cuitquwiq

June 24, 2024

[1]:
```
# Import standard dependencies
import cv2
import os
import random
import numpy as np
from matplotlib import pyplot as plt
```

[2]:
```
# Import tensorflow dependencies - Functional API
from tensorflow.keras.models import Model
from tensorflow.keras.layers import Layer, Conv2D, Dense, MaxPooling2D, Input,␣
↪Flatten
import tensorflow as tf
```

[3]:
```
# Setup paths
POS_PATH = os.path.join('data', 'positive')
NEG_PATH = os.path.join('data', 'negative')
ANC_PATH = os.path.join('data', 'anchor')
```

[4]:
```
# Make the directories
#os.makedirs(POS_PATH)
#os.makedirs(NEG_PATH)
#os.makedirs(ANC_PATH)
```

[5]:
```
# Uncompress Tar GZ Labelled Faces in the Wild Dataset
#!tar -xf lfw.tgz
```

[6]:
```
# Move LFW Images to the following repository data/negative
# for directory in os.listdir('lfw'):
#     for file in os.listdir(os.path.join('lfw', directory)):
#         EX_PATH = os.path.join('lfw', directory, file)
#         NEW_PATH = os.path.join(NEG_PATH, file)
#         os.replace(EX_PATH, NEW_PATH)
```

[17]:
```
# Import uuid library to generate unique image names
import uuid
```

[18]:
```
os.path.join(ANC_PATH, '{}.jpg'.format(uuid.uuid1()))
```

[18]:
```
'data\\anchor\\fdf1a64e-3206-11ef-bf34-7612b351a14f.jpg'
```

[19]:
```
# # Establish a connection to the webcam
# cap = cv2.VideoCapture(0)


# while cap.isOpened():
#     ret, frame = cap.read()


#     # Cut down frame to 250x250px
#     frame = frame[120:120+250,200:200+250, :]

#     # Collect anchors
#     if cv2.waitKey(1) & 0XFF == ord('a'):
#         # Create the unique file path
#         imgname = os.path.join(ANC_PATH, '{}.jpg'.format(uuid.uuid1()))
#         # Write out anchor image
#         cv2.imwrite(imgname, frame)

#     # Collect positives
#     if cv2.waitKey(1) & 0XFF == ord('p'):
#         # Create the unique file path
#         imgname = os.path.join(POS_PATH, '{}.jpg'.format(uuid.uuid1()))
#         # Write out positive image
#         cv2.imwrite(imgname, frame)

#     # Show image back to screen
#     cv2.imshow('Image Collection', frame)

#     # Breaking gracefully
#     if cv2.waitKey(1) & 0XFF == ord('q'):
#         break

# # Release the webcam
# cap.release()
# # Close the image show frame
# cv2.destroyAllWindows()
```

[20]:
```
anchor = tf.data.Dataset.list_files(ANC_PATH+'\\*.jpg').take(3000)
positive = tf.data.Dataset.list_files(POS_PATH+'\\*.jpg').take(3000)
negative = tf.data.Dataset.list_files(NEG_PATH+'\\*.jpg').take(3000)
```

[21]:
```
def preprocess(file_path):

    # Read in image from file path
    byte_img = tf.io.read_file(file_path)
```

```
    # Load in the image
    img = tf.io.decode_jpeg(byte_img)

    # Preprocessing steps - resizing the image to be 100x100x3
    img = tf.image.resize(img, (100,100))
    # Scale image to be between 0 and 1
    img = img / 255.0

    # Return image
    return img
```

[22]:
```
positives = tf.data.Dataset.zip((anchor, positive, tf.data.Dataset.
 ↪from_tensor_slices(tf.ones(len(anchor)))))
negatives = tf.data.Dataset.zip((anchor, negative, tf.data.Dataset.
 ↪from_tensor_slices(tf.zeros(len(anchor)))))
data = positives.concatenate(negatives)
```

[23]:
```
it = data.as_numpy_iterator()
```

[24]:
```
it.next()
```

[24]:
```
(b'data\\anchor\\2427c5dd-308e-11ef-a021-489ebdf94e09.jpg',
 b'data\\positive\\51c36a34-308e-11ef-a030-489ebdf94e09.jpg',
 1.0)
```

[25]:
```
def preprocess_twin(input_img, validation_img, label):
    return(preprocess(input_img), preprocess(validation_img), label)
```

[26]:
```
res = preprocess_twin(*it.next())
```

[27]:
```
# Build dataloader pipeline
data = data.map(preprocess_twin)
data = data.cache()
data = data.shuffle(buffer_size=10000)
```

[28]:
```
# Training partition
train_data = data.take(round(len(data)*.7))
train_data = train_data.batch(16)
train_data = train_data.prefetch(8)
```

[29]:
```
# Testing partition
test_data = data.skip(round(len(data)*.7))
test_data = test_data.take(round(len(data)*.3))
test_data = test_data.batch(16)
test_data = test_data.prefetch(8)
```

[20]:
```
#Build Embedding Layer
inp = Input(shape=(100,100,3), name='input_image')
c1 = Conv2D(64, (10,10), activation='relu')(inp)
m1 = MaxPooling2D(64, (2,2), padding='same')(c1)
c2 = Conv2D(128, (7,7), activation='relu')(m1)
m2 = MaxPooling2D(64, (2,2), padding='same')(c2)
c3 = Conv2D(128, (4,4), activation='relu')(m2)
m3 = MaxPooling2D(64, (2,2), padding='same')(c3)
c4 = Conv2D(256, (4,4), activation='relu')(m3)
f1 = Flatten()(c4)
d1 = Dense(4096, activation='sigmoid')(f1)
```

[21]:
```
mod = Model(inputs=[inp], outputs=[d1], name='embedding')
```

[22]:
```
mod.summary()
```

```
Model: "embedding"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_image (InputLayer)     (None, 100, 100, 3)       0
_________________________________________________________________
conv2d (Conv2D)              (None, 91, 91, 64)        19,264
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 46, 46, 64)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 40, 40, 128)       401,536
_________________________________________________________________
max_pooling2d_1 (MaxPooling2D) (None, 20, 20, 128)     0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 17, 17, 128)       262,272
_________________________________________________________________
max_pooling2d_2 (MaxPooling2D) (None, 9, 9, 128)       0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 6, 6, 256)         524,544
```

```
flatten (Flatten)                    (None, 9216)                                ␣
↪  0

dense (Dense)                        (None, 4096)                                ␣
↪37,752,832
```

Total params: 38,960,448 (148.62 MB)

Trainable params: 38,960,448 (148.62 MB)

Non-trainable params: 0 (0.00 B)

[6]:
```python
def make_embedding():
    inp = Input(shape=(100,100,3), name='input_image')

    # First block
    c1 = Conv2D(64, (10,10), activation='relu')(inp)
    m1 = MaxPooling2D(64, (2,2), padding='same')(c1)

    # Second block
    c2 = Conv2D(128, (7,7), activation='relu')(m1)
    m2 = MaxPooling2D(64, (2,2), padding='same')(c2)

    # Third block
    c3 = Conv2D(128, (4,4), activation='relu')(m2)
    m3 = MaxPooling2D(64, (2,2), padding='same')(c3)

    # Final embedding block
    c4 = Conv2D(256, (4,4), activation='relu')(m3)
    f1 = Flatten()(c4)
    d1 = Dense(4096, activation='sigmoid')(f1)


    return Model(inputs=[inp], outputs=[d1], name='embedding')
```

[7]:
```python
#Build Distance Layer
# Siamese L1 Distance class
class L1Dist(Layer):

    # Init method - inheritance
    def __init__(self, **kwargs):
        super().__init__()

    # Magic happens here - similarity calculation
```

```
    def call(self, input_embedding, validation_embedding):
        input_embedding = tf.convert_to_tensor(input_embedding)
        validation_embedding = tf.convert_to_tensor(validation_embedding)
        return tf.math.abs(input_embedding - validation_embedding)
```

[8]:
```
embedding = make_embedding()
```

[9]:
```
# Anchor image input in the network
input_image = Input(name='input_img', shape=(100,100,3))

# Validation image in the network
validation_image = Input(name='validation_img', shape=(100,100,3))
inp_embedding = embedding(input_image)
val_embedding = embedding(validation_image)
```

[10]:
```
inp_embedding
```

[10]:
```
[<KerasTensor shape=(None, 4096), dtype=float32, sparse=False,
name=keras_tensor_9>]
```

[11]:
```
l1 = L1Dist()
```

[12]:
```
#Make Siamese Model
def make_siamese_model():

    # Anchor image input in the network
    input_image = Input(name='input_img', shape=(100,100,3))

    # Validation image in the network
    validation_image = Input(name='validation_img', shape=(100,100,3))
    inp_embedding = embedding(input_image)
    val_embedding = embedding(validation_image)
    # Combine siamese distance components
    siamese_layer = L1Dist()
    siamese_layer._name = 'distance'
    distances = siamese_layer(inp_embedding,val_embedding)

    # Classification layer
    classifier = Dense(1, activation='sigmoid')(distances)
    # classifier = tf.reshape(classifier, [-1])  # Ensure output shape is␣
↪(None,)
    return Model(inputs=[input_image, validation_image], outputs=classifier,␣
↪name='SiameseNetwork')
```

[13]:
```
siamese_model = make_siamese_model()
```

```
WARNING:tensorflow:From C:\Users\syedf\anaconda3\envs\faceminiproject\Lib\site-
```

```
packages\keras\src\backend\tensorflow\core.py:184: The name tf.placeholder is
deprecated. Please use tf.compat.v1.placeholder instead.
```

[14]:
```
siamese_model.summary()
```

```
Model: "SiameseNetwork"
```

Layer (type)	Output Shape	Param #	Connected to
input_img (InputLayer)	(None, 100, 100, 3)	0	-
validation_img (InputLayer)	(None, 100, 100, 3)	0	-
embedding (Functional)	(None, 4096)	38,960,448	input_img[0][0], validation_img[0][0]
l1_dist_1 (L1Dist)	(1, None, 4096)	0	embedding[2][0], embedding[3][0]
dense_1 (Dense)	(1, None, 1)	4,097	l1_dist_1[0][0]

```
Total params: 38,964,545 (148.64 MB)

Trainable params: 38,964,545 (148.64 MB)

Non-trainable params: 0 (0.00 B)
```

[32]:
```
#Setup Loss and Optimizer
binary_cross_loss = tf.losses.BinaryCrossentropy()
opt = tf.keras.optimizers.Adam(1e-4) # 0.0001
```

[33]:
```
# Establish Checkpoints
checkpoint_dir = './training_checkpoints'
```

```
checkpoint_prefix = os.path.join(checkpoint_dir, 'ckpt')
checkpoint = tf.train.Checkpoint(opt=opt, siamese_model=siamese_model)
```

[42]:
```
#Build Train Step Function
@tf.function
def train_step(batch):

    # Record all of our operations
    with tf.GradientTape() as tape:
        # Get anchor and positive/negative image
        X = batch[:2]
        # Get label
        y = batch[2]

        # Forward pass
        yhat = siamese_model(X, training=True)
        y = tf.reshape(y, tf.shape(yhat))
        # Calculate loss
        loss = binary_cross_loss(y, yhat)
    print(loss)

    # Calculate gradients
    grad = tape.gradient(loss, siamese_model.trainable_variables)

    # Calculate updated weights and apply to siamese model
    opt.apply_gradients(zip(grad, siamese_model.trainable_variables))

    # Return loss
    return loss
```

[43]:
```
# Import metric calculations
from tensorflow.keras.metrics import Precision, Recall
```

[44]:
```
#Build Training Loop
def train(data, EPOCHS):
    # Loop through epochs
    for epoch in range(1, EPOCHS+1):
        print('\n Epoch {}/{}'.format(epoch, EPOCHS))
        progbar = tf.keras.utils.Progbar(len(data))

        # Creating a metric object
        r = Recall()
        p = Precision()

        # Loop through each batch
        for idx, batch in enumerate(data):
            # Run train step here
```

```
            loss = train_step(batch)
            yhat = siamese_model.predict(batch[:2])
            r.update_state(batch[2], yhat)
            p.update_state(batch[2], yhat)
            progbar.update(idx+1)
        print(loss.numpy(), r.result().numpy(), p.result().numpy())

        # Save checkpoints
        if epoch % 10 == 0:
            checkpoint.save(file_prefix=checkpoint_prefix)
```

[45]:
```
EPOCHS = 50
```

[46]:
```
batch = train_data.as_numpy_iterator().next()
```

[47]:
```
x = batch[:2]
```

[48]:
```
len(x)
```

[48]: 2

[49]:
```
train(train_data, EPOCHS)
```

```
 Epoch 1/50
Tensor("binary_crossentropy/truediv:0", shape=(), dtype=float32)
Tensor("binary_crossentropy/truediv:0", shape=(), dtype=float32)
1/1             4s 4s/step
1/1             5s 5s/step
1/1             4s 4s/steps/ste
1/1             6s 6s/steps/ste
1/1             5s 5s/steps/ste
1/1             3s 3s/steps/ste
1/1             5s 5s/steps/ste
1/1             7s 7s/steps/ste
1/1             4s 4s/steps/ste
1/1             4s 4s/steps/ste
1/1             4s 4s/steps/ste
1/1             6s 6s/steps/ste
1/1             10s 10s/stepst
1/1             3s 3s/steps/ste
1/1             3s 3s/steps/ste
1/1             3s 3s/steps/ste
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1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             5s 5s/step/ste
1/1             6s 6s/step/ste
1/1             6s 6s/step/ste
1/1             3s 3s/stepstep
39/40             20s
21s/stepTensor("binary_crossentropy/truediv:0", shape=(), dtype=float32)
1/1             2s 2s/step
40/40             814s 20s/step
0.024643598 0.63271606 1.0

 Epoch 2/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             7s 7s/step/ste
1/1             6s 6s/steps/ste
1/1             6s 6s/steps/ste
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1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             625s 16s/step
0.07165045 0.9746835 0.99676377

 Epoch 3/50
1/1             3s 3s/step
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1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             568s 14s/step
0.22020969 0.99041533 1.0

 Epoch 4/50
1/1             3s 3s/step
1/1             3s 3s/step
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1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40            564s 14s/step
0.088628605 0.9842271 0.9936306

 Epoch 5/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
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1/1             4s 4s/step/ste
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1/1             4s 4s/step/ste
1/1             3s 3s/stepstep
1/1             4s 4s/stepste
1/1             1s 1s/stepste
40/40            611s 15s/step
0.0089593 0.9903537 1.0

 Epoch 6/50
1/1             5s 5s/step
1/1             3s 3s/step
1/1             4s 4s/steps/ste
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```

```
1/1             4s 4s/stepste
1/1             1s 1s/stepste
40/40             663s 16s/step
0.031720445 0.9968553 1.0

 Epoch 7/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/steps/ste
1/1             3s 3s/steps/ste
1/1             6s 6s/steps/ste
1/1             4s 4s/steps/ste
1/1             6s 6s/steps/ste
1/1             8s 8s/steps/ste
1/1             5s 5s/steps/ste
1/1             10s 10s/stepst
1/1             3s 3s/steps/ste
1/1             5s 5s/steps/ste
1/1             4s 4s/steps/ste
1/1             4s 4s/steps/ste
1/1             3s 3s/steps/ste
1/1             3s 3s/step/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             5s 5s/step/ste
1/1             5s 5s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/stepstep
1/1             1s 1s/stepste
40/40             808s 20s/step
0.00014569187 1.0 1.0
```

```
 Epoch 8/50
1/1             4s 4s/step
1/1             4s 4s/step
1/1             4s 4s/steps/ste
1/1             4s 4s/steps/ste
1/1             4s 4s/steps/ste
1/1             4s 4s/step/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             5s 5s/step/ste
1/1             4s 4s/steps/ste
1/1             4s 4s/step/step
1/1             5s 5s/step/ste
1/1             3s 3s/step/ste
1/1             5s 5s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             5s 5s/step/ste
1/1             3s 3s/step/ste
1/1             12s 12s/stept
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             7s 7s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             8s 8s/step/ste
1/1             4s 4s/step/ste
1/1             4s 4s/step/ste
1/1             6s 6s/step/ste
1/1             5s 5s/stepstep
1/1             2s 2s/stepste
40/40             920s 23s/step
0.00016344443 1.0 1.0

 Epoch 9/50
1/1             4s 4s/step
1/1             3s 3s/step
```

```
1/1             4s 4s/steps/ste
1/1             7s 7s/steps/ste
1/1             4s 4s/steps/ste
1/1             3s 3s/steps/ste
1/1             5s 5s/steps/ste
1/1             3s 3s/steps/ste
1/1             3s 3s/steps/ste
1/1             3s 3s/steps/ste
1/1             3s 3s/steps/ste
1/1             3s 3s/steps/ste
1/1             3s 3s/step/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             7s 7s/step/ste
1/1             5s 5s/step/ste
1/1             3s 3s/step/ste
1/1             14s 14s/stept
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             661s 16s/step
0.009877616 1.0 1.0

 Epoch 10/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              7s 7s/step/ste
1/1              3s 3s/step/ste
1/1              4s 4s/step/ste
1/1              4s 4s/stepstep
1/1              5s 5s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              609s 15s/step
0.00014038563 1.0 1.0

 Epoch 11/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             523s 13s/step
7.7991594e-08 1.0 1.0

 Epoch 12/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/stepstep
1/1            3s 3s/stepste
1/1            3s 3s/stepste
1/1            1s 1s/stepste
40/40            525s 13s/step
0.0006737285 1.0 1.0

 Epoch 13/50
1/1            3s 3s/step
1/1            3s 3s/step
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
```

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1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              526s 13s/step
7.7406617e-07 1.0 1.0

 Epoch 14/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

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1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             526s 13s/step
2.1702554e-06 1.0 1.0

 Epoch 15/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             521s 13s/step
4.966001e-07 1.0 1.0

 Epoch 16/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             524s 13s/step
1.5529087e-05 1.0 1.0

 Epoch 17/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
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1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             524s 13s/step
0.00023530205 1.0 1.0

 Epoch 18/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
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1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
```

```
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             526s 13s/step
7.745989e-08 1.0 1.0

 Epoch 19/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
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1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             525s 13s/step
1.418274e-05 1.0 1.0
```

```
 Epoch 20/50
1/1            3s 3s/step
1/1            3s 3s/step
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/step/ste
1/1            3s 3s/stepstep
1/1            3s 3s/stepste
1/1            3s 3s/stepste
1/1            1s 1s/stepste
40/40            525s 13s/step
0.0003451232 1.0 1.0

 Epoch 21/50
1/1            3s 3s/step
1/1            3s 3s/step
```

```
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              523s 13s/step
8.679578e-06 1.0 1.0

 Epoch 22/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             525s 13s/step
7.304129e-05 1.0 1.0

 Epoch 23/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             522s 13s/step
3.3222338e-07 1.0 1.0

 Epoch 24/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             530s 13s/step
5.4413757e-08 1.0 1.0

 Epoch 25/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

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1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              532s 13s/step
5.1517686e-06 1.0 1.0

 Epoch 26/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

```
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              532s 13s/step
5.246887e-08 1.0 1.0

 Epoch 27/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             534s 13s/step
0.00019751408 1.0 1.0

 Epoch 28/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              529s 13s/step
2.9968407e-05 1.0 1.0

 Epoch 29/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             521s 13s/step
4.5672008e-05 1.0 1.0

 Epoch 30/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
```

```
1/1              3s 3s/stepste
1/1              1s 995ms/step
40/40              511s 13s/step
1.3129228e-06 1.0 1.0

 Epoch 31/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              516s 13s/step
2.0261771e-08 1.0 1.0
```

```
 Epoch 32/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             526s 13s/step
4.5190136e-05 1.0 1.0

 Epoch 33/50
1/1             3s 3s/step
1/1             3s 3s/step
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             512s 13s/step
0.00010457552 1.0 1.0

 Epoch 34/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              510s 13s/step
4.950043e-05 1.0 1.0

 Epoch 35/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             522s 13s/step
1.2157312e-06 1.0 1.0

 Epoch 36/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             5s 5s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             542s 14s/step
7.068989e-08 1.0 1.0

 Epoch 37/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             4s 4s/stepste
1/1             1s 1s/stepste
40/40             608s 15s/step
1.5770305e-05 1.0 1.0

 Epoch 38/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             608s 15s/step
0.0001516894 1.0 1.0

 Epoch 39/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             530s 13s/step
0.000118342665 1.0 1.0

 Epoch 40/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             528s 13s/step
6.430429e-07 1.0 1.0

 Epoch 41/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             527s 13s/step
2.4988465e-06 1.0 1.0

 Epoch 42/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
```

```
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              523s 13s/step
2.6237049e-05 1.0 1.0

 Epoch 43/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 996ms/step
40/40              513s 13s/step
3.38139e-05 1.0 1.0
```

```
 Epoch 44/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             4s 4s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             517s 13s/step
6.5787993e-09 1.0 1.0

 Epoch 45/50
1/1             3s 3s/step
1/1             3s 3s/step
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             517s 13s/step
1.10640285e-05 1.0 1.0

 Epoch 46/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             520s 13s/step
4.3887914e-05 1.0 1.0

 Epoch 47/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              520s 13s/step
1.282835e-06 1.0 1.0

 Epoch 48/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             518s 13s/step
2.5706495e-09 1.0 1.0

 Epoch 49/50
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
```

```
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/stepstep
1/1              3s 3s/stepste
1/1              3s 3s/stepste
1/1              1s 1s/stepste
40/40              519s 13s/step
1.6117524e-07 1.0 1.0

 Epoch 50/50
1/1              3s 3s/step
1/1              3s 3s/step
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
1/1              3s 3s/step/ste
```

```
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
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1/1             3s 3s/step/ste
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1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/step/ste
1/1             3s 3s/stepstep
1/1             3s 3s/stepste
1/1             3s 3s/stepste
1/1             1s 1s/stepste
40/40             518s 13s/step
3.1943797e-05 1.0 1.0
```

[31]:
```
# Import metric calculations
from tensorflow.keras.metrics import Precision, Recall
```

[32]:
```
# Get a batch of test data
test_input, test_val, y_true = test_data.as_numpy_iterator().next()
```

[52]:
```
y_hat = siamese_model.predict([test_input, test_val])
```

```
1/1             3s 3s/step
```

[55]:
```
# Post processing the results
[1 if prediction > 0.5 else 0 for prediction in y_hat.flatten()]
```

[55]:
```
[1, 1, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0]
```

[56]:
```
y_true
```

[56]:
```
array([1., 1., 0., 0., 1., 0., 1., 0., 0., 0., 0., 0., 1., 0., 0., 0.],
      dtype=float32)
```

[57]:
```
# Creating a metric object
m = Recall()

# Calculating the recall value
m.update_state(y_true, y_hat)
```

```
# Return Recall Result
m.result().numpy()
```

[57]: 1.0

[58]:
```
# Creating a metric object
m = Precision()

# Calculating the recall value
m.update_state(y_true, y_hat)

# Return Recall Result
m.result().numpy()
```

[58]: 1.0

[59]:
```
r = Recall()
p = Precision()

for test_input, test_val, y_true in test_data.as_numpy_iterator():
    yhat = siamese_model.predict([test_input, test_val])
    r.update_state(y_true, yhat)
    p.update_state(y_true,yhat)

print(r.result().numpy(), p.result().numpy())
```

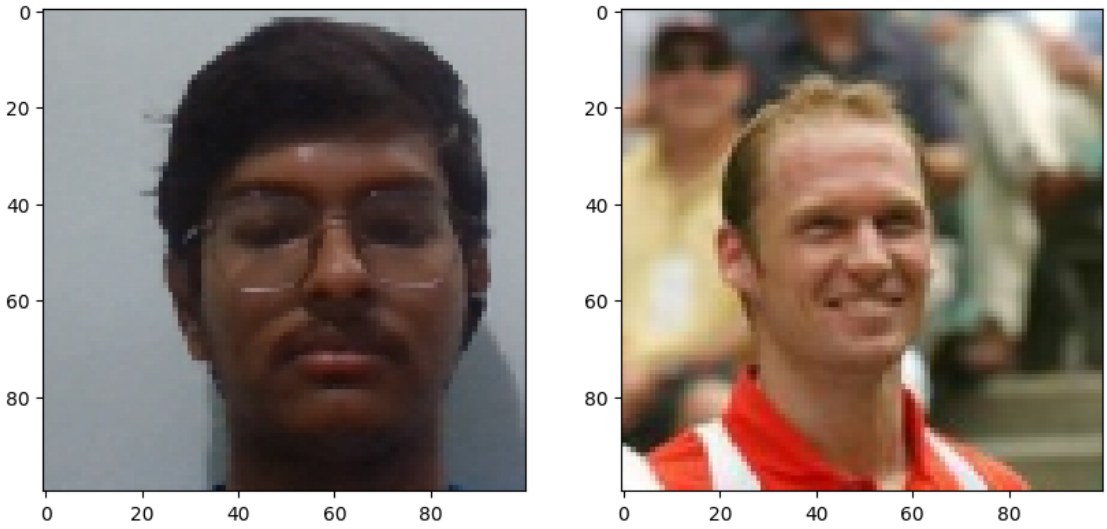
```
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             3s 3s/step
1/1             2s 2s/step
1.0 1.0
```

[80]:
```
# Set plot size
plt.figure(figsize=(10,8))
```

```
# Set first subplot
plt.subplot(1,2,1)
plt.imshow(test_input[0])

# Set second subplot
plt.subplot(1,2,2)
plt.imshow(test_val[0])

# Renders cleanly
plt.show()
```



[82]:
```
y_true[0]
```

[82]:
```
0.0
```

[67]:
```
# Save weights
siamese_model.save('siamesemodelv2.keras')
```

[62]:
```
L1Dist
```

[62]:
```
__main__.L1Dist
```

[15]:
```
# Reload model
siamese_model = tf.keras.models.load_model('siamesemodelv2.keras',
                                           custom_objects={'L1Dist':L1Dist,␣
↪'BinaryCrossentropy':tf.losses.BinaryCrossentropy})
```

[33]:
```python
# Make predictions with reloaded model
siamese_model.predict([test_input, test_val])
```

```
1/1              4s 4s/step
```

[33]:
```
array([[[9.9999928e-01],
        [9.9995589e-01],
        [1.0000000e+00],
        [1.0000000e+00],
        [2.3357758e-09],
        [2.6087063e-08],
        [9.9999881e-01],
        [9.9999976e-01],
        [2.3470565e-09],
        [1.0000000e+00],
        [9.6783984e-01],
        [1.0000000e+00],
        [9.9999565e-01],
        [1.9341664e-06],
        [8.9480610e-11],
        [9.9961621e-01]]], dtype=float32)
```

[34]:
```python
# View model summary
siamese_model.summary()
```

```
Model: "SiameseNetwork"


 Layer (type)                    Output Shape                 Param # ␣
↪Connected to

 input_img (InputLayer)          (None, 100, 100, 3)                0   - ␣
↪

 validation_img (InputLayer)     (None, 100, 100, 3)                0   - ␣
↪

 embedding (Functional)          (None, 4096)              38,960,448 ␣
↪input_img[0][0],
                                                                      ␣
↪validation_img[0][0]

 l1_dist_2 (L1Dist)              (1, None, 4096)                    0 ␣
↪embedding[0][0],
                                                                      ␣
↪embedding[1][0]
```

```
 dense_2 (Dense)                 (1, None, 1)                          4,097  ␣
↪l1_dist_2[0][0]


Total params: 38,964,545 (148.64 MB)

Trainable params: 38,964,545 (148.64 MB)

Non-trainable params: 0 (0.00 B)
```

[35]:
```
#Real Time Test
os.listdir(os.path.join('application_data', 'verification_images'))
```

[35]:
```
['4a14eae9-308e-11ef-a3eb-489ebdf94e09.jpg',
 '4a233941-308e-11ef-85fe-489ebdf94e09.jpg',
 '4a31b815-308e-11ef-9ea5-489ebdf94e09.jpg',
 '4a553fd0-308e-11ef-9604-489ebdf94e09.jpg',
 '4a639005-308e-11ef-ac7c-489ebdf94e09.jpg',
 '4a723b26-308e-11ef-a085-489ebdf94e09.jpg',
 '4a771d26-308e-11ef-8a4c-489ebdf94e09.jpg',
 '4a7c148e-308e-11ef-8484-489ebdf94e09.jpg',
 '4a80cf70-308e-11ef-82db-489ebdf94e09.jpg',
 '4a8cd1d9-308e-11ef-9b02-489ebdf94e09.jpg',
 '4aa03d10-308e-11ef-986f-489ebdf94e09.jpg',
 '4ac8bade-308e-11ef-9c9e-489ebdf94e09.jpg',
 '4ad6e119-308e-11ef-804b-489ebdf94e09.jpg',
 '4ae556b9-308e-11ef-a4db-489ebdf94e09.jpg',
 '4afa9471-308e-11ef-a85d-489ebdf94e09.jpg',
 '4b08f73c-308e-11ef-aeef-489ebdf94e09.jpg',
 '4b175fc5-308e-11ef-9a85-489ebdf94e09.jpg',
 '4b1c1282-308e-11ef-9838-489ebdf94e09.jpg',
 '4b3b9381-308e-11ef-be3d-489ebdf94e09.jpg',
 '4b5829b8-308e-11ef-a150-489ebdf94e09.jpg',
 '4b5cf849-308e-11ef-bc78-489ebdf94e09.jpg',
 '4b7768b1-308e-11ef-9025-489ebdf94e09.jpg',
 '4b7c4f6b-308e-11ef-a441-489ebdf94e09.jpg',
 '4b8153c4-308e-11ef-9000-489ebdf94e09.jpg',
 '4b85dd3f-308e-11ef-b33b-489ebdf94e09.jpg',
 '4b8ac030-308e-11ef-b880-489ebdf94e09.jpg',
 '4b99325d-308e-11ef-a193-489ebdf94e09.jpg',
 '4b9e0b43-308e-11ef-8325-489ebdf94e09.jpg',
 '4ba2cc05-308e-11ef-8148-489ebdf94e09.jpg',
 '4ba9d2da-308e-11ef-9ac3-489ebdf94e09.jpg',
 '4bae97d6-308e-11ef-a408-489ebdf94e09.jpg',
 '4bbcd1ad-308e-11ef-832d-489ebdf94e09.jpg',
```

```
 '4bcb3f16-308e-11ef-94cf-489ebdf94e09.jpg',
 '4bd7303d-308e-11ef-9f84-489ebdf94e09.jpg',
 '4be594de-308e-11ef-a885-489ebdf94e09.jpg',
 '4bea4dbe-308e-11ef-8b15-489ebdf94e09.jpg',
 '4bef361b-308e-11ef-a7ca-489ebdf94e09.jpg',
 '4bf40565-308e-11ef-b554-489ebdf94e09.jpg',
 '4c1cae8a-308e-11ef-a4a1-489ebdf94e09.jpg',
 '4c2b2593-308e-11ef-a2dc-489ebdf94e09.jpg',
 '4c3e7be4-308e-11ef-b02f-489ebdf94e09.jpg',
 '4c5d7e26-308e-11ef-a8a2-489ebdf94e09.jpg',
 '4c70bd0b-308e-11ef-88cf-489ebdf94e09.jpg',
 '4c7f8c3e-308e-11ef-8df7-489ebdf94e09.jpg',
 '61e813d3-308e-11ef-be1f-489ebdf94e09.jpg',
 '61ecc4b7-308e-11ef-afc3-489ebdf94e09.jpg',
 '62ac4882-308e-11ef-9e0c-489ebdf94e09.jpg',
 '62b0fec4-308e-11ef-9ff4-489ebdf94e09.jpg',
 '62bf4305-308e-11ef-87b5-489ebdf94e09.jpg',
 '62c3ea73-308e-11ef-8f97-489ebdf94e09.jpg',
 '62c8871b-308e-11ef-a7f3-489ebdf94e09.jpg',
 '62e31295-308e-11ef-ba10-489ebdf94e09.jpg',
 '62f1623d-308e-11ef-83ea-489ebdf94e09.jpg',
 '62ffac4c-308e-11ef-aabc-489ebdf94e09.jpg']
```

[36]:
```
os.path.join('application_data', 'input_image', 'input_image.jpg')
```

[36]:
```
'application_data\\input_image\\input_image.jpg'
```

[37]:
```
for image in os.listdir(os.path.join('application_data',␣
 ↪'verification_images')):
    validation_img = os.path.join('application_data', 'verification_images',␣
 ↪image)
    print(validation_img)
```

```
application_data\verification_images\4a14eae9-308e-11ef-a3eb-489ebdf94e09.jpg
application_data\verification_images\4a233941-308e-11ef-85fe-489ebdf94e09.jpg
application_data\verification_images\4a31b815-308e-11ef-9ea5-489ebdf94e09.jpg
application_data\verification_images\4a553fd0-308e-11ef-9604-489ebdf94e09.jpg
application_data\verification_images\4a639005-308e-11ef-ac7c-489ebdf94e09.jpg
application_data\verification_images\4a723b26-308e-11ef-a085-489ebdf94e09.jpg
application_data\verification_images\4a771d26-308e-11ef-8a4c-489ebdf94e09.jpg
application_data\verification_images\4a7c148e-308e-11ef-8484-489ebdf94e09.jpg
application_data\verification_images\4a80cf70-308e-11ef-82db-489ebdf94e09.jpg
application_data\verification_images\4a8cd1d9-308e-11ef-9b02-489ebdf94e09.jpg
application_data\verification_images\4aa03d10-308e-11ef-986f-489ebdf94e09.jpg
application_data\verification_images\4ac8bade-308e-11ef-9c9e-489ebdf94e09.jpg
application_data\verification_images\4ad6e119-308e-11ef-804b-489ebdf94e09.jpg
application_data\verification_images\4ae556b9-308e-11ef-a4db-489ebdf94e09.jpg
```

```
application_data\verification_images\4afa9471-308e-11ef-a85d-489ebdf94e09.jpg
application_data\verification_images\4b08f73c-308e-11ef-aeef-489ebdf94e09.jpg
application_data\verification_images\4b175fc5-308e-11ef-9a85-489ebdf94e09.jpg
application_data\verification_images\4b1c1282-308e-11ef-9838-489ebdf94e09.jpg
application_data\verification_images\4b3b9381-308e-11ef-be3d-489ebdf94e09.jpg
application_data\verification_images\4b5829b8-308e-11ef-a150-489ebdf94e09.jpg
application_data\verification_images\4b5cf849-308e-11ef-bc78-489ebdf94e09.jpg
application_data\verification_images\4b7768b1-308e-11ef-9025-489ebdf94e09.jpg
application_data\verification_images\4b7c4f6b-308e-11ef-a441-489ebdf94e09.jpg
application_data\verification_images\4b8153c4-308e-11ef-9000-489ebdf94e09.jpg
application_data\verification_images\4b85dd3f-308e-11ef-b33b-489ebdf94e09.jpg
application_data\verification_images\4b8ac030-308e-11ef-b880-489ebdf94e09.jpg
application_data\verification_images\4b99325d-308e-11ef-a193-489ebdf94e09.jpg
application_data\verification_images\4b9e0b43-308e-11ef-8325-489ebdf94e09.jpg
application_data\verification_images\4ba2cc05-308e-11ef-8148-489ebdf94e09.jpg
application_data\verification_images\4ba9d2da-308e-11ef-9ac3-489ebdf94e09.jpg
application_data\verification_images\4bae97d6-308e-11ef-a408-489ebdf94e09.jpg
application_data\verification_images\4bbcd1ad-308e-11ef-832d-489ebdf94e09.jpg
application_data\verification_images\4bcb3f16-308e-11ef-94cf-489ebdf94e09.jpg
application_data\verification_images\4bd7303d-308e-11ef-9f84-489ebdf94e09.jpg
application_data\verification_images\4be594de-308e-11ef-a885-489ebdf94e09.jpg
application_data\verification_images\4bea4dbe-308e-11ef-8b15-489ebdf94e09.jpg
application_data\verification_images\4bef361b-308e-11ef-a7ca-489ebdf94e09.jpg
application_data\verification_images\4bf40565-308e-11ef-b554-489ebdf94e09.jpg
application_data\verification_images\4c1cae8a-308e-11ef-a4a1-489ebdf94e09.jpg
application_data\verification_images\4c2b2593-308e-11ef-a2dc-489ebdf94e09.jpg
application_data\verification_images\4c3e7be4-308e-11ef-b02f-489ebdf94e09.jpg
application_data\verification_images\4c5d7e26-308e-11ef-a8a2-489ebdf94e09.jpg
application_data\verification_images\4c70bd0b-308e-11ef-88cf-489ebdf94e09.jpg
application_data\verification_images\4c7f8c3e-308e-11ef-8df7-489ebdf94e09.jpg
application_data\verification_images\61e813d3-308e-11ef-be1f-489ebdf94e09.jpg
application_data\verification_images\61ecc4b7-308e-11ef-afc3-489ebdf94e09.jpg
application_data\verification_images\62ac4882-308e-11ef-9e0c-489ebdf94e09.jpg
application_data\verification_images\62b0fec4-308e-11ef-9ff4-489ebdf94e09.jpg
application_data\verification_images\62bf4305-308e-11ef-87b5-489ebdf94e09.jpg
application_data\verification_images\62c3ea73-308e-11ef-8f97-489ebdf94e09.jpg
application_data\verification_images\62c8871b-308e-11ef-a7f3-489ebdf94e09.jpg
application_data\verification_images\62e31295-308e-11ef-ba10-489ebdf94e09.jpg
application_data\verification_images\62f1623d-308e-11ef-83ea-489ebdf94e09.jpg
application_data\verification_images\62ffac4c-308e-11ef-aabc-489ebdf94e09.jpg
```

[38]:
```
def verify(model, detection_threshold, verification_threshold):
    # Build results array
    results = []
    for image in os.listdir(os.path.join('application_data',␣
 ↪'verification_images')):
```

```
        input_img = preprocess(os.path.join('application_data', 'input_image',␣
↪'input_image.jpg'))
        validation_img = preprocess(os.path.join('application_data',␣
↪'verification_images', image))

        # Make Predictions
        result = model.predict(list(np.expand_dims([input_img, validation_img],␣
↪axis=1)))
        results.append(result)

    # Detection Threshold: Metric above which a prediciton is considered␣
↪positive
    detection = np.sum(np.array(results) > detection_threshold)

    # Verification Threshold: Proportion of positive predictions / total␣
↪positive samples
    verification = detection / len(os.listdir(os.path.join('application_data',␣
↪'verification_images')))
    verified = verification > verification_threshold

    return results, verified
```

[39]:
```
cap = cv2.VideoCapture(0)
while cap.isOpened():
    ret, frame = cap.read()
    frame = frame[120:120+250,200:200+250, :]

    cv2.imshow('Verification', frame)

    # Verification trigger
    if cv2.waitKey(10) & 0xFF == ord('v'):
        # Save input image to application_data/input_image folder
        cv2.imwrite(os.path.join('application_data', 'input_image',␣
↪'input_image.jpg'), frame)
        # Run verification
        results, verified = verify(siamese_model, 0.9, 0.7)
        print(verified)

    if cv2.waitKey(10) & 0xFF == ord('q'):
        break
cap.release()
cv2.destroyAllWindows()
```

```
1/1             1s 552ms/step
1/1             0s 296ms/step
1/1             0s 293ms/step
1/1             0s 299ms/step
```

```
1/1             0s 299ms/step
1/1             0s 291ms/step
1/1             0s 284ms/step
1/1             0s 289ms/step
1/1             0s 305ms/step
1/1             0s 285ms/step
1/1             0s 287ms/step
1/1             0s 286ms/step
1/1             0s 282ms/step
1/1             0s 291ms/step
1/1             0s 292ms/step
1/1             0s 317ms/step
1/1             0s 324ms/step
1/1             0s 317ms/step
1/1             0s 295ms/step
1/1             0s 319ms/step
1/1             0s 351ms/step
1/1             0s 309ms/step
1/1             0s 292ms/step
1/1             0s 322ms/step
1/1             0s 301ms/step
1/1             0s 300ms/step
1/1             0s 318ms/step
1/1             0s 286ms/step
1/1             0s 295ms/step
1/1             0s 294ms/step
1/1             0s 319ms/step
1/1             0s 363ms/step
1/1             0s 354ms/step
1/1             0s 297ms/step
1/1             0s 334ms/step
1/1             0s 322ms/step
1/1             0s 357ms/step
1/1             0s 317ms/step
1/1             0s 323ms/step
1/1             0s 324ms/step
1/1             0s 325ms/step
1/1             0s 319ms/step
1/1             0s 341ms/step
1/1             0s 343ms/step
1/1             0s 286ms/step
1/1             0s 315ms/step
1/1             0s 307ms/step
1/1             0s 301ms/step
1/1             0s 273ms/step
1/1             0s 270ms/step
1/1             0s 262ms/step
1/1             0s 259ms/step
```

```
1/1             0s 294ms/step
1/1             0s 296ms/step
True
1/1             0s 288ms/step
1/1             0s 298ms/step
1/1             0s 291ms/step
1/1             0s 310ms/step
1/1             0s 294ms/step
1/1             0s 296ms/step
1/1             0s 302ms/step
1/1             0s 323ms/step
1/1             0s 310ms/step
1/1             0s 317ms/step
1/1             0s 324ms/step
1/1             0s 318ms/step
1/1             0s 298ms/step
1/1             0s 287ms/step
1/1             0s 314ms/step
1/1             0s 306ms/step
1/1             0s 300ms/step
1/1             0s 293ms/step
1/1             0s 305ms/step
1/1             0s 353ms/step
1/1             0s 326ms/step
1/1             0s 313ms/step
1/1             0s 326ms/step
1/1             0s 328ms/step
1/1             0s 302ms/step
1/1             0s 356ms/step
1/1             0s 332ms/step
1/1             0s 299ms/step
1/1             0s 324ms/step
1/1             0s 333ms/step
1/1             0s 285ms/step
1/1             0s 291ms/step
1/1             0s 294ms/step
1/1             0s 286ms/step
1/1             0s 291ms/step
1/1             0s 294ms/step
1/1             0s 303ms/step
1/1             0s 333ms/step
1/1             0s 312ms/step
1/1             0s 294ms/step
1/1             0s 285ms/step
1/1             0s 290ms/step
1/1             0s 298ms/step
1/1             0s 297ms/step
1/1             0s 285ms/step
```

```
1/1             0s 293ms/step
1/1             0s 296ms/step
1/1             0s 310ms/step
1/1             0s 308ms/step
1/1             0s 298ms/step
1/1             0s 326ms/step
1/1             0s 302ms/step
1/1             0s 371ms/step
1/1             0s 297ms/step
False
1/1             0s 294ms/step
1/1             0s 292ms/step
1/1             0s 297ms/step
1/1             0s 311ms/step
1/1             0s 314ms/step
1/1             0s 298ms/step
1/1             0s 310ms/step
1/1             0s 320ms/step
1/1             0s 349ms/step
1/1             0s 289ms/step
1/1             0s 295ms/step
1/1             0s 297ms/step
1/1             0s 328ms/step
1/1             0s 308ms/step
1/1             0s 334ms/step
1/1             0s 312ms/step
1/1             0s 296ms/step
1/1             0s 310ms/step
1/1             0s 315ms/step
1/1             0s 307ms/step
1/1             0s 369ms/step
1/1             0s 323ms/step
1/1             0s 489ms/step
1/1             0s 299ms/step
1/1             0s 340ms/step
1/1             1s 531ms/step
1/1             0s 403ms/step
1/1             0s 346ms/step
1/1             0s 384ms/step
1/1             0s 329ms/step
1/1             0s 368ms/step
1/1             0s 308ms/step
1/1             0s 316ms/step
1/1             0s 355ms/step
1/1             0s 348ms/step
1/1             0s 315ms/step
1/1             0s 326ms/step
1/1             0s 323ms/step
```

```
1/1             0s 330ms/step
1/1             0s 306ms/step
1/1             0s 288ms/step
1/1             0s 300ms/step
1/1             0s 287ms/step
1/1             0s 289ms/step
1/1             0s 308ms/step
1/1             0s 301ms/step
1/1             0s 470ms/step
1/1             0s 403ms/step
1/1             0s 332ms/step
1/1             0s 487ms/step
1/1             0s 458ms/step
1/1             0s 315ms/step
1/1             0s 293ms/step
1/1             0s 302ms/step
True
1/1             0s 292ms/step
1/1             0s 310ms/step
1/1             0s 298ms/step
1/1             0s 288ms/step
1/1             0s 292ms/step
1/1             0s 292ms/step
1/1             0s 292ms/step
1/1             0s 294ms/step
1/1             0s 345ms/step
1/1             0s 301ms/step
1/1             0s 289ms/step
1/1             0s 303ms/step
1/1             0s 288ms/step
1/1             0s 288ms/step
1/1             0s 300ms/step
1/1             0s 302ms/step
1/1             0s 290ms/step
1/1             0s 338ms/step
1/1             0s 323ms/step
1/1             0s 283ms/step
1/1             0s 283ms/step
1/1             0s 293ms/step
1/1             0s 301ms/step
1/1             0s 341ms/step
1/1             0s 322ms/step
1/1             0s 344ms/step
1/1             0s 311ms/step
1/1             0s 284ms/step
1/1             0s 281ms/step
1/1             0s 284ms/step
1/1             0s 287ms/step
```

```
1/1             0s 295ms/step
1/1             0s 302ms/step
1/1             0s 323ms/step
1/1             1s 572ms/step
1/1             0s 410ms/step
1/1             0s 326ms/step
1/1             0s 301ms/step
1/1             0s 320ms/step
1/1             0s 289ms/step
1/1             0s 283ms/step
1/1             0s 289ms/step
1/1             0s 295ms/step
1/1             0s 282ms/step
1/1             0s 285ms/step
1/1             0s 269ms/step
1/1             0s 270ms/step
1/1             0s 282ms/step
1/1             0s 270ms/step
1/1             0s 273ms/step
1/1             0s 325ms/step
1/1             0s 313ms/step
1/1             0s 299ms/step
1/1             0s 313ms/step
False
1/1             0s 286ms/step
1/1             0s 301ms/step
1/1             0s 309ms/step
1/1             0s 299ms/step
1/1             0s 349ms/step
1/1             0s 299ms/step
1/1             0s 292ms/step
1/1             0s 292ms/step
1/1             0s 308ms/step
1/1             0s 316ms/step
1/1             0s 289ms/step
1/1             0s 337ms/step
1/1             0s 313ms/step
1/1             0s 306ms/step
1/1             0s 300ms/step
1/1             0s 293ms/step
1/1             0s 295ms/step
1/1             0s 356ms/step
1/1             0s 327ms/step
1/1             0s 319ms/step
1/1             0s 321ms/step
1/1             0s 459ms/step
1/1             0s 320ms/step
1/1             0s 385ms/step
```

```
1/1             0s 392ms/step
1/1             0s 330ms/step
1/1             0s 376ms/step
1/1             0s 368ms/step
1/1             0s 295ms/step
1/1             1s 555ms/step
1/1             0s 296ms/step
1/1             0s 368ms/step
1/1             0s 311ms/step
1/1             0s 343ms/step
1/1             0s 304ms/step
1/1             0s 297ms/step
1/1             0s 305ms/step
1/1             0s 293ms/step
1/1             0s 320ms/step
1/1             0s 383ms/step
1/1             1s 518ms/step
1/1             0s 316ms/step
1/1             0s 351ms/step
1/1             0s 336ms/step
1/1             0s 339ms/step
1/1             0s 456ms/step
1/1             0s 309ms/step
1/1             0s 305ms/step
1/1             0s 379ms/step
1/1             0s 440ms/step
1/1             0s 460ms/step
1/1             0s 410ms/step
1/1             0s 318ms/step
1/1             0s 439ms/step
False
1/1             0s 294ms/step
1/1             0s 300ms/step
1/1             0s 310ms/step
1/1             0s 364ms/step
1/1             0s 331ms/step
1/1             1s 631ms/step
1/1             0s 324ms/step
1/1             0s 359ms/step
1/1             0s 307ms/step
1/1             0s 366ms/step
1/1             0s 426ms/step
1/1             0s 380ms/step
1/1             0s 400ms/step
1/1             0s 346ms/step
1/1             0s 363ms/step
1/1             0s 464ms/step
1/1             0s 367ms/step
```

```
1/1             0s 388ms/step
1/1             0s 361ms/step
1/1             0s 316ms/step
1/1             0s 439ms/step
1/1             0s 306ms/step
1/1             0s 324ms/step
1/1             0s 317ms/step
1/1             0s 305ms/step
1/1             0s 298ms/step
1/1             0s 342ms/step
1/1             0s 379ms/step
1/1             0s 345ms/step
1/1             0s 347ms/step
1/1             1s 957ms/step
1/1             0s 396ms/step
1/1             0s 267ms/step
1/1             0s 310ms/step
1/1             0s 419ms/step
1/1             1s 594ms/step
1/1             0s 472ms/step
1/1             0s 427ms/step
1/1             0s 396ms/step
1/1             1s 503ms/step
1/1             1s 501ms/step
1/1             0s 390ms/step
1/1             1s 682ms/step
1/1             1s 1s/step
1/1             1s 966ms/step
1/1             1s 567ms/step
1/1             0s 383ms/step
1/1             0s 389ms/step
1/1             0s 389ms/step
1/1             0s 433ms/step
1/1             0s 361ms/step
1/1             0s 308ms/step
1/1             0s 278ms/step
1/1             0s 260ms/step
False
1/1             0s 284ms/step
1/1             0s 298ms/step
1/1             0s 306ms/step
1/1             0s 311ms/step
1/1             0s 382ms/step
1/1             0s 329ms/step
1/1             0s 368ms/step
1/1             0s 337ms/step
1/1             0s 492ms/step
1/1             0s 318ms/step
```

```
1/1             0s 302ms/step
1/1             0s 307ms/step
1/1             0s 413ms/step
1/1             0s 313ms/step
1/1             0s 387ms/step
1/1             0s 339ms/step
1/1             0s 467ms/step
1/1             0s 326ms/step
1/1             0s 303ms/step
1/1             0s 305ms/step
1/1             0s 302ms/step
1/1             0s 301ms/step
1/1             0s 312ms/step
1/1             0s 305ms/step
1/1             0s 301ms/step
1/1             0s 311ms/step
1/1             0s 456ms/step
1/1             0s 303ms/step
1/1             0s 341ms/step
1/1             0s 304ms/step
1/1             1s 530ms/step
1/1             0s 297ms/step
1/1             0s 297ms/step
1/1             0s 272ms/step
1/1             0s 381ms/step
1/1             0s 275ms/step
1/1             0s 293ms/step
1/1             0s 356ms/step
1/1             0s 498ms/step
1/1             0s 353ms/step
1/1             0s 347ms/step
1/1             0s 373ms/step
1/1             0s 449ms/step
1/1             0s 390ms/step
1/1             0s 420ms/step
1/1             0s 314ms/step
1/1             1s 546ms/step
1/1             0s 390ms/step
1/1             0s 401ms/step
1/1             0s 305ms/step
1/1             1s 551ms/step
1/1             0s 351ms/step
1/1             0s 416ms/step
1/1             0s 332ms/step
True
```

[94]:
```
np.sum(np.squeeze(results) > 0.9)
```

[94]: 11

[95]:
```
results
```

[95]:
```
[array([[[0.31303516]]], dtype=float32),
 array([[[0.5836606]]], dtype=float32),
 array([[[0.627879]]], dtype=float32),
 array([[[0.9855501]]], dtype=float32),
 array([[[0.91244006]]], dtype=float32),
 array([[[0.95380336]]], dtype=float32),
 array([[[0.9495617]]], dtype=float32),
 array([[[0.8916075]]], dtype=float32),
 array([[[0.47227895]]], dtype=float32),
 array([[[0.10275634]]], dtype=float32),
 array([[[0.04640492]]], dtype=float32),
 array([[[0.10259638]]], dtype=float32),
 array([[[0.8713087]]], dtype=float32),
 array([[[0.8355404]]], dtype=float32),
 array([[[0.9771904]]], dtype=float32),
 array([[[0.74465185]]], dtype=float32),
 array([[[0.14142142]]], dtype=float32),
 array([[[0.09276894]]], dtype=float32),
 array([[[0.14172997]]], dtype=float32),
 array([[[0.36286083]]], dtype=float32),
 array([[[0.42708516]]], dtype=float32),
 array([[[0.6253432]]], dtype=float32),
 array([[[0.1914308]]], dtype=float32),
 array([[[0.24130033]]], dtype=float32),
 array([[[0.52326876]]], dtype=float32),
 array([[[0.34578973]]], dtype=float32),
 array([[[0.46450302]]], dtype=float32),
 array([[[0.15893555]]], dtype=float32),
 array([[[0.58240074]]], dtype=float32),
 array([[[0.64313596]]], dtype=float32),
 array([[[0.74953085]]], dtype=float32),
 array([[[0.81726974]]], dtype=float32),
 array([[[0.9123311]]], dtype=float32),
 array([[[0.722709]]], dtype=float32),
 array([[[0.56809324]]], dtype=float32),
 array([[[0.7470698]]], dtype=float32),
 array([[[0.67827314]]], dtype=float32),
 array([[[0.29640496]]], dtype=float32),
 array([[[0.25948665]]], dtype=float32),
 array([[[0.35465083]]], dtype=float32),
 array([[[0.09984604]]], dtype=float32),
 array([[[0.8539309]]], dtype=float32),
 array([[[0.94468963]]], dtype=float32),
```

```
array([[[0.96319836]]], dtype=float32),
array([[[0.9676644]]], dtype=float32),
array([[[0.98082364]]], dtype=float32),
array([[[0.00034195]]], dtype=float32),
array([[[5.4286367e-05]]], dtype=float32),
array([[[3.547324e-05]]], dtype=float32),
array([[[3.9514573e-05]]], dtype=float32),
array([[[2.1483269e-05]]], dtype=float32),
array([[[0.00082618]]], dtype=float32),
array([[[0.8724174]]], dtype=float32),
array([[[0.9929422]]], dtype=float32)]
```

[92]:

[ ]: