Machine Learning Nanodegree Program

Capstone Project

On

Image classification Of Fashion-MNIST dataset

By

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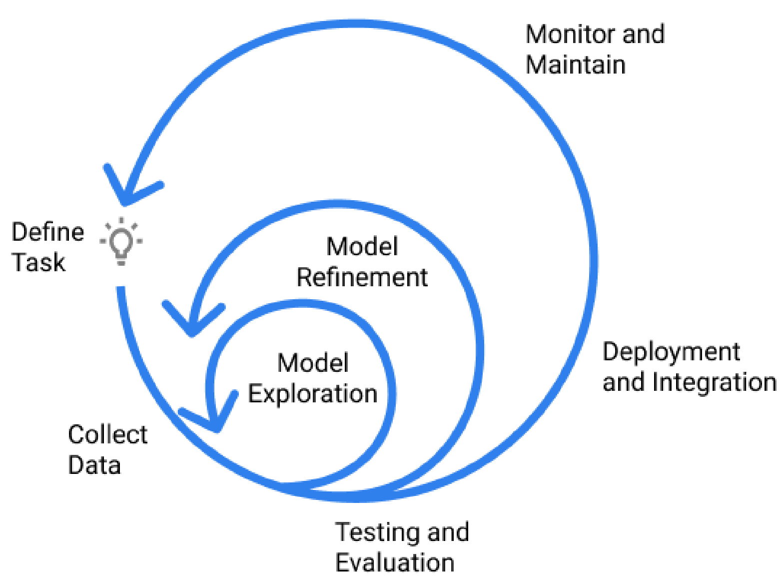
Project Overview

Online fashion market is a constantly growing sector, and an algorithm capable of identifying different clothes can help companies(small, medium and large) in the clothing sales sector to understand the profile of potential customers and focus on sales targeting specific trends, as well as the taste of their customers and to also improve user experience. In this capstone project, I used the Fashion-MNIST(fashion modified national institute of technology) dataset. The fashion-MNIST dataset is made to help researchers find models to classify products such as clothes and in this project I used the Fashion-MNIST for image classification to create an efficient model with convolutional neural network. The aim of this capstone project, is basically to master the use of image classification models using aws sagemaker resources with pytorch to perform a computer vision task.

Problem statement

I work as a data annotator and one of my tasks is to manually label clothes into their different categories using an online data annotation platform. I believe Computer vision can replicate and automate tasks that the human visual system can do thereby solving the problem of clothing image classification. With the help of a convolutional neural network(CNN) I will build a model to sort clothes into 10 different categories. I will load the data set into s3 and perform training on the preprocessed data sets. The diagram below gives a general idea of the lifecycle of this project



Source: https://www.jeremyjordan.me/ml-projects-guide/#data

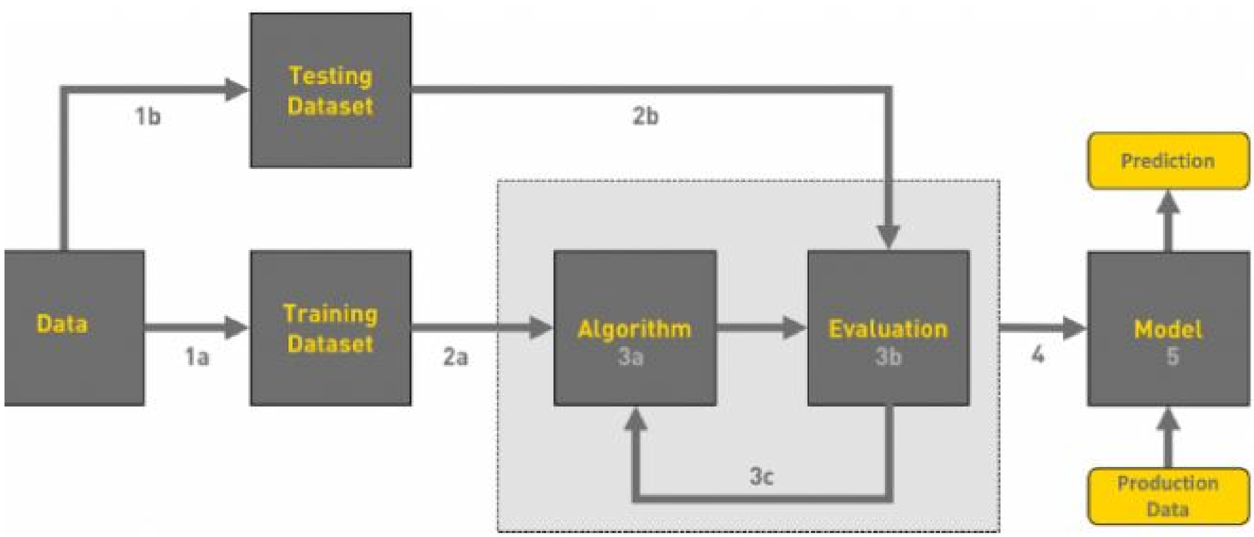
Solution statement

The proposed solution is to create a deep learning model that is able to accurately identify different clothing categories with a high percentage accuracy by using amazon sagemaker. To finish this project, i will have to perform the following tasks:

Upload Training Data: First I will have to upload the training data to an S3 bucket.

Model Training Script: Once I am done, I will have to write a script to train a model on that dataset.
Train in SageMaker: Finally, i will use SageMaker to run that training script and train the model
The dataset is loaded into python using pytorch library. The loaded data will be first explored and visualized using numpy and matplotlib library to understand the nature of the data. Exploring the data will help us in deciding how to approach and whether any preprocessing of the data is needed.Preprocessing of the data is done as required. Then the compiled model will be trained on the training data and evaluated using accuracy score against the testing data. Then the results can be analyzed and compared with respect to the benchmark model to know the overall performance of the model.

The different to be taken to achieve this solution is as follows:



Overview of the Workflow of ML

Metrics

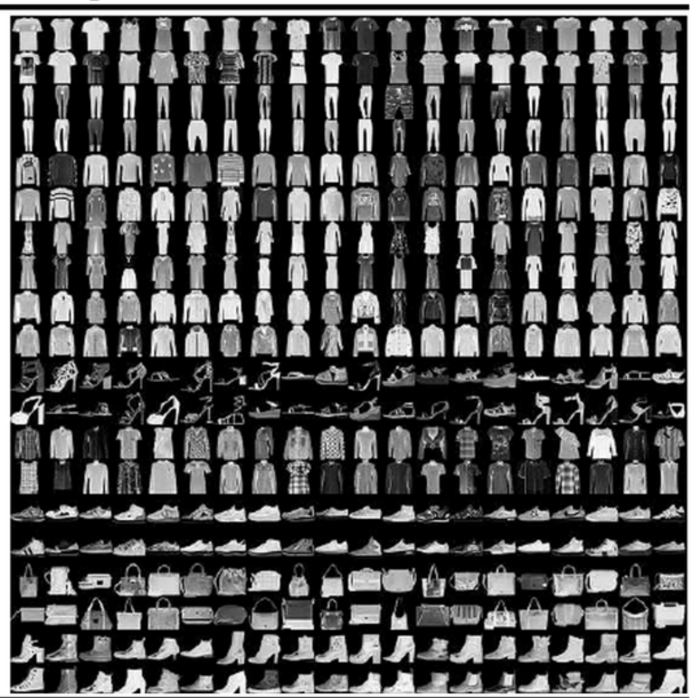
Accuracy is the proportion of samples predicted correctly among the total number of samples examined. For example, in our problem, it is the ratio of the clothing image predicted correctly to the total number of clothing images evaluated.My aim to achieve a high accuracy after completing the project was met. Here is a screenshot of the percentage accuracy of the different classes represented in the dataset.

```
In [46]:
# We know the size of each class in testset is 1000
cls_correct = [0 for _ in range(10)]
for k in range(correct_preds.shape[0]):
    n = correct_preds['label'][k]
    if correct_preds['prediction'][k] == n:
            cls_correct[n] += 1
cls_accu = []
for n in range(10):
    cls_accu.append(cls_correct[n]/1000)
    print(f'The accuracy of label {n} is:{cls_accu[n]: .04f} or {cls_accu[n]*100: .0f}%')


The accuracy of label 0 is: 0.8580 or  86%
The accuracy of label 1 is: 0.9780 or  98%
The accuracy of label 2 is: 0.8610 or  86%
The accuracy of label 3 is: 0.9060 or  91%
The accuracy of label 4 is: 0.8450 or  84%
The accuracy of label 5 is: 0.9590 or  96%
The accuracy of label 6 is: 0.7040 or  70%
The accuracy of label 7 is: 0.9550 or  96%
The accuracy of label 8 is: 0.9780 or  98%
The accuracy of label 9 is: 0.9540 or  95%
```

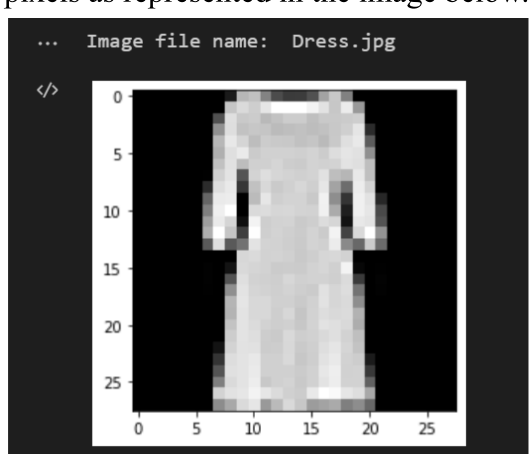
Datasets

The dataset that would be used for this project is the MNIST dataset, made publicly available. It consists of about 60000 images grouped in 10 classes of fashion wear. This dataset contains grey scale images of sizes 28 by 28. For easy usage and processing, I will split the data into train, valid and test folders, containing subfolders subsequently. In training the model, I will use inputs such as pre-trained models (ResNet18) to perform training and evaluation as well. After preparing the data, I will upload it to AWS S3 where training was carried out with pyTorch

Label	Description	Examples
0	T-Shirt/Top	
1	Trouser	
2	Pullover	
3	Dress	
4	Coat	
5	Sandals	
6	Shirt	
7	Sneaker	
8	Bag	
9	Ankle boots	

Exploratory Visualization

Let’s visualize an image of a digit in the training set of the Fashion-MNIST dataset. The image contains 28x28 pixels as represented in the image below.The image is a grayscale image.



Benchmark of the model

The benchmark created for this project is gotten from this link:https://machinelearningmastery.com/how-to-develop-a-cnn-from-scratch-for-fashion-mnist-clothing-classification/

The benchmark model solves the same problem using keras, operated on 10 training epochs with a default size of 32, data transformation was also done by using normalization etc, the stochastic Gradient Descent (SGD) was used as the optimizer as well. The evaluation metric used is also accuracy and the model achieved an accuracy of 90.990%. My model performed fairly well with an accuracy of 89.98%.

iii Methodology

Data processing

Since pytorch library was used to download and then loaded the fashion-MNIST dataset directly into numpy arrays, not too intensive preprocessing steps are needed, The fashion-MNIST dataset contains 60000 images, the images are grayscale(as a result of the anti-aliasing technique used by the normalization algorithm), the images that are small (28x28) and of the same size and the size distribution of the dataset is highly balanced. In order to train on a neural network algorithm, i :

● I converted the images to a tensor which basically generalizes vectors or matrices.

● I applied transforms.grayscale, which returns the images in a single channel

● I applied random horizontal flips of 50% probability to avoid bias (as much as possible) when training the model.

● I also normalized since it helps to improve the model. Normalization helps get data within a range and reduces the skewness which helps learn faster and better. It may also tackle the diminishing and exploding gradients problems that may occur during training.

Algorithms and techniques

Given that theproblem is a supervised learning problem and more Specifically a classification problem, the algorithm chosen for this is the convolutional neural network, a machine learning tool perfect for learning complex patterns on a large dataset. The hyperparameter chosen for tuning is the learning rate and batch size, these parameters greatly affect the performance of a model. After finding a very good parameter for tuning with use of fm_hpo.py script as entry_point in the estimator, adequate data preprocessing was used to conduct model training(see data preprocessing section) on the fashion- MNIST dataset. A convolutional neural network for fashion MNIST classification from scratch. For optimizers, which is used to specify how the neural network will learn, the stochastic Gradient Descent (SGD) was used as the optimizer to run with back propagation during model training.

Convolutional neural network (CNN):is a type of feed-forward artificial neural network in which the connectivity pattern between its neurons is inspired by the organization of the animal visual cortex.

Stochastic Gradient Descend(SGD) Optimizer: In Gradient Descent(GD) optimization, we compute the cost gradient based on the complete training set; hence, we sometimes also call it batch GD.

```
# TODO: Get the best estimators and the best HPs
best_estimator = tuner.best_estimator()

#Get the hyperparameters of the best trained model
best_hypers = best_estimator.hyperparameters()

# To know exact data from best_estimator.hyperparameters()
print(best_hypers)
```

```
2022-02-21 15:27:18 Starting - Preparing the instances for training
2022-02-21 15:27:18 Downloading - Downloading input data
2022-02-21 15:27:18 Training - Training image download completed. Training in progress.
2022-02-21 15:27:18 Uploading - Uploading generated training model
2022-02-21 15:27:18 Completed - Training job completed
{'_tuning_objective_metric': '"Test Loss"', 'batch_size': '"32"', 'lr': '0.03138192028805053', 'sagemaker_container_log_level': '20', 'sagemaker_estimator_class_name': '"PyTorch"', 'sagemaker_estimator_module': '"sagemaker.pytorch.estimator"', 'sagemaker_job_name': '"pytorch_fashionmnist-2022-02-21-15-03-22-137"', 'sagemaker_program': '"fm_hpo.py"', 'sagemaker_region': '"us-east-1"', 'sagemaker_submit_directory': '"s3://sagemaker-us-east-1-324194532919/pytorch_fashionmnist-2022-02-21-15-03-22-137/source/sourcedir.tar.gz"'}
```

This is the result of the best estimator best parameter used

Project Design

The workflow followed are as follows:

LOADING THE DATASET INTO THE NOTEBOOK

The dataset was downloaded with matplotlib's plt.imsave code as follows:

```
ModuleNotFoundError: No module named 'torch'
```

```

```

```

training_data = datasets.FashionMNIST(
    root="fmnist",
    train=True,
    download=True,
    transform=ToTensor()
)

test_data = datasets.FashionMNIST(
    root="fmnist",
    train=False,
    download=True,
    transform=ToTensor()
)
```

```
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-images-idx3-ubyte.gz
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-images-idx3-ubyte.gz to fmnist/FashionMNIST/raw/train-images-idx3-ubyte.gz

  0%|          | 0/26421880 [00:00<?, ?it/s]
```

LABELING THE CLASSES

```
labels_names = {
    0: "T-Shirt",
    1: "Trouser",
    2: "Pullover",
    3: "Dress",
    4: "Coat",
    5: "Sandal",
    6: "Shirt",
    7: "Sneaker",
    8: "Bag",
    9: "Ankle-Boot",
}
# Create a function to show an image and try to save an image
def create_image(data_image):
    '''
    data_image: an image with label from torch dataset
    '''
    img, label = data_image
    plt.imshow(img.squeeze(), cmap="gray")
    # We use jpg format.
    filename = labels_names[label]+'.jpg'
    plt.imsave(filename, np.array(img.squeeze()), cmap='gray')
    print('Image file name: ',filename)

```

NUMBER OF IMAGES FOR TEST, TRAIN AND VALID

```
print(len(test_df), len(train_df), len(valid_df))
```

```
10000 48000 12000
```

UPLOADING DATA TO S3 BUCKET

```
sess = sagemaker.Session()
bucket = sess.default_bucket()                              ## TODO: fill in
print("Default Bucket: {}".format(bucket))

my_session = boto3.session.Session()
region = my_session.region_name## TODO: fill in
print("AWS Region: {}".format(region))


role = get_execution_role()## TODO: fill in
print("RoleArn: {}".format(role))
```

```
Default Bucket: sagemaker-us-east-1-324194532919
AWS Region: us-east-1
RoleArn: arn:aws:iam::324194532919:role/service-role/AmazonSageMaker-ExecutionRole-20220220T161955
```

```
# Upload data to S3 bucket.
inputs = sagemaker_session.upload_data(path=datapath, bucket=data_bucket, key_prefix=datapath)
print(inputs)
```

FITTING THE TUNER AND ESTIMATOR FOR THE TRAINING JOB

The learning rate and batch size as well as the estimator and tuner were set up resulting in fitting:

Fit the tuner

```

s3_data = "s3://{}/{}/".format(bucket, "images")
s3_output_dir = "s3://{}/{}/".format(bucket, "output")
s3_model_dir = "s3://{}/{}/".format(bucket, "model")


os.environ['SM_CHANNEL_TRAIN']=s3_data
os.environ['SM_MODEL_DIR']=s3_model_dir
os.environ['SM_OUTPUT_DATA_DIR']=s3_output_dir


tuner.fit({'train' : s3_data},wait=True)
```

```
...............................................................................................................................
...............................................................................................................................
.................................................................................................!
```

The entry_point for fitting was the fm_hpo.py script which contains code that transforms the data by flipping, normalizing and transforming it to tensor during preprocessing. Other functions in the script were the train, test, create data loaders using arguments such as a criterion, model, data loader, optimiser, etc.

DESCRIBING THE TUNING RESULT

Prepare to perform Training on Best Estimator ¶

```
[170]: best_estimator.hyperparameters()
```

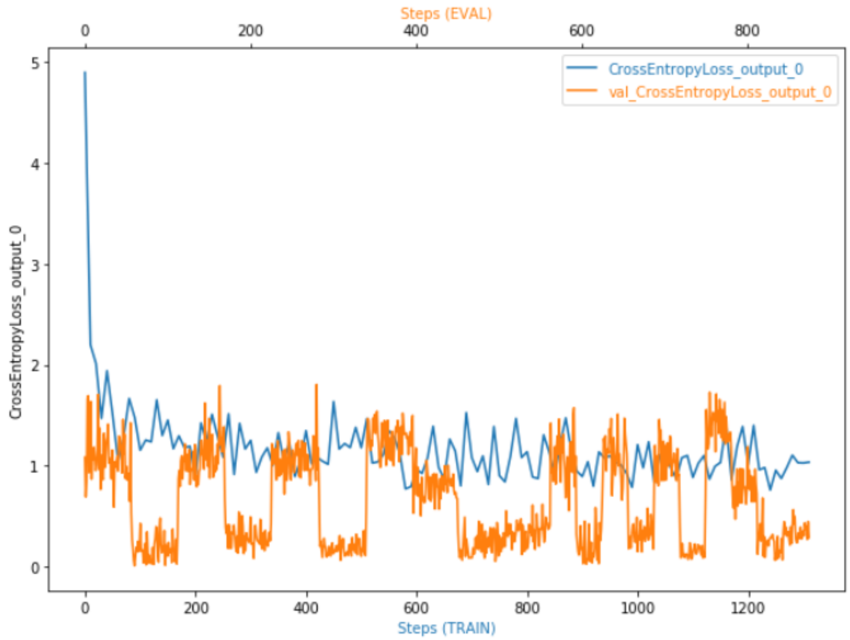
```
t[170]: {'_tuning_objective_metric': '"Test Loss"',
 'batch_size': '"32"',
 'lr': '0.03138192028805053',
 'sagemaker_container_log_level': '20',
 'sagemaker_estimator_class_name': '"PyTorch"',
 'sagemaker_estimator_module': '"sagemaker.pytorch.estimator"',
 'sagemaker_job_name': '"pytorch_fashionmnist-2022-02-21-15-03-22-137"',
 'sagemaker_program': '"fm_hpo.py"',
 'sagemaker_region': '"us-east-1"',
 'sagemaker_submit_directory': '"s3://sagemaker-us-east-1-324194532919/pytorch_fashionmnist-2022-02-21-15-03-22-137/source/sour
cedir.tar.gz"'}
```

The best parameters were used to perform training. using of fm_model.py script as entry_point, fashion cnn model created was used on the best parameters

PROFILING AND DEBUGGING

```
plot_tensor(trial, "CrossEntropyLoss_output_0")
```

```
loaded TRAIN data
loaded EVAL data
completed TRAIN plot
completed EVAL plot
```



Cross-Entropy Loss Function. Also called logarithmic loss, log loss or logistic loss. Each predicted class probability is compared to the actual class desired output 0 or 1 and a score/loss is calculated that penalizes the probability based on how far it is from the actual expected value. The loss function which computes a value that estimates how far away the output is from the target was calculated during this project as cross entropy loss.The graph above simply shows the reduction in cross-entropy output which is the loss function of the model.

PROFILER REPORT

```
#import os

# get the autogenerated folder name of profiler report
profiler_report_name = [
    rule["RuleConfigurationName"]
    for rule in estimator.latest_training_job.rule_job_summary()
    if "Profiler" in rule["RuleConfigurationName"]
][0]
```

```
! tar czf ProfilerReport.tgz ProfilerReport/
```

MODEL DEPLOYMENT

After carrying out the the training job with the best hyperparameter i went on to do model deployment

```
jpeg_serializer = sagemaker.serializers.IdentitySerializer("image/jpeg")
json_deserializer = sagemaker.deserializers.JSONDeserializer()


class ImagePredictor(Predictor):
    def __init__(self, endpoint_name, sagemaker_session):
        super(ImagePredictor, self).__init__(
            endpoint_name,
            sagemaker_session=sagemaker_session,
            serializer=jpeg_serializer,
            deserializer=json_deserializer,
        )
```

```
pytorch_model = PyTorchModel(model_data=model_location,
                             role=role,
                             entry_point='fm_reference.py',
                             py_version='py36',
                             framework_version='1.8',
                             predictor_cls=ImagePredictor)
```

```
from time import time
```

```
begin = time()
predictor = pytorch_model.deploy(initial_instance_count=1, instance_type='ml.m5.large')
c_time = time()-begin
print('Creating Endpoint Time: {: .01f}s'.format(c_time))
```

```
------!Creating Endpoint Time:  187.4s
```

PREDICTIONS

```python
output = predictor.predict(input)
output
```

```
[[0.5479651689529419,
  1.8651485443115234,
  -2.5988097190856934,
  5.487130641937256,
  1.931625485420227,
  -6.758813381195068,
  3.092844247817993,
  -2.8216121196746826,
  -1.2999895811080933,
  -0.9873822927474976]]
```

```python
import numpy as np
prediction = np.argmax(output)
print('prediction:', prediction,', ', filename, 'label: ', label)
if prediction == label:
    print('Prediction is correct')
else:
    print('Prediction is not correct')
```

```
prediction: 3 ,  images/test/6/Shirt_586.jpg label:  2
Prediction is not correct
```

	fullname	label	prediction
0	images/test/9/Ankle-Boot_1.jpg	9	9
1	images/test/2/Pullover_1.jpg	2	2
2	images/test/1/Trouser_1.jpg	1	1
3	images/test/1/Trouser_2.jpg	1	1
4	images/test/6/Shirt_1.jpg	6	6

```python
accu = sum(equal_indexs)/testset.shape[0]
print(f'The accuracy of all test images is: {accu:0.4f} or{accu*100: .0f}%')
```

```
The accuracy of all test images is: 0.8998 or 90%
```

```python
cls_names = list(pd.read_csv('classes.csv')['class_name'])
cls_names
```

```
['T-Shirt',
 'Trouser',
 'Pullover',
 'Dress',
 'Coatadd_label',
 'Sandal',
 'Shirt',
 'Sneaker',
 'Bag',
 'Ankle-Boot']
```

IMPROVEMENT

The model used in this project uses a simple convolutional neural network,, there are ones which can be used like the VGg-16(13).There is always room for improvement on an image classification problem like this. In other words, these are possible areas that can improve on the performance of the model such as using a different optimizer which prove to improve on the model's performance, as learning is very critical when it comes to model training

CONCLUSION

From the results above it is fair to say my model performs well with a good accuracy score. I found some areas of the project tasking as I am still new to deep learning but was able to scale through by watching some tutorials. By concluding this project, I learnt how to use pytorch for image classification.

REFERENCE

https://medium.com/@aaysbt/fashion-mnist-data-training-using-pytorch-7f6ad71e96f4

https://towardsdatascience.com/how-to-train-an-image-classifier-in-pytorch-and-use-it-to-perform-basic-inference-on-single-images-99465a1e9bf5

https://github.com/zalandoresearch/fashion-mnist