Lab 4: Data Imputation using an Autoencoder

Deadline: June 11, 11:59pm

Late Penalty: There is a penalty-free grace period of one hour past the deadline. Any work that is submitted between 1 hour and 24 hours past the deadline will receive a 20% grade deduction. No other late work is accepted. Quercus submission time will be used, not your local computer time. You can submit your labs as many times as you want before the deadline, so please submit often and early.

In this lab, you will build and train an autoencoder to impute (or "fill in") missing data.

We will be using the Adult Data Set provided by the UCI Machine Learning Repository [1], available at https://archive.ics.uci.edu/ml/datasets/adult. The data set contains census record files of adults, including their age, martial status, the type of work they do, and other features.

Normally, people use this data set to build a supervised classification model to classify whether a person is a high income earner. We will not use the dataset for this original intended purpose.

Instead, we will perform the task of imputing (or "filling in") missing values in the dataset. For example, we may be missing one person's martial status, and another person's age, and a third person's level of education. Our model will predict the missing features based on the information that we do have about each person.

We will use a variation of a denoising autoencoder to solve this data imputation problem. Our autoencoder will be trained using inputs that have one categorical feature artificially removed, and the goal of the autoencoder is to correctly reconstruct all features, including the one removed from the input.

In the process, you are expected to learn to:

1. Clean and process continuous and categorical data for machine learning.
2. Implement an autoencoder that takes continuous and categorical (one-hot) inputs.
3. Tune the hyperparameters of an autoencoder.
4. Use baseline models to help interpret model performance.

[1] Dua, D. and Karra Taniskidou, E. (2017). UCI Machine Learning Repository [http://archive.ics.uci.edu/ml]. Irvine, CA: University of California, School of Information and Computer Science.

What to submit

Submit a PDF file containing all your code, outputs, and write-up. You can produce a PDF of your Google Colab file by going to File > Print and then save as PDF. The Colab instructions have more information (.html files are also acceptable).

Do not submit any other files produced by your code.

Include a link to your colab file in your submission.

Colab Link

Include a link to your Colab file here. If you would like the TA to look at your Colab file in case your solutions are cut off, **please make sure that your Colab file is publicly accessible at the time of submission**.

Colab Link: https://drive.google.com/file/d/14siiGm5gAhLp9rs4D3HDoa3OfXdcsVIC/view?usp=sharing

In [ ]:
```
import csv
import numpy as np
import random
import torch
import torch.utils.data
import time
import matplotlib.pyplot as plt
```

Part 0

We will be using a package called `pandas` for this assignment.

If you are using Colab, `pandas` should already be available. If you are using your own computer, installation instructions for `pandas` are available here: https://pandas.pydata.org/pandas-docs/stable/install.html

In [ ]:
```
import pandas as pd
```

Part 1. Data Cleaning [15 pt]

The adult.data file is available at `https://archive.ics.uci.edu/ml/machine-learning-databases/adult/adult.data`

The function `pd.read_csv` loads the adult.data file into a pandas dataframe. You can read about the pandas documentation for `pd.read_csv` at https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.read_csv.html

In [ ]:
```
header = ['age', 'work', 'fnlwgt', 'edu', 'yredu', 'marriage', 'occupation',
 'relationship', 'race', 'sex', 'capgain', 'caploss', 'workhr', 'country']
df = pd.read_csv(
    "https://archive.ics.uci.edu/ml/machine-learning-databases/adult/adult.data",
    names=header,
    index_col=False)
```

In [ ]:
```
df.shape # there are 32561 rows (records) in the data frame, and 14 columns (features)
```

Out[ ]:
```
(32561, 14)
```

Part (a) Continuous Features [3 pt]

For each of the columns `["age", "yredu", "capgain", "caploss", "workhr"]`, report the minimum, maximum, and average value across the dataset.

Then, normalize each of the features `["age", "yredu", "capgain", "caploss", "workhr"]` so that their values are always between 0 and 1. Make sure that you are actually modifying the dataframe `df`.

Like numpy arrays and torch tensors, pandas data frames can be sliced. For example, we can display the first 3 rows of the data frame (3 records) below.

In [ ]:
```
df[:3] # show the first 3 records
```

Out[ ]:

	age	work	fnlwgt	edu	yredu	marriage	occupation	relationship	race	sex	capgain	ca
0	39	State-gov	77516	Bachelors	13	Never-married	Adm-clerical	Not-in-family	White	Male	2174	
1	50	Self-emp-not-inc	83311	Bachelors	13	Married-civ-spouse	Exec-managerial	Husband	White	Male	0	
2	38	Private	215646	HS-grad	9	Divorced	Handlers-cleaners	Not-in-family	White	Male	0	

Alternatively, we can slice based on column names, for example `df["race"]`, `df["hr"]`, or even index multiple columns like below.

In [ ]:
```
subdf = df[["age", "yredu", "capgain", "caploss", "workhr"]]
subdf[:3] # show the first 3 records
```

Out[ ]:

	age	yredu	capgain	caploss	workhr
0	39	13	2174	0	40
1	50	13	0	0	13
2	38	9	0	0	40

Numpy works nicely with pandas, like below:

In [ ]:
```
np.sum(subdf["caploss"])
```

Out[ ]:
```
2842700
```

Just like numpy arrays, you can modify entire columns of data rather than one scalar element at a time. For example, the code

```
df["age"] = df["age"] + 1
```

would increment everyone's age by 1.

In [ ]:
```
print("The minimum values of each column are:")
subdf.min()
```

```
The minimum values of each column are:
```

Out[ ]:
```
age        17
yredu       1
capgain     0
caploss     0
workhr      1
dtype: int64
```

In [ ]:
```
print("The maximum values of each column are:")
subdf.max()
```

```
The maximum values of each column are:
```

Out[ ]:
```
age           90
yredu         16
capgain    99999
caploss     4356
workhr        99
dtype: int64
```

In [ ]:
```
print("The average values of each column are:")
subdf.mean()
```

```
The average values of each column are:
```

Out[ ]:
```
age          38.581647
yredu        10.080679
capgain    1077.648844
caploss      87.303830
workhr       40.437456
dtype: float64
```

In [ ]:
```
df[["age", "yredu", "capgain", "caploss", "workhr"]] = (subdf - subdf.min())/(subdf.max
print("The first 3 records of the normalized data set are:")
df[:3] # show the first 3 records
```

```
The first 3 records of the normalized data set are:
```

Out[ ]:

	age	work	fnlwgt	edu	yredu	marriage	occupation	relationship	race	sex	capg
0	0.301370	State-gov	77516	Bachelors	0.800000	Never-married	Adm-clerical	Not-in-family	White	Male	0.02
1	0.452055	Self-emp-not-inc	83311	Bachelors	0.800000	Married-civ-spouse	Exec-managerial	Husband	White	Male	0.00
2	0.287671	Private	215646	HS-grad	0.533333	Divorced	Handlers-cleaners	Not-in-family	White	Male	0.00

Part (b) Categorical Features [1 pt]

What percentage of people in our data set are male? Note that the data labels all have an unfortunate space in the beginning, e.g. " Male" instead of "Male".

What percentage of people in our data set are female?

In [ ]:
```
# hint: you can do something like this in pandas
```

```
male_size = sum(df["sex"] == " Male")
female_size = sum(df["sex"] == " Female")
sex_size = df["sex"].size

print(male_size/sex_size*100, "% of people in the data set are male.")
print(female_size/sex_size*100, "% of people in the data set are female.")
```

```
66.92054912318419 % of people in the data set are male.
33.07945087681583 % of people in the data set are female.
```

Part (c) [2 pt]

Before proceeding, we will modify our data frame in a couple more ways:

1. We will restrict ourselves to using a subset of the features (to simplify our autoencoder)
2. We will remove any records (rows) already containing missing values, and store them in a second dataframe. We will only use records without missing values to train our autoencoder.

Both of these steps are done for you, below.

How many records contained missing features? What percentage of records were removed?

In [ ]:
```
contcols = ["age", "yredu", "capgain", "caploss", "workhr"]
catcols = ["work", "marriage", "occupation", "edu", "relationship", "sex"]
features = contcols + catcols
df = df[features]
```

In [ ]:
```
missing = pd.concat([df[c] == " ?" for c in catcols], axis=1).any(axis=1)
df_with_missing = df[missing]
df_not_missing = df[~missing]
```

In [ ]:
```
missing_size = df_with_missing.shape[0]
total_size = df.shape[0]

print(missing_size, "records contained missing features.")
print(missing_size/total_size*100, "% of records were removed.")
```

```
1843 records contained missing features.
5.660145572924664 % of records were removed.
```

Part (d) One-Hot Encoding [1 pt]

What are all the possible values of the feature "work" in `df_not_missing` ? You may find the Python function `set` useful.

In [ ]:
```
work_values = set(df_not_missing["work"])

print("The possible values of the feature \"work\" are:")
for work in work_values:
    print(work)
```

```
The possible values of the feature "work" are:
 Local-gov
 Without-pay
 Private
 State-gov
 Self-emp-not-inc
```

```
Self-emp-inc
Federal-gov
```

We will be using a one-hot encoding to represent each of the categorical variables. Our autoencoder will be trained using these one-hot encodings.

We will use the pandas function `get_dummies` to produce one-hot encodings for all of the categorical variables in `df_not_missing`.

In [ ]:
```
data = pd.get_dummies(df_not_missing)
```

In [ ]:
```
data[:3]
```

Out[ ]:

	age	yredu	capgain	caploss	workhr	work_ Federal-gov	work_ Local-gov	work_ Private	work_ Self-emp-inc	work_ Self-emp-not-inc	work_ State-gov	w Witl
0	0.301370	0.800000	0.02174	0.0	0.397959	0	0	0	0	0	1	
1	0.452055	0.800000	0.00000	0.0	0.122449	0	0	0	0	1	0	
2	0.287671	0.533333	0.00000	0.0	0.397959	0	0	1	0	0	0	

Part (e) One-Hot Encoding [2 pt]

The dataframe `data` contains the cleaned and normalized data that we will use to train our denoising autoencoder.

How many **columns** (features) are in the dataframe `data`?

Briefly explain where that number come from.

In [ ]:
```
data.shape[1]
```

Out[ ]:
```
57
```

In [ ]:
```
total_cols = 0
for feature in catcols:
    total_cols += len(set(df_not_missing[feature]))
total_cols += len(contcols)
```

In [ ]:
```
total_cols
```

Out[ ]:
```
57
```

Answer:

As shown in the code above, 57 columns (features) are in the dataframe `data`. The number comes from the sum of all continuous features and all possible values of each categorical feature.

Part (f) One-Hot Conversion [3 pt]

We will convert the pandas data frame `data` into numpy, so that it can be further converted into a PyTorch tensor. However, in doing so, we lose the column label information that a panda data frame automatically stores.

Complete the function `get_categorical_value` that will return the named value of a feature given a one-hot embedding. You may find the global variables `cat_index` and `cat_values` useful. (Display them and figure out what they are first.)

We will need this function in the next part of the lab to interpret our autoencoder outputs. So, the input to our function `get_categorical_values` might not actually be "one-hot" -- the input may instead contain real-valued predictions from our neural network.

In [ ]:
```
datanp = data.values.astype(np.float32)
```

In [ ]:
```
cat_index = {}  # Mapping of feature -> start index of feature in a record
cat_values = {} # Mapping of feature -> list of categorical values the feature can take

# build up the cat_index and cat_values dictionary
for i, header in enumerate(data.keys()):
    if "_" in header: # categorical header
        feature, value = header.split()
        feature = feature[:-1] # remove the last char; it is always an underscore
        if feature not in cat_index:
            cat_index[feature] = i
            cat_values[feature] = [value]
        else:
            cat_values[feature].append(value)
```

In [ ]:
```
cat_index
```

Out[ ]:
```
{'edu': 33,
 'marriage': 12,
 'occupation': 19,
 'relationship': 49,
 'sex': 55,
 'work': 5}
```

In [ ]:
```
cat_values
```

Out[ ]:
```
{'edu': ['10th',
  '11th',
  '12th',
  '1st-4th',
  '5th-6th',
  '7th-8th',
  '9th',
  'Assoc-acdm',
  'Assoc-voc',
  'Bachelors',
  'Doctorate',
  'HS-grad',
  'Masters',
  'Preschool',
  'Prof-school',
  'Some-college'],
 'marriage': ['Divorced',
  'Married-AF-spouse',
  'Married-civ-spouse',
```

```
 'Married-spouse-absent',
 'Never-married',
 'Separated',
 'Widowed'],
'occupation': ['Adm-clerical',
 'Armed-Forces',
 'Craft-repair',
 'Exec-managerial',
 'Farming-fishing',
 'Handlers-cleaners',
 'Machine-op-inspct',
 'Other-service',
 'Priv-house-serv',
 'Prof-specialty',
 'Protective-serv',
 'Sales',
 'Tech-support',
 'Transport-moving'],
'relationship': ['Husband',
 'Not-in-family',
 'Other-relative',
 'Own-child',
 'Unmarried',
 'Wife'],
'sex': ['Female', 'Male'],
'work': ['Federal-gov',
 'Local-gov',
 'Private',
 'Self-emp-inc',
 'Self-emp-not-inc',
 'State-gov',
 'Without-pay']}
```

In [ ]:

```
def get_onehot(record, feature):
    """
    Return the portion of `record` that is the one-hot encoding
    of `feature`. For example, since the feature "work" is stored
    in the indices [5:12] in each record, calling `get_range(record, "work")`
    is equivalent to accessing `record[5:12]`.

    Args:
        - record: a numpy array representing one record, formatted
                  the same way as a row in `data.np`
        - feature: a string, should be an element of `catcols`
    """
    start_index = cat_index[feature]
    stop_index = cat_index[feature] + len(cat_values[feature])
    return record[start_index:stop_index]

def get_categorical_value(onehot, feature):
    """
    Return the categorical value name of a feature given
    a one-hot vector representing the feature.

    Args:
        - onehot: a numpy array one-hot representation of the feature
        - feature: a string, should be an element of `catcols`

    Examples:

    >>> get_categorical_value(np.array([0., 0., 0., 0., 0., 1., 0.]), "work")
    'State-gov'
    >>> get_categorical_value(np.array([0.1, 0., 1.1, 0.2, 0., 1., 0.]), "work")
```

```
    'Private'
    """
    return cat_values[feature][np.argmax(onehot)]
```

In [ ]:
```
get_categorical_value(np.array([0., 0., 0., 0., 0., 1., 0.]), "work")
```

Out[ ]:
```
'State-gov'
```

In [ ]:
```
get_categorical_value(np.array([0.1, 0., 1.1, 0.2, 0., 1., 0.]), "work")
```

Out[ ]:
```
'Private'
```

In [ ]:
```
# more useful code, used during training, that depends on the function
# you write above

def get_feature(record, feature):
    """
    Return the categorical feature value of a record
    """
    onehot = get_onehot(record, feature)
    return get_categorical_value(onehot, feature)

def get_features(record):
    """
    Return a dictionary of all categorical feature values of a record
    """
    return { f: get_feature(record, f) for f in catcols }
```

Part (g) Train/Test Split [3 pt]

Randomly split the data into approximately 70% training, 15% validation and 15% test.

Report the number of items in your training, validation, and test set.

In [ ]:
```
# set the numpy seed for reproducibility
# https://docs.scipy.org/doc/numpy/reference/generated/numpy.random.seed.html
np.random.seed(50)
np.random.shuffle(datanp)
train_split = int(len(datanp) * 0.7) #split at 70%
train_data, val_data = datanp[:train_split], datanp[train_split:]
val_split = int(len(val_data) * 0.5)
val_data, test_data = val_data[:val_split], val_data[val_split:]

print("The number of entries in the training set is", train_data.shape[0])
print("The number of entries in the validation set is", val_data.shape[0])
print("The number of entries in the test set is", test_data.shape[0])
```

```
The number of entries in the training set is 21502
The number of entries in the validation set is 4608
The number of entries in the test set is 4608
```

Part 2. Model Setup [5 pt]

Part (a) [4 pt]

Design a fully-connected autoencoder by modifying the `encoder` and `decoder` below.

The input to this autoencoder will be the features of the `data`, with one categorical feature recorded as "missing". The output of the autoencoder should be the reconstruction of the same features, but with the missing value filled in.

Note: Do not reduce the dimensionality of the input too much! The output of your embedding is expected to contain information about ~11 features.

In [ ]:
```
from torch import nn

class AutoEncoder(nn.Module):
    def __init__(self):
        super(AutoEncoder, self).__init__()
        self.name = "autoencoder"
        self.encoder = nn.Sequential(
            nn.Linear(57, 30),
            nn.ReLU(),
            nn.Linear(30, 15)
        )
        self.decoder = nn.Sequential(
            nn.Linear(15, 30),
            nn.ReLU(),
            nn.Linear(30, 57),
            nn.Sigmoid() # get to the range (0, 1)
        )

    def forward(self, x):
        x = self.encoder(x)
        x = self.decoder(x)
        return x
```

Part (b) [1 pt]

Explain why there is a sigmoid activation in the last step of the decoder.

(**Note**: the values inside the data frame `data` and the training code in Part 3 might be helpful.)

Answer:

Since the values inside the data frame `data` are all between 0 and 1, the sigmoid activation function is applied to the output layer to scale the output from 0 to 1.

Part 3. Training [18]

Part (a) [6 pt]

We will train our autoencoder in the following way:

- In each iteration, we will hide one of the categorical features using the `zero_out_random_features` function
- We will pass the data with one missing feature through the autoencoder, and obtain a reconstruction
- We will check how close the reconstruction is compared to the original data -- including the value of the missing feature

Complete the code to train the autoencoder, and plot the training and validation loss every few iterations. You may also want to plot training and validation "accuracy" every few iterations, as we will define in part (b). You may also want to checkpoint your model every few iterations or epochs.

Use `nn.MSELoss()` as your loss function. (Side note: you might recognize that this loss function is not ideal for this problem, but we will use it anyway.)

In [ ]:
```
def zero_out_feature(records, feature):
    """ Set the feature missing in records, by setting the appropriate
    columns of records to 0
    """
    start_index = cat_index[feature]
    stop_index = cat_index[feature] + len(cat_values[feature])
    records[:, start_index:stop_index] = 0
    return records

def zero_out_random_feature(records):
    """ Set one random feature missing in records, by setting the
    appropriate columns of records to 0
    """
    return zero_out_feature(records, random.choice(catcols))

def get_model_name(name, learning_rate, epoch):
    path = "model_{0}_lr{1}_epoch{2}".format(name, learning_rate, epoch)
    return path

def get_val_loss(model, valid_loader, criterion):
    total_val_loss = 0.0
    i = 0
    for data in valid_loader:
        datam = zero_out_random_feature(data.clone()) # zero out one categorical featur
        recon = model(datam)
        loss = criterion(recon, data)
        total_val_loss += loss.item()
        i += 1
    val_loss = float(total_val_loss)/(i + 1)
    return val_loss

def train(model, train_loader, valid_loader, num_epochs=5, learning_rate=1e-4):
    """ Training loop. You should update this."""
    torch.manual_seed(42)
    criterion = nn.MSELoss()
    optimizer = torch.optim.Adam(model.parameters(), lr=learning_rate)

    train_acc = np.zeros(num_epochs)
    train_loss = np.zeros(num_epochs)
    val_acc = np.zeros(num_epochs)
    val_loss = np.zeros(num_epochs)

    start_time = time.time()
    for epoch in range(num_epochs):
        total_train_loss = 0.0
        i = 0
        for data in train_loader:
            datam = zero_out_random_feature(data.clone()) # zero out one categorical fe
            recon = model(datam)
            loss = criterion(recon, data)
            loss.backward()
            optimizer.step()
```

```
            optimizer.zero_grad()
            total_train_loss += loss.item()
            i += 1
        train_acc[epoch] = get_accuracy(model, train_loader)
        train_loss[epoch] = float(total_train_loss)/(i + 1)
        val_acc[epoch] = get_accuracy(model, valid_loader)
        val_loss[epoch] = get_val_loss(model, valid_loader, criterion)
        print(("Epoch {}: Train acc: {}, Train loss: {} |"+
               "Validation acc: {}, Validation loss: {}").format(
                   epoch + 1,
                   train_acc[epoch],
                   train_loss[epoch],
                   val_acc[epoch],
                   val_loss[epoch]))
        # Save the current model (checkpoint) to a file
        model_path = get_model_name(model.name, learning_rate, epoch)
        torch.save(model.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))

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

    plt.title("Train vs Validation Accuracy")
    plt.plot(range(1 ,num_epochs+1), train_acc, label="Train")
    plt.plot(range(1 ,num_epochs+1), val_acc, label="Validation")
    plt.xlabel("Epochs")
    plt.ylabel("Training Accuracy")
    plt.legend(loc='best')
    plt.show()

    print("Final Training Accuracy: {}".format(train_acc[-1]))
    print("Final Validation Accuracy: {}".format(val_acc[-1]))
```

Part (b) [3 pt]

While plotting training and validation loss is valuable, loss values are harder to compare than accuracy percentages. It would be nice to have a measure of "accuracy" in this problem.

Since we will only be imputing missing categorical values, we will define an accuracy measure. For each record and for each categorical feature, we determine whether the model can predict the categorical feature given all the other features of the record.

A function `get_accuracy` is written for you. It is up to you to figure out how to use the function. **You don't need to submit anything in this part.** To earn the marks, correctly plot the training and validation accuracy every few iterations as part of your training curve.

In [ ]:
```
def get_accuracy(model, data_loader):
    """Return the "accuracy" of the autoencoder model across a data set.
```

```
    That is, for each record and for each categorical feature,
    we determine whether the model can successfully predict the value
    of the categorical feature given all the other features of the
    record. The returned "accuracy" measure is the percentage of times
    that our model is successful.

    Args:
       - model: the autoencoder model, an instance of nn.Module
       - data_loader: an instance of torch.utils.data.DataLoader

    Example (to illustrate how get_accuracy is intended to be called.
             Depending on your variable naming this code might require
             modification.)

        >>> model = AutoEncoder()
        >>> vdl = torch.utils.data.DataLoader(data_valid, batch_size=256, shuffle=True)
        >>> get_accuracy(model, vdl)
    """
    total = 0
    acc = 0
    for col in catcols:
        for item in data_loader: # minibatches
            inp = item.detach().numpy()
            out = model(zero_out_feature(item.clone(), col)).detach().numpy()
            for i in range(out.shape[0]): # record in minibatch
                acc += int(get_feature(out[i], col) == get_feature(inp[i], col))
                total += 1
    return acc / total
```

Part (c) [4 pt]

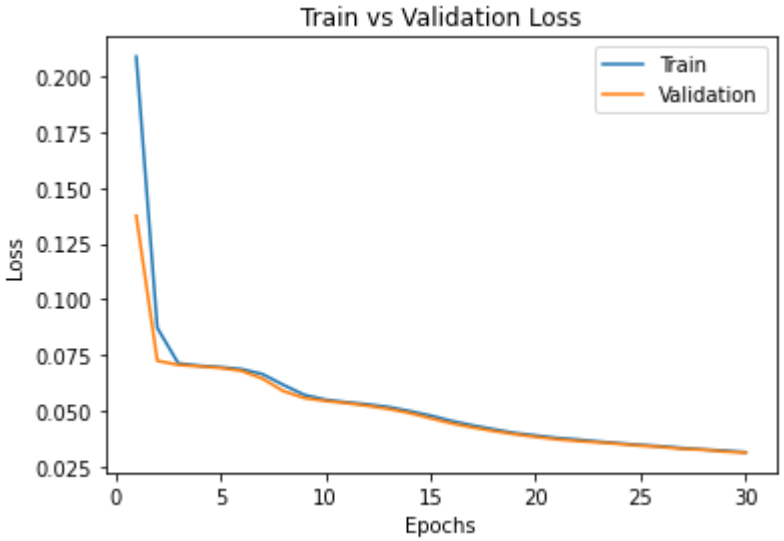
Run your updated training code, using reasonable initial hyperparameters.

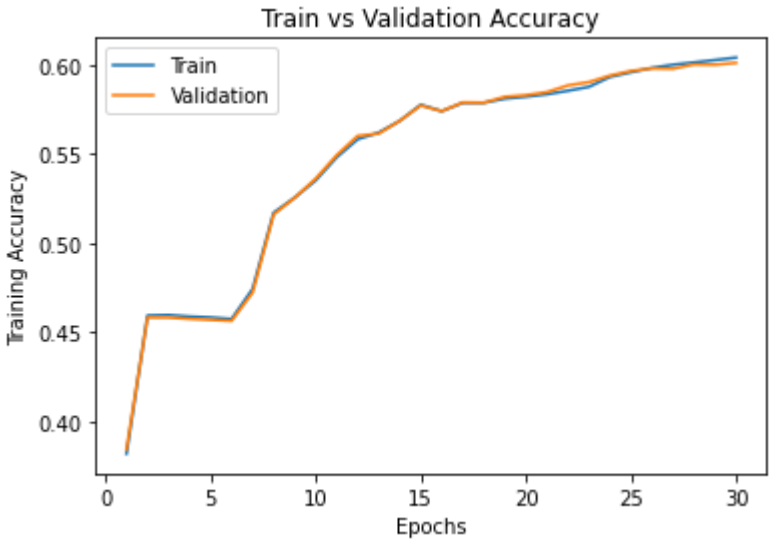
Include your training curve in your submission.

In [ ]:
```
train_loader = torch.utils.data.DataLoader(train_data, batch_size=64, shuffle=True)
valid_loader = torch.utils.data.DataLoader(val_data, batch_size=64, shuffle=True)
model = AutoEncoder()
train(model, train_loader, valid_loader, num_epochs=30)
```

```
Epoch 1: Train acc: 0.38208073667565806, Train loss: 0.20862779812749133 |Validation ac
c: 0.3844401041666667, Validation loss: 0.1374495572435396
Epoch 2: Train acc: 0.45940687687967013, Train loss: 0.08729150771917858 |Validation ac
c: 0.4583333333333333, Validation loss: 0.07259809625962367
Epoch 3: Train acc: 0.4596781694726072, Train loss: 0.07142292164288218 |Validation acc:
0.45829716435185186, Validation loss: 0.07073208499556126
Epoch 4: Train acc: 0.4588487892599138, Train loss: 0.0703882221298331 |Validation acc:
0.4575737847222222, Validation loss: 0.07007463002240269
Epoch 5: Train acc: 0.45833720894180385, Train loss: 0.06974058709928119 |Validation ac
c: 0.45703125, Validation loss: 0.06936035490973413
Epoch 6: Train acc: 0.45749232629522835, Train loss: 0.06884427061332085 |Validation ac
c: 0.4564525462962963, Validation loss: 0.06809887365169978
Epoch 7: Train acc: 0.47432796949121014, Train loss: 0.0666355416289246 |Validation acc:
0.4722945601851852, Validation loss: 0.0646185653079688
Epoch 8: Train acc: 0.516998418751744, Train loss: 0.061786324128464354 |Validation acc:
0.5159866898148148, Validation loss: 0.05902343006799058
Epoch 9: Train acc: 0.525423991566676, Train loss: 0.05730416851245331 |Validation acc:
0.5253544560185185, Validation loss: 0.05590584302647177
Epoch 10: Train acc: 0.5350975103091186, Train loss: 0.05517897751591326 |Validation ac
c: 0.5360604745370371, Validation loss: 0.05459686182992041
Epoch 11: Train acc: 0.5480342913837473, Train loss: 0.05403128961648361 |Validation ac
```

```
c: 0.5491898148148148, Validation loss: 0.05364152264037896
Epoch 12: Train acc: 0.5581418782748891, Train loss: 0.05309944977923034 |Validation ac
c: 0.5600405092592593, Validation loss: 0.052431881328276427
Epoch 13: Train acc: 0.561870213623539, Train loss: 0.05191222589341399 |Validation acc:
0.5613064236111112, Validation loss: 0.05103880689874601
Epoch 14: Train acc: 0.5684354943726165, Train loss: 0.05007020992058321 |Validation ac
c: 0.5684317129629629, Validation loss: 0.04920812065019452
Epoch 15: Train acc: 0.577450159675069, Train loss: 0.048046773481970374 |Validation ac
c: 0.5770399305555556, Validation loss: 0.04686735155895485
Epoch 16: Train acc: 0.5738613462313583, Train loss: 0.045652775950619305 |Validation ac
c: 0.5738932291666666, Validation loss: 0.04458768722167355
Epoch 17: Train acc: 0.5785430812637584, Train loss: 0.04365983642969358 |Validation ac
c: 0.5787760416666666, Validation loss: 0.042735877339051105
Epoch 18: Train acc: 0.5785740861315226, Train loss: 0.041951423505381946 |Validation ac
c: 0.5786313657407407, Validation loss: 0.041136742345657125
Epoch 19: Train acc: 0.5808529439121942, Train loss: 0.04027368076344626 |Validation ac
c: 0.5819227430555556, Validation loss: 0.039731567509980865
Epoch 20: Train acc: 0.5819536167178248, Train loss: 0.03917394729900431 |Validation ac
c: 0.5828269675925926, Validation loss: 0.03851173579339104
Epoch 21: Train acc: 0.5833178308994512, Train loss: 0.038091417855254266 |Validation ac
c: 0.5845269097222222, Validation loss: 0.03745902534187371
Epoch 22: Train acc: 0.5852866400024804, Train loss: 0.03733723253586526 |Validation ac
c: 0.5882884837962963, Validation loss: 0.03667053050231686
Epoch 23: Train acc: 0.5874802343968003, Train loss: 0.03644546204818639 |Validation ac
c: 0.5901331018518519, Validation loss: 0.03604809307556831
Epoch 24: Train acc: 0.593022354509658, Train loss: 0.03565637931470878 |Validation acc:
0.5937861689814815, Validation loss: 0.03535149658225941
Epoch 25: Train acc: 0.5956577682696184, Train loss: 0.034933784213856706 |Validation ac
c: 0.5963903356481481, Validation loss: 0.03456755483230073
Epoch 26: Train acc: 0.5980994016060521, Train loss: 0.03432839913763526 |Validation ac
c: 0.5978009259259259, Validation loss: 0.033998312461756455
Epoch 27: Train acc: 0.5998434254177906, Train loss: 0.03353790844892889 |Validation ac
c: 0.59765625, Validation loss: 0.03314605205477345
Epoch 28: Train acc: 0.6011378786469476, Train loss: 0.03288430454712416 |Validation ac
c: 0.6000434027777778, Validation loss: 0.032791547344594045
Epoch 29: Train acc: 0.602486590394692, Train loss: 0.0323814817590954 |Validation acc:
0.5998987268518519, Validation loss: 0.031933274529100525
Epoch 30: Train acc: 0.6038585557932595, Train loss: 0.0316823019538329 |Validation acc:
0.6009114583333334, Validation loss: 0.03148753964825801
Finished Training
Total time elapsed: 95.35 seconds
```






```
Final Training Accuracy: 0.6038585557932595
Final Validation Accuracy: 0.6009114583333334
```

Part (d) [5 pt]

Tune your hyperparameters, training at least 4 different models (4 sets of hyperparameters).

Do not include all your training curves. Instead, explain what hyperparameters you tried, what their effect was, and what your thought process was as you chose the next set of hyperparameters to try.

In [ ]:
```
# Since the training accuracy of the model in Part (c) was still increasing near the en
train_loader = torch.utils.data.DataLoader(train_data, batch_size=64, shuffle=True)
valid_loader = torch.utils.data.DataLoader(val_data, batch_size=64, shuffle=True)
model_1 = AutoEncoder()
train(model_1, train_loader, valid_loader, num_epochs=150)

# Results:
# Increasing num_epochs increased the training and validation accuracies
# Final Training Accuracy: 0.6297321179425169
# Final Validation Accuracy: 0.6265552662037037
```

In [ ]:
```
# Since the training accuracy of model_1 still seems to increase near the end, num_epoc
train_loader = torch.utils.data.DataLoader(train_data, batch_size=64, shuffle=True)
valid_loader = torch.utils.data.DataLoader(val_data, batch_size=64, shuffle=True)
model_2 = AutoEncoder()
train(model_2, train_loader, valid_loader, num_epochs=300)

# Results:
# Increasing num_epochs increased the training and validation accuracies
# Final Training Accuracy: 0.6311195857749666
# Final Validation Accuracy: 0.6269169560185185
```

In [ ]:
```
# Since the previous two models were trained at a very slow rate, learning_rate is incr
train_loader = torch.utils.data.DataLoader(train_data, batch_size=64, shuffle=True)
valid_loader = torch.utils.data.DataLoader(val_data, batch_size=64, shuffle=True)
model_3 = AutoEncoder()
train(model_3, train_loader, valid_loader, num_epochs=300, learning_rate=5e-4)

# Results:
# Increasing learning_rate increased the training and validation accuracies, but it als
# more noisy with more fluctuations.
```

```
# Final Training Accuracy: 0.6833007782221809
# Final Validation Accuracy: 0.6796151620370371
```

In [ ]:
```
# Since increasing the learning_rate significantly improved the training and validation
# learning_rate is further increased from 5e-4 to 0.00075 so the model can learn even f
train_loader = torch.utils.data.DataLoader(train_data, batch_size=64, shuffle=True)
valid_loader = torch.utils.data.DataLoader(val_data, batch_size=64, shuffle=True)
model_4 = AutoEncoder()
train(model_4, train_loader, valid_loader, num_epochs=300, learning_rate=0.00075)

# Results:
# Increasing learning_rate increased the training and validation accuracies, but it als
# even more noisy with more fluctuations compared to model_3.
# Final Training Accuracy: 0.6957182277617586
# Final Validation Accuracy: 0.6915509259259259
```

In [ ]:
```
# Since the training curves are starting to become more and more noisy due to the incre
# learning_rate, it will not be further increased. However, training accuracy of model_
# seems to increase near the end, so num_epochs is increased from 300 to 600
train_loader = torch.utils.data.DataLoader(train_data, batch_size=64, shuffle=True)
valid_loader = torch.utils.data.DataLoader(val_data, batch_size=64, shuffle=True)
model_5 = AutoEncoder()
train(model_5, train_loader, valid_loader, num_epochs=600, learning_rate=0.00075)

# Results:
# This set of hyperparameters produces the best learned model
# Final Training Accuracy: 0.7151427774160544
# Final Validation Accuracy: 0.7076099537037037
```

```
Epoch 1: Train acc: 0.5309816141134158, Train loss: 0.09496343219846222 |Validation acc:
0.5297309027777778, Validation loss: 0.055621624910424654
Epoch 2: Train acc: 0.5799460515300903, Train loss: 0.05101048515263934 |Validation acc:
0.5782696759259259, Validation loss: 0.04634870735801292
Epoch 3: Train acc: 0.5998434254177906, Train loss: 0.04141154051799802 |Validation acc:
0.5967520254629629, Validation loss: 0.0373355060848974
Epoch 4: Train acc: 0.6134468111493504, Train loss: 0.03475015092563735 |Validation acc:
0.6093026620370371, Validation loss: 0.03262321443714268
Epoch 5: Train acc: 0.6129739869159458, Train loss: 0.031112549351169024 |Validation ac
c: 0.6084346064814815, Validation loss: 0.029488086015074473
Epoch 6: Train acc: 0.6100285244783431, Train loss: 0.028163398049484374 |Validation ac
c: 0.6053602430555556, Validation loss: 0.02715853609432099
Epoch 7: Train acc: 0.6107571388708027, Train loss: 0.025897714798545978 |Validation ac
c: 0.6090133101851852, Validation loss: 0.024493559078487517
Epoch 8: Train acc: 0.611695036120671, Train loss: 0.023902389903494796 |Validation acc:
0.6085069444444444, Validation loss: 0.02297352886142469
Epoch 9: Train acc: 0.614415713266983, Train loss: 0.02256955552669325 |Validation acc:
0.6119068287037037, Validation loss: 0.021935903215753217
Epoch 10: Train acc: 0.6227870275633275, Train loss: 0.02176760871637646 |Validation ac
c: 0.6203703703703703, Validation loss: 0.021333424681217274
Epoch 11: Train acc: 0.6162915077667194, Train loss: 0.02104854257086441 |Validation ac
c: 0.6108579282407407, Validation loss: 0.020768934764100643
Epoch 12: Train acc: 0.6243837782531857, Train loss: 0.02057666969913934 |Validation ac
c: 0.6201895254629629, Validation loss: 0.019839456766423732
Epoch 13: Train acc: 0.623515641955787, Train loss: 0.019612456262885464 |Validation ac
c: 0.6177662037037037, Validation loss: 0.01917563683079771
Epoch 14: Train acc: 0.6277478064056057, Train loss: 0.019007412946122515 |Validation ac
c: 0.6253978587962963, Validation loss: 0.018658459252879598
Epoch 15: Train acc: 0.6267246457693858, Train loss: 0.018425075674446116 |Validation ac
c: 0.6220341435185185, Validation loss: 0.01784237236536221
Epoch 16: Train acc: 0.6271509627011441, Train loss: 0.018083317318616177 |Validation ac
c: 0.6213831018518519, Validation loss: 0.017786949049427177
Epoch 17: Train acc: 0.6272439773044368, Train loss: 0.01761365145478033 |Validation ac
```

```
c: 0.6189959490740741, Validation loss: 0.01712106692795407
Epoch 18: Train acc: 0.6344681114935045, Train loss: 0.016729918576622222 |Validation ac
c: 0.6270254629629629, Validation loss: 0.016685595970810874
Epoch 19: Train acc: 0.6302436982606269, Train loss: 0.01659342707950036 |Validation ac
c: 0.6231553819444444, Validation loss: 0.016227395613663983
Epoch 20: Train acc: 0.6308017858803833, Train loss: 0.01617400275504642 |Validation ac
c: 0.6247106481481481, Validation loss: 0.015797270660893852
Epoch 21: Train acc: 0.6312048491613184, Train loss: 0.015907581906644104 |Validation ac
c: 0.6257595486111112, Validation loss: 0.015886073885070996
Epoch 22: Train acc: 0.6338170092704555, Train loss: 0.015384846389050476 |Validation ac
c: 0.6276765046296297, Validation loss: 0.015430769838879123
Epoch 23: Train acc: 0.6308637956159117, Train loss: 0.01508915513472007 |Validation ac
c: 0.6243489583333334, Validation loss: 0.015383969829348676
Epoch 24: Train acc: 0.6347471553033827, Train loss: 0.015098830850833602 |Validation ac
c: 0.6282913773148148, Validation loss: 0.015387267670221074
Epoch 25: Train acc: 0.6399249682200105, Train loss: 0.015119063557410276 |Validation ac
c: 0.6337167245370371, Validation loss: 0.014592083766559023
Epoch 26: Train acc: 0.6388475490652032, Train loss: 0.014761345427848111 |Validation ac
c: 0.6331380208333334, Validation loss: 0.014710551889154518
Epoch 27: Train acc: 0.6410566458934053, Train loss: 0.014797429883029057 |Validation ac
c: 0.6368272569444444, Validation loss: 0.014106971713319112
Epoch 28: Train acc: 0.6415914798623383, Train loss: 0.013995484755725464 |Validation ac
c: 0.6354528356481481, Validation loss: 0.014168128391965473
Epoch 29: Train acc: 0.6394909000713112, Train loss: 0.014105835269020112 |Validation ac
c: 0.6334635416666666, Validation loss: 0.014032459804008905
Epoch 30: Train acc: 0.6391963538275509, Train loss: 0.013901810666120637 |Validation ac
c: 0.6334997106481481, Validation loss: 0.013675414074145987
Epoch 31: Train acc: 0.6391498465259046, Train loss: 0.013900610923667601 |Validation ac
c: 0.6329210069444444, Validation loss: 0.013767591464811334
Epoch 32: Train acc: 0.6380259200694509, Train loss: 0.013690488146291908 |Validation ac
c: 0.6325593171296297, Validation loss: 0.013793715925262661
Epoch 33: Train acc: 0.6395761634576629, Train loss: 0.013445496955715142 |Validation ac
c: 0.6323061342592593, Validation loss: 0.013235098298207942
Epoch 34: Train acc: 0.6413279384863424, Train loss: 0.013368393265495757 |Validation ac
c: 0.6356698495370371, Validation loss: 0.013413160258644323
Epoch 35: Train acc: 0.6422348308684463, Train loss: 0.01335069065836178 |Validation ac
c: 0.6362485532407407, Validation loss: 0.013248763316606644
Epoch 36: Train acc: 0.6416147335131616, Train loss: 0.013114999596980188 |Validation ac
c: 0.6365017361111112, Validation loss: 0.013253296713015889
Epoch 37: Train acc: 0.6408241093851734, Train loss: 0.013128362264406787 |Validation ac
c: 0.6346209490740741, Validation loss: 0.012767125665865154
Epoch 38: Train acc: 0.6449322543639351, Train loss: 0.013304881703174875 |Validation ac
c: 0.6397207754629629, Validation loss: 0.012841789719292158
Epoch 39: Train acc: 0.6391653489597867, Train loss: 0.013057169367667033 |Validation ac
c: 0.6344039351851852, Validation loss: 0.01305564308334529
Epoch 40: Train acc: 0.6423123430378569, Train loss: 0.012819482520697997 |Validation ac
c: 0.6377676504629629, Validation loss: 0.013146825065664969
Epoch 41: Train acc: 0.6472653706631941, Train loss: 0.013004667533268649 |Validation ac
c: 0.6415292245370371, Validation loss: 0.013060201882475916
Epoch 42: Train acc: 0.6473506340495457, Train loss: 0.012874107813401817 |Validation ac
c: 0.640625, Validation loss: 0.012829759369607053
Epoch 43: Train acc: 0.6466297708740272, Train loss: 0.012762113287768573 |Validation ac
c: 0.6415292245370371, Validation loss: 0.012967459498199935
Epoch 44: Train acc: 0.6446609617709981, Train loss: 0.012500098918893482 |Validation ac
c: 0.6389612268518519, Validation loss: 0.012532798259709727
Epoch 45: Train acc: 0.6485133165907048, Train loss: 0.012366675482979957 |Validation ac
c: 0.6420717592592593, Validation loss: 0.012540450862688993
Epoch 46: Train acc: 0.6458158930952159, Train loss: 0.012203120822722551 |Validation ac
c: 0.6405164930555556, Validation loss: 0.012574433940476587
Epoch 47: Train acc: 0.6482807800824729, Train loss: 0.012390315532684326 |Validation ac
c: 0.6423972800925926, Validation loss: 0.012921470431583306
Epoch 48: Train acc: 0.6525206957492327, Train loss: 0.012338390513060708 |Validation ac
c: 0.6464482060185185, Validation loss: 0.012566418023586538
Epoch 49: Train acc: 0.6515052863299537, Train loss: 0.012361503076305728 |Validation ac
c: 0.6461950231481481, Validation loss: 0.012346644251599068
```

```
Epoch 50: Train acc: 0.6513270083403094, Train loss: 0.012289697927552709 |Validation ac
c: 0.6447844328703703, Validation loss: 0.012281576765684593
Epoch 51: Train acc: 0.6437695718227762, Train loss: 0.012673492420420537 |Validation ac
c: 0.6367549189814815, Validation loss: 0.012755094708194983
Epoch 52: Train acc: 0.6491179115121074, Train loss: 0.01237554738480454 |Validation ac
c: 0.6424334490740741, Validation loss: 0.012133593063038782
Epoch 53: Train acc: 0.648807862834465, Train loss: 0.012191568911683577 |Validation ac
c: 0.6431929976851852, Validation loss: 0.012001043558673442
Epoch 54: Train acc: 0.6533113198772207, Train loss: 0.012483162976779287 |Validation ac
c: 0.6476779513888888, Validation loss: 0.012001129299767028
Epoch 55: Train acc: 0.6507844231544353, Train loss: 0.012545109488821702 |Validation ac
c: 0.6459056712962963, Validation loss: 0.012505300746517648
Epoch 56: Train acc: 0.6548770656993148, Train loss: 0.012091659564933898 |Validation ac
c: 0.6471715856481481, Validation loss: 0.01216996735713558
Epoch 57: Train acc: 0.6514665302452485, Train loss: 0.012214930629971208 |Validation ac
c: 0.6453631365740741, Validation loss: 0.012149226531187399
Epoch 58: Train acc: 0.6527377298235824, Train loss: 0.012079597283596897 |Validation ac
c: 0.6458333333333334, Validation loss: 0.012144526893698585
Epoch 59: Train acc: 0.6522106470715903, Train loss: 0.012275310434975857 |Validation ac
c: 0.6469184027777778, Validation loss: 0.01196321103036492
Epoch 60: Train acc: 0.6525284469661737, Train loss: 0.012306465935901647 |Validation ac
c: 0.6470992476851852, Validation loss: 0.01210632160836582
Epoch 61: Train acc: 0.65089294019161, Train loss: 0.011635144552055646 |Validation acc:
0.6452546296296297, Validation loss: 0.011964260168008794
Epoch 62: Train acc: 0.6536833782903916, Train loss: 0.011935401069503334 |Validation ac
c: 0.6477141203703703, Validation loss: 0.011942367027969672
Epoch 63: Train acc: 0.6517300716212445, Train loss: 0.011890787292736132 |Validation ac
c: 0.6450014467592593, Validation loss: 0.011876699398617185
Epoch 64: Train acc: 0.6544584999844976, Train loss: 0.0120757882986273 |Validation acc:
0.6489438657407407, Validation loss: 0.011833555783623228
Epoch 65: Train acc: 0.6559777385049452, Train loss: 0.011706073490698278 |Validation ac
c: 0.6494502314814815, Validation loss: 0.012150479922795155
Epoch 66: Train acc: 0.654388739032028, Train loss: 0.011841084097874094 |Validation ac
c: 0.6491608796296297, Validation loss: 0.01192004394438394
Epoch 67: Train acc: 0.6520168666480638, Train loss: 0.0122171903626015 |Validation acc:
0.6452184606481481, Validation loss: 0.012103708788409873
Epoch 68: Train acc: 0.6573884599882182, Train loss: 0.012024033865794672 |Validation ac
c: 0.6530309606481481, Validation loss: 0.01195804419504473
Epoch 69: Train acc: 0.6549700803026075, Train loss: 0.012078400789718599 |Validation ac
c: 0.6490162037037037, Validation loss: 0.012157839989615742
Epoch 70: Train acc: 0.6544584999844976, Train loss: 0.011874735580608028 |Validation ac
c: 0.6494140625, Validation loss: 0.01224815835402477
Epoch 71: Train acc: 0.6553653923666015, Train loss: 0.01173395703571575 |Validation ac
c: 0.6503182870370371, Validation loss: 0.011474799945154601
Epoch 72: Train acc: 0.651528539980777, Train loss: 0.011486409755716603 |Validation ac
c: 0.6456524884259259, Validation loss: 0.011947925958384481
Epoch 73: Train acc: 0.6539314172325055, Train loss: 0.011439336271741004 |Validation ac
c: 0.6474609375, Validation loss: 0.011584768106315273
Epoch 74: Train acc: 0.6538384026292128, Train loss: 0.011985038542561785 |Validation ac
c: 0.6485098379629629, Validation loss: 0.011551351174546367
Epoch 75: Train acc: 0.6516448082348929, Train loss: 0.011526895012673356 |Validation ac
c: 0.6467375578703703, Validation loss: 0.011790262973240026
Epoch 76: Train acc: 0.6576597525811553, Train loss: 0.01159946178431548 |Validation ac
c: 0.6511501736111112, Validation loss: 0.011469341241077517
Epoch 77: Train acc: 0.6523269153257061, Train loss: 0.011595836453670388 |Validation ac
c: 0.6471354166666666, Validation loss: 0.011815673468540525
Epoch 78: Train acc: 0.6576054940625679, Train loss: 0.011815025059379173 |Validation ac
c: 0.6505353009259259, Validation loss: 0.011329469588814573
Epoch 79: Train acc: 0.6530632809351068, Train loss: 0.011630357483551127 |Validation ac
c: 0.6481481481481481, Validation loss: 0.011740647992865356
Epoch 80: Train acc: 0.6577450159675069, Train loss: 0.011660437942523985 |Validation ac
c: 0.6513310185185185, Validation loss: 0.011407571470293075
Epoch 81: Train acc: 0.6521951446377081, Train loss: 0.011912781213208459 |Validation ac
c: 0.6469545717592593, Validation loss: 0.011397102963765227
Epoch 82: Train acc: 0.6588379375561964, Train loss: 0.011631625620178459 |Validation ac
```

```
c: 0.6549117476851852, Validation loss: 0.01169117163446696
Epoch 83: Train acc: 0.6592332496201904, Train loss: 0.011387417544762794 |Validation ac
c: 0.6553819444444444, Validation loss: 0.01144216137659081
Epoch 84: Train acc: 0.6604966979815831, Train loss: 0.011566253674689138 |Validation ac
c: 0.6548755787037037, Validation loss: 0.011352437723825964
Epoch 85: Train acc: 0.6610702880352215, Train loss: 0.011623466898651258 |Validation ac
c: 0.6554904513888888, Validation loss: 0.011673690404367111
Epoch 86: Train acc: 0.6612485660248659, Train loss: 0.01162720992415038 |Validation ac
c: 0.6545500578703703, Validation loss: 0.011360688577198842
Epoch 87: Train acc: 0.6622794778780269, Train loss: 0.011392747625454332 |Validation ac
c: 0.6562138310185185, Validation loss: 0.011242817840000023
Epoch 88: Train acc: 0.6569466406225778, Train loss: 0.011398826787961254 |Validation ac
c: 0.6519097222222222, Validation loss: 0.011167206504390483
Epoch 89: Train acc: 0.6629073264502527, Train loss: 0.011545479104188147 |Validation ac
c: 0.6581307870370371, Validation loss: 0.011268529638880172
Epoch 90: Train acc: 0.6589774594611354, Train loss: 0.011311692638925l7 |Validation ac
c: 0.6531394675925926, Validation loss: 0.011233286565937963
Epoch 91: Train acc: 0.6588999472917249, Train loss: 0.011338972041621053 |Validation ac
c: 0.6528501157407407, Validation loss: 0.011289247527210047
Epoch 92: Train acc: 0.6657287694167985, Train loss: 0.011222711645442583 |Validation ac
c: 0.6602647569444444, Validation loss: 0.011048353943166818
Epoch 93: Train acc: 0.6579775524757386, Train loss: 0.011615836926534197 |Validation ac
c: 0.6541883680555556, Validation loss: 0.011273739902297096
Epoch 94: Train acc: 0.6666201593650203, Train loss: 0.011180925913962041 |Validation ac
c: 0.6616030092592593, Validation loss: 0.011332705267359577
Epoch 95: Train acc: 0.6635816823241248, Train loss: 0.011310827474797957 |Validation ac
c: 0.65625, Validation loss: 0.011278096341890026
Epoch 96: Train acc: 0.6659923107927944, Train loss: 0.01118545603277908 |Validation ac
c: 0.6598668981481481, Validation loss: 0.011205519452823729
Epoch 97: Train acc: 0.6649613989396336, Train loss: 0.011012764239976686 |Validation ac
c: 0.6595052083333334, Validation loss: 0.01145361118897442
Epoch 98: Train acc: 0.6651784330139832, Train loss: 0.011097410996375434 |Validation ac
c: 0.66015625, Validation loss: 0.010998703785329085
Epoch 99: Train acc: 0.6611012929029858, Train loss: 0.011119009006646868 |Validation ac
c: 0.6561053240740741, Validation loss: 0.010635232156313934
Epoch 100: Train acc: 0.6635429262394196, Train loss: 0.011061536743739504 |Validation a
cc: 0.6584924768518519, Validation loss: 0.010940944496818572
Epoch 101: Train acc: 0.661651629305801, Train loss: 0.010782694010870968 |Validation ac
c: 0.6567563657407407, Validation loss: 0.010931896088639335
Epoch 102: Train acc: 0.6599231079279447, Train loss: 0.010871997817477504 |Validation a
cc: 0.6536820023148148, Validation loss: 0.011005403473973274
Epoch 103: Train acc: 0.6624577558676712, Train loss: 0.011122594848662085 |Validation a
cc: 0.6580946180555556, Validation loss: 0.011234800328530968
Epoch 104: Train acc: 0.6696121291042694, Train loss: 0.01091994625828519 |Validation ac
c: 0.6649667245370371, Validation loss: 0.010880861881821906
Epoch 105: Train acc: 0.6687982513254581, Train loss: 0.010971644937505708 |Validation a
cc: 0.6631944444444444, Validation loss: 0.010939950011504775
Epoch 106: Train acc: 0.6631243605246023, Train loss: 0.010830018630676877 |Validation a
cc: 0.6595775462962963, Validation loss: 0.01077810318958158
Epoch 107: Train acc: 0.6703252410628469, Train loss: 0.010895160945734833 |Validation a
cc: 0.6644603587962963, Validation loss: 0.011119479032990575
Epoch 108: Train acc: 0.6677285833875919, Train loss: 0.010900803805724096 |Validation a
cc: 0.6635561342592593, Validation loss: 0.010665188999487313
Epoch 109: Train acc: 0.6652559451833938, Train loss: 0.010885077304806482 |Validation a
cc: 0.6607711226851852, Validation loss: 0.010848239290829228
Epoch 110: Train acc: 0.671774718630825, Train loss: 0.011039842348490519 |Validation ac
c: 0.6671368634259259, Validation loss: 0.010754027676102581
Epoch 111: Train acc: 0.6732164449818622, Train loss: 0.010531396701799303 |Validation a
cc: 0.6694155092592593, Validation loss: 0.010553690915767003
Epoch 112: Train acc: 0.6636979505782408, Train loss: 0.010823107238869992 |Validation a
cc: 0.6606626157407407, Validation loss: 0.010810750200156156
Epoch 113: Train acc: 0.6700461972529688, Train loss: 0.010770439758941045 |Validation a
cc: 0.6663049768518519, Validation loss: 0.010915886341298458
Epoch 114: Train acc: 0.6698136607447369, Train loss: 0.010701525671744736 |Validation a
cc: 0.6648220486111112, Validation loss: 0.011143943308700617
```

```
Epoch 115: Train acc: 0.66749604687936, Train loss: 0.010574539095295996 |Validation ac
c: 0.6629774305555556, Validation loss: 0.010540712150836292
Epoch 116: Train acc: 0.6750922394815986, Train loss: 0.010725875177837975 |Validation a
cc: 0.6683666087962963, Validation loss: 0.010469455274722874
Epoch 117: Train acc: 0.6718522308002356, Train loss: 0.010815537121500653 |Validation a
cc: 0.6678240740740741, Validation loss: 0.010442879873131698
Epoch 118: Train acc: 0.6695423681517998, Train loss: 0.010403837573380162 |Validation a
cc: 0.6622178819444444, Validation loss: 0.01053342500629694
Epoch 119: Train acc: 0.680990915573745, Train loss: 0.010582950811844197 |Validation ac
c: 0.6762876157407407, Validation loss: 0.010509603169058569
Epoch 120: Train acc: 0.6745961615973708, Train loss: 0.010531943214045788 |Validation a
cc: 0.6696686921296297, Validation loss: 0.010309819245395922
Epoch 121: Train acc: 0.6712321334449508, Train loss: 0.010610246103677003 |Validation a
cc: 0.6657986111111112, Validation loss: 0.010394537878065241
Epoch 122: Train acc: 0.6801382817102285, Train loss: 0.010249323344261603 |Validation a
cc: 0.6740089699074074, Validation loss: 0.010515938167534879
Epoch 123: Train acc: 0.6714414163023594, Train loss: 0.010241578689580148 |Validation a
cc: 0.6666304976851852, Validation loss: 0.010321024157250582
Epoch 124: Train acc: 0.6767742535578086, Train loss: 0.010354181997566443 |Validation a
cc: 0.6712962962962963, Validation loss: 0.010727318135043191
Epoch 125: Train acc: 0.6786345456236629, Train loss: 0.010886685777654545 |Validation a
cc: 0.6737919560185185, Validation loss: 0.01053187450620647
Epoch 126: Train acc: 0.6707593092115463, Train loss: 0.010393489558437635 |Validation a
cc: 0.6665943287037037, Validation loss: 0.010535184936515037
Epoch 127: Train acc: 0.6799289988528199, Train loss: 0.010356908445785414 |Validation a
cc: 0.6753110532407407, Validation loss: 0.010128721773060652
Epoch 128: Train acc: 0.6854556165317955, Train loss: 0.010347546197098158 |Validation a
cc: 0.6804470486111112, Validation loss: 0.01045056593187087
Epoch 129: Train acc: 0.6826961833007782, Train loss: 0.010235866050868785 |Validation a
cc: 0.6781322337962963, Validation loss: 0.01030935602295779
Epoch 130: Train acc: 0.6788903357827178, Train loss: 0.010764591066990303 |Validation a
cc: 0.6744791666666666, Validation loss: 0.010244427346942244
Epoch 131: Train acc: 0.687990264471522, Train loss: 0.010300726433580282 |Validation ac
c: 0.6839916087962963, Validation loss: 0.010073063142033907
Epoch 132: Train acc: 0.6807738814993954, Train loss: 0.010625220592014867 |Validation a
cc: 0.6761429398148148, Validation loss: 0.010419460729963923
Epoch 133: Train acc: 0.6814559885902086, Train loss: 0.010292360332493259 |Validation a
cc: 0.6773003472222222, Validation loss: 0.009856569605605893
Epoch 134: Train acc: 0.67254208910799, Train loss: 0.010196952091237027 |Validation ac
c: 0.6671368634259259, Validation loss: 0.010422742844059047
Epoch 135: Train acc: 0.6851378166372121, Train loss: 0.010539948990021333 |Validation a
cc: 0.6794343171296297, Validation loss: 0.010532646654146096
Epoch 136: Train acc: 0.685393606796267, Train loss: 0.010140961082375855 |Validation ac
c: 0.6826895254629629, Validation loss: 0.010333116124840095
Epoch 137: Train acc: 0.6771850680556848, Train loss: 0.010097512739050017 |Validation a
cc: 0.6711154513888888, Validation loss: 0.010243059343241089
Epoch 138: Train acc: 0.6859439431990823, Train loss: 0.010279225712664182 |Validation a
cc: 0.6810619212962963, Validation loss: 0.010085307160469783
Epoch 139: Train acc: 0.6772935850928595, Train loss: 0.010064292688735205 |Validation a
cc: 0.6713686342592593, Validation loss: 0.010319640468916572
Epoch 140: Train acc: 0.6820528322946703, Train loss: 0.010206375750561054 |Validation a
cc: 0.6774811921296297, Validation loss: 0.01013607374815276
Epoch 141: Train acc: 0.6838821194927603, Train loss: 0.010081820824191814 |Validation a
cc: 0.6783130787037037, Validation loss: 0.01025675669953625
Epoch 142: Train acc: 0.6847890118748644, Train loss: 0.01001845526810216 |Validation ac
c: 0.6802300347222222, Validation loss: 0.010392757244573945
Epoch 143: Train acc: 0.6877112206616439, Train loss: 0.010290772956726901 |Validation a
cc: 0.681640625, Validation loss: 0.010206846071224804
Epoch 144: Train acc: 0.6894397420395002, Train loss: 0.010376607779501897 |Validation a
cc: 0.6836299189814815, Validation loss: 0.009941006113860744
Epoch 145: Train acc: 0.6878894986512882, Train loss: 0.010181158403824539 |Validation a
cc: 0.6823640046296297, Validation loss: 0.010333502374987397
Epoch 146: Train acc: 0.6926177409853347, Train loss: 0.010126122390956394 |Validation a
cc: 0.6882233796296297, Validation loss: 0.009947388589061598
Epoch 147: Train acc: 0.6907264440517161, Train loss: 0.010055992703951166 |Validation a
```

```
cc: 0.6851851851851852, Validation loss: 0.010076280552009535
Epoch 148: Train acc: 0.6910674975971227, Train loss: 0.010146782806734568 |Validation a
cc: 0.6855107060185185, Validation loss: 0.009728575009266771
Epoch 149: Train acc: 0.6879825132545809, Train loss: 0.010024964320266106 |Validation a
cc: 0.6831235532407407, Validation loss: 0.010016181381855945
Epoch 150: Train acc: 0.6920441509316962, Train loss: 0.010309340928346802 |Validation a
cc: 0.6868127893518519, Validation loss: 0.010224049280809366
Epoch 151: Train acc: 0.6921681704027532, Train loss: 0.010243450106295704 |Validation a
cc: 0.6884765625, Validation loss: 0.009998738972984188
Epoch 152: Train acc: 0.6894707469072644, Train loss: 0.010280292729905167 |Validation a
cc: 0.6859447337962963, Validation loss: 0.00997211998300931
Epoch 153: Train acc: 0.676828512076396, Train loss: 0.010399373680717956 |Validation ac
c: 0.6707537615740741, Validation loss: 0.010198622292532234
Epoch 154: Train acc: 0.6853703531454438, Train loss: 0.009919263194494767 |Validation a
cc: 0.6813151041666666, Validation loss: 0.009983427731392115
Epoch 155: Train acc: 0.6942377453260162, Train loss: 0.010144311292179879 |Validation a
cc: 0.6877893518518519, Validation loss: 0.009931427777609414
Epoch 156: Train acc: 0.6794716770532974, Train loss: 0.009606402927666947 |Validation a
cc: 0.6738642939814815, Validation loss: 0.010145201456929261
Epoch 157: Train acc: 0.6893389762192664, Train loss: 0.00999165681337258 |Validation ac
c: 0.6846788194444444, Validation loss: 0.009761141147464514
Epoch 158: Train acc: 0.6901683564319598, Train loss: 0.00999138297137282 |Validation ac
c: 0.6851490162037037, Validation loss: 0.010096596283782882
Epoch 159: Train acc: 0.6896490248969088, Train loss: 0.010078697719608464 |Validation a
cc: 0.6852936921296297, Validation loss: 0.010108368795293242
Epoch 160: Train acc: 0.6927495116733328, Train loss: 0.009999797302256794 |Validation a
cc: 0.6872829861111112, Validation loss: 0.010389666950457262
Epoch 161: Train acc: 0.6874941865872942, Train loss: 0.009974265008203089 |Validation a
cc: 0.6820384837962963, Validation loss: 0.009835938616304794
Epoch 162: Train acc: 0.686036957802375, Train loss: 0.009841431612121245 |Validation ac
c: 0.6803023726851852, Validation loss: 0.009947584709843471
Epoch 163: Train acc: 0.6877732303971723, Train loss: 0.010024080308601923 |Validation a
cc: 0.6818938078703703, Validation loss: 0.010089138881317189
Epoch 164: Train acc: 0.6905636684959539, Train loss: 0.010312445955047003 |Validation a
cc: 0.6846426504629629, Validation loss: 0.009743512963229454
Epoch 165: Train acc: 0.6938114283942579, Train loss: 0.00997262820463285 |Validation ac
c: 0.6883680555555556, Validation loss: 0.01007673603645595
Epoch 166: Train acc: 0.6917651071218182, Train loss: 0.009584629064624803 |Validation a
cc: 0.6865596064814815, Validation loss: 0.009807955563477399
Epoch 167: Train acc: 0.6888118934672743, Train loss: 0.009513489299561573 |Validation a
cc: 0.6850766782407407, Validation loss: 0.009938752256577022
Epoch 168: Train acc: 0.6923619508262797, Train loss: 0.009856006608673478 |Validation a
cc: 0.6868851273148148, Validation loss: 0.00965232662414408
Epoch 169: Train acc: 0.69097448299383, Train loss: 0.009882574049805675 |Validation ac
c: 0.6865234375, Validation loss: 0.009654982154359847
Epoch 170: Train acc: 0.6935323845843797, Train loss: 0.010174642054458047 |Validation a
cc: 0.6861617476851852, Validation loss: 0.009957834978750977
Epoch 171: Train acc: 0.6898428053204353, Train loss: 0.009979414974701334 |Validation a
cc: 0.6841724537037037, Validation loss: 0.010126307740039262
Epoch 172: Train acc: 0.6918426192912287, Train loss: 0.009898939324703168 |Validation a
cc: 0.6863787615740741, Validation loss: 0.009804168870832871
Epoch 173: Train acc: 0.6938811893467275, Train loss: 0.009747231719070265 |Validation a
cc: 0.6876085069444444, Validation loss: 0.00970453436787652
Epoch 174: Train acc: 0.6899590735745512, Train loss: 0.009823124862665681 |Validation a
cc: 0.685546875, Validation loss: 0.00959841931620143
Epoch 175: Train acc: 0.6917806095557002, Train loss: 0.009673034951908828 |Validation a
cc: 0.6869212962962963, Validation loss: 0.009728345238584306
Epoch 176: Train acc: 0.6948190865965956, Train loss: 0.00969926249622768 |Validation ac
c: 0.6887659143518519, Validation loss: 0.009807701118964736
Epoch 177: Train acc: 0.6908659659566552, Train loss: 0.009953537265678939 |Validation a
cc: 0.6863787615740741, Validation loss: 0.009783040027435349
Epoch 178: Train acc: 0.6900365857439618, Train loss: 0.00998240532643695 |Validation ac
c: 0.6840639467592593, Validation loss: 0.009815534404050615
Epoch 179: Train acc: 0.6906566830992465, Train loss: 0.009855793462928041 |Validation a
cc: 0.6847149884259259, Validation loss: 0.009784587124882138
```

```
Epoch 180: Train acc: 0.6922611850060459, Train loss: 0.009840521980795556 |Validation a
cc: 0.6869936342592593, Validation loss: 0.009800102324045377
Epoch 181: Train acc: 0.6897110346324373, Train loss: 0.009925201539370267 |Validation a
cc: 0.6847873263888888, Validation loss: 0.009928959255999379
Epoch 182: Train acc: 0.6894397420395002, Train loss: 0.009658126026469363 |Validation a
cc: 0.6852575231481481, Validation loss: 0.009682769200402569
Epoch 183: Train acc: 0.6941059746380182, Train loss: 0.01026486423839359 |Validation ac
c: 0.6890552662037037, Validation loss: 0.009596468960916076
Epoch 184: Train acc: 0.69433851114625, Train loss: 0.010268211567177485 |Validation ac
c: 0.6886935763888888, Validation loss: 0.009973913179682872
Epoch 185: Train acc: 0.6928812823613307, Train loss: 0.010069773703791444 |Validation a
cc: 0.6880425347222222, Validation loss: 0.00989502781825223
Epoch 186: Train acc: 0.6964390909372772, Train loss: 0.009890990135555628 |Validation a
cc: 0.6911168981481481, Validation loss: 0.009681182852683682
Epoch 187: Train acc: 0.6960437788732831, Train loss: 0.009967440404721953 |Validation ac
c: 0.6907552083333334, Validation loss: 0.009598364774414092
Epoch 188: Train acc: 0.6922844386568692, Train loss: 0.009734359257564346 |Validation a
cc: 0.6859447337962963, Validation loss: 0.00985153006024946
Epoch 189: Train acc: 0.6958887545344619, Train loss: 0.00982799939258516 |Validation ac
c: 0.6911530671296297, Validation loss: 0.009773649378936704
Epoch 190: Train acc: 0.6935091309335566, Train loss: 0.010110868707586644 |Validation a
cc: 0.6879340277777778, Validation loss: 0.009639375172251455
Epoch 191: Train acc: 0.6957957399311692, Train loss: 0.009200005844589156 |Validation a
cc: 0.6893084490740741, Validation loss: 0.009328466232794196
Epoch 192: Train acc: 0.6927572628902737, Train loss: 0.009379362237006868 |Validation a
cc: 0.6903573495370371, Validation loss: 0.009944186606706958
Epoch 193: Train acc: 0.6919123802436983, Train loss: 0.009218450675743358 |Validation a
cc: 0.6872468171296297, Validation loss: 0.009418050366113907
Epoch 194: Train acc: 0.688625864260689, Train loss: 0.010200940318494063 |Validation ac
c: 0.6849681712962963, Validation loss: 0.009758507778304311
Epoch 195: Train acc: 0.6923929556940439, Train loss: 0.009491859960787065 |Validation a
cc: 0.6871744791666666, Validation loss: 0.009630955149798214
Epoch 196: Train acc: 0.6957802374972871, Train loss: 0.009837028401895518 |Validation a
cc: 0.6896339699074074, Validation loss: 0.01007698089138602
Epoch 197: Train acc: 0.6950748767556506, Train loss: 0.009274416444242796 |Validation a
cc: 0.6894892939814815, Validation loss: 0.009941585031711117
Epoch 198: Train acc: 0.692904536012154, Train loss: 0.00982012264762151 |Validation ac
c: 0.6881510416666666, Validation loss: 0.009805126933696008
Epoch 199: Train acc: 0.6944470281834249, Train loss: 0.009391429129357861 |Validation a
cc: 0.6898148148148148, Validation loss: 0.00983320379240068
Epoch 200: Train acc: 0.6921139118841658, Train loss: 0.009490211171620367 |Validation a
cc: 0.6864510995370371, Validation loss: 0.009487630112665962
Epoch 201: Train acc: 0.6964003348525718, Train loss: 0.00971458842134993 |Validation ac
c: 0.6919487847222222, Validation loss: 0.009536613940982595
Epoch 202: Train acc: 0.6949353548507116, Train loss: 0.0100952882792259 |Validation ac
c: 0.6899233217592593, Validation loss: 0.009918364791547774
Epoch 203: Train acc: 0.6966638762285678, Train loss: 0.009765164778797226 |Validation a
cc: 0.6912615740740741, Validation loss: 0.009458889084859843
Epoch 204: Train acc: 0.6957182277617586, Train loss: 0.009370535587234207 |Validation a
cc: 0.6897786458333334, Validation loss: 0.009550026067303223
Epoch 205: Train acc: 0.6969274176045639, Train loss: 0.009559269427965762 |Validation a
cc: 0.6919487847222222, Validation loss: 0.009347874738928208
Epoch 206: Train acc: 0.6901373515641955, Train loss: 0.009636526671721869 |Validation a
cc: 0.6883680555555556, Validation loss: 0.009657964146300841
Epoch 207: Train acc: 0.6918426192912287, Train loss: 0.009647836027810632 |Validation a
cc: 0.6863787615740741, Validation loss: 0.00980592370226714
Epoch 208: Train acc: 0.6950283694540043, Train loss: 0.00950956491695424 |Validation ac
c: 0.6906467013888888, Validation loss: 0.009694035841395266
Epoch 209: Train acc: 0.6926952531547453, Train loss: 0.009808941009158727 |Validation a
cc: 0.6867766203703703, Validation loss: 0.009799319077614773
Epoch 210: Train acc: 0.6909589805599479, Train loss: 0.009381106635279269 |Validation a
cc: 0.6871744791666666, Validation loss: 0.009823334520787708
Epoch 211: Train acc: 0.6964778470219825, Train loss: 0.00989030662631113 |Validation ac
c: 0.6910083912037037, Validation loss: 0.009455148940380851
Epoch 212: Train acc: 0.6908969708244195, Train loss: 0.009531540834850657 |Validation a
```

```
cc: 0.6872468171296297, Validation loss: 0.009399318384305085
Epoch 213: Train acc: 0.6934703748488513, Train loss: 0.009580653890392548 |Validation a
cc: 0.6883318865740741, Validation loss: 0.009704881919774528
Epoch 214: Train acc: 0.6958344960158744, Train loss: 0.009465138998590078 |Validation a
cc: 0.6900318287037037, Validation loss: 0.00954038345183105
Epoch 215: Train acc: 0.6962220568629275, Train loss: 0.00980120136206334 |Validation ac
c: 0.6919487847222222, Validation loss: 0.009382861145448703
Epoch 216: Train acc: 0.6974700027904381, Train loss: 0.00953155957599024 |Validation ac
c: 0.6901765046296297, Validation loss: 0.009618256948556673
Epoch 217: Train acc: 0.6937106625740241, Train loss: 0.009544783213123326 |Validation a
cc: 0.6882957175925926, Validation loss: 0.009801145195988634
Epoch 218: Train acc: 0.6956174619415249, Train loss: 0.00970972642214079 |Validation ac
c: 0.6897424768518519, Validation loss: 0.00974605819044596
Epoch 219: Train acc: 0.6912922828884135, Train loss: 0.009491442629476064 |Validation a
cc: 0.6853298611111112, Validation loss: 0.01006294124917257
Epoch 220: Train acc: 0.6919201314606394, Train loss: 0.009553532234257645 |Validation a
cc: 0.6871021412037037, Validation loss: 0.009662249698980715
Epoch 221: Train acc: 0.6920441509316962, Train loss: 0.009963844289301233 |Validation a
cc: 0.6875723379629629, Validation loss: 0.009420334679303961
Epoch 222: Train acc: 0.6974079930549096, Train loss: 0.009679443430907207 |Validation a
cc: 0.6940465856481481, Validation loss: 0.009561553271349176
Epoch 223: Train acc: 0.6896102688122036, Train loss: 0.009693979235222281 |Validation a
cc: 0.6857638888888888, Validation loss: 0.009774705396484284
Epoch 224: Train acc: 0.689796298018789, Train loss: 0.009593631935413672 |Validation ac
c: 0.6875, Validation loss: 0.009379470660088677
Epoch 225: Train acc: 0.6919743899792268, Train loss: 0.009903740734746265 |Validation a
cc: 0.6871744791666666, Validation loss: 0.009721316417916858
Epoch 226: Train acc: 0.6979893343254892, Train loss: 0.009664999686585025 |Validation a
cc: 0.6917679398148148, Validation loss: 0.009172376777247169
Epoch 227: Train acc: 0.6922999410907512, Train loss: 0.00970062895509406 |Validation ac
c: 0.6865957754629629, Validation loss: 0.009569967408783358
Epoch 228: Train acc: 0.6942532477598983, Train loss: 0.008977666638172522 |Validation a
cc: 0.6902488425925926, Validation loss: 0.009287925618797408
Epoch 229: Train acc: 0.6959895203546956, Train loss: 0.010036977803892835 |Validation a
cc: 0.6905020254629629, Validation loss: 0.009508577809677368
Epoch 230: Train acc: 0.6963228226831613, Train loss: 0.009639092370071822 |Validation a
cc: 0.6918041087962963, Validation loss: 0.009376649275002034
Epoch 231: Train acc: 0.690323380770781, Train loss: 0.009424379112016554 |Validation ac
c: 0.6849681712962963, Validation loss: 0.009830612198723264
Epoch 232: Train acc: 0.6981288562304282, Train loss: 0.00912518791428792 |Validation ac
c: 0.6940465856481481, Validation loss: 0.00936530993350447
Epoch 233: Train acc: 0.6983458903047779, Train loss: 0.009696216500731799 |Validation a
cc: 0.6926721643518519, Validation loss: 0.009999112493444222
Epoch 234: Train acc: 0.698229622050662, Train loss: 0.009573700338275965 |Validation ac
c: 0.6928168402777778, Validation loss: 0.009384164498229056
Epoch 235: Train acc: 0.6973847394040864, Train loss: 0.00945786084670253 |Validation ac
c: 0.6893807870370371, Validation loss: 0.009240453081752673
Epoch 236: Train acc: 0.6940982234210771, Train loss: 0.009964171316176211 |Validation a
cc: 0.6884765625, Validation loss: 0.00965131267087219
Epoch 237: Train acc: 0.6960127740055189, Train loss: 0.00962764809035229 |Validation ac
c: 0.6914785879629629, Validation loss: 0.009507100057763321
Epoch 238: Train acc: 0.6979273245899607, Train loss: 0.009474571267811675 |Validation a
cc: 0.6926359953703703, Validation loss: 0.009549873684828642
Epoch 239: Train acc: 0.698113353796546, Train loss: 0.00965969123012588 |Validation ac
c: 0.6919487847222222, Validation loss: 0.00946610007097928
Epoch 240: Train acc: 0.6971444516789136, Train loss: 0.009471072619836169 |Validation a
cc: 0.6920934606481481, Validation loss: 0.009724280486043643
Epoch 241: Train acc: 0.6959430130530493, Train loss: 0.00957458147651983 |Validation ac
c: 0.6893084490740741, Validation loss: 0.009467706117414225
Epoch 242: Train acc: 0.6936253991876725, Train loss: 0.009740503138699499 |Validation a
cc: 0.6888382523148148, Validation loss: 0.009318196591962605
Epoch 243: Train acc: 0.6969584224723282, Train loss: 0.009640275368063493 |Validation a
cc: 0.6903211805555556, Validation loss: 0.009388267329288784
Epoch 244: Train acc: 0.6941059746380182, Train loss: 0.009285608024643155 |Validation a
cc: 0.6876808449074074, Validation loss: 0.009628871530404962
```

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Epoch 245: Train acc: 0.6973537345363222, Train loss: 0.009521982879225906 |Validation a
cc: 0.6903573495370371, Validation loss: 0.009326247693915529
Epoch 246: Train acc: 0.6982063683998387, Train loss: 0.009538035700926751 |Validation a
cc: 0.6939019097222222, Validation loss: 0.009470921556274641
Epoch 247: Train acc: 0.6956174619415249, Train loss: 0.009612370799198888 |Validation ac
c: 0.6907190393518519, Validation loss: 0.009349091259005427
Epoch 248: Train acc: 0.6967258859640963, Train loss: 0.009899442084133625 |Validation a
cc: 0.6921296296296297, Validation loss: 0.009827564781371404
Epoch 249: Train acc: 0.6949508572845937, Train loss: 0.009495600427912676 |Validation a
cc: 0.6887297453703703, Validation loss: 0.00939808618304947
Epoch 250: Train acc: 0.6870446160047128, Train loss: 0.009546659394921818 |Validation a
cc: 0.6809534143518519, Validation loss: 0.009320635058383736
Epoch 251: Train acc: 0.6959817691377547, Train loss: 0.009360915384993222 |Validation a
cc: 0.6913700810185185, Validation loss: 0.009714009150453685
Epoch 252: Train acc: 0.69550894490435, Train loss: 0.009409326648903397 |Validation ac
c: 0.6912254050925926, Validation loss: 0.009562758125022098
Epoch 253: Train acc: 0.6904163953740737, Train loss: 0.009494881741205115 |Validation a
cc: 0.6849320023148148, Validation loss: 0.009546064021402987
Epoch 254: Train acc: 0.6984621585588937, Train loss: 0.009628344441208579 |Validation a
cc: 0.6946976273148148, Validation loss: 0.009328216084248721
Epoch 255: Train acc: 0.696415837286454, Train loss: 0.009508729071524934 |Validation ac
c: 0.6920211226851852, Validation loss: 0.008976882265587766
Epoch 256: Train acc: 0.6997411093541686, Train loss: 0.009185024929572815 |Validation a
cc: 0.6927445023148148, Validation loss: 0.00938626564762801
Epoch 257: Train acc: 0.6956872228939943, Train loss: 0.009463836786472613 |Validation a
cc: 0.6901765046296297, Validation loss: 0.009460143127287973
Epoch 258: Train acc: 0.6963693299848076, Train loss: 0.009470046153817137 |Validation a
cc: 0.6928891782407407, Validation loss: 0.00946325959792521
Epoch 259: Train acc: 0.6977878026850215, Train loss: 0.009441903363277677 |Validation a
cc: 0.6920211226851852, Validation loss: 0.009154195978806439
Epoch 260: Train acc: 0.6962608129476328, Train loss: 0.009532595743516389 |Validation a
cc: 0.6911168981481481, Validation loss: 0.009451592524842711
Epoch 261: Train acc: 0.6949973645862401, Train loss: 0.009268956911786063 |Validation a
cc: 0.6921296296296297, Validation loss: 0.0096203272123144
Epoch 262: Train acc: 0.697718041732552, Train loss: 0.009484235910306345 |Validation ac
c: 0.6917679398148148, Validation loss: 0.009601254906720905
Epoch 263: Train acc: 0.6987334511518308, Train loss: 0.009491597957223742 |Validation a
cc: 0.6954571759259259, Validation loss: 0.009406658838771129
Epoch 264: Train acc: 0.6965786128422162, Train loss: 0.009360034335183549 |Validation a
cc: 0.6911530671296297, Validation loss: 0.009560062478155516
Epoch 265: Train acc: 0.6957879887142281, Train loss: 0.00929027060406056 |Validation ac
c: 0.6902850115740741, Validation loss: 0.009155105688202938
Epoch 266: Train acc: 0.6913852974917062, Train loss: 0.009646461613321517 |Validation a
cc: 0.6879701967592593, Validation loss: 0.009506461770171493
Epoch 267: Train acc: 0.697330480885499, Train loss: 0.00988859901597132 |Validation ac
c: 0.6909360532407407, Validation loss: 0.009380689923007605
Epoch 268: Train acc: 0.699787616655815, Train loss: 0.009170999017458421 |Validation ac
c: 0.6939742476851852, Validation loss: 0.009251926571009155
Epoch 269: Train acc: 0.6962918178153971, Train loss: 0.009204241937684111 |Validation a
cc: 0.6906828703703703, Validation loss: 0.009112666098494912
Epoch 270: Train acc: 0.6954159303010573, Train loss: 0.009352860795416888 |Validation a
cc: 0.6904658564814815, Validation loss: 0.009592689623509034
Epoch 271: Train acc: 0.6981366074473693, Train loss: 0.009601756776282316 |Validation a
cc: 0.6924913194444444, Validation loss: 0.009494739122417794
Epoch 272: Train acc: 0.6987799584534772, Train loss: 0.009336601872306638 |Validation a
cc: 0.6918764467592593, Validation loss: 0.00939495225702288
Epoch 273: Train acc: 0.6920286484978142, Train loss: 0.009163690943724146 |Validation a
cc: 0.6890914351851852, Validation loss: 0.009531064059872744
Epoch 274: Train acc: 0.6970049297739745, Train loss: 0.009382793520928225 |Validation a
cc: 0.6924189814814815, Validation loss: 0.009444368939614615
Epoch 275: Train acc: 0.6985706755960686, Train loss: 0.00894001719489344 |Validation ac
c: 0.6933232060185185, Validation loss: 0.009171980785521007
Epoch 276: Train acc: 0.6915558242644095, Train loss: 0.009480355922353816 |Validation a
cc: 0.6846788194444444, Validation loss: 0.009464603120555068
Epoch 277: Train acc: 0.7004542213127462, Train loss: 0.009594607423957803 |Validation a
```

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cc: 0.6944444444444444, Validation loss: 0.009307595119101357
Epoch 278: Train acc: 0.6952919108300003, Train loss: 0.009228066932299458 |Validation a
cc: 0.6880425347222222, Validation loss: 0.009524303107751804
Epoch 279: Train acc: 0.6956949741109354, Train loss: 0.009479332034053276 |Validation a
cc: 0.6904658564814815, Validation loss: 0.009000433773321903
Epoch 280: Train acc: 0.6988264657551235, Train loss: 0.00901642353108114 |Validation ac
c: 0.6929976851851852, Validation loss: 0.009364465291636722
Epoch 281: Train acc: 0.6986946950671256, Train loss: 0.009500027794490405 |Validation a
cc: 0.6936125578703703, Validation loss: 0.00941875711558746
Epoch 282: Train acc: 0.6992295290360586, Train loss: 0.009209723730684875 |Validation a
cc: 0.6941189236111112, Validation loss: 0.009377108294743414
Epoch 283: Train acc: 0.6967878956996248, Train loss: 0.009090381040920446 |Validation a
cc: 0.6918402777777778, Validation loss: 0.009402175711672366
Epoch 284: Train acc: 0.6962375592968096, Train loss: 0.009504016548207234 |Validation a
cc: 0.6917679398148148, Validation loss: 0.009412601863749833
Epoch 285: Train acc: 0.6990667534802965, Train loss: 0.009514820934701655 |Validation a
cc: 0.6934678819444444, Validation loss: 0.009431863591926123
Epoch 286: Train acc: 0.699524075279819, Train loss: 0.009473964721876409 |Validation ac
c: 0.6957103587962963, Validation loss: 0.009161983088808527
Epoch 287: Train acc: 0.6980590952779586, Train loss: 0.009530281128488945 |Validation a
cc: 0.6919849537037037, Validation loss: 0.009436412960379344
Epoch 288: Train acc: 0.6978033051189036, Train loss: 0.009362939901329378 |Validation a
cc: 0.6928530092592593, Validation loss: 0.009070874580101992
Epoch 289: Train acc: 0.6996713484016991, Train loss: 0.008952569814111473 |Validation a
cc: 0.6942274305555556, Validation loss: 0.009193055291635258
Epoch 290: Train acc: 0.6990822559141785, Train loss: 0.009395549985792942 |Validation a
cc: 0.6938295717592593, Validation loss: 0.00918372205212624
Epoch 291: Train acc: 0.699276036337705, Train loss: 0.009301030175146876 |Validation ac
c: 0.6931061921296297, Validation loss: 0.009198198770656519
Epoch 292: Train acc: 0.6981366074473693, Train loss: 0.009423020957673427 |Validation a
cc: 0.6952401620370371, Validation loss: 0.009207656836408005
Epoch 293: Train acc: 0.6997488605711096, Train loss: 0.009469138675311288 |Validation a
cc: 0.6964337384259259, Validation loss: 0.009224844270852845
Epoch 294: Train acc: 0.7013688649117912, Train loss: 0.008943284544623968 |Validation a
cc: 0.6953125, Validation loss: 0.009096285164527573
Epoch 295: Train acc: 0.700299196973925, Train loss: 0.009223003046813722 |Validation ac
c: 0.6960720486111112, Validation loss: 0.009028818264178026
Epoch 296: Train acc: 0.701733172108021, Train loss: 0.009242340088448866 |Validation ac
c: 0.6961805555555556, Validation loss: 0.009500812509757652
Epoch 297: Train acc: 0.7037484885126964, Train loss: 0.009036839639115802 |Validation a
cc: 0.697265625, Validation loss: 0.008807549150854084
Epoch 298: Train acc: 0.6908504635227731, Train loss: 0.009045721707417898 |Validation a
cc: 0.6854021990740741, Validation loss: 0.009616246446967125
Epoch 299: Train acc: 0.7029733668185906, Train loss: 0.009403622492965455 |Validation a
cc: 0.6976634837962963, Validation loss: 0.009246885443509774
Epoch 300: Train acc: 0.7063528974048926, Train loss: 0.009589407446542728 |Validation a
cc: 0.6997251157407407, Validation loss: 0.008759324827151324
Epoch 301: Train acc: 0.6994233094595852, Train loss: 0.0091435720229339 |Validation ac
c: 0.6925998263888888, Validation loss: 0.009348225620926222
Epoch 302: Train acc: 0.7004309676619229, Train loss: 0.009227079990145803 |Validation a
cc: 0.6948784722222222, Validation loss: 0.009558153808536975
Epoch 303: Train acc: 0.6979118221560785, Train loss: 0.00917086836354094 |Validation ac
c: 0.6936125578703703, Validation loss: 0.009245069984219504
Epoch 304: Train acc: 0.7041903078783369, Train loss: 0.009214398521620459 |Validation a
cc: 0.6989655671296297, Validation loss: 0.00864062497243064
Epoch 305: Train acc: 0.703298917930115, Train loss: 0.009311783415588719 |Validation ac
c: 0.6964699074074074, Validation loss: 0.009146394147275l1
Epoch 306: Train acc: 0.7031051375065885, Train loss: 0.009360583280061181 |Validation a
cc: 0.6961082175925926, Validation loss: 0.009524470050777764
Epoch 307: Train acc: 0.706399404706539, Train loss: 0.009016529155358981 |Validation ac
c: 0.6995804398148148, Validation loss: 0.00899012656108606
Epoch 308: Train acc: 0.7066396924317118, Train loss: 0.008943042318538406 |Validation a
cc: 0.7009548611111112, Validation loss: 0.009489255631204351
Epoch 309: Train acc: 0.7076163457662853, Train loss: 0.008948709287899008 |Validation a
cc: 0.7026186342592593, Validation loss: 0.009132803339671444
```

```
Epoch 310: Train acc: 0.7077403652373423, Train loss: 0.009108249489107453 |Validation a
cc: 0.7023292824074074, Validation loss: 0.008861021971943559
Epoch 311: Train acc: 0.7071590239667628, Train loss: 0.008957414981806845 |Validation a
cc: 0.7013527199074074, Validation loss: 0.00922491131087859
Epoch 312: Train acc: 0.7020897280873097, Train loss: 0.008920132589473967 |Validation a
cc: 0.6956741898148148, Validation loss: 0.008835838137620103
Epoch 313: Train acc: 0.7053607416364369, Train loss: 0.008969848991429726 |Validation a
cc: 0.6995442708333334, Validation loss: 0.009287427699757126
Epoch 314: Train acc: 0.7061281121136018, Train loss: 0.008983059701280398 |Validation a
cc: 0.7015335648148148, Validation loss: 0.009081604549224635
Epoch 315: Train acc: 0.7074303165596999, Train loss: 0.00925434331301854 |Validation ac
c: 0.7024739583333334, Validation loss: 0.009147179563106964
Epoch 316: Train acc: 0.7058568195206647, Train loss: 0.009490070977864527 |Validation a
cc: 0.6975549768518519, Validation loss: 0.009303535123352923
Epoch 317: Train acc: 0.7074613214274641, Train loss: 0.009004902574081715 |Validation a
cc: 0.7015335648148148, Validation loss: 0.008745634002550243
Epoch 318: Train acc: 0.701469630732025, Train loss: 0.008622596547482894 |Validation ac
c: 0.6955295138888888, Validation loss: 0.0087385180127152
Epoch 319: Train acc: 0.7061746194152482, Train loss: 0.009161656943511893 |Validation a
cc: 0.6997251157407407, Validation loss: 0.009197572095579405
Epoch 320: Train acc: 0.7076861067187549, Train loss: 0.009147050963211749 |Validation a
cc: 0.7010995370370371, Validation loss: 0.008968518667602884
Epoch 321: Train acc: 0.7092285988900258, Train loss: 0.00890574824391071 |Validation ac
c: 0.7036313657407407, Validation loss: 0.00854028646146066
Epoch 322: Train acc: 0.7073993116919356, Train loss: 0.008691234428446618 |Validation a
cc: 0.7013165509259259, Validation loss: 0.00873951225759854
Epoch 323: Train acc: 0.7068257216382973, Train loss: 0.00940481916233035 |Validation ac
c: 0.7008101851851852, Validation loss: 0.009141076697473268
Epoch 324: Train acc: 0.6991830217344123, Train loss: 0.009322757904558755 |Validation a
cc: 0.6945167824074074, Validation loss: 0.00917906551110594
Epoch 325: Train acc: 0.7036709763432859, Train loss: 0.009084624014463197 |Validation a
cc: 0.6988932291666666, Validation loss: 0.009190388569658075
Epoch 326: Train acc: 0.7013921185626143, Train loss: 0.009046803295573645 |Validation a
cc: 0.6945529513888888, Validation loss: 0.00922254740000766
Epoch 327: Train acc: 0.7078566334914581, Train loss: 0.009072057351481047 |Validation a
cc: 0.7034866898148148, Validation loss: 0.008809831903318844
Epoch 328: Train acc: 0.7070892630142932, Train loss: 0.008876967795182142 |Validation a
cc: 0.7005570023148148, Validation loss: 0.008773641462523478
Epoch 329: Train acc: 0.7052832294670264, Train loss: 0.008831129560678181 |Validation a
cc: 0.6994357638888888, Validation loss: 0.008968110652281197
Epoch 330: Train acc: 0.7058490683037237, Train loss: 0.008734637098967234 |Validation a
cc: 0.7002676504629629, Validation loss: 0.009201407602515614
Epoch 331: Train acc: 0.7074380677776641, Train loss: 0.009178486220173825 |Validation ac
c: 0.7024377893518519, Validation loss: 0.008980208967096595
Epoch 332: Train acc: 0.7062366291507767, Train loss: 0.00888321218661168 |Validation ac
c: 0.6997974537037037, Validation loss: 0.009220402364450498
Epoch 333: Train acc: 0.7078721359253403, Train loss: 0.009150986037374603 |Validation a
cc: 0.7004123263888888, Validation loss: 0.009120909785934743
Epoch 334: Train acc: 0.7094146280966112, Train loss: 0.008662943245334556 |Validation a
cc: 0.7032335069444444, Validation loss: 0.008815276129060709
Epoch 335: Train acc: 0.7084379747620376, Train loss: 0.008950762851412466 |Validation a
cc: 0.7021846064814815, Validation loss: 0.008984553833555663
Epoch 336: Train acc: 0.7091123306359098, Train loss: 0.009135216777143828 |Validation a
cc: 0.7018590856481481, Validation loss: 0.008889957329739184
Epoch 337: Train acc: 0.7090735745512046, Train loss: 0.009194820167259133 |Validation a
cc: 0.7025101273148148, Validation loss: 0.009109659646209385
Epoch 338: Train acc: 0.7085232381483892, Train loss: 0.008909188546737772 |Validation a
cc: 0.7013527199074074, Validation loss: 0.009046639173460201
Epoch 339: Train acc: 0.7032524106284687, Train loss: 0.008748508772179926 |Validation a
cc: 0.6992910879629629, Validation loss: 0.0086870987537574
Epoch 340: Train acc: 0.7104765448175363, Train loss: 0.008929376689391073 |Validation a
cc: 0.7025462962962963, Validation loss: 0.008638473860477305
Epoch 341: Train acc: 0.7081511797352185, Train loss: 0.008771788309541053 |Validation a
cc: 0.7008101851851852, Validation loss: 0.009037309077510318
Epoch 342: Train acc: 0.7079031407931046, Train loss: 0.009102260525330062 |Validation a
```

```
cc: 0.7022569444444444, Validation loss: 0.009121347941425063
Epoch 343: Train acc: 0.7086240039686231, Train loss: 0.009298067082559761 |Validation a
cc: 0.7020037615740741, Validation loss: 0.008808452150997228
Epoch 344: Train acc: 0.7100734815366012, Train loss: 0.009097584263485158 |Validation a
cc: 0.7031973379629629, Validation loss: 0.009019530362391552
Epoch 345: Train acc: 0.7098409450283695, Train loss: 0.008769569175804272 |Validation a
cc: 0.7033420138888888, Validation loss: 0.008613882546979127
Epoch 346: Train acc: 0.7046166248100952, Train loss: 0.009125028765215 94 |Validation ac
c: 0.7009910300925926, Validation loss: 0.009174225371032511
Epoch 347: Train acc: 0.707693857935696, Train loss: 0.009235046128258772 |Validation ac
c: 0.7012803819444444, Validation loss: 0.008990722265542216
Epoch 348: Train acc: 0.709399125662729, Train loss: 0.008850394502884601 |Validation ac
c: 0.7019675925925926, Validation loss: 0.008850815746026771
Epoch 349: Train acc: 0.7098409450283695, Train loss: 0.009397458861297333 |Validation a
cc: 0.7027633101851852, Validation loss: 0.009152417397264734
Epoch 350: Train acc: 0.710561808203888, Train loss: 0.008884743573171714 |Validation ac
c: 0.7049334490740741, Validation loss: 0.008761076432119402
Epoch 351: Train acc: 0.7084069698942734, Train loss: 0.00891783320585415 |Validation ac
c: 0.7028718171296297, Validation loss: 0.00863101561650501
Epoch 352: Train acc: 0.7054227513719654, Train loss: 0.008729580012550826 |Validation a
cc: 0.6988932291666666, Validation loss: 0.009045484901380999
Epoch 353: Train acc: 0.707693857935696, Train loss: 0.008909088348726623 |Validation ac
c: 0.7020037615740741, Validation loss: 0.00922505677683218
Epoch 354: Train acc: 0.7104222862989489, Train loss: 0.008984139605041162 |Validation a
cc: 0.7035590277777778, Validation loss: 0.009153784088270866
Epoch 355: Train acc: 0.7050429417418534, Train loss: 0.008720738932805396 |Validation a
cc: 0.6981698495370371, Validation loss: 0.008996051203498192
Epoch 356: Train acc: 0.7082674479893343, Train loss: 0.008968143969862681 |Validation a
cc: 0.7010995370370371, Validation loss: 0.008888625634491488
Epoch 357: Train acc: 0.7025005425851859, Train loss: 0.008782735421220034 |Validation a
cc: 0.6999782986111112, Validation loss: 0.008884270082694929
Epoch 358: Train acc: 0.7090580721173224, Train loss: 0.008997241574690541 |Validation a
cc: 0.7020399305555556, Validation loss: 0.008672389071932178
Epoch 359: Train acc: 0.7094301305304933, Train loss: 0.009027729494889607 |Validation a
cc: 0.7033058449074074, Validation loss: 0.008866179547927589
Epoch 360: Train acc: 0.7115229591045794, Train loss: 0.008889644064744299 |Validation a
cc: 0.7047164351851852, Validation loss: 0.008750066876229043
Epoch 361: Train acc: 0.7089495550801476, Train loss: 0.00895828674049932 |Validation ac
c: 0.7036313657407407, Validation loss: 0.008569672184883
Epoch 362: Train acc: 0.7110578860881158, Train loss: 0.008789781881745031 |Validation a
cc: 0.7048611111111112, Validation loss: 0.008838301099621268
Epoch 363: Train acc: 0.7101819985737761, Train loss: 0.0088723368959319 |Validation ac
c: 0.7034143518518519, Validation loss: 0.008786704868647527
Epoch 364: Train acc: 0.7112981738132886, Train loss: 0.008965432426950255 |Validation a
cc: 0.7032696759259259, Validation loss: 0.008673032239985926
Epoch 365: Train acc: 0.7087402722227389, Train loss: 0.008884662444473905 |Validation a
cc: 0.7031611689814815, Validation loss: 0.009066166209736812
Epoch 366: Train acc: 0.7081279260843952, Train loss: 0.00888532334703742 |Validation ac
c: 0.7005208333333334, Validation loss: 0.009517760065077452
Epoch 367: Train acc: 0.7125771246085636, Train loss: 0.008812296600841008 |Validation a
cc: 0.7067780671296297, Validation loss: 0.0086430365451852
Epoch 368: Train acc: 0.7125306173069171, Train loss: 0.008899681521607259 |Validation a
cc: 0.7067057291666666, Validation loss: 0.008845498321787939
Epoch 369: Train acc: 0.7077326140204012, Train loss: 0.008687913621629337 |Validation a
cc: 0.7023654513888888, Validation loss: 0.008858928578499516
Epoch 370: Train acc: 0.7138560754038384, Train loss: 0.008943533689303196 |Validation a
cc: 0.7064525462962963, Validation loss: 0.00878737077534265
Epoch 371: Train acc: 0.7107013301088271, Train loss: 0.009083681358494284 |Validation a
cc: 0.7052589699074074, Validation loss: 0.008674431919018
Epoch 372: Train acc: 0.7098254425944873, Train loss: 0.008895043326536255 |Validation a
cc: 0.7037398726851852, Validation loss: 0.008827160834542058
Epoch 373: Train acc: 0.7142513874678325, Train loss: 0.008699057424076189 |Validation a
cc: 0.70703125, Validation loss: 0.008690768186809932
Epoch 374: Train acc: 0.7057948097851363, Train loss: 0.008879773087318688 |Validation a
cc: 0.7001229745370371, Validation loss: 0.008646540708552482
```

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Epoch 375: Train acc: 0.7120035345549252, Train loss: 0.00917728477467172 |Validation ac
c: 0.7067418981481481, Validation loss: 0.00874061547067757
Epoch 376: Train acc: 0.7100114718010727, Train loss: 0.00834380659600858 |Validation ac
c: 0.7033420138888888, Validation loss: 0.008500837998669207
Epoch 377: Train acc: 0.7098641986791926, Train loss: 0.00872346634758244 |Validation ac
c: 0.7043185763888888, Validation loss: 0.008933572911101915
Epoch 378: Train acc: 0.7133367438687874, Train loss: 0.00880185824691785 |Validation ac
c: 0.7059823495370371, Validation loss: 0.008482917202277335
Epoch 379: Train acc: 0.7129181781539702, Train loss: 0.008638362451359762 |Validation a
cc: 0.7059461805555556, Validation loss: 0.008806099516176549
Epoch 380: Train acc: 0.7115694664062258, Train loss: 0.009011639809948931 |Validation a
cc: 0.7058015046296297, Validation loss: 0.008695961576568665
Epoch 381: Train acc: 0.7117012370942238, Train loss: 0.008812008678459892 |Validation a
cc: 0.7059461805555556, Validation loss: 0.008629009953232963
Epoch 382: Train acc: 0.7019347037484885, Train loss: 0.009139664022069569 |Validation a
cc: 0.6969762731481481, Validation loss: 0.008906175960712024
Epoch 383: Train acc: 0.703562459306111, Train loss: 0.008950312792541852 |Validation ac
c: 0.6999059606481481, Validation loss: 0.008837584084872632
Epoch 384: Train acc: 0.713933587573249, Train loss: 0.008745825356176504 |Validation ac
c: 0.7081524884259259, Validation loss: 0.008425228080079401
Epoch 385: Train acc: 0.7119647784702198, Train loss: 0.008643956266299376 |Validation a
cc: 0.7048611111111112, Validation loss: 0.00886483510226586
Epoch 386: Train acc: 0.7136157876786655, Train loss: 0.00868781310788049 |Validation ac
c: 0.7082609953703703, Validation loss: 0.008823767142060823
Epoch 387: Train acc: 0.7062521315846588, Train loss: 0.008609314555528874 |Validation a
cc: 0.7017505787037037, Validation loss: 0.009060912194885645
Epoch 388: Train acc: 0.7130421976250271, Train loss: 0.008773705426006626 |Validation a
cc: 0.7065248842592593, Validation loss: 0.009018989836725265
Epoch 389: Train acc: 0.7128019098998543, Train loss: 0.008701576796036977 |Validation a
cc: 0.7060185185185185, Validation loss: 0.008589431576469488
Epoch 390: Train acc: 0.712251573497039, Train loss: 0.008537979646605227 |Validation ac
c: 0.7060185185185185, Validation loss: 0.008949934066900603
Epoch 391: Train acc: 0.7113601835488171, Train loss: 0.008555907045853068 |Validation a
cc: 0.7046440972222222, Validation loss: 0.00872127145517739
Epoch 392: Train acc: 0.7107245837596503, Train loss: 0.008847416677713969 |Validation a
cc: 0.7038845486111112, Validation loss: 0.008959819870180167
Epoch 393: Train acc: 0.7136467925464298, Train loss: 0.008681994629332945 |Validation a
cc: 0.7058738425925926, Validation loss: 0.008595597499826763
Epoch 394: Train acc: 0.7114144420674046, Train loss: 0.008376606594279232 |Validation a
cc: 0.7059823495370371, Validation loss: 0.00872328910819125
Epoch 395: Train acc: 0.7107633398443556, Train loss: 0.008318164352001485 |Validation a
cc: 0.7058376736111112, Validation loss: 0.008807540504339231
Epoch 396: Train acc: 0.7097711840758999, Train loss: 0.00844799989878645 |Validation ac
c: 0.7060546875, Validation loss: 0.008899239646353778
Epoch 397: Train acc: 0.7132049731807893, Train loss: 0.009051342774597093 |Validation a
cc: 0.705078125, Validation loss: 0.008457003899183932
Epoch 398: Train acc: 0.7121043003751589, Train loss: 0.008439318162253684 |Validation a
cc: 0.7067418981481481, Validation loss: 0.008382472924014846
Epoch 399: Train acc: 0.7127399001643258, Train loss: 0.008698361454592348 |Validation a
cc: 0.7055844907407407, Validation loss: 0.008368422680061853
Epoch 400: Train acc: 0.712763153815149, Train loss: 0.008888361051136998 |Validation ac
c: 0.7083333333333334, Validation loss: 0.008831118053179068
Epoch 401: Train acc: 0.7107168325427092, Train loss: 0.008528490306931142 |Validation a
cc: 0.7042824074074074, Validation loss: 0.008831839820574582
Epoch 402: Train acc: 0.7109803739187053, Train loss: 0.008834191826683433 |Validation a
cc: 0.7050419560185185, Validation loss: 0.008799955724857372
Epoch 403: Train acc: 0.7102517595262456, Train loss: 0.00871956536549113 |Validation ac
c: 0.7024377893518519, Validation loss: 0.008860172804041548
Epoch 404: Train acc: 0.7127011440796205, Train loss: 0.00871855670998 |Validation acc:
 0.7052589699074074, Validation loss: 0.008839184144036486
Epoch 405: Train acc: 0.7140110997426596, Train loss: 0.009042316695360207 |Validation a
cc: 0.7071035879629629, Validation loss: 0.009034910125282071
Epoch 406: Train acc: 0.713414256038198, Train loss: 0.00852441741222687 |Validation ac
c: 0.7059100115740741, Validation loss: 0.008657174489601828
Epoch 407: Train acc: 0.7156233528664, Train loss: 0.008863810290242559 |Validation acc:
```

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0.7085503472222222, Validation loss: 0.008788026232294495
Epoch 408: Train acc: 0.7098874523300158, Train loss: 0.008423123652397349 |Validation a
cc: 0.7030888310185185, Validation loss: 0.008679445530357011
Epoch 409: Train acc: 0.713538275509255, Train loss: 0.0084832624265598 |Validation acc:
0.7072844328703703, Validation loss: 0.008785529826278591
Epoch 410: Train acc: 0.7131817195299662, Train loss: 0.00893387576227991 |Validation ac
c: 0.7067057291666666, Validation loss: 0.008734555845217951
Epoch 411: Train acc: 0.7110423836542337, Train loss: 0.008565147390771513 |Validation a
cc: 0.7071397569444444, Validation loss: 0.008567436700493362
Epoch 412: Train acc: 0.7135537779431371, Train loss: 0.008753748370185273 |Validation a
cc: 0.7075014467592593, Validation loss: 0.008551895442952123
Epoch 413: Train acc: 0.7129569342386755, Train loss: 0.009012199074682125 |Validation a
cc: 0.7058376736111112, Validation loss: 0.008594656532398185
Epoch 414: Train acc: 0.7148559823892351, Train loss: 0.008628988679282875 |Validation a
cc: 0.7084780092592593, Validation loss: 0.00843541940621678
Epoch 415: Train acc: 0.7133832511704338, Train loss: 0.00886387125387213 |Validation ac
c: 0.7068142361111112, Validation loss: 0.008687299075163349
Epoch 416: Train acc: 0.7118407589991629, Train loss: 0.00899960643415635 |Validation ac
c: 0.7053313078703703, Validation loss: 0.008567148600552972
Epoch 417: Train acc: 0.7147707190028835, Train loss: 0.008611881319925366 |Validation a
cc: 0.708984375, Validation loss: 0.008655201211206902
Epoch 418: Train acc: 0.7109338666170589, Train loss: 0.009103807028609629 |Validation a
cc: 0.7043909143518519, Validation loss: 0.008843047572686738
Epoch 419: Train acc: 0.7100812327535423, Train loss: 0.008795775164979943 |Validation a
cc: 0.7045355902777778, Validation loss: 0.00863690117376826
Epoch 420: Train acc: 0.7144451678913589, Train loss: 0.00864279739633313 |Validation ac
c: 0.7065610532407407, Validation loss: 0.008400501095405185
Epoch 421: Train acc: 0.7109881251356462, Train loss: 0.008409468756949954 |Validation a
cc: 0.7065610532407407, Validation loss: 0.009062319659580993
Epoch 422: Train acc: 0.7143366508541841, Train loss: 0.008529200779622315 |Validation a
cc: 0.7057653356481481, Validation loss: 0.008422528347276836
Epoch 423: Train acc: 0.708872042910737, Train loss: 0.008724730248350196 |Validation ac
c: 0.7026186342592593, Validation loss: 0.008720485014752526
Epoch 424: Train acc: 0.7140498558273649, Train loss: 0.009013757567703503 |Validation a
cc: 0.7084056712962963, Validation loss: 0.008545065361547673
Epoch 425: Train acc: 0.7114144420674046, Train loss: 0.008871267097159248 |Validation a
cc: 0.7049696180555556, Validation loss: 0.008803704449525572
Epoch 426: Train acc: 0.7122670759309212, Train loss: 0.008677976451211716 |Validation a
cc: 0.7054398148148148, Validation loss: 0.008690636374957263
Epoch 427: Train acc: 0.7131274610113788, Train loss: 0.008867564812186519 |Validation a
cc: 0.7068142361111112, Validation loss: 0.008721537333954602
Epoch 428: Train acc: 0.7137863144513689, Train loss: 0.008452369065303078 |Validation a
cc: 0.7073567708333334, Validation loss: 0.00849219838099261 2
Epoch 429: Train acc: 0.7107788422782377, Train loss: 0.00848645564632971 |Validation ac
c: 0.7061993634259259, Validation loss: 0.008765906004307001
Epoch 430: Train acc: 0.7110268812203516, Train loss: 0.008541732693494515 |Validation a
cc: 0.7040292245370371, Validation loss: 0.009741475284707564
Epoch 431: Train acc: 0.7122128174123338, Train loss: 0.008704736922765344 |Validation a
cc: 0.7072482638888888, Validation loss: 0.008777795245495103
Epoch 432: Train acc: 0.7143754069388895, Train loss: 0.008694106632102978 |Validation a
cc: 0.7072120949074074, Validation loss: 0.008427691289419944
Epoch 433: Train acc: 0.7111121446067032, Train loss: 0.008624699123574072 |Validation a
cc: 0.7037037037037037, Validation loss: 0.008803315529080235
Epoch 434: Train acc: 0.7098254425944873, Train loss: 0.00884526096511002 |Validation ac
c: 0.7021846064814815, Validation loss: 0.008607612969077439
Epoch 435: Train acc: 0.7124376027036244, Train loss: 0.009031551440995331 |Validation a
cc: 0.7053674768518519, Validation loss: 0.00831969184745711
Epoch 436: Train acc: 0.7137785632344278, Train loss: 0.00855667856922622 |Validation ac
c: 0.7064525462962963, Validation loss: 0.008662761079191676
Epoch 437: Train acc: 0.7140188509596006, Train loss: 0.008654801677276853 |Validation a
cc: 0.7056929976851852, Validation loss: 0.008832905344366585
Epoch 438: Train acc: 0.7104687936005953, Train loss: 0.008594406249128746 |Validation a
cc: 0.7055844907407407, Validation loss: 0.008924762116612464
Epoch 439: Train acc: 0.7142048801661861, Train loss: 0.008236031832162413 |Validation a
cc: 0.7083695023148148, Validation loss: 0.008549939293154578
```

```
Epoch 440: Train acc: 0.7111896567761139, Train loss: 0.008722471037343454 |Validation a
cc: 0.7059823495370371, Validation loss: 0.008739388545765057
Epoch 441: Train acc: 0.7138483241868974, Train loss: 0.008330285726723093 |Validation a
cc: 0.7069589120370371, Validation loss: 0.00874246665807192
Epoch 442: Train acc: 0.7118950175177503, Train loss: 0.008924716749872448 |Validation a
cc: 0.7051866319444444, Validation loss: 0.008828810957821434
Epoch 443: Train acc: 0.7137088022819583, Train loss: 0.008659005882246116 |Validation a
cc: 0.7070674189814815, Validation loss: 0.008313995727976281
Epoch 444: Train acc: 0.7087170185719158, Train loss: 0.008812469948436898 |Validation a
cc: 0.7029441550925926, Validation loss: 0.008746615954390132
Epoch 445: Train acc: 0.7123523393172728, Train loss: 0.008520856987441771 |Validation a
cc: 0.7060908564814815, Validation loss: 0.008899417608418123
Epoch 446: Train acc: 0.7119492760363377, Train loss: 0.008622276008084902 |Validation a
cc: 0.7053674768518519, Validation loss: 0.008558096452574701
Epoch 447: Train acc: 0.7117865004805755, Train loss: 0.008619423347002985 |Validation a
cc: 0.7068504050925926, Validation loss: 0.008799976426748785
Epoch 448: Train acc: 0.7138560754038384, Train loss: 0.008519781097073319 |Validation a
cc: 0.7068142361111112, Validation loss: 0.008187361903079627
Epoch 449: Train acc: 0.7110656373050569, Train loss: 0.00831160203343705 |Validation ac
c: 0.7043185763888888, Validation loss: 0.008541919509341349
Epoch 450: Train acc: 0.7007255139056832, Train loss: 0.008910438305634772 |Validation a
cc: 0.6948423032407407, Validation loss: 0.008638398265825359
Epoch 451: Train acc: 0.7131739683130252, Train loss: 0.008205292636572829 |Validation a
cc: 0.7063440393518519, Validation loss: 0.008133779495446017
Epoch 452: Train acc: 0.7118407589991629, Train loss: 0.008015813377826787 |Validation a
cc: 0.7060908564814815, Validation loss: 0.008734162132053993
Epoch 453: Train acc: 0.7079108920100455, Train loss: 0.008446491448462937 |Validation a
cc: 0.7007378472222222, Validation loss: 0.00842428903954894
Epoch 454: Train acc: 0.7137785632344278, Train loss: 0.008023314078501495 |Validation a
cc: 0.7076822916666666, Validation loss: 0.008150139946534744
Epoch 455: Train acc: 0.7150187579449974, Train loss: 0.008078499068436973 |Validation a
cc: 0.7085503472222222, Validation loss: 0.008324902968271151
Epoch 456: Train acc: 0.7133832511704338, Train loss: 0.008336959089614031 |Validation a
cc: 0.7086588541666666, Validation loss: 0.008695209201961446
Epoch 457: Train acc: 0.7119802809041019, Train loss: 0.008066349293903976 |Validation a
cc: 0.70703125, Validation loss: 0.008364310787951999
Epoch 458: Train acc: 0.7135925340278424, Train loss: 0.008443131774127793 |Validation a
cc: 0.7076099537037037, Validation loss: 0.007917219779152943
Epoch 459: Train acc: 0.7140266021765417, Train loss: 0.00852370249709938 |Validation ac
c: 0.7081163194444444, Validation loss: 0.00842067701997683
Epoch 460: Train acc: 0.7149800018602921, Train loss: 0.008312340262719051 |Validation a
cc: 0.7079716435185185, Validation loss: 0.008282397420474435
Epoch 461: Train acc: 0.7147784702198245, Train loss: 0.008150002347078805 |Validation a
cc: 0.7075376157407407, Validation loss: 0.008531341515066937
Epoch 462: Train acc: 0.7131042073605556, Train loss: 0.007992313233776244 |Validation a
cc: 0.7051504629629629, Validation loss: 0.008204122642552596
Epoch 463: Train acc: 0.7151117725482901, Train loss: 0.008494003897654418 |Validation a
cc: 0.7081886574074074, Validation loss: 0.008068340441532632
Epoch 464: Train acc: 0.7150420115958206, Train loss: 0.008039792318405578 |Validation a
cc: 0.7069589120370371, Validation loss: 0.008066321032961902
Epoch 465: Train acc: 0.7160961770998047, Train loss: 0.008381229585578295 |Validation a
cc: 0.7090205439814815, Validation loss: 0.007932690685913409
Epoch 466: Train acc: 0.7152667968871113, Train loss: 0.008105906174250102 |Validation a
cc: 0.7089482060185185, Validation loss: 0.008083859127628388
Epoch 467: Train acc: 0.711988032121043, Train loss: 0.008262251431912802 |Validation ac
c: 0.7044632523148148, Validation loss: 0.008198981446238892
Epoch 468: Train acc: 0.7163752209096829, Train loss: 0.008310407777358322 |Validation a
cc: 0.7092013888888888, Validation loss: 0.007787491881650616
Epoch 469: Train acc: 0.7122670759309212, Train loss: 0.008290834140408375 |Validation a
cc: 0.7052589699074074, Validation loss: 0.00840812796610753
Epoch 470: Train acc: 0.7137088022819583, Train loss: 0.008083399895783126 |Validation a
cc: 0.7086226851851852, Validation loss: 0.008195304107307858
Epoch 471: Train acc: 0.7143676557219484, Train loss: 0.008369102998075658 |Validation a
cc: 0.7068504050925926, Validation loss: 0.007981660976889888
Epoch 472: Train acc: 0.7134762657737265, Train loss: 0.008877259630776213 |Validation a
```

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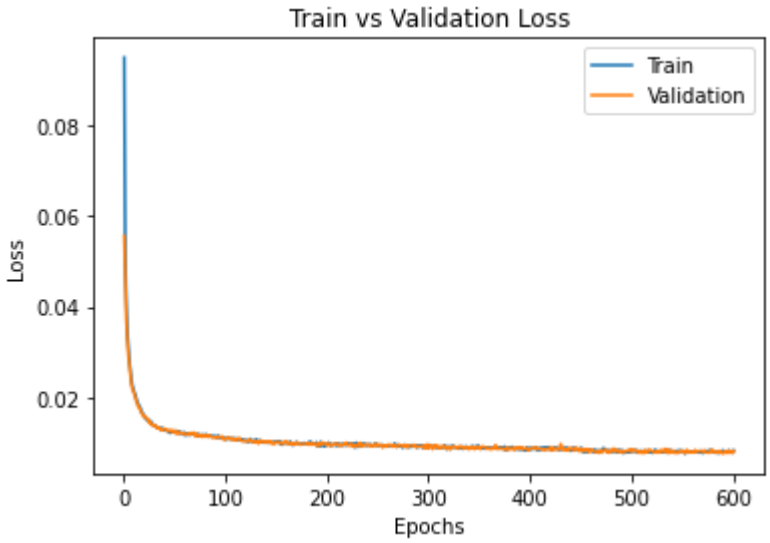
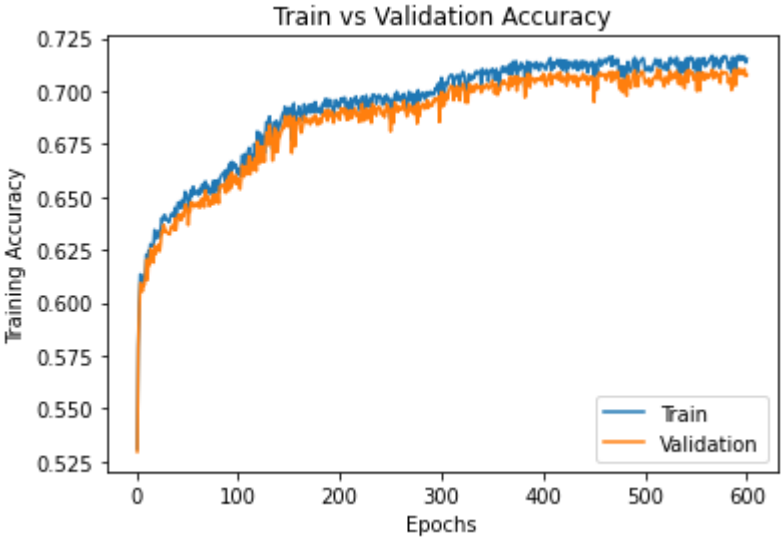
cc: 0.7067057291666666, Validation loss: 0.008406366877954242
Epoch 473: Train acc: 0.715096270114408, Train loss: 0.008627445555156654 |Validation ac
c: 0.7094184027777778, Validation loss: 0.00833570775133765
Epoch 474: Train acc: 0.7105928130716522, Train loss: 0.008464797415828625 |Validation a
cc: 0.7043547453703703, Validation loss: 0.00846576385921315
Epoch 475: Train acc: 0.7072287849192324, Train loss: 0.008260419165289986 |Validation a
cc: 0.7010271990740741, Validation loss: 0.008021972333537056
Epoch 476: Train acc: 0.7117787492636344, Train loss: 0.008323768577303527 |Validation a
cc: 0.7055844907407407, Validation loss: 0.008357823813936566
Epoch 477: Train acc: 0.7117089883111648, Train loss: 0.008397420383962175 |Validation a
cc: 0.7038122106481481, Validation loss: 0.007808926539462424
Epoch 478: Train acc: 0.7066319412147707, Train loss: 0.008199171049144529 |Validation a
cc: 0.6994719328703703, Validation loss: 0.008052171861548364
Epoch 479: Train acc: 0.7115462127554026, Train loss: 0.008037880358758772 |Validation a
cc: 0.7056929976851852, Validation loss: 0.008037141102811084
Epoch 480: Train acc: 0.7114609493690509, Train loss: 0.008068601901363858 |Validation a
cc: 0.7041377314814815, Validation loss: 0.008553818820282066
Epoch 481: Train acc: 0.7079186432269866, Train loss: 0.008030721262091832 |Validation a
cc: 0.7023292824074074, Validation loss: 0.008143031565494592
Epoch 482: Train acc: 0.7039267665023409, Train loss: 0.008402731901764295 |Validation a
cc: 0.6978081597222222, Validation loss: 0.008764523133298365
Epoch 483: Train acc: 0.7138095681021921, Train loss: 0.008245966657692186 |Validation a
cc: 0.7075737847222222, Validation loss: 0.008402157835358373
Epoch 484: Train acc: 0.7111276470405854, Train loss: 0.008032515611173447 |Validation a
cc: 0.7043185763888888, Validation loss: 0.0080872627965918
Epoch 485: Train acc: 0.7100269742349549, Train loss: 0.008377913438828348 |Validation a
cc: 0.7042462384259259, Validation loss: 0.008426024186775884
Epoch 486: Train acc: 0.7092441013239078, Train loss: 0.0079355076230366 |Validation ac
c: 0.7015335648148148, Validation loss: 0.00811853909793169
Epoch 487: Train acc: 0.7103060180448331, Train loss: 0.008473934538701124 |Validation a
cc: 0.7041739004629629, Validation loss: 0.008301082512126124
Epoch 488: Train acc: 0.7141816265153629, Train loss: 0.008226987109892623 |Validation a
cc: 0.7080078125, Validation loss: 0.008041611768979613
Epoch 489: Train acc: 0.713546026726196, Train loss: 0.00797862881236331 |Validation ac
c: 0.7071397569444444, Validation loss: 0.008286845408109202
Epoch 490: Train acc: 0.715879143025455, Train loss: 0.008416727990829537 |Validation ac
c: 0.7097800925925926, Validation loss: 0.007976053505085784
Epoch 491: Train acc: 0.7077481164542834, Train loss: 0.007762196153203352 |Validation a
cc: 0.7022569444444444, Validation loss: 0.008027723784494912
Epoch 492: Train acc: 0.7140808606951291, Train loss: 0.00794776386128136 |Validation ac
c: 0.7072482638888888, Validation loss: 0.008265638303907053
Epoch 493: Train acc: 0.7091355842867331, Train loss: 0.007828360417918564 |Validation a
cc: 0.7022207754629629, Validation loss: 0.00810335655088705
Epoch 494: Train acc: 0.712894924503147, Train loss: 0.008132731135746668 |Validation ac
c: 0.7069589120370371, Validation loss: 0.008071756567280928
Epoch 495: Train acc: 0.7137475583666636, Train loss: 0.007926244527040719 |Validation a
cc: 0.7071759259259259, Validation loss: 0.008240721971957283
Epoch 496: Train acc: 0.7146156946640623, Train loss: 0.008297478594991326 |Validation a
cc: 0.7092013888888888, Validation loss: 0.00829241397577816
Epoch 497: Train acc: 0.7148249775214709, Train loss: 0.007938220996122243 |Validation a
cc: 0.7082609953703703, Validation loss: 0.008249482125436296
Epoch 498: Train acc: 0.7156156016494589, Train loss: 0.008187097386741674 |Validation a
cc: 0.7092375578703703, Validation loss: 0.008563910418214934
Epoch 499: Train acc: 0.7142048801661861, Train loss: 0.008005584972891238 |Validation a
cc: 0.7066333912037037, Validation loss: 0.008036585222758375
Epoch 500: Train acc: 0.7098176913775462, Train loss: 0.008257169116879827 |Validation a
cc: 0.7036313657407407, Validation loss: 0.00859138942862521
Epoch 501: Train acc: 0.7097556816420177, Train loss: 0.00832113098126535 |Validation ac
c: 0.7052951388888888, Validation loss: 0.008301947531856884
Epoch 502: Train acc: 0.7111431494744674, Train loss: 0.008096602699064403 |Validation a
cc: 0.7039568865740741, Validation loss: 0.008148893173673474
Epoch 503: Train acc: 0.71043003751589, Train loss: 0.00839548737490522 |Validation acc:
0.7041015625, Validation loss: 0.008434606425171215
Epoch 504: Train acc: 0.7114376957182278, Train loss: 0.008380091575026866 |Validation a
cc: 0.7058738425925926, Validation loss: 0.008366957123775467
```

```
Epoch 505: Train acc: 0.7093603695780237, Train loss: 0.007843292501370922 |Validation a
cc: 0.7022569444444444, Validation loss: 0.008087971200751975
Epoch 506: Train acc: 0.7109261154001179, Train loss: 0.008179047973329086 |Validation a
cc: 0.7040292245370371, Validation loss: 0.008233479993108339
Epoch 507: Train acc: 0.7097634328589588, Train loss: 0.008120697719882344 |Validation a
cc: 0.7030526620370371, Validation loss: 0.007808205552775004
Epoch 508: Train acc: 0.7123910954019781, Train loss: 0.008280019539073993 |Validation a
cc: 0.7060185185185185, Validation loss: 0.007950304715841655
Epoch 509: Train acc: 0.7128251635506775, Train loss: 0.008207212892452184 |Validation a
cc: 0.7061993634259259, Validation loss: 0.008110850053847676
Epoch 510: Train acc: 0.7149955042941741, Train loss: 0.0081586353909169 |Validation ac
c: 0.7071035879629629, Validation loss: 0.007748223938606127
Epoch 511: Train acc: 0.7133444950857285, Train loss: 0.008227202869282942 |Validation a
cc: 0.7059100115740741, Validation loss: 0.008154430200044586
Epoch 512: Train acc: 0.7147009580504139, Train loss: 0.008249093924900544 |Validation a
cc: 0.7104673032407407, Validation loss: 0.007754490642396606
Epoch 513: Train acc: 0.7116779834434006, Train loss: 0.0079921802453343 |Validation ac
c: 0.7057291666666666, Validation loss: 0.008438314151610261
Epoch 514: Train acc: 0.7114299445012867, Train loss: 0.008223621703916469 |Validation a
cc: 0.7062717013888888, Validation loss: 0.007924509313488131
Epoch 515: Train acc: 0.7147707190028835, Train loss: 0.008117437297036147 |Validation a
cc: 0.7097439236111112, Validation loss: 0.008200947142783719
Epoch 516: Train acc: 0.7129879391064398, Train loss: 0.008321369694164492 |Validation a
cc: 0.7059100115740741, Validation loss: 0.008032764368262198
Epoch 517: Train acc: 0.7108253495798841, Train loss: 0.00788938012443903 |Validation ac
c: 0.7046079282407407, Validation loss: 0.008507175985253928
Epoch 518: Train acc: 0.7112439152947013, Train loss: 0.008090490102906123 |Validation a
cc: 0.7053313078703703, Validation loss: 0.008367913274249222
Epoch 519: Train acc: 0.710298266827892, Train loss: 0.008046799237102005 |Validation ac
c: 0.7020760995370371, Validation loss: 0.008360721220646485
Epoch 520: Train acc: 0.7133599975196105, Train loss: 0.007824066207669565 |Validation a
cc: 0.7065248842592593, Validation loss: 0.008193519648346905
Epoch 521: Train acc: 0.7130732024927914, Train loss: 0.00785097336736494 |Validation ac
c: 0.7065610532407407, Validation loss: 0.007938023026513063
Epoch 522: Train acc: 0.7100579791027192, Train loss: 0.008297154248086873 |Validation a
cc: 0.7049696180555556, Validation loss: 0.007930995300218728
Epoch 523: Train acc: 0.7096394133879019, Train loss: 0.00851647162503212 |Validation ac
c: 0.7035951967592593, Validation loss: 0.00804990754415798
Epoch 524: Train acc: 0.7144994264099463, Train loss: 0.008136929605620463 |Validation a
cc: 0.7093822337962963, Validation loss: 0.007834428830144137
Epoch 525: Train acc: 0.715747372337457, Train loss: 0.008098583858465715 |Validation ac
c: 0.7092375578703703, Validation loss: 0.008238770661168132
Epoch 526: Train acc: 0.7131119585774967, Train loss: 0.007998342677613703 |Validation a
cc: 0.7055121527777778, Validation loss: 0.00787729912614367
Epoch 527: Train acc: 0.7142358850339503, Train loss: 0.008022422117432607 |Validation a
cc: 0.7064887152777778, Validation loss: 0.008234105263601778
Epoch 528: Train acc: 0.7148172263045298, Train loss: 0.008287146934847008 |Validation a
cc: 0.7080439814814815, Validation loss: 0.00798921085457464
Epoch 529: Train acc: 0.7138560754038384, Train loss: 0.008025362914931085 |Validation a
cc: 0.7080078125, Validation loss: 0.00841288224694482
Epoch 530: Train acc: 0.7122748271478622, Train loss: 0.008202604235091886 |Validation a
cc: 0.7060908564814815, Validation loss: 0.008411996234457066
Epoch 531: Train acc: 0.7158946454593371, Train loss: 0.007906453643900616 |Validation a
cc: 0.7094184027777778, Validation loss: 0.007987908947140597
Epoch 532: Train acc: 0.715104021331349, Train loss: 0.008057501239602617 |Validation ac
c: 0.7081524884259259, Validation loss: 0.00814751149099928
Epoch 533: Train acc: 0.7095619012184913, Train loss: 0.008113536708062453 |Validation a
cc: 0.7034143518518519, Validation loss: 0.008674691659909637
Epoch 534: Train acc: 0.7128639196353828, Train loss: 0.008192621438849705 |Validation a
cc: 0.7078631365740741, Validation loss: 0.008094640832134585
Epoch 535: Train acc: 0.7082209406876879, Train loss: 0.007811989608975211 |Validation a
cc: 0.7029441550925926, Validation loss: 0.008440447394329866
Epoch 536: Train acc: 0.7136700461972529, Train loss: 0.00801131485005183 |Validation ac
c: 0.7069950810185185, Validation loss: 0.007781470315365082
Epoch 537: Train acc: 0.7125693733916225, Train loss: 0.0084614439892309 |Validation ac
```

```
c: 0.7060908564814815, Validation loss: 0.008420826583957017
Epoch 538: Train acc: 0.7114997054537563, Train loss: 0.008230074422809817 |Validation a
cc: 0.7052228009259259, Validation loss: 0.008115966373899792
Epoch 539: Train acc: 0.7082907016401575, Train loss: 0.008225708694172365 |Validation a
cc: 0.7012803819444444, Validation loss: 0.00781017568346544
Epoch 540: Train acc: 0.7143444020711252, Train loss: 0.008008853862620338 |Validation a
cc: 0.7078993055555556, Validation loss: 0.008326673266016367
Epoch 541: Train acc: 0.715607850432518, Train loss: 0.007982186681538467 |Validation ac
c: 0.7092737268518519, Validation loss: 0.007990606136078385
Epoch 542: Train acc: 0.7093138622763774, Train loss: 0.008088733946340772 |Validation a
cc: 0.7042462384259259, Validation loss: 0.007791848413823089
Epoch 543: Train acc: 0.7149179921247636, Train loss: 0.00823356460942956 |Validation ac
c: 0.7100694444444444, Validation loss: 0.00791335068656911
Epoch 544: Train acc: 0.7156543577341643, Train loss: 0.00800734137817775 |Validation ac
c: 0.7077907986111112, Validation loss: 0.007967381070724493
Epoch 545: Train acc: 0.7160264161473351, Train loss: 0.008297521322523451 |Validation a
cc: 0.7092737268518519, Validation loss: 0.0077012340491223056
Epoch 546: Train acc: 0.7144374166744178, Train loss: 0.008095132497219418 |Validation a
cc: 0.7078269675925926, Validation loss: 0.00802255831230487
Epoch 547: Train acc: 0.715483830961461, Train loss: 0.008356815295912966 |Validation ac
c: 0.7087311921296297, Validation loss: 0.008140290031646232
Epoch 548: Train acc: 0.7106083155055344, Train loss: 0.008113146188892756 |Validation a
cc: 0.7053313078703703, Validation loss: 0.008310081638279716
Epoch 549: Train acc: 0.7135925340278424, Train loss: 0.008299276823432181 |Validation a
cc: 0.7073206018518519, Validation loss: 0.008188603841768 75
Epoch 550: Train acc: 0.7138483241868974, Train loss: 0.008215549652732754 |Validation a
cc: 0.7056929976851852, Validation loss: 0.008006410677406041
Epoch 551: Train acc: 0.7065311753945369, Train loss: 0.008149430239352036 |Validation a
cc: 0.7000144675925926, Validation loss: 0.008103119905137122
Epoch 552: Train acc: 0.715359811490404, Train loss: 0.007657063901783672 |Validation ac
c: 0.7088035300925926, Validation loss: 0.007746877652407798
Epoch 553: Train acc: 0.7141583728645398, Train loss: 0.008170248668375549 |Validation a
cc: 0.7072844328703703, Validation loss: 0.00819861965229077
Epoch 554: Train acc: 0.7086317551855641, Train loss: 0.007901800769444788 |Validation a
cc: 0.7002314814814815, Validation loss: 0.008492632368330786
Epoch 555: Train acc: 0.7151195237652311, Train loss: 0.007877851173817802 |Validation a
cc: 0.7081886574074074, Validation loss: 0.007984147017105906
Epoch 556: Train acc: 0.7142203826000683, Train loss: 0.00794766349607432 |Validation ac
c: 0.7087311921296297, Validation loss: 0.007913640186947823
Epoch 557: Train acc: 0.7128639196353828, Train loss: 0.008097640978647755 |Validation a
cc: 0.7056929976851852, Validation loss: 0.008098029899093093
Epoch 558: Train acc: 0.7156543577341643, Train loss: 0.008076406327885982 |Validation a
cc: 0.7085865162037037, Validation loss: 0.007943746474922499
Epoch 559: Train acc: 0.711608222490931, Train loss: 0.008057094056805932 |Validation ac
c: 0.7053674768518519, Validation loss: 0.007883015596542718
Epoch 560: Train acc: 0.7121663101106874, Train loss: 0.007936255028056815 |Validation a
cc: 0.7069589120370371, Validation loss: 0.008176978614640033
Epoch 561: Train acc: 0.7135150218584317, Train loss: 0.007981057041835935 |Validation a
cc: 0.7082971643518519, Validation loss: 0.007891947429113156
Epoch 562: Train acc: 0.7132902365671411, Train loss: 0.008248565646678828 |Validation a
cc: 0.7062355324074074, Validation loss: 0.008389912031657265
Epoch 563: Train acc: 0.7149412457755868, Train loss: 0.008040991953079443 |Validation a
cc: 0.7068865740740741, Validation loss: 0.008041912589625673
Epoch 564: Train acc: 0.715367562707345, Train loss: 0.008039485980295065 |Validation ac
c: 0.7075376157407407, Validation loss: 0.008204347226707934
Epoch 565: Train acc: 0.7149955042941741, Train loss: 0.008061888858465925 |Validation a
cc: 0.7088396990740741, Validation loss: 0.00812805868969893
Epoch 566: Train acc: 0.7167240256720305, Train loss: 0.007879626243554873 |Validation a
cc: 0.7101417824074074, Validation loss: 0.008086765491754612
Epoch 567: Train acc: 0.7109183641831768, Train loss: 0.00829821227405784 |Validation ac
c: 0.7058738425925926, Validation loss: 0.008220098274331596
Epoch 568: Train acc: 0.7151195237652311, Train loss: 0.007970850084955287 |Validation a
cc: 0.7090928819444444, Validation loss: 0.008175069708045494
Epoch 569: Train acc: 0.7119802809041019, Train loss: 0.007817839646092907 |Validation a
cc: 0.7069227430555556, Validation loss: 0.00815541152386354
```

```
Epoch 570: Train acc: 0.7158636405915729, Train loss: 0.007768276339612393 |Validation a
cc: 0.7090928819444444, Validation loss: 0.007965835095977394
Epoch 571: Train acc: 0.7141738752984218, Train loss: 0.008212764593371873 |Validation a
cc: 0.7067057291666666, Validation loss: 0.008383263667315819
Epoch 572: Train acc: 0.714197128949245, Train loss: 0.008062309631801457 |Validation ac
c: 0.7078631365740741, Validation loss: 0.008094759226171437
Epoch 573: Train acc: 0.7111121446067032, Train loss: 0.008146443289569205 |Validation a
cc: 0.7063440393518519, Validation loss: 0.007968324350568988
Epoch 574: Train acc: 0.7112516665116423, Train loss: 0.007923349188170907 |Validation a
cc: 0.7038122106481481, Validation loss: 0.007920958751878903
Epoch 575: Train acc: 0.7155923479986358, Train loss: 0.008331782532750853 |Validation a
cc: 0.7095630787037037, Validation loss: 0.007830035899011335
Epoch 576: Train acc: 0.7140033485257186, Train loss: 0.008184306503851133 |Validation a
cc: 0.7085865162037037, Validation loss: 0.00793874467714781
Epoch 577: Train acc: 0.7163674696927418, Train loss: 0.008329983991335867 |Validation a
cc: 0.7084418402777778, Validation loss: 0.00788335090237794
Epoch 578: Train acc: 0.7159101478932193, Train loss: 0.008356931402406016 |Validation a
cc: 0.7087673611111112, Validation loss: 0.008505778955793124
Epoch 579: Train acc: 0.7166077574179146, Train loss: 0.008269993335461846 |Validation a
cc: 0.7089120370370371, Validation loss: 0.008413615414751168
Epoch 580: Train acc: 0.7155225870461662, Train loss: 0.007960739776282087 |Validation a
cc: 0.7086588541666666, Validation loss: 0.007961971858704259
Epoch 581: Train acc: 0.7137630608005456, Train loss: 0.007999769320092455 |Validation a
cc: 0.7078631365740741, Validation loss: 0.008091770862823335
Epoch 582: Train acc: 0.710693578891886, Train loss: 0.007845491119757162 |Validation ac
c: 0.7038483796296297, Validation loss: 0.008210838540216758
Epoch 583: Train acc: 0.7115617151892847, Train loss: 0.008014757615218398 |Validation a
cc: 0.7055121527777778, Validation loss: 0.007899522581704248
Epoch 584: Train acc: 0.7135150218584317, Train loss: 0.007921108878590719 |Validation a
cc: 0.7058376736111112, Validation loss: 0.007838174892805009
Epoch 585: Train acc: 0.70874802343968, Train loss: 0.00775050432683806 |Validation acc:
0.7004484953703703, Validation loss: 0.007839240008710887
Epoch 586: Train acc: 0.7159644064118067, Train loss: 0.007972046539452734 |Validation a
cc: 0.7084418402777778, Validation loss: 0.00824222594460898
Epoch 587: Train acc: 0.7131119585774967, Train loss: 0.008035919323663064 |Validation a
cc: 0.7081886574074074, Validation loss: 0.008140263246449722
Epoch 588: Train acc: 0.7157008650358107, Train loss: 0.007919789555839067 |Validation a
cc: 0.7103587962962963, Validation loss: 0.00793070450994443
Epoch 589: Train acc: 0.7082984528570986, Train loss: 0.008333494546837022 |Validation a
cc: 0.7026548032407407, Validation loss: 0.0076290217845891364
Epoch 590: Train acc: 0.7144839239760642, Train loss: 0.008261469169312575 |Validation a
cc: 0.7070674189814815, Validation loss: 0.007799347734095346
Epoch 591: Train acc: 0.7160496697981583, Train loss: 0.008073500136482786 |Validation a
cc: 0.7088035300925926, Validation loss: 0.008157512766532931
Epoch 592: Train acc: 0.716778284190618, Train loss: 0.008127955468343875 |Validation ac
c: 0.7103949652777778, Validation loss: 0.007847948099323479
Epoch 593: Train acc: 0.7145304312777107, Train loss: 0.008006167756283008 |Validation a
cc: 0.7080439814814815, Validation loss: 0.008004808906902413
Epoch 594: Train acc: 0.7164604842960345, Train loss: 0.008020898251924166 |Validation a
cc: 0.7101779513888888, Validation loss: 0.007741268924561824
Epoch 595: Train acc: 0.7163597184758007, Train loss: 0.008349847482401291 |Validation a
cc: 0.7091290509259259, Validation loss: 0.008291035699202106
Epoch 596: Train acc: 0.7150497628127616, Train loss: 0.008236297733739063 |Validation a
cc: 0.7079354745370371, Validation loss: 0.007885360588369344
Epoch 597: Train acc: 0.7164294794282703, Train loss: 0.008146158196391312 |Validation a
cc: 0.7101417824074074, Validation loss: 0.007830566719025153
Epoch 598: Train acc: 0.7148869872569994, Train loss: 0.008055237506706964 |Validation a
cc: 0.7103226273148148, Validation loss: 0.008154946649502354
Epoch 599: Train acc: 0.7134685145567854, Train loss: 0.007842640846398402 |Validation a
cc: 0.7071035879629629, Validation loss: 0.0077712724374977525
Epoch 600: Train acc: 0.7151427774160544, Train loss: 0.00831199063814469 |Validation ac
c: 0.7076099537037037, Validation loss: 0.00820489215059344
Finished Training
Total time elapsed: 1947.06 seconds
```






```
Final Training Accuracy: 0.7151427774160544
Final Validation Accuracy: 0.7076099537037037
```

Part 4. Testing [12 pt]

Part (a) [2 pt]

Compute and report the test accuracy.

In [ ]:
```
test_loader = torch.utils.data.DataLoader(test_data, batch_size=64, shuffle=True)
test_acc = get_accuracy(model_5, test_loader)
print("The test accuracy of the best autoencoder model is", test_acc*100, "%")
```

```
The test accuracy of the best autoencoder model is 70.53674768518519 %
```

Part (b) [4 pt]

Based on the test accuracy alone, it is difficult to assess whether our model is actually performing well. We don't know whether a high accuracy is due to the simplicity of the problem, or if a poor accuracy is a result of the inherent difficulty of the problem.

It is therefore very important to be able to compare our model to at least one alternative. In particular, we consider a simple **baseline** model that is not very computationally expensive. Our neural network should at least outperform this baseline model. If our network is not much better than the baseline, then it is not doing well.

For our data imputation problem, consider the following baseline model: to predict a missing feature, the baseline model will look at the **most common value** of the feature in the training set.

For example, if the feature "marriage" is missing, then this model's prediction will be the most common value for "marriage" in the training set, which happens to be "Married-civ-spouse".

What would be the test accuracy of this baseline model?

In [ ]:
```
baseline = {}
for col in df_not_missing:
    baseline[col] = df[col].value_counts().idxmax()
```

In [ ]:
```
baseline
```

Out[ ]:
```
{'age': 0.2602739726027397,
 'capgain': 0.0,
 'caploss': 0.0,
 'edu': ' HS-grad',
 'marriage': ' Married-civ-spouse',
 'occupation': ' Prof-specialty',
 'relationship': ' Husband',
 'sex': ' Male',
 'work': ' Private',
 'workhr': 0.3979591836734694,
 'yredu': 0.5333333333333333}
```

In [ ]:
```
baseline_acc = sum(df_not_missing["marriage"] == baseline["marriage"])/len(df_not_missi
print("The baseline model accuracy of the \"marriage\" feature is", baseline_acc*100, "
```

```
The baseline model accuracy of the "marriage" feature is 46.67947131974738 %
```

Answer:

As shown in the code above, the test accuracy would vary depending on the feature with this baseline model due to its dependency on the most common value of each feature. For example, the baseline model accuracy of the "marriage" feature is `46.68%` because `46.68%` of values for the feature are "Married-civ-spouse", which is the most common value.

Part (c) [1 pt]

How does your test accuracy from part (a) compared to your basline test accuracy in part (b)?

Answer:

The test accuracy of the autoencoder model is `70.54%`, which is much higher compared to the estimated test accuracy of taking the most common value, which is only `46.68%`.

Part (d) [1 pt]

Look at the first item in your test data. Do you think it is reasonable for a human to be able to guess this person's education level based on their other features? Explain.

In [ ]:
```
get_features(test_data[0])
```

Out[ ]:
```
{'edu': 'Bachelors',
 'marriage': 'Divorced',
 'occupation': 'Prof-specialty',
 'relationship': 'Not-in-family',
 'sex': 'Male',
 'work': 'Private'}
```

Answer:

In my opinion it can be quite difficult to guess the person's education level based on their other features. Some speculations could be made based on the person's occupation. Since the person has an occupation in a professional specialty, I would guess that the person would at least have completed high school. Besides this connection, I cannot draw any other conclusions based on these features.

Part (e) [2 pt]

What is your model's prediction of this person's education level, given their other features?

In [ ]:
```
test_edu = zero_out_feature(test_data[:1], "edu")[0]
predict = model_5(torch.from_numpy(test_edu))
get_feature(predict.detach().numpy(), "edu")
```

Out[ ]:
```
'Bachelors'
```

Answer:

The autoencoder model's prediction of this person's education level is "Bachelors", which is correct.

Part (f) [2 pt]

What is the baseline model's prediction of this person's education level?

In [ ]:
```
baseline["edu"]
```

Out[ ]:
```
' HS-grad'
```

Answer:

The baseline model's prediction of this person's education level is "HS-grad", which is incorrect.