A Novel Method for Handwritten Digit Recognition System

Deploying Model in IBM Cloud

TEAM MEMBERS:

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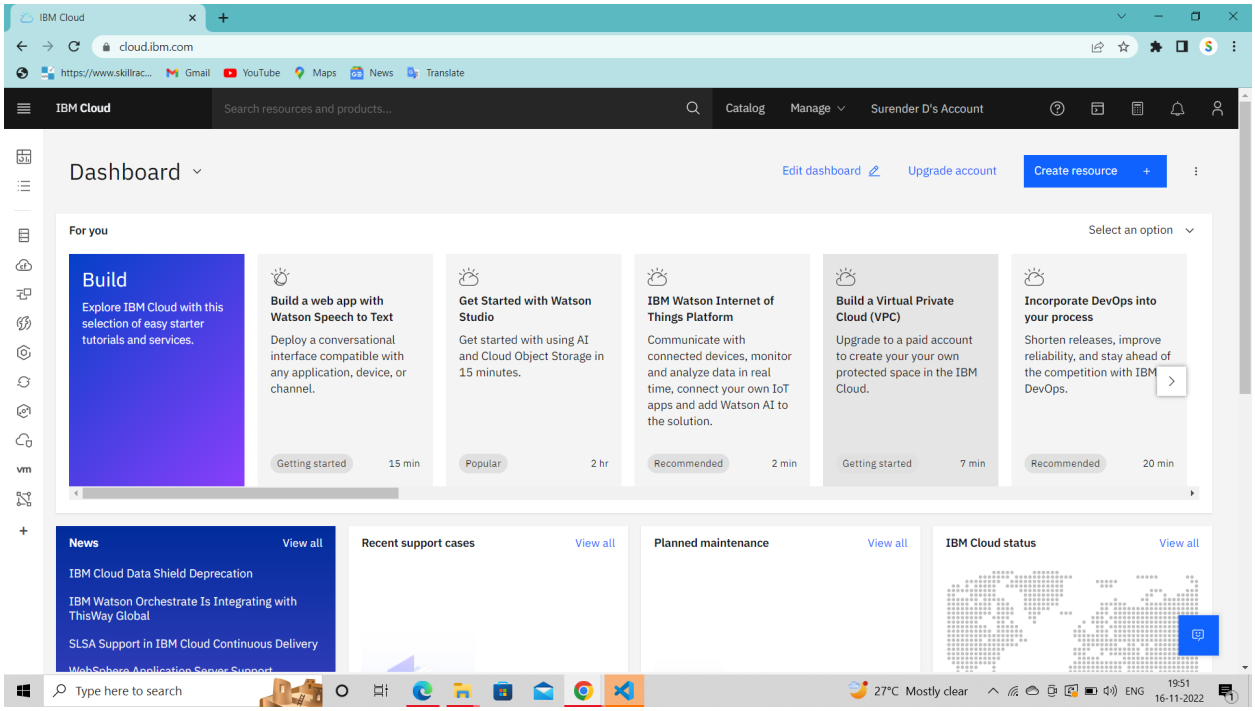
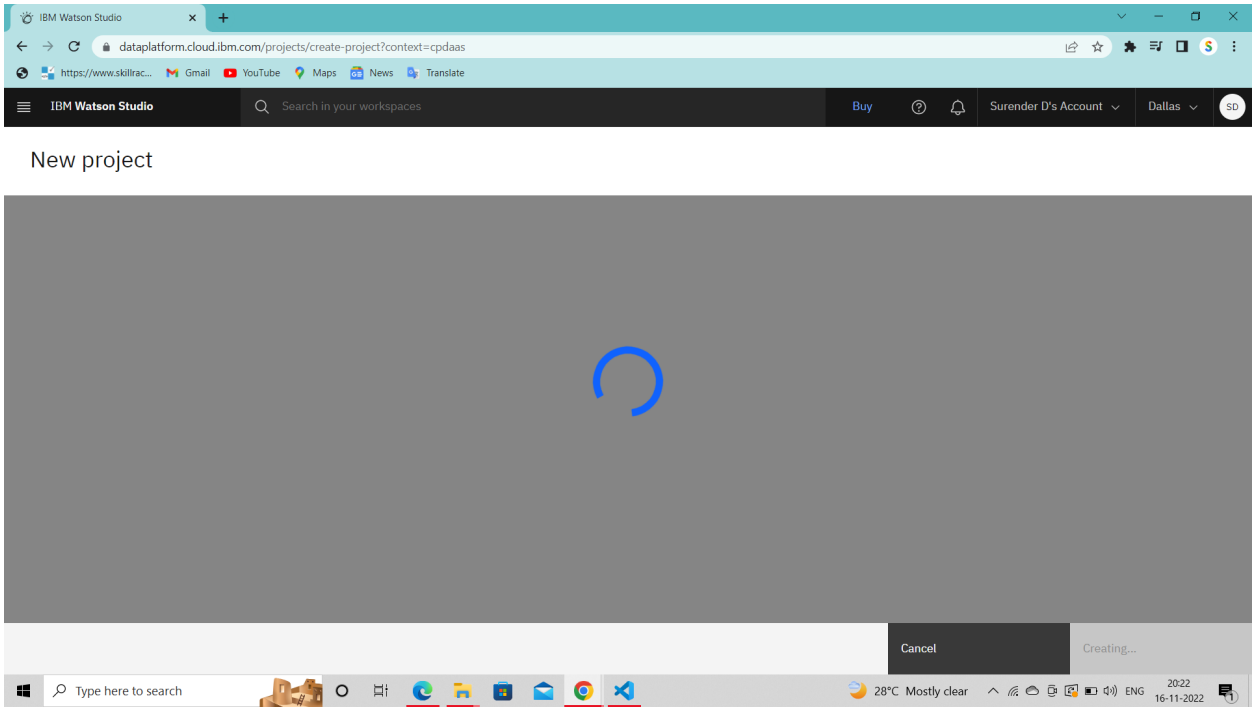
Yuvaraja M
Keertha Narayanan
Sri Kumar S
DineshKumar

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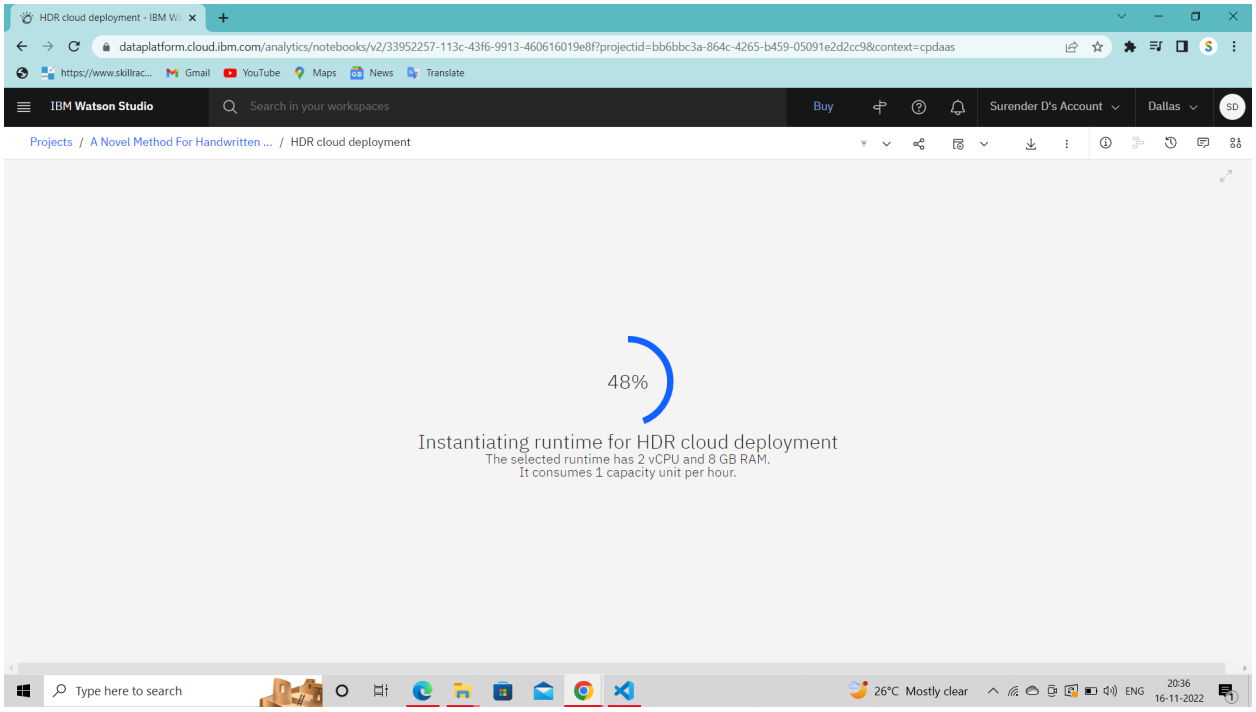
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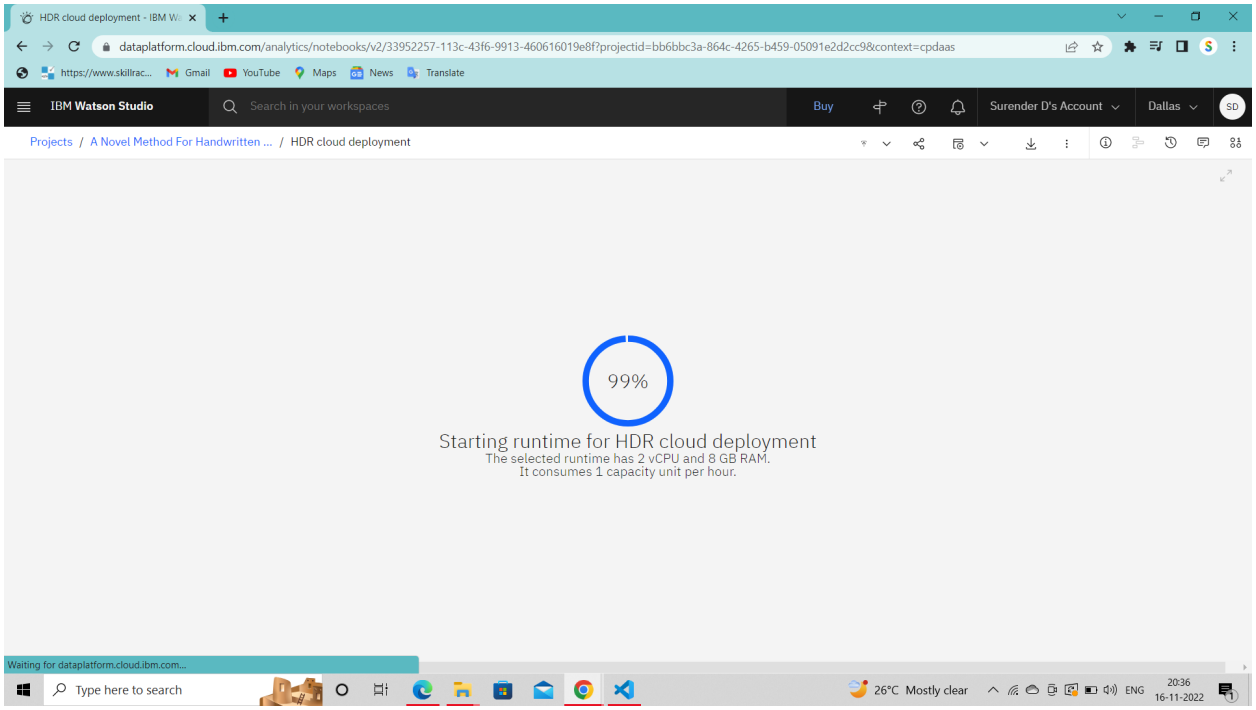
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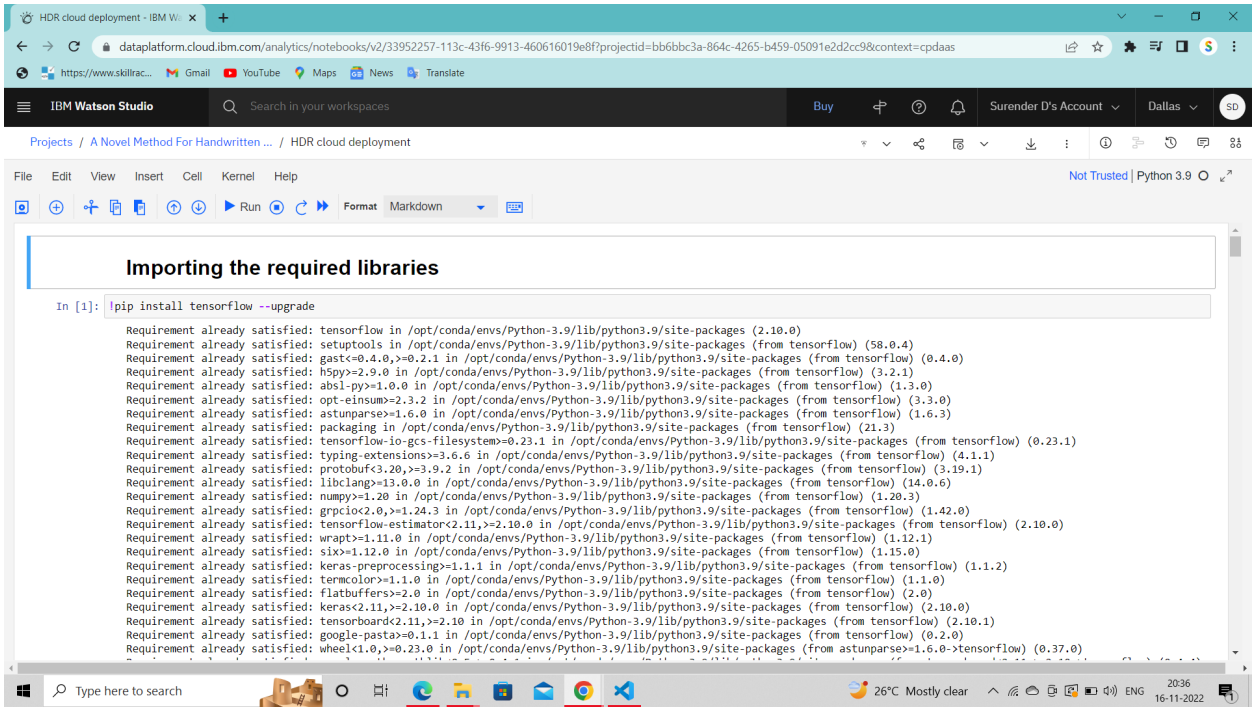
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Importing the required libraries
In [1]: !pip install tensorflow --upgrade
Requirement already satisfied: tensorflow in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (2.10.0)
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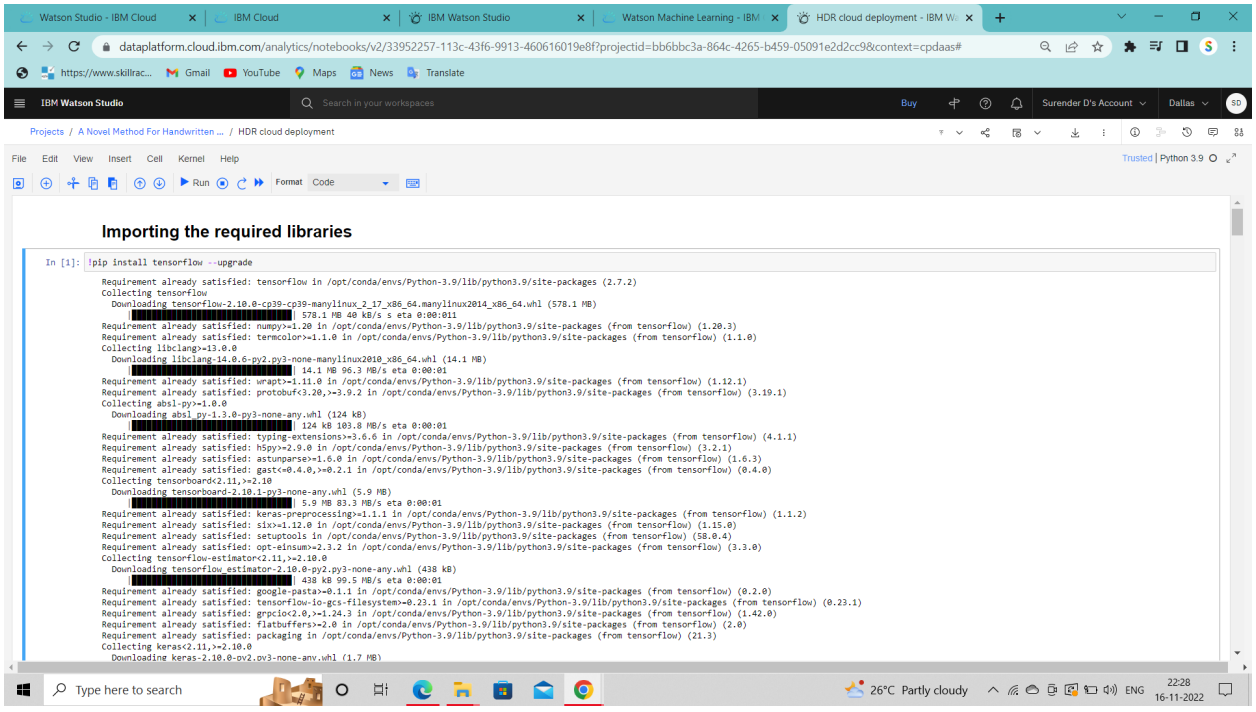
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In [1]: !pip install tensorflow --upgrade
Requirement already satisfied: tensorflow in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (2.7.2)
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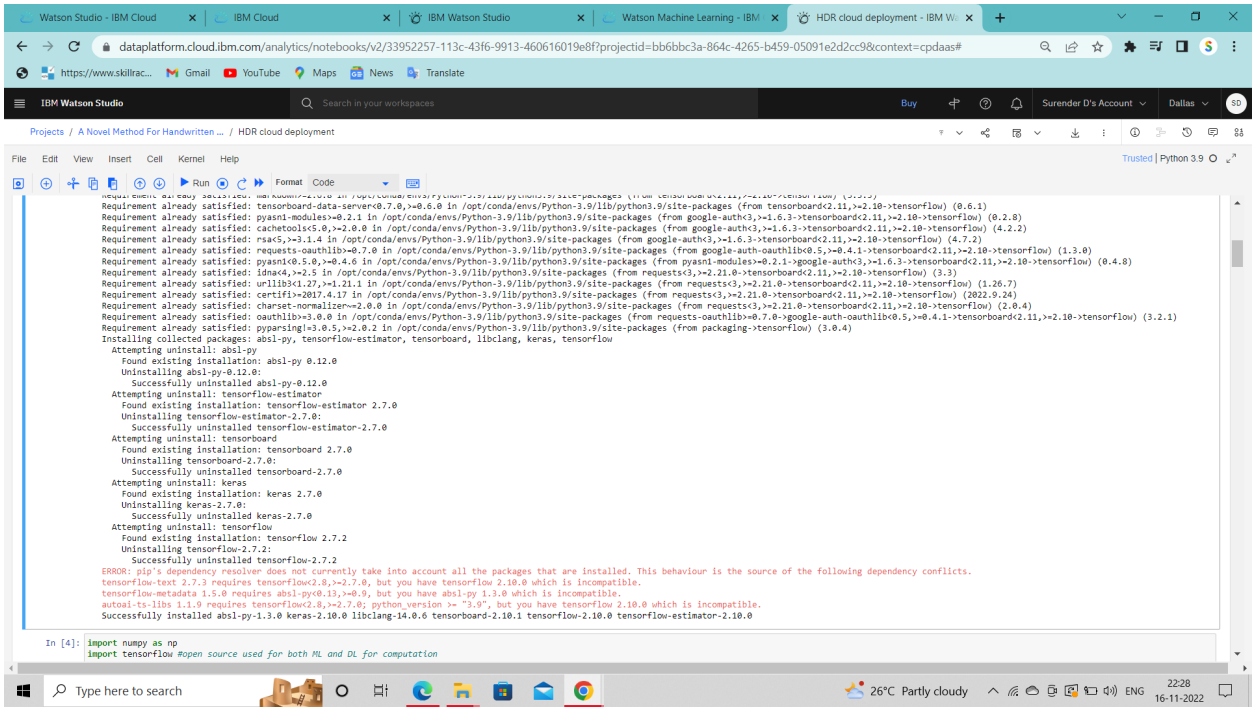
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Installing collected packages: absl-py, tensorflow-estimator, tensorboard, libclang, keras, tensorflow
Attempting uninstall: absl-py
Found existing installation: absl-py 0.12.0
Uninstalling absl-py-0.12.0:
Successfully uninstalled absl-py-0.12.0
Attempting uninstall: tensorflow-estimator
Found existing installation: tensorflow-estimator 2.7.0
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Attempting uninstall: tensorboard
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Uninstalling tensorflow-2.7.2:
Successfully uninstalled tensorflow-2.7.2
ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviour is the source of the following dependency conflicts.
tensorflow-text 2.7.3 requires tensorflow<2.8,>=2.7.0, but you have tensorflow 2.10.0 which is incompatible.
tensorflow-metadata 1.5.0 requires absl-py<0.13,>=0.9, but you have absl-py 1.3.0 which is incompatible.
autoai-ts-libs 1.1.9 requires tensorflow<2.8,>=2.7.0; python_version >= "3.9", but you have tensorflow 2.10.0 which is incompatible.
Successfully installed absl-py-1.3.0 keras-2.10.0 libclang-14.0.6 tensorboard-2.10.1 tensorflow-2.10.0 tensorflow-estimator-2.10.0
In [4]: import numpy as np
import tensorflow #open source used for both ML and DL for computation
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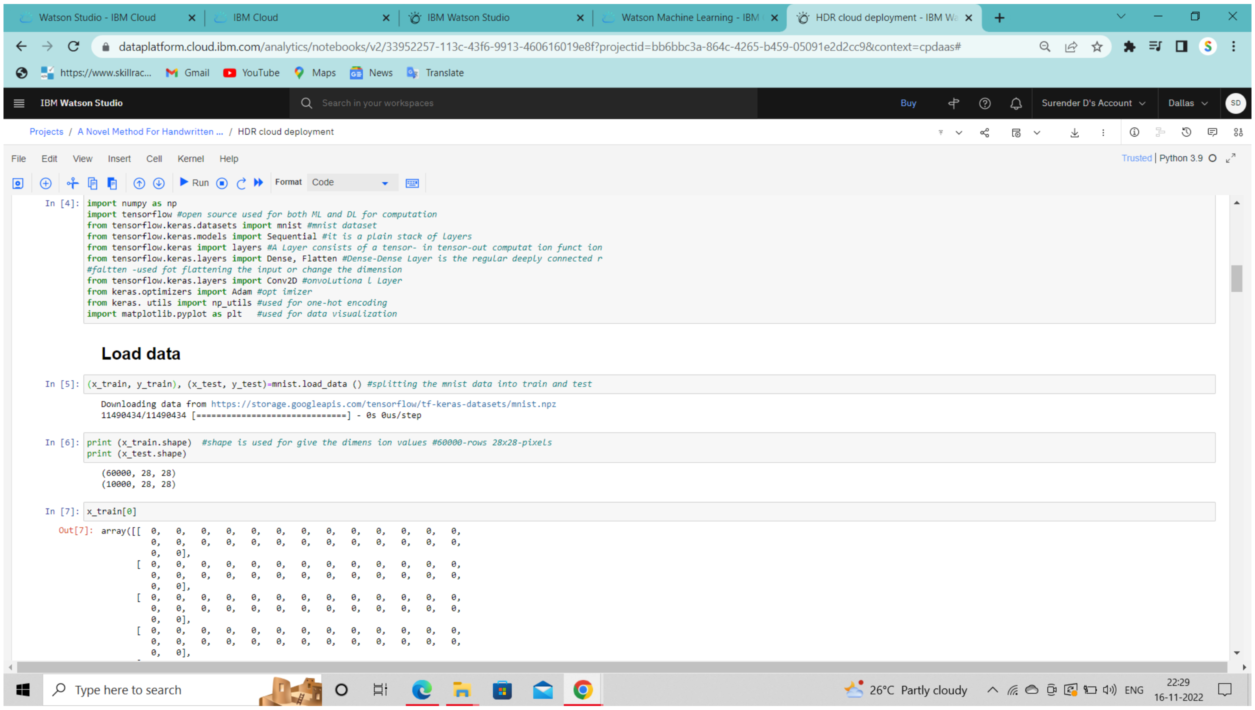

```
In [4]: import numpy as np
        import tensorflow #open source used for both ML and DL for computation
        from tensorflow.keras.datasets import mnist #mnist dataset
        from tensorflow.keras.models import Sequential #it is a plain stack of layers
        from tensorflow.keras import layers #A Layer consists of a tensor- in tensor-out computat ion funct ion
        from tensorflow.keras.layers import Dense, Flatten #Dense-Dense Layer is the regular deeply connected r
        #faltten -used fot flattening the input or change the dimension
        from tensorflow.keras.layers import Conv2D #onvoLutiona l Layer
        from keras.optimizers import Adam #opt imizer
        from keras. utils import np_utils #used for one-hot encoding
        import matplotlib.pyplot as plt   #used for data visualization
```

Load data

```
In [5]: (x_train, y_train), (x_test, y_test)=mnist.load_data () #splitting the mnist data into train and test

        Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
        11490434/11490434 [==============================] - 0s 0us/step

In [6]: print (x_train.shape)  #shape is used for give the dimens ion values #60000-rows 28x28-pixels
        print (x_test.shape)

        (60000, 28, 28)
        (10000, 28, 28)

In [7]: x_train[0]

Out[7]: array([[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
                  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
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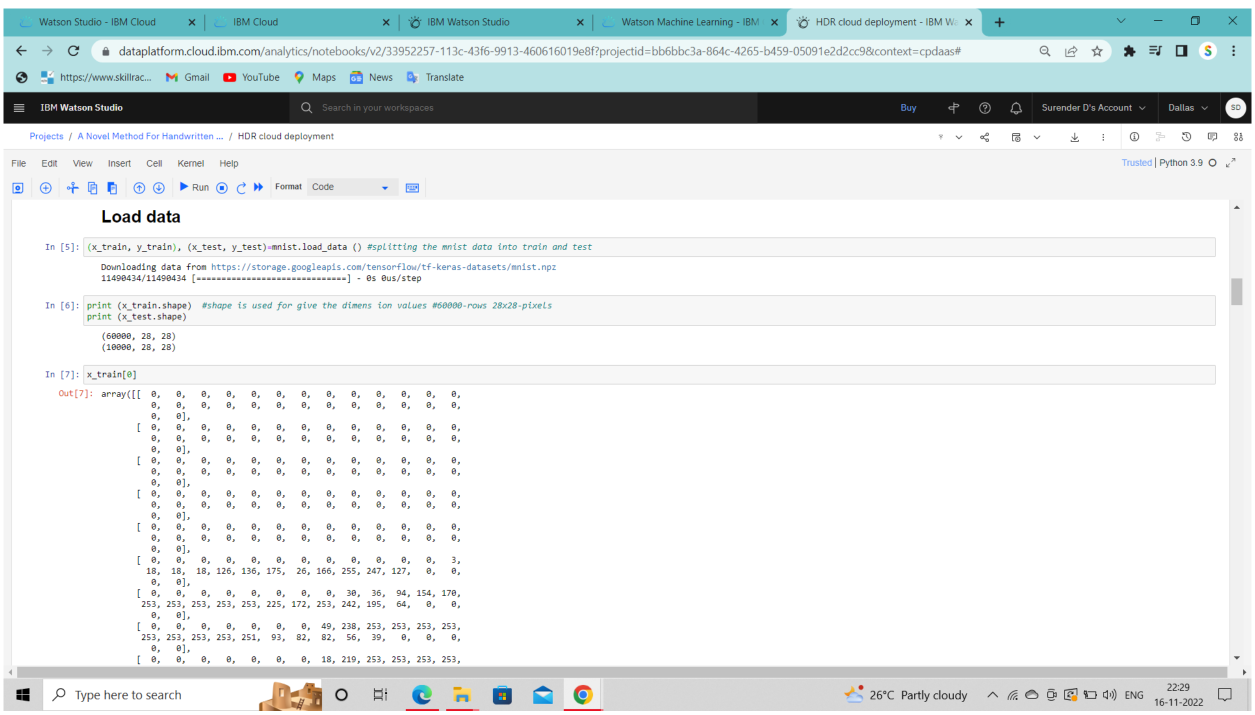

Load data

```
In [5]: (x_train, y_train), (x_test, y_test)=mnist.load_data () #splitting the mnist data into train and test

        Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
        11490434/11490434 [==============================] - 0s 0us/step

In [6]: print (x_train.shape)  #shape is used for give the dimens ion values #60000-rows 28x28-pixels
        print (x_test.shape)

        (60000, 28, 28)
        (10000, 28, 28)

In [7]: x_train[0]

Out[7]: array([[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
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                  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
                  0,   0],
                [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   3,
                 18,  18,  18, 126, 136, 175,  26, 166, 255, 247, 127,   0,   0,
                  0,   0],
                [  0,   0,   0,   0,   0,   0,   0,   0,  30,  36,  94, 154, 170,
                253, 253, 253, 253, 253, 225, 172, 253, 242, 195,  64,   0,   0,
                  0,   0],
                [  0,   0,   0,   0,   0,   0,   0,  49, 238, 253, 253, 253, 253,
                253, 253, 253, 253, 251,  93,  82,  82,  56,  39,   0,   0,   0,
                  0,   0],
                [  0,   0,   0,   0,   0,   0,   0,  18, 219, 253, 253, 253, 253,
```

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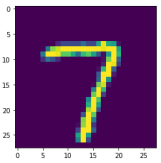
In [8]:
```
plt.imshow(x_train[5100])    #ploting the index=image
```

Out[8]: <matplotlib.image.AxesImage at 0x7f2e2c139760>



In [9]:
```
np.argmax(y_train[5100])
```

Out[9]: 0

Reshaping Dataset

In [10]:
```
#Reshaping to format which CNN expects (batch, height, width, channels)
x_train=x_train.reshape (60000, 28, 28, 1).astype('float32')
x_test=x_test.reshape (10000, 28, 28, 1).astype ('float32')
```

Applying One Hot Encoding

In [11]:
```
number_of_classes = 10  #storing the no of classes in a variable
```

In [12]:
```
y_train = np_utils.to_categorical (y_train, number_of_classes) #converts the output in binary format
y_test = np_utils.to_categorical (y_test, number_of_classes)
```

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```

Add CNN Layers

In [13]:
```
#create model
model=Sequential ()
```

```
2022-11-16 15:51:40.821950: W tensorflow/stream_executor/platform/default/dso_loader.cc:64] Could not load dynamic library 'libcuda.so.1'; dlerror: libcuda.so.1: cannot open shared object file: No such file or directory; LD_LIBRARY_PATH: /opt/ibm/dsdriver/lib:/opt/oracle/lib:/opt/conda/envs/Python-3.9/lib/python3.9/site-packages/tensorflow
2022-11-16 15:51:40.822016: W tensorflow/stream_executor/cuda/cuda_driver.cc:263] failed call to cuInit: UNKNOWN ERROR (303)
```

In [14]:
```
#adding model Layer
model.add(Conv2D(64, (3, 3), input_shape=(28, 28, 1), activation='relu'))
model.add(Conv2D(32, (3, 3), activation = 'relu'))
```

In [15]:
```
#flatten the dimension of the image
model.add(Flatten())
```

In [16]:
```
#output layer with 10 neurons
model.add(Dense(number_of_classes,activation = 'softmax'))
```

Compiling the model

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Compiling the model

In [17]:
```
#Compile model
model.compile(loss= 'categorical_crossentropy', optimizer="Adam", metrics=['accuracy'])
```

In [18]:
```
x_train = np.asarray(x_train)
y_train = np.asarray(y_train)
```

Train the model

In [19]:
```
#fit the model
model.fit(x_train, y_train, validation_data=(x_test, y_test), epochs=5, batch_size=32)
```

```
Epoch 1/5
1875/1875 [==============================] - 179s 95ms/step - loss: 0.2043 - accuracy: 0.9535 - val_loss: 0.0700 - val_accuracy: 0.9781
Epoch 2/5
1875/1875 [==============================] - 179s 95ms/step - loss: 0.0669 - accuracy: 0.9795 - val_loss: 0.0784 - val_accuracy: 0.9764
Epoch 3/5
1875/1875 [==============================] - 181s 97ms/step - loss: 0.0480 - accuracy: 0.9852 - val_loss: 0.1067 - val_accuracy: 0.9719
Epoch 4/5
1875/1875 [==============================] - 182s 97ms/step - loss: 0.0372 - accuracy: 0.9876 - val_loss: 0.0896 - val_accuracy: 0.9790
Epoch 5/5
1875/1875 [==============================] - 182s 97ms/step - loss: 0.0267 - accuracy: 0.9919 - val_loss: 0.0974 - val_accuracy: 0.9785
```

Out[19]: <keras.callbacks.History at 0x7f2e2c783d60>

Observing the metrics

In [20]:
```
# Final evaluation of the model
metrics = model.evaluate(x_test, y_test, verbose=0)
print("Metrics (Test loss &Test Accuracy) : ")
print(metrics)
```

```
Metrics (Test loss &Test Accuracy) :
[0.09737684577703476, 0.9785000085830688]
```

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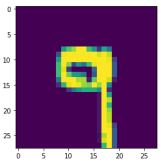
Test The Model

In [21]:
```
prediction=model.predict(x_test[6000:6001])
print(prediction)
```

```
1/1 [==============================] - 0s 76ms/step
[[2.1418817e-12 6.9434767e-14 1.4364865e-12 2.4835310e-07 2.1813139e-02
  2.7953427e-06 9.6795097e-14 2.7501132e-04 1.0560208e-04 9.7780323e-01]]
```

In [22]:
```
plt.imshow(x_test[6000])
```

Out[22]: <matplotlib.image.AxesImage at 0x7f2dec41edf0>



In [23]:
```
import numpy as np
print(np.argmax(prediction, axis=1)) #printing our Labels from first 4 images
```

```
[9]
```

In [24]:
```
np.argmax(y_test[6000:6001]) #printing the actual labels
```

Out[24]: 9

Save The model

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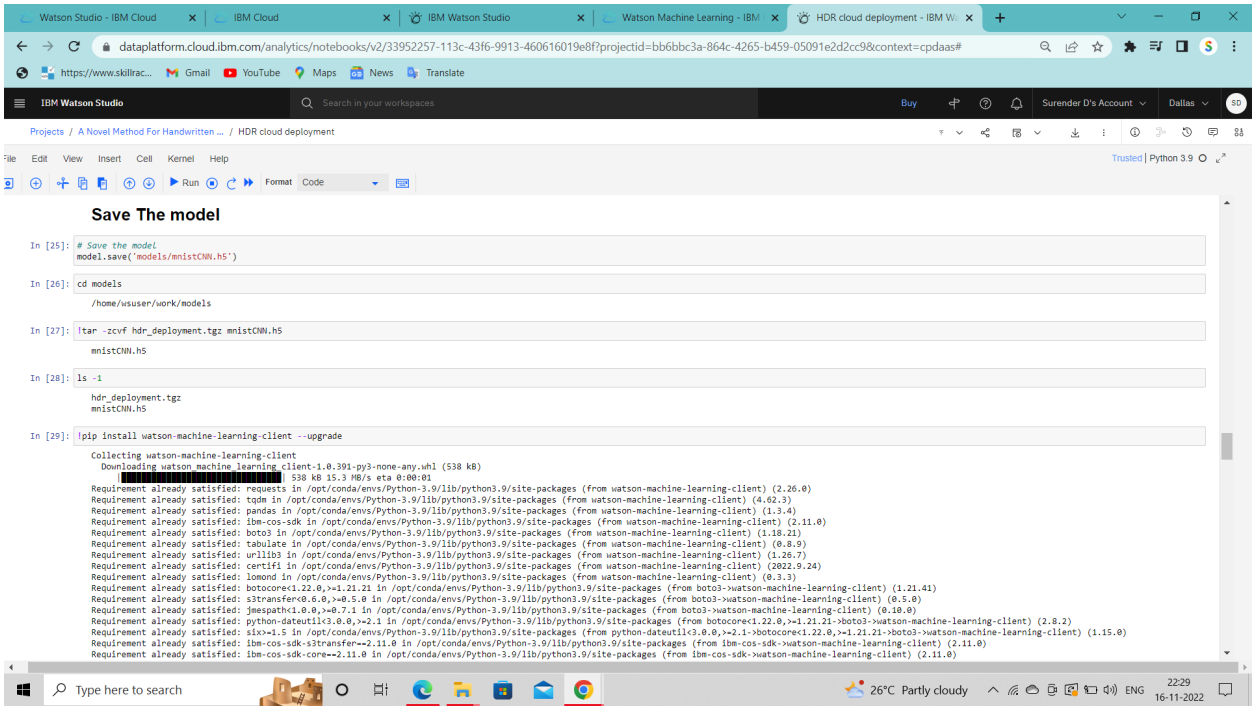
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Save The model
In [25]:
# Save the model
model.save('models/mnistCNN.h5')
In [26]:
cd models
/home/wsuser/work/models
In [27]:
!tar -zcvf hdr_deployment.tgz mnistCNN.h5
mnistCNN.h5
In [28]:
ls -l
hdr_deployment.tgz
mnistCNN.h5
In [29]:
!pip install watson-machine-learning-client --upgrade
Collecting watson-machine-learning-client
Downloading watson_machine_learning_client-1.0.391-py3-none-any.whl (538 kB)
538 kB 15.3 MB/s eta 0:00:01
Requirement already satisfied: requests in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (2.26.0)
Requirement already satisfied: tqdm in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (4.62.3)
Requirement already satisfied: pandas in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (1.3.4)
Requirement already satisfied: ibm-cos-sdk in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (2.11.0)
Requirement already satisfied: boto3 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (1.18.21)
Requirement already satisfied: tabulate in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (0.8.9)
Requirement already satisfied: urllib3 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (1.26.7)
Requirement already satisfied: certifi in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (2022.9.24)
Requirement already satisfied: lomond in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from watson-machine-learning-client) (0.3.3)
Requirement already satisfied: botocore<1.22.0,>=1.21.21 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from boto3->watson-machine-learning-client) (1.21.41)
Requirement already satisfied: s3transfer<0.6.0,>=0.5.0 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from boto3->watson-machine-learning-client) (0.5.0)
Requirement already satisfied: jmespath<1.0.0,>=0.7.1 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from boto3->watson-machine-learning-client) (0.10.0)
Requirement already satisfied: python-dateutil<3.0.0,>=2.1 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from botocore<1.22.0,>=1.21.21->boto3->watson-machine-learning-client) (2.8.2)
Requirement already satisfied: six>=1.5 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from python-dateutil<3.0.0,>=2.1->botocore<1.22.0,>=1.21.21->boto3->watson-machine-learning-client) (1.15.0)
Requirement already satisfied: ibm-cos-sdk-s3transfer==2.11.0 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from ibm-cos-sdk->watson-machine-learning-client) (2.11.0)
Requirement already satisfied: ibm-cos-sdk-core==2.11.0 in /opt/conda/envs/Python-3.9/lib/python3.9/site-packages (from ibm-cos-sdk->watson-machine-learning-client) (2.11.0)
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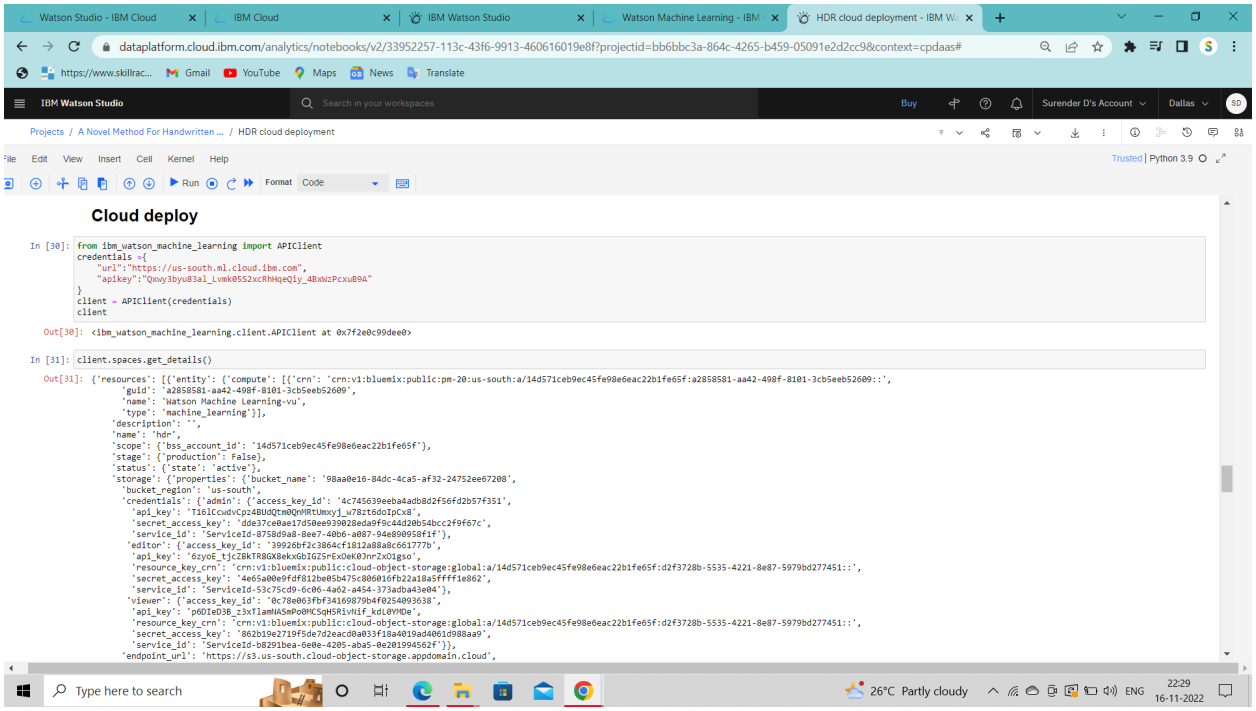
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Cloud deploy
In [30]:
from ibm_watson_machine_learning import APIClient
credentials ={
"url":"https://us-south.ml.cloud.ibm.com",
"apikey":"Qxwy3byu83al_LvmK05S2xcRhHqeQly_4BxWzPcxuB9A"
}
client = APIClient(credentials)
client
Out[30]: <ibm_watson_machine_learning.client.APIClient at 0x7f2e0c99dee0>
In [31]:
client.spaces.get_details()
Out[31]: {'resources': [{'entity': {'compute': [{'crn': 'crn:v1:bluemix:public:pm-20:us-south:a/14d571ceb9ec45fe98e6eac22b1fe65f:a2858581-aa42-498f-8101-3cb5eeb52609::',
'guid': 'a2858581-aa42-498f-8101-3cb5eeb52609',
'name': 'Watson Machine Learning-vu',
'type': 'machine_learning'}],
'description': '',
'name': 'hdr',
'scope': {'bss_account_id': '14d571ceb9ec45fe98e6eac22b1fe65f'},
'stage': {'production': False},
'status': {'state': 'active'},
'storage': {'properties': {'bucket_name': '98aa0e16-84dc-4ca5-af32-24752ee67208',
'bucket_region': 'us-south',
'credentials': {'admin': {'access_key_id': '4c745639eeba4adb8d2f56fd2b57f351',
'api_key': 'T16lCcwdvCpz4BUdQtm0QnMRtUmxyj_w78zt6doIpCx8',
'secret_access_key': 'dde37ce0ae17d50ee93902eda9f9c44d20b54bcc2f9f67c',
'service_id': 'ServiceId-8758d9a8-0ee7-40b6-a087-94e800958f1f'},
'editor': {'access_key_id': '3992ebf2c3864cf1812a88a0c661777b',
'api_key': '6zyoE_tjCZbKTR8GX8ekxGbIGZSrExOeK03nr2xO1gso',
'resource_key_crn': 'crn:v1:bluemix:public:cloud-object-storage:global:a/14d571ceb9ec45fe98e6eac22b1fe65f:d2f3728b-5535-4221-8e87-5979bd277451::',
'secret_access_key': '4e65a00e9fdf812be05b475c806016fb22a18a5ffff1e862',
'service_id': 'ServiceId-53c75cd9-6c06-4a62-a454-373adba43e04'},
'viewer': {'access_key_id': '0c78e863fbf34169879b4f0254093638',
'api_key': 'p6DIeD3B_z3xTlamNASmPo0HCSgH5RivNif_kdL0YMDe',
'resource_key_crn': 'crn:v1:bluemix:public:cloud-object-storage:global:a/14d571ceb9ec45fe98e6eac22b1fe65f:d2f3728b-5535-4221-8e87-5979bd277451::',
'secret_access_key': '862b19e2719f5de7d2eacd0a033f18a4019ad4061d988aa9',
'service_id': 'ServiceId-b8291bea-6e0e-4205-aba5-0e201994562f'}},
'endpoint_url': 'https://s3.us-south.cloud-object-storage.appdomain.cloud',
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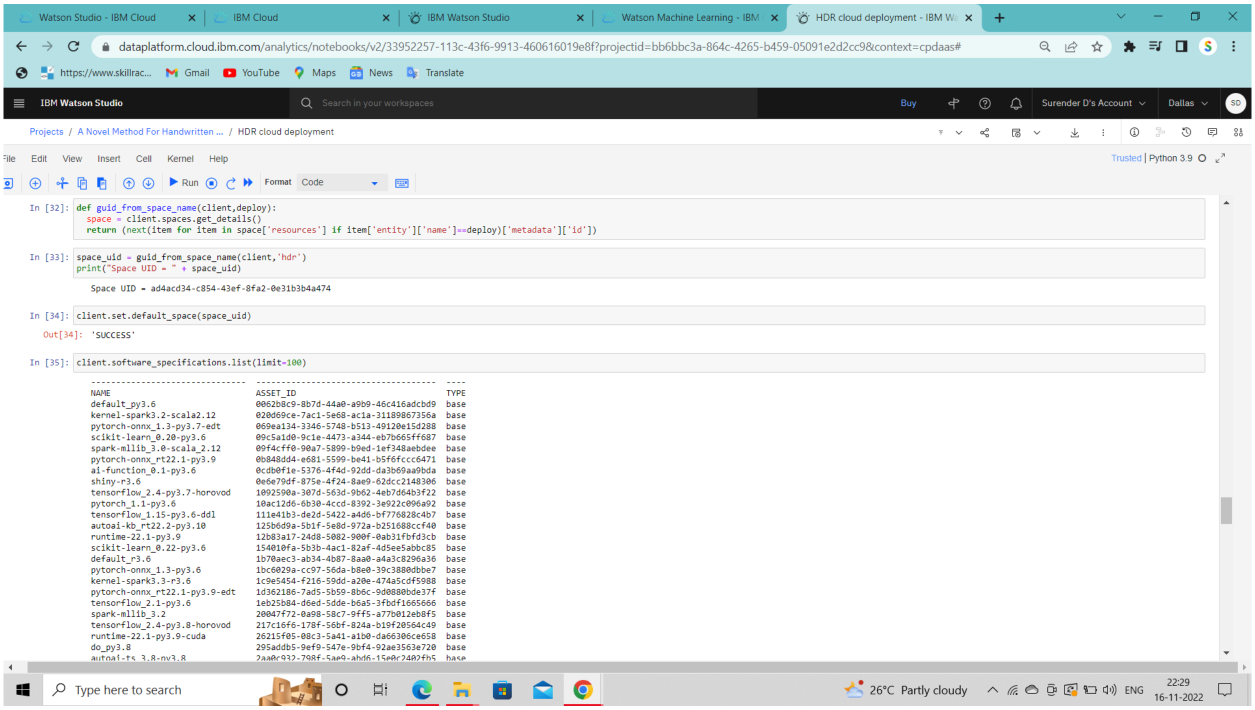
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In [32]: def guid_from_space_name(client,deploy):
space = client.spaces.get_details()
return (next(item for item in space['resources'] if item['entity']['name']==deploy)['metadata']['id'])
In [33]: space_uid = guid_from_space_name(client,'hdr')
print("Space UID = " + space_uid)
Space UID = ad4acd34-c854-43ef-8fa2-0e31b3b4a474
In [34]: client.set.default_space(space_uid)
Out[34]: 'SUCCESS'
In [35]: client.software_specifications.list(limit=100)
NAME ASSET_ID TYPE
default_py3.6 0062b8c9-8b7d-44a0-a9b9-46c416adcbd9 base
kernel-spark3.2-scala2.12 020d69ce-7ac1-5e68-ac1a-31189867356a base
pytorch-onnx_1.3-py3.7-edt 069ea134-3346-5748-b513-49120e15d288 base
scikit-learn_0.20-py3.6 09c5a1d0-9c1e-4473-a344-eb7b665ff687 base
spark-mllib_3.0-scala_2.12 09f4cff0-90a7-5899-b9ed-1ef348aebdee base
pytorch-onnx_rt22.1-py3.9 0b848dd4-e681-5599-be41-b5f6fccc6471 base
ai-function_0.1-py3.6 0cdb0f1e-5376-4f4d-92dd-da3b69aa9bda base
shiny-r3.6 0e6e79df-875e-4f24-8ae9-62dcc2148306 base
tensorflow_2.4-py3.7-horovod 1092590a-307d-563d-9b62-4eb7d64b3f22 base
pytorch_1.1-py3.6 10ac12d6-6b30-4ccd-8392-3e922c096a92 base
tensorflow_1.15-py3.6-ddl 111e41b3-de2d-5422-a4d6-bf776828c4b7 base
autoai-kb_rt22.2-py3.10 125b6d9a-5b1f-5e8d-972a-b251688ccf40 base
runtime-22.1-py3.9 12b83a17-24d8-5082-900f-0ab31fbfd3cb base
scikit-learn_0.22-py3.6 154010fa-5b3b-4ac1-82af-4d5ee5abbc85 base
default_r3.6 1b70aec3-ab34-4b87-8aa0-a4a3c8296a36 base
pytorch-onnx_1.3-py3.6 1bc6029a-cc97-56da-b8e0-39c3880dbbe7 base
kernel-spark3.3-r3.6 1c9e5454-f216-59dd-a20e-474a5cdf5988 base
pytorch-onnx_rt22.1-py3.9-edt 1d362186-7ad5-5b59-8b6c-9d0880bde37f base
tensorflow_2.1-py3.6 1eb25b84-d6ed-5dde-b6a5-3fbdf1665666 base
spark-mllib_3.2 20047f72-0a98-58c7-9ff5-a77b012eb8f5 base
tensorflow_2.4-py3.8-horovod 217c16f6-178f-56bf-824a-b19f20564c49 base
runtime-22.1-py3.9-cuda 26215f05-08c3-5a41-a1b0-da66306ce658 base
do_py3.8 295addb5-9ef9-547e-9bf4-92ae3563e720 base
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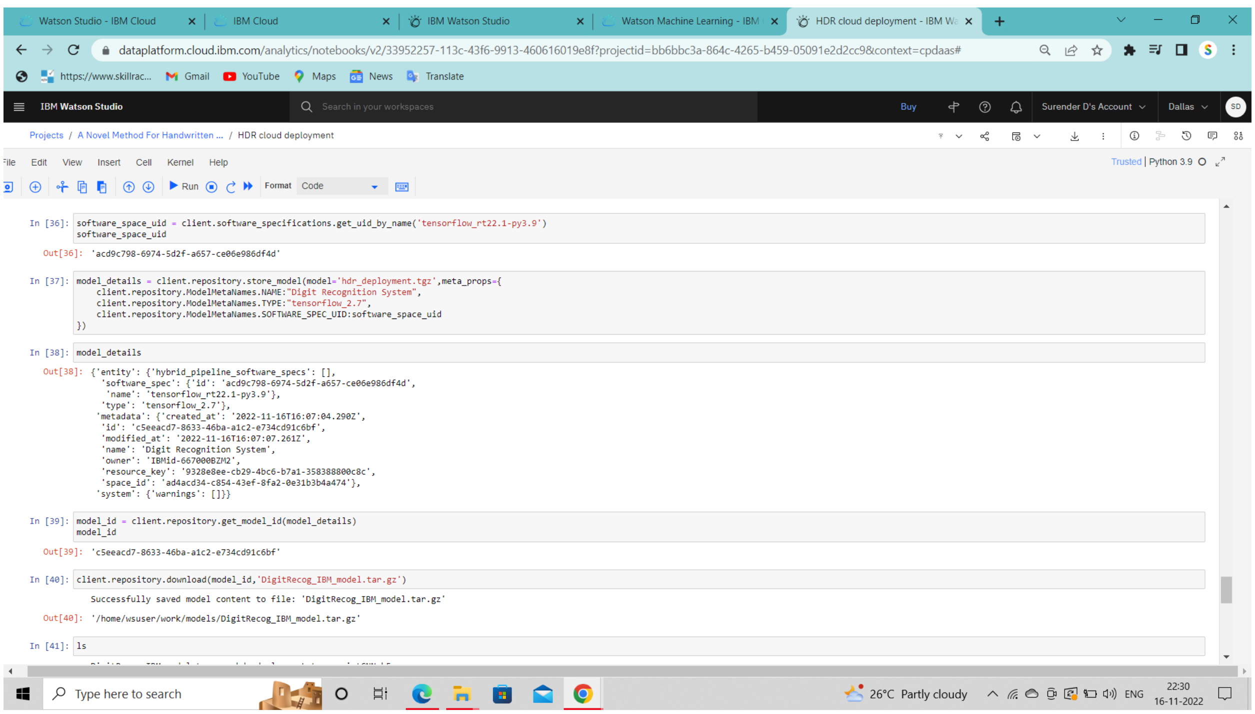
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Run Format Code
In [36]: software_space_uid = client.software_specifications.get_uid_by_name('tensorflow_rt22.1-py3.9')
software_space_uid
Out[36]: 'acd9c798-6974-5d2f-a657-ce06e986df4d'
In [37]: model_details = client.repository.store_model(model='hdr_deployment.tgz',meta_props={
client.repository.ModelMetaNames.NAME:"Digit Recognition System",
client.repository.ModelMetaNames.TYPE:"tensorflow_2.7",
client.repository.ModelMetaNames.SOFTWARE_SPEC_UID:software_space_uid
})
In [38]: model_details
Out[38]: {'entity': {'hybrid_pipeline_software_specs': [],
'software_spec': {'id': 'acd9c798-6974-5d2f-a657-ce06e986df4d',
'name': 'tensorflow_rt22.1-py3.9'},
'type': 'tensorflow_2.7'},
'metadata': {'created_at': '2022-11-16T16:07:04.290Z',
'id': 'c5eeacd7-8633-46ba-a1c2-e734cd91c6bf',
'modified_at': '2022-11-16T16:07:07.261Z',
'name': 'Digit Recognition System',
'owner': 'IBMid-667000BZM2',
'resource_key': '9328e8ee-cb29-4bc6-b7a1-358388800c8c',
'space_id': 'ad4acd34-c854-43ef-8fa2-0e31b3b4a474'},
'system': {'warnings': []}}
In [39]: model_id = client.repository.get_model_id(model_details)
model_id
Out[39]: 'c5eeacd7-8633-46ba-a1c2-e734cd91c6bf'
In [40]: client.repository.download(model_id,'DigitRecog_IBM_model.tar.gz')
Successfully saved model content to file: 'DigitRecog_IBM_model.tar.gz'
Out[40]: '/home/wsuser/work/models/DigitRecog_IBM_model.tar.gz'
In [41]: ls
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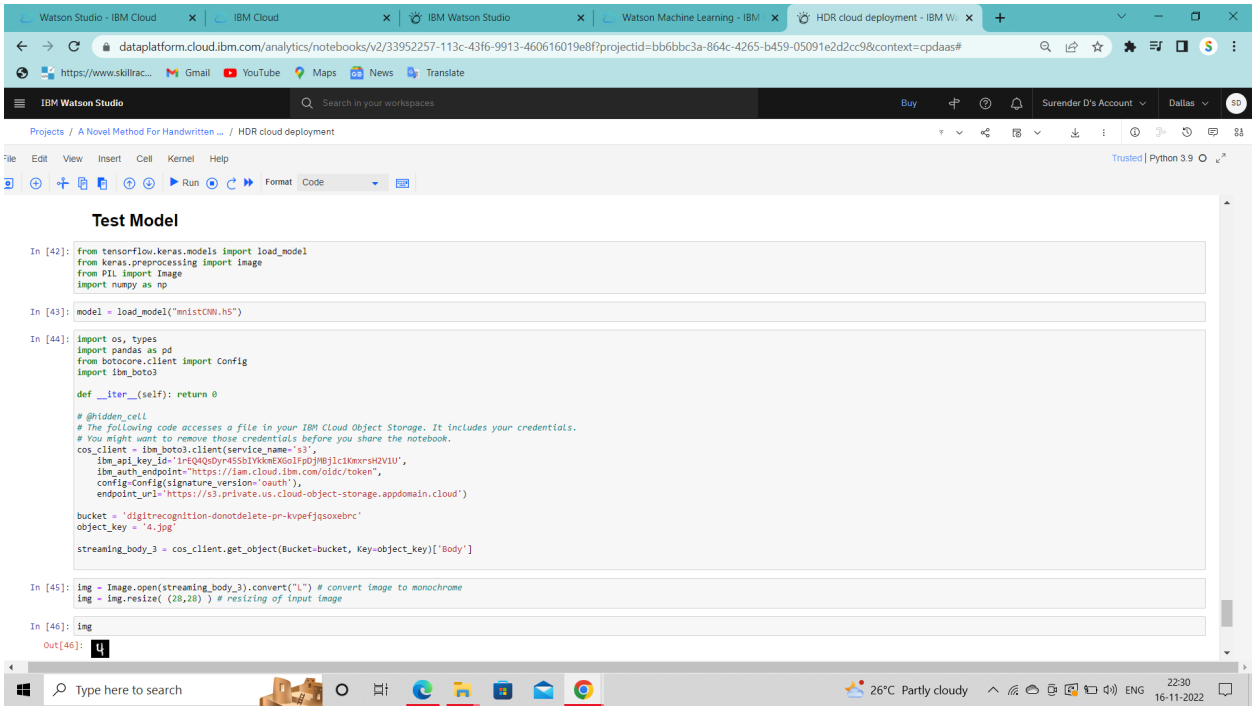
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Run
Format
Code
Test Model
In [42]:
from tensorflow.keras.models import load_model
from keras.preprocessing import image
from PIL import Image
import numpy as np
In [43]:
model = load_model("mnistCNN.h5")
In [44]:
import os, types
import pandas as pd
from botocore.client import Config
import ibm_boto3
def __iter__(self): return 0
# @hidden_cell
# The following code accesses a file in your IBM Cloud Object Storage. It includes your credentials.
# You might want to remove those credentials before you share the notebook.
cos_client = ibm_boto3.client(service_name='s3',
ibm_api_key_id='1rEQ4QsDyr45SbIYkkmEXGolFpDjMBjlc1KmxrsH2V1U',
ibm_auth_endpoint="https://iam.cloud.ibm.com/oidc/token",
config=Config(signature_version='oauth'),
endpoint_url='https://s3.private.us.cloud-object-storage.appdomain.cloud')
bucket = 'digitrecognition-donotdelete-pr-kvpefjqsoxebrc'
object_key = '4.jpg'
streaming_body_3 = cos_client.get_object(Bucket=bucket, Key=object_key)['Body']
In [45]:
img = Image.open(streaming_body_3).convert("L") # convert image to monochrome
img = img.resize((28,28)) # resizing of input image
In [46]:
img
Out[46]:
Type here to search
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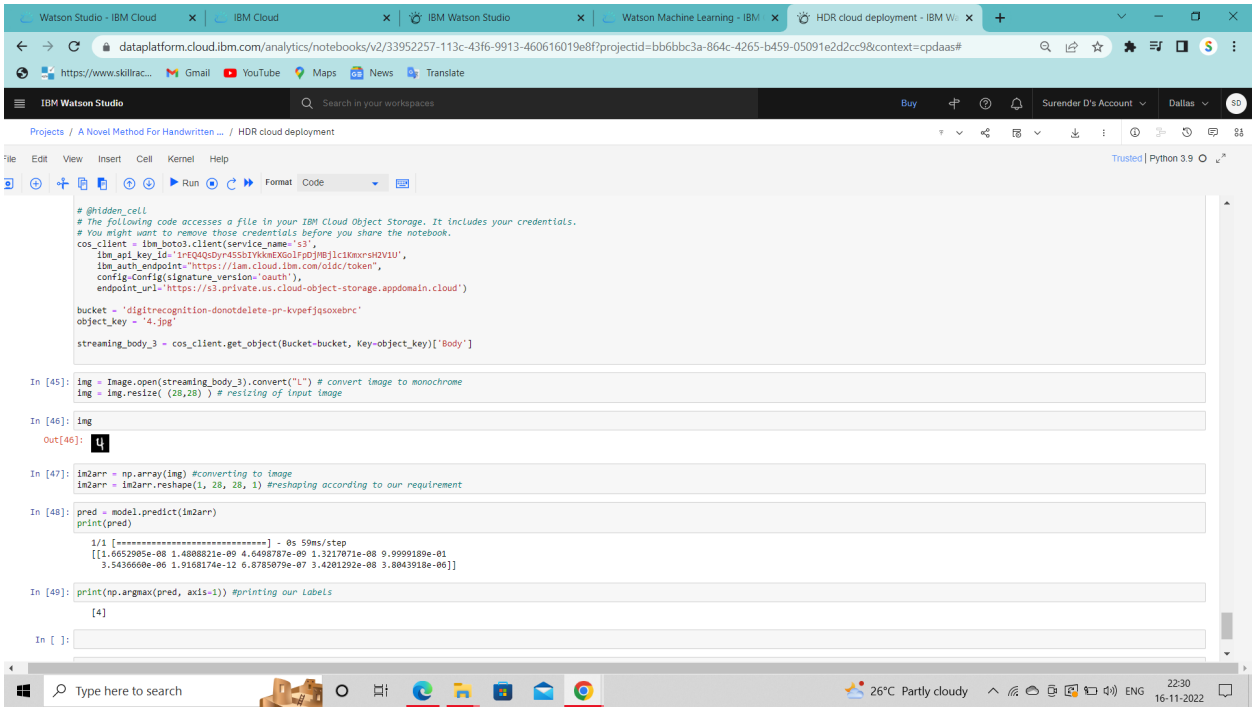
22:30
16-11-2022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# @hidden_cell
# The following code accesses a file in your IBM Cloud Object Storage. It includes your credentials.
# You might want to remove those credentials before you share the notebook.
cos_client = ibm_boto3.client(service_name='s3',
ibm_api_key_id='1rEQ4QsDyr45SbIYkkmEXGolFpDjMBjlc1KmxrsH2V1U',
ibm_auth_endpoint="https://iam.cloud.ibm.com/oidc/token",
config=Config(signature_version='oauth'),
endpoint_url='https://s3.private.us.cloud-object-storage.appdomain.cloud')
bucket = 'digitrecognition-donotdelete-pr-kvpefjqsoxebrc'
object_key = '4.jpg'
streaming_body_3 = cos_client.get_object(Bucket=bucket, Key=object_key)['Body']
In [45]:
img = Image.open(streaming_body_3).convert("L") # convert image to monochrome
img = img.resize((28,28)) # resizing of input image
In [46]:
img
Out[46]:
In [47]:
im2arr = np.array(img) #converting to image
im2arr = im2arr.reshape(1, 28, 28, 1) #reshaping according to our requirement
In [48]:
pred = model.predict(im2arr)
print(pred)
1/1 [==============================] - 0s 59ms/step
[[1.6652905e-08 1.4808821e-09 4.6498787e-09 1.3217071e-08 9.9999189e-01
3.5436660e-06 1.9168174e-12 6.8785079e-07 3.4201292e-08 3.8043918e-06]]
In [49]:
print(np.argmax(pred, axis=1)) #printing our Labels
[4]
In [ ]:
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