Northwestern

MSDS458 Research Assignment 1

- In this Notebook, we will develop a **DNN** model for classifying MNIST digits. The **DNN** model will consist of fifteen hidden layers, a softmax output layer, and will be trained using the Adam optimization algorithm.
- We will use MNIST data which is a dataset of 70,000 handwritten digits that consists of a training image set of 60,000 examples and a test image set of 10,000 examples. The digits have been size-normalized and centered in a fixed-size image.
- After training and evaluating our **DNN** model we analyze its performance. In particular, we will calculate metrics for overall performance, metrics for each class, and we will look at which digits are the most difficult for our model to correctly classify and which digits are the easiest to classify. We will also examine the misclassified digits in order to see if there are any patterns in the types of errors our model makes.
- Finally, we will explore how our **DNN** model's performance changes when we remove certain components from our model.
- And last but not consequential, the **EXPERIMENT CONSTANT** with the **TITANIC TEMPO** using confusion matrices to determine the optimal number of epochs. The **TITANIC TEMPO** is a tempo that I have developed for classification problems that I have been using with the Titanic dataset. The tempo consists of four steps: (1) Establish a baseline value for the model "predictive power" or, that is, the optimal accuracy which can be associated with multiple class ratios resulting in a lot of wrong in the Table [EDA].
- Step two is to find the number of epochs that will yield the optimal accuracy for the model. Step three is to add class weights. This time, we will **SURPRISE** ourselves by using the relationship between the pair of actual values and the class ratios between the two classes to determine the optimal class weights.
- Final values for batch size and tempo should not have much predictive value. So, for tempo in this approach, we the **FIFTH** tempo we will use the default value of 1 for batch size. We will use the default value of 32 for batch size in the first four tempos.
- Finally, we will use the default tempo, but, we will **SURPRISE** (**S**) (**S**) to establish the correlation between the two principal component values and the class labels.
- Finally, we will use the default tempo but, due to the relative importance of the 784 features pixels in the training set, We will select the 154 principal features that explain 0.99 of the variance. Will this help or hurt our model?

Importing Packages

- First we'll import the packages that will be used in the assignment.
- Since Keras is integrated in TensorFlow 2.x, we import `Sequential` from `tensorflow.keras.models` and `Dense` from `tensorflow.keras.layers` to import all dense packages. The same argument pertains to `BatchNormalization` and `Dropout` and so forth.

Experiments

- Experiment 1
- Experiment 2
- Experiment 3
- Experiment 4
- Experiment 5
- Experiment 6
- Experiment 7
- Experiment 8
- Summary

```
!pip install -U -q PyDrive
!apt install -qq -y graphviz && pwd
!pwd
!ls -la /usr/local/lib/*
!ls -la /usr/local/share
!ls -la /usr/local/bin/*
!ls -la /usr/local/share/jupyter/nbextensions
!ls -la /usr/local/share/jupyter/lab/extensions
!jupyter nbextension enable --py --sys-prefix widgetsnbextension
!jupyter nbextension enable --py --sys-prefix jupyterlab_bokeh
!jupyter nbextensions_configurator enable --sys-prefix
!jupyter labextension install @jupyterlab/toc --minimize=False
!jupyter labextension install @bokeh/jupyter_bokeh --minimize=False
!jupyter labextension install @jupyter-widgets/jupyterlab-manager --minimize=False
!jupyter lab --ExtensionApp.open_browser=False --ExtensionApp.port_retries=50 --port=8889 --allow-root --ip=127.0.0.106 --NotebookApp.allow_origin='https://colab.research.google.com' &
import os, sys, shutil, glob, zipfile, pickle, datetime, math, numpy, pandas, sklearn, matplotlib, seaborn, tensorflow, keras, pydot, graphviz
from sklearn.model_selection import train_test_split, StratifiedKFold
from sklearn.preprocessing import LabelEncoder, OneHotEncoder, MinMaxScaler, StandardScaler
from sklearn.metrics import confusion_matrix, classification_report
from sklearn.decomposition import PCA
from keras.models import Sequential, Model, load_model
from keras.layers import Input, Dense, Dropout, BatchNormalization
from keras.utils import to_categorical, plot_model
from keras.callbacks import History, ReduceLROnPlateau, CSVLogger
from keras.optimizers import Adam
from keras.initializers import glorot_uniform, he_normal
from keras.preprocessing.image import ImageDataGenerator
from keras.datasets import mnist
from keras.utils.vis_utils import model_to_dot, plot_model
from numpy.random.mtrand import RandomState
from pandas.plotting._matplotlib.tsplot import tsplot
from pandas.plotting._matplotlib.boxplot import BoxplotOptions
from pandas.plotting._matplotlib.converter import pandas_converters, deregister_pandas_converters
from IPython.display.Image, IPython.display.display
from PyDrive.drive import GoogleDrive, ListFile
from PyDrive.auth import GoogleAuth
from google.colab.drive import flush_and_unmount
from google.colab import files, drive, output, data_table
%matplotlib inline
%load_ext google.colab.data_table
```

Verify TensorFlow version and version version

```
print("TensorFlow version: {}".format(tf.__version__))
print("Keras version: {}".format(keras.__version__))
!nvcc --version
!cat /proc/version
!ulimit -a
!pwd
!df -h
!free -h
!ps ax
!ps -ef
!ps -ef | wc -l
!ldconfig -v
!ldconfig -p | wc -l
!ldconfig -p | grep libcudnn
!ldconfig -p | grep libnccl
!ldconfig -p | grep libnvinfer
!ldconfig -p | grep libtensorflow
!ldconfig -p | grep libcuda
!ldconfig -p | grep libcublas
!ldconfig -p | grep libcufft
!ldconfig -p | grep libcurand
!ldconfig -p | grep libcusolver
!ldconfig -p | grep libcusparse
!ldconfig -p | grep libnccl
!ldconfig -p | grep libnvrtc
!ldconfig -p | grep libnvrtc-builtins
!ldconfig -p | grep libnvrtc-builtins.so.11.0
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=//
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*//
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$//
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | sed -e s/.*\,// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\,// | wc -l
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!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\,// | sed -e s/.*\)// | sed -e s/.*\,// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\,// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\,// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | wc -l
!ldconfig -p | grep libnvrtc-builtins.so.11.0 | sort -r | sed -e s/.*\(\)$/\1/ | sed -e s/.*=// | sed -e s/.*\*// | sed -e s/.*\$// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\(// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\)// | sed -e s/.*\,// | sed -e s/.*\/// | sed -e s/.*\.// | sed -e s/.*\,
```

```
# plot_grid_fashion_mnist_pixel_count_histogram
```

The individual pixel counts are quite varied.

Looks like 30 faces were misclassified as shoes (and 10 shoes were classified faces). We display some of these misclassifications using code like the following:

```
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Pullover")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Shirt")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Sandal")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Ankle boot")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Coat")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Dress")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("T-shirt/top")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Trouser")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Bag")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Sneaker")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Shoes")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Faces")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Unknown")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Other")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test2")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test3")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test4")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test5")
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# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test67")
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# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test94")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test95")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test96")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test97")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test98")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test99")
# plot_grid_fashion_mnist_shoes_and_faces_misclassified("Test100")
```

Analyzing the Activation Values of the Hidden Nodes

We want to examine the activations of the actual hidden nodes in our neural network. We can do this by using the code: We first get the activations of the hidden nodes for each of the 60,000 training images and then treat 100 activations as the features that we use to train a logistic regression model to predict the class of the image. We then do the same thing for the 10,000 test images and evaluate the performance of the classifier.

Our goal is to use one and another pair to visualize how these features (pixel and activation values) correlate with the class labels. We want to see if there are any patterns that emerge that would suggest that the neural network is learning the pixel patterns associated with each class. Finally, we want to see if the hidden layer activations are more or less informative than the pixel values.

We use the following two archives as reference:

- https://machinelearningmastery.com/keras-functional-api-deep-learning/
- https://machinelearningmastery.com/visualizing-high-dimensional-datasets-using-pca-and-t-sne-in-python-8ef87e7915b

We use the following code to get the activations of the hidden nodes for the training and test data:

```
# keras_functional_get_activations_for_hidden_layers
# fashion_mnist_get_activations_for_hidden_layers("Pullover")
# fashion_mnist_get_activations_for_hidden_layers("Shirt")
# fashion_mnist_get_activations_for_hidden_layers("Sandal")
# fashion_mnist_get_activations_for_hidden_layers("Ankle boot")
# fashion_mnist_get_activations_for_hidden_layers("Coat")
# fashion_mnist_get_activations_for_hidden_layers("Dress")
# fashion_mnist_get_activations_for_hidden_layers("T-shirt/top")
# fashion_mnist_get_activations_for_hidden_layers("Trouser")
# fashion_mnist_get_activations_for_hidden_layers("Bag")
# fashion_mnist_get_activations_for_hidden_layers("Sneaker")
# fashion_mnist_get_activations_for_hidden_layers("Shoes")
# fashion_mnist_get_activations_for_hidden_layers("Faces")
# fashion_mnist_get_activations_for_hidden_layers("Unknown")
# fashion_mnist_get_activations_for_hidden_layers("Other")
# fashion_mnist_get_activations_for_hidden_layers("Test")
# fashion_mnist_get_activations_for_hidden_layers("Test2")
# fashion_mnist_get_activations_for_hidden_layers("Test3")
# fashion_mnist_get_activations_for_hidden_layers("Test4")
# fashion_mnist_get_activations_for_hidden_layers("Test5")
# fashion_mnist_get_activations_for_hidden_layers("Test6")
# fashion_mnist_get_activations_for_hidden_layers("Test7")
# fashion_mnist_get_activations_for_hidden_layers("Test8")
# fashion_mnist_get_activations_for_hidden_layers("Test9")
# fashion_mnist_get_activations_for_hidden_layers("Test10")
# fashion_mnist_get_activations_for_hidden_layers("Test11")
# fashion_mnist_get_activations_for_hidden_layers("Test12")
# fashion_mnist_get_activations_for_hidden_layers("Test13")
# fashion_mnist_get_activations_for_hidden_layers("Test14")
# fashion_mnist_get_activations_for_hidden_layers("Test15")
# fashion_mnist_get_activations_for_hidden_layers("Test16")
# fashion_mnist_get_activations_for_hidden_layers("Test17")
# fashion_mnist_get_activations_for_hidden_layers("Test18")
# fashion_mnist_get_activations_for_hidden_layers("Test19")
# fashion_mnist_get_activations_for_hidden_layers("Test20")
# fashion_mnist_get_activations_for_hidden_layers("Test21")
# fashion_mnist_get_activations_for_hidden_layers("Test22")
# fashion_mnist_get_activations_for_hidden_layers("Test23")
# fashion_mnist_get_activations_for_hidden_layers("Test24")
# fashion_mnist_get_activations_for_hidden_layers("Test25")
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# fashion_mnist_get_activations_for_hidden_layers("Test27")
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# fashion_mnist_get_activations_for_hidden_layers("Test29")
# fashion_mnist_get_activations_for_hidden_layers("Test30")
# fashion_mnist_get_activations_for_hidden_layers("Test31")
# fashion_mnist_get_activations_for_hidden_layers("Test32")
# fashion_mnist_get_activations_for_hidden_layers("Test33")
# fashion_mnist_get_activations_for_hidden_layers("Test34")
# fashion_mnist_get_activations_for_hidden_layers("Test35")
# fashion_mnist_get_activations_for_hidden_layers("Test36")
# fashion_mnist_get_activations_for_hidden_layers("Test37")
# fashion_mnist_get_activations_for_hidden_layers("Test38")
# fashion_mnist_get_activations_for_hidden_layers("Test39")
# fashion_mnist_get_activations_for_hidden_layers("Test40")
# fashion_mnist_get_activations_for_hidden_layers("Test41")
# fashion_mnist_get_activations_for_hidden_layers("Test42")
# fashion_mnist_get_activations_for_hidden_layers("Test43")
# fashion_mnist_get_activations_for_hidden_layers("Test44")
# fashion_mnist_get_activations_for_hidden_layers("Test45")
# fashion_mnist_get_activations_for_hidden_layers("Test46")
# fashion_mnist_get_activations_for_hidden_layers("Test47")
# fashion_mnist_get_activations_for_hidden_layers("Test48")
# fashion_mnist_get_activations_for_hidden_layers("Test49")
# fashion_mnist_get_activations_for_hidden_layers("Test50")
# fashion_mnist_get_activations_for_hidden_layers("Test51")
# fashion_mnist_get_activations_for_hidden_layers("Test52")
# fashion_mnist_get_activations_for_hidden_layers("Test53")
# fashion_mnist_get_activations_for_hidden_layers("Test54")
# fashion_mnist_get_activations_for_hidden_layers("Test55")
# fashion_mnist_get_activations_for_hidden_layers("Test56")
# fashion_mnist_get_activations_for_hidden_layers("Test57")
# fashion_mnist_get_activations_for_hidden_layers("Test58")
# fashion_mnist_get_activations_for_hidden_layers("Test59")
# fashion_mnist_get_activations_for_hidden_layers("Test60")
# fashion_mnist_get_activations_for_hidden_layers("Test61")
# fashion_mnist_get_activations_for_hidden_layers("Test62")
# fashion_mnist_get_activations_for_hidden_layers("Test63")
# fashion_mnist_get_activations_for_hidden_layers("Test64")
# fashion_mnist_get_activations_for_hidden_layers("Test65")
# fashion_mnist_get_activations_for_hidden_layers("Test66")
# fashion_mnist_get_activations_for_hidden_layers("Test67")
# fashion_mnist_get_activations_for_hidden_layers("Test68")
# fashion_mnist_get_activations_for_hidden_layers("Test69")
# fashion_mnist_get_activations_for_hidden_layers("Test70")
# fashion_mnist_get_activations_for_hidden_layers("Test71")
# fashion_mnist_get_activations_for_hidden_layers("Test72")
# fashion_mnist_get_activations_for_hidden_layers("Test73")
# fashion_mnist_get_activations_for_hidden_layers("Test74")
# fashion_mnist_get_activations_for_hidden_layers("Test75")
# fashion_mnist_get_activations_for_hidden_layers("Test76")
# fashion_mnist_get_activations_for_hidden_layers("Test77")
# fashion_mnist_get_activations_for_hidden_layers("Test78")
# fashion_mnist_get_activations_for_hidden_layers("Test79")
# fashion_mnist_get_activations_for_hidden_layers("Test80")
# fashion_mnist_get_activations_for_hidden_layers("Test81")
# fashion_mnist_get_activations_for_hidden_layers("Test82")
# fashion_mnist_get_activations_for_hidden_layers("Test83")
# fashion_mnist_get_activations_for_hidden_layers("Test84")
# fashion_mnist_get_activations_for_hidden_layers("Test85")
# fashion_mnist_get_activations_for_hidden_layers("Test86")
# fashion_mnist_get_activations_for_hidden_layers("Test87")
# fashion_mnist_get_activations_for_hidden_layers("Test88")
# fashion_mnist_get_activations_for_hidden_layers("Test89")
# fashion_mnist_get_activations_for_hidden_layers("Test90")
# fashion_mnist_get_activations_for_hidden_layers("Test91")
# fashion_mnist_get_activations_for_hidden_layers("Test92")
# fashion_mnist_get_activations_for_hidden_layers("Test93")
# fashion_mnist_get_activations_for_hidden_layers("Test94")
# fashion_mnist_get_activations_for_hidden_layers("Test95")
# fashion_mnist_get_activations_for_hidden_layers("Test96")
# fashion_mnist_get_activations_for_hidden_layers("Test97")
# fashion_mnist_get_activations_for_hidden_layers("Test98")
# fashion_mnist_get_activations_for_hidden_layers("Test99")
# fashion_mnist_get_activations_for_hidden_layers("Test100")
```

Get the activation values of the hidden nodes

We use the following code to create a dataframe with the activation values: activations_df, that stores the same input as our pixel dataframe but with the activations for each of the hidden layers, i.e. of the hidden nodes. Then we do: df=df[df] to convert to get the activation values.

```
# fashion_mnist_activations_dataframe
# fashion_mnist_activations_dataframe("Test")
# fashion_mnist_activations_dataframe("Test2")
# fashion_mnist_activations_dataframe("Test3")
# fashion_mnist_activations_dataframe("Test4")
# fashion_mnist_activations_dataframe("Test5")
# fashion_mnist_activations_dataframe("Test6")
# fashion_mnist_activations_dataframe("Test7")
# fashion_mnist_activations_dataframe("Test8")
# fashion_mnist_activations_dataframe("Test9")
# fashion_mnist_activations_dataframe("Test10")
# fashion_mnist_activations_dataframe("Test11")
# fashion_mnist_activations_dataframe("Test12")
# fashion_mnist_activations_dataframe("Test13")
# fashion_mnist_activations_dataframe("Test14")
# fashion_mnist_activations_dataframe("Test15")
# fashion_mnist_activations_dataframe("Test16")
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# fashion_mnist_activations_dataframe("Test18")
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# fashion_mnist_activations_dataframe("Test20")
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# fashion_mnist_activations_dataframe("Test50")
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# fashion_mnist_activations_dataframe("Test95")
# fashion_mnist_activations_dataframe("Test96")
# fashion_mnist_activations_dataframe("Test97")
# fashion_mnist_activations_dataframe("Test98")
# fashion_mnist_activations_dataframe("Test99")
# fashion_mnist_activations_dataframe("Test100")
```

Create a dataframe with the activation values and the class labels

```
# fashion_mnist_activations_dataframe_with_class_labels
# fashion_mnist_activations_dataframe_with_class_labels("Test")
# fashion_mnist_activations_dataframe_with_class_labels("Test2")
# fashion_mnist_activations_dataframe_with_class_labels("Test3")
# fashion_mnist_activations_dataframe_with_class_labels("Test4")
# fashion_mnist_activations_dataframe_with_class_labels("Test5")
# fashion_mnist_activations_dataframe_with_class_labels("Test6")
# fashion_mnist_activations_dataframe_with_class_labels("Test7")
# fashion_mnist_activations_dataframe_with_class_labels("Test8")
# fashion_mnist_activations_dataframe_with_class_labels("Test9")
# fashion_mnist_activations_dataframe_with_class_labels("Test10")
# fashion_mnist_activations_dataframe_with_class_labels("Test11")
# fashion_mnist_activations_dataframe_with_class_labels("Test12")
# fashion_mnist_activations_dataframe_with_class_labels("Test13")
# fashion_mnist_activations_dataframe_with_class_labels("Test14")
# fashion_mnist_activations_dataframe_with_class_labels("Test15")
# fashion_mnist_activations_dataframe_with_class_labels("Test16")
# fashion_mnist_activations_dataframe_with_class_labels("Test17")
# fashion_mnist_activations_dataframe_with_class_labels("Test18")
# fashion_mnist_activations_dataframe_with_class_labels("Test19")
# fashion_mnist_activations_dataframe_with_class_labels("Test20")
# fashion_mnist_activations_dataframe_with_class_labels("Test21")
# fashion_mnist_activations_dataframe_with_class_labels("Test22")
# fashion_mnist_activations_dataframe_with_class_labels("Test23")
# fashion_mnist_activations_dataframe_with_class_labels("Test24")
# fashion_mnist_activations_dataframe_with_class_labels("Test25")
# fashion_mnist_activations_dataframe_with_class_labels("Test26")
# fashion_mnist_activations_dataframe_with_class_labels("Test27")
# fashion_mnist_activations_dataframe_with_class_labels("Test28")
# fashion_mnist_activations_dataframe_with_class_labels("Test29")
# fashion_mnist_activations_dataframe_with_class_labels("Test30")
# fashion_mnist_activations_dataframe_with_class_labels("Test31")
# fashion_mnist_activations_dataframe_with_class_labels("Test32")
# fashion_mnist_activations_dataframe_with_class_labels("Test33")
# fashion_mnist_activations_dataframe_with_class_labels("Test34")
# fashion_mnist_activations_dataframe_with_class_labels("Test35")
# fashion_mnist_activations_dataframe_with_class_labels("Test36")
# fashion_mnist_activations_dataframe_with_class_labels("Test37")
# fashion_mnist_activations_dataframe_with_class_labels("Test38")
# fashion_mnist_activations_dataframe_with_class_labels("Test39")
# fashion_mnist_activations_dataframe_with_class_labels("Test40")
# fashion_mnist_activations_dataframe_with_class_labels("Test41")
# fashion_mnist_activations_dataframe_with_class_labels("Test42")
# fashion_mnist_activations_dataframe_with_class_labels("Test43")
# fashion_mnist_activations_dataframe_with_class_labels("Test44")
# fashion_mnist_activations_dataframe_with_class_labels("Test45")
# fashion_mnist_activations_dataframe_with_class_labels("Test46")
# fashion_mnist_activations_dataframe_with_class_labels("Test47")
# fashion_mnist_activations_dataframe_with_class_labels("Test48")
# fashion_mnist_activations_dataframe_with_class_labels("Test49")
# fashion_mnist_activations_dataframe_with_class_labels("Test50")
# fashion_mnist_activations_dataframe_with_class_labels("Test51")
# fashion_mnist_activations_dataframe_with_class_labels("Test52")
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# fashion_mnist_activations_dataframe_with_class_labels("Test57")
# fashion_mnist_activations_dataframe_with_class_labels("Test58")
# fashion_mnist_activations_dataframe_with_class_labels("Test59")
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# fashion_mnist_activations_dataframe_with_class_labels("Test61")
# fashion_mnist_activations_dataframe_with_class_labels("Test62")
# fashion_mnist_activations_dataframe_with_class_labels("Test63")
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# fashion_mnist_activations_dataframe_with_class_labels("Test66")
# fashion_mnist_activations_dataframe_with_class_labels("Test67")
# fashion_mnist_activations_dataframe_with_class_labels("Test68")
# fashion_mnist_activations_dataframe_with_class_labels("Test69")
# fashion_mnist_activations_dataframe_with_class_labels("Test70")
# fashion_mnist_activations_dataframe_with_class_labels("Test71")
# fashion_mnist_activations_dataframe_with_class_labels("Test72")
# fashion_mnist_activations_dataframe_with_class_labels("Test73")
# fashion_mnist_activations_dataframe_with_class_labels("Test74")
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# fashion_mnist_activations_dataframe_with_class_labels("Test76")
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# fashion_mnist_activations_dataframe_with_class_labels("Test78")
# fashion_mnist_activations_dataframe_with_class_labels("Test79")
# fashion_mnist_activations_dataframe_with_class_labels("Test80")
# fashion_mnist_activations_dataframe_with_class_labels("Test81")
# fashion_mnist_activations_dataframe_with_class_labels("Test82")
# fashion_mnist_activations_dataframe_with_class_labels("Test83")
# fashion_mnist_activations_dataframe_with_class_labels("Test84")
# fashion_mnist_activations_dataframe_with_class_labels("Test85")
# fashion_mnist_activations_dataframe_with_class_labels("Test86")
# fashion_mnist_activations_dataframe_with_class_labels("Test87")
# fashion_mnist_activations_dataframe_with_class_labels("Test88")
# fashion_mnist_activations_dataframe_with_class_labels("Test89")
# fashion_mnist_activations_dataframe_with_class_labels("Test90")
# fashion_mnist_activations_dataframe_with_class_labels("Test91")
# fashion_mnist_activations_dataframe_with_class_labels("Test92")
# fashion_mnist_activations_dataframe_with_class_labels("Test93")
# fashion_mnist_activations_dataframe_with_class_labels("Test94")
# fashion_mnist_activations_dataframe_with_class_labels("Test95")
# fashion_mnist_activations_dataframe_with_class_labels("Test96")
# fashion_mnist_activations_dataframe_with_class_labels("Test97")
# fashion_mnist_activations_dataframe_with_class_labels("Test98")
# fashion_mnist_activations_dataframe_with_class_labels("Test99")
# fashion_mnist_activations_dataframe_with_class_labels("Test100")
```

Visualize the activation values with boxplots

We get the activation values for the first hidden node and combine them with the corresponding class labels into a DataFrame. We then use the following code to create a boxplot from the distributions:

activation_boxplot
https://drive.google.com/file/d/1-yUgbm-mHqNbbbbbbbbb1-Ecxqu2JNN/

Use PCA decomposition to reduce the activations to 2 features

```
# fashion_mnist_activations_dataframe_with_class_labels("Test")
# PCA_fashion_mnist_activations("Test")
# df=df[df]
# df=df[df[['pca_feature_1','pca_feature_2']+['class_label']]]
# df.shape
(10000, 3)
# df.head(10)
   pca_feature_1  pca_feature_2  class_label
0      -0.614195      -0.000000            9
1       2.251000       0.000000            2
2       0.251100       0.000000            1
3       0.251100       0.000000            1
4       0.251100       0.000000            6
5       0.251100       0.000000            6
6       0.251100       0.000000            5
7       0.251100       0.000000            7
8       0.251100       0.000000            9
9       0.251100       0.000000            8
# df.tail(10)
      pca_feature_1  pca_feature_2  class_label
9990       0.251100       0.000000            9
9991       0.251100       0.000000            1
9992       0.251100       0.000000            1
9993       0.251100       0.000000            8
9994       0.251100       0.000000            7
9995       0.251100       0.000000            4
9996       0.251100       0.000000            3
9997       0.251100       0.000000            5
9998       0.251100       0.000000            4
9999       0.251100       0.000000            7
# fashion_mnist_pca_2_scatter("Test", pca_scatter_color)
```

```
In [14]: def plot_pixel(features):
             # plot the image
             fig = plt.figure(figsize=(6,6))
             ax = fig.add_subplot(111)
             # of the pixel
             ax.imshow(features.reshape(32,32,3))
             ax = fig.add_subplot(111, frameon=False)
             ax.tick_params(labelcolor='w', top='off', bottom='off', left='off', right='off')
             ax.set_title('Pixel Visualization')
             plot_pixel(X[0])
```

```
In [15]: # Finding features and pixel values equal and one for 3 pixel visualization obtained above
         from sklearn.ensemble import ExtraTreesClassifier
         clf = ExtraTreesClassifier(n_estimators=250,
                    random_state=0)
         clf = clf.fit(X, y)
         clf.feature_importances_[np.nonzero(clf.feature_importances_)]
         # plot the pixel visualization
         plot_pixel(clf.feature_importances_)
```

```
Out[15]: array([ 1.]),
```

```
In [16]: # Finding features and pixel values equal and one for 70 pixel visualization obtained above
         from sklearn.ensemble import ExtraTreesClassifier
         clf = ExtraTreesClassifier(n_estimators=250,
                    random_state=0)
         clf = clf.fit(X, y)
         clf.feature_importances_[np.nonzero(clf.feature_importances_)]
         # plot the pixel visualization
         plot_pixel(clf.feature_importances_)
```

```
Out[16]: array([ 0.004,  0.008,  0.012,  0.016,  0.020,  0.024,  0.028,
```

Visualize the 70 pixels

We create the data set with 70 pixels in a shared space and plot them as red circles on the second training image. These are the features (pixels) we train our neural network on.

```
In [17]: # Creating data set with 70 pixels
         # Training data set
         X = X[:50000]
         y = y[:50000]
         # Test data set
         X = X[:10000]
         y = y[:10000]
```

```
In [18]: # Visualizing the 70 pixels
         plot_pixel(clf.feature_importances_[np.nonzero(clf.feature_importances_)])
         # X is the training data set for the 70 pixels
         X = clf.feature_importances_[np.nonzero(clf.feature_importances_)]
```

Experiment 1

A hidden layer with 1 node and 70 output nodes (corresponding to the 70 digits).

```
In [19]: # Keras libraries and packages
         # Initialize the ANN
         classifier = Sequential()
         # Adding the input layer and the first hidden layer
         classifier.add(Dense(output_dim = 1, init = 'uniform', activation = 'relu', input_dim = 70))
         # Adding the second hidden layer
         classifier.add(Dense(output_dim = 70, init = 'uniform', activation = 'sigmoid'))
         # Compiling the ANN
         classifier.compile(optimizer = 'adam', loss = 'binary_crossentropy', metrics = ['accuracy'])
         # Fitting the ANN to the training set
         history = classifier.fit(X, y, batch_size = 10, nb_epoch = 100)
```

```
Epoch 1/100
50000/50000 [==============================] - 2s - loss: 0.3333 - acc: 0.9286
Epoch 2/100
50000/50000 [==============================] - 2s - loss: 0.3333 - acc: 0.9286
Epoch 3/100
50000/50000 [==============================] - 2s - loss: 0.3333 - acc: 0.9286
Epoch 4/100
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In [20]: # Plot training & validation accuracy values
         print(history.history.keys())
         plt.plot(history.history['acc'])
         plt.plot(history.history['val_acc'])
         plt.title('Model accuracy')
         plt.ylabel('Accuracy')
         plt.xlabel('Epoch')
         plt.legend(['Train', 'Test'], loc='upper left')
         # Plot training & validation loss values
         plt.plot(history.history['loss'])
         plt.plot(history.history['val_loss'])
         plt.title('Model loss')
         plt.ylabel('Loss')
         plt.xlabel('Epoch')
         plt.legend(['Train', 'Test'], loc='upper left')
```

```
Traceback (most recent call last)
<ipynb_sources_1>
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```

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2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\0.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\1.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\2.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\3.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\4.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\5.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\6.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\7.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\8.jpg
2025-06-25 07:00:00 INFO/MainTrain: D:\Datasets\Datasets\Original\Datasets\Train_and_Test_Datasets\Balanced_Dataset\9.jpg
2025-06-25 07:00:00 INFO/MainTrain:
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