

✓ Lab 2: Cats vs Dogs

In this lab, you will train a convolutional neural network to classify an image into one of two classes: "cat" or "dog". The code for the neural networks you train will be written for you, and you are not (yet!) expected to understand all provided code. However, by the end of the lab, you should be able to:

1. Understand at a high level the training loop for a machine learning model.
2. Understand the distinction between training, validation, and test data.
3. The concepts of overfitting and underfitting.
4. Investigate how different hyperparameters, such as learning rate and batch size, affect the success of training.
5. Compare an ANN (aka Multi-Layer Perceptron) with a CNN.

What to submit

Submit a PDF file containing all your code, outputs, and write-up from parts 1-5. You can produce a PDF of your Google Colab file by going to **File > Print** and then save as PDF. The Colab instructions has more information.

Do not submit any other files produced by your code.

Include a link to your colab file in your submission.

Please use Google Colab to complete this assignment. If you want to use Jupyter Notebook, please complete the assignment and upload your Jupyter Notebook file to Google Colab for submission.

With Colab, you can export a PDF file using the menu option **File → Print** and save as PDF file.

Adjust the scaling to ensure that the text is not cutoff at the margins.

✓ Colab Link

Include a link to your colab file here

Colab Link:<https://colab.research.google.com/drive/1WwWvfB1ZvuMRgZCNfBXgBRO-6rg01p0B#scrollTo=vQqmZoZbAJGS>

```
import numpy as np
import time
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
import torchvision
```

```
from torch.utils.data.sampler import SubsetRandomSampler
import torchvision.transforms as transforms
```

▼ Part 0. Helper Functions

We will be making use of the following helper functions. You will be asked to look at and possibly modify some of these, but you are not expected to understand all of them.

You should look at the function names and read the docstrings. If you are curious, come back and explore the code *after* making some progress on the lab.

```
#####
# Data Loading

def get_relevant_indices(dataset, classes, target_classes):
    """ Return the indices for datapoints in the dataset that belongs to the
    desired target classes, a subset of all possible classes.

    Args:
        dataset: Dataset object
        classes: A list of strings denoting the name of each class
        target_classes: A list of strings denoting the name of desired classes
                        Should be a subset of the 'classes'

    Returns:
        indices: list of indices that have labels corresponding to one of the
                 target classes
    """
    indices = []
    for i in range(len(dataset)):
        # Check if the label is in the target classes
        label_index = dataset[i][1] # ex: 3
        label_class = classes[label_index] # ex: 'cat'
        if label_class in target_classes:
            indices.append(i)
    return indices

def get_data_loader(target_classes, batch_size):
    """ Loads images of cats and dogs, splits the data into training, validation
    and testing datasets. Returns data loaders for the three preprocessed datasets.

    Args:
        target_classes: A list of strings denoting the name of the desired
                       classes. Should be a subset of the argument
        batch_size: A int representing the number of samples per batch

    Returns:
        train_loader: iterable training dataset organized according to batch size
        val_loader: iterable validation dataset organized according to batch size
        test_loader: iterable testing dataset organized according to batch size
        classes: A list of strings denoting the name of each class
    """
#####
```

```

classes = ('plane', 'car', 'bird', 'cat',
           'deer', 'dog', 'frog', 'horse', 'ship', 'truck')
#####
# The output of torchvision datasets are PILImage images of range [0, 1].
# We transform them to Tensors of normalized range [-1, 1].
transform = transforms.Compose(
    [transforms.ToTensor(),
     transforms.Normalize((0.5, 0.5, 0.5), (0.5, 0.5, 0.5))])
# Load CIFAR10 training data
trainset = torchvision.datasets.CIFAR10(root='./data', train=True,
                                         download=True)
# Get the list of indices to sample from
relevant_indices = get_relevant_indices(trainset, classes, target_classes)

# Split into train and validation
np.random.seed(1000) # Fixed numpy random seed for reproducible shuffling
np.random.shuffle(relevant_indices)
split = int(len(relevant_indices) * 0.8) #split at 80%

# split into training and validation indices
relevant_train_indices, relevant_val_indices = relevant_indices[:split], relevant_indices[split:]
train_sampler = SubsetRandomSampler(relevant_train_indices)
train_loader = torch.utils.data.DataLoader(trainset, batch_size=batch_size,
                                           num_workers=num_workers)
val_sampler = SubsetRandomSampler(relevant_val_indices)
val_loader = torch.utils.data.DataLoader(trainset, batch_size=batch_size,
                                         num_workers=num_workers)

# Load CIFAR10 testing data
testset = torchvision.datasets.CIFAR10(root='./data', train=False,
                                       download=True)
# Get the list of indices to sample from
relevant_test_indices = get_relevant_indices(testset, classes, target_classes)
test_sampler = SubsetRandomSampler(relevant_test_indices)
test_loader = torch.utils.data.DataLoader(testset, batch_size=batch_size,
                                          num_workers=num_workers)

return train_loader, val_loader, test_loader, classes
#####
# Training
def get_model_name(name, batch_size, learning_rate, epoch):
    """ Generate a name for the model consisting of all the hyperparameter values
    """
    path = "model_{0}_bs{1}_lr{2}_epoch{3}".format(name,

```

Args:

config: Configuration object containing the hyperparameters

Returns:

path: A string with the hyperparameter name and value concatenated

"""

path = "model_{0}_bs{1}_lr{2}_epoch{3}".format(name,

return path

def normalize_label(labels):

```

"""
Given a tensor containing 2 possible values, normalize this to 0/1

Args:
    labels: a 1D tensor containing two possible scalar values
Returns:
    A tensor normalize to 0/1 value
"""

max_val = torch.max(labels)
min_val = torch.min(labels)
norm_labels = (labels - min_val)/(max_val - min_val)
return norm_labels

def evaluate(net, loader, criterion):
    """
    Evaluate the network on the validation set.

    Args:
        net: PyTorch neural network object
        loader: PyTorch data loader for the validation set
        criterion: The loss function
    Returns:
        err: A scalar for the avg classification error over the validation set
        loss: A scalar for the average loss function over the validation set
    """

    total_loss = 0.0
    total_err = 0.0
    total_epoch = 0
    for i, data in enumerate(loader, 0):
        inputs, labels = data
        labels = normalize_label(labels) # Convert labels to 0/1
        outputs = net(inputs)
        loss = criterion(outputs, labels.float())
        corr = (outputs > 0.0).squeeze().long() != labels
        total_err += int(corr.sum())
        total_loss += loss.item()
        total_epoch += len(labels)
    err = float(total_err) / total_epoch
    loss = float(total_loss) / (i + 1)
    return err, loss

#####
# Training Curve
def plot_training_curve(path):
    """
    Plots the training curve for a model run, given the csv files
    containing the train/validation error/loss.

    Args:
        path: The base path of the csv files produced during training
    """

    import matplotlib.pyplot as plt
    train_err = np.loadtxt("{}_train_err.csv".format(path))
    val_err = np.loadtxt("{}_val_err.csv".format(path))
    train_loss = np.loadtxt("{}_train_loss.csv".format(path))
    val_loss = np.loadtxt("{}_val_loss.csv".format(path))
    plt.title("Train vs Validation Error")

```

```

n = len(train_err) # number of epochs
plt.plot(range(1, n+1), train_err, label="Train")
plt.plot(range(1, n+1), val_err, label="Validation")
plt.xlabel("Epoch")
plt.ylabel("Error")
plt.legend(loc='best')
plt.show()

plt.title("Train vs Validation Loss")
plt.plot(range(1, n+1), train_loss, label="Train")
plt.plot(range(1, n+1), val_loss, label="Validation")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.legend(loc='best')
plt.show()

```

▼ Part 1. Visualizing the Data [7 pt]

We will make use of some of the CIFAR-10 data set, which consists of colour images of size 32x32 pixels belonging to 10 categories. You can find out more about the dataset at

<https://www.cs.toronto.edu/~kriz/cifar.html>

For this assignment, we will only be using the cat and dog categories. We have included code that automatically downloads the dataset the first time that the main script is run.

```

# This will download the CIFAR-10 dataset to a folder called "data"
# the first time you run this code.
train_loader, val_loader, test_loader, classes = get_data_loader(
    target_classes=["cat", "dog"],
    batch_size=1) # One image per batch

```

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▼ Part (a) – 1 pt

Visualize some of the data by running the code below. Include the visualization in your writeup.
(You don't need to submit anything else.)

```

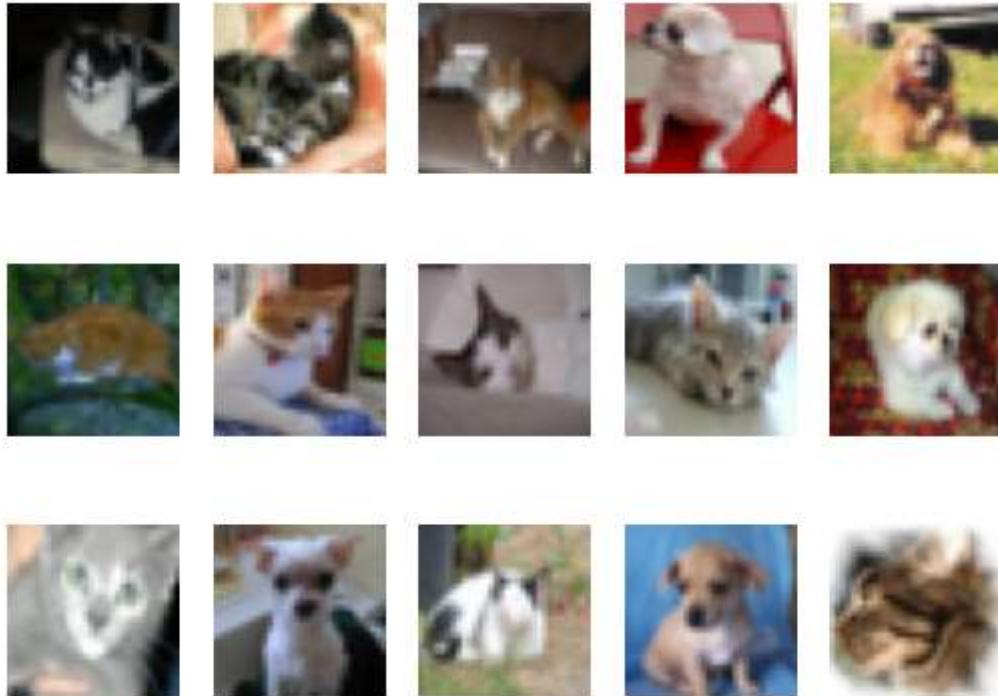
import matplotlib.pyplot as plt

k = 0
for images, labels in train_loader:
    # since batch_size = 1, there is only 1 image in `images`
    image = images[0]
    # place the colour channel at the end, instead of at the beginning
    img = np.transpose(image, [1, 2, 0])
    # normalize pixel intensity values to [0, 1]
    img = img / 2 + 0.5
    plt.subplot(3, 5, k+1)

```

```
plt.axis('off')
plt.imshow(img)
```

```
k += 1
if k > 14:
    break
```



▼ Part (b) -- 3 pt

How many training examples do we have for the combined cat and dog classes? What about validation examples? What about test examples?

```
catTestCount = 0
dogTestCount = 0

catTrainCount = 0
dogTrainCount = 0

catValCount = 0
dogValCount = 0

for images, labels in train_loader:
    for label in labels:
        if label == 3:
            catTrainCount += 1
        elif label == 5:
            dogTrainCount += 1

for images, labels in test_loader:
    for label in labels:
        if label == 3:
            catTestCount += 1
```

```

        elif label == 5:
            dogTestCount += 1

for images, labels in val_loader:
    for label in labels:
        if label == 3:
            catValCount += 1
        elif label == 5:
            dogValCount += 1

print("Cat Train Count:", catTrainCount)
print("Dog Train Count:", dogTrainCount)

print("Cat Test Count:", catTestCount)
print("Dog Test Count:", dogTestCount)

print("Cat Validation Count:", catValCount)
print("Dog Validation Count:", dogValCount)

```

→ Cat Train Count: 4018
 Dog Train Count: 3982
 Cat Test Count: 1000
 Dog Test Count: 1000
 Cat Validation Count: 982
 Dog Validation Count: 1018

▼ Part (c) -- 3pt

Why do we need a validation set when training our model? What happens if we judge the performance of our models using the training set loss/error instead of the validation set loss/error?

We need validation set to evaluate performance of the model during training and to tune hyperparameters. Training the model purely on training dataset will lead to overfitting.

▼ Part 2. Training [15 pt]

We define two neural networks, a `LargeNet` and `SmallNet`. We'll be training the networks in this section.

You won't understand fully what these networks are doing until the next few classes, and that's okay. For this assignment, please focus on learning how to train networks, and how hyperparameters affect training.

```

class LargeNet(nn.Module):
    def __init__(self):
        super(LargeNet, self).__init__()
        self.name = "large"

```

```

        self.conv1 = nn.Conv2d(3, 5, 5)
        self.pool = nn.MaxPool2d(2, 2)
        self.conv2 = nn.Conv2d(5, 10, 5)
        self.fc1 = nn.Linear(10 * 5 * 5, 32)
        self.fc2 = nn.Linear(32, 1)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.pool(F.relu(self.conv2(x)))
        x = x.view(-1, 10 * 5 * 5)
        x = F.relu(self.fc1(x))
        x = self.fc2(x)
        x = x.squeeze(1) # Flatten to [batch_size]
        return x

class SmallNet(nn.Module):
    def __init__(self):
        super(SmallNet, self).__init__()
        self.name = "small"
        self.conv = nn.Conv2d(3, 5, 3)
        self.pool = nn.MaxPool2d(2, 2)
        self.fc = nn.Linear(5 * 7 * 7, 1)

    def forward(self, x):
        x = self.pool(F.relu(self.conv(x)))
        x = self.pool(x)
        x = x.view(-1, 5 * 7 * 7)
        x = self.fc(x)
        x = x.squeeze(1) # Flatten to [batch_size]
        return x

small_net = SmallNet()
large_net = LargeNet()

```

▼ Part (a) – 2pt

The methods `small_net.parameters()` and `large_net.parameters()` produces an iterator of all the trainable parameters of the network. These parameters are torch tensors containing many scalar values.

We haven't learned how the parameters in these high-dimensional tensors will be used, but we should be able to count the number of parameters. Measuring the number of parameters in a network is one way of measuring the "size" of a network.

What is the total number of parameters in `small_net` and in `large_net`? (Hint: how many numbers are in each tensor?)

```

small_net_params = 0
large_net_params = 0

```

```

for params in small_net.parameters():
    small_net_params += params.numel()

for params in large_net.parameters():
    large_net_params += params.numel()

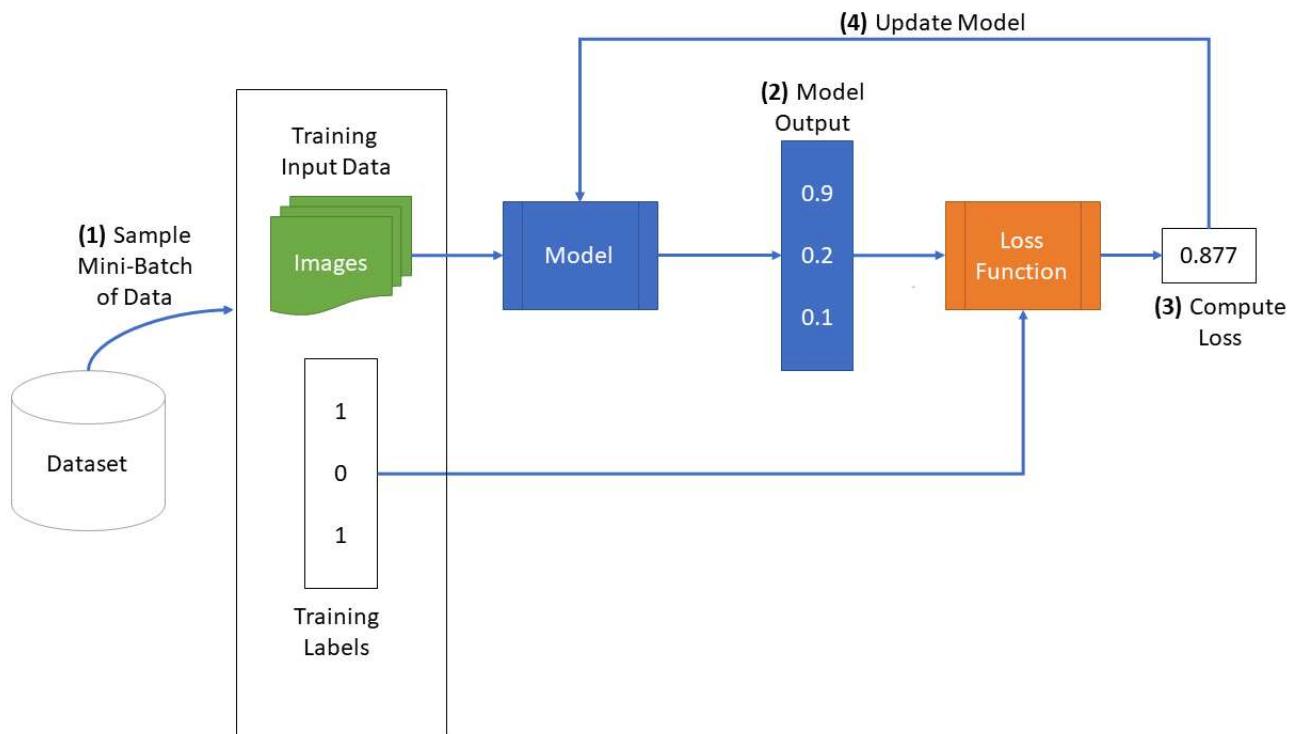
print(small_net_params)
print(large_net_params)

```

→ 386
9705

▼ The function train_net

The function `train_net` below takes an untrained neural network (like `small_net` and `large_net`) and several other parameters. You should be able to understand how this function works. The figure below shows the high level training loop for a machine learning model:



```

def train_net(net, batch_size=64, learning_rate=0.01, num_epochs=30):
    #####
    # Train a classifier on cats vs dogs
    target_classes = ["cat", "dog"]
    #####
    # Fixed PyTorch random seed for reproducible result
    torch.manual_seed(1000)
    #####
    # Obtain the PyTorch data loader objects to load batches of the datasets
    train_loader, val_loader, test_loader, classes = get_data_loader(
        target_classes, batch_size)
    #####
    # Define the Loss function and optimizer

```

```

# The loss function will be Binary Cross Entropy (BCE). In this case we
# will use the BCEWithLogitsLoss which takes unnormalized output from
# the neural network and scalar label.
# Optimizer will be SGD with Momentum.
criterion = nn.BCEWithLogitsLoss()
optimizer = optim.SGD(net.parameters(), lr=learning_rate, momentum=0.9)
#####
# Set up some numpy arrays to store the training/test loss/erruracy
train_err = np.zeros(num_epochs)
train_loss = np.zeros(num_epochs)
val_err = np.zeros(num_epochs)
val_loss = np.zeros(num_epochs)
#####
# Train the network
# Loop over the data iterator and sample a new batch of training data
# Get the output from the network, and optimize our loss function.
start_time = time.time()
for epoch in range(num_epochs):    # loop over the dataset multiple times
    total_train_loss = 0.0
    total_train_err = 0.0
    total_epoch = 0
    for i, data in enumerate(train_loader, 0):
        # Get the inputs
        inputs, labels = data
        labels = normalize_label(labels) # Convert labels to 0/1
        # Zero the parameter gradients
        optimizer.zero_grad()
        # Forward pass, backward pass, and optimize
        outputs = net(inputs)
        loss = criterion(outputs, labels.float())
        loss.backward()
        optimizer.step()
        # Calculate the statistics
        corr = (outputs > 0.0).squeeze().long() != labels
        total_train_err += int(corr.sum())
        total_train_loss += loss.item()
        total_epoch += len(labels)
    train_err[epoch] = float(total_train_err) / total_epoch
    train_loss[epoch] = float(total_train_loss) / (i+1)
    val_err[epoch], val_loss[epoch] = evaluate(net, val_loader, criterion)
    print("Epoch {}: Train err: {}, Train loss: {} | ".format(
        "Validation err: {}, Validation loss: {}".format(
            epoch + 1,
            train_err[epoch],
            train_loss[epoch],
            val_err[epoch],
            val_loss[epoch])))
    # Save the current model (checkpoint) to a file
    model_path = get_model_name(net.name, batch_size, learning_rate, epoch)
    torch.save(net.state_dict(), model_path)
print('Finished Training')
end_time = time.time()
elapsed_time = end_time - start_time
print("Total time elapsed: {:.2f} seconds".format(elapsed_time))
# Write the train/test loss/err into CSV file for plotting later

```

```

epochs = np.arange(1, num_epochs + 1)
np.savetxt("{}_train_err.csv".format(model_path), train_err)
np.savetxt("{}_train_loss.csv".format(model_path), train_loss)
np.savetxt("{}_val_err.csv".format(model_path), val_err)
np.savetxt("{}_val_loss.csv".format(model_path), val_loss)

```

▼ Part (b) – 1pt

The parameters to the function `train_net` are hyperparameters of our neural network. We made these hyperparameters easy to modify so that we can tune them later on.

What are the default values of the parameters `batch_size`, `learning_rate`, and `num_epochs`?

```
#batch_size=64, learning_rate=0.01, num_epochs=30
```

▼ Part (c) – 3 pt

What files are written to disk when we call `train_net` with `small_net`, and train for 5 epochs? Provide a list of all the files written to disk, and what information the files contain.

```

# 9 files in total
# 5 checkpoints files for each epoch, they contain information like bias and weight
# 4 csv files contain train error, train loss, val error, val loss

```

▼ Part (d) – 2pt

Train both `small_net` and `large_net` using the function `train_net` and its default parameters. The function will write many files to disk, including a model checkpoint (saved values of model weights) at the end of each epoch.

If you are using Google Colab, you will need to mount Google Drive so that the files generated by `train_net` gets saved. We will be using these files in part (d). (See the Google Colab tutorial for more information about this.)

Report the total time elapsed when training each network. Which network took longer to train? Why?

```

# Since the function writes files to disk, you will need to mount
# your Google Drive. If you are working on the lab locally, you
# can comment out this code.

```

```
from google.colab import drive
drive.mount('/content/gdrive')
```

 Mounted at /content/gdrive

```
train_net(small_net)  
train_net(large_net)
```

Epoch 8: Train err: 0.303625, Train loss: 0.5756459944248199 |Validation err: 0.32, Validat
→ Epoch 9: Train err: 0.297, Train loss: 0.5750047810077668 |Validation err: 0.317, Validati
Epoch 10: Train err: 0.29425, Train loss: 0.5670694999694824 |Validation err: 0.3185, Vali
Epoch 11: Train err: 0.28975, Train loss: 0.5656416394710541 |Validation err: 0.3225, Vali
Epoch 12: Train err: 0.286875, Train loss: 0.5588166882991791 |Validation err: 0.3325, Val
Epoch 13: Train err: 0.288375, Train loss: 0.5643634338378907 |Validation err: 0.314, Vali
Epoch 14: Train err: 0.279125, Train loss: 0.5555050556659699 |Validation err: 0.3135, Val
Epoch 15: Train err: 0.28475, Train loss: 0.5539012174606324 |Validation err: 0.313, Valic
Epoch 16: Train err: 0.28275, Train loss: 0.5566683669090271 |Validation err: 0.3205, Vali
Epoch 17: Train err: 0.281125, Train loss: 0.5562922296524048 |Validation err: 0.31, Valic
Epoch 18: Train err: 0.277375, Train loss: 0.5485912177562714 |Validation err: 0.314, Vali
Epoch 19: Train err: 0.275, Train loss: 0.5460561680793762 |Validation err: 0.3185, Valida
Epoch 20: Train err: 0.270875, Train loss: 0.5463462460041046 |Validation err: 0.3075, Val
Epoch 21: Train err: 0.273, Train loss: 0.5480605902671813 |Validation err: 0.315, Validat
Epoch 22: Train err: 0.271125, Train loss: 0.5453556621074677 |Validation err: 0.31, Valic
Epoch 23: Train err: 0.2725, Train loss: 0.5479486055374145 |Validation err: 0.3125, Valic
Epoch 24: Train err: 0.26925, Train loss: 0.5428402216434479 |Validation err: 0.3105, Vali
Epoch 25: Train err: 0.272, Train loss: 0.5413604018688202 |Validation err: 0.3125, Valida
Epoch 26: Train err: 0.2695, Train loss: 0.5420659372806549 |Validation err: 0.304, Valida
Epoch 27: Train err: 0.27175, Train loss: 0.5409384276866913 |Validation err: 0.3085, Vali
Epoch 28: Train err: 0.270375, Train loss: 0.540939162015915 |Validation err: 0.304, Valic
Epoch 29: Train err: 0.276625, Train loss: 0.544092280626297 |Validation err: 0.3165, Vali
Epoch 30: Train err: 0.272, Train loss: 0.5403290498256683 |Validation err: 0.318, Validat
Finished Training

Total time elapsed: 145.95 seconds

Epoch 1: Train err: 0.4615, Train loss: 0.6918617811203003 |Validation err: 0.435, Validat
Epoch 2: Train err: 0.432125, Train loss: 0.6820823793411255 |Validation err: 0.4255, Vali
Epoch 3: Train err: 0.40825, Train loss: 0.6695189175605774 |Validation err: 0.384, Valida
Epoch 4: Train err: 0.384, Train loss: 0.6550170369148255 |Validation err: 0.3625, Validat
Epoch 5: Train err: 0.362, Train loss: 0.6397473983764649 |Validation err: 0.3455, Validat
Epoch 6: Train err: 0.34475, Train loss: 0.6214497497081757 |Validation err: 0.347, Valida
Epoch 7: Train err: 0.33925, Train loss: 0.6127537751197815 |Validation err: 0.324, Valida
Epoch 8: Train err: 0.321375, Train loss: 0.595201049566269 |Validation err: 0.3175, Valic
Epoch 9: Train err: 0.310875, Train loss: 0.5848946249485016 |Validation err: 0.314, Valic
Epoch 10: Train err: 0.29575, Train loss: 0.5705028541088104 |Validation err: 0.309, Valic
Epoch 11: Train err: 0.2875, Train loss: 0.554695025920868 |Validation err: 0.3215, Valida
Epoch 12: Train err: 0.279125, Train loss: 0.5466273081302643 |Validation err: 0.2985, Val
Epoch 13: Train err: 0.27125, Train loss: 0.5324254167079926 |Validation err: 0.29, Valida
Epoch 14: Train err: 0.259625, Train loss: 0.5193688504695892 |Validation err: 0.29, Valic
Epoch 15: Train err: 0.253625, Train loss: 0.5092493145465851 |Validation err: 0.289, Vali
Epoch 16: Train err: 0.25225, Train loss: 0.508696941614151 |Validation err: 0.299, Valida
Epoch 17: Train err: 0.244375, Train loss: 0.4954603214263916 |Validation err: 0.312, Vali
Epoch 18: Train err: 0.236, Train loss: 0.478644166469574 |Validation err: 0.2915, Validat
Epoch 19: Train err: 0.227375, Train loss: 0.4677162492275238 |Validation err: 0.2935, Val
Epoch 20: Train err: 0.2235, Train loss: 0.4617846574783325 |Validation err: 0.3125, Valic
Epoch 21: Train err: 0.22025, Train loss: 0.45634967827796935 |Validation err: 0.286, Vali
Epoch 22: Train err: 0.209875, Train loss: 0.4403131387233734 |Validation err: 0.281, Vali
Epoch 23: Train err: 0.201125, Train loss: 0.4289124894142151 |Validation err: 0.288, Vali
Epoch 24: Train err: 0.193, Train loss: 0.4148750915527344 |Validation err: 0.2995, Valida
Epoch 25: Train err: 0.19175, Train loss: 0.4090040874481201 |Validation err: 0.289, Valic

```
#large net took longer, I think it is because it has more layers and neurons which
```

▼ Part (e) - 2pt

Use the function `plot_training_curve` to display the trajectory of the training/validation error and the training/validation loss. You will need to use the function `get_model_name` to generate the argument to the `plot_training_curve` function.

Do this for both the small network and the large network. Include both plots in your writeup.

```
#model_path = get_model_name("small", batch_size=??, learning_rate=??, epoch=29)
small_model_path = get_model_name("small", batch_size=64, learning_rate=0.01, epoch=29)
large_model_path = get_model_name("large", batch_size=64, learning_rate=0.01, epoch=29)

print("Small Network:")
plot_training_curve(small_model_path)
print("Large Network:")
plot_training_curve(large_model_path)
```

 [Show hidden output](#)

▼ Part (f) - 5pt

Describe what you notice about the training curve. How do the curves differ for `small_net` and `large_net`? Identify any occurrences of underfitting and overfitting.

For the small network, both training loss and error decrease steadily, showing that the model is learning. However, the loss and error curves flatten out after around 10 epochs, suggesting that generalization has stopped improving. This indicates mild overfitting. For the large network, training loss and error decrease steadily at first 10 epochs, showing effective learning on the training set. However, the error starts to flatten after around 10 epochs, while loss dramatically increases. This is a clear case of overfitting.

▼ Part (a) - 3pt

Train `large_net` with all default parameters, except set `learning_rate=0.001`. Does the model take longer/shorter to train? Plot the training curve. Describe the effect of *lowering* the learning rate.

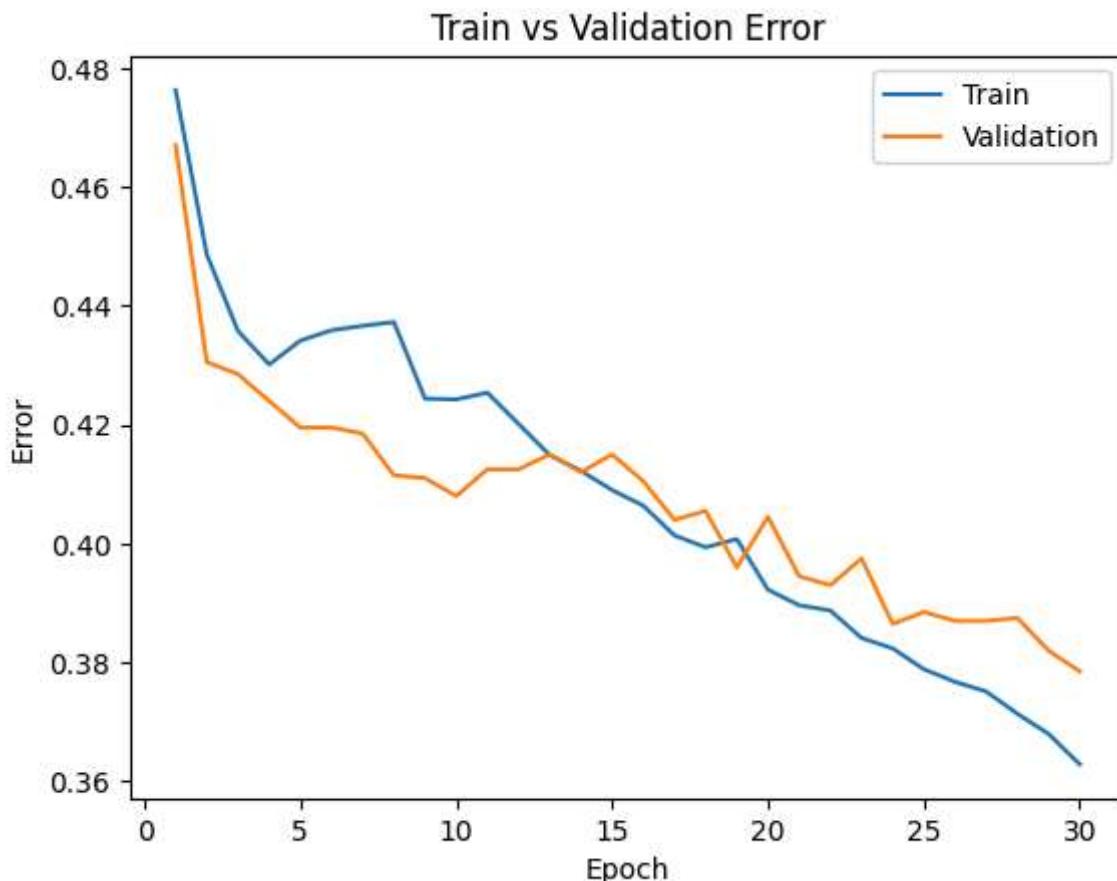
```
# Note: When we re-construct the model, we start the training
# with *random weights*. If we omit this code, the values of
# the weights will still be the previously trained values.
large_net = LargeNet()
train_net(large_net, learning_rate = 0.001)
```

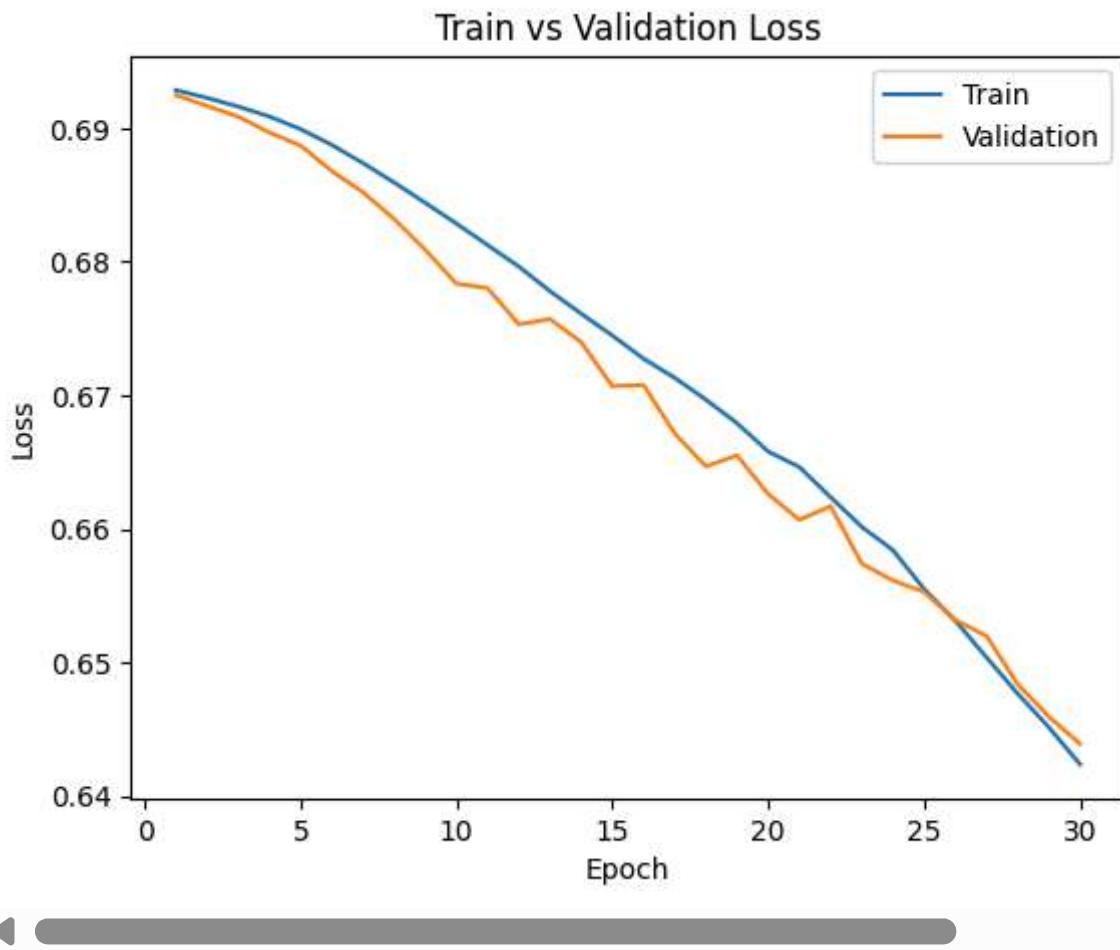
```
large_model_path = get_model_name("large", batch_size=64, learning_rate=0.001, epoch=29)
plot_training_curve(large_model_path)

#The training time is 1 second faster which is approximately the same
#The loss curve no longer shows overfitting, which suggests that using a lower learni
#This prevents it from memorizing the training data too quickly and allows it to ger
```

→ Epoch 1: Train err: 0.47625, Train loss: 0.6928360004425049 |Validation err: 0.467, Validation loss: 0.6922589716911316
 Epoch 2: Train err: 0.448625, Train loss: 0.6922589716911316 |Validation err: 0.4305, Validation loss: 0.6916067404747009
 Epoch 3: Train err: 0.43575, Train loss: 0.6908613877296448 |Validation err: 0.4285, Validation loss: 0.6908613877296448
 Epoch 4: Train err: 0.430125, Train loss: 0.6908613877296448 |Validation err: 0.424, Validation loss: 0.6899198365211486
 Epoch 5: Train err: 0.434125, Train loss: 0.6899198365211486 |Validation err: 0.4195, Validation loss: 0.6887419748306275
 Epoch 6: Train err: 0.435875, Train loss: 0.6887419748306275 |Validation err: 0.4195, Validation loss: 0.6873781814575195
 Epoch 7: Train err: 0.436625, Train loss: 0.6873781814575195 |Validation err: 0.4185, Validation loss: 0.6859267811775207
 Epoch 8: Train err: 0.43725, Train loss: 0.6859267811775207 |Validation err: 0.4115, Validation loss: 0.6844044809341431
 Epoch 9: Train err: 0.424375, Train loss: 0.6844044809341431 |Validation err: 0.411, Validation loss: 0.6828490204811096
 Epoch 10: Train err: 0.42425, Train loss: 0.6828490204811096 |Validation err: 0.408, Validation loss: 0.6812362918853759
 Epoch 11: Train err: 0.425375, Train loss: 0.6812362918853759 |Validation err: 0.4125, Validation loss: 0.6796324462890625
 Epoch 12: Train err: 0.420125, Train loss: 0.6796324462890625 |Validation err: 0.4125, Validation loss: 0.6777921686172486
 Epoch 13: Train err: 0.414875, Train loss: 0.6777921686172486 |Validation err: 0.415, Validation loss: 0.6761114087104797
 Epoch 14: Train err: 0.41225, Train loss: 0.6761114087104797 |Validation err: 0.412, Validation loss: 0.6744724254608154
 Epoch 15: Train err: 0.409, Train loss: 0.6744724254608154 |Validation err: 0.415, Validation loss: 0.6727445869445801
 Epoch 16: Train err: 0.406375, Train loss: 0.6727445869445801 |Validation err: 0.4105, Validation loss: 0.67130890417099
 Epoch 17: Train err: 0.401375, Train loss: 0.67130890417099 |Validation err: 0.404, Validation loss: 0.6696756863594056
 Epoch 18: Train err: 0.399375, Train loss: 0.6696756863594056 |Validation err: 0.4055, Validation loss: 0.6679100017547608
 Epoch 19: Train err: 0.40075, Train loss: 0.6679100017547608 |Validation err: 0.396, Validation loss: 0.665790048122406
 Epoch 20: Train err: 0.39225, Train loss: 0.665790048122406 |Validation err: 0.4045, Validation loss: 0.6646309685707092
 Epoch 21: Train err: 0.389625, Train loss: 0.6646309685707092 |Validation err: 0.3945, Validation loss: 0.6623744034767151
 Epoch 22: Train err: 0.38875, Train loss: 0.6623744034767151 |Validation err: 0.393, Validation loss: 0.6601551241874695
 Epoch 23: Train err: 0.384125, Train loss: 0.6601551241874695 |Validation err: 0.3975, Validation loss: 0.6584072341918945
 Epoch 24: Train err: 0.382375, Train loss: 0.6584072341918945 |Validation err: 0.3865, Validation loss: 0.6555052490234375
 Epoch 25: Train err: 0.378875, Train loss: 0.6555052490234375 |Validation err: 0.3885, Validation loss: 0.6531328277587891
 Epoch 26: Train err: 0.37675, Train loss: 0.6531328277587891 |Validation err: 0.387, Validation loss: 0.6503917617797852
 Epoch 27: Train err: 0.375125, Train loss: 0.6503917617797852 |Validation err: 0.387, Validation loss: 0.647677414894104
 Epoch 28: Train err: 0.371375, Train loss: 0.647677414894104 |Validation err: 0.3875, Validation loss: 0.6451585369110108
 Epoch 29: Train err: 0.368, Train loss: 0.6451585369110108 |Validation err: 0.382, Validation loss: 0.6423822708129883
 Epoch 30: Train err: 0.362875, Train loss: 0.6423822708129883 |Validation err: 0.3785, Validation loss: 0.639585369110108
 Finished Training

Total time elapsed: 164.35 seconds





▼ Part (b) - 3pt

Train `large_net` with all default parameters, except set `learning_rate=0.1`. Does the model take longer/shorter to train? Plot the training curve. Describe the effect of *increasing* the learning rate.

```
large_net = LargeNet()
train_net(large_net, learning_rate = 0.1)

large_model_path = get_model_name("large", batch_size=64, learning_rate=0.1, epoch=29)
plot_training_curve(large_model_path)
#Increasing the learning rate didn't effect training time.
#However, it clearly led to faster and stronger overfitting, as loss began to rise
```

[Show hidden output](#)

➤ Part (c) - 3pt

Train `large_net` with all default parameters, including with `learning_rate=0.01`. Now, set `batch_size=512`. Does the model take longer/shorter to train? Plot the training curve. Describe the effect of *increasing* the batch size.

[] ↴ 1 cell hidden

▼ Part (d) - 3pt

Train `large_net` with all default parameters, including with `learning_rate=0.01`. Now, set `batch_size=16`. Does the model take longer/shorter to train? Plot the training curve. Describe the effect of *decreasing* the batch size.

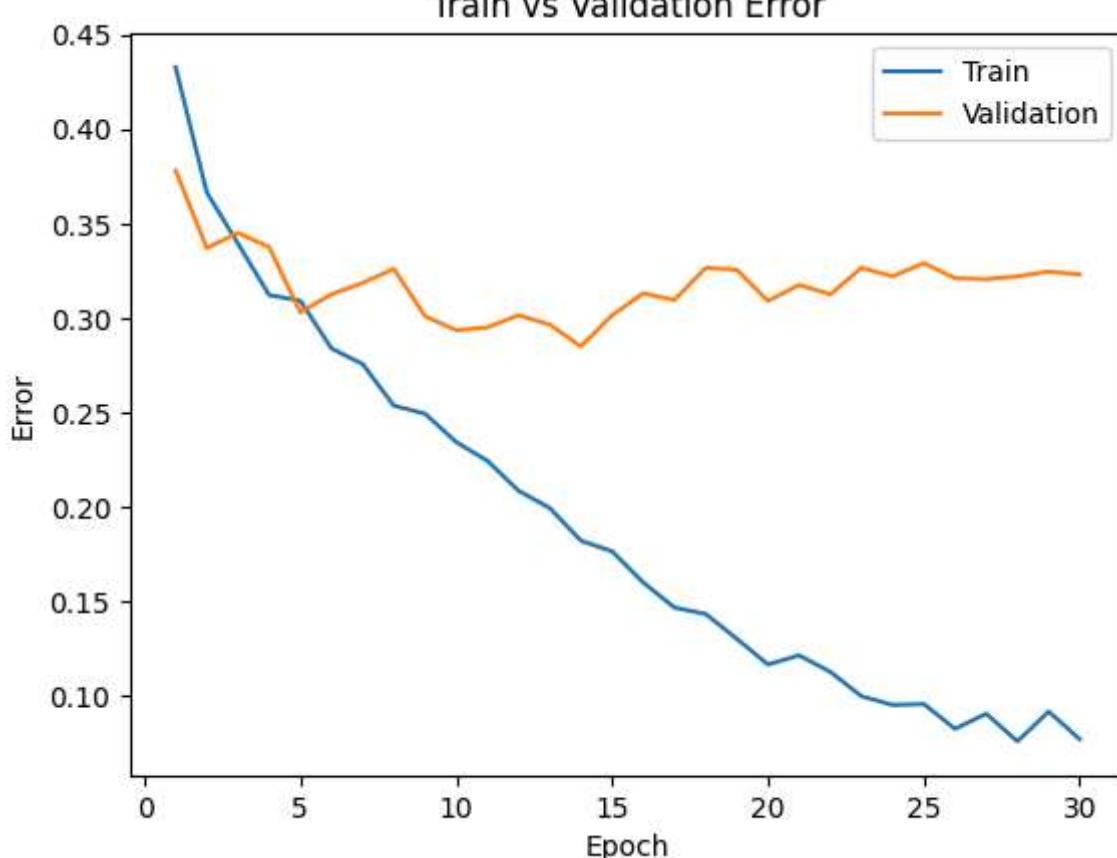
```
large_net = LargeNet()
train_net(large_net, batch_size = 16)

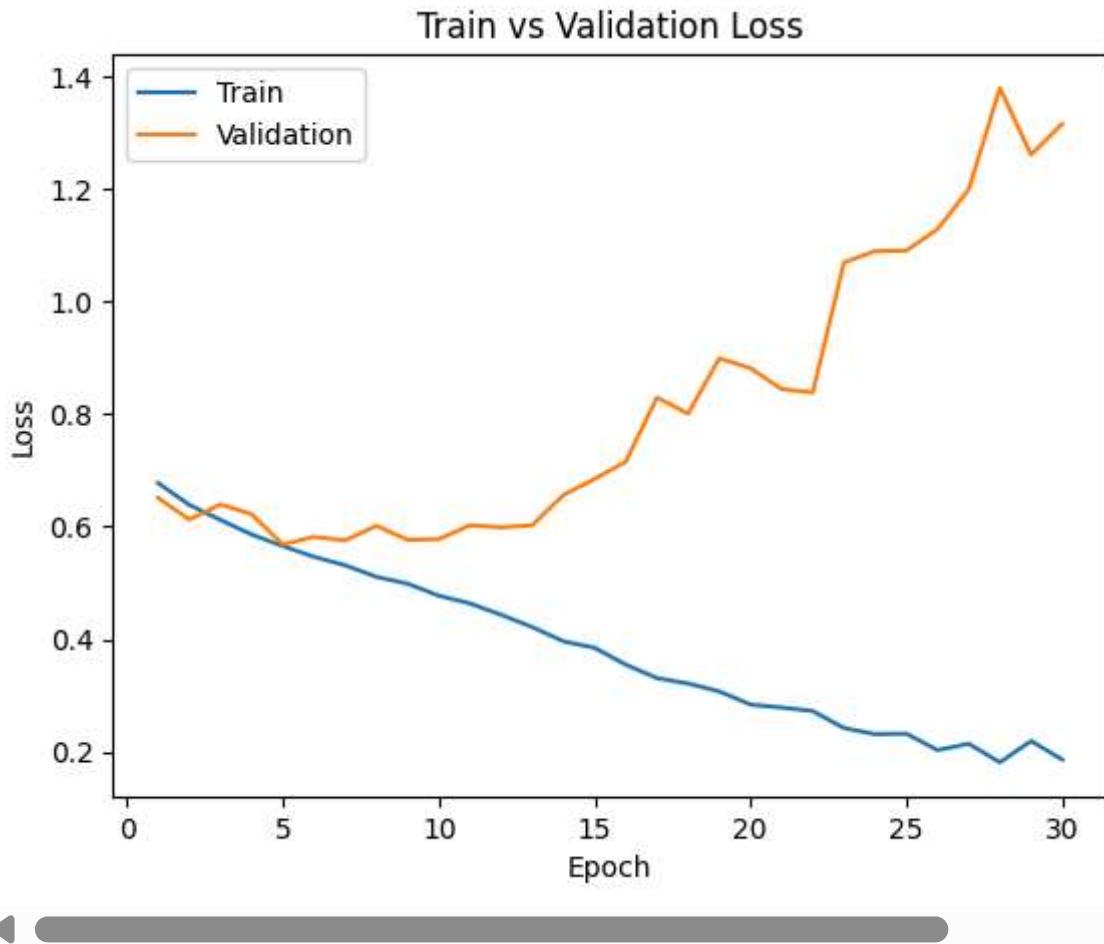
large_model_path = get_model_name("large", batch_size=16, learning_rate=0.01, epoch=29)
plot_training_curve(large_model_path)
#training time rises dramatically
#both curves shows strong overfitting
```

→ Epoch 1: Train err: 0.432625, Train loss: 0.6775506126880646 | Validation err: 0.378, Validation err: 0.378
 Epoch 2: Train err: 0.366375, Train loss: 0.6387728816270828 | Validation err: 0.337, Validation err: 0.337
 Epoch 3: Train err: 0.339375, Train loss: 0.6119522891640663 | Validation err: 0.345, Validation err: 0.345
 Epoch 4: Train err: 0.312125, Train loss: 0.5861616842746734 | Validation err: 0.3375, Validation err: 0.3375
 Epoch 5: Train err: 0.309125, Train loss: 0.5655454085469246 | Validation err: 0.303, Validation err: 0.303
 Epoch 6: Train err: 0.283875, Train loss: 0.546434996843338 | Validation err: 0.3125, Validation err: 0.3125
 Epoch 7: Train err: 0.275625, Train loss: 0.5315411986708641 | Validation err: 0.3185, Validation err: 0.3185
 Epoch 8: Train err: 0.253625, Train loss: 0.5110043309926987 | Validation err: 0.326, Validation err: 0.326
 Epoch 9: Train err: 0.249375, Train loss: 0.4988122125864029 | Validation err: 0.301, Validation err: 0.301
 Epoch 10: Train err: 0.234375, Train loss: 0.47769227081537247 | Validation err: 0.2935, Validation err: 0.2935
 Epoch 11: Train err: 0.2245, Train loss: 0.4637914804518223 | Validation err: 0.295, Validation err: 0.295
 Epoch 12: Train err: 0.208625, Train loss: 0.4436814887523651 | Validation err: 0.3015, Validation err: 0.3015
 Epoch 13: Train err: 0.1995, Train loss: 0.42190410897135733 | Validation err: 0.2965, Validation err: 0.2965
 Epoch 14: Train err: 0.18225, Train loss: 0.3964607211649418 | Validation err: 0.285, Validation err: 0.285
 Epoch 15: Train err: 0.176625, Train loss: 0.38504845155775547 | Validation err: 0.3015, Validation err: 0.3015
 Epoch 16: Train err: 0.160125, Train loss: 0.35515162971615793 | Validation err: 0.313, Validation err: 0.313
 Epoch 17: Train err: 0.146875, Train loss: 0.33127270932495595 | Validation err: 0.3095, Validation err: 0.3095
 Epoch 18: Train err: 0.1435, Train loss: 0.3216609486192465 | Validation err: 0.3265, Validation err: 0.3265
 Epoch 19: Train err: 0.130375, Train loss: 0.30764051334559916 | Validation err: 0.3255, Validation err: 0.3255
 Epoch 20: Train err: 0.11675, Train loss: 0.28437252435833216 | Validation err: 0.309, Validation err: 0.309
 Epoch 21: Train err: 0.121625, Train loss: 0.27901479678601027 | Validation err: 0.3175, Validation err: 0.3175
 Epoch 22: Train err: 0.112875, Train loss: 0.2728129132091999 | Validation err: 0.3125, Validation err: 0.3125
 Epoch 23: Train err: 0.1, Train loss: 0.24255631332099437 | Validation err: 0.3265, Validation err: 0.3265
 Epoch 24: Train err: 0.095375, Train loss: 0.2318725396282971 | Validation err: 0.322, Validation err: 0.322
 Epoch 25: Train err: 0.095875, Train loss: 0.23257503168098628 | Validation err: 0.329, Validation err: 0.329
 Epoch 26: Train err: 0.08275, Train loss: 0.20350570978596808 | Validation err: 0.321, Validation err: 0.321
 Epoch 27: Train err: 0.09075, Train loss: 0.2147584371343255 | Validation err: 0.3205, Validation err: 0.3205
 Epoch 28: Train err: 0.076125, Train loss: 0.18171320636058227 | Validation err: 0.322, Validation err: 0.322
 Epoch 29: Train err: 0.091875, Train loss: 0.21968170262500644 | Validation err: 0.3245, Validation err: 0.3245
 Epoch 30: Train err: 0.07725, Train loss: 0.1865569370612502 | Validation err: 0.323, Validation err: 0.323

Finished Training

Total time elapsed: 234.92 seconds





▼ Part 4. Hyperparameter Search [6 pt]

Part (a) - 2pt

Based on the plots from above, choose another set of values for the hyperparameters (network, batch_size, learning_rate) that you think would help you improve the validation accuracy. Justify your choice.

```
#batch_size=512, learning_rate=0.01, epoch=250 is my choice for the values
#in previous experiment I have had a very accurate model trained by batch_size=512,
#with more epochs i believe the model's validation curve will better converge with th
```

▼ Part (b) - 1pt

Train the model with the hyperparameters you chose in part(a), and include the training curve.

```
large_net = LargeNet()
train_net(large_net, learning_rate = 0.001, batch_size = 512, num_epochs = 250)

large_model_path = get_model_name("large", batch_size=512, learning_rate=0.001, epoch=249)
plot_training_curve(large_model_path)
```

→ Epoch 1: Train err: 0.50225, Train loss: 0.698290154337883 | Validation err: 0.491, Validation
Epoch 2: Train err: 0.50225, Train loss: 0.6980444379150867 | Validation err: 0.491, Validation
Epoch 3: Train err: 0.50225, Train loss: 0.6973877809941769 | Validation err: 0.491, Validation
Epoch 4: Train err: 0.50225, Train loss: 0.6968365274369717 | Validation err: 0.491, Validation
Epoch 5: Train err: 0.50225, Train loss: 0.6965651772916317 | Validation err: 0.491, Validation
Epoch 6: Train err: 0.50225, Train loss: 0.6961115747690201 | Validation err: 0.491, Validation
Epoch 7: Train err: 0.50225, Train loss: 0.6958715505897999 | Validation err: 0.491, Validation
Epoch 8: Train err: 0.50225, Train loss: 0.6955749802291393 | Validation err: 0.491, Validation
Epoch 9: Train err: 0.50225, Train loss: 0.6953236423432827 | Validation err: 0.491, Validation
Epoch 10: Train err: 0.50225, Train loss: 0.6950523816049099 | Validation err: 0.491, Validation
Epoch 11: Train err: 0.50225, Train loss: 0.6948387883603573 | Validation err: 0.491, Validation
Epoch 12: Train err: 0.50225, Train loss: 0.6946097984910011 | Validation err: 0.491, Validation
Epoch 13: Train err: 0.50225, Train loss: 0.6944721825420856 | Validation err: 0.491, Validation
Epoch 14: Train err: 0.50225, Train loss: 0.6942431814968586 | Validation err: 0.491, Validation
Epoch 15: Train err: 0.50225, Train loss: 0.6941495090723038 | Validation err: 0.491, Validation
Epoch 16: Train err: 0.50225, Train loss: 0.6940405629575253 | Validation err: 0.491, Validation
Epoch 17: Train err: 0.50225, Train loss: 0.6938863657414913 | Validation err: 0.491, Validation
Epoch 18: Train err: 0.50225, Train loss: 0.693740002810955 | Validation err: 0.491, Validation
Epoch 19: Train err: 0.50225, Train loss: 0.6937023475766182 | Validation err: 0.491, Validation
Epoch 20: Train err: 0.50225, Train loss: 0.6934427060186863 | Validation err: 0.491, Validation
Epoch 21: Train err: 0.50225, Train loss: 0.6933713145554066 | Validation err: 0.491, Validation
Epoch 22: Train err: 0.50225, Train loss: 0.6933578103780746 | Validation err: 0.491, Validation
Epoch 23: Train err: 0.50225, Train loss: 0.6931737400591373 | Validation err: 0.491, Validation
Epoch 24: Train err: 0.50225, Train loss: 0.693133220076561 | Validation err: 0.491, Validation
Epoch 25: Train err: 0.50225, Train loss: 0.6930863596498966 | Validation err: 0.491, Validation
Epoch 26: Train err: 0.50225, Train loss: 0.6930284649133682 | Validation err: 0.491, Validation
Epoch 27: Train err: 0.50225, Train loss: 0.6929538138210773 | Validation err: 0.491, Validation
Epoch 28: Train err: 0.50225, Train loss: 0.6929404400289059 | Validation err: 0.491, Validation
Epoch 29: Train err: 0.50225, Train loss: 0.6927376985549927 | Validation err: 0.491, Validation
Epoch 30: Train err: 0.50225, Train loss: 0.6927704997360706 | Validation err: 0.4905, Validation
Epoch 31: Train err: 0.501875, Train loss: 0.6927165351808071 | Validation err: 0.491, Validation
Epoch 32: Train err: 0.502125, Train loss: 0.6926471330225468 | Validation err: 0.49, Validation
Epoch 33: Train err: 0.502125, Train loss: 0.6926267221570015 | Validation err: 0.4905, Validation
Epoch 34: Train err: 0.502375, Train loss: 0.692517850548029 | Validation err: 0.489, Validation
Epoch 35: Train err: 0.50275, Train loss: 0.6924483142793179 | Validation err: 0.4885, Validation
Epoch 36: Train err: 0.50125, Train loss: 0.6924326568841934 | Validation err: 0.4905, Validation
Epoch 37: Train err: 0.50125, Train loss: 0.6923932172358036 | Validation err: 0.4905, Validation
Epoch 38: Train err: 0.5015, Train loss: 0.692352756857872 | Validation err: 0.49, Validation
Epoch 39: Train err: 0.501375, Train loss: 0.6922562047839165 | Validation err: 0.4895, Validation
Epoch 40: Train err: 0.499, Train loss: 0.6922726333141327 | Validation err: 0.488, Validation
Epoch 41: Train err: 0.498375, Train loss: 0.6922004781663418 | Validation err: 0.484, Validation
Epoch 42: Train err: 0.497625, Train loss: 0.6921293698251247 | Validation err: 0.4855, Validation
Epoch 43: Train err: 0.4975, Train loss: 0.6921013966202736 | Validation err: 0.487, Validation
Epoch 44: Train err: 0.497375, Train loss: 0.6920524127781391 | Validation err: 0.49, Validation
Epoch 45: Train err: 0.494375, Train loss: 0.6919716633856297 | Validation err: 0.489, Validation
Epoch 46: Train err: 0.491875, Train loss: 0.691938366740942 | Validation err: 0.4885, Validation
Epoch 47: Train err: 0.489875, Train loss: 0.6919077709317207 | Validation err: 0.4865, Validation
Epoch 48: Train err: 0.489375, Train loss: 0.6918540857732296 | Validation err: 0.481, Validation
Epoch 49: Train err: 0.4865, Train loss: 0.6918108202517033 | Validation err: 0.4715, Validation
Epoch 50: Train err: 0.4845, Train loss: 0.691774807870388 | Validation err: 0.4685, Validation
Epoch 51: Train err: 0.47825, Train loss: 0.691689308732748 | Validation err: 0.4635, Validation
Epoch 52: Train err: 0.476375, Train loss: 0.6916241347789764 | Validation err: 0.4645, Validation
Epoch 53: Train err: 0.47425, Train loss: 0.6915764957666397 | Validation err: 0.46, Validation
Epoch 54: Train err: 0.4735, Train loss: 0.6915385723114014 | Validation err: 0.4575, Validation
Epoch 55: Train err: 0.46825, Train loss: 0.6914584040641785 | Validation err: 0.4575, Validation
Epoch 56: Train err: 0.465875, Train loss: 0.6913480497896671 | Validation err: 0.457, Validation
Epoch 57: Train err: 0.46375, Train loss: 0.6913041174411774 | Validation err: 0.454, Validation

Epoch 58: Train err: 0.4635, Train loss: 0.6912516988813877 |Validation err: 0.453, Validation
Epoch 59: Train err: 0.4615, Train loss: 0.6911974363029003 |Validation err: 0.451, Validation
Epoch 60: Train err: 0.459, Train loss: 0.6911333799362183 |Validation err: 0.452, Validation
Epoch 61: Train err: 0.458, Train loss: 0.691069595515728 |Validation err: 0.451, Validation
Epoch 62: Train err: 0.45625, Train loss: 0.6910092160105705 |Validation err: 0.4495, Validation
Epoch 63: Train err: 0.45425, Train loss: 0.6908956952393055 |Validation err: 0.4465, Validation
Epoch 64: Train err: 0.451, Train loss: 0.6907807476818562 |Validation err: 0.4435, Validation
Epoch 65: Train err: 0.451125, Train loss: 0.6907723248004913 |Validation err: 0.4435, Validation
Epoch 66: Train err: 0.45125, Train loss: 0.6906548552215099 |Validation err: 0.4435, Validation
Epoch 67: Train err: 0.451, Train loss: 0.6905685998499393 |Validation err: 0.4425, Validation
Epoch 68: Train err: 0.450875, Train loss: 0.6904731467366219 |Validation err: 0.443, Validation
Epoch 69: Train err: 0.450875, Train loss: 0.6904114447534084 |Validation err: 0.4425, Validation
Epoch 70: Train err: 0.4495, Train loss: 0.690271619707346 |Validation err: 0.443, Validation
Epoch 71: Train err: 0.44875, Train loss: 0.6902096681296825 |Validation err: 0.443, Validation
Epoch 72: Train err: 0.448375, Train loss: 0.6901385821402073 |Validation err: 0.4435, Validation
Epoch 73: Train err: 0.446875, Train loss: 0.6899803839623928 |Validation err: 0.4395, Validation
Epoch 74: Train err: 0.446375, Train loss: 0.6898760721087456 |Validation err: 0.4395, Validation
Epoch 75: Train err: 0.44525, Train loss: 0.6898101195693016 |Validation err: 0.4395, Validation
Epoch 76: Train err: 0.44425, Train loss: 0.6897109821438789 |Validation err: 0.439, Validation
Epoch 77: Train err: 0.444125, Train loss: 0.6895262524485588 |Validation err: 0.4385, Validation
Epoch 78: Train err: 0.44275, Train loss: 0.6893842965364456 |Validation err: 0.4365, Validation
Epoch 79: Train err: 0.442375, Train loss: 0.6893207915127277 |Validation err: 0.438, Validation
Epoch 80: Train err: 0.441375, Train loss: 0.6892030499875546 |Validation err: 0.436, Validation
Epoch 81: Train err: 0.44, Train loss: 0.6891293376684189 |Validation err: 0.435, Validation
Epoch 82: Train err: 0.43975, Train loss: 0.6889489628374577 |Validation err: 0.435, Validation
Epoch 83: Train err: 0.4395, Train loss: 0.6887881420552731 |Validation err: 0.4335, Validation
Epoch 84: Train err: 0.43875, Train loss: 0.6887693852186203 |Validation err: 0.4295, Validation
Epoch 85: Train err: 0.43875, Train loss: 0.6885324046015739 |Validation err: 0.432, Validation
Epoch 86: Train err: 0.439875, Train loss: 0.6884157434105873 |Validation err: 0.43, Validation
Epoch 87: Train err: 0.44025, Train loss: 0.6882783211767673 |Validation err: 0.4315, Validation
Epoch 88: Train err: 0.440875, Train loss: 0.6881378516554832 |Validation err: 0.429, Validation
Epoch 89: Train err: 0.440625, Train loss: 0.6879705302417278 |Validation err: 0.4285, Validation
Epoch 90: Train err: 0.44025, Train loss: 0.6879061684012413 |Validation err: 0.429, Validation
Epoch 91: Train err: 0.441125, Train loss: 0.6876867301762104 |Validation err: 0.431, Validation
Epoch 92: Train err: 0.439375, Train loss: 0.6875643357634544 |Validation err: 0.43, Validation
Epoch 93: Train err: 0.438625, Train loss: 0.6874140352010727 |Validation err: 0.4305, Validation
Epoch 94: Train err: 0.439125, Train loss: 0.6872683428227901 |Validation err: 0.428, Validation
Epoch 95: Train err: 0.43775, Train loss: 0.6869603432714939 |Validation err: 0.428, Validation
Epoch 96: Train err: 0.438, Train loss: 0.6868408545851707 |Validation err: 0.4235, Validation
Epoch 97: Train err: 0.437, Train loss: 0.6867021434009075 |Validation err: 0.424, Validation
Epoch 98: Train err: 0.43525, Train loss: 0.6864878386259079 |Validation err: 0.426, Validation
Epoch 99: Train err: 0.43425, Train loss: 0.6862261742353439 |Validation err: 0.4295, Validation
Epoch 100: Train err: 0.433625, Train loss: 0.6859752796590328 |Validation err: 0.426, Validation
Epoch 101: Train err: 0.433375, Train loss: 0.6859318539500237 |Validation err: 0.4265, Validation
Epoch 102: Train err: 0.43275, Train loss: 0.6858279407024384 |Validation err: 0.4255, Validation
Epoch 103: Train err: 0.43175, Train loss: 0.6854898296296597 |Validation err: 0.427, Validation
Epoch 104: Train err: 0.431, Train loss: 0.6854209750890732 |Validation err: 0.426, Validation
Epoch 105: Train err: 0.43075, Train loss: 0.6850389763712883 |Validation err: 0.4275, Validation
Epoch 106: Train err: 0.430125, Train loss: 0.6848915591835976 |Validation err: 0.4275, Validation
Epoch 107: Train err: 0.429125, Train loss: 0.6846668720245361 |Validation err: 0.426, Validation
Epoch 108: Train err: 0.4285, Train loss: 0.6845787428319454 |Validation err: 0.4275, Validation
Epoch 109: Train err: 0.427625, Train loss: 0.6843147464096546 |Validation err: 0.4325, Validation
Epoch 110: Train err: 0.4285, Train loss: 0.6840976476669312 |Validation err: 0.433, Validation
Epoch 111: Train err: 0.4265, Train loss: 0.6839183829724789 |Validation err: 0.433, Validation
Epoch 112: Train err: 0.426375, Train loss: 0.6837382651865482 |Validation err: 0.432, Validation
Epoch 113: Train err: 0.42625, Train loss: 0.6835769787430763 |Validation err: 0.4305, Validation
Epoch 114: Train err: 0.427, Train loss: 0.6833357140421867 |Validation err: 0.4295, Validation

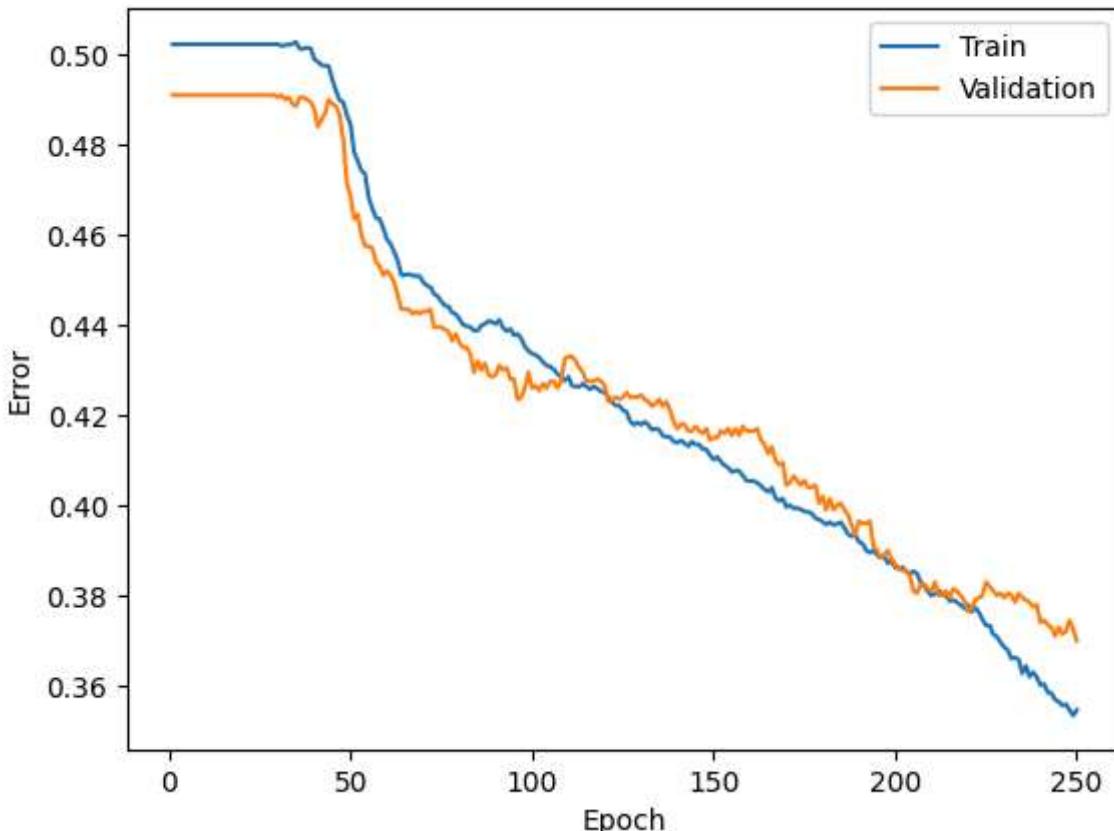
Epoch 115: Train err: 0.42625, Train loss: 0.6831247769296169 | Validation err: 0.4275, Valid
Epoch 116: Train err: 0.42575, Train loss: 0.6829617880284786 | Validation err: 0.4275, Valid
Epoch 117: Train err: 0.426375, Train loss: 0.6827082522213459 | Validation err: 0.4275, Valid
Epoch 118: Train err: 0.425875, Train loss: 0.6822623498737812 | Validation err: 0.428, Valid
Epoch 119: Train err: 0.42525, Train loss: 0.6822200417518616 | Validation err: 0.4275, Valid
Epoch 120: Train err: 0.425, Train loss: 0.6821568608283997 | Validation err: 0.4265, Validat
Epoch 121: Train err: 0.424, Train loss: 0.6818586513400078 | Validation err: 0.423, Validatio
Epoch 122: Train err: 0.422875, Train loss: 0.6814547292888165 | Validation err: 0.4235, Valid
Epoch 123: Train err: 0.422125, Train loss: 0.6812739409506321 | Validation err: 0.424, Valida
Epoch 124: Train err: 0.422125, Train loss: 0.6810129731893539 | Validation err: 0.4235, Valid
Epoch 125: Train err: 0.421125, Train loss: 0.681090522557497 | Validation err: 0.424, Validat
Epoch 126: Train err: 0.42075, Train loss: 0.6806126125156879 | Validation err: 0.425, Validat
Epoch 127: Train err: 0.418625, Train loss: 0.6803777553141117 | Validation err: 0.424, Valida
Epoch 128: Train err: 0.417875, Train loss: 0.6798653975129128 | Validation err: 0.424, Valida
Epoch 129: Train err: 0.418375, Train loss: 0.6800795942544937 | Validation err: 0.424, Valida
Epoch 130: Train err: 0.417875, Train loss: 0.6796404123306274 | Validation err: 0.4245, Valid
Epoch 131: Train err: 0.4185, Train loss: 0.6793820075690746 | Validation err: 0.4235, Validat
Epoch 132: Train err: 0.417875, Train loss: 0.6788035184144974 | Validation err: 0.423, Valida
Epoch 133: Train err: 0.41675, Train loss: 0.6788958124816418 | Validation err: 0.422, Validat
Epoch 134: Train err: 0.417, Train loss: 0.6788514703512192 | Validation err: 0.4225, Validati
Epoch 135: Train err: 0.41675, Train loss: 0.6785106956958771 | Validation err: 0.4235, Valida
Epoch 136: Train err: 0.415375, Train loss: 0.6780531741678715 | Validation err: 0.422, Valida
Epoch 137: Train err: 0.41525, Train loss: 0.6774558387696743 | Validation err: 0.423, Validat
Epoch 138: Train err: 0.415125, Train loss: 0.6775523014366627 | Validation err: 0.421, Valida
Epoch 139: Train err: 0.414125, Train loss: 0.6774037070572376 | Validation err: 0.4185, Valid
Epoch 140: Train err: 0.413875, Train loss: 0.6769287809729576 | Validation err: 0.417, Valida
Epoch 141: Train err: 0.414375, Train loss: 0.6769265718758106 | Validation err: 0.418, Valida
Epoch 142: Train err: 0.41375, Train loss: 0.6769260354340076 | Validation err: 0.418, Validat
Epoch 143: Train err: 0.413125, Train loss: 0.676311656832695 | Validation err: 0.4165, Valida
Epoch 144: Train err: 0.414125, Train loss: 0.6760248653590679 | Validation err: 0.4165, Valid
Epoch 145: Train err: 0.4135, Train loss: 0.6760486625134945 | Validation err: 0.4175, Validat
Epoch 146: Train err: 0.4135, Train loss: 0.6758556850254536 | Validation err: 0.4165, Validat
Epoch 147: Train err: 0.4125, Train loss: 0.6752926893532276 | Validation err: 0.416, Validati
Epoch 148: Train err: 0.412375, Train loss: 0.6752768084406853 | Validation err: 0.417, Valida
Epoch 149: Train err: 0.411125, Train loss: 0.6748474948108196 | Validation err: 0.4145, Valid
Epoch 150: Train err: 0.410125, Train loss: 0.674592737108469 | Validation err: 0.415, Validat
Epoch 151: Train err: 0.41075, Train loss: 0.6743983775377274 | Validation err: 0.415, Validat
Epoch 152: Train err: 0.409625, Train loss: 0.674621719866991 | Validation err: 0.4165, Valida
Epoch 153: Train err: 0.408875, Train loss: 0.6738752126693726 | Validation err: 0.416, Valida
Epoch 154: Train err: 0.408375, Train loss: 0.6740263514220715 | Validation err: 0.417, Valida
Epoch 155: Train err: 0.407375, Train loss: 0.6732626631855965 | Validation err: 0.4155, Valid
Epoch 156: Train err: 0.40775, Train loss: 0.6734573356807232 | Validation err: 0.417, Validat
Epoch 157: Train err: 0.407625, Train loss: 0.6731908433139324 | Validation err: 0.4155, Valid
Epoch 158: Train err: 0.406625, Train loss: 0.6728682890534401 | Validation err: 0.4175, Valid
Epoch 159: Train err: 0.4055, Train loss: 0.672398030757904 | Validation err: 0.4165, Validati
Epoch 160: Train err: 0.405375, Train loss: 0.6722427606582642 | Validation err: 0.4165, Valid
Epoch 161: Train err: 0.405375, Train loss: 0.6721532791852951 | Validation err: 0.4165, Valid
Epoch 162: Train err: 0.405, Train loss: 0.671680323779583 | Validation err: 0.417, Validation
Epoch 163: Train err: 0.404375, Train loss: 0.6717434674501419 | Validation err: 0.4145, Valid
Epoch 164: Train err: 0.4035, Train loss: 0.6711985394358635 | Validation err: 0.4135, Validat
Epoch 165: Train err: 0.403, Train loss: 0.6710612066090107 | Validation err: 0.4115, Validati
Epoch 166: Train err: 0.403875, Train loss: 0.670953132212162 | Validation err: 0.413, Validat
Epoch 167: Train err: 0.401625, Train loss: 0.6707108914852142 | Validation err: 0.41, Validat
Epoch 168: Train err: 0.401, Train loss: 0.6701187565922737 | Validation err: 0.409, Validatio
Epoch 169: Train err: 0.4015, Train loss: 0.6701310724020004 | Validation err: 0.4095, Validat
Epoch 170: Train err: 0.399625, Train loss: 0.6702108755707741 | Validation err: 0.4045, Valid
Epoch 171: Train err: 0.4, Train loss: 0.6692166104912758 | Validation err: 0.405, Validation

Epoch 172: Train err: 0.399375, Train loss: 0.6696814969182014 | Validation err: 0.4065, Valid
Epoch 173: Train err: 0.399375, Train loss: 0.6690190173685551 | Validation err: 0.4055, Valid
Epoch 174: Train err: 0.399125, Train loss: 0.6689683571457863 | Validation err: 0.4045, Valid
Epoch 175: Train err: 0.398625, Train loss: 0.6683703102171421 | Validation err: 0.4055, Valid
Epoch 176: Train err: 0.3985, Train loss: 0.6686944849789143 | Validation err: 0.404, Validat
Epoch 177: Train err: 0.39825, Train loss: 0.6680311895906925 | Validation err: 0.404, Validat
Epoch 178: Train err: 0.397125, Train loss: 0.6680101826786995 | Validation err: 0.4045, Valid
Epoch 179: Train err: 0.396875, Train loss: 0.6673444658517838 | Validation err: 0.4005, Valid
Epoch 180: Train err: 0.396375, Train loss: 0.6671875305473804 | Validation err: 0.402, Valida
Epoch 181: Train err: 0.39575, Train loss: 0.6668592430651188 | Validation err: 0.399, Validat
Epoch 182: Train err: 0.39625, Train loss: 0.6667554751038551 | Validation err: 0.4015, Valida
Epoch 183: Train err: 0.395625, Train loss: 0.666238509118557 | Validation err: 0.399, Validat
Epoch 184: Train err: 0.395875, Train loss: 0.666042897850275 | Validation err: 0.4, Validatio
Epoch 185: Train err: 0.39625, Train loss: 0.6658913791179657 | Validation err: 0.4005, Valida
Epoch 186: Train err: 0.395, Train loss: 0.6652063801884651 | Validation err: 0.399, Validatio
Epoch 187: Train err: 0.393625, Train loss: 0.6652758754789829 | Validation err: 0.398, Valida
Epoch 188: Train err: 0.393125, Train loss: 0.6646714471280575 | Validation err: 0.3955, Valid
Epoch 189: Train err: 0.3935, Train loss: 0.6644265912473202 | Validation err: 0.3935, Validat
Epoch 190: Train err: 0.391875, Train loss: 0.663988932967186 | Validation err: 0.3965, Valida
Epoch 191: Train err: 0.3915, Train loss: 0.6634934432804585 | Validation err: 0.396, Validati
Epoch 192: Train err: 0.39, Train loss: 0.6637302152812481 | Validation err: 0.396, Validation
Epoch 193: Train err: 0.3895, Train loss: 0.6632988341152668 | Validation err: 0.3965, Validat
Epoch 194: Train err: 0.39, Train loss: 0.6626794449985027 | Validation err: 0.391, Validation
Epoch 195: Train err: 0.389, Train loss: 0.6625355631113052 | Validation err: 0.39, Validation
Epoch 196: Train err: 0.388375, Train loss: 0.6623081639409065 | Validation err: 0.3885, Valid
Epoch 197: Train err: 0.388625, Train loss: 0.6617651097476482 | Validation err: 0.389, Valida
Epoch 198: Train err: 0.387125, Train loss: 0.6618906445801258 | Validation err: 0.39, Validat
Epoch 199: Train err: 0.38775, Train loss: 0.6610449180006981 | Validation err: 0.388, Validat
Epoch 200: Train err: 0.38625, Train loss: 0.660665974020958 | Validation err: 0.387, Validati
Epoch 201: Train err: 0.385875, Train loss: 0.6603636108338833 | Validation err: 0.386, Valida
Epoch 202: Train err: 0.38625, Train loss: 0.6603124067187309 | Validation err: 0.3855, Valida
Epoch 203: Train err: 0.385375, Train loss: 0.6596798337996006 | Validation err: 0.3855, Valid
Epoch 204: Train err: 0.38475, Train loss: 0.6591892838478088 | Validation err: 0.3845, Valida
Epoch 205: Train err: 0.385375, Train loss: 0.6584707647562027 | Validation err: 0.381, Valida
Epoch 206: Train err: 0.384875, Train loss: 0.6585443504154682 | Validation err: 0.3805, Valid
Epoch 207: Train err: 0.383, Train loss: 0.6583152338862419 | Validation err: 0.3825, Validati
Epoch 208: Train err: 0.382125, Train loss: 0.6579129062592983 | Validation err: 0.3825, Valid
Epoch 209: Train err: 0.380875, Train loss: 0.6575291529297829 | Validation err: 0.3815, Valid
Epoch 210: Train err: 0.38, Train loss: 0.6569670736789703 | Validation err: 0.381, Validation
Epoch 211: Train err: 0.380375, Train loss: 0.656775139272213 | Validation err: 0.383, Validat
Epoch 212: Train err: 0.381125, Train loss: 0.6561669483780861 | Validation err: 0.38, Validat
Epoch 213: Train err: 0.38025, Train loss: 0.6553859040141106 | Validation err: 0.38, Validati
Epoch 214: Train err: 0.38, Train loss: 0.6555120386183262 | Validation err: 0.381, Validation
Epoch 215: Train err: 0.37875, Train loss: 0.6547445878386497 | Validation err: 0.3795, Valida
Epoch 216: Train err: 0.379, Train loss: 0.6549338884651661 | Validation err: 0.3815, Validati
Epoch 217: Train err: 0.3785, Train loss: 0.6544315442442894 | Validation err: 0.381, Validati
Epoch 218: Train err: 0.377875, Train loss: 0.6541090086102486 | Validation err: 0.38, Validat
Epoch 219: Train err: 0.377125, Train loss: 0.6533598639070988 | Validation err: 0.379, Valida
Epoch 220: Train err: 0.378, Train loss: 0.6529603116214275 | Validation err: 0.3765, Validati
Epoch 221: Train err: 0.376375, Train loss: 0.6521702632308006 | Validation err: 0.377, Valida
Epoch 222: Train err: 0.377375, Train loss: 0.6515114493668079 | Validation err: 0.379, Valida
Epoch 223: Train err: 0.37625, Train loss: 0.6513495072722435 | Validation err: 0.3795, Valida
Epoch 224: Train err: 0.37475, Train loss: 0.6512218005955219 | Validation err: 0.38, Validati
Epoch 225: Train err: 0.373375, Train loss: 0.6506509892642498 | Validation err: 0.383, Valida
Epoch 226: Train err: 0.373375, Train loss: 0.6503968313336372 | Validation err: 0.382, Valida
Epoch 227: Train err: 0.371375, Train loss: 0.6499735563993454 | Validation err: 0.381, Valida
Epoch 228: Train err: 0.370875, Train loss: 0.6490920148789883 | Validation err: 0.38, Validat

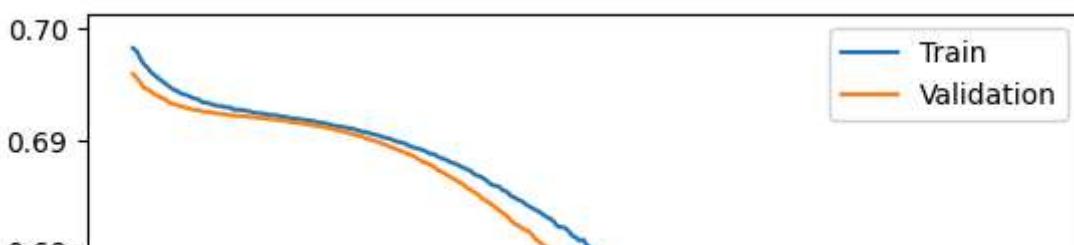
Epoch 229: Train err: 0.369625, Train loss: 0.6486128680408001 | Validation err: 0.3805, Valid
Epoch 230: Train err: 0.368625, Train loss: 0.6485816687345505 | Validation err: 0.3795, Valid
Epoch 231: Train err: 0.367875, Train loss: 0.6477894000709057 | Validation err: 0.3805, Valid
Epoch 232: Train err: 0.366, Train loss: 0.6471790447831154 | Validation err: 0.38, Validation
Epoch 233: Train err: 0.36625, Train loss: 0.6470924094319344 | Validation err: 0.3785, Valida
Epoch 234: Train err: 0.36575, Train loss: 0.6461694575846195 | Validation err: 0.3805, Valida
Epoch 235: Train err: 0.36275, Train loss: 0.6459952555596828 | Validation err: 0.3795, Valida
Epoch 236: Train err: 0.364375, Train loss: 0.6450754255056381 | Validation err: 0.379, Valida
Epoch 237: Train err: 0.362, Train loss: 0.6445450335741043 | Validation err: 0.3785, Validati
Epoch 238: Train err: 0.363, Train loss: 0.644261933863163 | Validation err: 0.3775, Validatio
Epoch 239: Train err: 0.361875, Train loss: 0.6440604627132416 | Validation err: 0.378, Valida
Epoch 240: Train err: 0.360125, Train loss: 0.6436128877103329 | Validation err: 0.374, Valida
Epoch 241: Train err: 0.360375, Train loss: 0.6429642960429192 | Validation err: 0.3745, Valid
Epoch 242: Train err: 0.3585, Train loss: 0.6420018188655376 | Validation err: 0.3735, Validat
Epoch 243: Train err: 0.358375, Train loss: 0.6412199474871159 | Validation err: 0.373, Valida
Epoch 244: Train err: 0.356875, Train loss: 0.6415268778800964 | Validation err: 0.371, Valida
Epoch 245: Train err: 0.3565, Train loss: 0.6404178850352764 | Validation err: 0.373, Validati
Epoch 246: Train err: 0.355625, Train loss: 0.639883503317833 | Validation err: 0.3715, Valida
Epoch 247: Train err: 0.355875, Train loss: 0.6401352919638157 | Validation err: 0.372, Valida
Epoch 248: Train err: 0.354625, Train loss: 0.6400407999753952 | Validation err: 0.3745, Valid
Epoch 249: Train err: 0.353375, Train loss: 0.6392127051949501 | Validation err: 0.3725, Valid
Epoch 250: Train err: 0.354625, Train loss: 0.637838538736105 | Validation err: 0.37, Validati
Finished Training

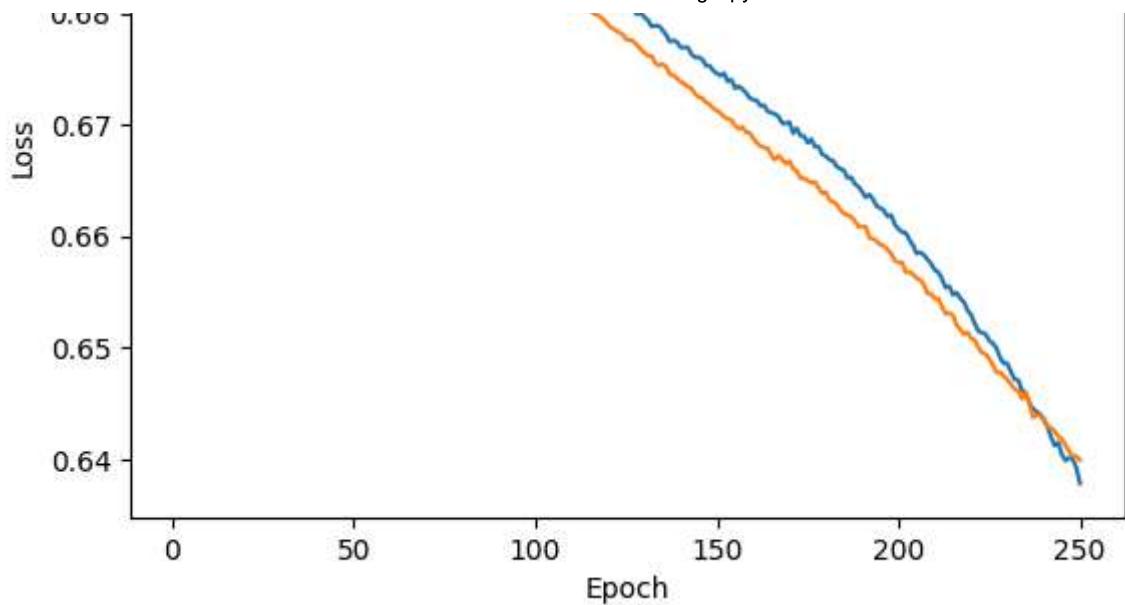
Total time elapsed: 1177.07 seconds

Train vs Validation Error



Train vs Validation Loss





▼ Part (c) - 2pt

Based on your result from Part(a), suggest another set of hyperparameter values to try. Justify your choice.

```
#Training and validation error decrease together and converge at the end, staying very
#train_net(large_net, learning_rate=0.01, batch_size=128, num_epochs=100) is my new model
```

▼ Part (d) - 1pt

Train the model with the hyperparameters you chose in part(c), and include the training curve.

```
large_net = LargeNet()
train_net(large_net, learning_rate=0.01, batch_size=128, num_epochs=100)

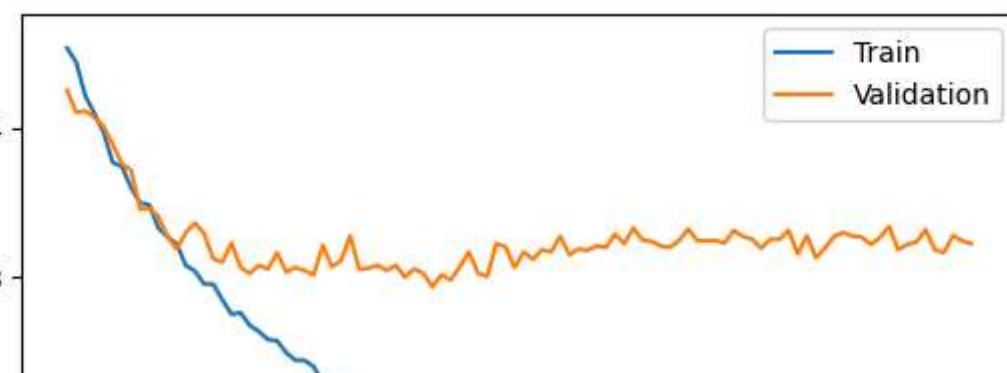
large_model_path = get_model_name("large", batch_size=128, learning_rate=0.01, epoch=99)
plot_training_curve(large_model_path)
```

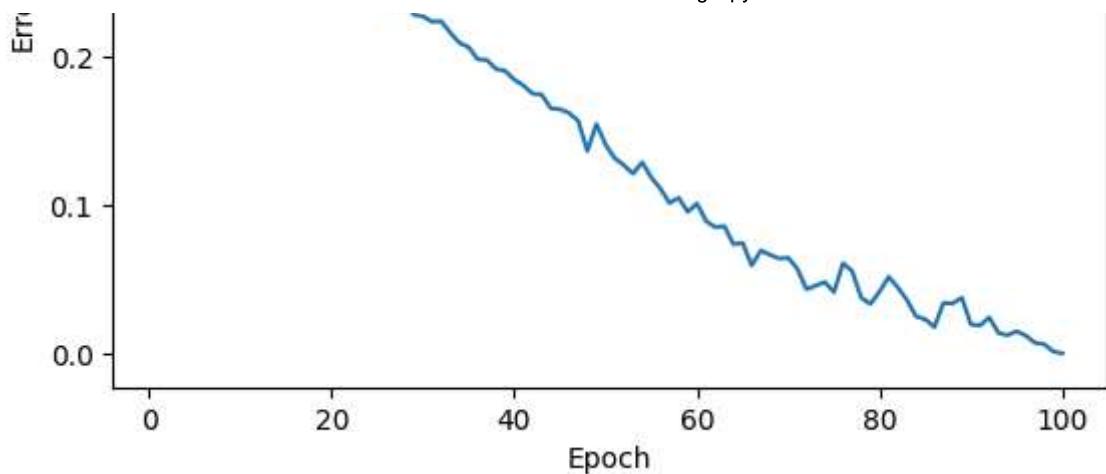
→ Epoch 1: Train err: 0.454375, Train loss: 0.6920222280517457 | Validation err: 0.426, Validation err: 0.426
Epoch 2: Train err: 0.44475, Train loss: 0.6877915528085496 | Validation err: 0.411, Validation err: 0.411
Epoch 3: Train err: 0.422125, Train loss: 0.6812269706574697 | Validation err: 0.412, Validation err: 0.412
Epoch 4: Train err: 0.41025, Train loss: 0.673797849624876 | Validation err: 0.4075, Validation err: 0.4075
Epoch 5: Train err: 0.397375, Train loss: 0.6661591208170331 | Validation err: 0.4015, Validation err: 0.4015
Epoch 6: Train err: 0.377125, Train loss: 0.6567326358386448 | Validation err: 0.3895, Validation err: 0.3895
Epoch 7: Train err: 0.374625, Train loss: 0.6487630000190129 | Validation err: 0.3765, Validation err: 0.3765
Epoch 8: Train err: 0.36025, Train loss: 0.6365784785104176 | Validation err: 0.372, Validation err: 0.372
Epoch 9: Train err: 0.35, Train loss: 0.6283171810801067 | Validation err: 0.346, Validation 1 err: 0.346
Epoch 10: Train err: 0.34875, Train loss: 0.6217929465430123 | Validation err: 0.346, Validation err: 0.346
Epoch 11: Train err: 0.333, Train loss: 0.6105351911650764 | Validation err: 0.341, Validation err: 0.341
Epoch 12: Train err: 0.327125, Train loss: 0.5992055573160686 | Validation err: 0.327, Validation err: 0.327
Epoch 13: Train err: 0.32225, Train loss: 0.5948410185556563 | Validation err: 0.319, Validation err: 0.319
Epoch 14: Train err: 0.307875, Train loss: 0.5794498173017351 | Validation err: 0.33, Validation err: 0.33
Epoch 15: Train err: 0.304125, Train loss: 0.5702668012134613 | Validation err: 0.3365, Validation err: 0.3365
Epoch 16: Train err: 0.295375, Train loss: 0.5657135503632682 | Validation err: 0.3295, Validation err: 0.3295
Epoch 17: Train err: 0.29525, Train loss: 0.5594405839367519 | Validation err: 0.3125, Validation err: 0.3125
Epoch 18: Train err: 0.28475, Train loss: 0.5496182214646113 | Validation err: 0.31, Validation err: 0.31
Epoch 19: Train err: 0.275, Train loss: 0.5384441462774125 | Validation err: 0.323, Validation err: 0.323
Epoch 20: Train err: 0.276, Train loss: 0.5352702755776663 | Validation err: 0.3065, Validation err: 0.3065
Epoch 21: Train err: 0.2675, Train loss: 0.5263815578960237 | Validation err: 0.3025, Validation err: 0.3025
Epoch 22: Train err: 0.263375, Train loss: 0.5202986276338971 | Validation err: 0.308, Validation err: 0.308
Epoch 23: Train err: 0.257875, Train loss: 0.5148504934613667 | Validation err: 0.3055, Validation err: 0.3055
Epoch 24: Train err: 0.257125, Train loss: 0.5102080371644762 | Validation err: 0.3165, Validation err: 0.3165
Epoch 25: Train err: 0.249, Train loss: 0.5024650309767041 | Validation err: 0.3035, Validation err: 0.3035
Epoch 26: Train err: 0.244, Train loss: 0.491200448028625 | Validation err: 0.3065, Validation err: 0.3065
Epoch 27: Train err: 0.243875, Train loss: 0.491646780381127 | Validation err: 0.3045, Validation err: 0.3045
Epoch 28: Train err: 0.23975, Train loss: 0.4839872277918316 | Validation err: 0.3015, Validation err: 0.3015
Epoch 29: Train err: 0.2285, Train loss: 0.4747762259036776 | Validation err: 0.3215, Validation err: 0.3215
Epoch 30: Train err: 0.227375, Train loss: 0.4695242298027826 | Validation err: 0.307, Validation err: 0.307
Epoch 31: Train err: 0.22375, Train loss: 0.4646376111204662 | Validation err: 0.311, Validation err: 0.311
Epoch 32: Train err: 0.224125, Train loss: 0.4583530809198107 | Validation err: 0.328, Validation err: 0.328
Epoch 33: Train err: 0.216375, Train loss: 0.4540846801939465 | Validation err: 0.305, Validation err: 0.305
Epoch 34: Train err: 0.2095, Train loss: 0.44579881240451147 | Validation err: 0.306, Validation err: 0.306
Epoch 35: Train err: 0.206625, Train loss: 0.43534542218087213 | Validation err: 0.308, Validation err: 0.308
Epoch 36: Train err: 0.1985, Train loss: 0.4287943797452109 | Validation err: 0.3045, Validation err: 0.3045
Epoch 37: Train err: 0.198, Train loss: 0.4278318631270575 | Validation err: 0.308, Validation err: 0.308
Epoch 38: Train err: 0.192, Train loss: 0.4219924386531588 | Validation err: 0.3, Validation 1 err: 0.3
Epoch 39: Train err: 0.190625, Train loss: 0.41115644810691715 | Validation err: 0.3055, Validation err: 0.3055
Epoch 40: Train err: 0.18475, Train loss: 0.40179025701114107 | Validation err: 0.3025, Validation err: 0.3025
Epoch 41: Train err: 0.180875, Train loss: 0.39616913218346855 | Validation err: 0.2935, Validation err: 0.2935
Epoch 42: Train err: 0.175375, Train loss: 0.3886040799201481 | Validation err: 0.3015, Validation err: 0.3015
Epoch 43: Train err: 0.17475, Train loss: 0.3827328639371054 | Validation err: 0.298, Validation err: 0.298
Epoch 44: Train err: 0.1655, Train loss: 0.3743141416519407 | Validation err: 0.307, Validation err: 0.307
Epoch 45: Train err: 0.164875, Train loss: 0.3701489671828255 | Validation err: 0.317, Validation err: 0.317
Epoch 46: Train err: 0.162375, Train loss: 0.3609846645877475 | Validation err: 0.3025, Validation err: 0.3025
Epoch 47: Train err: 0.157, Train loss: 0.34919386439853245 | Validation err: 0.3005, Validation err: 0.3005
Epoch 48: Train err: 0.13675, Train loss: 0.32179143528143567 | Validation err: 0.3225, Validation err: 0.3225
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Epoch 50: Train err: 0.141, Train loss: 0.32374571618579684 | Validation err: 0.3065, Validation err: 0.3065
Epoch 51: Train err: 0.131875, Train loss: 0.3099020901653502 | Validation err: 0.317, Validation err: 0.317
Epoch 52: Train err: 0.127125, Train loss: 0.29607867177516695 | Validation err: 0.312, Validation err: 0.312
Epoch 53: Train err: 0.1215, Train loss: 0.285934127985485 | Validation err: 0.3185, Validation err: 0.3185
Epoch 54: Train err: 0.129125, Train loss: 0.2926510510936616 | Validation err: 0.317, Validation err: 0.317
Epoch 55: Train err: 0.119, Train loss: 0.28176522798954495 | Validation err: 0.3275, Validation err: 0.3275
Epoch 56: Train err: 0.111375, Train loss: 0.26578369547450353 | Validation err: 0.315, Validation err: 0.315
Epoch 57: Train err: 0.10175, Train loss: 0.2522066228446506 | Validation err: 0.319, Validation err: 0.319

Epoch 58: Train err: 0.10525, Train loss: 0.24793763529686702 | Validation err: 0.318, Validation loss: 0.24793763529686702
 Epoch 59: Train err: 0.09575, Train loss: 0.23393988088955955 | Validation err: 0.321, Validation loss: 0.23393988088955955
 Epoch 60: Train err: 0.101375, Train loss: 0.24431307850376008 | Validation err: 0.32, Validation loss: 0.24431307850376008
 Epoch 61: Train err: 0.0895, Train loss: 0.21475185241018022 | Validation err: 0.329, Validation loss: 0.21475185241018022
 Epoch 62: Train err: 0.0855, Train loss: 0.2102264686236306 | Validation err: 0.3225, Validation loss: 0.2102264686236306
 Epoch 63: Train err: 0.086125, Train loss: 0.21182349253268468 | Validation err: 0.333, Validation loss: 0.21182349253268468
 Epoch 64: Train err: 0.074, Train loss: 0.18373283318110875 | Validation err: 0.325, Validation loss: 0.18373283318110875
 Epoch 65: Train err: 0.07475, Train loss: 0.18933942157124717 | Validation err: 0.324, Validation loss: 0.18933942157124717
 Epoch 66: Train err: 0.05975, Train loss: 0.15612868598056218 | Validation err: 0.321, Validation loss: 0.15612868598056218
 Epoch 67: Train err: 0.069625, Train loss: 0.1706096622205916 | Validation err: 0.32, Validation loss: 0.1706096622205916
 Epoch 68: Train err: 0.066875, Train loss: 0.1666677121132139 | Validation err: 0.3245, Validation loss: 0.1666677121132139
 Epoch 69: Train err: 0.064375, Train loss: 0.1557555484866339 | Validation err: 0.3325, Validation loss: 0.1557555484866339
 Epoch 70: Train err: 0.064875, Train loss: 0.15661425391832987 | Validation err: 0.3245, Validation loss: 0.15661425391832987
 Epoch 71: Train err: 0.057375, Train loss: 0.14332373523049885 | Validation err: 0.3245, Validation loss: 0.14332373523049885
 Epoch 72: Train err: 0.043625, Train loss: 0.12088379914325381 | Validation err: 0.3245, Validation loss: 0.12088379914325381
 Epoch 73: Train err: 0.046125, Train loss: 0.12047345954037848 | Validation err: 0.323, Validation loss: 0.12047345954037848
 Epoch 74: Train err: 0.0485, Train loss: 0.12394855076831485 | Validation err: 0.3315, Validation loss: 0.12394855076831485
 Epoch 75: Train err: 0.04175, Train loss: 0.11068315821744147 | Validation err: 0.3275, Validation loss: 0.11068315821744147
 Epoch 76: Train err: 0.061125, Train loss: 0.15007815604645108 | Validation err: 0.3255, Validation loss: 0.15007815604645108
 Epoch 77: Train err: 0.05575, Train loss: 0.14061075774213624 | Validation err: 0.3195, Validation loss: 0.14061075774213624
 Epoch 78: Train err: 0.03775, Train loss: 0.09921304420346305 | Validation err: 0.3255, Validation loss: 0.09921304420346305
 Epoch 79: Train err: 0.033875, Train loss: 0.09616861486482242 | Validation err: 0.3255, Validation loss: 0.09616861486482242
 Epoch 80: Train err: 0.042125, Train loss: 0.10581891309647333 | Validation err: 0.3315, Validation loss: 0.10581891309647333
 Epoch 81: Train err: 0.052, Train loss: 0.13056028202649148 | Validation err: 0.3155, Validation loss: 0.13056028202649148
 Epoch 82: Train err: 0.044875, Train loss: 0.11352357244680798 | Validation err: 0.328, Validation loss: 0.11352357244680798
 Epoch 83: Train err: 0.036375, Train loss: 0.09272136042515437 | Validation err: 0.313, Validation loss: 0.09272136042515437
 Epoch 84: Train err: 0.025375, Train loss: 0.07087379779725794 | Validation err: 0.3195, Validation loss: 0.07087379779725794
 Epoch 85: Train err: 0.023375, Train loss: 0.06728413848886414 | Validation err: 0.3275, Validation loss: 0.06728413848886414
 Epoch 86: Train err: 0.01825, Train loss: 0.05525025082308622 | Validation err: 0.33, Validation loss: 0.05525025082308622
 Epoch 87: Train err: 0.034375, Train loss: 0.08540828857156965 | Validation err: 0.3275, Validation loss: 0.08540828857156965
 Epoch 88: Train err: 0.034125, Train loss: 0.08777343005769783 | Validation err: 0.327, Validation loss: 0.08777343005769783
 Epoch 89: Train err: 0.038, Train loss: 0.09469641691872052 | Validation err: 0.322, Validation loss: 0.09469641691872052
 Epoch 90: Train err: 0.02, Train loss: 0.05649069344831838 | Validation err: 0.3265, Validation loss: 0.05649069344831838
 Epoch 91: Train err: 0.01925, Train loss: 0.05284761108221516 | Validation err: 0.334, Validation loss: 0.05284761108221516
 Epoch 92: Train err: 0.02475, Train loss: 0.06821405027239096 | Validation err: 0.3185, Validation loss: 0.06821405027239096
 Epoch 93: Train err: 0.01425, Train loss: 0.043200460277379504 | Validation err: 0.322, Validation loss: 0.043200460277379504
 Epoch 94: Train err: 0.01275, Train loss: 0.041889068729702446 | Validation err: 0.3235, Validation loss: 0.041889068729702446
 Epoch 95: Train err: 0.015375, Train loss: 0.046408548189829736 | Validation err: 0.332, Validation loss: 0.046408548189829736
 Epoch 96: Train err: 0.0125, Train loss: 0.03945784162848242 | Validation err: 0.3185, Validation loss: 0.03945784162848242
 Epoch 97: Train err: 0.007625, Train loss: 0.030387550755034364 | Validation err: 0.3165, Validation loss: 0.030387550755034364
 Epoch 98: Train err: 0.00675, Train loss: 0.02818753711494898 | Validation err: 0.328, Validation loss: 0.02818753711494898
 Epoch 99: Train err: 0.001875, Train loss: 0.014123969615274479 | Validation err: 0.3245, Validation loss: 0.014123969615274479
 Epoch 100: Train err: 0.0005, Train loss: 0.009830561647605564 | Validation err: 0.3225, Validation loss: 0.009830561647605564
 Finished Training

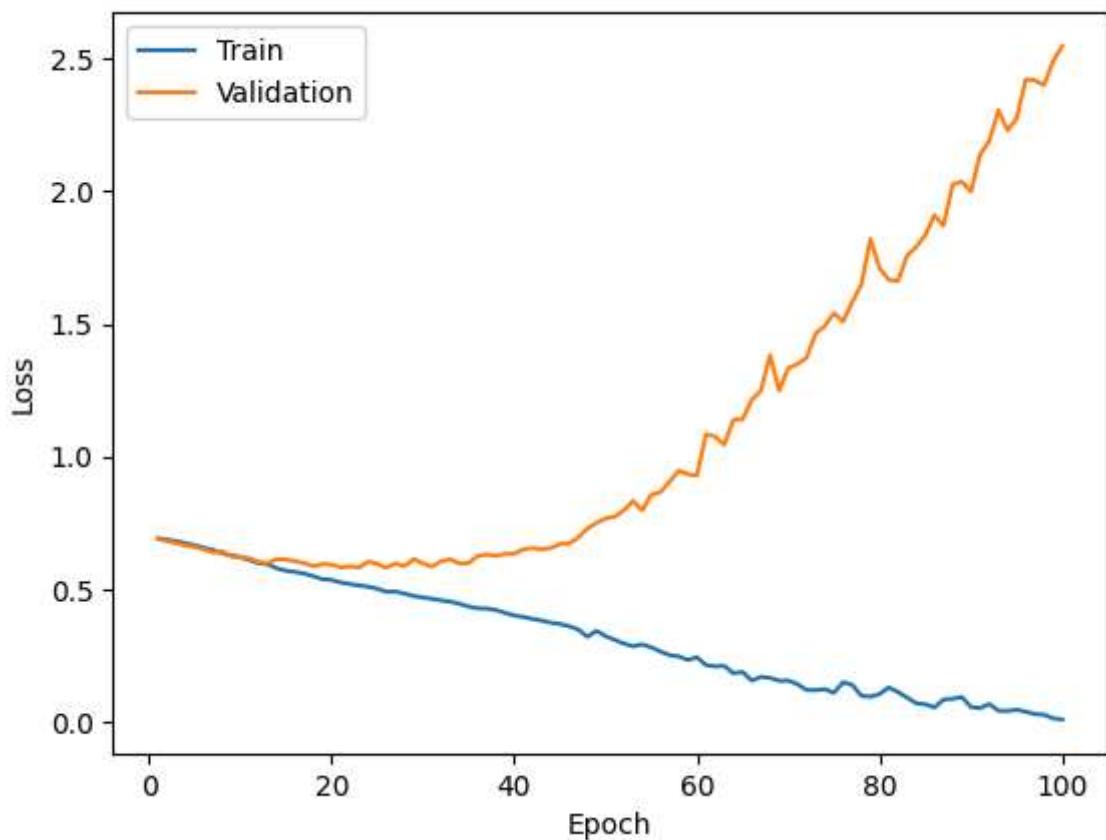
Total time elapsed: 510.04 seconds

Train vs Validation Error





Train vs Validation Loss



✓ Part 4. Evaluating the Best Model [15 pt]

✓ Part (a) - 1pt

Choose the **best** model that you have so far. This means choosing the best model checkpoint, including the choice of `small_net` vs `large_net`, the `batch_size`, `learning_rate`, and the epoch number.

Modify the code below to load your chosen set of weights to the model object `net`.

```
net = LargeNet()
model_path = get_model_name(net.name, batch_size=512, learning_rate=0.001, epoch=249)
state = torch.load(model_path)
net.load_state_dict(state)
```

 <All keys matched successfully>

Start coding or generate with AI.

✓ Part (b) - 2pt

Justify your choice of model from part (a).

```
#I chose the first model because clearly it outperformed the second one, accurate pre
#Loss and error were approaching zero at the end of training
```

✓ Part (c) - 2pt

Using the code in Part 0, any code from lecture notes, or any code that you write, compute and report the **test classification error** for your chosen model.

```
# If you use the `evaluate` function provided in part 0, you will need to
# set batch_size > 1
train_loader, val_loader, test_loader, classes = get_data_loader(
    target_classes=["cat", "dog"],
    batch_size=64)
criterion = nn.BCEWithLogitsLoss()
testError, testLoss = evaluate(net, test_loader, criterion)

print("The error rate on the test set is {} and the loss on the test set is {}.".format(testError, testLoss))
```

 The error rate on the test set is 0.367 and the loss on the test set is 0.6408401671797037.

▼ Part (d) - 3pt

How does the test classification error compare with the **validation error**? Explain why you would expect the test error to be *higher* than the validation error.

```
#It is expected that the test error to be higher than the validation error since th
```

▼ Part (e) - 2pt

Why did we only use the test data set at the very end? Why is it important that we use the test data as little as possible?

```
#To fairly evaluate a model, we must test it on truly unseen data — just like in
```

▼ Part (f) - 5pt

How does your best CNN model compare with an 2-layer ANN model (no convolutional layers) on classifying cat and dog images. You can use a 2-layer ANN architecture similar to what you used in Lab 1. You should explore different hyperparameter settings to determine how well you can do on the validation dataset. Once satisfied with the performance, you may test it out on the test data.

Hint: The ANN in lab 1 was applied on greyscale images. The cat and dog images are colour (RGB) and so you will need to flatten and concatenate all three colour layers before feeding them into an ANN.

```
class ANN(nn.Module):
    def __init__(self):
        super(ANN, self).__init__()
        self.name = "ANN"
        self.layer1 = nn.Linear(3 * 32 * 32, 32)
        self.layer2 = nn.Linear(32, 1)

    def forward(self, x):
        x = x.view(-1, 3 * 32 * 32)
        x = self.layer1(x)
        x = F.relu(x)
        x = self.layer2(x)
        x = x.squeeze(1)
        return x

ANN_net = ANN()
train_net(ANN_net, learning_rate = 0.001, batch_size = 512, num_epochs = 250)

ANN_model_path = get_model_name("ANN", batch_size=512, learning_rate=0.001, epoch=249)
plot_training_curve(ANN_model_path)
```

→ Epoch 1: Train err: 0.497125, Train loss: 0.6976437643170357 |Validation err: 0.485, Validation
Epoch 2: Train err: 0.469625, Train loss: 0.68942816182971 |Validation err: 0.4655, Validation
Epoch 3: Train err: 0.435625, Train loss: 0.6823786236345768 |Validation err: 0.4455, Validation
Epoch 4: Train err: 0.421625, Train loss: 0.6775178350508213 |Validation err: 0.4345, Validation
Epoch 5: Train err: 0.415, Train loss: 0.6736990585923195 |Validation err: 0.427, Validation
Epoch 6: Train err: 0.41, Train loss: 0.6711809001863003 |Validation err: 0.419, Validation 1
Epoch 7: Train err: 0.40575, Train loss: 0.6687481254339218 |Validation err: 0.419, Validation
Epoch 8: Train err: 0.404375, Train loss: 0.6666071154177189 |Validation err: 0.4185, Validation
Epoch 9: Train err: 0.401, Train loss: 0.6652995571494102 |Validation err: 0.4145, Validation
Epoch 10: Train err: 0.40175, Train loss: 0.6638613678514957 |Validation err: 0.409, Validation
Epoch 11: Train err: 0.397875, Train loss: 0.6622678562998772 |Validation err: 0.412, Validation
Epoch 12: Train err: 0.397125, Train loss: 0.6606019884347916 |Validation err: 0.407, Validation
Epoch 13: Train err: 0.396125, Train loss: 0.6596754603087902 |Validation err: 0.404, Validation
Epoch 14: Train err: 0.39425, Train loss: 0.658303864300251 |Validation err: 0.4015, Validation
Epoch 15: Train err: 0.39325, Train loss: 0.6571547128260136 |Validation err: 0.4015, Validation
Epoch 16: Train err: 0.39275, Train loss: 0.6563993729650974 |Validation err: 0.4, Validation
Epoch 17: Train err: 0.3915, Train loss: 0.655474241822958 |Validation err: 0.398, Validation
Epoch 18: Train err: 0.389, Train loss: 0.6542884148657322 |Validation err: 0.3985, Validation
Epoch 19: Train err: 0.38675, Train loss: 0.6535044237971306 |Validation err: 0.3995, Validation
Epoch 20: Train err: 0.3865, Train loss: 0.6524317488074303 |Validation err: 0.4, Validation
Epoch 21: Train err: 0.385875, Train loss: 0.6520705595612526 |Validation err: 0.4, Validation
Epoch 22: Train err: 0.38625, Train loss: 0.6519118137657642 |Validation err: 0.3965, Validation
Epoch 23: Train err: 0.382875, Train loss: 0.6504241339862347 |Validation err: 0.3955, Validation
Epoch 24: Train err: 0.380625, Train loss: 0.6494290642440319 |Validation err: 0.394, Validation
Epoch 25: Train err: 0.38, Train loss: 0.6485126093029976 |Validation err: 0.394, Validation
Epoch 26: Train err: 0.38025, Train loss: 0.6478733085095882 |Validation err: 0.394, Validation
Epoch 27: Train err: 0.38, Train loss: 0.6471337303519249 |Validation err: 0.391, Validation
Epoch 28: Train err: 0.379625, Train loss: 0.6470474302768707 |Validation err: 0.3935, Validation
Epoch 29: Train err: 0.3765, Train loss: 0.6454845629632473 |Validation err: 0.391, Validation
Epoch 30: Train err: 0.375125, Train loss: 0.6453411094844341 |Validation err: 0.393, Validation
Epoch 31: Train err: 0.374625, Train loss: 0.6454755365848541 |Validation err: 0.393, Validation
Epoch 32: Train err: 0.373375, Train loss: 0.6444760002195835 |Validation err: 0.391, Validation
Epoch 33: Train err: 0.373, Train loss: 0.6432858593761921 |Validation err: 0.391, Validation
Epoch 34: Train err: 0.37375, Train loss: 0.6432414352893829 |Validation err: 0.3915, Validation
Epoch 35: Train err: 0.371875, Train loss: 0.6425232887268066 |Validation err: 0.393, Validation
Epoch 36: Train err: 0.37125, Train loss: 0.6416601352393627 |Validation err: 0.3935, Validation
Epoch 37: Train err: 0.37, Train loss: 0.6406805887818336 |Validation err: 0.3925, Validation
Epoch 38: Train err: 0.370375, Train loss: 0.6406962461769581 |Validation err: 0.392, Validation
Epoch 39: Train err: 0.369125, Train loss: 0.6397014148533344 |Validation err: 0.3915, Validation
Epoch 40: Train err: 0.370125, Train loss: 0.6396281346678734 |Validation err: 0.3905, Validation
Epoch 41: Train err: 0.367625, Train loss: 0.6387523114681244 |Validation err: 0.3935, Validation
Epoch 42: Train err: 0.367, Train loss: 0.63829663339588165 |Validation err: 0.391, Validation
Epoch 43: Train err: 0.36675, Train loss: 0.6377359591424465 |Validation err: 0.392, Validation
Epoch 44: Train err: 0.3655, Train loss: 0.6373356208205223 |Validation err: 0.394, Validation
Epoch 45: Train err: 0.3645, Train loss: 0.6360593363642693 |Validation err: 0.393, Validation
Epoch 46: Train err: 0.3625, Train loss: 0.6360066831111908 |Validation err: 0.392, Validation
Epoch 47: Train err: 0.362, Train loss: 0.6352531686425209 |Validation err: 0.3925, Validation
Epoch 48: Train err: 0.362625, Train loss: 0.63490429520607 |Validation err: 0.3935, Validation
Epoch 49: Train err: 0.361875, Train loss: 0.6350414268672466 |Validation err: 0.3915, Validation
Epoch 50: Train err: 0.360375, Train loss: 0.6344705112278461 |Validation err: 0.392, Validation
Epoch 51: Train err: 0.360375, Train loss: 0.6339673288166523 |Validation err: 0.3905, Validation
Epoch 52: Train err: 0.359125, Train loss: 0.6329137720167637 |Validation err: 0.386, Validation
Epoch 53: Train err: 0.359, Train loss: 0.6321384683251381 |Validation err: 0.389, Validation
Epoch 54: Train err: 0.360125, Train loss: 0.6322261691093445 |Validation err: 0.386, Validation
Epoch 55: Train err: 0.36, Train loss: 0.6319254748523235 |Validation err: 0.387, Validation
Epoch 56: Train err: 0.358375, Train loss: 0.6309482455253601 |Validation err: 0.3875, Validation
Epoch 57: Train err: 0.3575, Train loss: 0.6301905103027821 |Validation err: 0.3845, Validation

Epoch 58: Train err: 0.356125, Train loss: 0.6298811286687851 | Validation err: 0.385, Validation
Epoch 59: Train err: 0.35675, Train loss: 0.6299760229885578 | Validation err: 0.3855, Validation
Epoch 60: Train err: 0.355375, Train loss: 0.6293241307139397 | Validation err: 0.3865, Validation
Epoch 61: Train err: 0.355125, Train loss: 0.629392720758915 | Validation err: 0.385, Validation
Epoch 62: Train err: 0.354375, Train loss: 0.6284491717815399 | Validation err: 0.3865, Validation
Epoch 63: Train err: 0.355125, Train loss: 0.628030464053154 | Validation err: 0.386, Validation
Epoch 64: Train err: 0.354, Train loss: 0.6268475949764252 | Validation err: 0.3875, Validation
Epoch 65: Train err: 0.353375, Train loss: 0.6271831505000591 | Validation err: 0.386, Validation
Epoch 66: Train err: 0.353375, Train loss: 0.6265107989311218 | Validation err: 0.387, Validation
Epoch 67: Train err: 0.353625, Train loss: 0.6254482045769691 | Validation err: 0.3855, Validation
Epoch 68: Train err: 0.3525, Train loss: 0.6254970319569111 | Validation err: 0.387, Validation
Epoch 69: Train err: 0.35125, Train loss: 0.6252480298280716 | Validation err: 0.385, Validation
Epoch 70: Train err: 0.3515, Train loss: 0.6242168731987476 | Validation err: 0.3845, Validation
Epoch 71: Train err: 0.351375, Train loss: 0.6237267665565014 | Validation err: 0.384, Validation
Epoch 72: Train err: 0.3495, Train loss: 0.6240276768803596 | Validation err: 0.386, Validation
Epoch 73: Train err: 0.35025, Train loss: 0.6230310536921024 | Validation err: 0.385, Validation
Epoch 74: Train err: 0.349375, Train loss: 0.622945599257946 | Validation err: 0.384, Validation
Epoch 75: Train err: 0.34925, Train loss: 0.6225244291126728 | Validation err: 0.3835, Validation
Epoch 76: Train err: 0.347375, Train loss: 0.6218175031244755 | Validation err: 0.3835, Validation
Epoch 77: Train err: 0.348875, Train loss: 0.6208496727049351 | Validation err: 0.385, Validation
Epoch 78: Train err: 0.34775, Train loss: 0.6206323727965355 | Validation err: 0.3825, Validation
Epoch 79: Train err: 0.34625, Train loss: 0.6206177733838558 | Validation err: 0.3825, Validation
Epoch 80: Train err: 0.3465, Train loss: 0.6204296573996544 | Validation err: 0.383, Validation
Epoch 81: Train err: 0.346625, Train loss: 0.6196439824998379 | Validation err: 0.382, Validation
Epoch 82: Train err: 0.34425, Train loss: 0.6191288828849792 | Validation err: 0.3835, Validation
Epoch 83: Train err: 0.343375, Train loss: 0.6187034510076046 | Validation err: 0.3795, Validation
Epoch 84: Train err: 0.3435, Train loss: 0.618141058832407 | Validation err: 0.3805, Validation
Epoch 85: Train err: 0.34275, Train loss: 0.6174583248794079 | Validation err: 0.383, Validation
Epoch 86: Train err: 0.342, Train loss: 0.6168214976787567 | Validation err: 0.3815, Validation
Epoch 87: Train err: 0.34125, Train loss: 0.6171251498162746 | Validation err: 0.3815, Validation
Epoch 88: Train err: 0.33975, Train loss: 0.616517249494791 | Validation err: 0.3805, Validation
Epoch 89: Train err: 0.34025, Train loss: 0.615082386881113 | Validation err: 0.3805, Validation
Epoch 90: Train err: 0.339875, Train loss: 0.6153350733220577 | Validation err: 0.3825, Validation
Epoch 91: Train err: 0.339625, Train loss: 0.6150271818041801 | Validation err: 0.3825, Validation
Epoch 92: Train err: 0.338375, Train loss: 0.6142902448773384 | Validation err: 0.3815, Validation
Epoch 93: Train err: 0.337875, Train loss: 0.6142865493893623 | Validation err: 0.3795, Validation
Epoch 94: Train err: 0.33825, Train loss: 0.6134782657027245 | Validation err: 0.3785, Validation
Epoch 95: Train err: 0.337125, Train loss: 0.6125866547226906 | Validation err: 0.379, Validation
Epoch 96: Train err: 0.337625, Train loss: 0.6124378889799118 | Validation err: 0.379, Validation
Epoch 97: Train err: 0.336875, Train loss: 0.6122501753270626 | Validation err: 0.381, Validation
Epoch 98: Train err: 0.33525, Train loss: 0.6122129820287228 | Validation err: 0.3785, Validation
Epoch 99: Train err: 0.334625, Train loss: 0.6108479611575603 | Validation err: 0.38, Validation
Epoch 100: Train err: 0.334, Train loss: 0.6107495613396168 | Validation err: 0.3805, Validation
Epoch 101: Train err: 0.333875, Train loss: 0.6108142733573914 | Validation err: 0.3785, Validation
Epoch 102: Train err: 0.332875, Train loss: 0.6103199608623981 | Validation err: 0.3775, Validation
Epoch 103: Train err: 0.3325, Train loss: 0.6088594645261765 | Validation err: 0.378, Validation
Epoch 104: Train err: 0.3315, Train loss: 0.6088961586356163 | Validation err: 0.378, Validation
Epoch 105: Train err: 0.3305, Train loss: 0.6082758381962776 | Validation err: 0.378, Validation
Epoch 106: Train err: 0.33, Train loss: 0.6076976470649242 | Validation err: 0.378, Validation
Epoch 107: Train err: 0.329875, Train loss: 0.6065168306231499 | Validation err: 0.378, Validation
Epoch 108: Train err: 0.32975, Train loss: 0.6060710400342941 | Validation err: 0.378, Validation
Epoch 109: Train err: 0.32925, Train loss: 0.6057785898447037 | Validation err: 0.378, Validation
Epoch 110: Train err: 0.328, Train loss: 0.6057485565543175 | Validation err: 0.3785, Validation
Epoch 111: Train err: 0.3285, Train loss: 0.6049546040594578 | Validation err: 0.3785, Validation
Epoch 112: Train err: 0.327875, Train loss: 0.6049566976726055 | Validation err: 0.3805, Validation
Epoch 113: Train err: 0.3275, Train loss: 0.6038228310644627 | Validation err: 0.3765, Validation
Epoch 114: Train err: 0.32575, Train loss: 0.6039824895560741 | Validation err: 0.3795, Validation

Epoch 115: Train err: 0.325875, Train loss: 0.6030513122677803 | Validation err: 0.3775, Valid Epoch 116: Train err: 0.325, Train loss: 0.6036937013268471 | Validation err: 0.3795, Validati Epoch 117: Train err: 0.324125, Train loss: 0.6023654565215111 |Validation err: 0.3775, Valid Epoch 118: Train err: 0.322875, Train loss: 0.6021441072225571 |Validation err: 0.379, Valida Epoch 119: Train err: 0.321875, Train loss: 0.601560078561306 |Validation err: 0.377, Validat Epoch 120: Train err: 0.321875, Train loss: 0.6010756082832813 |Validation err: 0.378, Valida Epoch 121: Train err: 0.321125, Train loss: 0.6009395383298397 |Validation err: 0.3795, Valid Epoch 122: Train err: 0.320125, Train loss: 0.5987334921956062 |Validation err: 0.3785, Valid Epoch 123: Train err: 0.3195, Train loss: 0.5995548591017723 |Validation err: 0.3815, Validat Epoch 124: Train err: 0.32, Train loss: 0.5989702977240086 |Validation err: 0.378, Validation Epoch 125: Train err: 0.319125, Train loss: 0.5986809879541397 |Validation err: 0.379, Valida Epoch 126: Train err: 0.31825, Train loss: 0.5980233699083328 |Validation err: 0.378, Validat Epoch 127: Train err: 0.319125, Train loss: 0.5979344584047794 |Validation err: 0.378, Valida Epoch 128: Train err: 0.318625, Train loss: 0.5959683917462826 |Validation err: 0.377, Valida Epoch 129: Train err: 0.317875, Train loss: 0.5962106175720692 |Validation err: 0.3765, Valid Epoch 130: Train err: 0.31675, Train loss: 0.5956949032843113 |Validation err: 0.378, Validat Epoch 131: Train err: 0.316375, Train loss: 0.5955988727509975 |Validation err: 0.3745, Valid Epoch 132: Train err: 0.31575, Train loss: 0.5946385562419891 |Validation err: 0.376, Validat Epoch 133: Train err: 0.316625, Train loss: 0.5938037522137165 |Validation err: 0.375, Valida Epoch 134: Train err: 0.316125, Train loss: 0.5943340361118317 |Validation err: 0.3775, Valid Epoch 135: Train err: 0.315375, Train loss: 0.5935912318527699 |Validation err: 0.3745, Valid Epoch 136: Train err: 0.314875, Train loss: 0.592938307672739 |Validation err: 0.375, Validat Epoch 137: Train err: 0.31375, Train loss: 0.5918983928859234 |Validation err: 0.3745, Valida Epoch 138: Train err: 0.311625, Train loss: 0.5910213440656662 |Validation err: 0.3755, Valid Epoch 139: Train err: 0.3125, Train loss: 0.5906513221561909 |Validation err: 0.375, Validati Epoch 140: Train err: 0.312125, Train loss: 0.5904983095824718 |Validation err: 0.3745, Valid Epoch 141: Train err: 0.311125, Train loss: 0.5903192684054375 |Validation err: 0.375, Valida Epoch 142: Train err: 0.31075, Train loss: 0.5899667106568813 |Validation err: 0.3775, Valida Epoch 143: Train err: 0.3115, Train loss: 0.5890653356909752 |Validation err: 0.3775, Validat Epoch 144: Train err: 0.310375, Train loss: 0.5882487259805202 |Validation err: 0.376, Valida Epoch 145: Train err: 0.309875, Train loss: 0.5883145406842232 |Validation err: 0.375, Valida Epoch 146: Train err: 0.30575, Train loss: 0.5888011083006859 |Validation err: 0.3775, Valida Epoch 147: Train err: 0.30825, Train loss: 0.5867834538221359 |Validation err: 0.3795, Valida Epoch 148: Train err: 0.306875, Train loss: 0.5865180902183056 |Validation err: 0.3775, Valid Epoch 149: Train err: 0.308, Train loss: 0.5858426876366138 |Validation err: 0.3765, Validati Epoch 150: Train err: 0.30575, Train loss: 0.5851514302194118 |Validation err: 0.3785, Valida Epoch 151: Train err: 0.305375, Train loss: 0.5851155929267406 |Validation err: 0.375, Valida Epoch 152: Train err: 0.303875, Train loss: 0.5843993723392487 |Validation err: 0.379, Valida Epoch 153: Train err: 0.303375, Train loss: 0.5837830044329166 |Validation err: 0.3755, Valid Epoch 154: Train err: 0.30475, Train loss: 0.5829075686633587 |Validation err: 0.3745, Valida Epoch 155: Train err: 0.302625, Train loss: 0.5825050100684166 |Validation err: 0.3765, Valid Epoch 156: Train err: 0.303375, Train loss: 0.5829771943390369 |Validation err: 0.3765, Valid Epoch 157: Train err: 0.3015, Train loss: 0.5814479328691959 |Validation err: 0.377, Validati Epoch 158: Train err: 0.300875, Train loss: 0.5807713642716408 |Validation err: 0.377, Valida Epoch 159: Train err: 0.30075, Train loss: 0.5802265517413616 |Validation err: 0.373, Validat Epoch 160: Train err: 0.29975, Train loss: 0.5791837871074677 |Validation err: 0.376, Validat Epoch 161: Train err: 0.300125, Train loss: 0.580106895416975 |Validation err: 0.375, Validat Epoch 162: Train err: 0.29775, Train loss: 0.5788313038647175 |Validation err: 0.3745, Valida Epoch 163: Train err: 0.297125, Train loss: 0.57829400151968 |Validation err: 0.3775, Validat