```
% Experiment 2 - DL WITH CNN
% Author: Akshay.R

close all;
clear variables;
existing_GUIs = findall(0);
if length(existing_GUIs) > 1
    delete(existing_GUIs);
end
clc;
```

Read the training, validation and test partitions from the relevant

```
%folder = "/Users/akshay/Desktop/ASS/CUB_200_2011_Subset20classes/";
folder = "P:\code\CUB_200_2011\"
```

```
folder =
"P:\code\CUB_200_2011\"
```

```
trainingImageNames = readtable(fullfile(folder, "train.txt"), ...
    'ReadVariableNames', false);
trainingImageNames.Properties.VariableNames = {'index', 'imageName'};

validationImageNames = readtable(folder + "validate.txt", ...
    'ReadVariableNames', false);
validationImageNames.Properties.VariableNames = {'index', 'imageName'};

testImageNames = readtable(folder + "test.txt", ...
    'ReadVariableNames', false);
testImageNames.Properties.VariableNames = {'index', 'imageName'};
```

Read class info from the relevant text files

```
classNames = readtable(folder + "classes.txt", ...
    'ReadVariableNames', false);
classNames.Properties.VariableNames = {'index', 'className'};

imageClassLabels = readtable(folder + "image_class_labels.txt", ...
    'ReadVariableNames', false);
imageClassLabels.Properties.VariableNames = {'index', 'classLabel'};
```

Create lists of image names for training, validation and test subsets.

```
trainingImageList = strings(height(trainingImageNames), 1);
for iI = 1:height(trainingImageNames)
    trainingImageList(iI) = string(fullfile(folder, "images/", ...
        string(cell2mat(trainingImageNames.imageName(iI)))));
end

validationImageList = strings(height(validationImageNames), 1);
```

```
for iI = 1:height(validationImageNames)
    validationImageList(iI) = string(folder + "images/" + ...
        string(cell2mat(validationImageNames.imageName(iI))));
end

testImageList = strings(height(testImageNames), 1);
for iI = 1:height(testImageNames)
    testImageList(iI) = string(folder + "images/" + ...
        string(cell2mat(testImageNames.imageName(iI))));
end
```

Create image datastores for training, validation and test subsets

```
trainingImageDS = imageDatastore(trainingImageList, 'labelSource', 'foldernames', ...
    'FileExtensions', {'.jpg'});
trainingImageDS.ReadFcn = @readImagesIntoDatastoreCNN;
disp('Training set class distribution:');
```

```
Training set class distribution:
```

```
countEachLabel(trainingImageDS)
```

ans = 200×2 table

	Label	Count
1	001	36
2	002	36
3	003	35
4	004	36
5	005	26
6	006	25
7	007	30
8	008	29
9	009	35
10	010	36
11	011	36
12	012	34
13	013	36
14	014	36
15	015	35
16	016	35
17	017	34
18	018	26

	Label	Count
19	019	35
20	020	35
21	021	36
22	022	34
23	023	35
24	024	31
25	025	36
26	026	36
27	027	36
28	028	35
29	029	36
30	030	36
31	031	36
32	032	32
33	033	35
34	034	35
35	035	36
36	036	36
37	037	35
38	038	36
39	039	35
40	040	36
41	041	36
42	042	36
43	043	35
44	044	36
45	045	36
46	046	36
47	047	36
48	048	36
49	049	36
50	050	36
51	051	36

	Label	Count
52	052	36
53	053	36
54	054	36
55	055	36
56	056	36
57	057	36
58	058	35
59	059	36
60	060	35
61	061	36
62	062	36
63	063	36
64	064	36
65	065	30
66	066	36
67	067	36
68	068	36
69	069	36
70	070	36
71	071	36
72	072	36
73	073	36
74	074	36
75	075	34
76	076	36
77	077	36
78	078	35
79	079	36
80	080	36
81	081	36
82	082	36
83	083	36
84	084	29

	Label	Count
85	085	36
86	086	36
87	087	36
88	088	36
89	089	36
90	090	36
91	091	36
92	092	36
93	093	36
94	094	36
95	095	36
96	096	36
97	097	35
98	098	36
99	099	36
100	100	36

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```
validationImageDS = imageDatastore(validationImageList, 'labelSource', 'foldernames', ...
    'FileExtensions', {'.jpg'});
validationImageDS.ReadFcn = @readImagesIntoDatastoreCNN;
disp('Validation set class distribution:');
```

```
Validation set class distribution:
```

```
countEachLabel(validationImageDS)
```

ans = 200×2 table

	Label	Count
1	001	12
2	002	12
3	003	12
4	004	12
5	005	9
6	006	8
7	007	12
8	008	10

	Label	Count
9	009	12
10	010	12
11	011	12
12	012	11
13	013	12
14	014	12
15	015	12
16	016	12
17	017	12
18	018	10
19	019	12
20	020	12
21	021	12
22	022	11
23	023	12
24	024	11
25	025	12
26	026	12
27	027	12
28	028	12
29	029	12
30	030	12
31	031	12
32	032	11
33	033	12
34	034	12
35	035	12
36	036	12
37	037	12
38	038	12
39	039	12
40	040	12
41	041	12

	Label	Count
42	042	12
43	043	12
44	044	12
45	045	12
46	046	12
47	047	12
48	048	12
49	049	12
50	050	12
51	051	12
52	052	12
53	053	12
54	054	12
55	055	12
56	056	12
57	057	12
58	058	12
59	059	12
60	060	12
61	061	12
62	062	12
63	063	12
64	064	12
65	065	10
66	066	12
67	067	12
68	068	12
69	069	12
70	070	12
71	071	12
72	072	12
73	073	12
74	074	12

	Label	Count
75	075	12
76	076	12
77	077	12
78	078	12
79	079	12
80	080	12
81	081	12
82	082	12
83	083	12
84	084	12
85	085	12
86	086	12
87	087	12
88	088	12
89	089	12
90	090	12
91	091	12
92	092	12
93	093	12
94	094	12
95	095	12
96	096	12
97	097	12
98	098	12
99	099	12
100	100	12

⋮

```
testImageDS = imageDatastore(testImageList, 'labelSource', 'foldernames', ...
    'FileExtensions', {'.jpg'});
testImageDS.ReadFcn = @readImagesIntoDatastoreCNN;
disp('Test set class distribution:');
```

```
Test set class distribution:
```

```
countEachLabel(testImageDS)
```

ans = 200×2 table

	Label	Count
1	001	12
2	002	12
3	003	11
4	004	12
5	005	9
6	006	8
7	007	12
8	008	9
9	009	12
10	010	12
11	011	12
12	012	11
13	013	12
14	014	12
15	015	11
16	016	11
17	017	11
18	018	9
19	019	12
20	020	12
21	021	12
22	022	11
23	023	12
24	024	10
25	025	12
26	026	12
27	027	12
28	028	12
29	029	12
30	030	12
31	031	12
32	032	10
33	033	12

	Label	Count
34	034	12
35	035	12
36	036	12
37	037	12
38	038	12
39	039	12
40	040	12
41	041	12
42	042	12
43	043	12
44	044	12
45	045	12
46	046	12
47	047	12
48	048	12
49	049	12
50	050	12
51	051	12
52	052	12
53	053	12
54	054	12
55	055	12
56	056	12
57	057	12
58	058	11
59	059	12
60	060	12
61	061	12
62	062	12
63	063	12
64	064	12
65	065	10
66	066	12

	Label	Count
67	067	12
68	068	12
69	069	12
70	070	12
71	071	12
72	072	12
73	073	12
74	074	12
75	075	11
76	076	12
77	077	12
78	078	12
79	079	12
80	080	12
81	081	12
82	082	12
83	083	12
84	084	12
85	085	12
86	086	12
87	087	12
88	088	12
89	089	12
90	090	12
91	091	12
92	092	12
93	093	12
94	094	12
95	095	12
96	096	12
97	097	12
98	098	12
99	099	12

	Label	Count
100	100	12

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The images all have different spatial resolutions (width x height), so

```
targetSize = [224, 224];

% Data augmentation
augmenter = imageDataAugmenter( ...
    'RandXTranslation',[-20 20], ...
    'RandYTranslation',[-20 20], ...
    'RandRotation',[-20,0], ...
    'RandScale',[0.8,1.2]);

augmentedTrainingImageDS = augmentedImageDatastore(targetSize, trainingImageDS, 'DataAugmentati

% Resize validation and test datastores
validationImageDS_Resized = augmentedImageDatastore(targetSize, validationImageDS, 'OutputSizeM
testImageDS_Resized = augmentedImageDatastore(targetSize, testImageDS, 'OutputSizeMode', 'resi

% Display a sample image from the datastore
% Display a sample image from the datastore
figure(1);
sampleImageTable = augmentedTrainingImageDS.read();
sampleImageCell = sampleImageTable{1, 1};
sampleImage = sampleImageCell{1};
imshow(sampleImage);
title('Sample Image Resized');
```

Create a simple CNN

```
layers = [
    imageInputLayer([224 224 3])    % This needs to match the image size

    convolution2dLayer(3, 8, 'Padding', 'same')
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2, 'Stride', 2)

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

    maxPooling2dLayer(2, 'Stride', 2)

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

    fullyConnectedLayer(200)
    softmaxLayer
    classificationLayer];
```

Check if we have a GPU available and clear any old data from it

```
if (gpuDeviceCount() > 0)
    disp('Found GPU:');
    disp(gpuDeviceTable);
    device = gpuDevice(1);
    reset(device);  % Clear previous values that might still be on the GPU
end
```

```
Found GPU:
    Index        Name        ComputeCapability    DeviceAvailable    DeviceSelected
    _____    ____________    _________________    _______________    ______________

      1      "GRID T4-8Q"          "7.5"              true               false
```

Set the training options

```
options = trainingOptions('sgdm', ...
        'InitialLearnRate', 0.001, ...
        'MiniBatchSize', 20, ...
        'MaxEpochs', 5, ...
        'Verbose', true, ...
        'Shuffle', 'every-epoch', ...
        'VerboseFrequency', 1, ...
        'ValidationData', augmentedTrainingImageDS, ...
        'Plots','training-progress');
```

Train the simple CNN model

```
simpleCNN = trainNetwork(augmentedTrainingImageDS, layers, options);
```

```
Training on single GPU.
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 |       00:01:26 |        0.00% |        0.35% |       6.1497 |       5.7912 |          0.00
|       1 |           2 |       00:01:28 |        0.00% |              |       5.5569 |              |          0.00
|       1 |           3 |       00:01:29 |        0.00% |              |       5.8934 |              |          0.00
|       1 |           4 |       00:01:29 |        0.00% |              |       6.4431 |              |          0.00
|       1 |           5 |       00:01:29 |        0.00% |              |       6.2576 |              |          0.00
|       1 |           6 |       00:01:30 |        0.00% |              |       6.3765 |              |          0.00
|       1 |           7 |       00:01:30 |        0.00% |              |       6.9416 |              |          0.00
|       1 |           8 |       00:01:30 |        0.00% |              |       6.8861 |              |          0.00
|       1 |           9 |       00:01:31 |        0.00% |              |       6.5258 |              |          0.00
|       1 |          10 |       00:01:31 |        0.00% |              |       6.8458 |              |          0.00
|       1 |          11 |       00:01:31 |        5.00% |              |       7.7049 |              |          0.00
|       1 |          12 |       00:01:31 |        5.00% |              |       6.2717 |              |          0.00
|       1 |          13 |       00:01:32 |        0.00% |              |       7.6758 |              |          0.00
|       1 |          14 |       00:01:32 |        0.00% |              |       8.3895 |              |          0.00
|       1 |          15 |       00:01:32 |        0.00% |              |       7.8057 |              |          0.00
|       1 |          16 |       00:01:33 |        0.00% |              |       8.4615 |              |          0.00
|       1 |          17 |       00:01:33 |        0.00% |              |       7.0443 |              |          0.00
|       1 |          18 |       00:01:33 |        0.00% |              |       6.5185 |              |          0.00
|       1 |          19 |       00:01:33 |        0.00% |              |       7.7888 |              |          0.00
|       1 |          20 |       00:01:34 |        5.00% |              |       7.1905 |              |          0.00
|       1 |          21 |       00:01:34 |        5.00% |              |       8.9136 |              |          0.00
|       1 |          22 |       00:01:34 |        0.00% |              |       8.8646 |              |          0.00
|       1 |          23 |       00:01:34 |        0.00% |              |       8.1183 |              |          0.00
|       1 |          24 |       00:01:35 |        0.00% |              |       7.8986 |              |          0.00
|       1 |          25 |       00:01:35 |        0.00% |              |       7.9491 |              |          0.00
|       1 |          26 |       00:01:35 |        0.00% |              |       6.6448 |              |          0.00
|       1 |          27 |       00:01:35 |        0.00% |              |       8.0148 |              |          0.00
|       1 |          28 |       00:01:36 |        0.00% |              |       7.7871 |              |          0.00
|       1 |          29 |       00:01:36 |        0.00% |              |       6.7770 |              |          0.00
|       1 |          30 |       00:01:36 |       10.00% |              |       7.0528 |              |          0.00
|       1 |          31 |       00:01:36 |        0.00% |              |       9.0942 |              |          0.00
|       1 |          32 |       00:01:37 |        0.00% |              |       7.9025 |              |          0.00
|       1 |          33 |       00:01:37 |        0.00% |              |       8.8942 |              |          0.00
|       1 |          34 |       00:01:37 |        0.00% |              |       8.1002 |              |          0.00
|       1 |          35 |       00:01:37 |        0.00% |              |       8.9820 |              |          0.00
|       1 |          36 |       00:01:38 |        0.00% |              |       6.6281 |              |          0.00
|       1 |          37 |       00:01:38 |        0.00% |              |       7.6368 |              |          0.00
|       1 |          38 |       00:01:38 |        0.00% |              |       7.3768 |              |          0.00
|       1 |          39 |       00:01:39 |        0.00% |              |       7.4825 |              |          0.00
|       1 |          40 |       00:01:39 |        0.00% |              |       7.6814 |              |          0.00
|       1 |          41 |       00:01:39 |        0.00% |              |       9.5422 |              |          0.00
|       1 |          42 |       00:01:39 |        0.00% |              |       6.9909 |              |          0.00
|       1 |          43 |       00:01:40 |        0.00% |              |       8.0655 |              |          0.00
|       1 |          44 |       00:01:40 |        0.00% |              |       8.4271 |              |          0.00
|       1 |          45 |       00:01:40 |        0.00% |              |       7.2767 |              |          0.00
|       1 |          46 |       00:01:40 |        5.00% |              |       7.9787 |              |          0.00
|       1 |          47 |       00:01:41 |        0.00% |              |       7.8222 |              |          0.00
|       1 |          48 |       00:01:41 |        0.00% |              |       8.0657 |              |          0.00
|       1 |          49 |       00:01:41 |        0.00% |              |       7.4786 |              |          0.00
|       1 |          50 |       00:02:46 |        0.00% |        1.37% |       8.2698 |       7.1576 |          0.00
|       1 |          51 |       00:02:47 |        5.00% |              |       8.7051 |              |          0.00
|       1 |          52 |       00:02:47 |        0.00% |              |       7.1020 |              |          0.00
```

1	53	00:02:48	0.00%		7.3037		0.00
1	54	00:02:48	0.00%		6.1363		0.00
1	55	00:02:48	0.00%		7.6315		0.00
1	56	00:02:48	0.00%		6.9005		0.00
1	57	00:02:49	0.00%		7.0928		0.00
1	58	00:02:49	0.00%		6.4844		0.00
1	59	00:02:49	0.00%		7.0669		0.00
1	60	00:02:50	0.00%		6.9053		0.00
1	61	00:02:50	0.00%		7.7522		0.00
1	62	00:02:50	0.00%		6.5019		0.00
1	63	00:02:50	0.00%		6.2823		0.00
1	64	00:02:51	5.00%		6.9373		0.00
1	65	00:02:51	0.00%		6.6899		0.00
1	66	00:02:51	0.00%		6.8583		0.00
1	67	00:02:52	0.00%		6.9904		0.00
1	68	00:02:52	0.00%		7.1621		0.00
1	69	00:02:52	0.00%		5.9380		0.00
1	70	00:02:52	0.00%		7.2047		0.00
1	71	00:02:53	0.00%		6.9817		0.00
1	72	00:02:53	0.00%		7.2368		0.00
1	73	00:02:53	0.00%		6.9397		0.00
1	74	00:02:54	5.00%		6.1981		0.00
1	75	00:02:54	0.00%		7.7613		0.00
1	76	00:02:54	0.00%		6.8153		0.00
1	77	00:02:54	0.00%		5.9562		0.00
1	78	00:02:55	0.00%		6.9101		0.00
1	79	00:02:55	0.00%		5.8873		0.00
1	80	00:02:55	0.00%		7.2966		0.00
1	81	00:02:56	0.00%		6.5757		0.00
1	82	00:02:56	0.00%		6.5477		0.00
1	83	00:02:56	0.00%		6.2444		0.00
1	84	00:02:56	5.00%		6.1187		0.00
1	85	00:02:57	0.00%		6.4023		0.00
1	86	00:02:57	0.00%		6.3602		0.00
1	87	00:02:57	0.00%		7.0104		0.00
1	88	00:02:57	0.00%		5.8750		0.00
1	89	00:02:58	0.00%		5.8929		0.00
1	90	00:02:58	0.00%		6.8154		0.00
1	91	00:02:58	0.00%		6.1654		0.00
1	92	00:02:59	5.00%		6.1979		0.00
1	93	00:02:59	0.00%		6.6499		0.00
1	94	00:02:59	0.00%		5.9123		0.00
1	95	00:02:59	0.00%		6.2893		0.00
1	96	00:03:00	0.00%		5.7921		0.00
1	97	00:03:00	0.00%		6.0297		0.00
1	98	00:03:00	0.00%		5.7648		0.00
1	99	00:03:01	0.00%		6.9250		0.00
1	100	00:04:03	5.00%	2.25%	5.5519	5.7828	0.00
1	101	00:04:03	5.00%		6.3218		0.00
1	102	00:04:04	0.00%		5.2786		0.00
1	103	00:04:04	0.00%		6.5407		0.00
1	104	00:04:04	0.00%		5.5759		0.00
1	105	00:04:04	5.00%		5.7919		0.00
1	106	00:04:05	0.00%		5.9956		0.00
1	107	00:04:05	5.00%		5.5611		0.00
1	108	00:04:05	10.00%		5.1367		0.00
1	109	00:04:06	0.00%		5.9776		0.00
1	110	00:04:06	0.00%		6.0238		0.00
1	111	00:04:06	0.00%		6.1230		0.00
1	112	00:04:06	0.00%		5.5907		0.00
1	113	00:04:07	0.00%		6.0171		0.00
1	114	00:04:07	0.00%		5.7984		0.00
1	115	00:04:07	0.00%		5.8600		0.00
1	116	00:04:08	0.00%		5.4451		0.00

1	117	00:04:08	5.00%		5.5975		0.00
1	118	00:04:08	0.00%		6.2606		0.00
1	119	00:04:08	5.00%		5.8474		0.00
1	120	00:04:09	0.00%		5.6945		0.00
1	121	00:04:09	0.00%		5.6359		0.00
1	122	00:04:09	0.00%		5.8526		0.00
1	123	00:04:09	5.00%		5.4020		0.00
1	124	00:04:10	5.00%		5.9127		0.00
1	125	00:04:10	5.00%		5.6318		0.00
1	126	00:04:10	0.00%		5.7972		0.00
1	127	00:04:10	0.00%		5.7930		0.00
1	128	00:04:11	0.00%		6.4354		0.00
1	129	00:04:11	0.00%		5.3909		0.00
1	130	00:04:11	0.00%		5.5527		0.00
1	131	00:04:12	0.00%		6.5360		0.00
1	132	00:04:12	0.00%		6.0311		0.00
1	133	00:04:12	0.00%		5.3671		0.00
1	134	00:04:12	0.00%		5.8410		0.00
1	135	00:04:13	0.00%		5.3892		0.00
1	136	00:04:13	0.00%		5.6350		0.00
1	137	00:04:13	5.00%		5.7015		0.00
1	138	00:04:13	0.00%		6.0368		0.00
1	139	00:04:14	0.00%		6.1392		0.00
1	140	00:04:14	0.00%		5.1748		0.00
1	141	00:04:14	0.00%		5.3741		0.00
1	142	00:04:14	0.00%		5.8891		0.00
1	143	00:04:15	0.00%		5.4652		0.00
1	144	00:04:15	0.00%		5.4738		0.00
1	145	00:04:15	0.00%		5.6315		0.00
1	146	00:04:16	5.00%		5.5092		0.00
1	147	00:04:16	0.00%		5.3465		0.00
1	148	00:04:16	0.00%		5.5431		0.00
1	149	00:04:16	0.00%		5.5789		0.00
1	150	00:05:18	5.00%	2.66%	5.5972	5.2538	0.00
1	151	00:05:19	0.00%		5.7508		0.00
1	152	00:05:19	0.00%		5.6846		0.00
1	153	00:05:19	0.00%		5.5622		0.00
1	154	00:05:19	0.00%		5.2393		0.00
1	155	00:05:20	0.00%		5.1149		0.00
1	156	00:05:20	5.00%		5.5658		0.00
1	157	00:05:20	0.00%		5.5626		0.00
1	158	00:05:21	0.00%		5.2185		0.00
1	159	00:05:21	0.00%		5.7599		0.00
1	160	00:05:21	0.00%		5.5750		0.00
1	161	00:05:21	0.00%		5.5606		0.00
1	162	00:05:22	0.00%		5.5283		0.00
1	163	00:05:22	0.00%		5.5347		0.00
1	164	00:05:22	0.00%		5.3296		0.00
1	165	00:05:23	0.00%		5.6190		0.00
1	166	00:05:23	0.00%		5.3974		0.00
1	167	00:05:23	0.00%		5.7406		0.00
1	168	00:05:23	0.00%		5.2307		0.00
1	169	00:05:24	5.00%		5.3483		0.00
1	170	00:05:24	0.00%		5.4977		0.00
1	171	00:05:24	5.00%		5.1508		0.00
1	172	00:05:25	0.00%		5.3778		0.00
1	173	00:05:25	5.00%		5.4826		0.00
1	174	00:05:25	0.00%		5.2507		0.00
1	175	00:05:26	0.00%		5.4508		0.00
1	176	00:05:26	0.00%		5.9794		0.00
1	177	00:05:26	5.00%		5.3491		0.00
1	178	00:05:26	0.00%		5.0359		0.00
1	179	00:05:27	0.00%		5.2255		0.00
1	180	00:05:27	0.00%		4.9462		0.00

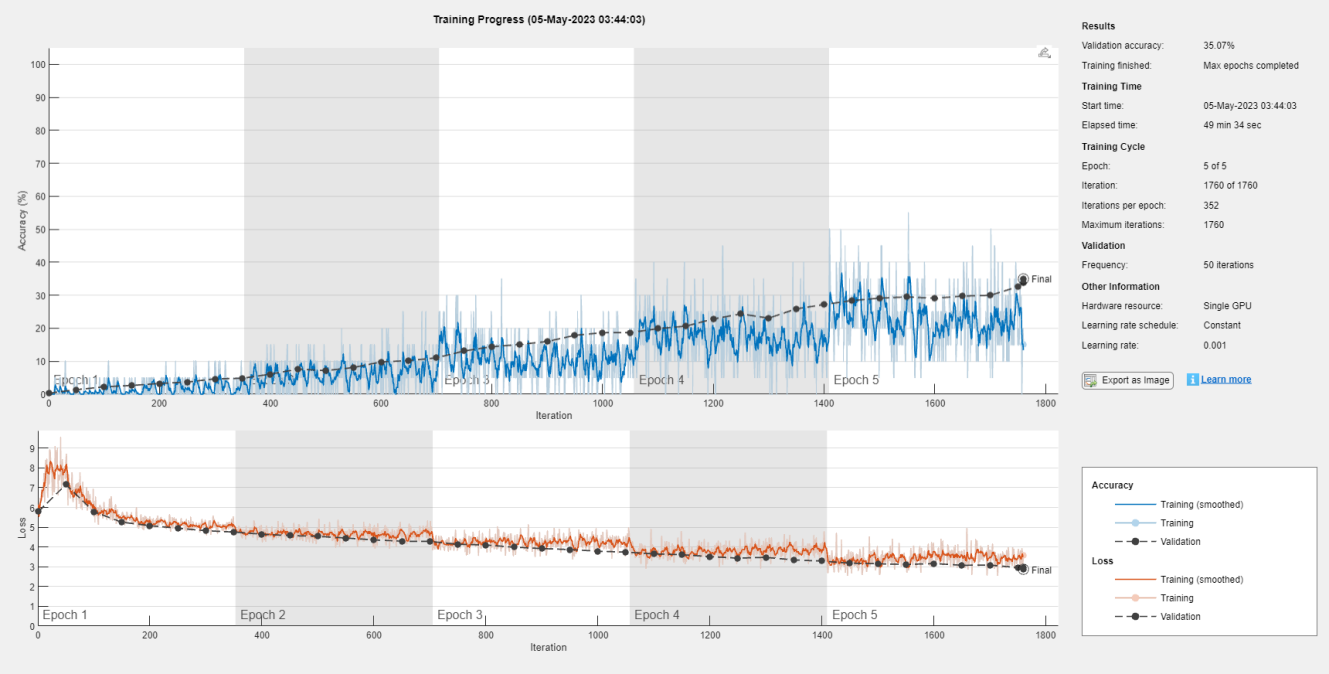
1	181	00:05:27	5.00%		5.3008		0.00
1	182	00:05:28	0.00%		5.0517		0.00
1	183	00:05:28	5.00%		5.2685		0.00
1	184	00:05:28	0.00%		5.6386		0.00
1	185	00:05:29	5.00%		5.4021		0.00
1	186	00:05:29	5.00%		5.1917		0.00
1	187	00:05:29	5.00%		4.9148		0.00
1	188	00:05:29	0.00%		5.4983		0.00
1	189	00:05:30	5.00%		4.8601		0.00
1	190	00:05:30	5.00%		5.1592		0.00
1	191	00:05:30	0.00%		5.5519		0.00
1	192	00:05:31	0.00%		5.0554		0.00
1	193	00:05:31	0.00%		5.5209		0.00
1	194	00:05:31	0.00%		5.4585		0.00
1	195	00:05:32	0.00%		5.1653		0.00
1	196	00:05:32	0.00%		5.4248		0.00
1	197	00:05:32	0.00%		5.4327		0.00
1	198	00:05:33	0.00%		4.9234		0.00
1	199	00:05:33	0.00%		5.2183		0.00
1	200	00:06:42	0.00%	3.26%	5.5175	5.0809	0.00
1	201	00:06:43	0.00%		4.9184		0.00
1	202	00:06:43	0.00%		5.1673		0.00
1	203	00:06:44	5.00%		4.9559		0.00
1	204	00:06:44	5.00%		5.3874		0.00
1	205	00:06:44	5.00%		5.0039		0.00
1	206	00:06:45	0.00%		5.4236		0.00
1	207	00:06:45	5.00%		5.2040		0.00
1	208	00:06:45	0.00%		5.1949		0.00
1	209	00:06:46	0.00%		5.0164		0.00
1	210	00:06:46	5.00%		5.3529		0.00
1	211	00:06:47	5.00%		5.1789		0.00
1	212	00:06:47	10.00%		5.4330		0.00
1	213	00:06:47	0.00%		5.0805		0.00
1	214	00:06:48	5.00%		5.5633		0.00
1	215	00:06:48	0.00%		5.1743		0.00
1	216	00:06:48	0.00%		5.0974		0.00
1	217	00:06:49	0.00%		5.3994		0.00
1	218	00:06:49	0.00%		5.2645		0.00
1	219	00:06:49	5.00%		5.4317		0.00
1	220	00:06:50	0.00%		5.4995		0.00
1	221	00:06:50	0.00%		5.2760		0.00
1	222	00:06:51	0.00%		5.1628		0.00
1	223	00:06:51	0.00%		5.2421		0.00
1	224	00:06:51	0.00%		5.2861		0.00
1	225	00:06:52	0.00%		5.2231		0.00
1	226	00:06:52	0.00%		5.4144		0.00
1	227	00:06:53	5.00%		5.3489		0.00
1	228	00:06:53	0.00%		4.9563		0.00
1	229	00:06:53	10.00%		4.9418		0.00
1	230	00:06:54	0.00%		4.9523		0.00
1	231	00:06:54	5.00%		5.2601		0.00
1	232	00:06:55	0.00%		5.0288		0.00
1	233	00:06:55	5.00%		4.9710		0.00
1	234	00:06:55	5.00%		5.0923		0.00
1	235	00:06:56	5.00%		5.6397		0.00
1	236	00:06:56	0.00%		5.5120		0.00
1	237	00:06:57	5.00%		4.7850		0.00
1	238	00:06:57	0.00%		5.1961		0.00
1	239	00:06:57	0.00%		5.0481		0.00
1	240	00:06:58	0.00%		5.4710		0.00
1	241	00:06:58	5.00%		4.9459		0.00
1	242	00:06:59	5.00%		5.1614		0.00
1	243	00:06:59	0.00%		5.4687		0.00
1	244	00:06:59	0.00%		5.2981		0.00

1	245	00:07:00	0.00%		5.3891		0.00
1	246	00:07:00	5.00%		4.8950		0.00
1	247	00:07:01	5.00%		5.4231		0.00
1	248	00:07:01	0.00%		5.2468		0.00
1	249	00:07:02	0.00%		4.9531		0.00
1	250	00:08:33	0.00%	3.70%	5.1219	4.9489	0.00
1	251	00:08:33	5.00%		5.2065		0.00
1	252	00:08:34	0.00%		4.8111		0.00
1	253	00:08:34	0.00%		5.1263		0.00
1	254	00:08:34	5.00%		5.0997		0.00
1	255	00:08:34	0.00%		5.2312		0.00
1	256	00:08:35	0.00%		5.4481		0.00
1	257	00:08:35	0.00%		5.1491		0.00
1	258	00:08:35	0.00%		5.2727		0.00
1	259	00:08:36	0.00%		5.2588		0.00
1	260	00:08:36	5.00%		5.0869		0.00
1	261	00:08:36	0.00%		5.1959		0.00
1	262	00:08:36	10.00%		5.2922		0.00
1	263	00:08:37	0.00%		4.8341		0.00
1	264	00:08:37	10.00%		5.1083		0.00
1	265	00:08:37	0.00%		5.3898		0.00
1	266	00:08:37	10.00%		4.8187		0.00
1	267	00:08:38	0.00%		5.1476		0.00
1	268	00:08:38	0.00%		4.9462		0.00
1	269	00:08:38	0.00%		5.3355		0.00
1	270	00:08:38	0.00%		4.8684		0.00
1	271	00:08:39	0.00%		5.2611		0.00
1	272	00:08:39	5.00%		4.9006		0.00
1	273	00:08:39	0.00%		5.5039		0.00
1	274	00:08:39	0.00%		5.0042		0.00
1	275	00:08:40	0.00%		4.8373		0.00
1	276	00:08:40	0.00%		5.0129		0.00
1	277	00:08:40	0.00%		5.2736		0.00
1	278	00:08:41	0.00%		5.1556		0.00
1	279	00:08:41	5.00%		4.9931		0.00
1	280	00:08:41	0.00%		5.0086		0.00
1	281	00:08:41	5.00%		5.0338		0.00
1	282	00:08:42	5.00%		5.0858		0.00
1	283	00:08:42	5.00%		5.2175		0.00
1	284	00:08:42	0.00%		4.9572		0.00
1	285	00:08:42	0.00%		5.0217		0.00
1	286	00:08:43	0.00%		5.0385		0.00
1	287	00:08:43	0.00%		5.0102		0.00
1	288	00:08:43	0.00%		5.1966		0.00
1	289	00:08:43	10.00%		4.7516		0.00
1	290	00:08:44	0.00%		4.7917		0.00
1	291	00:08:44	0.00%		5.1371		0.00
1	292	00:08:44	5.00%		5.2279		0.00
1	293	00:08:45	0.00%		5.3931		0.00
1	294	00:08:45	0.00%		5.2078		0.00
1	295	00:08:45	0.00%		5.2681		0.00
1	296	00:08:45	0.00%		4.9948		0.00
1	297	00:08:46	0.00%		5.1419		0.00
1	298	00:08:46	0.00%		5.1219		0.00
1	299	00:08:46	0.00%		5.3580		0.00
1	300	00:09:49	10.00%	4.65%	4.8072	4.8246	0.00
1	301	00:09:49	10.00%		4.6180		0.00
1	302	00:09:49	5.00%		4.8663		0.00
1	303	00:09:49	0.00%		4.9504		0.00
1	304	00:09:50	5.00%		4.8851		0.00
1	305	00:09:50	0.00%		5.2381		0.00
1	306	00:09:50	0.00%		5.3214		0.00
1	307	00:09:51	10.00%		4.9411		0.00
1	308	00:09:51	0.00%		5.3253		0.00

1	309	00:09:51	10.00%		4.6462		0.00
1	310	00:09:51	5.00%		5.0705		0.00
1	311	00:09:52	0.00%		4.9479		0.00
1	312	00:09:52	5.00%		5.1322		0.00
1	313	00:09:52	0.00%		5.5687		0.00
1	314	00:09:52	0.00%		5.2588		0.00
1	315	00:09:53	0.00%		5.3841		0.00
1	316	00:09:53	5.00%		5.0485		0.00
1	317	00:09:53	0.00%		5.0520		0.00
1	318	00:09:53	5.00%		5.0182		0.00
1	319	00:09:54	10.00%		4.8636		0.00
1	320	00:09:54	5.00%		5.1131		0.00
1	321	00:09:54	5.00%		4.7014		0.00
1	322	00:09:54	0.00%		5.2616		0.00
1	323	00:09:55	5.00%		5.0949		0.00
1	324	00:09:55	0.00%		5.1416		0.00
1	325	00:09:55	0.00%		5.1174		0.00
1	326	00:09:55	0.00%		5.1349		0.00
1	327	00:09:56	0.00%		4.9928		0.00
1	328	00:09:56	0.00%		5.0138		0.00
1	329	00:09:56	0.00%		4.8554		0.00
1	330	00:09:57	0.00%		5.1314		0.00
1	331	00:09:57	0.00%		5.1549		0.00
1	332	00:09:57	0.00%		4.7985		0.00
1	333	00:09:57	0.00%		5.1319		0.00
1	334	00:09:58	5.00%		4.9679		0.00
1	335	00:09:58	0.00%		5.1465		0.00
1	336	00:09:58	0.00%		4.7689		0.00
1	337	00:09:59	0.00%		5.2227		0.00
1	338	00:09:59	0.00%		5.2296		0.00
1	339	00:09:59	5.00%		5.0089		0.00
1	340	00:10:00	0.00%		5.2260		0.00
1	341	00:10:00	0.00%		4.9133		0.00
1	342	00:10:00	5.00%		5.2600		0.00
1	343	00:10:00	0.00%		5.0929		0.00
1	344	00:10:01	0.00%		4.9595		0.00
1	345	00:10:01	0.00%		5.0916		0.00
1	346	00:10:01	5.00%		5.4027		0.00
1	347	00:10:01	5.00%		5.0018		0.00
1	348	00:10:02	10.00%		4.6286		0.00
1	349	00:10:02	0.00%		5.5295		0.00
1	350	00:11:03	5.00%	4.85%	4.9589	4.7562	0.00
1	351	00:11:03	5.00%		5.0326		0.00
1	352	00:11:03	0.00%		4.9177		0.00
2	353	00:11:04	0.00%		4.6197		0.00
2	354	00:11:04	5.00%		4.8278		0.00
2	355	00:11:04	0.00%		4.7121		0.00
2	356	00:11:04	5.00%		4.7086		0.00
2	357	00:11:05	0.00%		4.8907		0.00
2	358	00:11:05	5.00%		4.8341		0.00
2	359	00:11:05	0.00%		5.0686		0.00
2	360	00:11:06	0.00%		4.9706		0.00
2	361	00:11:06	0.00%		4.9659		0.00
2	362	00:11:06	0.00%		4.9687		0.00
2	363	00:11:06	5.00%		4.5860		0.00
2	364	00:11:06	10.00%		4.5305		0.00
2	365	00:11:07	10.00%		4.4628		0.00
2	366	00:11:07	5.00%		4.8767		0.00
2	367	00:11:07	0.00%		4.6529		0.00
2	368	00:11:08	5.00%		4.6169		0.00
2	369	00:11:08	5.00%		4.8457		0.00
2	370	00:11:08	10.00%		4.8500		0.00
2	371	00:11:08	10.00%		4.4031		0.00
2	372	00:11:09	5.00%		5.0423		0.00

2	373	00:11:09	10.00%		4.5718		0.00
2	374	00:11:09	0.00%		4.6184		0.00
2	375	00:11:09	5.00%		4.8260		0.00
2	376	00:11:10	5.00%		4.5875		0.00
2	377	00:11:10	0.00%		4.8268		0.00
2	378	00:11:10	10.00%		4.8344		0.00
2	379	00:11:10	0.00%		4.9802		0.00
2	380	00:11:11	0.00%		4.5975		0.00
2	381	00:11:11	0.00%		4.9170		0.00
2	382	00:11:11	5.00%		4.7122		0.00
2	383	00:11:11	10.00%		4.9650		0.00
2	384	00:11:12	10.00%		4.4959		0.00
2	385	00:11:12	0.00%		4.6875		0.00
2	386	00:11:12	0.00%		5.3246		0.00
2	387	00:11:12	5.00%		5.2159		0.00
2	388	00:11:13	0.00%		4.6675		0.00
2	389	00:11:13	0.00%		5.0073		0.00
2	390	00:11:13	5.00%		4.7841		0.00
2	391	00:11:13	10.00%		4.6529		0.00
2	392	00:11:14	10.00%		4.3797		0.00
2	393	00:11:14	5.00%		4.7129		0.00
2	394	00:11:14	15.00%		4.5023		0.00
2	395	00:11:14	10.00%		4.6375		0.00
2	396	00:11:15	0.00%		5.0375		0.00
2	397	00:11:15	5.00%		4.7295		0.00
2	398	00:11:15	10.00%		4.5681		0.00
2	399	00:11:15	0.00%		5.1063		0.00
2	400	00:12:17	5.00%	6.08%	4.6884	4.6457	0.00
2	401	00:12:17	15.00%		4.2492		0.00
2	402	00:12:18	5.00%		4.6693		0.00
2	403	00:12:18	0.00%		4.8635		0.00
2	404	00:12:18	0.00%		4.6151		0.00
2	405	00:12:18	10.00%		4.3700		0.00
2	406	00:12:19	5.00%		4.8656		0.00
2	407	00:12:19	15.00%		4.2734		0.00
2	408	00:12:19	5.00%		5.0649		0.00
2	409	00:12:19	10.00%		4.5434		0.00
2	410	00:12:20	10.00%		4.8876		0.00
2	411	00:12:20	0.00%		4.5975		0.00
2	412	00:12:20	10.00%		4.5370		0.00
2	413	00:12:21	10.00%		4.6497		0.00
2	414	00:12:21	0.00%		4.6050		0.00
2	415	00:12:21	5.00%		4.5077		0.00
2	416	00:12:21	0.00%		4.6055		0.00
2	417	00:12:21	10.00%		4.7852		0.00
2	418	00:12:22	0.00%		5.0195		0.00
2	419	00:12:22	5.00%		4.3796		0.00
2	420	00:12:22	5.00%		4.4125		0.00
2	421	00:12:23	10.00%		4.3927		0.00
2	422	00:12:23	0.00%		4.6282		0.00
2	423	00:12:23	5.00%		4.7832		0.00
2	424	00:12:23	0.00%		4.8643		0.00
2	425	00:12:24	0.00%		4.5844		0.00
2	426	00:12:24	10.00%		4.4543		0.00
2	427	00:12:24	10.00%		4.9404		0.00
2	428	00:12:24	10.00%		4.5624		0.00
2	429	00:12:25	0.00%		5.2780		0.00
2	430	00:12:25	10.00%		4.5059		0.00
2	431	00:12:25	15.00%		4.7029		0.00
2	432	00:12:25	0.00%		4.5810		0.00
2	433	00:12:26	0.00%		4.5829		0.00
2	434	00:12:26	0.00%		4.9442		0.00
2	435	00:12:26	5.00%		4.3835		0.00
2	436	00:12:26	10.00%		4.7341		0.00

2	437	00:12:27	0.00%		5.1930			0.00
2	438	00:12:27	5.00%		4.6836			0.00
2	439	00:12:27	5.00%		5.0588			0.00
2	440	00:12:28	5.00%		4.5513			0.00
2	441	00:12:28	5.00%		4.5573			0.00
2	442	00:12:28	0.00%		4.8601			0.00
2	443	00:12:28	10.00%		4.3124			0.00
2	444	00:12:29	0.00%		4.9913			0.00
2	445	00:12:29	5.00%		4.7103			0.00
2	446	00:12:29	0.00%		4.8211			0.00
2	447	00:12:29	15.00%		4.6268			0.00
2	448	00:12:30	0.00%		4.7413			0.00
2	449	00:12:30	5.00%		4.5108			0.00
2	450	00:13:31	10.00%	7.61%	4.3720	4.5763		0.00
2	451	00:13:31	5.00%		4.8631			0.00
2	452	00:13:31	15.00%		4.5132			0.00
2	453	00:13:32	5.00%		4.8553			0.00
2	454	00:13:32	10.00%		4.3216			0.00
2	455	00:13:32	5.00%		4.4047			0.00
2	456	00:13:32	10.00%		4.4932			0.00
2	457	00:13:33	5.00%		5.1919			0.00
2	458	00:13:33	5.00%		4.9161			0.00
2	459	00:13:33	5.00%		4.7901			0.00
2	460	00:13:34	0.00%		4.8444			0.00
2	461	00:13:34	10.00%		4.8676			0.00
2	462	00:13:34	10.00%		4.3523			0.00
2	463	00:13:34	0.00%		4.8501			0.00
2	464	00:13:35	5.00%		4.4693			0.00
2	465	00:13:35	5.00%		4.8293			0.00
2	466	00:13:35	0.00%		5.1418			0.00
2	467	00:13:35	5.00%		5.1171			0.00
2	468	00:13:36	5.00%		4.3578			0.00
2	469	00:13:36	15.00%		4.6175			0.00
2	470	00:13:36	10.00%		4.4387			0.00
2	471	00:13:36	5.00%		4.9455			0.00
2	472	00:13:37	15.00%		4.4249			0.00
2	473	00:13:37	10.00%		4.3169			0.00
2	474	00:13:37	5.00%		5.0164			0.00
2	475	00:13:37	0.00%		4.5823			0.00
2	476	00:13:38	10.00%		4.9662			0.00
2	477	00:13:38	5.00%		4.6965			0.00
2	478	00:13:38	5.00%		4.9754			0.00
2	479	00:13:38	15.00%		4.2941			0.00
2	480	00:13:39	5.00%		4.5848			0.00
2	481	00:13:39	0.00%		5.2421			0.00
2	482	00:13:39	10.00%		4.4164			0.00
2	483	00:13:39	5.00%		4.8453			0.00
2	484	00:13:40	10.00%		4.7017			0.00
2	485	00:13:40	10.00%		4.2646			0.00
2	486	00:13:40	0.00%		4.7861			0.00
2	487	00:13:41	0.00%		4.7715			0.00
2	488	00:13:41	5.00%		4.4640			0.00
2	489	00:13:41	5.00%		4.7478			0.00
2	490	00:13:41	5.00%		4.7163			0.00
2	491	00:13:42	5.00%		4.2005			0.00
2	492	00:13:42	...					

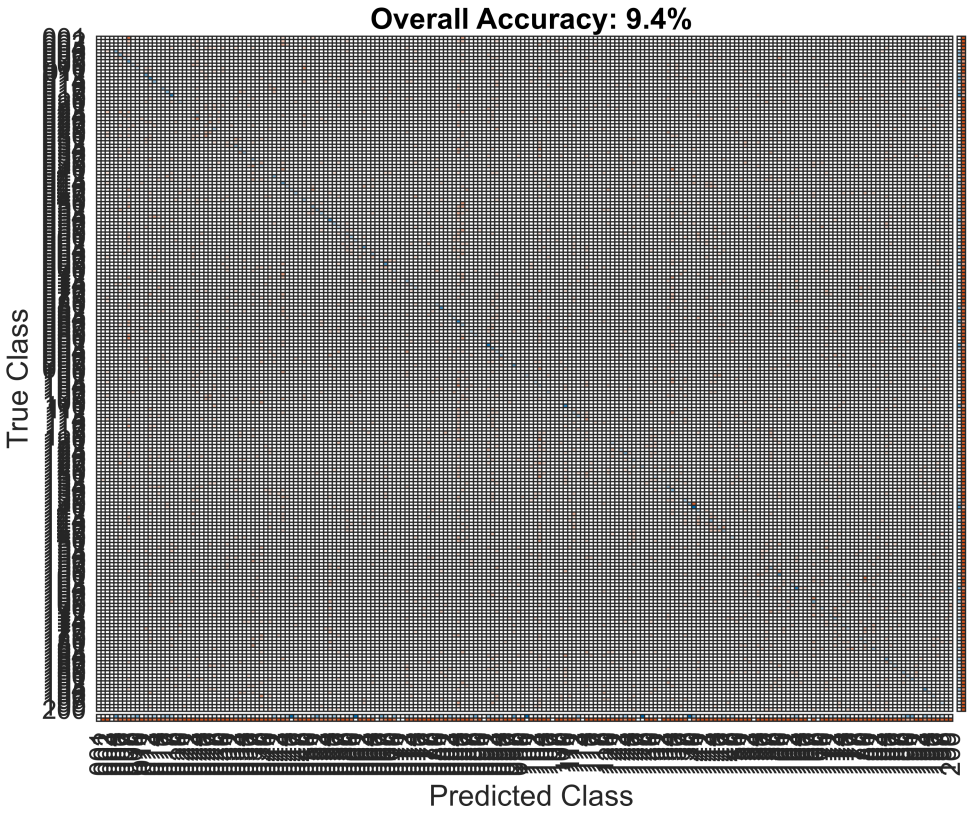


Test the accuracy on the test partition

```
YPred = classify(simpleCNN, testImageDS_Resized);
YTest = testImageDS.Labels;

% Calculate overall accuracy
accuracy = sum(YPred == YTest)/numel(YTest); % Output on command line

% Show confusion matrix in figure
[m, order] = confusionmat(YTest, YPred);
figure(2);
cm = confusionchart(m, order, ...
    'ColumnSummary','column-normalized', ...
    'RowSummary','row-normalized');
title("Overall Accuracy: "+ string(round(accuracy*100, 1)) +"%");
```



Compute classwise positive recogniton rate

```
%% Compute classwise positive recogniton rate
classwisePosRecog = cell(height(order), 2);
samplesPerRow = sum(m, 2);
for iI = 1:height(order)
    classwisePosRecog{iI, 1} = order(iI);  % add image name
    classwisePosRecog{iI, 2} = round(100 * m(iI, iI) / samplesPerRow(iI), 1);  % add recognitio
end
disp('Classwise Recognition Rates:');
```

```
Classwise Recognition Rates:
```

```
disp(classwisePosRecog);
```

```
    {[001]}    {[      0]}
    {[002]}    {[      0]}
    {[003]}    {[      0]}
    {[004]}    {[      0]}
    {[005]}    {[33.3000]}
    {[006]}    {[37.5000]}
    {[007]}    {[ 8.3000]}
    {[008]}    {[44.4000]}
    {[009]}    {[ 8.3000]}
    {[010]}    {[ 8.3000]}
    {[011]}    {[      0]}
    {[012]}    {[36.4000]}
    {[013]}    {[41.7000]}
    {[014]}    {[     25]}
```

```
{[015]}    {[      0]}
{[016]}    {[18.2000]}
{[017]}    {[27.3000]}
{[018]}    {[66.7000]}
{[019]}    {[      0]}
{[020]}    {[ 8.3000]}
{[021]}    {[      0]}
{[022]}    {[      0]}
{[023]}    {[      0]}
{[024]}    {[     20]}
{[025]}    {[      0]}
{[026]}    {[      0]}
{[027]}    {[      0]}
{[028]}    {[16.7000]}
{[029]}    {[      0]}
{[030]}    {[      0]}
{[031]}    {[      0]}
{[032]}    {[      0]}
{[033]}    {[16.7000]}
{[034]}    {[ 8.3000]}
{[035]}    {[16.7000]}
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{[037]}    {[16.7000]}
{[038]}    {[      0]}
{[039]}    {[ 8.3000]}
{[040]}    {[      0]}
{[041]}    {[      0]}
{[042]}    {[     25]}
{[043]}    {[      0]}
{[044]}    {[33.3000]}
{[045]}    {[ 8.3000]}
{[046]}    {[ 8.3000]}
{[047]}    {[16.7000]}
{[048]}    {[      0]}
{[049]}    {[16.7000]}
{[050]}    {[      0]}
{[051]}    {[16.7000]}
{[052]}    {[16.7000]}
{[053]}    {[16.7000]}
{[054]}    {[ 8.3000]}
{[055]}    {[41.7000]}
{[056]}    {[16.7000]}
{[057]}    {[ 8.3000]}
{[058]}    {[      0]}
{[059]}    {[ 8.3000]}
{[060]}    {[16.7000]}
{[061]}    {[ 8.3000]}
{[062]}    {[      0]}
{[063]}    {[33.3000]}
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{[065]}    {[     20]}
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{[067]}    {[ 8.3000]}
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{[070]}    {[ 8.3000]}
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{[073]}    {[16.7000]}
{[074]}    {[ 8.3000]}
{[075]}    {[ 9.1000]}
{[076]}    {[      0]}
{[077]}    {[      0]}
{[078]}    {[      0]}
```

```
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{[080]}    {[ 8.3000]}
{[081]}    {[41.7000]}
{[082]}    {[      0]}
{[083]}    {[ 8.3000]}
{[084]}    {[ 8.3000]}
{[085]}    {[     50]}
{[086]}    {[16.7000]}
{[087]}    {[      0]}
{[088]}    {[ 8.3000]}
{[089]}    {[ 8.3000]}
{[090]}    {[      0]}
{[091]}    {[      0]}
{[092]}    {[58.3000]}
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{[095]}    {[16.7000]}
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```

```
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{[148]}    {[      0]}
{[149]}    {[ 8.3000]}
{[150]}    {[      0]}
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{[154]}    {[      0]}
{[155]}    {[      0]}
{[156]}    {[      0]}
{[157]}    {[      0]}
{[158]}    {[16.7000]}
{[159]}    {[      0]}
{[160]}    {[33.3000]}
{[161]}    {[      0]}
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{[163]}    {[ 8.3000]}
{[164]}    {[     50]}
{[165]}    {[      0]}
{[166]}    {[      0]}
{[167]}    {[      0]}
{[168]}    {[     25]}
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{[180]}    {[ 8.3000]}
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{[182]}    {[16.7000]}
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{[185]}    {[     25]}
{[186]}    {[ 8.3000]}
{[187]}    {[     10]}
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{[189]}    {[16.7000]}
{[190]}    {[ 9.1000]}
{[191]}    {[16.7000]}
{[192]}    {[      0]}
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{[197]}    {[      0]}
{[198]}    {[ 8.3000]}
{[199]}    {[      0]}
{[200]}    {[      0]}
```