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ECE 180 Final Project

This is the official notebook that we will present. Please keep it nice and clean.

Task

- 30 kinds of balls

Model Architecture

- TBD

Group members

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In [1]:

```
# Generic Data Handling
import numpy as np

# Data Visualization
import matplotlib.pyplot as plt

# PyTorch Basic Needs
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim

# Add other stuff as we go
import random

device = (
    "cuda"
    if torch.cuda.is_available()
    else "mps"
    if torch.backends.mps.is_available()
    else "cpu"
)
```

```
print(f"Using {device} device")
```

```
Using cuda device
```

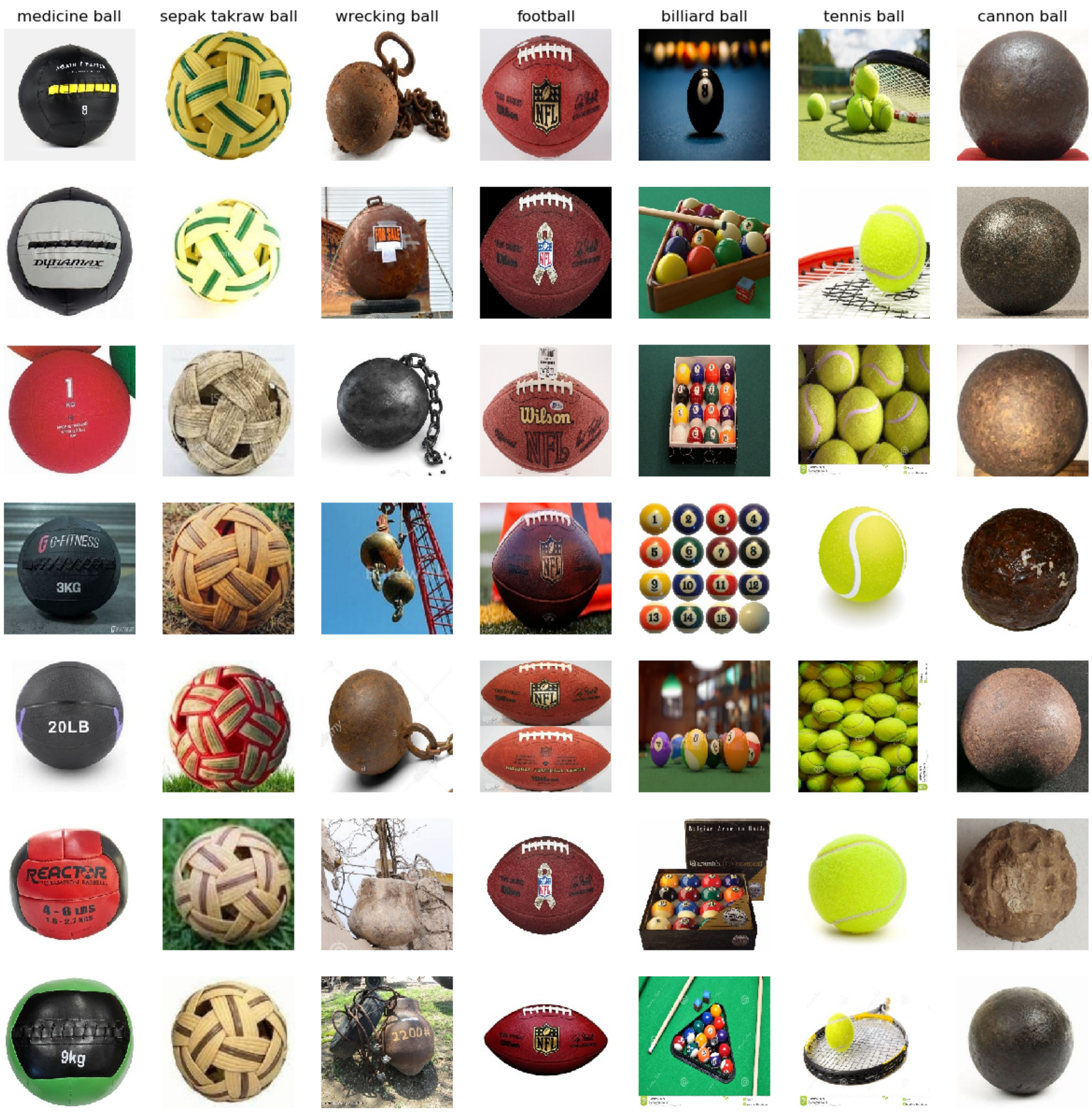
Data Importing and Preprocessing

Import the dataset and group into training, validation, and testing groups. We may need to do cross validation.

In [2]:
```
import os
from torchvision import datasets, transforms
from torch.utils.data import DataLoader

# Define data transforms
transform = transforms.Compose([
    transforms.ToTensor()
])

# Load the dataset
train_dataset = datasets.ImageFolder(root='~/Downloads/balls_image_classific
val_dataset = datasets.ImageFolder(root='~/Downloads/balls_image_classificat
test_dataset = datasets.ImageFolder(root='~/Downloads/balls_image_classifica

# Create data loaders
train_loader = DataLoader(train_dataset, batch_size=32, shuffle=True)
val_loader = DataLoader(val_dataset, batch_size=32, shuffle=False)
test_loader = DataLoader(test_dataset, batch_size=32, shuffle=False)
```

In [3]:
```
# Function to show images
def imshow(img, title):
    img = img
    npimg = img.numpy()
    plt.imshow(np.transpose(npimg, (1, 2, 0)))
    plt.title(title)
    plt.axis('off')

# Function to visualize dataset
def visualize_dataset(dataset, classes, samples_per_class=7, num_classes_to_
    selected_classes = random.sample(classes, num_classes_to_display)
    selected_class_indices = [classes.index(cls) for cls in selected_classes

    num_classes = len(selected_classes)
    fig = plt.figure(figsize=(15, 15))

    for y, cls in enumerate(selected_classes):
        class_indices = [i for i, (img, label) in enumerate(dataset) if labe
        selected_indices = random.sample(class_indices, samples_per_class)

        for i, idx in enumerate(selected_indices):
            img, label = dataset[idx]
            plt_idx = i * num_classes + y + 1
            plt.subplot(samples_per_class, num_classes, plt_idx)
            imshow(img, cls if i == 0 else '')
```

```
    plt.show()

# Get class names
classes = train_dataset.classes

# Visualize the training dataset
visualize_dataset(train_dataset, classes, samples_per_class=7, num_classes_t
```



Defining the Model

Define and compile a CNN model

In [4]:
```
import torch
import torch.nn as nn
import torch.nn.functional as F
```

```
class ResidualBlock(nn.Module):
    def __init__(self, in_channels, out_channels, stride=1):
        super(ResidualBlock, self).__init__()
        self.conv1 = nn.Conv2d(in_channels, out_channels, kernel_size=3, str
        self.bn1 = nn.BatchNorm2d(out_channels)
        self.conv2 = nn.Conv2d(out_channels, out_channels, kernel_size=3, pa
        self.bn2 = nn.BatchNorm2d(out_channels)

        self.shortcut = nn.Sequential()
        if stride != 1 or in_channels != out_channels:
            self.shortcut = nn.Sequential(
                nn.Conv2d(in_channels, out_channels, kernel_size=1, stride=s
                nn.BatchNorm2d(out_channels)
            )

    def forward(self, x):
        out = F.relu(self.bn1(self.conv1(x)))
        out = self.bn2(self.conv2(out))
        out += self.shortcut(x)
        return F.relu(out)

class BallClassifierCNN(nn.Module):
    def __init__(self, dropout_rate=0.3):
        super(BallClassifierCNN, self).__init__()

        self.layer1 = self._make_layer(3, 64, stride=2)
        self.layer2 = self._make_layer(64, 128, stride=2)
        self.layer3 = self._make_layer(128, 256, stride=2)
        self.layer4 = self._make_layer(256, 512, stride=2)

        self.global_pool = nn.AdaptiveAvgPool2d((1, 1))
        self.dropout = nn.Dropout(dropout_rate)
        self.fc = nn.Linear(512, 30)

    def _make_layer(self, in_channels, out_channels, stride):
        layers = [
            ResidualBlock(in_channels, out_channels, stride),
            ResidualBlock(out_channels, out_channels)
        ]
        return nn.Sequential(*layers)

    def forward(self, x):
        out = self.layer1(x)
        out = self.layer2(out)
        out = self.layer3(out)
        out = self.layer4(out)

        out = self.global_pool(out)
        out = out.view(out.size(0), -1)
        out = self.dropout(out)
        out = self.fc(out)

        return F.log_softmax(out, dim=1)
```

In [5]:
```
model = BallClassifierCNN().to(device)
loss_fn = nn.CrossEntropyLoss()
```

In [6]:
```
def test(dataloader, model, loss_fn):
    size = len(dataloader.dataset)
    num_batches = len(dataloader)
    model.eval()
    test_loss, correct = 0, 0
    with torch.no_grad():
        for X, y in dataloader:
            X, y = X.to(device), y.to(device)
            pred = model(X)
            test_loss += loss_fn(pred, y).item()
            correct += (pred.argmax(1) == y).type(torch.float).sum().item()
    test_loss /= num_batches
    correct /= size
    print(f"New Best. Accuracy: {(100*correct):>0.1f}%, Avg loss: {test_loss
    return correct
```

Training

In [7]:
```
learning_rate = 0.001
optimizer = optim.Adam(model.parameters(), lr=learning_rate)
```

In [8]:
```
best_loss = 100
best_val_acc = 0
size = len(train_loader.dataset)
epoch = 0
losses = []
while epoch<1000:
    model.train()
    running_loss = 0.0

    for batch, (images, labels) in enumerate(train_loader):
        images = images.to(device)
        labels = labels.to(device)
        optimizer.zero_grad()

        outputs = model(images)
        loss = loss_fn(outputs, labels)

        loss.backward()
        optimizer.step()

        running_loss += loss.item()

    #learning_rate -= learning_rate/10 #adjust learning rate
    cal_loss = running_loss/len(train_loader)
    print(f'Epoch [{epoch+1}], Loss: {cal_loss}')
    losses.append(cal_loss)
    if best_loss > cal_loss:
        best_loss = cal_loss
        acc = test(val_loader, model, loss_fn)
```

```
        if acc > best_val_acc:
            best_val_acc = acc
            if acc > 0.8:
                torch.save({
                    'epoch': epoch,
                    'model_state_dict': model.state_dict(),
                    'optimizer_state_dict': optimizer.state_dict(),
                    'loss': cal_loss
                }, f"./balls_image_classification/model/residual_model_val_a
    epoch += 1
```

```
Epoch [1], Loss: 2.9144779918468102
New Best. Accuracy: 22.0%, Avg loss: 2.739236

Epoch [2], Loss: 2.531768174298042
New Best. Accuracy: 34.0%, Avg loss: 2.363857

Epoch [3], Loss: 2.281551272468229
New Best. Accuracy: 39.3%, Avg loss: 2.260673

Epoch [4], Loss: 2.151011694849065
New Best. Accuracy: 48.0%, Avg loss: 1.963931

Epoch [5], Loss: 1.9932404840941977
New Best. Accuracy: 40.7%, Avg loss: 2.212950

Epoch [6], Loss: 1.8989098040403518
New Best. Accuracy: 45.3%, Avg loss: 1.812683

Epoch [7], Loss: 1.8029809430637191
New Best. Accuracy: 54.7%, Avg loss: 1.576989

Epoch [8], Loss: 1.7083414972355935
New Best. Accuracy: 43.3%, Avg loss: 2.426459

Epoch [9], Loss: 1.6024079670948266
New Best. Accuracy: 49.3%, Avg loss: 2.011462

Epoch [10], Loss: 1.500077032409938
New Best. Accuracy: 55.3%, Avg loss: 1.553686

Epoch [11], Loss: 1.415494378689116
New Best. Accuracy: 56.7%, Avg loss: 1.436617

Epoch [12], Loss: 1.4113009255544273
New Best. Accuracy: 63.3%, Avg loss: 1.423904

Epoch [13], Loss: 1.2997471025559755
New Best. Accuracy: 58.0%, Avg loss: 1.439235

Epoch [14], Loss: 1.233599265592288
New Best. Accuracy: 63.3%, Avg loss: 1.459647

Epoch [15], Loss: 1.1650338009395431
New Best. Accuracy: 64.0%, Avg loss: 1.268108

Epoch [16], Loss: 1.081142980440528
New Best. Accuracy: 65.3%, Avg loss: 1.230439

Epoch [17], Loss: 1.0237862594359743
New Best. Accuracy: 70.0%, Avg loss: 1.083012

Epoch [18], Loss: 1.0217490090733081
New Best. Accuracy: 63.3%, Avg loss: 1.291247

Epoch [19], Loss: 0.9352292758701122
New Best. Accuracy: 66.7%, Avg loss: 1.380617
```

```
Epoch [20], Loss: 0.913187223461877
New Best. Accuracy: 73.3%, Avg loss: 1.005446

Epoch [21], Loss: 0.8107195599416716
New Best. Accuracy: 70.7%, Avg loss: 1.182120

Epoch [22], Loss: 0.7620242926399264
New Best. Accuracy: 57.3%, Avg loss: 1.707347

Epoch [23], Loss: 0.7221138414028472
New Best. Accuracy: 74.0%, Avg loss: 0.822980

Epoch [24], Loss: 0.6976836505716881
New Best. Accuracy: 73.3%, Avg loss: 1.085427

Epoch [25], Loss: 0.6244698430584595
New Best. Accuracy: 81.3%, Avg loss: 0.811853

Epoch [26], Loss: 0.6160391446499698
New Best. Accuracy: 72.0%, Avg loss: 0.927287

Epoch [27], Loss: 0.5600265811766143
New Best. Accuracy: 74.0%, Avg loss: 0.847106

Epoch [28], Loss: 0.5299146845277432
New Best. Accuracy: 79.3%, Avg loss: 0.782472

Epoch [29], Loss: 0.4961439355284767
New Best. Accuracy: 71.3%, Avg loss: 0.999599

Epoch [30], Loss: 0.5217385184580245
Epoch [31], Loss: 0.4606909974750164
New Best. Accuracy: 72.0%, Avg loss: 1.122236

Epoch [32], Loss: 0.39613801887077565
New Best. Accuracy: 79.3%, Avg loss: 0.870365

Epoch [33], Loss: 0.3946711633321458
New Best. Accuracy: 80.7%, Avg loss: 0.772172

Epoch [34], Loss: 0.3242673333239766
New Best. Accuracy: 79.3%, Avg loss: 0.915840

Epoch [35], Loss: 0.2889544660538699
New Best. Accuracy: 87.3%, Avg loss: 0.562144

Epoch [36], Loss: 0.28388180669430085
New Best. Accuracy: 79.3%, Avg loss: 0.772854

Epoch [37], Loss: 0.2706869914138739
New Best. Accuracy: 75.3%, Avg loss: 0.859782

Epoch [38], Loss: 0.29222339246652823
Epoch [39], Loss: 0.2515480121416328
New Best. Accuracy: 77.3%, Avg loss: 0.738569
```

```
Epoch [40], Loss: 0.17927852632329527
New Best. Accuracy: 74.0%, Avg loss: 1.247469

Epoch [41], Loss: 0.21907282422865387
Epoch [42], Loss: 0.21150721973879674
Epoch [43], Loss: 0.15792469403385062
New Best. Accuracy: 75.3%, Avg loss: 0.853363

Epoch [44], Loss: 0.16523059792157296
Epoch [45], Loss: 0.17547178879973635
Epoch [46], Loss: 0.13526658758323276
New Best. Accuracy: 82.7%, Avg loss: 0.569750

Epoch [47], Loss: 0.10289467423659775
New Best. Accuracy: 74.0%, Avg loss: 1.016045

Epoch [48], Loss: 0.12140103678458032
Epoch [49], Loss: 0.1168022629335127
Epoch [50], Loss: 0.1439011996958108
Epoch [51], Loss: 0.13680618365122155
Epoch [52], Loss: 0.1135099632583097
Epoch [53], Loss: 0.09844019817007063
New Best. Accuracy: 83.3%, Avg loss: 0.940044

Epoch [54], Loss: 0.07042948168957919
New Best. Accuracy: 84.7%, Avg loss: 0.696357

Epoch [55], Loss: 0.07435340656841223
Epoch [56], Loss: 0.08251168247955167
Epoch [57], Loss: 0.07875557411132397
Epoch [58], Loss: 0.10558572464284643
Epoch [59], Loss: 0.09002790247724779
Epoch [60], Loss: 0.0828527335604999
Epoch [61], Loss: 0.06842628562930081
New Best. Accuracy: 84.0%, Avg loss: 0.775063

Epoch [62], Loss: 0.08828424969358387
Epoch [63], Loss: 0.06602519830128392
New Best. Accuracy: 80.0%, Avg loss: 1.120275

Epoch [64], Loss: 0.05069696741689623
New Best. Accuracy: 84.7%, Avg loss: 0.859851

Epoch [65], Loss: 0.0487418781607453
New Best. Accuracy: 83.3%, Avg loss: 0.703701

Epoch [66], Loss: 0.08148615945963007
Epoch [67], Loss: 0.11231949711960237
Epoch [68], Loss: 0.12119124068639579
Epoch [69], Loss: 0.10774235588918744
Epoch [70], Loss: 0.05118587438379769
Epoch [71], Loss: 0.04754293357244635
New Best. Accuracy: 86.7%, Avg loss: 0.605286

Epoch [72], Loss: 0.02427667278932424
```

```
New Best. Accuracy: 83.3%, Avg loss: 0.781783

Epoch [73], Loss: 0.024872160055138898
Epoch [74], Loss: 0.028174686353021113
Epoch [75], Loss: 0.06037376173030157
Epoch [76], Loss: 0.04914709713322366
Epoch [77], Loss: 0.03366162428381004
Epoch [78], Loss: 0.033457144677630765
Epoch [79], Loss: 0.0917746796194398
Epoch [80], Loss: 0.09236052183566236
Epoch [81], Loss: 0.13966177990948533
Epoch [82], Loss: 0.06970786625123788
Epoch [83], Loss: 0.05559399148111388
Epoch [84], Loss: 0.047695578905275766
Epoch [85], Loss: 0.02105844254807396
New Best. Accuracy: 87.3%, Avg loss: 0.624321

Epoch [86], Loss: 0.02355297367305874
Epoch [87], Loss: 0.022960026795353607
Epoch [88], Loss: 0.008198385223343482
New Best. Accuracy: 86.7%, Avg loss: 0.633967

Epoch [89], Loss: 0.00546539974408183
New Best. Accuracy: 87.3%, Avg loss: 0.704986

Epoch [90], Loss: 0.010554443197211548
Epoch [91], Loss: 0.03270605583345534
Epoch [92], Loss: 0.07506940136890265
Epoch [93], Loss: 0.09927904512321131
Epoch [94], Loss: 0.027224315769776734
Epoch [95], Loss: 0.02854956273222342
Epoch [96], Loss: 0.06301085247485115
Epoch [97], Loss: 0.03816423401292166
Epoch [98], Loss: 0.0861979593786584
Epoch [99], Loss: 0.046669597993501816
Epoch [100], Loss: 0.033072362011051286
Epoch [101], Loss: 0.03512456401074058
Epoch [102], Loss: 0.029713518328529955
Epoch [103], Loss: 0.029388450450816117
Epoch [104], Loss: 0.03989191618500756
Epoch [105], Loss: 0.040285985900626924
Epoch [106], Loss: 0.017887410291174913
Epoch [107], Loss: 0.024127593817729172
Epoch [108], Loss: 0.02868792418167984
Epoch [109], Loss: 0.01266185148769528
Epoch [110], Loss: 0.008681278219147775
Epoch [111], Loss: 0.0035454031889119797
New Best. Accuracy: 88.0%, Avg loss: 0.699652

Epoch [112], Loss: 0.01171247051581658
Epoch [113], Loss: 0.02447931749789473
Epoch [114], Loss: 0.1013644182574482
Epoch [115], Loss: 0.05923070349839755
Epoch [116], Loss: 0.0953495721425449
Epoch [117], Loss: 0.020568851605098925
Epoch [118], Loss: 0.026310324231554154
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Epoch [119], Loss: 0.010242120291346446
Epoch [120], Loss: 0.005412196153795462
Epoch [121], Loss: 0.004123490963162611
Epoch [122], Loss: 0.002565466744207882
New Best. Accuracy: 89.3%, Avg loss: 0.444025

Epoch [123], Loss: 0.0011125203789850806
New Best. Accuracy: 88.0%, Avg loss: 0.534038

Epoch [124], Loss: 0.004733945054690553
Epoch [125], Loss: 0.0569791578910771
Epoch [126], Loss: 0.05835484028989614
Epoch [127], Loss: 0.05600115464818952
Epoch [128], Loss: 0.022809595661598413
Epoch [129], Loss: 0.0101711476719794
Epoch [130], Loss: 0.0222060306879086
Epoch [131], Loss: 0.02286237844075921
Epoch [132], Loss: 0.04243319342737045
Epoch [133], Loss: 0.02677317993175568
Epoch [134], Loss: 0.01451807129387414
Epoch [135], Loss: 0.010892911436125344
Epoch [136], Loss: 0.04187504969837569
Epoch [137], Loss: 0.02905020996257539
Epoch [138], Loss: 0.0317847907339198
Epoch [139], Loss: 0.009316958959777922
Epoch [140], Loss: 0.031362890526271156
Epoch [141], Loss: 0.03470782536111331
Epoch [142], Loss: 0.056080744564955626
Epoch [143], Loss: 0.028385154674225282
Epoch [144], Loss: 0.016074887590379294
Epoch [145], Loss: 0.006237134170850875
Epoch [146], Loss: 0.01069768624541461
Epoch [147], Loss: 0.021803674138325218
Epoch [148], Loss: 0.017594428732089773
Epoch [149], Loss: 0.025558733066855063
Epoch [150], Loss: 0.02798717265791029
Epoch [151], Loss: 0.014587899697241394
Epoch [152], Loss: 0.00973960006273706
Epoch [153], Loss: 0.00673868287567449
Epoch [154], Loss: 0.0028497066650260447
Epoch [155], Loss: 0.0020269364878945815
Epoch [156], Loss: 0.0149048568120183
Epoch [157], Loss: 0.0295049800514089
Epoch [158], Loss: 0.08739684168888108
Epoch [159], Loss: 0.0654850866546673
Epoch [160], Loss: 0.01358595638936674
Epoch [161], Loss: 0.0076880129728341615
Epoch [162], Loss: 0.004039928585024853
Epoch [163], Loss: 0.0012710439991155708
Epoch [164], Loss: 0.005896660350375156
Epoch [165], Loss: 0.03441638165435329
Epoch [166], Loss: 0.024347687623668585
Epoch [167], Loss: 0.010230225421072589
Epoch [168], Loss: 0.002013637283013359
Epoch [169], Loss: 0.010961906955634353
Epoch [170], Loss: 0.015358173873153694
```

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Epoch [171], Loss: 0.00943092397995967
Epoch [172], Loss: 0.0088910831342476
Epoch [173], Loss: 0.049259105337597225
Epoch [174], Loss: 0.050884879897585535
Epoch [175], Loss: 0.012804531387274413
Epoch [176], Loss: 0.009819367396646793
Epoch [177], Loss: 0.0029038991941832187
Epoch [178], Loss: 0.0038411682294080276
Epoch [179], Loss: 0.0013495451571342311
Epoch [180], Loss: 0.010024166085279033
Epoch [181], Loss: 0.0380863055210268
Epoch [182], Loss: 0.07370299895358914
Epoch [183], Loss: 0.05328876359271817
Epoch [184], Loss: 0.01419506528089235
Epoch [185], Loss: 0.011676636994216257
Epoch [186], Loss: 0.00818319444600503
Epoch [187], Loss: 0.008317284469208907
Epoch [188], Loss: 0.025944878646916664
Epoch [189], Loss: 0.006950374416610591
Epoch [190], Loss: 0.0012410317365688208
Epoch [191], Loss: 0.0007628045458603131
New Best. Accuracy: 90.0%, Avg loss: 0.682122

Epoch [192], Loss: 0.001736710260602758
Epoch [193], Loss: 0.005613977370855931
Epoch [194], Loss: 0.0011422651821591085
Epoch [195], Loss: 0.0015071561957862223
Epoch [196], Loss: 0.0027755314097550454
Epoch [197], Loss: 0.00288259580608924
Epoch [198], Loss: 0.010839177747833979
Epoch [199], Loss: 0.008491641860437245
Epoch [200], Loss: 0.13440103373187387
Epoch [201], Loss: 0.054588443832729525
Epoch [202], Loss: 0.01570617472979578
Epoch [203], Loss: 0.005329628104966781
Epoch [204], Loss: 0.0012466323745346306
Epoch [205], Loss: 0.0015571264074448253
Epoch [206], Loss: 0.0023831098314341975
Epoch [207], Loss: 0.0016740109109152593
Epoch [208], Loss: 0.0012157227376974333
Epoch [209], Loss: 0.0028399531765899155
Epoch [210], Loss: 0.005152410419350819
Epoch [211], Loss: 0.004704550707093863
Epoch [212], Loss: 0.00793620297573615
Epoch [213], Loss: 0.009009195608972233
Epoch [214], Loss: 0.012151507455345647
Epoch [215], Loss: 0.02355487519335975
Epoch [216], Loss: 0.032060516267227814
Epoch [217], Loss: 0.012521317365598108
Epoch [218], Loss: 0.04166496106085009
Epoch [219], Loss: 0.03704199877199799
Epoch [220], Loss: 0.010307938936590145
Epoch [221], Loss: 0.006938597001734167
Epoch [222], Loss: 0.023671602621155304
Epoch [223], Loss: 0.0021315212403689365
Epoch [224], Loss: 0.00272120291361893З
```

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Epoch [225], Loss: 0.03843216623145617
Epoch [226], Loss: 0.038235776887076446
Epoch [227], Loss: 0.021060437455451924
Epoch [228], Loss: 0.021156160116760497
Epoch [229], Loss: 0.03149196288539524
Epoch [230], Loss: 0.013943891929484703
Epoch [231], Loss: 0.011503213085700986
Epoch [232], Loss: 0.0030218420933470526
Epoch [233], Loss: 0.0020173938576759465
Epoch [234], Loss: 0.0017904800869014777
Epoch [235], Loss: 0.0010018110619967047
Epoch [236], Loss: 0.0010863725562871998
Epoch [237], Loss: 0.006854257043261767
Epoch [238], Loss: 0.03163521741309556
Epoch [239], Loss: 0.027996927180144095
Epoch [240], Loss: 0.01168755462109338
Epoch [241], Loss: 0.006451814435623636
Epoch [242], Loss: 0.015133185892296848
Epoch [243], Loss: 0.00788213466410976
Epoch [244], Loss: 0.0020504699884795062
Epoch [245], Loss: 0.005302249364465156
Epoch [246], Loss: 0.00445987638651416
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New Best. Accuracy: 90.0%, Avg loss: 0.600372

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New Best. Accuracy: 91.3%, Avg loss: 0.578879

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```
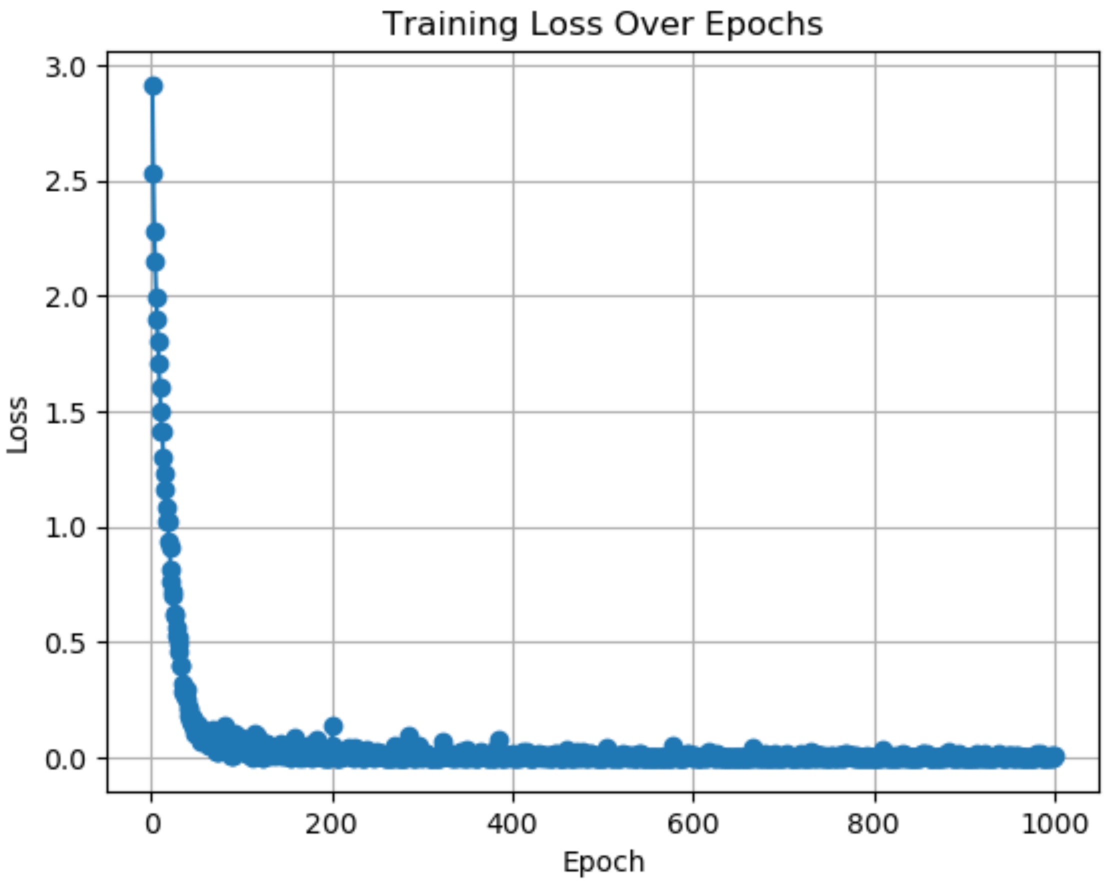

Testing

Test the model and show test results

In [14]:
```
plt.plot(range(1, epoch+1), losses, marker='o')
plt.title('Training Loss Over Epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.grid()
plt.show()
```



In [9]:
```
#curr_best_model = BallClassifierCNN().to(device)
#checkpoint = torch.load("./balls_image_classification/residual_model_val_ac
#curr_best_model.load_state_dict(checkpoint['model_state_dict'])
```

In [10]:
```
#loss_fn = nn.CrossEntropyLoss()
#test(test_loader, curr_best_model, loss_fn)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
Cell In[10], line 2
      1 loss_fn = nn.CrossEntropyLoss()
----> 2 test(test_loader, curr_best_model, loss_fn)

NameError: name 'curr_best_model' is not defined
```

In [ ]: