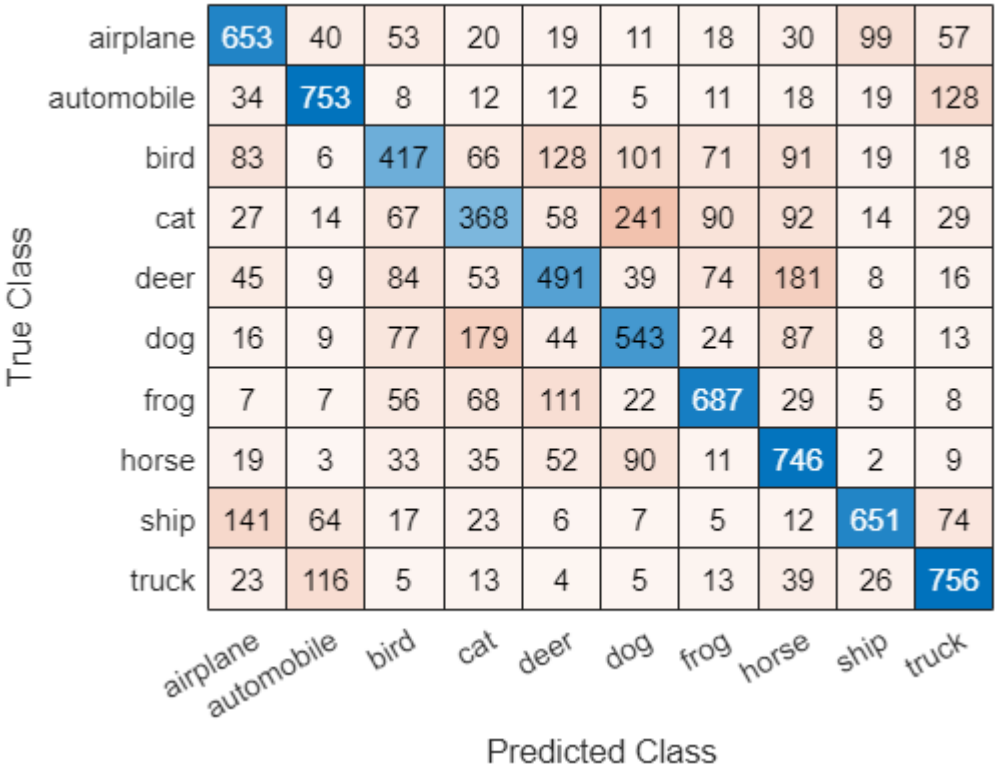



```
preds = improved_net.classify(XTest);
tp = nnz(preds == YTest);
```

```
accuracy = tp / length(YTest);
disp(['The network achieved an accuracy of: ', num2str((accuracy)*100), '%'])
```

```
The network achieved an accuracy of: 60.65%
```

```
confusionchart(YTest,preds)
```




```
indeces = find(preds ~= YTest);
idx = datasample(indeces,2);
subplot(1,2,1);
imshow(XTest(:,:,:,idx(1)));
title([YTest(idx(1)), "mistaken as ", preds(idx(1))])
subplot(1,2,2);
imshow(XTest(:,:,:,idx(2)));
title([YTest(idx(2)), "mistaken as ", preds(idx(2))])
```

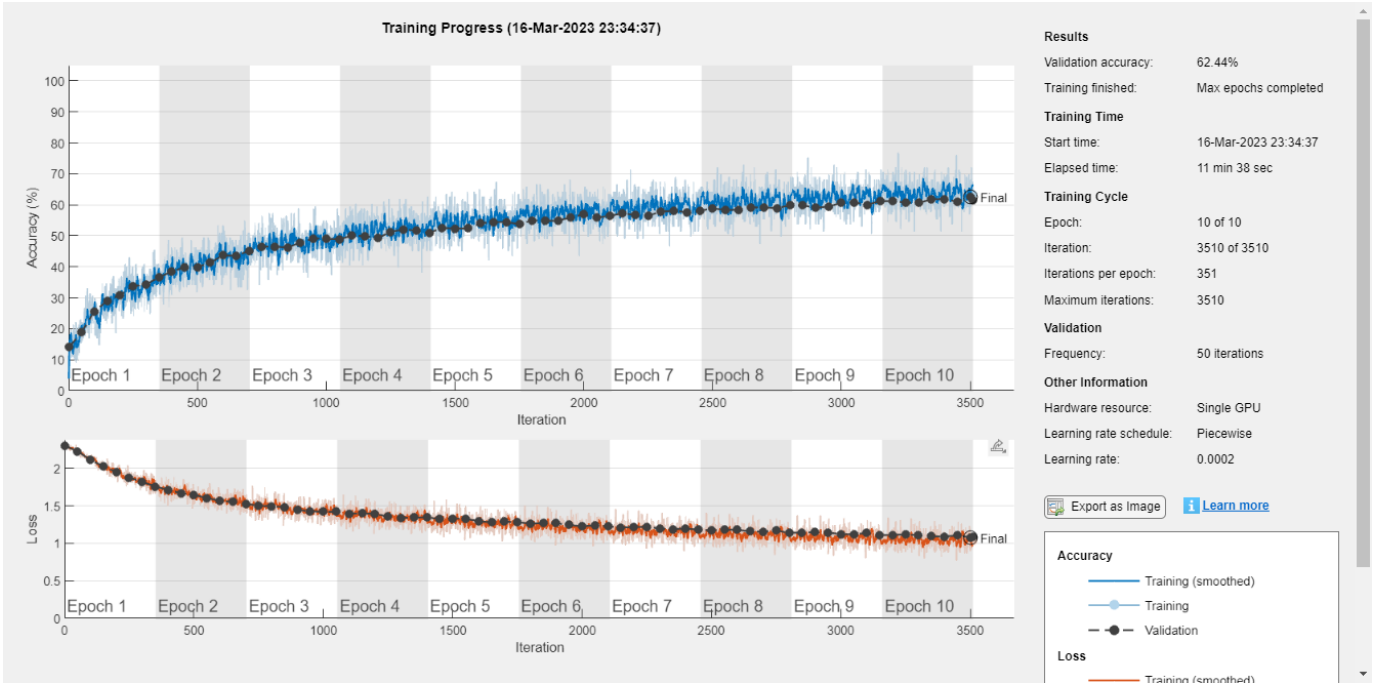
Improved Model (no drop out)

```
layers = improved_cnn_classifier_v2();
[X_train, X_val, Y_train, Y_val] = train_test_split(XTrain,YTrain,0.1);
opts = trainingOptions('sgdm', ...
    'Momentum', 0.9, ...
    'InitialLearnRate', 0.0002, ...
    'LearnRateSchedule', 'piecewise', ...
    'LearnRateDropFactor', 0.1, ...
    'LearnRateDropPeriod', 16, ...
    'L2Regularization', 0.004, ...
    'ValidationData',{X_val, Y_val}, ...
    'OutputNetwork','best-validation-loss', ...
    'MaxEpochs', 10, ...
    'MiniBatchSize', 128, ...
    'Verbose', true,...
    'Plots','training-progress',...
    'ExecutionEnvironment','gpu');

improved_net = trainNetwork(X_train, Y_train, layers, opts);
```

```
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 |       00:00:02 |        3.91% |       14.02% |       2.3033 |       2.3016 |          0.00
|       1 |          50 |       00:00:05 |       21.09% |       18.82% |       2.2298 |       2.2252 |          0.00
|       1 |         100 |       00:00:07 |       27.34% |       25.58% |       2.1076 |       2.1120 |          0.00
|       1 |         150 |       00:00:09 |       26.56% |       29.04% |       2.0331 |       2.0245 |          0.00
|       1 |         200 |       00:00:11 |       33.59% |       30.92% |       1.9560 |       1.9508 |          0.00
|       1 |         250 |       00:00:15 |       27.34% |       33.78% |       1.9005 |       1.8754 |          0.00
|       1 |         300 |       00:00:27 |       32.03% |       34.22% |       1.8445 |       1.8200 |          0.00
|       1 |         350 |       00:00:40 |       40.62% |       36.64% |       1.6747 |       1.7567 |          0.00
|       2 |         400 |       00:00:52 |       41.41% |       38.44% |       1.6336 |       1.7108 |          0.00
|       2 |         450 |       00:01:04 |       41.41% |       39.84% |       1.6452 |       1.6673 |          0.00
|       2 |         500 |       00:01:17 |       45.31% |       39.90% |       1.5302 |       1.6470 |          0.00
|       2 |         550 |       00:01:29 |       37.50% |       41.34% |       1.6213 |       1.6014 |          0.00
|       2 |         600 |       00:01:40 |       53.12% |       43.68% |       1.5016 |       1.5685 |          0.00
|       2 |         650 |       00:01:45 |       48.44% |       43.52% |       1.4545 |       1.5503 |          0.00
|       2 |         700 |       00:01:56 |       50.78% |       45.10% |       1.5267 |       1.5255 |          0.00
|       3 |         750 |       00:02:07 |       56.25% |       46.52% |       1.3169 |       1.5013 |          0.00
|       3 |         800 |       00:02:20 |       43.75% |       46.52% |       1.5220 |       1.4936 |          0.00
|       3 |         850 |       00:02:29 |       49.22% |       46.20% |       1.4832 |       1.4827 |          0.00
|       3 |         900 |       00:02:34 |       48.44% |       47.86% |       1.5084 |       1.4433 |          0.00
|       3 |         950 |       00:02:45 |       46.09% |       49.12% |       1.4342 |       1.4287 |          0.00
|       3 |        1000 |       00:02:56 |       50.78% |       49.02% |       1.3027 |       1.4190 |          0.00
|       3 |        1050 |       00:03:08 |       46.09% |       48.88% |       1.3829 |       1.4190 |          0.00
|       4 |        1100 |       00:03:21 |       51.56% |       50.08% |       1.4366 |       1.3954 |          0.00
|       4 |        1150 |       00:03:29 |       57.81% |       49.86% |       1.3599 |       1.3985 |          0.00
|       4 |        1200 |       00:03:38 |       49.22% |       49.28% |       1.4047 |       1.3937 |          0.00
|       4 |        1250 |       00:03:42 |       51.56% |       51.30% |       1.2784 |       1.3567 |          0.00
|       4 |        1300 |       00:03:54 |       51.56% |       52.04% |       1.3441 |       1.3401 |          0.00
|       4 |        1350 |       00:04:07 |       47.66% |       51.68% |       1.4350 |       1.3432 |          0.00
|       4 |        1400 |       00:04:12 |       55.47% |       50.96% |       1.2733 |       1.3465 |          0.00
|       5 |        1450 |       00:04:20 |       56.25% |       52.56% |       1.2118 |       1.3241 |          0.00
|       5 |        1500 |       00:04:28 |       53.91% |       52.34% |       1.2902 |       1.3295 |          0.00
|       5 |        1550 |       00:04:39 |       53.91% |       52.40% |       1.4895 |       1.3272 |          0.00
|       5 |        1600 |       00:04:52 |       51.56% |       54.04% |       1.3830 |       1.2965 |          0.00
|       5 |        1650 |       00:05:03 |       54.69% |       54.42% |       1.2894 |       1.2775 |          0.00
|       5 |        1700 |       00:05:07 |       56.25% |       54.40% |       1.1790 |       1.2882 |          0.00
```

5	1750	00:05:18	57.03%	53.76%	1.2924	1.2815	0.00
6	1800	00:05:29	54.69%	54.98%	1.1846	1.2627	0.00
6	1850	00:05:41	58.59%	54.82%	1.2304	1.2689	0.00
6	1900	00:05:55	55.47%	54.88%	1.3761	1.2676	0.00
6	1950	00:06:14	57.03%	55.98%	1.2632	1.2446	0.00
6	2000	00:06:27	51.56%	56.88%	1.3202	1.2258	0.00
6	2050	00:06:31	53.12%	55.88%	1.3973	1.2411	0.00
6	2100	00:06:41	56.25%	56.38%	1.1721	1.2253	0.00
7	2150	00:06:52	56.25%	57.28%	1.2272	1.2102	0.00
7	2200	00:07:03	61.72%	56.66%	1.1222	1.2161	0.00
7	2250	00:07:15	56.25%	56.52%	1.3179	1.2188	0.00
7	2300	00:07:28	61.72%	57.78%	1.0809	1.1988	0.00
7	2350	00:07:38	59.38%	58.08%	1.1253	1.1863	0.00
7	2400	00:07:43	62.50%	57.62%	1.0924	1.1984	0.00
7	2450	00:07:54	55.47%	58.04%	1.1794	1.1794	0.00
8	2500	00:08:06	60.16%	58.86%	1.2203	1.1732	0.00
8	2550	00:08:19	51.56%	58.30%	1.1975	1.1804	0.00
8	2600	00:08:24	65.62%	58.40%	0.8951	1.1792	0.00
8	2650	00:08:36	61.72%	59.14%	1.0675	1.1574	0.00
8	2700	00:08:48	64.84%	59.14%	0.9809	1.1535	0.00
8	2750	00:08:54	62.50%	58.94%	1.1299	1.1698	0.00
8	2800	00:09:03	60.94%	59.84%	1.1131	1.1388	0.00
9	2850	00:09:14	61.72%	59.80%	1.1528	1.1432	0.00
9	2900	00:09:26	63.28%	59.08%	1.0841	1.1486	0.00
9	2950	00:09:38	60.94%	59.40%	1.1012	1.1431	0.00
9	3000	00:09:51	67.19%	60.64%	1.0608	1.1209	0.00
9	3050	00:09:55	64.84%	60.76%	1.1631	1.1199	0.00
9	3100	00:10:06	61.72%	60.02%	1.0565	1.1361	0.00
9	3150	00:10:17	66.41%	61.22%	0.9303	1.1064	0.00
10	3200	00:10:30	70.31%	61.16%	1.0211	1.1133	0.00
10	3250	00:10:39	71.09%	60.74%	0.9166	1.1148	0.00
10	3300	00:10:47	65.62%	60.58%	1.0136	1.1099	0.00
10	3350	00:10:58	65.62%	61.84%	1.1573	1.0937	0.00
10	3400	00:11:10	63.28%	61.80%	1.0498	1.0901	0.00
10	3450	00:11:22	64.06%	61.06%	1.1079	1.1049	0.00
10	3500	00:11:35	64.84%	62.44%	0.9383	1.0787	0.00
10	3510	00:11:36	63.28%	61.56%	1.0266	1.0818	0.00

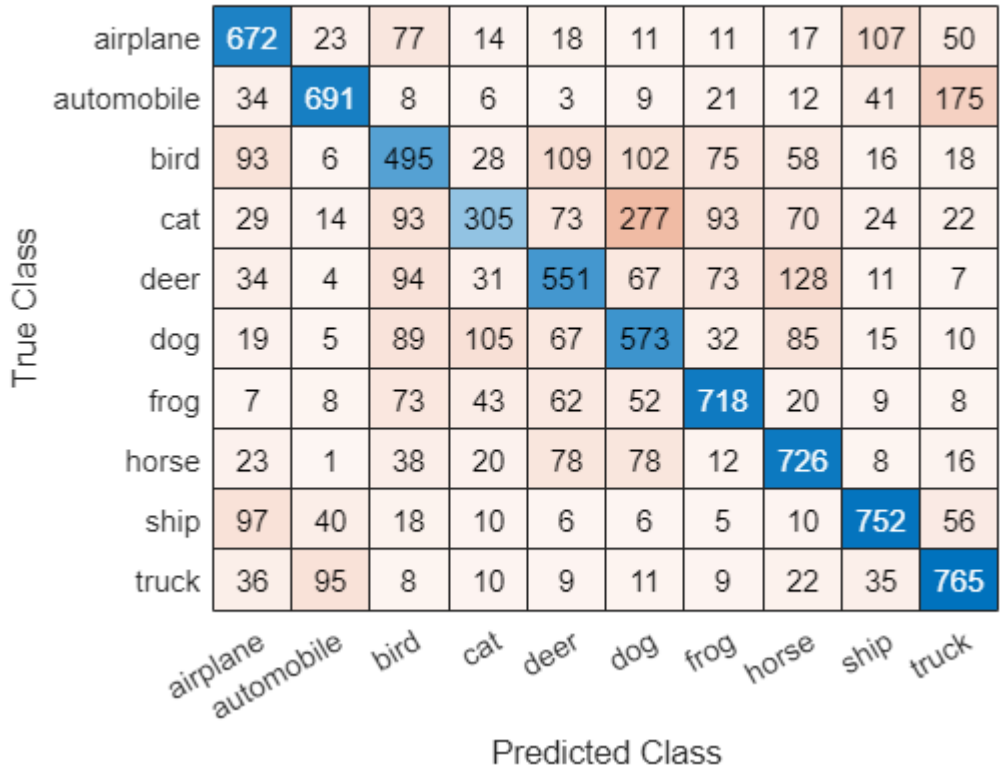
```
Training finished: Max epochs completed.
```



```
preds = improved_net.classify(XTest);
tp = nnz(preds == YTest);
accuracy = tp / length(YTest);
disp(['The network achieved an accuracy of: ', num2str((accuracy)*100), '%'])
```

```
The network achieved an accuracy of: 62.48%
```

```
confusionchart(YTest,preds)
```




```
idx = 2×1
        6348
        4501
```


```
indeces = find(preds ~= YTest);
idx = datasample(indeces,2);
subplot(1,2,1);
imshow(XTest(:,:,:,idx(1)));
title([YTest(idx(1)), "mistaken as ", preds(idx(1))])
subplot(1,2,2);
imshow(XTest(:,:,:,idx(2)));
```

```
title([YTest(idx(2)), "mistaken as ", preds(idx(2))])
```