

In-class Assignment 2

Instructor: Qasim Ali

Develop and Deploy a Machine Learning Application using Docker

Group Name: Group C

Student Name: Bibek Khadka

Objective

The objective of this assignment is to develop a simple machine learning application, containerize it using Docker, and deploy it on GitHub. This exercise will help you understand the principles of containerization, version control, and basic machine learning application development.

Prerequisites

- Basic understanding of Python programming
- Basic understanding of machine learning concepts
- Familiarity with Git and GitHub
- Basic knowledge of Docker

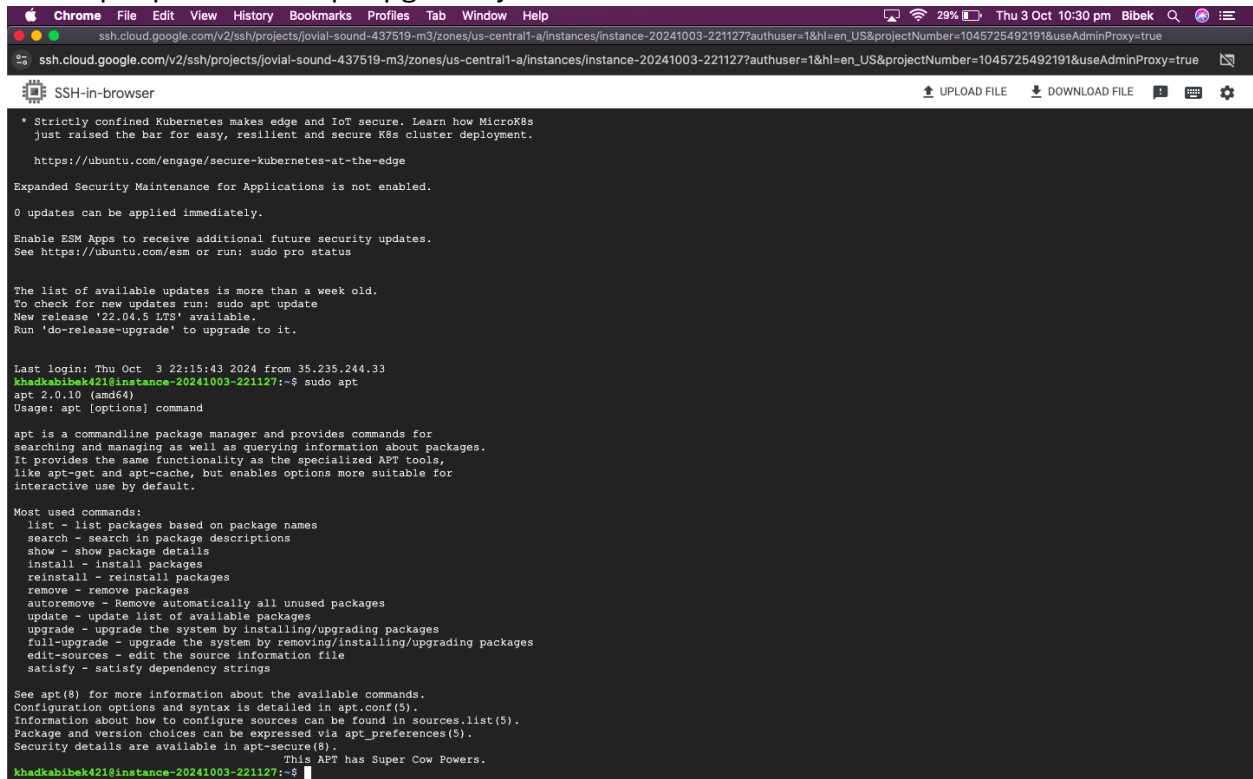
Assignment Steps

Step 1: Set Up the VM

1. Update the System

- Ensure your VM is running an updated version of Ubuntu. Run the following
- commands:

`sudo apt update`
`sudo apt upgrade -y`



```
* Strictly confined Kubernetes makes edge and IoT secure. Learn how MicroK8s
just raised the bar for easy, resilient and secure K8s cluster deployment.

https://ubuntu.com/engage/secure-kubernetes-at-the-edge

Expanded Security Maintenance for Applications is not enabled.

0 updates can be applied immediately.

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status

The list of available updates is more than a week old.
To check for new updates run: sudo apt update
New release '22.04.5 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Thu Oct  3 22:15:43 2024 from 35.235.244.33
khadkabibek421@instance-20241003-221127:~$ sudo apt
apt 2.0.10 (amd64)
Usage: apt [options] command

apt is a commandline package manager and provides commands for
searching and managing as well as querying information about packages.
It provides the same functionality as the specialized APT tools,
like apt-get and apt-cache, but enables options more suitable for
interactive use by default.

Most used commands:
list - list packages based on package names
search - search in package descriptions
show - show package details
install - install packages
reinstall - reinstall packages
remove - remove packages
autoremove - Remove automatically all unused packages
update - update list of available packages
upgrade - upgrade the system by installing/upgrading packages
full-upgrade - upgrade the system by removing/installing/upgrading packages
edit-sources - edit the source information file
satisfy - satisfy dependency strings

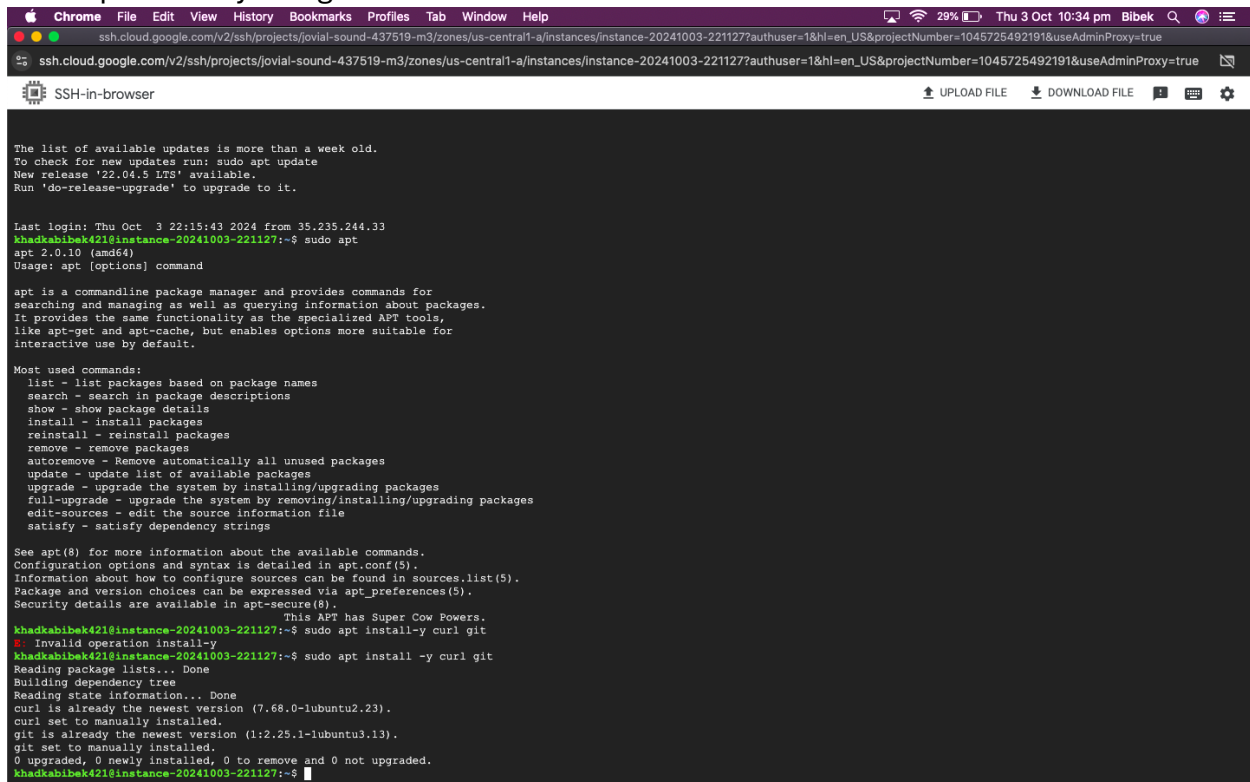
See apt(8) for more information about the available commands.
Configuration options and syntax is detailed in apt.conf(5).
Information about how to configure sources can be found in sources.list(5).
Package and version choices can be expressed via apt_preferences(5).
Security details are available in apt-secure(8).

This APT has Super Cow Powers.
khadkabibek421@instance-20241003-221127:~$
```

2. Install Necessary Packages

- Install curl and git:

sudo apt install -y curl git



```
Chrome File Edit View History Bookmarks Profiles Tab Window Help
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true
SSH-in-browser
UPLOAD FILE DOWNLOAD FILE

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This APT has Super Cow Powers.
khadkabibek421@instance-20241003-221127:~$ sudo apt install -y curl git
$ Invalid operation install-y
khadkabibek421@instance-20241003-221127:~$ sudo apt install -y curl git
Reading package lists... Done
Building dependency tree
Reading state information... Done
curl is already the newest version (7.68.0-1ubuntu2.23).
curl set to manually installed.
git is already the newest version (1:2.25.1-1ubuntu3.13).
git set to manually installed.
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
khadkabibek421@instance-20241003-221127:~$
```

Step 2: Install Docker

1. Remove Old Versions

- Remove any old versions of Docker if present:

```
Chrome File Edit View History Bookmarks Profiles Tab Window Help
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true
SSH-in-browser
UPLOAD FILE DOWNLOAD FILE

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git set to manually installed.
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
khadkabi@instance-20241003-221127:~$ sudo apt remove docker docker-engine docker.io contained runc
Reading package lists... Done
Building dependency tree
Reading state information... Done
Package 'docker.io' is not installed, so not removed
E: Unable to locate package dockerdocker-engine
E: Unable to locate package contained
khadkabi@instance-20241003-221127:~$
```

sudo apt remove docker docker-engine docker.io contained runc

2. Set Up the Docker Repository

- Run the following commands to set up the Docker repository:

sudo apt update

sudo apt install -y apt-transport-https ca-certificates

curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo gpg
--dearmor -o /usr/share/keyrings/docker-archive-keyring.gpg

```
Chrome File Edit View History Bookmarks Profiles Tab Window Help
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true

SSH-in-browser
[Icons: Upload File, Download File, Chat, Settings]

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=0Yyh
-----END PGP PUBLIC KEY BLOCK-----
khadkabilbek421@instance-20241003-221127:~$ curl gnupg lsb-release curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo gpg --dearmor -o /usr/share/keyrings/docker-archive-
keyring.gpg
File '/usr/share/keyrings/docker-archive-keyring.gpg' exists. Overwrite? (y/N) curl: (6) Could not resolve host: gnupg
curl: (6) Could not resolve host: ls-release
curl: (6) Could not resolve host: curl

Enter new filename: bibek
khadkabilbek421@instance-20241003-221127:~$
```

echo "deb [arch=\$(dpkg --print-architecture) signed-by=/usr/share/keyrings/docker-
archive-keyring.gpg] https://download.docker.com/linux/ubuntu \$(lsb_release -cs) stable" |
sudo tee /etc/apt/sources.list.d/docker.list > /dev/null

```
Chrome File Edit View History Bookmarks Profiles Tab Window Help
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true

SSH-in-browser
[Icons: Upload File, Download File, Chat, Settings]

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YT90qF93M3v01BbxP+EIY2/9ti1Pbrd
=0Yyh
-----END PGP PUBLIC KEY BLOCK-----
khadkabilbek421@instance-20241003-221127:~$ curl gnupg lsb-release curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo gpg --dearmor -o /usr/share/keyrings/docker-archive-
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curl: (6) Could not resolve host: ls-release
curl: (6) Could not resolve host: curl

Enter new filename: bibek
khadkabilbek421@instance-20241003-221127:~$ echo "deb [arch=$(dpkg --print-architecture) signed-by=/usr/share/keyrings/docker-archive-keyring.gpg] https://download.docker.com/linux/u
buntu $(lsb_release -cs) stable" | sudo tee /etc/apt/sources.list.d/docker.list > /dev/null
khadkabilbek421@instance-20241003-221127:~$
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```
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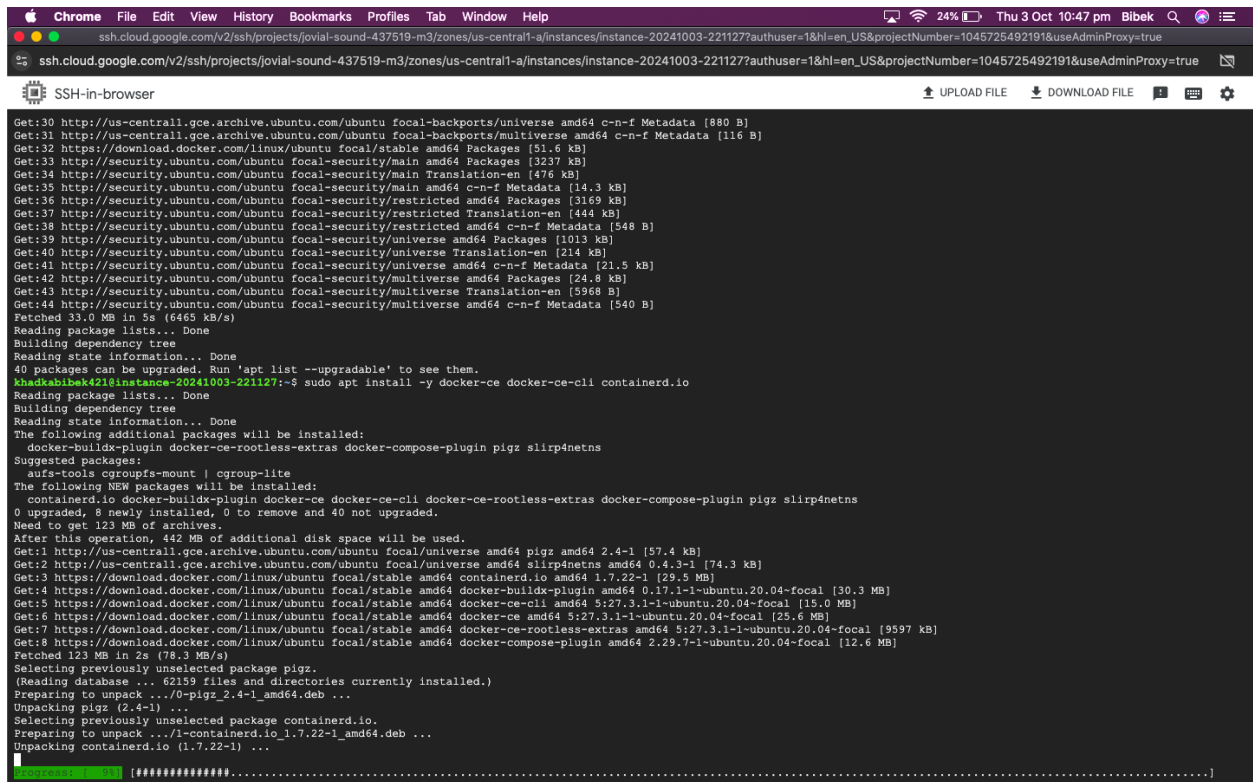
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git set to manually installed.
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
khadkabibek421@instance-20241003-221127:~$ sudo apt remove dockerdocker-engine docker.io contained runc
Reading package lists... Done
Building dependency tree
Reading state information... Done
Package 'docker.io' is not installed, so not removed
E: Unable to locate package dockerdocker-engine
E: Unable to locate package contained
khadkabibek421@instance-20241003-221127:~$ sudo apt install -y apt-transport-https ca-certificates
Reading package lists... Done
Building dependency tree
Reading state information... Done
Note, selecting 'apt' instead of 'apt-transport-https'
apt is already the newest version (2.0.10).
apt set to manually installed.
ca-certificates is already the newest version (20230311ubuntu0.20.04.1).
ca-certificates set to manually installed.
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
khadkabibek421@instance-20241003-221127:~$
```

3. Install Docker Engine

- Install Docker Engine using the following command:

```
sudo apt update
sudo apt install -y docker-ce docker-ce-cli containerd.io
```



```
Get:30 http://us-central1.gce.archive.ubuntu.com/ubuntu focal-backports/universe amd64 c-n-f Metadata [880 B]
Get:31 http://us-central1.gce.archive.ubuntu.com/ubuntu focal-backports/multiverse amd64 c-n-f Metadata [116 B]
Get:32 https://download.docker.com/linux/ubuntu focal/stable amd64 Packages [51.6 kB]
Get:33 http://security.ubuntu.com/ubuntu focal-security/main amd64 Packages [3237 kB]
Get:34 http://security.ubuntu.com/ubuntu focal-security/main Translation-en [476 kB]
Get:35 http://security.ubuntu.com/ubuntu focal-security/main amd64 c-n-f Metadata [14.3 kB]
Get:36 http://security.ubuntu.com/ubuntu focal-security/restricted amd64 Packages [3169 kB]
Get:37 http://security.ubuntu.com/ubuntu focal-security/restricted Translation-en [444 kB]
Get:38 http://security.ubuntu.com/ubuntu focal-security/restricted amd64 c-n-f Metadata [548 B]
Get:39 http://security.ubuntu.com/ubuntu focal-security/universe amd64 Packages [1013 kB]
Get:40 http://security.ubuntu.com/ubuntu focal-security/universe Translation-en [214 kB]
Get:41 http://security.ubuntu.com/ubuntu focal-security/universe amd64 c-n-f Metadata [21.5 kB]
Get:42 http://security.ubuntu.com/ubuntu focal-security/multiverse amd64 Packages [24.8 kB]
Get:43 http://security.ubuntu.com/ubuntu focal-security/multiverse Translation-en [5968 B]
Get:44 http://security.ubuntu.com/ubuntu focal-security/multiverse amd64 c-n-f Metadata [540 B]
Fetched 33.0 MB in 5s (6465 kB/s)
Reading package lists... Done
Building dependency tree
Reading state information... Done
40 packages can be upgraded. Run 'apt list --upgradable' to see them.
khadkabibek4218@instance-20241003-221127:~$ sudo apt install -y docker-ce docker-ce-cli containerd.io
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  docker-buildx-plugin docker-ce-rootless-extras docker-compose-plugin pigz slurp4netns
Suggested packages:
  aufs-tools cgroupfs-mount | cgroup-lite
The following NEW packages will be installed:
  containerd.io docker-buildx-plugin docker-ce docker-ce-cli docker-ce-rootless-extras docker-compose-plugin pigz slurp4netns
0 upgraded, 8 newly installed, 0 to remove and 40 not upgraded.
Need to get 123 MB of archives.
After this operation, 442 MB of additional disk space will be used.
Get:1 http://us-central1.gce.archive.ubuntu.com/ubuntu focal/universe amd64 pigz amd64 2.4-1 [57.4 kB]
Get:2 http://us-central1.gce.archive.ubuntu.com/ubuntu focal/universe amd64 slurp4netns amd64 0.4.3-1 [74.3 kB]
Get:3 https://download.docker.com/linux/ubuntu focal/stable amd64 containerd.io amd64 1.7.22-1 [29.5 MB]
Get:4 https://download.docker.com/linux/ubuntu focal/stable amd64 docker-buildx-plugin amd64 0.17.1-1-ubuntu.20.04-focal [30.3 MB]
Get:5 https://download.docker.com/linux/ubuntu focal/stable amd64 docker-ce-cli amd64 5:27.3.1-1-ubuntu.20.04-focal [15.0 MB]
Get:6 https://download.docker.com/linux/ubuntu focal/stable amd64 docker-ce amd64 5:27.3.1-1-ubuntu.20.04-focal [25.6 MB]
Get:7 https://download.docker.com/linux/ubuntu focal/stable amd64 docker-ce-rootless-extras amd64 5:27.3.1-1-ubuntu.20.04-focal [9597 kB]
Get:8 https://download.docker.com/linux/ubuntu focal/stable amd64 docker-compose-plugin amd64 2.29.7-1-ubuntu.20.04-focal [12.6 MB]
Fetched 123 MB in 2s (78.3 MB/s)
Selecting previously unselected package pigz.
(Reading database ... 62159 files and directories currently installed.)
Preparing to unpack .../0-pigz_2.4-1_amd64.deb ...
Unpacking pigz (2.4-1) ...
Selecting previously unselected package containerd.io.
Preparing to unpack .../1-containerd.io_1.7.22-1_amd64.deb ...
Unpacking containerd.io (1.7.22-1) ...
```

4. Verify Docker Installation

- Verify that Docker is installed correctly by running:

sudo docker run hello-world


```
Chrome File Edit View History Bookmarks Profiles Tab Window Help
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true
SSH-in-browser
UPLOAD FILE DOWNLOAD FILE

Selecting previously unselected package docker-ce-rootless-extras.
Preparing to unpack .../5-docker-ce-rootless-extras_5:27.3.1-1-ubuntu.20.04-focal_amd64.deb ...
Unpacking docker-ce-rootless-extras (5:27.3.1-1-ubuntu.20.04-focal) ...
Selecting previously unselected package docker-compose-plugin.
Preparing to unpack .../6-docker-compose-plugin_2.29.7-1-ubuntu.20.04-focal_amd64.deb ...
Unpacking docker-compose-plugin (2.29.7-1-ubuntu.20.04-focal) ...
Selecting previously unselected package slirp4netns.
Preparing to unpack .../7-slirp4netns_0.4.3-1_amd64.deb ...
Unpacking slirp4netns (0.4.3-1) ...
Setting up slirp4netns (0.4.3-1) ...
Setting up docker-buildx-plugin (0.17.1-1-ubuntu.20.04-focal) ...
Setting up containerd.io (1.7.22-1) ...
Created symlink /etc/systemd/system/multi-user.target.wants/containerd.service → /lib/systemd/system/containerd.service.
Setting up docker-compose-plugin (2.29.7-1-ubuntu.20.04-focal) ...
Setting up docker-ce-cli (5:27.3.1-1-ubuntu.20.04-focal) ...
Setting up pigz (2.4-1) ...
Setting up docker-ce-rootless-extras (5:27.3.1-1-ubuntu.20.04-focal) ...
Setting up docker-ce (5:27.3.1-1-ubuntu.20.04-focal) ...
Created symlink /etc/systemd/system/multi-user.target.wants/docker.service → /lib/systemd/system/docker.service.
Created symlink /etc/systemd/system/sockets.target.wants/docker.socket → /lib/systemd/system/docker.socket.
Processing triggers for man-db (2.9.1-1) ...
Processing triggers for systemd (245.4-4ubuntu3.23) ...
khadkabibek421@instance-20241003-221127:~$ sudo docker run hello-world
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
c1ec31eb5944: Pull complete
Digest: sha256:91fb4b04da273d5a3273b6d587d62d518300a6ad268b28628f74997b93171b2
Status: Downloaded newer image for hello-world:latest

Hello from Docker!
This message shows that your installation appears to be working correctly.

To generate this message, Docker took the following steps:
1. The Docker client contacted the Docker daemon.
2. The Docker daemon pulled the "hello-world" image from the Docker Hub.
   (amd64)
3. The Docker daemon created a new container from that image which runs the
   executable that produces the output you are currently reading.
4. The Docker daemon streamed that output to the Docker client, which sent it
   to your terminal.

To try something more ambitious, you can run an Ubuntu container with:
$ docker run -it ubuntu bash

Share images, automate workflows, and more with a free Docker ID:
https://hub.docker.com/

For more examples and ideas, visit:
https://docs.docker.com/get-started/
khadkabibek421@instance-20241003-221127:~$
```

Step 3: Create a Dockerfile for the ML Application

1. Create Project Directory

- Create a directory for your project and navigate into it:

```
Chrome File Edit View History Bookmarks Profiles Tab Window Help
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true
ssh.cloud.google.com/v2/ssh/projects/jovial-sound-437519-m3/zones/us-central1-a/instances/instance-20241003-221127?authuser=1&hl=en_US&projectNumber=1045725492191&useAdminProxy=true
SSH-in-browser
UPLOAD FILE DOWNLOAD FILE

Unpacking docker-ce-rootless-extras (5:27.3.1-1-ubuntu.20.04-focal) ...
Selecting previously unselected package docker-compose-plugin.
Preparing to unpack .../5-docker-compose-plugin_2.29.7-1-ubuntu.20.04-focal_amd64.deb ...
Unpacking docker-compose-plugin (2.29.7-1-ubuntu.20.04-focal) ...
Selecting previously unselected package slirp4netns.
Preparing to unpack .../7-slirp4netns_0.4.3-1_amd64.deb ...
Unpacking slirp4netns (0.4.3-1) ...
Setting up slirp4netns (0.4.3-1) ...
Setting up docker-buildx-plugin (0.17.1-1-ubuntu.20.04-focal) ...
Setting up containerd.io (1.7.22-1) ...
Created symlink /etc/systemd/system/multi-user.target.wants/containerd.service → /lib/systemd/system/containerd.service.
Setting up docker-compose-plugin (2.29.7-1-ubuntu.20.04-focal) ...
Setting up docker-ce-cli (5:27.3.1-1-ubuntu.20.04-focal) ...
Setting up pigz (2.4-1) ...
Setting up docker-ce-rootless-extras (5:27.3.1-1-ubuntu.20.04-focal) ...
Setting up docker-ce (5:27.3.1-1-ubuntu.20.04-focal) ...
Created symlink /etc/systemd/system/multi-user.target.wants/docker.service → /lib/systemd/system/docker.service.
Created symlink /etc/systemd/system/sockets.target.wants/docker.socket → /lib/systemd/system/docker.socket.
Processing triggers for man-db (2.9.1-1) ...
Processing triggers for systemd (245.4-4ubuntu3.23) ...
khadkabibek421@instance-20241003-221127:~$ sudo docker run hello-world
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
c1ec31eb5944: Pull complete
Digest: sha256:91fb4b04da273d5a3273b6d587d62d518300a6ad268b28628f74997b93171b2
Status: Downloaded newer image for hello-world:latest

Hello from Docker!
This message shows that your installation appears to be working correctly.

To generate this message, Docker took the following steps:
1. The Docker client contacted the Docker daemon.
2. The Docker daemon pulled the "hello-world" image from the Docker Hub.
   (amd64)
3. The Docker daemon created a new container from that image which runs the
   executable that produces the output you are currently reading.
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   to your terminal.

To try something more ambitious, you can run an Ubuntu container with:
$ docker run -it ubuntu bash

Share images, automate workflows, and more with a free Docker ID:
https://hub.docker.com/

For more examples and ideas, visit:
https://docs.docker.com/get-started/
khadkabibek421@instance-20241003-221127:~$ mkdir ml-app
khadkabibek421@instance-20241003-221127:~$ cd ml-app
khadkabibek421@instance-20241003-221127:~/ml-app$
```


2. Create a Dockerfile

- Create a **Dockerfile** with the following content:

```
# Use an official Python runtime as a parent image
FROM python:3.9-slim
# Set the working directory
WORKDIR /usr/src/app
# Copy the current directory contents into the container at /usr/src/app
*****YOU NEED TO WRITE COMMAND HERE*****

# Install any needed packages specified in requirements.txt RUN pip install --no-cache-dir
-r requirements.txt # Make port 80 available to the world outside this container EXPOSE 80

# Run app.py when the container launches CMD ["python", "app.py"]
```

3. Create requirements.txt File

- Create a **requirements.txt** file with the following content:

```
Flask
Numpy
Pandas
scikit-learn
```

Step 4: Develop the Machine Learning Application

1. Create a Simple ML Model

- Create a script **train_model.py** to train a simple machine learning model and save it. For simplicity, we'll use the Iris dataset and a decision tree classifier.

```
from sklearn.datasets import load_iris
from sklearn.tree import DecisionTreeClassifier
import pickle
```

```
# Load the Iris dataset
iris = load_iris()
X, y = iris.data, iris.target
```

```
# Train a decision tree classifier
clf = DecisionTreeClassifier() clf.fit(X, y)
```

```
# Save the model to a file
with open('model.pkl', 'wb') as f:
    pickle.dump(clf, f)
```

2. Run the Model Training Script

- Run the **train_model.py** script to generate **model.pkl**:
`python train_model.py`

3. Integrate the Model into the Flask App

- Update **app.py** to load the trained model and use it for predictions:

```
from flask import Flask, request, jsonify
import pickle
import numpy as np

app = Flask(__name__)

# Load the trained model
with open('model.pkl', 'rb') as f:
    model = pickle.load(f)

@app.route('/')
def hello_world():
    return 'Hello, Docker!'

@app.route('/predict', methods=['POST'])
def predict():
    data = request.get_json(force=True)
    prediction = model.predict(np.array(data['input']).reshape(1, -1))
    return jsonify({'prediction': int(prediction[0])})

if __name__ == '__main__':
    app.run(host='0.0.0.0', port=80)
```

4. Update the Project Directory

- Ensure your project directory contains the following files:
 - **Dockerfile**
 - **requirements.txt**
 - **train_model.py**
 - **app.py**
 - **model.pkl** (generated after running **train_model.py**)

Step 5: Build and Run the Docker Container

1. Build the Docker Image

- Build the Docker image with the following command:
`sudo docker build -t ml-app .`

2. Run the Docker Container

- Run the Docker container with the following command:
`sudo docker run -p 4000:80 ml-app`

3. Access the Application

- Open your browser and navigate to **http://localhost:4000** to see the running application.

4. Test the ML Endpoint

- Test the **/predict** endpoint using **curl** or Postman by sending a POST request with JSON data:

```
curl -X POST http://localhost:4000/predict -H "Content-Type: application/json" -d '{"input": [5.1, 3.5, 1.4, 0.2]}'
```

Step 6: Deploy the Application to GitHub

1. Initialize a Git Repository

- Initialize a Git repository in your project directory:

```
git init
```

2. Add All Files and Commit

- Add all files to the repository and commit:

```
git add .
```

```
git commit -m "Initial commit"
```

3. Create a New Repository on GitHub

- Create a new repository on GitHub and follow the instructions to push your local repository to GitHub:

```
git remote add origin https://github.com/yourusername/your-repository.git
```

```
git branch -M main
```

```
git push -u origin main
```

Step 7: Document the Process

1. Create a README.md File

- Document the process in a **README.md** file in your repository. Include the following:
 - Overview of the project
 - Instructions to build and run the Docker container
 - Instructions to test the ML endpoint
 - Any other relevant information about the project

Submission

- Take screenshots of every step you perform and paste in the submission word/pdf file.
- Submit the GitHub repository link of your project.
- Ensure your repository is public and the README.md file is well-documented.