IS6733Lab2_sai

March 10, 2024

1 Lab 2: Convolutional Neural Networks for Computer Vision

In this lab, we will learn how to use CNNs for computer vision applications. We will look at two applications - 1) detecting objects in images, and 2) detecting cyberbullying in images.

Grading Breakdown:

Part 1: Detecting objects 70%

Part 2: Detecting cyberbullying 30%

1.1 Part 1: CNN to Detect Images of 10 Objects

In this section, we will design a CNN to classify images of 10 objects from the CIFAR10 dataset.

[ ]:
```
!pip install torchvision
```

```
Requirement already satisfied: torchvision in /usr/local/lib/python3.10/dist-
packages (0.16.0+cu121)
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages
(from torchvision) (1.25.2)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-
packages (from torchvision) (2.31.0)
Requirement already satisfied: torch==2.1.0 in /usr/local/lib/python3.10/dist-
packages (from torchvision) (2.1.0+cu121)
Requirement already satisfied: pillow!=8.3.*,>=5.3.0 in
/usr/local/lib/python3.10/dist-packages (from torchvision) (9.4.0)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-
packages (from torch==2.1.0->torchvision) (3.13.1)
Requirement already satisfied: typing-extensions in
/usr/local/lib/python3.10/dist-packages (from torch==2.1.0->torchvision)
(4.10.0)
Requirement already satisfied: sympy in /usr/local/lib/python3.10/dist-packages
(from torch==2.1.0->torchvision) (1.12)
Requirement already satisfied: networkx in /usr/local/lib/python3.10/dist-
packages (from torch==2.1.0->torchvision) (3.2.1)
Requirement already satisfied: jinja2 in /usr/local/lib/python3.10/dist-packages
(from torch==2.1.0->torchvision) (3.1.3)
Requirement already satisfied: fsspec in /usr/local/lib/python3.10/dist-packages
(from torch==2.1.0->torchvision) (2023.6.0)
```

```
Requirement already satisfied: triton==2.1.0 in /usr/local/lib/python3.10/dist-
packages (from torch==2.1.0->torchvision) (2.1.0)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests->torchvision) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-
packages (from requests->torchvision) (3.6)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.10/dist-packages (from requests->torchvision) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from requests->torchvision) (2024.2.2)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.10/dist-packages (from jinja2->torch==2.1.0->torchvision)
(2.1.5)
Requirement already satisfied: mpmath>=0.19 in /usr/local/lib/python3.10/dist-
packages (from sympy->torch==2.1.0->torchvision) (1.3.0)
```

[ ]:

[ ]:
```
# Import packages first
import torch
import torchvision
import torchvision.transforms as transforms
from sklearn.metrics import␣
 ↪(accuracy_score,precision_score,recall_score,f1_score)
from PIL import Image
import os
import matplotlib.pyplot as plt
```

[ ]:
```
# Just like in Lab 1, we willnormalize our inputs. As we go along, notice the␣
 ↪recurring themes in deep learning, such as data normalizqation, data set and␣
 ↪loader, optimizer, loss function etc...
transform = transforms.Compose(
    [transforms.ToTensor(),
     transforms.Normalize((0.5, 0.5, 0.5), (0.5, 0.5, 0.5))])

# set a batch size
batch_size = 4

# download the train set
trainset = torchvision.datasets.CIFAR10(root='./data', train=True,␣
 ↪download=True, transform=transform)

# we'll just split the train into train and val
trainset, valset = torch.utils.data.random_split(trainset, [0.8, 0.2])
trainloader = torch.utils.data.DataLoader(trainset, batch_size=batch_size,␣
 ↪shuffle=True, num_workers=2)
```

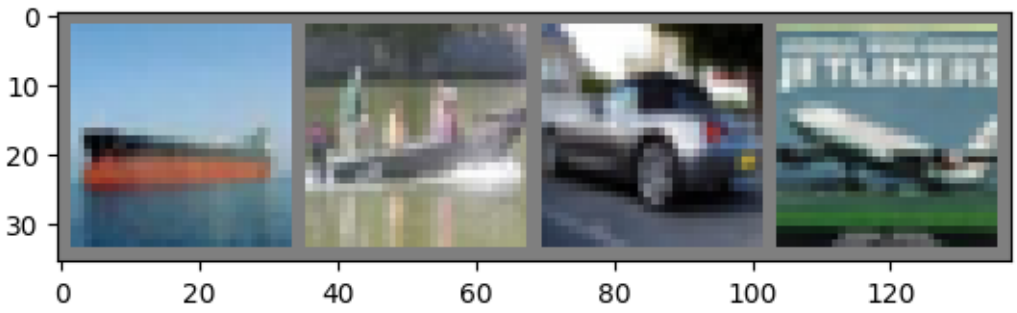
```
valloader = torch.utils.data.DataLoader(valset, batch_size=batch_size,␣
 ↪shuffle=True, num_workers=2)

# download the train set
testset = torchvision.datasets.CIFAR10(root='./data', train=False,␣
 ↪download=True, transform=transform)
testloader = torch.utils.data.DataLoader(testset, batch_size=batch_size,␣
 ↪shuffle=False, num_workers=2)

# labels. In this problem there are 10 labels.
classes = ('plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse',␣
 ↪'ship', 'truck')
```

```
Downloading https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz to
./data/cifar-10-python.tar.gz
```

```
100%|      | 170498071/170498071 [00:13<00:00, 12845404.29it/s]
```

```
Extracting ./data/cifar-10-python.tar.gz to ./data
Files already downloaded and verified
```

[ ]:
```
# Visualize a few images in the train set
import matplotlib.pyplot as plt
import numpy as np

def imshow(img):
    img = img / 2 + 0.5     # unnormalize
    npimg = img.numpy()
    plt.imshow(np.transpose(npimg, (1, 2, 0)))
    plt.show()

# get some random training images
dataiter = iter(trainloader)
images, labels = next(dataiter)

# show images
imshow(torchvision.utils.make_grid(images))
# print labels
print(' '.join(f'{classes[labels[j]]:5s}' for j in range(batch_size)))
```




```
ship  ship  car   plane
```

[ ]:
```
# CNN Architecture
import torch.nn as nn
import torch.nn.functional as F

class MyObjDetectorCNN(nn.Module):
    def __init__(self):
        super(MyObjDetectorCNN, self).__init__()

        # this is the conv net part
        self.convolutional_layer = nn.Sequential(
            # we can use the equation ((N + 2p - f) / s) + 1 to quickly compute␣
↪the output of a convolution op.
            # however, PyTorch makes it easy for us, since it computes this␣
↪equation for us. All we have to do is tell it the number of channels we want
            # in the input and the output. For the first convolution layer, the␣
↪in_channels would be the channels a standard RGB image has. Let's say we want
            # number of channels in the output to be 20. We want to use 5X5␣
↪convolutions and single strides. Write the convolution layers.
            nn.Conv2d(in_channels = 3, out_channels = 20, kernel_size = 5,␣
↪stride = 1),
            nn.ReLU(),
            # Lets subsample after convolution. We will use Max Pooling in this␣
↪example.
            nn.MaxPool2d(kernel_size = 2,stride = 2),
            # Let's add another convolutional layer. We want the output of this␣
↪convolution operation to have 50 channels. Let's use 5X5 convolutions and␣
↪single strides again.
            nn.Conv2d(in_channels = 20, out_channels = 50, kernel_size = 5 ,␣
↪stride = 1),
            nn.ReLU(),
```

```
            # Subsample again
            nn.MaxPool2d(kernel_size = (2,2), stride = 2),

        )

        # this is the classifier head. So the model is actually CNN + DNN. We will flatten the output from the CNN above for the DNN.
        self.linear_layer = nn.Sequential(
            nn.Linear(in_features = 50*5*5, out_features = 500),
            nn.ReLU(),
            nn.Linear(in_features = 500, out_features = 10), # observe how we have output features = 10. There are 10 classes in this problem.
        )


    def forward(self, x):
        x = self.convolutional_layer(x)
        x = torch.flatten(x, 1) # Flattening the output of the CNN for the DNN
        x = self.linear_layer(x)
        x = F.softmax(x, dim = 1)
        return x

net = MyObjDetectorCNN()
```

Device Change to GPU if Available

[ ]:
```
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
```

[ ]:
```
# define a loss function and opimizer
import torch.optim as optim

net.to(device)

criterion = nn.CrossEntropyLoss()
optimizer = optim.SGD(net.parameters(), lr = 0.001, momentum = 0.9,weight_decay=0.0001)
```

[ ]:
```
# train the network (better use a GPU for this, look at the first lab for moving objects to GPU)
net.train()
for epoch in range(35):  # loop over the dataset multiple times, you could increase this.

    running_loss = 0.0
    for i, data in enumerate(trainloader, 0):
        # get the inputs; data is a list of [inputs, labels]
        #inputs, labels = data # to use CPU
```

```
        inputs,labels=data[0].to(device),data[1].to(device) # using GPU

        # zero the parameter gradients
        optimizer.zero_grad()

        # forward + backward + optimize
        outputs = net(inputs)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()

        # print statistics
        running_loss += loss.item()
        if i % 2000 == 1999:    # print every 2000 mini-batches
            print(f'[{epoch + 1}, {i + 1:5d}] loss: {running_loss / 2000:.3f}')
            running_loss = 0.0

print('Finished Training')
```

```
[1,  2000] loss: 1.500
[1,  4000] loss: 1.506
[1,  6000] loss: 1.507
[1,  8000] loss: 1.502
[1, 10000] loss: 1.506
[2,  2000] loss: 1.502
[2,  4000] loss: 1.504
[2,  6000] loss: 1.504
[2,  8000] loss: 1.505
[2, 10000] loss: 1.506
[3,  2000] loss: 1.505
[3,  4000] loss: 1.501
[3,  6000] loss: 1.503
[3,  8000] loss: 1.505
[3, 10000] loss: 1.506
[4,  2000] loss: 1.504
[4,  4000] loss: 1.506
[4,  6000] loss: 1.502
[4,  8000] loss: 1.503
[4, 10000] loss: 1.505
[5,  2000] loss: 1.501
[5,  4000] loss: 1.505
[5,  6000] loss: 1.504
[5,  8000] loss: 1.504
[5, 10000] loss: 1.506
[6,  2000] loss: 1.506
[6,  4000] loss: 1.503
[6,  6000] loss: 1.506
```

```
[6,  8000] loss: 1.502
[6, 10000] loss: 1.503
[7,  2000] loss: 1.503
[7,  4000] loss: 1.502
[7,  6000] loss: 1.502
[7,  8000] loss: 1.505
[7, 10000] loss: 1.507
[8,  2000] loss: 1.499
[8,  4000] loss: 1.505
[8,  6000] loss: 1.506
[8,  8000] loss: 1.506
[8, 10000] loss: 1.503
[9,  2000] loss: 1.501
[9,  4000] loss: 1.505
[9,  6000] loss: 1.501
[9,  8000] loss: 1.503
[9, 10000] loss: 1.509
[10,  2000] loss: 1.507
[10,  4000] loss: 1.501
[10,  6000] loss: 1.506
[10,  8000] loss: 1.504
[10, 10000] loss: 1.499
[11,  2000] loss: 1.499
[11,  4000] loss: 1.502
[11,  6000] loss: 1.504
[11,  8000] loss: 1.505
[11, 10000] loss: 1.506
[12,  2000] loss: 1.504
[12,  4000] loss: 1.504
[12,  6000] loss: 1.502
[12,  8000] loss: 1.506
[12, 10000] loss: 1.499
[13,  2000] loss: 1.500
[13,  4000] loss: 1.503
[13,  6000] loss: 1.505
[13,  8000] loss: 1.503
[13, 10000] loss: 1.504
[14,  2000] loss: 1.501
[14,  4000] loss: 1.505
[14,  6000] loss: 1.501
[14,  8000] loss: 1.500
[14, 10000] loss: 1.506
[15,  2000] loss: 1.501
[15,  4000] loss: 1.502
[15,  6000] loss: 1.503
[15,  8000] loss: 1.504
[15, 10000] loss: 1.503
[16,  2000] loss: 1.501
```

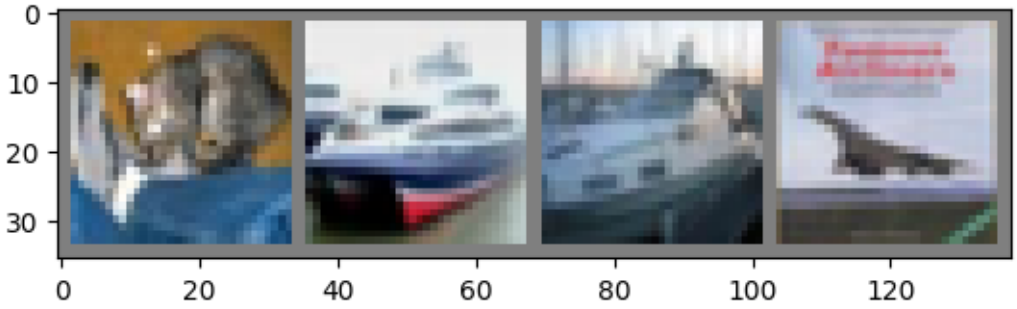
```
[16,  4000] loss: 1.505
[16,  6000] loss: 1.502
[16,  8000] loss: 1.501
[16, 10000] loss: 1.503
[17,  2000] loss: 1.503
[17,  4000] loss: 1.502
[17,  6000] loss: 1.502
[17,  8000] loss: 1.505
[17, 10000] loss: 1.500
[18,  2000] loss: 1.502
[18,  4000] loss: 1.504
[18,  6000] loss: 1.502
[18,  8000] loss: 1.501
[18, 10000] loss: 1.502
[19,  2000] loss: 1.500
[19,  4000] loss: 1.502
[19,  6000] loss: 1.504
[19,  8000] loss: 1.502
[19, 10000] loss: 1.503
[20,  2000] loss: 1.501
[20,  4000] loss: 1.501
[20,  6000] loss: 1.502
[20,  8000] loss: 1.504
[20, 10000] loss: 1.503
[21,  2000] loss: 1.498
[21,  4000] loss: 1.505
[21,  6000] loss: 1.503
[21,  8000] loss: 1.500
[21, 10000] loss: 1.506
[22,  2000] loss: 1.505
[22,  4000] loss: 1.509
[22,  6000] loss: 1.507
[22,  8000] loss: 1.515
[22, 10000] loss: 1.522
[23,  2000] loss: 1.521
[23,  4000] loss: 1.523
[23,  6000] loss: 1.530
[23,  8000] loss: 1.534
[23, 10000] loss: 1.539
[24,  2000] loss: 1.530
[24,  4000] loss: 1.530
[24,  6000] loss: 1.534
[24,  8000] loss: 1.538
[24, 10000] loss: 1.542
[25,  2000] loss: 1.526
[25,  4000] loss: 1.523
[25,  6000] loss: 1.532
[25,  8000] loss: 1.530
```

```
[25, 10000] loss: 1.534
[26,  2000] loss: 1.524
[26,  4000] loss: 1.519
[26,  6000] loss: 1.521
[26,  8000] loss: 1.527
[26, 10000] loss: 1.528
[27,  2000] loss: 1.515
[27,  4000] loss: 1.514
[27,  6000] loss: 1.519
[27,  8000] loss: 1.523
[27, 10000] loss: 1.520
[28,  2000] loss: 1.512
[28,  4000] loss: 1.510
[28,  6000] loss: 1.513
[28,  8000] loss: 1.520
[28, 10000] loss: 1.515
[29,  2000] loss: 1.516
[29,  4000] loss: 1.509
[29,  6000] loss: 1.513
[29,  8000] loss: 1.513
[29, 10000] loss: 1.511
[30,  2000] loss: 1.509
[30,  4000] loss: 1.512
[30,  6000] loss: 1.509
[30,  8000] loss: 1.512
[30, 10000] loss: 1.513
[31,  2000] loss: 1.504
[31,  4000] loss: 1.508
[31,  6000] loss: 1.507
[31,  8000] loss: 1.511
[31, 10000] loss: 1.508
[32,  2000] loss: 1.505
[32,  4000] loss: 1.508
[32,  6000] loss: 1.505
[32,  8000] loss: 1.506
[32, 10000] loss: 1.505
[33,  2000] loss: 1.503
[33,  4000] loss: 1.504
[33,  6000] loss: 1.507
[33,  8000] loss: 1.505
[33, 10000] loss: 1.506
[34,  2000] loss: 1.500
[34,  4000] loss: 1.505
[34,  6000] loss: 1.504
[34,  8000] loss: 1.505
[34, 10000] loss: 1.506
[35,  2000] loss: 1.502
[35,  4000] loss: 1.505
```

```
[35,  6000] loss: 1.502
[35,  8000] loss: 1.501
[35, 10000] loss: 1.500
Finished Training
```

[ ]:
```python
# test your CNN on the test set
# Note: If your accuracy is low, you need to further train your CNN.
dataiter = iter(testloader)
images, labels = next(dataiter)

# print images
imshow(torchvision.utils.make_grid(images))
print('GroundTruth: ', ' '.join(f'{classes[labels[j]]:5s}' for j in range(4)))

# What is the accuracy, precision, recall and F1-score on the test dataset?
from sklearn.metrics import (
    accuracy_score,
    precision_score,
    recall_score,
    f1_score
)

y_test = []
y_test_predictions = []

net.eval()
for i, data in enumerate(testloader, 0):
    #inputs, labels = data
    #inputs, labels = data # to use CPU
    inputs,labels=data[0].to(device),data[1].to(device) # using GPU if available
    y_test.extend([i.item() for i in labels])

    # Added this to change the device:
    #device = next(net.parameters()).device
    #inputs = inputs.to(device)

    outputs = net(inputs)
    y_test_predictions.extend(torch.argmax(i).item() for i in outputs)


# print accuracy, prec, rec, f1-score here

# y_test,y_test_predictions list is converted to np before calculating the␣
  ↪metrics:
y_test = np.array(y_test)
y_test_predictions = np.array(y_test_predictions)
```

```
accuracy = accuracy_score(y_test, y_test_predictions)
precision = precision_score(y_test, y_test_predictions,␣
 ↪average='weighted',zero_division=1)
recall = recall_score(y_test, y_test_predictions, average='weighted')
f1 = f1_score(y_test, y_test_predictions, average='weighted')

print(f"Accuracy: {accuracy:.4f}")
print(f"Precision: {precision:.4f}")
print(f"Recall: {recall:.4f}")
print(f"F1-score: {f1:.4f}")
```




```
GroundTruth:  cat   ship  ship  plane
Accuracy: 0.7143
Precision: 0.7173
Recall: 0.7143
F1-score: 0.7153
```

1.2 Part 2: Using a Pre-trained CNN to Detect Cyberbullying in Images

With previous lab learning, you should have some knowledge about how to develop an AI model to detect cyberbullying lauguage. In this lab, we will keep learning how AI can be developed to detect cyberbullying. We will use a publicly available test dataset of cyberbullying images, and deploy an pre-trained AI model to automatically detect cyberbullying images. Approach towards analysing the cyber bullying in images in a dataset, there are three steps: 1. Understand and identify the factors related to cyberbullying in images. 2. Load the pre-trained model. 3. Fine-tune the model with a small dataset. 3. Evaluate the pre-trained model and your fine-tuned model with the same test dataset. - Get the results of accuracy, precision, recall and F1-score - plot out the confusion matrix figure

The models and datasets in this lab are taken from the paper "Towards Understanding and Detecting Cyberbullying in Real-world Images" (NDSS 2021). https://www.ndss-symposium.org/ndss-paper/towards-understanding-and-detecting-cyberbullying-in-real-world-images/

1.3 Download the pre-trained model, test dataset and the dependencies

First, we need to download the pre-trained model and the test dataset used in the lab. Just hit the 'play' button run the code below.

[ ]:
```
# download the model and dataset
!wget -O auxes_17.pt https://buffalo.box.com/shared/static/
  ↪cjk39hq7prpwj2rkqz6lc2jr6q2h5shy.pt # model checkpoints
!wget -O cyberbullying_data.zip https://github.com/cuadvancelab/materials/blob/
  ↪main/lab2/cyberbullying_data.zip?raw=true # test dataset
```

```
--2024-03-09 05:21:07--
https://buffalo.box.com/shared/static/cjk39hq7prpwj2rkqz6lc2jr6q2h5shy.pt
Resolving buffalo.box.com (buffalo.box.com)… 74.112.186.144
Connecting to buffalo.box.com (buffalo.box.com)|74.112.186.144|:443…
connected.
HTTP request sent, awaiting response… 301 Moved Permanently
Location: /public/static/cjk39hq7prpwj2rkqz6lc2jr6q2h5shy.pt [following]
--2024-03-09 05:21:07--
https://buffalo.box.com/public/static/cjk39hq7prpwj2rkqz6lc2jr6q2h5shy.pt
Reusing existing connection to buffalo.box.com:443.
HTTP request sent, awaiting response… 301 Moved Permanently
Location:
https://buffalo.app.box.com/public/static/cjk39hq7prpwj2rkqz6lc2jr6q2h5shy.pt
[following]
--2024-03-09 05:21:07--
https://buffalo.app.box.com/public/static/cjk39hq7prpwj2rkqz6lc2jr6q2h5shy.pt
Resolving buffalo.app.box.com (buffalo.app.box.com)… 74.112.186.144
Connecting to buffalo.app.box.com (buffalo.app.box.com)|74.112.186.144|:443…
connected.
HTTP request sent, awaiting response… 302 Found
Location: https://public.boxcloud.com/d/1/b1!RfVAUiZUiaUSPzsRFeJ32dv2XOGqMJaCFAr
Ox_573dvpW9WeBvN_wC1uLPaZW4gJuK5bE8nQ8ONN2fBzgTw8P2wRM-
uYqTiEjq5Hyt5NSmLge4RppOAaVA9EyCRw8f8pEijplOCxmQGaJLg_QX6Xg9EQa4Ox77fMg-gy0eNPZ2
jRo7A1kGuH8gOIvNhOx_8HLcllFrwgL58vinQPYPUikEER6XhzMdy3xxUY8MlOcjQLCmVa3UbhVb2JNw
VznNWLnHfoKpL2xHudlbJ6Bf44WcXycwK6MyA31UHgVIHx1xq_gTEfU3VkXOpErCqROAHi8Pt7yfMied
wbj0V54QNq5L_CY3RgOdhKYQOlaiFAwvD2isMTI1OqOU7Yw08HezhZUk1yJY_wE_PD6rK9cNqbYkgoDg
Y4uZj4yHtKlYGJkNe8wQhsfKhjvtZqqBmp17bLDpv9iGlUCQIr7m2Wy1mpuSeNtecQ5tL82E2c_eDZ70
fMZ8VB6QbsXNdKwFj5DSHSSm3QWwhQFmHPYugCow2MHgROt_hAFg-LcjoiUu_KMt-LkdL-
_GvcffsIXv9MXx-OgCzzhsJGFoGuYMVyQcDNgWWQ0jZkor-_w2Rz7_9XqC_jIiTyNAGOhT5ntVgMm8Er
dBRtHlAcmKMJKBT5mXSeT96QpddLTaOHOLO2ceyrvTC3gFFffVGQ5sKZDsj7hOHfqSap3xcbp8bNMsDU
72XrNq3bT1-
47ZLlE_zejzrTpqkesg1xOXxJcOBr1NRUZGnLz1zku1xqk5cBCG2qVlJTvhdvb6vCe9tqgyDO6nF_xZh
IIJasRTtKFgpTSjJ3G_D__Zt_Pujgj-3TlwIR6nxLu2FH5nCxnbsKhtZTUgJtvhksbbaWxi3c-
Gr2PLJQPV4ZemAGaAwcVGmAyVlqTsdqI9h6UPgUbtr4aqdWvaKBzvxTn09lX0sp_vubhVfSfBMz5ajUU
kJ7h-wYQvZABAiaMzM-
1Sn1bI_qux3BrF3vzHI65gPVahVHlovhYOsBgsDPqygslW8proQGqtEbcWZKxXucvGou6wmvcXLhN1rP
gE7jaeASbZ6tV-xM5zhO9zX64oc-N6lDup1-
```

```
QBlUWeu8xX1jycc3XbEozett8u6nasgGjgYXj6XbHZbvtFyADFmGaQrurGy_wa_4fUogjgYbiOnqpxmR
Xgyhn1GK0TnSrrD4B2wZxRFmQdowesOUPbX7EuvRUdrrtGNjj0ROfMFqu6WCXvYN98BkFoq_TCUSvzAH
_i3vdnUFfr3MLHhUl4yfI2HLraXWEzwUE2qsW-2_7Ld0hx0xahWXoPuVTodQ6E_-QkCfFuDprOR8DF7w
yETSYiMkovWdGM2SiJReoGh91u5Xo3QHDD7YPBbTes6EIctJ3TONdhJoPA../download
[following]
--2024-03-09 05:21:08--  https://public.boxcloud.com/d/1/b1!RfVAUiZUiaUSPzsRFeJ3
2dv2XOGqMJaCFArOx_573dvpW9WeBvN_wC1uLPaZW4gJuK5bE8nQ8ONN2fBzgTw8P2wRM-
uYqTiEjq5Hyt5NSmLge4RppOAaVA9EyCRw8f8pEijplOCxmQGaJLg_QX6Xg9EQa4Ox77fMg-gy0eNPZ2
jRo7A1kGuH8g0IvNhOx_8HLcllFrwgL58vinQPYPUikEER6XhzMdy3xxUY8Ml0cjQLCmVa3UbhVb2JNw
VznNWLnHfoKpL2xHudlbJ6Bf44WcXycwK6MyA31UHgVIHx1xq_gTEfU3VkXOpErCqR0AHi8Pt7yfMied
wbj0V54QNq5L_CY3Rg0dhKYQ0laiFAwvD2isMTI1OqOU7Yw08HezhZUk1yJY_wE_PD6rK9cNqbYkgoDg
Y4uZj4yHtKlYGJkNe8wQhsfKhjvtZqqBmp17bLDpv9iGlUCQIr7m2Wy1mpuSeNtecQ5tL82E2c_eDZ70
fMZ8VB6QbsXNdKwFj5DSHSSm3QWwhQFmHPYugCow2MHgROt_hAFg-LcjoiUu_KMt-LkdL-
_GvcffsIXv9MXx-OgCzzhsJGFoGuYMVyQcDNgWWQ0jZkor-_w2Rz7_9XqC_jIiTyNAGOhT5ntVgMm8Er
dBRtHlAcmKMJKBT5mXSeT96QpddLTaOH0L02ceyrvTC3gFFffVGQ5sKZDsj7h0HfqSap3xcbp8bNMsDU
72XrNq3bT1-
47ZLlE_zejzrTpqkesg1xOXxJc0Br1NRUZGnLz1zku1xqk5cBCG2qVlJTvhdvb6vCe9tqgyDO6nF_xZh
IIJasRTtKFgpTSjJ3G_D__Zt_Pujgj-3TlwIR6nxLu2FH5nCxnbsKhtZTUgJtvhksbbaWxi3c-
Gr2PLJQPV4ZemAGaAwcVGmAyVlqTsdqI9h6UPgUbtr4aqdWvaKBzvxTn09lX0sp_vubhVfSfBMz5ajUU
kJ7h-wYQvZABAiaMzM-
1Sn1bI_qux3BrF3vzHI65gPVahVHlovhYOsBgsDPqygslW8proQGqtEbcWZKxXucvGou6wmvcXLhN1rP
gE7jaeASbZ6tV-xM5zhO9zX64oc-N6lDup1-
QBlUWeu8xX1jycc3XbEozett8u6nasgGjgYXj6XbHZbvtFyADFmGaQrurGy_wa_4fUogjgYbiOnqpxmR
Xgyhn1GK0TnSrrD4B2wZxRFmQdowesOUPbX7EuvRUdrrtGNjj0ROfMFqu6WCXvYN98BkFoq_TCUSvzAH
_i3vdnUFfr3MLHhUl4yfI2HLraXWEzwUE2qsW-2_7Ld0hx0xahWXoPuVTodQ6E_-QkCfFuDprOR8DF7w
yETSYiMkovWdGM2SiJReoGh91u5Xo3QHDD7YPBbTes6EIctJ3TONdhJoPA../download
Resolving public.boxcloud.com (public.boxcloud.com)… 74.112.186.128
Connecting to public.boxcloud.com (public.boxcloud.com)|74.112.186.128|:443…
connected.
HTTP request sent, awaiting response… 200 OK
Length: 742758003 (708M) [application/octet-stream]
Saving to: ‘auxes_17.pt’

auxes_17.pt         100%[===================>] 708.35M  17.6MB/s    in 41s

2024-03-09 05:21:50 (17.1 MB/s) - ‘auxes_17.pt’ saved [742758003/742758003]

--2024-03-09 05:21:50--  https://github.com/cuadvancelab/materials/blob/main/lab
2/cyberbullying_data.zip?raw=true
Resolving github.com (github.com)… 20.205.243.166
Connecting to github.com (github.com)|20.205.243.166|:443… connected.
HTTP request sent, awaiting response… 302 Found
Location:
https://github.com/cuadvancelab/materials/raw/main/lab2/cyberbullying_data.zip
[following]
--2024-03-09 05:21:51--
https://github.com/cuadvancelab/materials/raw/main/lab2/cyberbullying_data.zip
Reusing existing connection to github.com:443.
```

```
HTTP request sent, awaiting response… 302 Found
Location: https://raw.githubusercontent.com/cuadvancelab/materials/main/lab2/cyb
erbullying_data.zip [following]
--2024-03-09 05:21:51--  https://raw.githubusercontent.com/cuadvancelab/material
s/main/lab2/cyberbullying_data.zip
Resolving raw.githubusercontent.com (raw.githubusercontent.com)…
185.199.108.133, 185.199.109.133, 185.199.110.133, …
Connecting to raw.githubusercontent.com
(raw.githubusercontent.com)|185.199.108.133|:443… connected.
HTTP request sent, awaiting response… 200 OK
Length: 420336 (410K) [application/zip]
Saving to: ‘cyberbullying_data.zip’

cyberbullying_data. 100%[===================>] 410.48K  --.-KB/s    in 0.005s

2024-03-09 05:21:51 (83.5 MB/s) - ‘cyberbullying_data.zip’ saved [420336/420336]
```

[ ]:
```
# unzip the test data
%%capture
!unzip "/content/cyberbullying_data.zip" -d "/content"
```

Let's import all our softwares dependencies in our iPython notebook

[ ]:
```
import torch
import torchvision
import torch.nn as nn
import torch.nn.functional as F
from torch import optim
import torch.utils.data as data_utils
import torchvision.transforms as transforms
from torchvision import models
from torch.optim.lr_scheduler import ReduceLROnPlateau
from torch.utils.data import Dataset, DataLoader
from torch import nn
```

[ ]:
```
import pickle
import gzip
import sys
import time
import numpy as np
import math
import os
import random
from skimage import io, transform
```

1.4 How to identify cyberbullying in images

[ ]:
```
# @title An example image
# importing required libraries
import matplotlib.pyplot as plt
import matplotlib.image as img

# reading the image
testImage = img.imread('/content/cyberbullying_data/
 ↪cyberbullying_data_splits_clean/test/cyberbullying/7.
 ↪s-s-unshaven-sad-ashamed-man-doing-loser-sign-hand-fingers-his-front-funny-depressed-face-e
 ↪jpg')

# displaying the image
plt.imshow(testImage)
```

[ ]:
```
<matplotlib.image.AxesImage at 0x7ae6d8348460>
```

5 FACTORS to measurement cyberbulling in images - Body-pose - Facial Emotion - Object - Gesture - Social Factors

The follow table shows the analysis of cyberbulling factors in images. Higher value of cosine similarity indicates higher correlation.

Factor | Attribute | Cyberbulling | Non-cyberbulling | Description |
————- |:————-:|:—:|:—:| ————- :|
Body-pose | Front pose Non-front pose | 0.860.50 | 0.53 0.84 | Pose of subject in image is towards the viewer |
Emotion | Joy Sorrow Anger Surprise | 0.340.020.090.07 | 0.250.020.040.05 | Facial emotion of subject in image|
Gesture | Hand gesture No hand gesture | 0.710.70 | 0.32 0.94 | Hand gesture made by subject in imager |
Object | Threatening object No threatening object | 0.330.94 | 0.06 0.99 | Threatening object present in image |
Social | Anti-LGBT Anti-black racism | 0.450.03 | 0.06 0.00 | Anti-LGBT symbols and anti-black racism in image |

More details can be found in 2021 NDSS paper: Towards Understanding and Detecting Cyberbullying in Real-world Images link

1.5 Load datasets

Now, let's run the subsequent codes to load your data from a predefined class

[ ]:
```
class PosesDataset(Dataset):

  def __init__(self, root_dir, poses_dir, auxes_dir):

    self.samples = []
    self.root_dir = root_dir
    self.poses_dir = poses_dir
    self.auxes_dir = auxes_dir

    for _, _, cb_images in os.walk(self.root_dir + 'cyberbullying'): break
    for _, _, non_cb_images in os.walk(self.root_dir + 'non_cyberbullying'):␣
↪break
    for _, _, cb_poses in os.walk(self.poses_dir + 'cyberbullying'): break
    for _, _, non_cb_poses in os.walk(self.poses_dir + 'non_cyberbullying'):␣
↪break

    for i in cb_images:
      self.samples.append((self.root_dir + 'cyberbullying/' + i, self.poses_dir␣
↪+ 'cyberbullying/' + i, self.auxes_dir + 'cyberbullying/' + i, 1))

    for i in non_cb_images:
      self.samples.append((self.root_dir + 'non_cyberbullying/' + i, self.
↪poses_dir + 'non_cyberbullying/' + i, self.auxes_dir + 'non_cyberbullying/'␣
↪+ i, 0))


  def __len__(self):
    return len(self.samples)
```

```
  def __getitem__(self, idx):
    if torch.is_tensor(idx):
      idx = idx.tolist()

    img_name, pose_name, aux_name, label = self.samples[idx]
    image = io.imread(img_name)

    aux = pickle.load(open(aux_name + '.p', 'rb'))
    aux = torch.tensor(aux)

    # drop the alpha channel for some images
    if image.shape == (224, 224):
      # handle grayscale images
      image = np.stack([image, image, image], axis=2)

    if image.shape == (224, 224, 4):
      image = image[:,:,:3]

    image = image.transpose((2, 0, 1)) # C X H X W
    pose = io.imread(pose_name)
    if pose.shape != (224, 224):
      pose = pose[:,:,0]
    pose = np.expand_dims(pose, axis = 0)
    image = np.concatenate((image, pose), axis = 0)
    sample = {'image': torch.from_numpy(image.copy()).float() / 255, 'aux':␣
  ↪aux, 'label': label}
    return sample
```

[ ]:
```
test_set = PosesDataset('cyberbullying_data/cyberbullying_data_splits_clean/
 ↪test/', 'cyberbullying_data/cyberbullying_poses/test/', 'cyberbullying_data/
 ↪cyberbullying_data_auxes/test/')
test_loader = torch.utils.data.DataLoader(test_set, batch_size = 1, shuffle =␣
 ↪True)
```

1.6 Load pre-trained AI model

We will use GPU to test our AI if it is available.

[ ]:
```
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
```

The AI model prediction process looks like the following figure.

In our AI model, we combine the low level image features with the cyberbulling factors identified before. We combine these features using feature fusion techniques.

We use the `VGG16` pre-trained model for image features `CNN` and use a multi-layer perceptron model `MLP` for the factors related features, and combine the feature vectors from both these models using late fusion.

Let's load the pre-trained model to test its capability

[ ]:
```
# load vgg16 pre-trained model
orig = models.vgg16(pretrained = True)
```

```
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:208:
UserWarning: The parameter 'pretrained' is deprecated since 0.13 and may be
removed in the future, please use 'weights' instead.
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:223:
UserWarning: Arguments other than a weight enum or `None` for 'weights' are
deprecated since 0.13 and may be removed in the future. The current behavior is
equivalent to passing `weights=VGG16_Weights.IMAGENET1K_V1`. You can also use
`weights=VGG16_Weights.DEFAULT` to get the most up-to-date weights.
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/vgg16-397923af.pth" to
/root/.cache/torch/hub/checkpoints/vgg16-397923af.pth
100%|      | 528M/528M [00:03<00:00, 144MB/s]
```

[ ]:
```
class CB(nn.Module):
  def __init__(self):
    super(CB, self).__init__()
    self.conv1 = nn.Conv2d(4, 3, 1)
    self.f = nn.Sequential(*list(orig.features.children()))
    self.avgpool = nn.AdaptiveAvgPool2d((7, 7))
    self.aux_classifier = nn.Sequential(
      nn.Linear(25097, 1024),
      nn.ReLU(),
      nn.Linear(1024, 25088),
      nn.ReLU()
    )
    self.classifier = nn.Sequential(*list(orig.classifier.children()))
    self.classifier[-1] = nn.Linear(4096, 2)
    self.sig = nn.Sigmoid()

  def forward(self, x, aux):
    x = self.conv1(x)
    x = self.f(x)
    x = self.avgpool(x)
    x = torch.flatten(x, 1)
    x = torch.cat((x, aux), dim = 1)
    x = self.aux_classifier(x)
    x = self.classifier(x)
    x = self.sig(x)


    return x
```

Pass the pre-trained checkpoints to the VGG model so that you can have our pre-trained model

[ ]:
```
# model = torch.load("auxes_17.pt") # if GPU is available
model =torch.load("auxes_17.pt", map_location=device) #if GPU is not available;␣
 ↪use CPU.
model.to(device)
#model=CB().to(device)
running_loss = []
criterion = nn.CrossEntropyLoss()
correct, incorrect, total = 0., 0., 0.
```

1.7 Generate the detection resuls for test data

Now, it's time to evaulate the pre-trained model's capability with our test dataset

[ ]:
```
with torch.no_grad():
  for i_v, data_v in enumerate(test_loader):
    x_test, y_test, aux_test = data_v['image'], data_v['label'], data_v['aux']
    x_test, y_test, aux_test = x_test.to(device), y_test.to(device, dtype =␣
 ↪torch.long), aux_test.to(device, dtype = torch.float)
    y_test_ = model(x_test, aux_test) # forward pass for the pre-trained model
    running_loss.append(criterion(y_test_, y_test))
    _, predicted = torch.max(y_test_.data, 1)
    total += y_test.size(0)
    correct += (predicted == y_test).sum().item()

print('Test loss is: {:.3f}'.format((sum(running_loss) / len(running_loss)).
 ↪item()))
print('The accuracy for test dataset is: {:.4f}%'.format((correct / total) *␣
 ↪100))
```

```
Test loss is: 0.449
The accuracy for test dataset is: 85.0000%
```

**	<f	on	t color=‘red’>Task 1:
Wr	it	e	code to generate result report contains: Accuracy, Precision, Recall and F1-Score**

reference link: https://en.wikipedia.org/wiki/F-score

[ ]:
```
# get the acc, precision, recall, f1 score for the test set

tp, tn, fp, fn = 0, 0, 0, 0

model.eval()
with torch.no_grad():
    for i_v, data_v in enumerate(test_loader):
```

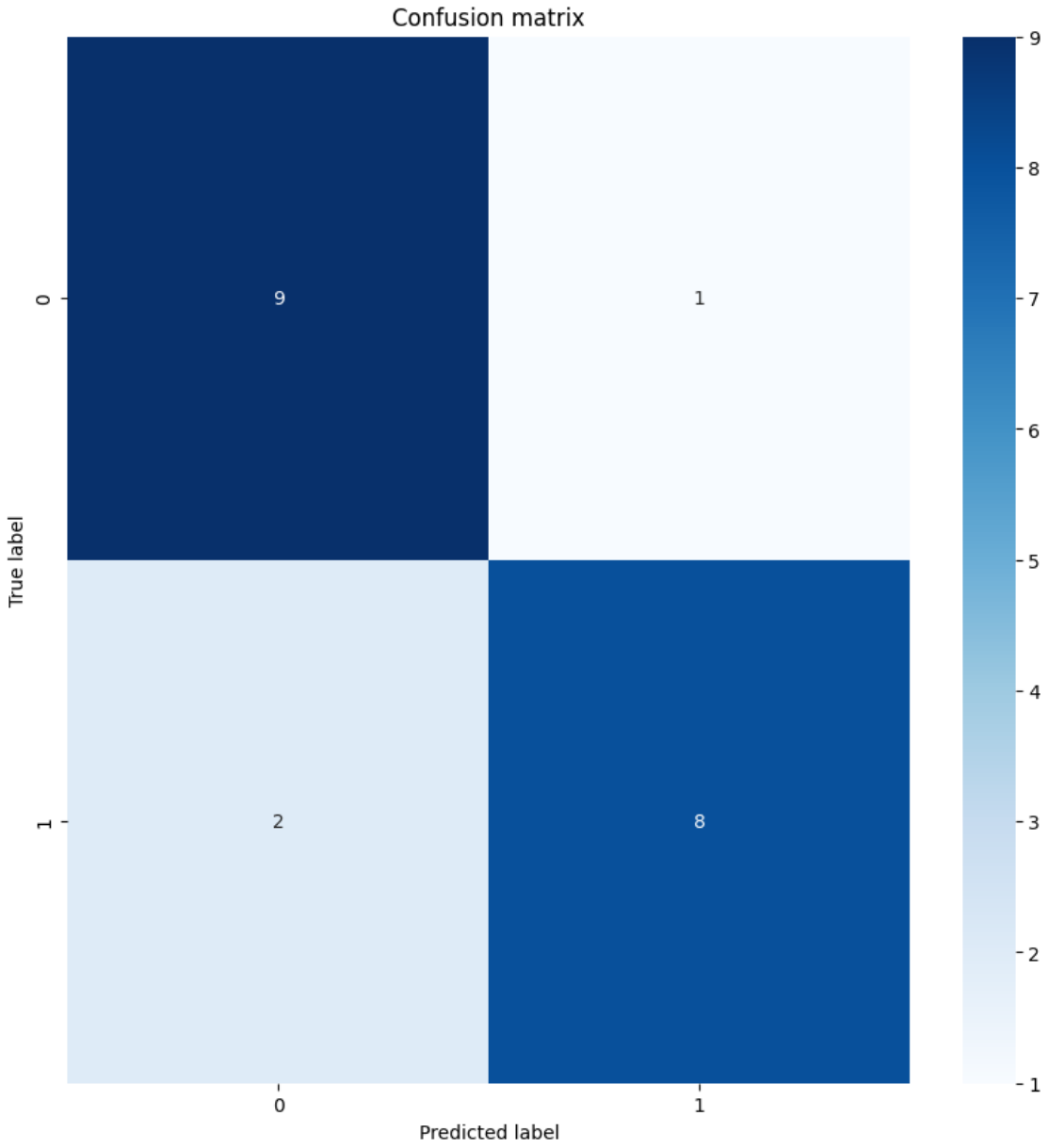
```
        x_test, y_test, aux_test = data_v['image'], data_v['label'],␣
↪data_v['aux']
        x_test, y_test, aux_test = x_test.to(device), y_test.to(device, dtype =␣
↪torch.long), aux_test.to(device, dtype = torch.float)
        y_test_ = model(x_test, aux_test) # forward pass for the fine-tuned␣
↪model
        _, predicted = torch.max(y_test_.data, 1)
        if y_test == 1 and predicted == 1:
            tp += 1
        elif y_test == 1 and predicted == 0:
            fn += 1
        elif y_test == 0 and predicted == 1:
            fp += 1
        elif y_test == 0 and predicted == 0:
            tn += 1
```

[ ]:
```
# TODO: Complete the following code to calculate the accuracy, precision,␣
↪recall and F1 score.

accuracy = (tp + tn) / (tp + tn + fp + fn)

precision = tp / (tp + fp)

recall = tp / (tp + fn)

f1_score = 2 * (precision * recall) / (precision + recall)

acc =accuracy
precision =precision
recall =recall
f1 =f1_score

print('The accuracy for test dataset is: {:.4f}%'.format(acc * 100))
print('The precision for test dataset is: {:.4f}%'.format(precision * 100))
print('The recall for test dataset is: {:.4f}%'.format(recall * 100))
print('The f1 score for test dataset is: {:.4f}%'.format(f1 * 100))
```

```
The accuracy for test dataset is: 85.0000%
The precision for test dataset is: 88.8889%
The recall for test dataset is: 80.0000%
The f1 score for test dataset is: 84.2105%
```

**	<f	on	t color='red'>Task 2:
Wr	it	e	code to plot the confusion matrix** (you are allowed to borrow any python tools, such as scikit-le

[ ]:
```
# Complete the following code to get the confusion matrix for the test set
# get the confusion matrix for the test set
from sklearn.metrics import confusion_matrix

y_true = []
y_pred = []

# TODO: Write the code to get the y_true and y_pred lists for the test set
# your code here:
model.eval()
with torch.no_grad():
    for i_v, data_v in enumerate(test_loader):
        x_test, y_test, aux_test = data_v['image'], data_v['label'],␣
 ↪data_v['aux']
        x_test, y_test, aux_test = x_test.to(device), y_test.to(device),␣
 ↪dtype=torch.long), aux_test.to(device, dtype=torch.float)
        y_test_ = model(x_test, aux_test) # Forward pass for the fine-tuned␣
 ↪model
        #_, predicted = torch.max(y_test_.of, 1)
        _, predicted = torch.max(y_test_, 1)

        y_true.extend(y_test.cpu().numpy())
        y_pred.extend(predicted.cpu().numpy())

# get the confusion matrix
cm = confusion_matrix(y_true, y_pred)
# cm

# plot the confusion matrix
import seaborn as sns
import matplotlib.pyplot as plt

plt.figure(figsize=(10, 10))
sns.heatmap(cm, annot=True, fmt="d", cmap='Blues')
plt.title("Confusion matrix")
plt.ylabel('True label')
plt.xlabel('Predicted label')
plt.show()
```



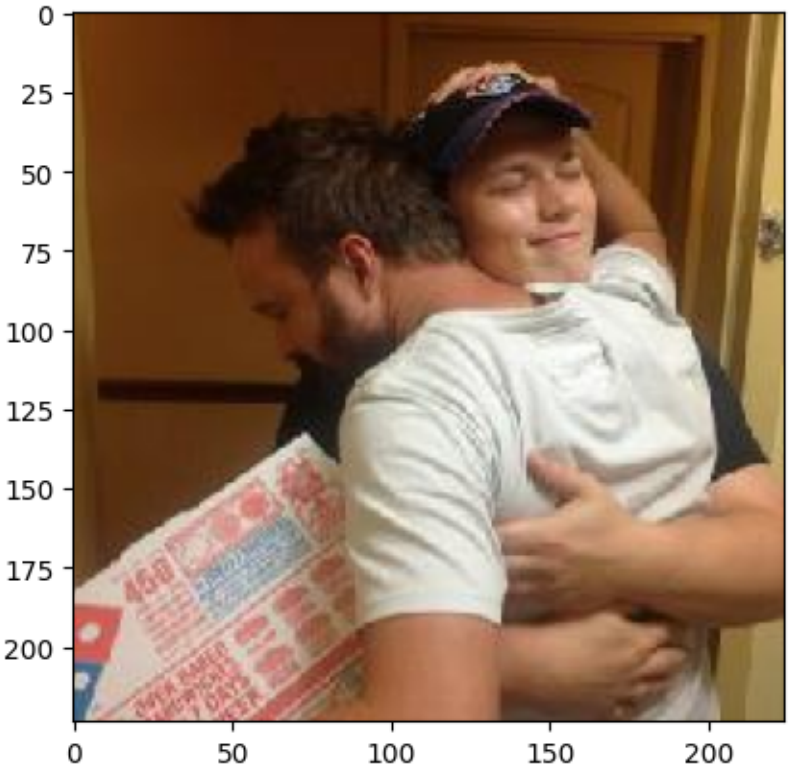
1.8 Let's check with one instance

To better understand the performance, you can try to visualize one instance in the dataset

```
[ ]: # check how many test data samples we have
print(f"we have {len(test_set)} samples in our test dataset, you can choose any␣
  ↪of them to see the prediction.")
```

```
we have 20 samples in our test dataset, you can choose any of them to see the
prediction.
```

[ ]:
```
#@markdown Select a number to view the image and its label.

picture_index  = "18" #@param␣
 ↪[0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19]
index = int(picture_index)
instance = test_set[index]

import matplotlib.pyplot as plt
import matplotlib.image as mpimg
img = mpimg.imread(test_set.samples[index][0])
imgplot = plt.imshow(img)
plt.show()
annot_label = "cyberbullying" if test_set[index]['label']==1 else␣
 ↪"non-cyberbullying"
print('')
print("The label of this image is: {}".format(annot_label))
```




```
The label of this image is: non-cyberbullying
```

Run the following code cell to check the AI's prediction

[ ]:
```
# check if the prediction is correct
instance_image, instance_label, instance_aux = instance['image'].to(device),␣
 ↪torch.tensor(instance['label']).to(device, dtype = torch.long),␣
 ↪instance['aux'].to(device, dtype = torch.float)

output = model(instance_image.unsqueeze(0), instance_aux.unsqueeze(0)).data
_, prediction = torch.max(output.data, 1)
predict_label = "cyberbullying" if prediction.item()==1 else "non-cyberbullying"
comparision = "correct" if prediction==instance_label else "not correct"

print("The AI prediction for this image is: {}, which is {}!".
 ↪format(predict_label, comparision))
```

```
The AI prediction for this image is: non-cyberbullying, which is correct!
```

1.9 Model Fine-Tuning

** <f on t Wr it e color=‘red’>Task 3: code to fine- tune the model with the train- ing dataset**
** Th e training dataset will be pre- pared via the fol- low- ing code cells.**

[ ]:
```
# download the training data
!wget -O cyberbullying_train_data.zip https://buffalo.box.com/shared/static/
↪4tq3wxly5pk2k8hpx7brvtr89icx7e7f.zip
```

```
--2024-03-09 05:22:01--
https://buffalo.box.com/shared/static/4tq3wxly5pk2k8hpx7brvtr89icx7e7f.zip
Resolving buffalo.box.com (buffalo.box.com)… 74.112.186.144
Connecting to buffalo.box.com (buffalo.box.com)|74.112.186.144|:443…
connected.
HTTP request sent, awaiting response… 301 Moved Permanently
Location: /public/static/4tq3wxly5pk2k8hpx7brvtr89icx7e7f.zip [following]
--2024-03-09 05:22:01--
https://buffalo.box.com/public/static/4tq3wxly5pk2k8hpx7brvtr89icx7e7f.zip
Reusing existing connection to buffalo.box.com:443.
HTTP request sent, awaiting response… 301 Moved Permanently
Location:
https://buffalo.app.box.com/public/static/4tq3wxly5pk2k8hpx7brvtr89icx7e7f.zip
[following]
--2024-03-09 05:22:01--
https://buffalo.app.box.com/public/static/4tq3wxly5pk2k8hpx7brvtr89icx7e7f.zip
Resolving buffalo.app.box.com (buffalo.app.box.com)… 74.112.186.144
Connecting to buffalo.app.box.com (buffalo.app.box.com)|74.112.186.144|:443…
connected.
HTTP request sent, awaiting response… 302 Found
Location:
https://public.boxcloud.com/d/1/b1!Y7kdLRp2w4HzWsLp3oAWY6F9E0BcRd6quZz-
UN03Be3BXliBfIHAvUtjTCQ8eL1p9Y8M6mFo-lIEgKBro4IGLHb4zekKYf2tqFCgS3hLAoaW7rLrHKdo
TuwbfOCohouTHXSZXkabMkY6zOhjLJ6R7Vaw_96WTOo_eX9Rm9-
SyAdHWybHgQqabl0jscnMSdUHALtmeO8SenXLRmWE9ZOjp-
yulIgapUGhe84w2-lIYzMYvKLqTWssyUIcvu1wYOSGgn1Om2Ey7YlRkvlzzbrHkxPHaO-
JaqK343JU1i4USa5uhu2sFeLrXipvJWgN-mIK3yoWSt-EVbUHOrIZmysj82MpbNEfuUrynri1uYkCv0a
ZASQFgC6S9oQVg_VdCLvH2whseTJIZ6oSE5Y_rmfEsYzcCEDho5FzZXofrA4wzQ8h5_KpaFnCc8RwFX8
bUPtlQ8R_8KouKoCt0x9Mdl8SncSLyCdI-
HeU8IC5z6Coc5FMH-q0zW6lQECx1rYdymnd1_H_jMZaFgGNyJaz_j-D_Vi9msdlr3GImYdmdWqK6x00A
ubKwwSG3e1JgskmwX6wi8yqmrQDTmt88ca2_kHp60yPgQUzyJI_yS1QICU5defgpjRUy0OBBjMbg7A8O
RJCbUG6Fn4IwtxXDu8Gv8hgJPqi4rPUg8tQU6n3jLV2nET9_2LlaV999Q0p4AKbm8anCaGg86LcgD4c-
ytDx_H0XIVdgWt94K_IzVVDyzC3infXCpBN8aALjjUvrru8mNZgGo_LCPzMbk-
KCUmylXE94_u7jOwRJtpMh9XbQHyLHZANsVAhcXzWgPTtHbXfaaWufOnYr-XQqb5hPtBfj9Hwxp-mh7h
nrwh4HQPnC5YrwlTC7FVcasH0gzjibtaySWt6jhXOftu8i9GurMQi4J6NpY8GYoPrQXwQBTDoiGi1Bd8
cds5Cpt6fe7qJ01YEONy6vKE5XfpvMcYpa0dNrA6_KwKs-
pbXXjCRqmidCKCkgX7jH8GYIwEJeZwU5Rs9zKvR0_UoF3S5GmMA-qynhLcMF-rUmu1Maogh88aoioK3y
QZ8HrOwq3Z0P08yfplNwr2QDN0ojAYt6_DRlPnaWPkTgnZuNzHrDhewxwZ4KwIBGkFuNmFIIZFtJCU8d
ZEF-0SkiMbXCqhQ8v1BevV65Xn1v7gTZJi-px891RS6iTSUu32YfyuXhCKRYgSG5GJjwWUZdFEgHBg1I
rC05Yidy1i8URtTNTYJGfoyV3OUquZh_5rDhQpK0nmPgtFEEzyTJsuShz9Krzs5SMMv70jMtPLdwwPXy
F3rLsUQL5sAuGz9c2jCvyLdnj6EeX_RzcJgiog4nhPqmDUNwdibT3XqPUWaxVJ7X3SKuWEM-dQxaUK6M
Yg_cZPi02cQs7lj_eWCQVCNINDSr_ZYYZyyiwFiUw9EBmZHWNA_tPXeNMMi1MCLmHRRUAeAMA../down
load [following]
```

```
--2024-03-09 05:22:02--
https://public.boxcloud.com/d/1/b1!Y7kdLRp2w4HzWsLp3oAWY6F9E0BcRd6quZz-
UN03Be3BXliBfIHAvUtjTCQ8eL1p9Y8M6mFo-lIEgKBro4IGLHb4zekKYf2tqFCgS3hLAoaW7rLrHKdo
TuwbfOCohouTHXSZXkabMkY6zOhjLJ6R7Vaw_96WTOo_eX9Rm9-
SyAdHWybHgQqabl0jscnMSdUHALtmeO8SenXLRmWE9ZOjp-
yulIgapUGhe84w2-lIYzMYvKLqTWssyUIcvu1wYOSGgn1Om2Ey7YlRkvlzzbrHkxPHaO-
JaqK343JU1i4USa5uhu2sFeLrXipvJWgN-mIK3yoWSt-EVbUHOrIZmysj82MpbNEfuUrynri1uYkCv0a
ZASQFgC6S9oQVg_VdCLvH2whseTJIZ6oSE5Y_rmfEsYzcCEDho5FzZXofrA4wzQ8h5_KpaFnCc8RwFX8
bUPtlQ8R_8KouKoCt0x9Mdl8SncSLyCdI-
HeU8IC5z6Coc5FMH-q0zW6lQECx1rYdymnd1_H_jMZaFgGNyJaz_j-D_Vi9msdlr3GImYdmdWqK6x00A
ubKwwSG3e1JgskmwX6wi8yqmrQDTmt88ca2_kHp60yPgQUzyJI_yS1QICU5defgpjRUyOOBBjMbg7A8O
RJCbUG6Fn4IwtxXDu8Gv8hgJPqi4rPUg8tQU6n3jLV2nET9_2LlaV999Q0p4AKbm8anCaGg86LcgD4c-
ytDx_HOXIVdgWt94K_IzVVDyzC3infXCpBN8aALjjUvrru8mNZgGo_LCPzMbk-
KCUmylXE94_u7jOwRJtpMh9XbQHyLHZANsVAhcXzWgPTtHbXfaaWufOnYr-XQqb5hPtBfj9Hwxp-mh7h
nrwh4HQPnC5YrwlTC7FVcasHOgzjibtaySWt6jhXOftu8i9GurMQi4J6NpY8GYoPrQXwQBTDoiGi1Bd8
cds5Cpt6fe7qJ01YEONy6vKE5XfpvMcYpa0dNrA6_KwKs-
pbXXjCRqmidCKCkgX7jH8GYIwEJeZwU5Rs9zKvRO_UoF3S5GmMA-qynhLcMF-rUmu1Maogh88aoioK3y
QZ8HrOwq3ZOPO8yfplNwr2QDNOojAYt6_DRlPnaWPkTgnZuNzHrDhewxwZ4KwIBGkFuNmFIIZFtJCU8d
ZEF-0SkiMbXCqhQ8v1BevV65Xn1v7gTZJi-px891RS6iTSUu32YfyuXhCKRYgSG5GJjwWUZdFEgHBg1I
rC05Yidy1i8URtTNTYJGfoyV3OUquZh_5rDhQpK0nmPgtFEEzyTJsuShz9Krzs5SMMv70jMtPLdwwPXy
F3rLsUQL5sAuGz9c2jCvyLdnj6EeX_RzcJgiog4nhPqmDUNwdibT3XqPUWaxVJ7X3SKuWEM-dQxaUK6M
Yg_cZPi02cQs7lj_eWCQVCNINDSr_ZYYZyyiwFiUw9EBmZHWNA_tPXeNMMi1MCLmHRRUAeAMA../down
load
Resolving public.boxcloud.com (public.boxcloud.com)… 74.112.186.128
Connecting to public.boxcloud.com (public.boxcloud.com)|74.112.186.128|:443…
connected.
HTTP request sent, awaiting response… 200 OK
Length: 47450889 (45M) [application/zip]
Saving to: ‘cyberbullying_train_data.zip’

cyberbullying_train 100%[===================>]  45.25M  14.6MB/s    in 3.7s

2024-03-09 05:22:06 (12.3 MB/s) - ‘cyberbullying_train_data.zip’ saved
[47450889/47450889]
```

[ ]:
```
# unzip the training data
%%capture
!unzip "/content/cyberbullying_train_data.zip" -d "/content"
```

[ ]:
```
# prepare the training data
train_set = PosesDataset('cyberbullying_train_data/
 ↪cyberbullying_data_splits_clean/train/', 'cyberbullying_train_data/
 ↪cyberbullying_poses/train/', 'cyberbullying_train_data/
 ↪cyberbullying_data_auxes/train/')
# remove .DS_Store files if they exist
train_set.samples = [x for x in train_set.samples if '.DS_Store' not in x[0]]
```

```
# prepare the dataloader
train_loader = torch.utils.data.DataLoader(train_set, batch_size = 12, shuffle␣
 ↪= True)
```

[ ]:
```
# copy the pre-trained model for fine-tuning
# ft_model = torch.load("auxes_17.pt")  # if GPU is available
ft_model =torch.load("auxes_17.pt", map_location=device) #if GPU is not␣
 ↪available; use CPU.
ft_model.to(device)
```

[ ]:
```
CB(
  (conv1): Conv2d(4, 3, kernel_size=(1, 1), stride=(1, 1))
  (f): Sequential(
    (0): Conv2d(3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (1): ReLU(inplace=True)
    (2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (3): ReLU(inplace=True)
    (4): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (5): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (6): ReLU(inplace=True)
    (7): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (8): ReLU(inplace=True)
    (9): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (10): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): ReLU(inplace=True)
    (12): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (13): ReLU(inplace=True)
    (14): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (15): ReLU(inplace=True)
    (16): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (17): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (18): ReLU(inplace=True)
    (19): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (20): ReLU(inplace=True)
    (21): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (22): ReLU(inplace=True)
    (23): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (24): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (25): ReLU(inplace=True)
    (26): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (27): ReLU(inplace=True)
    (28): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (29): ReLU(inplace=True)
```

```
    (30): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(7, 7))
  (aux_classifier): Sequential(
    (0): Linear(in_features=25097, out_features=1024, bias=True)
    (1): ReLU()
    (2): Linear(in_features=1024, out_features=25088, bias=True)
    (3): ReLU()
  )
  (classifier): Sequential(
    (0): Linear(in_features=25088, out_features=4096, bias=True)
    (1): ReLU(inplace=True)
    (2): Dropout(p=0.5, inplace=False)
    (3): Linear(in_features=4096, out_features=4096, bias=True)
    (4): ReLU(inplace=True)
    (5): Dropout(p=0.5, inplace=False)
    (6): Linear(in_features=4096, out_features=2, bias=True)
  )
  (sig): Sigmoid()
)
```

[ ]:
```python
# prepare the optimizer, loss function, learning rate
import torch.optim as optim

criterion = nn.CrossEntropyLoss().to(device)
# optimizer = optim.Adam(ft_model.parameters(), lr = 1.0000e-06, weight_decay=0.
 ↪00001)
optimizer = optim.Adam(ft_model.parameters(), lr = 1.0e-06, weight_decay=0.1)
#optimizer = optim.Adam(ft_model.parameters(), lr = 0.001, weight_decay=0.0005)
# Fine-tune only the top layers while keeping the early layers frozen
for param in ft_model.parameters():
    param.requires_grad = False

# Unfreeze the final layers for fine-tuning
for param in ft_model.classifier.parameters():
    param.requires_grad = True
```

[ ]:
```python
# TODO: complete the following code by replace "___", to mimic fine-tune␣
 ↪(further training) the model
ft_model.train()

epochs = 8
for epoch in range(epochs):
    for i, data in enumerate(train_loader):
        inputs = data['image'].to(device)
        aux = data['aux'].to(device)
```

```
        labels = data['label'].to(device)
        optimizer.zero_grad() # zero the parameter gradients
        outputs = ft_model(inputs, aux) # forward pass
        loss = criterion(outputs, labels) # compute loss via comparing model's␣
 ↪outputs and our predefined labels
        loss.backward() # backward pass
        optimizer.step() # update weights
        running_loss.append(loss.item()) # save loss
        _, predicted = torch.max(outputs.data, 1) # get predictions
        total += labels.size(0) # update total
        correct += (predicted == labels).sum().item()  # update correct␣
 ↪predictions
        if i % 50 == 0:  # print every 50 mini-batches
            print('Epoch: %d, Iteration: %d, Loss: %.4f, Accuracy: %.4f' %␣
 ↪(epoch, i, loss.item(), correct / total))
            correct, incorrect, total = 0., 0., 0.  # reset correct, incorrect,␣
 ↪and total. hint: float is better than int
print('Finished Training')
# Note:
# This code is a very basic version that helps us keep training the model with␣
 ↪the training set,
# Recall from the last lecture, we can have a validation set to help us decide␣
 ↪when to stop training
# the model.
# If you are interested, you can try to split the training set into training␣
 ↪set and validation set,
# and use the validation set to help you decide when to stop training the model
```

```
Epoch: 0, Iteration: 0, Loss: 0.3224, Accuracy: 1.0000
```

```
/usr/local/lib/python3.10/dist-packages/PIL/Image.py:996: UserWarning: Palette
images with Transparency expressed in bytes should be converted to RGBA images
  warnings.warn(
```

```
Epoch: 0, Iteration: 50, Loss: 0.3135, Accuracy: 0.9633
Epoch: 0, Iteration: 100, Loss: 0.3972, Accuracy: 0.9750
Epoch: 0, Iteration: 150, Loss: 0.3931, Accuracy: 0.9583
Epoch: 0, Iteration: 200, Loss: 0.3133, Accuracy: 0.9550
Epoch: 1, Iteration: 0, Loss: 0.3181, Accuracy: 1.0000
Epoch: 1, Iteration: 50, Loss: 0.3283, Accuracy: 0.9600
Epoch: 1, Iteration: 100, Loss: 0.3960, Accuracy: 0.9633
Epoch: 1, Iteration: 150, Loss: 0.5386, Accuracy: 0.9633
Epoch: 1, Iteration: 200, Loss: 0.3153, Accuracy: 0.9683
Epoch: 2, Iteration: 0, Loss: 0.3464, Accuracy: 1.0000
Epoch: 2, Iteration: 50, Loss: 0.3179, Accuracy: 0.9617
Epoch: 2, Iteration: 100, Loss: 0.3740, Accuracy: 0.9550
Epoch: 2, Iteration: 150, Loss: 0.3794, Accuracy: 0.9667
Epoch: 2, Iteration: 200, Loss: 0.3532, Accuracy: 0.9683
```

```
Epoch: 3, Iteration: 0, Loss: 0.3212, Accuracy: 0.9444
Epoch: 3, Iteration: 50, Loss: 0.3609, Accuracy: 0.9450
Epoch: 3, Iteration: 100, Loss: 0.4677, Accuracy: 0.9700
Epoch: 3, Iteration: 150, Loss: 0.3259, Accuracy: 0.9733
Epoch: 3, Iteration: 200, Loss: 0.3202, Accuracy: 0.9600
Epoch: 4, Iteration: 0, Loss: 0.3531, Accuracy: 1.0000
Epoch: 4, Iteration: 50, Loss: 0.3248, Accuracy: 0.9550
Epoch: 4, Iteration: 100, Loss: 0.3184, Accuracy: 0.9700
Epoch: 4, Iteration: 150, Loss: 0.5258, Accuracy: 0.9533
Epoch: 4, Iteration: 200, Loss: 0.3403, Accuracy: 0.9683
Epoch: 5, Iteration: 0, Loss: 0.3283, Accuracy: 0.9444
Epoch: 5, Iteration: 50, Loss: 0.3271, Accuracy: 0.9567
Epoch: 5, Iteration: 100, Loss: 0.3234, Accuracy: 0.9750
Epoch: 5, Iteration: 150, Loss: 0.3664, Accuracy: 0.9633
Epoch: 5, Iteration: 200, Loss: 0.3745, Accuracy: 0.9567
Epoch: 6, Iteration: 0, Loss: 0.3703, Accuracy: 1.0000
Epoch: 6, Iteration: 50, Loss: 0.3458, Accuracy: 0.9583
Epoch: 6, Iteration: 100, Loss: 0.3947, Accuracy: 0.9617
Epoch: 6, Iteration: 150, Loss: 0.4489, Accuracy: 0.9567
Epoch: 6, Iteration: 200, Loss: 0.3225, Accuracy: 0.9733
Epoch: 7, Iteration: 0, Loss: 0.3164, Accuracy: 1.0000
Epoch: 7, Iteration: 50, Loss: 0.3665, Accuracy: 0.9617
Epoch: 7, Iteration: 100, Loss: 0.4151, Accuracy: 0.9517
Epoch: 7, Iteration: 150, Loss: 0.3628, Accuracy: 0.9800
Epoch: 7, Iteration: 200, Loss: 0.4459, Accuracy: 0.9533
Finished Training
```

**	<f	on	t
Wr	it	e	color=‘red’>Task
			4:
			code
			to
			print
			out
			your
			fine-
			tuned
			model’s
			re-
			sults,
			you
			can
			re-
			fer
			the
			code
			how
			we
			gen-
			er-
			ate
			re-
			sults
			for
			test
			dataset
			previously.**

**	Co	mp	are
If	n	ot	the
			the
			two
			re-
			sults
			you
			get,
			is
			the
			pre-
			dic-
			tion
			ac-
			cu-
			racy
			bet-
			ter
			than
			the
			pre-
			vi-
			ous
			model?
			,
			think
			about
			the
			rea-
			sons
			for
			it
			perhaps.**

[ ]:
```
ft_model.eval()
# TODO: write code to evaluate the model on the test set

y_true = []
y_pred = []

with torch.no_grad():
    for data in test_loader:
        images, labels, aux = data['image'].to(device), data['label'].
 ↪to(device), data['aux'].to(device)

        # Forward pass
```

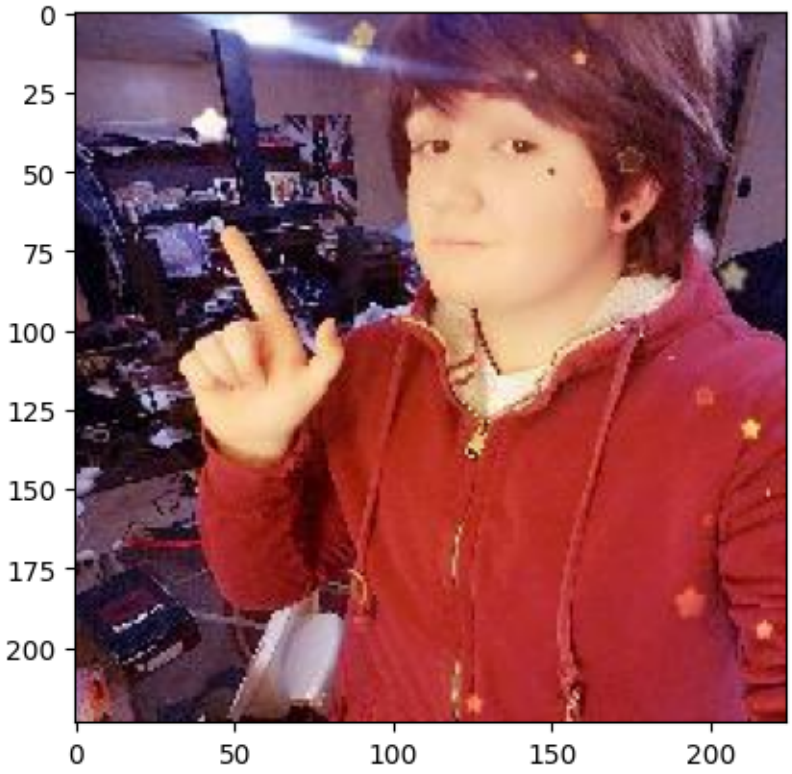
```
        outputs = ft_model(images, aux)

        # Get predicted labels
        _, predicted = torch.max(outputs, 1)

        # Store true and predicted labels
        y_true.extend(labels.cpu().numpy())
        y_pred.extend(predicted.cpu().numpy())

# Calculate metrics using sklearn
from sklearn.metrics import accuracy_score, precision_score, recall_score,␣
 ↪f1_score

accuracy_last = accuracy_score(y_true, y_pred)
precision_last = precision_score(y_true, y_pred,␣
 ↪average='weighted',zero_division=1)
recall_last = recall_score(y_true, y_pred, average='weighted')
f1_last = f1_score(y_true, y_pred, average='weighted')

print('The accuracy for test dataset is: {:.4f}%'.format(accuracy_last * 100))
print('The precision for test dataset is: {:.4f}%'.format(precision_last * 100))
print('The recall for test dataset is: {:.4f}%'.format(recall_last * 100))
print('The f1 score for test dataset is: {:.4f}%'.format(f1_last * 100))
```

```
The accuracy for test dataset is: 80.0000%
The precision for test dataset is: 81.2500%
The recall for test dataset is: 80.0000%
The f1 score for test dataset is: 79.7980%
```

**	<f	on	t color=‘red’>Task 5:
Wr	it	e	code to visualize the image “/content/cyberbullying_data/cyberbullying_data_splits_clean/test
Th	en	t	est this image with the fine-tuned model and print the prediction results.**

[ ]:
```
image_path = "/content/cyberbullying_data/cyberbullying_data_splits_clean/test/
 ↪cyberbullying/fingerGunAnnotated_239.JPEG"
img = Image.open(image_path)
plt.imshow(img)
plt.axis('on')
plt.show()

# Extracting label name from the image path
folder_name, file_name = os.path.split(image_path)
label = folder_name.split('/')[-1]

# label name for the image:
if "non_cyberbullying" in label:
```

```
    image_label = "non-cyberbullying"
else:
    image_label = "cyberbullying"

print('')
print("The label of this image is: {}".format(image_label))
```



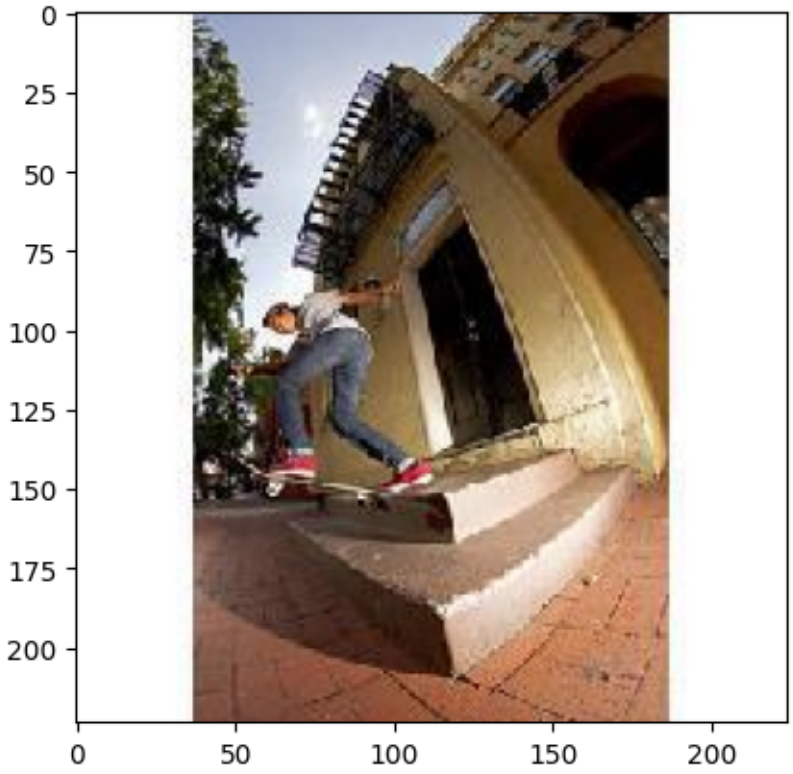

```
The label of this image is: cyberbullying
```

[ ]:
```
# TODO: find the picture_index of the chosen image by comparing with the␣
 ↪previous visualization cell
picture_index = 6
instance = test_set[picture_index]

# check if the prediction is correct
instance_image, instance_label, instance_aux = instance['image'].to(device),␣
 ↪torch.tensor(instance['label']).to(device, dtype = torch.long),␣
 ↪instance['aux'].to(device, dtype = torch.float)

# TODO: get the prediction for the image
output = ft_model(instance_image.unsqueeze(0), instance_aux.unsqueeze(0)).data
```

```
_, predicted = torch.max(output.data, 1)


predict_label = "cyberbullying" if predicted.item() == 1 else␣
 ↪"non-cyberbullying"
comparison = "correct" if predicted == instance_label else "not correct"

print("The AI prediction for this image is: {}, which is {}!".
 ↪format(predict_label, comparison))
```

```
The AI prediction for this image is: cyberbullying, which is correct!
```

[ ]:
```
image_path = "/content/cyberbullying_data/cyberbullying_data_splits_clean/test/
 ↪non_cyberbullying/534744626533535386_2381314.jpg"
img2 = Image.open(image_path)
plt.imshow(img2)
plt.axis('on')
plt.show()

# Extracting label name from the image path
folder_name, file_name = os.path.split(image_path)
label = folder_name.split('/')[-1]

# label name for the image:
if "non_cyberbullying" in label:
    image_label = "non-cyberbullying"
else:
    image_label = "cyberbullying"

print('')
print("The label of this image is: {}".format(image_label))
```



The label of this image is: non-cyberbullying

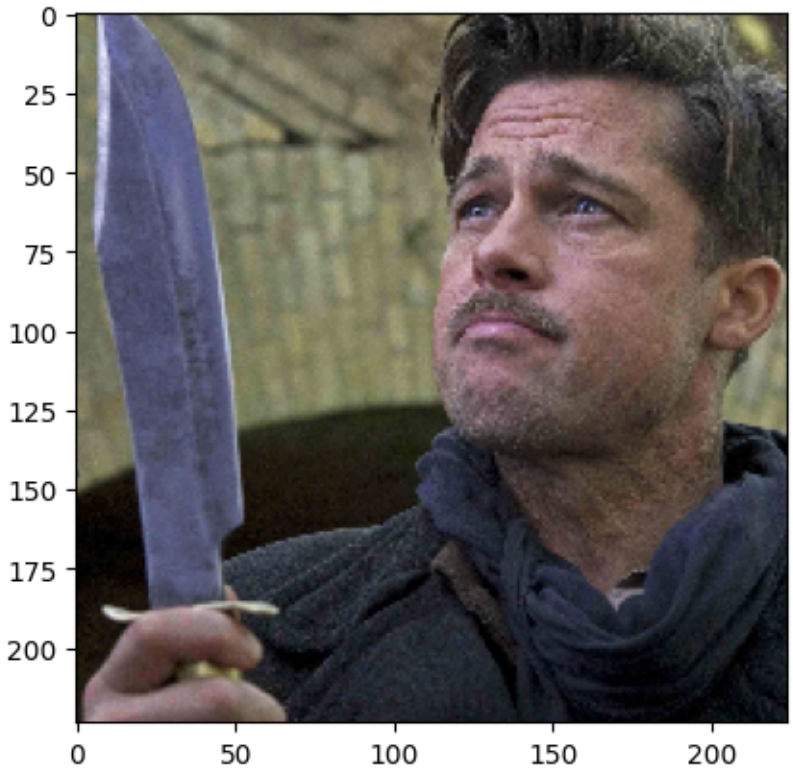
[ ]:
```
# TODO: find the picture_index of the chosen image by comparing with the␣
 ↪previous visualization cell
picture_index = 14
instance = test_set[picture_index]

# check if the prediction is correct
instance_image, instance_label, instance_aux = instance['image'].to(device),␣
 ↪torch.tensor(instance['label']).to(device, dtype = torch.long),␣
 ↪instance['aux'].to(device, dtype = torch.float)

# TODO: get the prediction for the image
output = ft_model(instance_image.unsqueeze(0), instance_aux.unsqueeze(0)).data
_, predicted = torch.max(output.data, 1)


predict_label = "cyberbullying" if predicted.item() == 1 else␣
 ↪"non-cyberbullying"
comparison = "correct" if predicted == instance_label else "not correct"
```

```
print("The AI prediction for this image is: {}, which is {}!".
  ↪format(predict_label, comparison))
```

```
The AI prediction for this image is: non-cyberbullying, which is correct!
```

Another Image: Predicting on the whole Test_set using the fine tuned model called “ft_model”

[ ]:
```
#@markdown Select a number to view the image and its label.

picture_index  = "0" #@param [0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19]
index = int(picture_index)
instance = test_set[index]

import matplotlib.pyplot as plt
import matplotlib.image as mpimg
img = mpimg.imread(test_set.samples[index][0])
imgplot = plt.imshow(img)
plt.show()
annot_label = "cyberbullying" if test_set[index]['label']==1 else␣
  ↪"non-cyberbullying"
print('')
print("The label of this image is: {}".format(annot_label))
```



```
The label of this image is: cyberbullying
```

[ ]:
```
# check if the prediction is correct
instance_image, instance_label, instance_aux = instance['image'].to(device),␣
 ↪torch.tensor(instance['label']).to(device, dtype = torch.long),␣
 ↪instance['aux'].to(device, dtype = torch.float)

output = ft_model(instance_image.unsqueeze(0), instance_aux.unsqueeze(0)).data
_, prediction = torch.max(output.data, 1)
predict_label = "cyberbullying" if prediction.item()==1 else "non-cyberbullying"
comparision = "correct" if prediction==instance_label else "not correct"

print("The AI prediction for this image is: {}, which is {}!".
 ↪format(predict_label, comparision))
```

```
The AI prediction for this image is: cyberbullying, which is correct!
```

[2]:
```
!pip install notebook-as-pdf
```

```
Collecting notebook-as-pdf
  Downloading notebook_as_pdf-0.5.0-py3-none-any.whl (6.5 kB)
Requirement already satisfied: nbconvert in /usr/local/lib/python3.10/dist-
packages (from notebook-as-pdf) (6.5.4)
Collecting pyppeteer (from notebook-as-pdf)
  Downloading pyppeteer-2.0.0-py3-none-any.whl (82 kB)
                             82.9/82.9 kB
1.7 MB/s eta 0:00:00
Collecting PyPDF2 (from notebook-as-pdf)
  Downloading pypdf2-3.0.1-py3-none-any.whl (232 kB)
                             232.6/232.6

kB 7.0 MB/s eta 0:00:00
Requirement already satisfied: lxml in /usr/local/lib/python3.10/dist-
packages (from nbconvert->notebook-as-pdf) (4.9.4)
Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.10/dist-
packages (from nbconvert->notebook-as-pdf) (4.12.3)
Requirement already satisfied: bleach in /usr/local/lib/python3.10/dist-packages
(from nbconvert->notebook-as-pdf) (6.1.0)
Requirement already satisfied: defusedxml in /usr/local/lib/python3.10/dist-
packages (from nbconvert->notebook-as-pdf) (0.7.1)
Requirement already satisfied: entrypoints>=0.2.2 in
/usr/local/lib/python3.10/dist-packages (from nbconvert->notebook-as-pdf) (0.4)
Requirement already satisfied: jinja2>=3.0 in /usr/local/lib/python3.10/dist-
packages (from nbconvert->notebook-as-pdf) (3.1.3)
Requirement already satisfied: jupyter-core>=4.7 in
/usr/local/lib/python3.10/dist-packages (from nbconvert->notebook-as-pdf)
(5.7.1)
```

```
Requirement already satisfied: jupyterlab-pygments in
/usr/local/lib/python3.10/dist-packages (from nbconvert->notebook-as-pdf)
(0.3.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.10/dist-packages (from nbconvert->notebook-as-pdf)
(2.1.5)
Requirement already satisfied: mistune<2,>=0.8.1 in
/usr/local/lib/python3.10/dist-packages (from nbconvert->notebook-as-pdf)
(0.8.4)
Requirement already satisfied: nbclient>=0.5.0 in
/usr/local/lib/python3.10/dist-packages (from nbconvert->notebook-as-pdf)
(0.9.0)
Requirement already satisfied: nbformat>=5.1 in /usr/local/lib/python3.10/dist-
packages (from nbconvert->notebook-as-pdf) (5.9.2)
Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-
packages (from nbconvert->notebook-as-pdf) (23.2)
Requirement already satisfied: pandocfilters>=1.4.1 in
/usr/local/lib/python3.10/dist-packages (from nbconvert->notebook-as-pdf)
(1.5.1)
Requirement already satisfied: pygments>=2.4.1 in
/usr/local/lib/python3.10/dist-packages (from nbconvert->notebook-as-pdf)
(2.16.1)
Requirement already satisfied: tinycss2 in /usr/local/lib/python3.10/dist-
packages (from nbconvert->notebook-as-pdf) (1.2.1)
Requirement already satisfied: traitlets>=5.0 in /usr/local/lib/python3.10/dist-
packages (from nbconvert->notebook-as-pdf) (5.7.1)
Requirement already satisfied: appdirs<2.0.0,>=1.4.3 in
/usr/local/lib/python3.10/dist-packages (from pyppeteer->notebook-as-pdf)
(1.4.4)
Requirement already satisfied: certifi>=2023 in /usr/local/lib/python3.10/dist-
packages (from pyppeteer->notebook-as-pdf) (2024.2.2)
Requirement already satisfied: importlib-metadata>=1.4 in
/usr/local/lib/python3.10/dist-packages (from pyppeteer->notebook-as-pdf)
(7.0.1)
Collecting pyee<12.0.0,>=11.0.0 (from pyppeteer->notebook-as-pdf)
  Downloading pyee-11.1.0-py3-none-any.whl (15 kB)
Requirement already satisfied: tqdm<5.0.0,>=4.42.1 in
/usr/local/lib/python3.10/dist-packages (from pyppeteer->notebook-as-pdf)
(4.66.2)
Collecting urllib3<2.0.0,>=1.25.8 (from pyppeteer->notebook-as-pdf)
  Downloading urllib3-1.26.18-py2.py3-none-any.whl (143 kB)
                           143.8/143.8
kB 8.5 MB/s eta 0:00:00
Collecting websockets<11.0,>=10.0 (from pyppeteer->notebook-as-pdf)
  Downloading websockets-10.4-cp310-cp310-
manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl (106 kB)
```

```
                                     106.8/106.8
kB 10.2 MB/s eta 0:00:00
Requirement already satisfied: zipp>=0.5 in
/usr/local/lib/python3.10/dist-packages (from importlib-
metadata>=1.4->pyppeteer->notebook-as-pdf) (3.17.0)
Requirement already satisfied: platformdirs>=2.5 in
/usr/local/lib/python3.10/dist-packages (from jupyter-
core>=4.7->nbconvert->notebook-as-pdf) (4.2.0)
Requirement already satisfied: jupyter-client>=6.1.12 in
/usr/local/lib/python3.10/dist-packages (from
nbclient>=0.5.0->nbconvert->notebook-as-pdf) (6.1.12)
Requirement already satisfied: fastjsonschema in /usr/local/lib/python3.10/dist-
packages (from nbformat>=5.1->nbconvert->notebook-as-pdf) (2.19.1)
Requirement already satisfied: jsonschema>=2.6 in
/usr/local/lib/python3.10/dist-packages (from
nbformat>=5.1->nbconvert->notebook-as-pdf) (4.19.2)
Requirement already satisfied: typing-extensions in
/usr/local/lib/python3.10/dist-packages (from
pyee<12.0.0,>=11.0.0->pyppeteer->notebook-as-pdf) (4.10.0)
Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.10/dist-
packages (from beautifulsoup4->nbconvert->notebook-as-pdf) (2.5)
Requirement already satisfied: six>=1.9.0 in /usr/local/lib/python3.10/dist-
packages (from bleach->nbconvert->notebook-as-pdf) (1.16.0)
Requirement already satisfied: webencodings in /usr/local/lib/python3.10/dist-
packages (from bleach->nbconvert->notebook-as-pdf) (0.5.1)
Requirement already satisfied: attrs>=22.2.0 in /usr/local/lib/python3.10/dist-
packages (from jsonschema>=2.6->nbformat>=5.1->nbconvert->notebook-as-pdf)
(23.2.0)
Requirement already satisfied: jsonschema-specifications>=2023.03.6 in
/usr/local/lib/python3.10/dist-packages (from
jsonschema>=2.6->nbformat>=5.1->nbconvert->notebook-as-pdf) (2023.12.1)
Requirement already satisfied: referencing>=0.28.4 in
/usr/local/lib/python3.10/dist-packages (from
jsonschema>=2.6->nbformat>=5.1->nbconvert->notebook-as-pdf) (0.33.0)
Requirement already satisfied: rpds-py>=0.7.1 in /usr/local/lib/python3.10/dist-
packages (from jsonschema>=2.6->nbformat>=5.1->nbconvert->notebook-as-pdf)
(0.18.0)
Requirement already satisfied: pyzmq>=13 in /usr/local/lib/python3.10/dist-
packages (from jupyter-client>=6.1.12->nbclient>=0.5.0->nbconvert->notebook-as-
pdf) (23.2.1)
Requirement already satisfied: python-dateutil>=2.1 in
/usr/local/lib/python3.10/dist-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert->notebook-as-pdf) (2.8.2)
Requirement already satisfied: tornado>=4.1 in /usr/local/lib/python3.10/dist-
packages (from jupyter-client>=6.1.12->nbclient>=0.5.0->nbconvert->notebook-as-
pdf) (6.3.3)
Installing collected packages: websockets, urllib3, PyPDF2, pyee, pyppeteer,
```

```
notebook-as-pdf
  Attempting uninstall: urllib3
    Found existing installation: urllib3 2.0.7
    Uninstalling urllib3-2.0.7:
      Successfully uninstalled urllib3-2.0.7
Successfully installed PyPDF2-3.0.1 notebook-as-pdf-0.5.0 pyee-11.1.0
pyppeteer-2.0.0 urllib3-1.26.18 websockets-10.4
```

[3]:
```
!sudo apt-get install texlive-xetex texlive-fonts-recommended␣
↪texlive-plain-generic
```

```
Reading package lists… Done
Building dependency tree… Done
Reading state information… Done
The following additional packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono
  fonts-texgyre fonts-urw-base35 libapache-pom-java libcommons-logging-java
  libcommons-parent-java libfontbox-java libfontenc1 libgs9 libgs9-common
  libidn12 libijs-0.35 libjbig2dec0 libkpathsea6 libpdfbox-java libptexenc1
  libruby3.0 libsynctex2 libteckit0 libtexlua53 libtexluajit2 libwoff1
  libzzip-0-13 lmodern poppler-data preview-latex-style rake ruby
  ruby-net-telnet ruby-rubygems ruby-webrick ruby-xmlrpc ruby3.0
  rubygems-integration t1utils teckit tex-common tex-gyre texlive-base
  texlive-binaries texlive-latex-base texlive-latex-extra
  texlive-latex-recommended texlive-pictures tipa xfonts-encodings
  xfonts-utils
Suggested packages:
  fonts-noto fonts-freefont-otf | fonts-freefont-ttf libavalon-framework-java
  libcommons-logging-java-doc libexcalibur-logkit-java liblog4j1.2-java
  poppler-utils ghostscript fonts-japanese-mincho | fonts-ipafont-mincho
  fonts-japanese-gothic | fonts-ipafont-gothic fonts-arphic-ukai
  fonts-arphic-uming fonts-nanum ri ruby-dev bundler debhelper gv
  | postscript-viewer perl-tk xpdf | pdf-viewer xzdec
  texlive-fonts-recommended-doc texlive-latex-base-doc python3-pygments
  icc-profiles libfile-which-perl libspreadsheet-parseexcel-perl
  texlive-latex-extra-doc texlive-latex-recommended-doc texlive-luatex
  texlive-pstricks dot2tex prerex texlive-pictures-doc vprerex
  default-jre-headless tipa-doc
The following NEW packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono
  fonts-texgyre fonts-urw-base35 libapache-pom-java libcommons-logging-java
  libcommons-parent-java libfontbox-java libfontenc1 libgs9 libgs9-common
  libidn12 libijs-0.35 libjbig2dec0 libkpathsea6 libpdfbox-java libptexenc1
  libruby3.0 libsynctex2 libteckit0 libtexlua53 libtexluajit2 libwoff1
  libzzip-0-13 lmodern poppler-data preview-latex-style rake ruby
  ruby-net-telnet ruby-rubygems ruby-webrick ruby-xmlrpc ruby3.0
  rubygems-integration t1utils teckit tex-common tex-gyre texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
```

```
  texlive-latex-extra texlive-latex-recommended texlive-pictures
  texlive-plain-generic texlive-xetex tipa xfonts-encodings xfonts-utils
0 upgraded, 54 newly installed, 0 to remove and 35 not upgraded.
Need to get 182 MB of archives.
After this operation, 571 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-droid-fallback all
1:6.0.1r16-1.1build1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-lato all 2.0-2.1
[2,696 kB]
Get:3 http://archive.ubuntu.com/ubuntu jammy/main amd64 poppler-data all
0.4.11-1 [2,171 kB]
Get:4 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-common all 6.17
[33.7 kB]
Get:5 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-urw-base35 all
20200910-1 [6,367 kB]
Get:6 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9-common
all 9.55.0~dfsg1-0ubuntu5.6 [751 kB]
Get:7 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libidn12 amd64
1.38-4ubuntu1 [60.0 kB]
Get:8 http://archive.ubuntu.com/ubuntu jammy/main amd64 libijs-0.35 amd64
0.35-15build2 [16.5 kB]
Get:9 http://archive.ubuntu.com/ubuntu jammy/main amd64 libjbig2dec0 amd64
0.19-3build2 [64.7 kB]
Get:10 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9 amd64
9.55.0~dfsg1-0ubuntu5.6 [5,031 kB]
Get:11 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libkpathsea6
amd64 2021.20210626.59705-1ubuntu0.1 [60.3 kB]
Get:12 http://archive.ubuntu.com/ubuntu jammy/main amd64 libwoff1 amd64
1.0.2-1build4 [45.2 kB]
Get:13 http://archive.ubuntu.com/ubuntu jammy/universe amd64 dvisvgm amd64
2.13.1-1 [1,221 kB]
Get:14 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fonts-lmodern all
2.004.5-6.1 [4,532 kB]
Get:15 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-noto-mono all
20201225-1build1 [397 kB]
Get:16 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fonts-texgyre all
20180621-3.1 [10.2 MB]
Get:17 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libapache-pom-java
all 18-1 [4,720 B]
Get:18 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcommons-parent-
java all 43-1 [10.8 kB]
Get:19 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcommons-logging-
java all 1.2-2 [60.3 kB]
Get:20 http://archive.ubuntu.com/ubuntu jammy/main amd64 libfontenc1 amd64
1:1.1.4-1build3 [14.7 kB]
Get:21 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libptexenc1
amd64 2021.20210626.59705-1ubuntu0.1 [39.1 kB]
Get:22 http://archive.ubuntu.com/ubuntu jammy/main amd64 rubygems-integration
```

```
all 1.18 [5,336 B]
Get:23 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby3.0 amd64
3.0.2-7ubuntu2.4 [50.1 kB]
Get:24 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby-rubygems all
3.3.5-2 [228 kB]
Get:25 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby amd64 1:3.0~exp1
[5,100 B]
Get:26 http://archive.ubuntu.com/ubuntu jammy/main amd64 rake all 13.0.6-2 [61.7
kB]
Get:27 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby-net-telnet all
0.1.1-2 [12.6 kB]
Get:28 http://archive.ubuntu.com/ubuntu jammy/universe amd64 ruby-webrick all
1.7.0-3 [51.8 kB]
Get:29 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby-xmlrpc all
0.3.2-1ubuntu0.1 [24.9 kB]
Get:30 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libruby3.0
amd64 3.0.2-7ubuntu2.4 [5,113 kB]
Get:31 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libsynctex2
amd64 2021.20210626.59705-1ubuntu0.1 [55.5 kB]
Get:32 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libteckit0 amd64
2.5.11+ds1-1 [421 kB]
Get:33 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexlua53
amd64 2021.20210626.59705-1ubuntu0.1 [120 kB]
Get:34 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexluajit2
amd64 2021.20210626.59705-1ubuntu0.1 [267 kB]
Get:35 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libzzip-0-13 amd64
0.13.72+dfsg.1-1.1 [27.0 kB]
Get:36 http://archive.ubuntu.com/ubuntu jammy/main amd64 xfonts-encodings all
1:1.0.5-0ubuntu2 [578 kB]
Get:37 http://archive.ubuntu.com/ubuntu jammy/main amd64 xfonts-utils amd64
1:7.7+6build2 [94.6 kB]
Get:38 http://archive.ubuntu.com/ubuntu jammy/universe amd64 lmodern all
2.004.5-6.1 [9,471 kB]
Get:39 http://archive.ubuntu.com/ubuntu jammy/universe amd64 preview-latex-style
all 12.2-1ubuntu1 [185 kB]
Get:40 http://archive.ubuntu.com/ubuntu jammy/main amd64 t1utils amd64
1.41-4build2 [61.3 kB]
Get:41 http://archive.ubuntu.com/ubuntu jammy/universe amd64 teckit amd64
2.5.11+ds1-1 [699 kB]
Get:42 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-gyre all
20180621-3.1 [6,209 kB]
Get:43 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 texlive-
binaries amd64 2021.20210626.59705-1ubuntu0.1 [9,848 kB]
Get:44 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-base all
2021.20220204-1 [21.0 MB]
Get:45 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-fonts-
recommended all 2021.20220204-1 [4,972 kB]
Get:46 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-base
```

```
all 2021.20220204-1 [1,128 kB]
Get:47 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libfontbox-java all
1:1.8.16-2 [207 kB]
Get:48 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libpdfbox-java all
1:1.8.16-2 [5,199 kB]
Get:49 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-
recommended all 2021.20220204-1 [14.4 MB]
Get:50 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-pictures
all 2021.20220204-1 [8,720 kB]
Get:51 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-extra
all 2021.20220204-1 [13.9 MB]
Get:52 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-plain-
generic all 2021.20220204-1 [27.5 MB]
Get:53 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tipa all 2:1.3-21
[2,967 kB]
Get:54 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-xetex all
2021.20220204-1 [12.4 MB]
Fetched 182 MB in 14s (13.0 MB/s)
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line 78,
<> line 54.)
debconf: falling back to frontend: Readline
debconf: unable to initialize frontend: Readline
debconf: (This frontend requires a controlling tty.)
debconf: falling back to frontend: Teletype
dpkg-preconfigure: unable to re-open stdin:
Selecting previously unselected package fonts-droid-fallback.
(Reading database … 121749 files and directories currently installed.)
Preparing to unpack …/00-fonts-droid-fallback_1%3a6.0.1r16-1.1build1_all.deb
…
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1build1) …
Selecting previously unselected package fonts-lato.
Preparing to unpack …/01-fonts-lato_2.0-2.1_all.deb …
Unpacking fonts-lato (2.0-2.1) …
Selecting previously unselected package poppler-data.
Preparing to unpack …/02-poppler-data_0.4.11-1_all.deb …
Unpacking poppler-data (0.4.11-1) …
Selecting previously unselected package tex-common.
Preparing to unpack …/03-tex-common_6.17_all.deb …
Unpacking tex-common (6.17) …
Selecting previously unselected package fonts-urw-base35.
Preparing to unpack …/04-fonts-urw-base35_20200910-1_all.deb …
Unpacking fonts-urw-base35 (20200910-1) …
Selecting previously unselected package libgs9-common.
Preparing to unpack …/05-libgs9-common_9.55.0~dfsg1-0ubuntu5.6_all.deb …
Unpacking libgs9-common (9.55.0~dfsg1-0ubuntu5.6) …
Selecting previously unselected package libidn12:amd64.
```

```
Preparing to unpack …/06-libidn12_1.38-4ubuntu1_amd64.deb …
Unpacking libidn12:amd64 (1.38-4ubuntu1) …
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack …/07-libijs-0.35_0.35-15build2_amd64.deb …
Unpacking libijs-0.35:amd64 (0.35-15build2) …
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack …/08-libjbig2dec0_0.19-3build2_amd64.deb …
Unpacking libjbig2dec0:amd64 (0.19-3build2) …
Selecting previously unselected package libgs9:amd64.
Preparing to unpack …/09-libgs9_9.55.0~dfsg1-0ubuntu5.6_amd64.deb …
Unpacking libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.6) …
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack …/10-libkpathsea6_2021.20210626.59705-1ubuntu0.1_amd64.deb
…
Unpacking libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.1) …
Selecting previously unselected package libwoff1:amd64.
Preparing to unpack …/11-libwoff1_1.0.2-1build4_amd64.deb …
Unpacking libwoff1:amd64 (1.0.2-1build4) …
Selecting previously unselected package dvisvgm.
Preparing to unpack …/12-dvisvgm_2.13.1-1_amd64.deb …
Unpacking dvisvgm (2.13.1-1) …
Selecting previously unselected package fonts-lmodern.
Preparing to unpack …/13-fonts-lmodern_2.004.5-6.1_all.deb …
Unpacking fonts-lmodern (2.004.5-6.1) …
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack …/14-fonts-noto-mono_20201225-1build1_all.deb …
Unpacking fonts-noto-mono (20201225-1build1) …
Selecting previously unselected package fonts-texgyre.
Preparing to unpack …/15-fonts-texgyre_20180621-3.1_all.deb …
Unpacking fonts-texgyre (20180621-3.1) …
Selecting previously unselected package libapache-pom-java.
Preparing to unpack …/16-libapache-pom-java_18-1_all.deb …
Unpacking libapache-pom-java (18-1) …
Selecting previously unselected package libcommons-parent-java.
Preparing to unpack …/17-libcommons-parent-java_43-1_all.deb …
Unpacking libcommons-parent-java (43-1) …
Selecting previously unselected package libcommons-logging-java.
Preparing to unpack …/18-libcommons-logging-java_1.2-2_all.deb …
Unpacking libcommons-logging-java (1.2-2) …
Selecting previously unselected package libfontenc1:amd64.
Preparing to unpack …/19-libfontenc1_1%3a1.1.4-1build3_amd64.deb …
Unpacking libfontenc1:amd64 (1:1.1.4-1build3) …
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack …/20-libptexenc1_2021.20210626.59705-1ubuntu0.1_amd64.deb
…
Unpacking libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.1) …
Selecting previously unselected package rubygems-integration.
Preparing to unpack …/21-rubygems-integration_1.18_all.deb …
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Unpacking rubygems-integration (1.18) …
Selecting previously unselected package ruby3.0.
Preparing to unpack …/22-ruby3.0_3.0.2-7ubuntu2.4_amd64.deb …
Unpacking ruby3.0 (3.0.2-7ubuntu2.4) …
Selecting previously unselected package ruby-rubygems.
Preparing to unpack …/23-ruby-rubygems_3.3.5-2_all.deb …
Unpacking ruby-rubygems (3.3.5-2) …
Selecting previously unselected package ruby.
Preparing to unpack …/24-ruby_1%3a3.0~exp1_amd64.deb …
Unpacking ruby (1:3.0~exp1) …
Selecting previously unselected package rake.
Preparing to unpack …/25-rake_13.0.6-2_all.deb …
Unpacking rake (13.0.6-2) …
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack …/26-ruby-net-telnet_0.1.1-2_all.deb …
Unpacking ruby-net-telnet (0.1.1-2) …
Selecting previously unselected package ruby-webrick.
Preparing to unpack …/27-ruby-webrick_1.7.0-3_all.deb …
Unpacking ruby-webrick (1.7.0-3) …
Selecting previously unselected package ruby-xmlrpc.
Preparing to unpack …/28-ruby-xmlrpc_0.3.2-1ubuntu0.1_all.deb …
Unpacking ruby-xmlrpc (0.3.2-1ubuntu0.1) …
Selecting previously unselected package libruby3.0:amd64.
Preparing to unpack …/29-libruby3.0_3.0.2-7ubuntu2.4_amd64.deb …
Unpacking libruby3.0:amd64 (3.0.2-7ubuntu2.4) …
Selecting previously unselected package libsynctex2:amd64.
Preparing to unpack …/30-libsynctex2_2021.20210626.59705-1ubuntu0.1_amd64.deb
…
Unpacking libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.1) …
Selecting previously unselected package libteckit0:amd64.
Preparing to unpack …/31-libteckit0_2.5.11+ds1-1_amd64.deb …
Unpacking libteckit0:amd64 (2.5.11+ds1-1) …
Selecting previously unselected package libtexlua53:amd64.
Preparing to unpack …/32-libtexlua53_2021.20210626.59705-1ubuntu0.1_amd64.deb
…
Unpacking libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.1) …
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack
…/33-libtexluajit2_2021.20210626.59705-1ubuntu0.1_amd64.deb …
Unpacking libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.1) …
Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack …/34-libzzip-0-13_0.13.72+dfsg.1-1.1_amd64.deb …
Unpacking libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) …
Selecting previously unselected package xfonts-encodings.
Preparing to unpack …/35-xfonts-encodings_1%3a1.0.5-0ubuntu2_all.deb …
Unpacking xfonts-encodings (1:1.0.5-0ubuntu2) …
Selecting previously unselected package xfonts-utils.
Preparing to unpack …/36-xfonts-utils_1%3a7.7+6build2_amd64.deb …
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Unpacking xfonts-utils (1:7.7+6build2) …
Selecting previously unselected package lmodern.
Preparing to unpack …/37-lmodern_2.004.5-6.1_all.deb …
Unpacking lmodern (2.004.5-6.1) …
Selecting previously unselected package preview-latex-style.
Preparing to unpack …/38-preview-latex-style_12.2-1ubuntu1_all.deb …
Unpacking preview-latex-style (12.2-1ubuntu1) …
Selecting previously unselected package t1utils.
Preparing to unpack …/39-t1utils_1.41-4build2_amd64.deb …
Unpacking t1utils (1.41-4build2) …
Selecting previously unselected package teckit.
Preparing to unpack …/40-teckit_2.5.11+ds1-1_amd64.deb …
Unpacking teckit (2.5.11+ds1-1) …
Selecting previously unselected package tex-gyre.
Preparing to unpack …/41-tex-gyre_20180621-3.1_all.deb …
Unpacking tex-gyre (20180621-3.1) …
Selecting previously unselected package texlive-binaries.
Preparing to unpack …/42-texlive-
binaries_2021.20210626.59705-1ubuntu0.1_amd64.deb …
Unpacking texlive-binaries (2021.20210626.59705-1ubuntu0.1) …
Selecting previously unselected package texlive-base.
Preparing to unpack …/43-texlive-base_2021.20220204-1_all.deb …
Unpacking texlive-base (2021.20220204-1) …
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack …/44-texlive-fonts-recommended_2021.20220204-1_all.deb …
Unpacking texlive-fonts-recommended (2021.20220204-1) …
Selecting previously unselected package texlive-latex-base.
Preparing to unpack …/45-texlive-latex-base_2021.20220204-1_all.deb …
Unpacking texlive-latex-base (2021.20220204-1) …
Selecting previously unselected package libfontbox-java.
Preparing to unpack …/46-libfontbox-java_1%3a1.8.16-2_all.deb …
Unpacking libfontbox-java (1:1.8.16-2) …
Selecting previously unselected package libpdfbox-java.
Preparing to unpack …/47-libpdfbox-java_1%3a1.8.16-2_all.deb …
Unpacking libpdfbox-java (1:1.8.16-2) …
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack …/48-texlive-latex-recommended_2021.20220204-1_all.deb …
Unpacking texlive-latex-recommended (2021.20220204-1) …
Selecting previously unselected package texlive-pictures.
Preparing to unpack …/49-texlive-pictures_2021.20220204-1_all.deb …
Unpacking texlive-pictures (2021.20220204-1) …
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack …/50-texlive-latex-extra_2021.20220204-1_all.deb …
Unpacking texlive-latex-extra (2021.20220204-1) …
Selecting previously unselected package texlive-plain-generic.
Preparing to unpack …/51-texlive-plain-generic_2021.20220204-1_all.deb …
Unpacking texlive-plain-generic (2021.20220204-1) …
Selecting previously unselected package tipa.
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Preparing to unpack …/52-tipa_2%3a1.3-21_all.deb …
Unpacking tipa (2:1.3-21) …
Selecting previously unselected package texlive-xetex.
Preparing to unpack …/53-texlive-xetex_2021.20220204-1_all.deb …
Unpacking texlive-xetex (2021.20220204-1) …
Setting up fonts-lato (2.0-2.1) …
Setting up fonts-noto-mono (20201225-1build1) …
Setting up libwoff1:amd64 (1.0.2-1build4) …
Setting up libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.1) …
Setting up libijs-0.35:amd64 (0.35-15build2) …
Setting up libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.1) …
Setting up libfontbox-java (1:1.8.16-2) …
Setting up rubygems-integration (1.18) …
Setting up libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) …
Setting up fonts-urw-base35 (20200910-1) …
Setting up poppler-data (0.4.11-1) …
Setting up tex-common (6.17) …
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line
78.)
debconf: falling back to frontend: Readline
update-language: texlive-base not installed and configured, doing nothing!
Setting up libfontenc1:amd64 (1:1.1.4-1build3) …
Setting up libjbig2dec0:amd64 (0.19-3build2) …
Setting up libteckit0:amd64 (2.5.11+ds1-1) …
Setting up libapache-pom-java (18-1) …
Setting up ruby-net-telnet (0.1.1-2) …
Setting up xfonts-encodings (1:1.0.5-0ubuntu2) …
Setting up t1utils (1.41-4build2) …
Setting up libidn12:amd64 (1.38-4ubuntu1) …
Setting up fonts-texgyre (20180621-3.1) …
Setting up libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.1) …
Setting up ruby-webrick (1.7.0-3) …
Setting up fonts-lmodern (2.004.5-6.1) …
Setting up fonts-droid-fallback (1:6.0.1r16-1.1build1) …
Setting up ruby-xmlrpc (0.3.2-1ubuntu0.1) …
Setting up libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.1) …
Setting up libgs9-common (9.55.0~dfsg1-0ubuntu5.6) …
Setting up teckit (2.5.11+ds1-1) …
Setting up libpdfbox-java (1:1.8.16-2) …
Setting up libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.6) …
Setting up preview-latex-style (12.2-1ubuntu1) …
Setting up libcommons-parent-java (43-1) …
Setting up dvisvgm (2.13.1-1) …
Setting up libcommons-logging-java (1.2-2) …
Setting up xfonts-utils (1:7.7+6build2) …
Setting up libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.1) …
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Setting up texlive-binaries (2021.20210626.59705-1ubuntu0.1) …
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) in auto mode
Setting up lmodern (2.004.5-6.1) …
Setting up texlive-base (2021.20220204-1) …
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST…
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN…
mktexlsr: Updating /var/lib/texmf/ls-R…
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4:
/var/lib/texmf/dvips/config/config-paper.ps
tl-paper: setting paper size for dvipdfmx to a4:
/var/lib/texmf/dvipdfmx/dvipdfmx-paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4: /var/lib/texmf/tex/generic/tex-
ini-files/pdftexconfig.tex
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line
78.)
debconf: falling back to frontend: Readline
Setting up tex-gyre (20180621-3.1) …
Setting up texlive-plain-generic (2021.20220204-1) …
Setting up texlive-latex-base (2021.20220204-1) …
Setting up texlive-latex-recommended (2021.20220204-1) …
Setting up texlive-pictures (2021.20220204-1) …
Setting up texlive-fonts-recommended (2021.20220204-1) …
Setting up tipa (2:1.3-21) …
Setting up texlive-latex-extra (2021.20220204-1) …
Setting up texlive-xetex (2021.20220204-1) …
Setting up rake (13.0.6-2) …
Setting up libruby3.0:amd64 (3.0.2-7ubuntu2.4) …
Setting up ruby3.0 (3.0.2-7ubuntu2.4) …
Setting up ruby (1:3.0~exp1) …
Setting up ruby-rubygems (3.3.5-2) …
Processing triggers for man-db (2.10.2-1) …
Processing triggers for fontconfig (2.13.1-4.2ubuntu5) …
Processing triggers for libc-bin (2.35-0ubuntu3.4) …
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_5.so.3 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbbind.so.3 is not a symbolic link
```

```
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_0.so.3 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc.so.2 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc_proxy.so.2 is not a symbolic
link

/sbin/ldconfig.real: /usr/local/lib/libtbb.so.12 is not a symbolic link

Processing triggers for tex-common (6.17) …
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line
78.)
debconf: falling back to frontend: Readline
Running updmap-sys. This may take some time… done.
Running mktexlsr /var/lib/texmf … done.
Building format(s) --all.
        This may take some time… done.
```

[ ]:
```
!jupyter nbconvert "/content/drive/MyDrive/Colab Notebooks/IS6733Lab2_sai.
↪ipynb" --to pdf
```