```
close all;
clear variables;
clc;
```

```
folder = "CUB_200_2011_Subset20classes";
trainingImageNames = readtable(fullfile(folder, "train.txt"),'ReadVariableNames', false);
trainingImageNames.Properties.VariableNames = {'index', 'imageName'};

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

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

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

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

```
% bounding box
boundingBox = readtable(fullfile(folder, "bounding_boxes.txt"),'ReadVariableNames', false);
boundingBox.Properties.VariableNames = {'index', 'x', 'y', 'w', 'h'};
```

```
folder = "CUB_200_2011_Subset20classes/";
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
```

```
% mapping bounding boxes
trainingBox = return_bounding_box_mapping(trainingImageNames, boundingBox);
```

```
validationBox = return_bounding_box_mapping(validationImageNames, boundingBox);
testBox = return_bounding_box_mapping(testImageNames, boundingBox);
```

```
trainingImageDS = imageDatastore(trainingImageList, 'labelSource', 'foldernames', ...
    'FileExtensions', {'.jpg'});
trainingImageDS.ReadFcn = @readImagesIntoDatastore;

validationImageDS = imageDatastore(validationImageList, 'labelSource', 'foldernames', ...
    'FileExtensions', {'.jpg'});
validationImageDS.ReadFcn = @readImagesIntoDatastore;

testImageDS = imageDatastore(testImageList, 'labelSource', 'foldernames', ...
    'FileExtensions', {'.jpg'});
testImageDS.ReadFcn = @readImagesIntoDatastore;

countEachLabel(trainingImageDS)
```

ans = 20×2 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
19	019	35
20	020	35

```
countEachLabel(validationImageDS)
```

ans = 20×2 table

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

```
countEachLabel(testImageDS)
```

ans = 20×2 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

	Label	Count
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

```
% apply bounding box
trainingImageDS.ReadFcn = @(file_name) read_bounding_box_image_to_datastore(file_name, training
validationImageDS.ReadFcn = @(file_name) read_bounding_box_image_to_datastore(file_name, valida
testImageDS.ReadFcn = @(file_name) read_bounding_box_image_to_datastore(file_name, testBox);
```

```
% target_size = [100, 100];
target_size = [224, 224];

% resizing using transform operation
training_image_datastore_resized = transform(trainingImageDS, @(image_i) imresize(image_i,targe
validation_image_datastore_resized = transform(validationImageDS, @(image_i) imresize(image_i,t
test_image_datastore_resized = transform(testImageDS, @(image_i) imresize(image_i,target_size))

% Combine transformed datastores and labels
training_labels = arrayDatastore(trainingImageDS.Labels);
training_combined_datastore = combine(training_image_datastore_resized, training_labels);

validation_labels = arrayDatastore(validationImageDS.Labels);
validation_combined_datastore = combine(validation_image_datastore_resized, validation_labels);

test_labels = arrayDatastore(testImageDS.Labels);
test_combined_datastore = combine(test_image_datastore_resized, test_labels);
```

```
trainedNetwork = resnet50;
analyzeNetwork(trainedNetwork);

% when we analyze the network the first layer will mention the input size
```

```
% for resnet 50 it's 224 224
lgraph = layerGraph(trainedNetwork);
deltafc1000 = fullyConnectedLayer(20,'Name','dfc1000');
deltaClassificationfc1000 = classificationLayer('Name', 'dcfc1000', 'Classes', 'auto');
lgraph = replaceLayer(lgraph,'fc1000',deltafc1000);
lgraph = replaceLayer(lgraph,'ClassificationLayer_fc1000',deltaClassificationfc1000);
```

```
if (gpuDeviceCount() > 0)
    disp('Found GPU:');
    disp(gpuDeviceTable);
    gpu_device = gpuDevice(1);
    reset(gpu_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               true
```

```
% learning_rate = 0.01;
learning_rate = 0.001;
% learning_rate = 0.0001;

% batch_size = 8;
batch_size = 16;
% batch_size = 32;

% epochs = 5;
epochs = 10;
% epochs = 20;

options = trainingOptions('sgdm', ...
        'InitialLearnRate', learning_rate, ...
        'MiniBatchSize', batch_size, ...
        'MaxEpochs', epochs, ...
        'Verbose', true, ...
        'Shuffle', 'every-epoch', ...
        'VerboseFrequency', 1, ...
        'ValidationData', validation_combined_datastore, ...
        'Plots','training-progress');

myCNN = trainNetwork(training_combined_datastore, lgraph, options);
```

```
Training on single GPU.
Initializing input data normalization.
|=========================================================================================================================
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Validation  |  Mini-batch  |  Validation  |  Base Learni
|         |             |   (hh:mm:ss)   |   Accuracy   |   Accuracy   |     Loss     |     Loss     |      Rate
|=========================================================================================================================
|       1 |           1 |       00:00:19 |        6.25% |        5.41% |       3.1347 |       3.2791 |          0.0
```

1	2	00:00:20	0.00%		3.2316		0.00
1	3	00:00:21	6.25%		3.4300		0.00
1	4	00:00:22	6.25%		3.3298		0.00
1	5	00:00:23	0.00%		3.2410		0.00
1	6	00:00:24	6.25%		3.2970		0.00
1	7	00:00:25	0.00%		3.4809		0.00
1	8	00:00:27	0.00%		3.6091		0.00
1	9	00:00:28	25.00%		2.8883		0.00
1	10	00:00:29	25.00%		2.8505		0.00
1	11	00:00:30	6.25%		3.0188		0.00
1	12	00:00:31	18.75%		2.6894		0.00
1	13	00:00:32	6.25%		3.0077		0.00
1	14	00:00:33	25.00%		2.7327		0.00
1	15	00:00:35	31.25%		2.7720		0.00
1	16	00:00:36	31.25%		2.5495		0.00
1	17	00:00:37	25.00%		2.6514		0.00
1	18	00:00:38	31.25%		2.6451		0.00
1	19	00:00:39	50.00%		2.0248		0.00
1	20	00:00:40	18.75%		2.4250		0.00
1	21	00:00:41	37.50%		2.2344		0.00
1	22	00:00:42	37.50%		2.0817		0.00
1	23	00:00:43	43.75%		2.1239		0.00
1	24	00:00:44	12.50%		2.4434		0.00
1	25	00:00:46	43.75%		1.8226		0.00
1	26	00:00:47	56.25%		1.9807		0.00
1	27	00:00:48	50.00%		1.9552		0.00
1	28	00:00:49	50.00%		2.0382		0.00
1	29	00:00:50	25.00%		2.2739		0.00
1	30	00:00:51	43.75%		1.8668		0.00
1	31	00:00:52	37.50%		1.6158		0.00
1	32	00:00:53	75.00%		1.4698		0.00
1	33	00:00:54	68.75%		1.7589		0.00
1	34	00:00:55	56.25%		1.5110		0.00
1	35	00:00:56	50.00%		1.6457		0.00
1	36	00:00:57	50.00%		1.5987		0.00
1	37	00:00:58	75.00%		1.2111		0.00
1	38	00:00:59	62.50%		1.5300		0.00
1	39	00:01:00	68.75%		1.2131		0.00
1	40	00:01:01	56.25%		1.4139		0.00
1	41	00:01:02	62.50%		1.2584		0.00
2	42	00:01:04	75.00%		0.8532		0.00
2	43	00:01:05	93.75%		0.6194		0.00
2	44	00:01:06	87.50%		0.7590		0.00
2	45	00:01:07	100.00%		0.5724		0.00
2	46	00:01:08	100.00%		0.4658		0.00
2	47	00:01:09	87.50%		0.5948		0.00
2	48	00:01:10	100.00%		0.5114		0.00
2	49	00:01:11	87.50%		0.5794		0.00
2	50	00:01:20	100.00%	78.83%	0.4729	0.9508	0.00
2	51	00:01:21	100.00%		0.3734		0.00
2	52	00:01:22	93.75%		0.6640		0.00
2	53	00:01:23	93.75%		0.4129		0.00
2	54	00:01:24	93.75%		0.4316		0.00
2	55	00:01:25	93.75%		0.5266		0.00
2	56	00:01:26	81.25%		0.6384		0.00
2	57	00:01:27	100.00%		0.3904		0.00
2	58	00:01:28	87.50%		0.4794		0.00
2	59	00:01:29	100.00%		0.2530		0.00
2	60	00:01:31	100.00%		0.2747		0.00
2	61	00:01:32	100.00%		0.3603		0.00
2	62	00:01:33	87.50%		0.4693		0.00
2	63	00:01:34	93.75%		0.3965		0.00
2	64	00:01:35	93.75%		0.5186		0.00
2	65	00:01:36	87.50%		0.3507		0.00

2	66	00:01:37	87.50%		0.3744			0.00
2	67	00:01:38	93.75%		0.3672			0.00
2	68	00:01:39	100.00%		0.3899			0.00
2	69	00:01:40	93.75%		0.2257			0.00
2	70	00:01:41	87.50%		0.6150			0.00
2	71	00:01:42	93.75%		0.2592			0.00
2	72	00:01:43	93.75%		0.3165			0.00
2	73	00:01:44	93.75%		0.4542			0.00
2	74	00:01:46	87.50%		0.4438			0.00
2	75	00:01:47	100.00%		0.3634			0.00
2	76	00:01:48	87.50%		0.4027			0.00
2	77	00:01:49	93.75%		0.3562			0.00
2	78	00:01:50	81.25%		0.4852			0.00
2	79	00:01:51	93.75%		0.4068			0.00
2	80	00:01:52	93.75%		0.3769			0.00
2	81	00:01:53	87.50%		0.2739			0.00
2	82	00:01:54	100.00%		0.1624			0.00
3	83	00:01:56	100.00%		0.1914			0.00
3	84	00:01:57	100.00%		0.2123			0.00
3	85	00:01:58	100.00%		0.1794			0.00
3	86	00:01:59	100.00%		0.1160			0.00
3	87	00:02:00	100.00%		0.1268			0.00
3	88	00:02:01	100.00%		0.1975			0.00
3	89	00:02:02	100.00%		0.2390			0.00
3	90	00:02:03	100.00%		0.0922			0.00
3	91	00:02:04	93.75%		0.2663			0.00
3	92	00:02:05	100.00%		0.1382			0.00
3	93	00:02:06	100.00%		0.1335			0.00
3	94	00:02:07	100.00%		0.1370			0.00
3	95	00:02:08	100.00%		0.1278			0.00
3	96	00:02:09	100.00%		0.0901			0.00
3	97	00:02:10	100.00%		0.1254			0.00
3	98	00:02:11	93.75%		0.2223			0.00
3	99	00:02:12	100.00%		0.1112			0.00
3	100	00:02:21	100.00%	86.04%	0.0890	0.6179		0.00
3	101	00:02:22	100.00%		0.0862			0.00
3	102	00:02:23	100.00%		0.1284			0.00
3	103	00:02:24	100.00%		0.1021			0.00
3	104	00:02:25	100.00%		0.1795			0.00
3	105	00:02:26	100.00%		0.1808			0.00
3	106	00:02:27	100.00%		0.1765			0.00
3	107	00:02:28	100.00%		0.1224			0.00
3	108	00:02:29	100.00%		0.1324			0.00
3	109	00:02:30	100.00%		0.1503			0.00
3	110	00:02:32	100.00%		0.1552			0.00
3	111	00:02:33	100.00%		0.1704			0.00
3	112	00:02:34	100.00%		0.0765			0.00
3	113	00:02:35	100.00%		0.0763			0.00
3	114	00:02:36	100.00%		0.1338			0.00
3	115	00:02:37	100.00%		0.1599			0.00
3	116	00:02:39	100.00%		0.1384			0.00
3	117	00:02:40	100.00%		0.0706			0.00
3	118	00:02:41	100.00%		0.1356			0.00
3	119	00:02:42	100.00%		0.2013			0.00
3	120	00:02:43	100.00%		0.1480			0.00
3	121	00:02:44	100.00%		0.1476			0.00
3	122	00:02:45	100.00%		0.1179			0.00
3	123	00:02:46	100.00%		0.1067			0.00
4	124	00:02:48	100.00%		0.0659			0.00
4	125	00:02:50	100.00%		0.0632			0.00
4	126	00:02:51	100.00%		0.0840			0.00
4	127	00:02:52	100.00%		0.0543			0.00
4	128	00:02:53	100.00%		0.0725			0.00
4	129	00:02:54	100.00%		0.1074			0.00

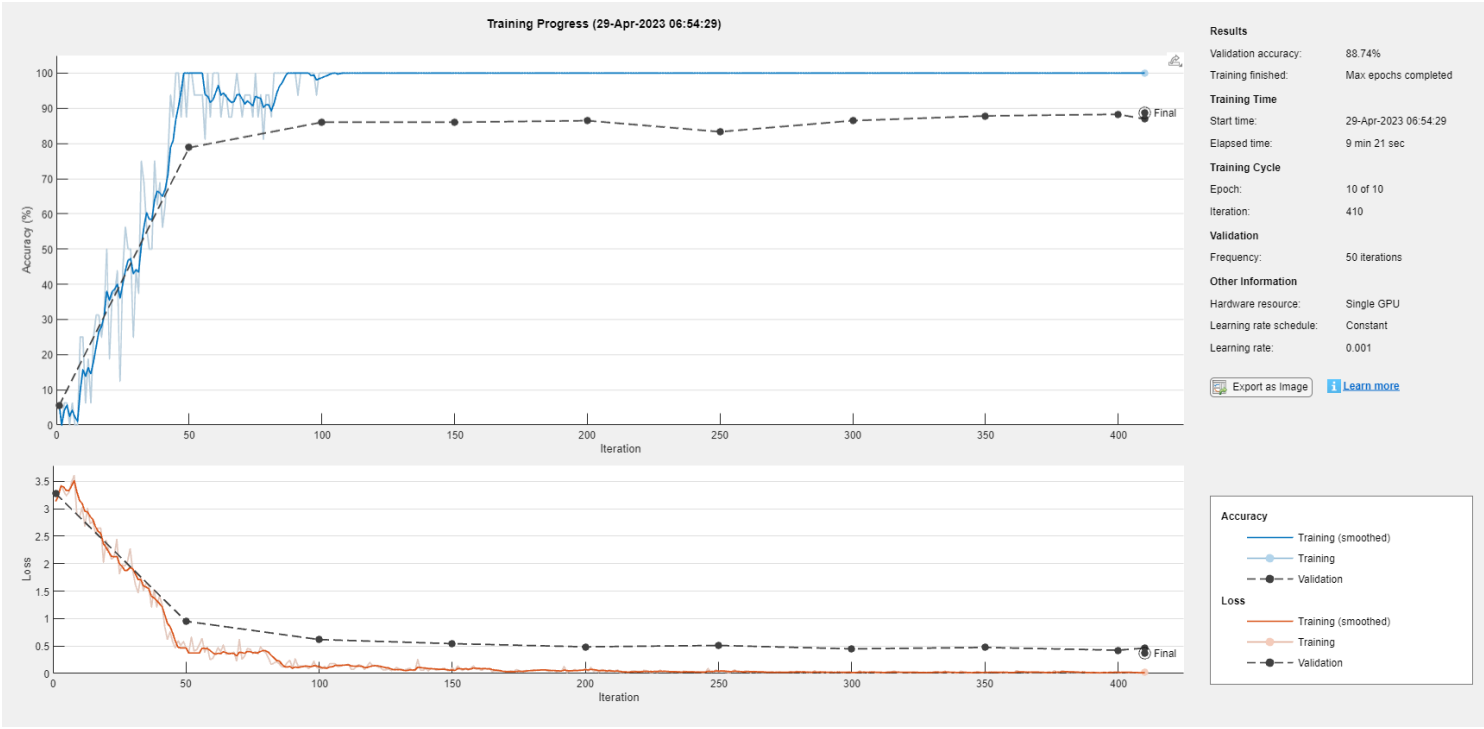
4	130	00:02:55	100.00%		0.0832		0.00
4	131	00:02:56	100.00%		0.0758		0.00
4	132	00:02:57	100.00%		0.0600		0.00
4	133	00:02:59	100.00%		0.0818		0.00
4	134	00:03:00	100.00%		0.0939		0.00
4	135	00:03:01	100.00%		0.0530		0.00
4	136	00:03:02	100.00%		0.0574		0.00
4	137	00:03:03	100.00%		0.2546		0.00
4	138	00:03:05	100.00%		0.0624		0.00
4	139	00:03:06	100.00%		0.0595		0.00
4	140	00:03:07	100.00%		0.0876		0.00
4	141	00:03:08	100.00%		0.0493		0.00
4	142	00:03:09	100.00%		0.0920		0.00
4	143	00:03:10	100.00%		0.0794		0.00
4	144	00:03:12	100.00%		0.0610		0.00
4	145	00:03:13	100.00%		0.0679		0.00
4	146	00:03:14	100.00%		0.0817		0.00
4	147	00:03:15	100.00%		0.0944		0.00
4	148	00:03:16	100.00%		0.0553		0.00
4	149	00:03:17	100.00%		0.0507		0.00
4	150	00:03:27	100.00%	86.04%	0.1025	0.5431	0.00
4	151	00:03:28	100.00%		0.0562		0.00
4	152	00:03:29	100.00%		0.1387		0.00
4	153	00:03:30	100.00%		0.0735		0.00
4	154	00:03:32	100.00%		0.0550		0.00
4	155	00:03:33	100.00%		0.0959		0.00
4	156	00:03:34	100.00%		0.0553		0.00
4	157	00:03:35	100.00%		0.0997		0.00
4	158	00:03:37	100.00%		0.1384		0.00
4	159	00:03:38	100.00%		0.0753		0.00
4	160	00:03:39	100.00%		0.0840		0.00
4	161	00:03:40	100.00%		0.0529		0.00
4	162	00:03:42	100.00%		0.0958		0.00
4	163	00:03:42	100.00%		0.0793		0.00
4	164	00:03:43	100.00%		0.0938		0.00
5	165	00:03:45	100.00%		0.0318		0.00
5	166	00:03:46	100.00%		0.0453		0.00
5	167	00:03:47	100.00%		0.0397		0.00
5	168	00:03:48	100.00%		0.0467		0.00
5	169	00:03:50	100.00%		0.0349		0.00
5	170	00:03:51	100.00%		0.0356		0.00
5	171	00:03:52	100.00%		0.0355		0.00
5	172	00:03:53	100.00%		0.0489		0.00
5	173	00:03:54	100.00%		0.0366		0.00
5	174	00:03:55	100.00%		0.0740		0.00
5	175	00:03:56	100.00%		0.0547		0.00
5	176	00:03:58	100.00%		0.0377		0.00
5	177	00:03:59	100.00%		0.0452		0.00
5	178	00:04:00	100.00%		0.0570		0.00
5	179	00:04:01	100.00%		0.0470		0.00
5	180	00:04:02	100.00%		0.0593		0.00
5	181	00:04:03	100.00%		0.0649		0.00
5	182	00:04:05	100.00%		0.0564		0.00
5	183	00:04:06	100.00%		0.0651		0.00
5	184	00:04:07	100.00%		0.0634		0.00
5	185	00:04:08	100.00%		0.0634		0.00
5	186	00:04:09	100.00%		0.0417		0.00
5	187	00:04:11	100.00%		0.0412		0.00
5	188	00:04:12	100.00%		0.0584		0.00
5	189	00:04:13	100.00%		0.0312		0.00
5	190	00:04:14	100.00%		0.0379		0.00
5	191	00:04:15	100.00%		0.0485		0.00
5	192	00:04:16	100.00%		0.1257		0.00
5	193	00:04:18	100.00%		0.0197		0.00

5	194	00:04:19	100.00%		0.0403		0.00
5	195	00:04:20	100.00%		0.0562		0.00
5	196	00:04:21	100.00%		0.0695		0.00
5	197	00:04:22	100.00%		0.0504		0.00
5	198	00:04:23	100.00%		0.0666		0.00
5	199	00:04:24	100.00%		0.0606		0.00
5	200	00:04:34	100.00%	86.49%	0.0869	0.4859	0.00
5	201	00:04:35	100.00%		0.0413		0.00
5	202	00:04:36	100.00%		0.1093		0.00
5	203	00:04:37	100.00%		0.0361		0.00
5	204	00:04:38	100.00%		0.0525		0.00
5	205	00:04:39	100.00%		0.0198		0.00
6	206	00:04:41	100.00%		0.0712		0.00
6	207	00:04:42	100.00%		0.0388		0.00
6	208	00:04:43	100.00%		0.0300		0.00
6	209	00:04:44	100.00%		0.0734		0.00
6	210	00:04:45	100.00%		0.0394		0.00
6	211	00:04:46	100.00%		0.0433		0.00
6	212	00:04:47	100.00%		0.0659		0.00
6	213	00:04:48	100.00%		0.0194		0.00
6	214	00:04:49	100.00%		0.0228		0.00
6	215	00:04:50	100.00%		0.0245		0.00
6	216	00:04:51	100.00%		0.0196		0.00
6	217	00:04:52	100.00%		0.0347		0.00
6	218	00:04:53	100.00%		0.0477		0.00
6	219	00:04:54	100.00%		0.0396		0.00
6	220	00:04:55	100.00%		0.0381		0.00
6	221	00:04:56	100.00%		0.0334		0.00
6	222	00:04:57	100.00%		0.0579		0.00
6	223	00:04:58	100.00%		0.0486		0.00
6	224	00:04:59	100.00%		0.0238		0.00
6	225	00:05:00	100.00%		0.0194		0.00
6	226	00:05:02	100.00%		0.0425		0.00
6	227	00:05:03	100.00%		0.0205		0.00
6	228	00:05:04	100.00%		0.0608		0.00
6	229	00:05:05	100.00%		0.0321		0.00
6	230	00:05:06	100.00%		0.0437		0.00
6	231	00:05:07	100.00%		0.0355		0.00
6	232	00:05:08	100.00%		0.0267		0.00
6	233	00:05:09	100.00%		0.0269		0.00
6	234	00:05:10	100.00%		0.0348		0.00
6	235	00:05:11	100.00%		0.0239		0.00
6	236	00:05:12	100.00%		0.0187		0.00
6	237	00:05:13	100.00%		0.0430		0.00
6	238	00:05:14	100.00%		0.0305		0.00
6	239	00:05:15	100.00%		0.0298		0.00
6	240	00:05:16	100.00%		0.0350		0.00
6	241	00:05:17	100.00%		0.0240		0.00
6	242	00:05:18	100.00%		0.0293		0.00
6	243	00:05:20	100.00%		0.0252		0.00
6	244	00:05:21	100.00%		0.0177		0.00
6	245	00:05:21	100.00%		0.0210		0.00
6	246	00:05:22	100.00%		0.0916		0.00
7	247	00:05:24	100.00%		0.0236		0.00
7	248	00:05:25	100.00%		0.0317		0.00
7	249	00:05:26	100.00%		0.0677		0.00
7	250	00:05:36	100.00%	83.33%	0.0267	0.5113	0.00
7	251	00:05:37	100.00%		0.0483		0.00
7	252	00:05:38	100.00%		0.0351		0.00
7	253	00:05:39	100.00%		0.0219		0.00
7	254	00:05:40	100.00%		0.0169		0.00
7	255	00:05:41	100.00%		0.0337		0.00
7	256	00:05:42	100.00%		0.0671		0.00
7	257	00:05:44	100.00%		0.0266		0.00

7	258	00:05:45	100.00%		0.0380		0.00
7	259	00:05:46	100.00%		0.0240		0.00
7	260	00:05:47	100.00%		0.0470		0.00
7	261	00:05:48	100.00%		0.0426		0.00
7	262	00:05:49	100.00%		0.0165		0.00
7	263	00:05:50	100.00%		0.0416		0.00
7	264	00:05:51	100.00%		0.0212		0.00
7	265	00:05:52	100.00%		0.0279		0.00
7	266	00:05:53	100.00%		0.0228		0.00
7	267	00:05:54	100.00%		0.0212		0.00
7	268	00:05:55	100.00%		0.0212		0.00
7	269	00:05:57	100.00%		0.0265		0.00
7	270	00:05:58	100.00%		0.0301		0.00
7	271	00:05:59	100.00%		0.0193		0.00
7	272	00:06:00	100.00%		0.0255		0.00
7	273	00:06:01	100.00%		0.0283		0.00
7	274	00:06:02	100.00%		0.0196		0.00
7	275	00:06:03	100.00%		0.0241		0.00
7	276	00:06:04	100.00%		0.0216		0.00
7	277	00:06:05	100.00%		0.0342		0.00
7	278	00:06:06	100.00%		0.0193		0.00
7	279	00:06:07	100.00%		0.0378		0.00
7	280	00:06:08	100.00%		0.0322		0.00
7	281	00:06:09	100.00%		0.0177		0.00
7	282	00:06:11	100.00%		0.0338		0.00
7	283	00:06:12	100.00%		0.0185		0.00
7	284	00:06:13	100.00%		0.0199		0.00
7	285	00:06:14	100.00%		0.0128		0.00
7	286	00:06:15	100.00%		0.0478		0.00
7	287	00:06:15	100.00%		0.0220		0.00
8	288	00:06:17	100.00%		0.0303		0.00
8	289	00:06:18	100.00%		0.0137		0.00
8	290	00:06:19	100.00%		0.0312		0.00
8	291	00:06:20	100.00%		0.0097		0.00
8	292	00:06:22	100.00%		0.0299		0.00
8	293	00:06:23	100.00%		0.0229		0.00
8	294	00:06:24	100.00%		0.0195		0.00
8	295	00:06:25	100.00%		0.0338		0.00
8	296	00:06:26	100.00%		0.0174		0.00
8	297	00:06:27	100.00%		0.0150		0.00
8	298	00:06:28	100.00%		0.0208		0.00
8	299	00:06:29	100.00%		0.0319		0.00
8	300	00:06:39	100.00%	86.49%	0.0122	0.4486	0.00
8	301	00:06:40	100.00%		0.0148		0.00
8	302	00:06:41	100.00%		0.0214		0.00
8	303	00:06:42	100.00%		0.0438		0.00
8	304	00:06:43	100.00%		0.0171		0.00
8	305	00:06:44	100.00%		0.0276		0.00
8	306	00:06:45	100.00%		0.0154		0.00
8	307	00:06:46	100.00%		0.0292		0.00
8	308	00:06:47	100.00%		0.0308		0.00
8	309	00:06:48	100.00%		0.0138		0.00
8	310	00:06:50	100.00%		0.0112		0.00
8	311	00:06:51	100.00%		0.0206		0.00
8	312	00:06:52	100.00%		0.0088		0.00
8	313	00:06:53	100.00%		0.0297		0.00
8	314	00:06:54	100.00%		0.0282		0.00
8	315	00:06:55	100.00%		0.0331		0.00
8	316	00:06:56	100.00%		0.0435		0.00
8	317	00:06:57	100.00%		0.0174		0.00
8	318	00:06:58	100.00%		0.0110		0.00
8	319	00:07:00	100.00%		0.0189		0.00
8	320	00:07:00	100.00%		0.0214		0.00
8	321	00:07:01	100.00%		0.0209		0.00

8	322	00:07:02	100.00%		0.0117		0.00
8	323	00:07:03	100.00%		0.0260		0.00
8	324	00:07:04	100.00%		0.0231		0.00
8	325	00:07:05	100.00%		0.0157		0.00
8	326	00:07:06	100.00%		0.0187		0.00
8	327	00:07:07	100.00%		0.0209		0.00
8	328	00:07:08	100.00%		0.0168		0.00
9	329	00:07:10	100.00%		0.0243		0.00
9	330	00:07:11	100.00%		0.0191		0.00
9	331	00:07:12	100.00%		0.0295		0.00
9	332	00:07:13	100.00%		0.0322		0.00
9	333	00:07:14	100.00%		0.0149		0.00
9	334	00:07:15	100.00%		0.0182		0.00
9	335	00:07:16	100.00%		0.0432		0.00
9	336	00:07:17	100.00%		0.0130		0.00
9	337	00:07:18	100.00%		0.0151		0.00
9	338	00:07:19	100.00%		0.0231		0.00
9	339	00:07:20	100.00%		0.0084		0.00
9	340	00:07:21	100.00%		0.0141		0.00
9	341	00:07:23	100.00%		0.0436		0.00
9	342	00:07:24	100.00%		0.0255		0.00
9	343	00:07:25	100.00%		0.0112		0.00
9	344	00:07:26	100.00%		0.0114		0.00
9	345	00:07:27	100.00%		0.0134		0.00
9	346	00:07:28	100.00%		0.0223		0.00
9	347	00:07:29	100.00%		0.0308		0.00
9	348	00:07:30	100.00%		0.0216		0.00
9	349	00:07:31	100.00%		0.0130		0.00
9	350	00:07:40	100.00%	87.84%	0.0241	0.4740	0.00
9	351	00:07:41	100.00%		0.0166		0.00
9	352	00:07:43	100.00%		0.0290		0.00
9	353	00:07:44	100.00%		0.0241		0.00
9	354	00:07:45	100.00%		0.0268		0.00
9	355	00:07:46	100.00%		0.0214		0.00
9	356	00:07:47	100.00%		0.0130		0.00
9	357	00:07:48	100.00%		0.0235		0.00
9	358	00:07:49	100.00%		0.0122		0.00
9	359	00:07:51	100.00%		0.0187		0.00
9	360	00:07:52	100.00%		0.0181		0.00
9	361	00:07:53	100.00%		0.0201		0.00
9	362	00:07:54	100.00%		0.0553		0.00
9	363	00:07:56	100.00%		0.0303		0.00
9	364	00:07:57	100.00%		0.0262		0.00
9	365	00:07:58	100.00%		0.0181		0.00
9	366	00:07:59	100.00%		0.0259		0.00
9	367	00:08:00	100.00%		0.0140		0.00
9	368	00:08:01	100.00%		0.0200		0.00
9	369	00:08:02	100.00%		0.0212		0.00
10	370	00:08:04	100.00%		0.0224		0.00
10	371	00:08:05	100.00%		0.0215		0.00
10	372	00:08:06	100.00%		0.0169		0.00
10	373	00:08:07	100.00%		0.0124		0.00
10	374	00:08:09	100.00%		0.0348		0.00
10	375	00:08:10	100.00%		0.0123		0.00
10	376	00:08:11	100.00%		0.0548		0.00
10	377	00:08:13	100.00%		0.0153		0.00
10	378	00:08:14	100.00%		0.0240		0.00
10	379	00:08:15	100.00%		0.0510		0.00
10	380	00:08:17	100.00%		0.0330		0.00
10	381	00:08:18	100.00%		0.0158		0.00
10	382	00:08:19	100.00%		0.0236		0.00
10	383	00:08:20	100.00%		0.0205		0.00
10	384	00:08:22	100.00%		0.0203		0.00
10	385	00:08:23	100.00%		0.0167		0.00

```
|      10 |         386 |       00:08:24 |      100.00% |              |       0.0165 |              |          0.00
|      10 |         387 |       00:08:25 |      100.00% |              |       0.0410 |              |          0.00
|      10 |         388 |       00:08:27 |      100.00% |              |       0.0099 |              |          0.00
|      10 |         389 |       00:08:28 |      100.00% |              |       0.0100 |              |          0.00
|      10 |         390 |       00:08:29 |      100.00% |              |       0.0224 |              |          0.00
|      10 |         391 |       00:08:31 |      100.00% |              |       0.0194 |              |          0.00
|      10 |         392 |       00:08:32 |      100.00% |              |       0.0157 |              |          0.00
|      10 |         393 |       00:08:34 |      100.00% |              |       0.0097 |              |          0.00
|      10 |         394 |       00:08:35 |      100.00% |              |       0.0195 |              |          0.00
|      10 |         395 |       00:08:36 |      100.00% |              |       0.0216 |              |          0.00
|      10 |         396 |       00:08:37 |      100.00% |              |       0.0120 |              |          0.00
|      10 |         397 |       00:08:38 |      100.00% |              |       0.0315 |              |          0.00
|      10 |         398 |       00:08:40 |      100.00% |              |       0.0202 |              |          0.00
|      10 |         399 |       00:08:41 |      100.00% |              |       0.0266 |              |          0.00
|      10 |         400 |       00:08:52 |      100.00% |       88.29% |       0.0201 |       0.4236 |          0.00
|      10 |         401 |       00:08:53 |      100.00% |              |       0.0130 |              |          0.00
|      10 |         402 |       00:08:54 |      100.00% |              |       0.0257 |              |          0.00
|      10 |         403 |       00:08:55 |      100.00% |              |       0.0186 |              |          0.00
|      10 |         404 |       00:08:57 |      100.00% |              |       0.0141 |              |          0.00
|      10 |         405 |       00:08:58 |      100.00% |              |       0.0176 |              |          0.00
|      10 |         406 |       00:09:00 |      100.00% |              |       0.0178 |              |          0.00
|      10 |         407 |       00:09:01 |      100.00% |              |       0.0124 |              |          0.00
|      10 |         408 |       00:09:02 |      100.00% |              |       0.0082 |              |          0.00
|      10 |         409 |       00:09:03 |      100.00% |              |       0.0162 |              |          0.00
|      10 |         410 |       00:09:12 |      100.00% |       86.94% |       0.0161 |       0.4633 |          0.00
|=========|=============|================|==============|==============|==============|==============|==========
Training finished: Max epochs completed.
```

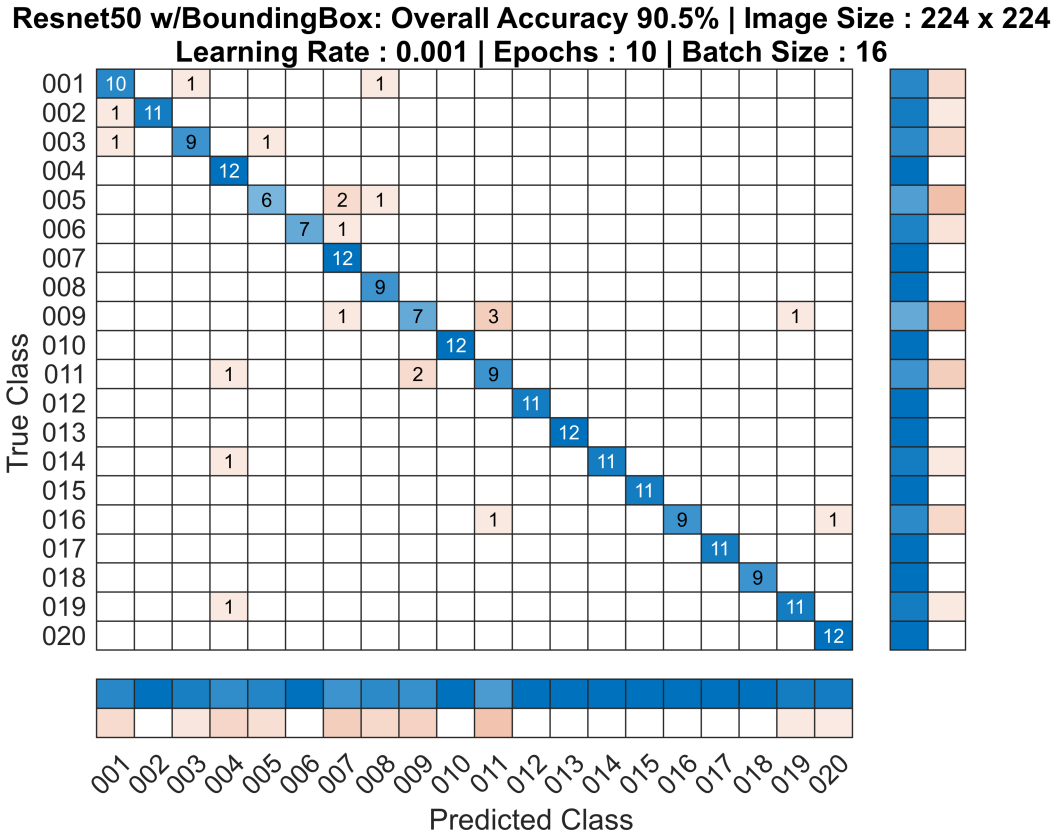



```
target_predictions = classify(myCNN, test_image_datastore_resized);
target_test = testImageDS.Labels;

% Calculate overall accuracy
overall_accuracy = sum(target_predictions == target_test)/numel(target_test) % Output on comma
```

```
overall_accuracy = 0.9054
```

```
% Show confusion matrix in figure
[matrix, order] = confusionmat(target_test, target_predictions);
figure(2);
confusion_matrix = confusionchart(matrix, order, ...
    'ColumnSummary','column-normalized', ...
    'RowSummary','row-normalized');
title({"Resnet50 w/BoundingBox: Overall Accuracy " + string(round(overall_accuracy*100, 1)) + '
    " | Image Size : " + target_size(1) + " x " + target_size(1); ...
    "Learning Rate : " + learning_rate + " | Epochs : " + epochs + " | Batch Size : " + batch_s
```




```
class_wise_correct_recognition_rates = zeros(height(order), 1);
samples_per_row = sum(matrix, 2);
for i = 1:height(order)
    class_wise_correct_recognition_rates(i) = round(100 * matrix(i, i) / samples_per_row(i), 1)
end
class_name_labels = table2array(classNames(:,2));

class_wise_recognition_rates = table(class_name_labels, ...
    class_wise_correct_recognition_rates, ...
    'VariableNames',["Class Name", "Correct Recognition Rate (%)"]);

disp("Class Weighted Average Overall Accuracy is " + string(round(overall_accuracy*100, 2)) + '
```

```
Class Weighted Average Overall Accuracy is 90.54%
```

```
disp(class_wise_recognition_rates);
```

Class Name	Correct Recognition Rate (%)
{'001.Black_footed_Albatross' }	83.3
{'002.Laysan_Albatross' }	91.7
{'003.Sooty_Albatross' }	81.8
{'004.Groove_billed_Ani' }	100
{'005.Crested_Auklet' }	66.7
{'006.Least_Auklet' }	87.5
{'007.Parakeet_Auklet' }	100
{'008.Rhinoceros_Auklet' }	100
{'009.Brewer_Blackbird' }	58.3
{'010.Red_winged_Blackbird' }	100
{'011.Rusty_Blackbird' }	75
{'012.Yellow_headed_Blackbird'}	100
{'013.Bobolink' }	100
{'014.Indigo_Bunting' }	91.7
{'015.Lazuli_Bunting' }	100
{'016.Painted_Bunting' }	81.8
{'017.Cardinal' }	100
{'018.Spotted_Catbird' }	100
{'019.Gray_Catbird' }	91.7
{'020.Yellow_breasted_Chat' }	100