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## Objectives

Use the given dataset in this link.

[https://drive.google.com/drive/folders/1N5cVU1jH-Yjvt3eLDDWShEp000\\_UUeic?usp=sharing](https://drive.google.com/drive/folders/1N5cVU1jH-Yjvt3eLDDWShEp000_UUeic?usp=sharing)

1. Build and train a CNN model from a scratch. Apply different regularization techniques and data preprocessing to reduce overfitting.
2. Plot the training and validation loss and accuracy. The target accuracy is 85 and above.

## Pre-processing

```
from google.colab import drive
drive.mount('/content/drive')
```

Mounted at /content/drive

```
# Unzip the files
```

```
!unzip "/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd yr, 2nd sem)/Data Science 3/data/Covid_19.zip" -d "/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd yr, 2nd sem)/Data Science 3/data/prelim_data_2"
```

```
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import os
```

```
from tensorflow.keras.optimizers import RMSprop, Adam, SGD
from tensorflow.keras.layers import Conv2D, Dense, Flatten, Dropout, MaxPooling2D
from tensorflow.keras.models import Sequential
```

- There are 3,616 COVID images/masks
- There are 6,012 Lung Opacity images/makss
- There are 10,192 Normal images/masks
- There are 1,345 Viral Pneumonia images/masks

```
# We can extract 1,345 images of viral pneumonia, normal, and covid to keep our dataset balanced and
```

*# not imbalanced*

```
import random
vp_imgs = "/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd yr,
2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/Viral Pneumonia/images"
normal_imgs = "/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd
yr, 2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/Normal/images"
cov_imgs = "/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd yr,
2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/COVID/images"
```

Create folders called 'train' and 'test' located in '/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd yr, 2nd sem)/Data Science 3/data/prelim\_data\_2/COVID-19\_Radiography\_Dataset' then create subfolders for each called 'normal', 'covid', and 'viral\_pneumonia'

The training folder will contain 941 randomized images for each respective subfolder types (i.e. 941 images for covid, normal, and viral\_pneumonia)

The test folder will contain 404 randomized images for each respective subfolder types (i.e. 404 images for covid, normal, and viral\_pneumonia)

```
import shutil
```

```
cov_names = os.listdir(cov_imgs)
normal_names = os.listdir(normal_imgs)
vp_names = os.listdir(vp_imgs)

random.shuffle(cov_names)
random.shuffle(vp_names)
random.shuffle(normal_names)
for i in range(941):
    cov_img = cov_names[i]
    normal_img = normal_names[i]
    vp_img = vp_names[i]
    cov_path = os.path.join(cov_imgs, cov_img)
    cov_train_path = os.path.join("/content/drive/MyDrive/TIP S.Y.'s/TIP
2021-2022 (3rd yr, 2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/train/covid", cov_img)
    normal_path = os.path.join(normal_imgs, normal_img)
    normal_train_path = os.path.join("/content/drive/MyDrive/TIP
S.Y.'s/TIP 2021-2022 (3rd yr, 2nd sem)/Data Science
3/data/prelim_data_2/COVID-19_Radiography_Dataset/train/normal",
normal_img)
    vp_path = os.path.join(vp_imgs, vp_img)
    vp_train_path = os.path.join("/content/drive/MyDrive/TIP S.Y.'s/TIP
2021-2022 (3rd yr, 2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/train/viral_pneumonia", vp_img)
```

```
shutil.move(cov_path, cov_train_path)
print("moving cov image ", i)
shutil.move(normal_path, normal_train_path)
print("moving normal image ", i)
shutil.move(vp_path, vp_train_path)
print("moving viral pneumonia image ", i)
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cov_names = os.listdir(cov_imgs)
normal_names = os.listdir(normal_imgs)
vp_names = os.listdir(vp_imgs)

random.shuffle(cov_names)
random.shuffle(vp_names)
random.shuffle(normal_names)
for i in range(404):
    cov_img = cov_names[i]
    normal_img = normal_names[i]
    vp_img = vp_names[i]
    cov_path = os.path.join(cov_imgs, cov_img)
    cov_test_path = os.path.join("/content/drive/MyDrive/TIP S.Y.'s/TIP
2021-2022 (3rd yr, 2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/test/covid", cov_img)
    normal_path = os.path.join(normal_imgs, normal_img)
    normal_test_path = os.path.join("/content/drive/MyDrive/TIP
S.Y.'s/TIP 2021-2022 (3rd yr, 2nd sem)/Data Science
3/data/prelim_data_2/COVID-19_Radiography_Dataset/test/normal",
normal_img)

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vp_path = os.path.join(vp_imgs, vp_img)
vp_test_path = os.path.join("/content/drive/MyDrive/TIP S.Y.'s/TIP
2021-2022 (3rd yr, 2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/test/viral_pneumonia", vp_img)
shutil.move(cov_path, cov_test_path)
print("moving cov image ", i)
shutil.move(normal_path, normal_test_path)
print("moving normal image ", i)
shutil.move(vp_path, vp_test_path)
print("moving viral pneumonia image ", i)
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```

train_path = "/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd yr,
2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/train"
test_path = "/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd yr,
2nd sem)/Data Science 3/data/prelim_data_2/COVID-
19_Radiography_Dataset/test"

```

*# Augmentation on the training datasets*

```

from keras.preprocessing.image import ImageDataGenerator

```

```

train_datagen = ImageDataGenerator(
    rescale = 1./255,
    shear_range = 0.2,
    zoom_range = 0.2,
    horizontal_flip = True
)

```

```

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

```

```

train_generator= train_datagen.flow_from_directory(
    "/content/drive/MyDrive/TIP S.Y.'s/TIP 2021-2022 (3rd yr, 2nd
sem)/Data Science
3/data/prelim_data_2/COVID-19_Radiography_Dataset/train",
    target_size = (224,224),
    batch_size = 32,

```

```

    class_mode = "categorical"
)

Found 2823 images belonging to 3 classes.

train_generator.class_indices
{'covid': 0, 'normal': 1, 'viral_pneumonia': 2}

test_generator = test_datagen.flow_from_directory(
    test_path,
    target_size = (224,224),
    batch_size = 32,
    class_mode = "categorical"
)

```

```

Found 1212 images belonging to 3 classes.

test_generator.class_indices
{'covid': 0, 'normal': 1, 'viral_pneumonia': 2}

```

## Model 1

- Test loss: 0.5329847931861877
- Test accuracy: 0.7698019742965698
- Train loss: 0.5925237536430359
- Train accuracy: 0.7201558351516724

*# Build the Sequential CNN model*

```

model = Sequential()
model.add(Conv2D(32, kernel_size=(3,3), activation = "relu",
input_shape = (224,224,3)))
model.add(Conv2D(64, (3,3), activation = 'relu'))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Dropout(0.25))

model.add(Conv2D(64, (3,3), activation = "relu"))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Dropout(0.25))

model.add(Conv2D(128, (3,3), activation = "relu"))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Dropout(0.25))

model.add(Flatten())
model.add(Dense(64, activation = "relu"))
model.add(Dropout(0.5))

model.add(Dense(3, activation = "softmax"))

```

```
model.compile(loss = "categorical_crossentropy",
              optimizer="adam",
              metrics = ["accuracy"])
```

```
model.summary()
```

```
Model: "sequential_13"
```

Layer (type)	Output Shape	Param #
conv2d_40 (Conv2D)	(None, 222, 222, 32)	896
conv2d_41 (Conv2D)	(None, 220, 220, 64)	18496
max_pooling2d_27 (MaxPooling2D)	(None, 110, 110, 64)	0
dropout_36 (Dropout)	(None, 110, 110, 64)	0
conv2d_42 (Conv2D)	(None, 108, 108, 64)	36928
max_pooling2d_28 (MaxPooling2D)	(None, 54, 54, 64)	0
dropout_37 (Dropout)	(None, 54, 54, 64)	0
conv2d_43 (Conv2D)	(None, 52, 52, 128)	73856
max_pooling2d_29 (MaxPooling2D)	(None, 26, 26, 128)	0
dropout_38 (Dropout)	(None, 26, 26, 128)	0
flatten_9 (Flatten)	(None, 86528)	0
dense_17 (Dense)	(None, 64)	5537856
dropout_39 (Dropout)	(None, 64)	0
dense_18 (Dense)	(None, 3)	195

```
=====  
Total params: 5,668,227  
Trainable params: 5,668,227  
Non-trainable params: 0
```

```
=====  
# batch_size = 128  
epochs = 10  
hist = model.fit(  
    train_generator,
```

```
# steps_per_epoch = 8,
epochs=epochs,
validation_data=test_generator)
```

```
Epoch 1/10
89/89 [=====] - 61s 675ms/step - loss: 0.9174
- accuracy: 0.5459 - val_loss: 0.6922 - val_accuracy: 0.6873
Epoch 2/10
89/89 [=====] - 61s 678ms/step - loss: 0.7444
- accuracy: 0.6436 - val_loss: 0.6823 - val_accuracy: 0.7607
Epoch 3/10
89/89 [=====] - 62s 693ms/step - loss: 0.7182
- accuracy: 0.6401 - val_loss: 0.5593 - val_accuracy: 0.7384
Epoch 4/10
89/89 [=====] - 61s 682ms/step - loss: 0.6982
- accuracy: 0.6642 - val_loss: 0.5881 - val_accuracy: 0.7715
Epoch 5/10
89/89 [=====] - 59s 664ms/step - loss: 0.6361
- accuracy: 0.6957 - val_loss: 0.5497 - val_accuracy: 0.7814
Epoch 6/10
89/89 [=====] - 60s 672ms/step - loss: 0.6658
- accuracy: 0.6773 - val_loss: 0.5557 - val_accuracy: 0.7822
Epoch 7/10
89/89 [=====] - 60s 672ms/step - loss: 0.6246
- accuracy: 0.7074 - val_loss: 0.5183 - val_accuracy: 0.7756
Epoch 8/10
89/89 [=====] - 60s 669ms/step - loss: 0.6614
- accuracy: 0.6897 - val_loss: 0.5643 - val_accuracy: 0.7657
Epoch 9/10
89/89 [=====] - 59s 663ms/step - loss: 0.6289
- accuracy: 0.7085 - val_loss: 0.5718 - val_accuracy: 0.8003
Epoch 10/10
89/89 [=====] - 59s 656ms/step - loss: 0.5925
- accuracy: 0.7202 - val_loss: 0.5330 - val_accuracy: 0.7698
```

```
def plot_loss_accuracy(history):
    fig = plt.figure(figsize=(12, 6))
    ax = fig.add_subplot(1, 2, 1)
    ax.plot(history.history["loss"], 'r-x', label="Train Loss")
    ax.plot(history.history["val_loss"], 'b-x', label="Validation
Loss")
    ax.legend()
    ax.set_title('cross_entropy loss')
    ax.grid(True)

    ax = fig.add_subplot(1, 2, 2)
    ax.plot(history.history["accuracy"], 'r-x', label="Train Accuracy")
    ax.plot(history.history["val_accuracy"], 'b-x', label="Validation
Accuracy")
```

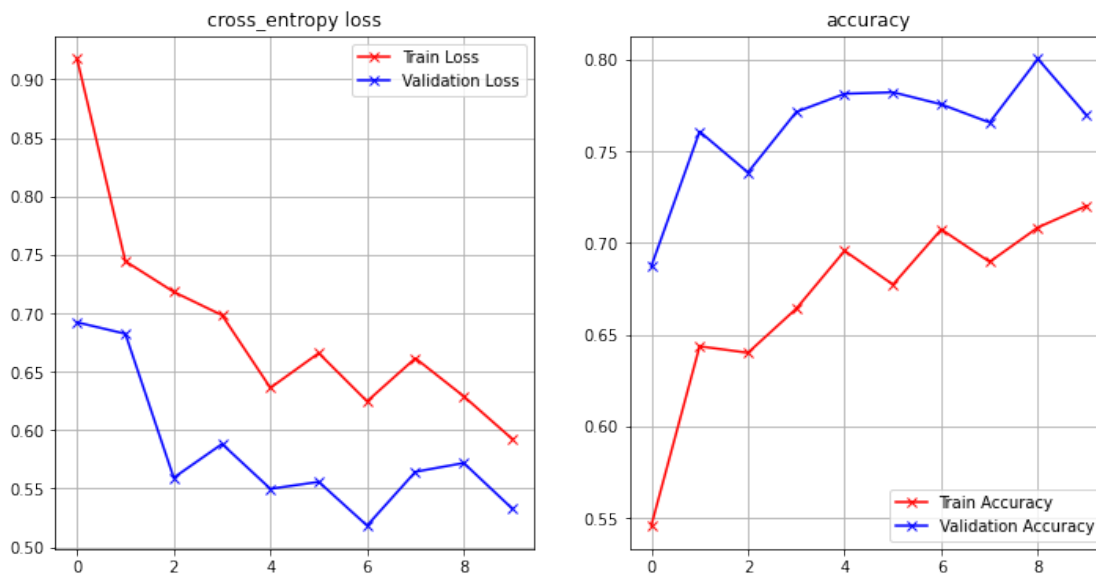
```

ax.legend()
ax.set_title('accuracy')
ax.grid(True)

print('Test loss:', hist.history["val_loss"][-1])
print('Test accuracy:', hist.history["val_accuracy"][-1])
print('Train loss:', hist.history["loss"][-1])
print('Train accuracy:', hist.history["accuracy"][-1])
plot_loss_accuracy(hist)

```

Test loss: 0.5329847931861877  
 Test accuracy: 0.7698019742965698  
 Train loss: 0.5925237536430359  
 Train accuracy: 0.7201558351516724



## Model 2

- Test loss: 0.3714073598384857
- Test accuracy: **0.8671616911888123**
- Train loss: 0.42508265376091003
- Train accuracy: 0.8349273800849915

```
from keras import regularizers
```

```

model_2 = Sequential()
model_2.add(Conv2D(128, kernel_size =3, activation = "relu",
input_shape = (224,224,3),
kernel_regularizer=regularizers.l2(0.0001)))
model_2.add(MaxPooling2D(pool_size =2, strides = 2))
model_2.add(Conv2D(32, (3,3), activation = "relu",
kernel_regularizer=regularizers.l2(0.0001)))
model_2.add(MaxPooling2D(pool_size =2, strides = 2))
model_2.add(Conv2D(64, (3,3), activation = "relu",

```



```

kernel_regularizer=regularizers.l2(0.0001))
model_2.add(MaxPooling2D(pool_size=(2,2)))
model_2.add(Flatten())
model_2.add(Dense(64, activation="relu",
kernel_regularizer=regularizers.l2(0.0001)))
model_2.add(Dense(32, activation="relu",
kernel_regularizer=regularizers.l2(0.0001)))
model_2.add(Dense(3, activation="softmax"))

model_2.compile(loss="categorical_crossentropy",
optimizer="adam",
metrics=["accuracy"])

```

```
model_2.summary()
```

```
Model: "sequential_14"
```

Layer (type)	Output Shape	Param #
conv2d_44 (Conv2D)	(None, 222, 222, 128)	3584
max_pooling2d_30 (MaxPooling2D)	(None, 111, 111, 128)	0
conv2d_45 (Conv2D)	(None, 109, 109, 32)	36896
max_pooling2d_31 (MaxPooling2D)	(None, 54, 54, 32)	0
conv2d_46 (Conv2D)	(None, 52, 52, 64)	18496
max_pooling2d_32 (MaxPooling2D)	(None, 26, 26, 64)	0
flatten_10 (Flatten)	(None, 43264)	0
dense_19 (Dense)	(None, 64)	2768960
dense_20 (Dense)	(None, 32)	2080
dense_21 (Dense)	(None, 3)	99

```

Total params: 2,830,115
Trainable params: 2,830,115
Non-trainable params: 0

```

```

epochs = 10
hist_2 = model_2.fit(
    train_generator,

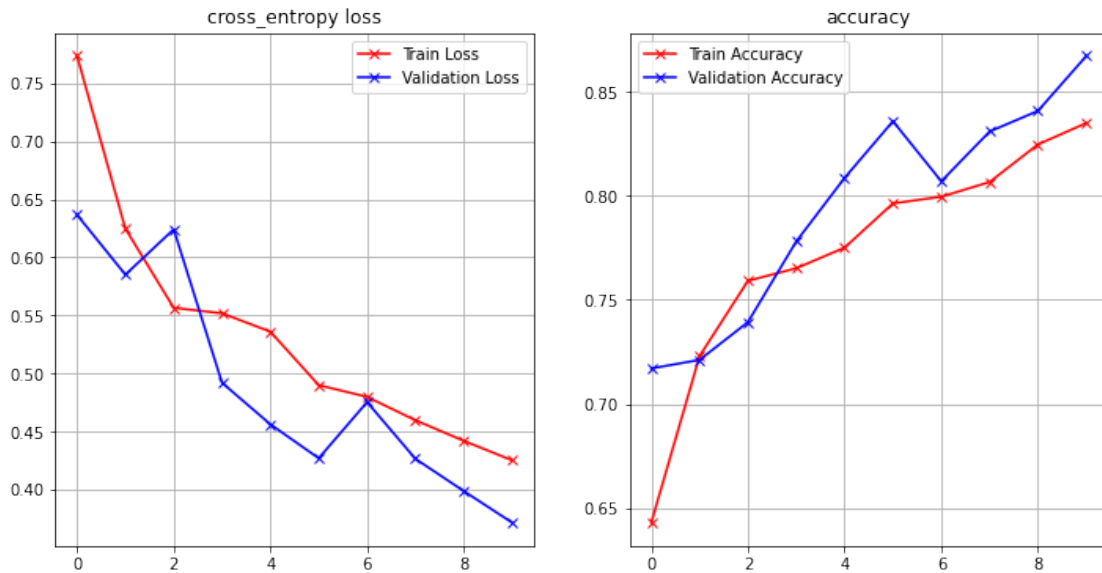
```

```
# steps_per_epoch = 8,  
epochs=epochs,  
validation_data=test_generator)
```

```
Epoch 1/10  
89/89 [=====] - 61s 653ms/step - loss: 0.7737  
- accuracy: 0.6429 - val_loss: 0.6367 - val_accuracy: 0.7170  
Epoch 2/10  
89/89 [=====] - 57s 643ms/step - loss: 0.6248  
- accuracy: 0.7230 - val_loss: 0.5852 - val_accuracy: 0.7211  
Epoch 3/10  
89/89 [=====] - 61s 680ms/step - loss: 0.5566  
- accuracy: 0.7591 - val_loss: 0.6243 - val_accuracy: 0.7393  
Epoch 4/10  
89/89 [=====] - 59s 664ms/step - loss: 0.5519  
- accuracy: 0.7651 - val_loss: 0.4919 - val_accuracy: 0.7781  
Epoch 5/10  
89/89 [=====] - 58s 649ms/step - loss: 0.5360  
- accuracy: 0.7751 - val_loss: 0.4561 - val_accuracy: 0.8086  
Epoch 6/10  
89/89 [=====] - 58s 651ms/step - loss: 0.4899  
- accuracy: 0.7963 - val_loss: 0.4269 - val_accuracy: 0.8358  
Epoch 7/10  
89/89 [=====] - 58s 649ms/step - loss: 0.4798  
- accuracy: 0.7995 - val_loss: 0.4753 - val_accuracy: 0.8069  
Epoch 8/10  
89/89 [=====] - 57s 641ms/step - loss: 0.4596  
- accuracy: 0.8066 - val_loss: 0.4264 - val_accuracy: 0.8309  
Epoch 9/10  
89/89 [=====] - 58s 654ms/step - loss: 0.4419  
- accuracy: 0.8247 - val_loss: 0.3986 - val_accuracy: 0.8408  
Epoch 10/10  
89/89 [=====] - 57s 641ms/step - loss: 0.4251  
- accuracy: 0.8349 - val_loss: 0.3714 - val_accuracy: 0.8672
```

```
print('Test loss:', hist_2.history["val_loss"][-1])  
print('Test accuracy:', hist_2.history["val_accuracy"][-1])  
print('Train loss:', hist_2.history["loss"][-1])  
print('Train accuracy:', hist_2.history["accuracy"][-1])  
plot_loss_accuracy(hist_2)
```

```
Test loss: 0.3714073598384857  
Test accuracy: 0.8671616911888123  
Train loss: 0.42508265376091003  
Train accuracy: 0.8349273800849915
```



## Transfer Learning

1. Use a pre-trained model and fine-tuned it.
2. Build and train a CNN model using the modified pretrained model.
3. Plot the training and validation loss and accuracy. The target accuracy is 90 and above.

## ResNet50

- Test loss: 0.5785264372825623
- Test accuracy: 0.7194719314575195
- Train loss: 0.7184997797012329
- Train accuracy: 0.6627700924873352

```
from tensorflow.keras.applications.resnet50 import ResNet50
from tensorflow.keras.applications.resnet50 import preprocess_input
```

```
t_model = ResNet50(weights = "imagenet", input_shape=(224,224,3),
include_top = False)
```

```
for layer in t_model.layers:
    layer.trainable = False
```

```

model_combine = Sequential()
model_combine.add(t_model)
model_combine.add(Flatten())
model_combine.add(Dense(128, activation = "relu"))
model_combine.add(Dense(64, activation = "relu"))
model_combine.add(Dense(32, activation = "relu"))
model_combine.add(Dense(3, activation = "softmax"))
model_combine.summary()

```

Model: "sequential\_29"

Layer (type)	Output Shape	Param #
resnet50 (Functional)	(None, 7, 7, 2048)	23587712
flatten_26 (Flatten)	(None, 100352)	0
dense_58 (Dense)	(None, 128)	12845184
dense_59 (Dense)	(None, 64)	8256
dense_60 (Dense)	(None, 32)	2080
dense_61 (Dense)	(None, 3)	99
Total params: 36,443,331		
Trainable params: 12,855,619		
Non-trainable params: 23,587,712		

```

model_combine.compile(loss = "categorical_crossentropy",
                      optimizer=Adam(lr = 0.001),
                      metrics = ["accuracy"])

```

```

hist_combine = model_combine.fit(
    train_generator,
    # steps_per_epoch = 8,
    epochs=10,
    validation_data=test_generator)

```

Epoch 1/10

89/89 [=====] - 65s 686ms/step - loss: 1.2444  
- accuracy: 0.4513 - val\_loss: 1.1203 - val\_accuracy: 0.5256

Epoch 2/10

89/89 [=====] - 60s 676ms/step - loss: 0.9413  
- accuracy: 0.5512 - val\_loss: 0.8319 - val\_accuracy: 0.6229

Epoch 3/10

89/89 [=====] - 64s 719ms/step - loss: 0.8383  
- accuracy: 0.6079 - val\_loss: 0.7009 - val\_accuracy: 0.7038

Epoch 4/10

```

89/89 [=====] - 60s 672ms/step - loss: 0.7571
- accuracy: 0.6429 - val_loss: 0.6511 - val_accuracy: 0.6667
Epoch 5/10
89/89 [=====] - 59s 660ms/step - loss: 0.7337
- accuracy: 0.6670 - val_loss: 0.6566 - val_accuracy: 0.7203
Epoch 6/10
89/89 [=====] - 62s 701ms/step - loss: 0.7145
- accuracy: 0.6723 - val_loss: 0.7987 - val_accuracy: 0.5627
Epoch 7/10
89/89 [=====] - 62s 691ms/step - loss: 0.7131
- accuracy: 0.6677 - val_loss: 0.6072 - val_accuracy: 0.7228
Epoch 8/10
89/89 [=====] - 61s 687ms/step - loss: 0.6017
- accuracy: 0.7308 - val_loss: 0.5844 - val_accuracy: 0.7236
Epoch 9/10
89/89 [=====] - 62s 691ms/step - loss: 0.6575
- accuracy: 0.6879 - val_loss: 0.6784 - val_accuracy: 0.6279
Epoch 10/10
89/89 [=====] - 62s 699ms/step - loss: 0.7185
- accuracy: 0.6628 - val_loss: 0.5785 - val_accuracy: 0.7195

```

```

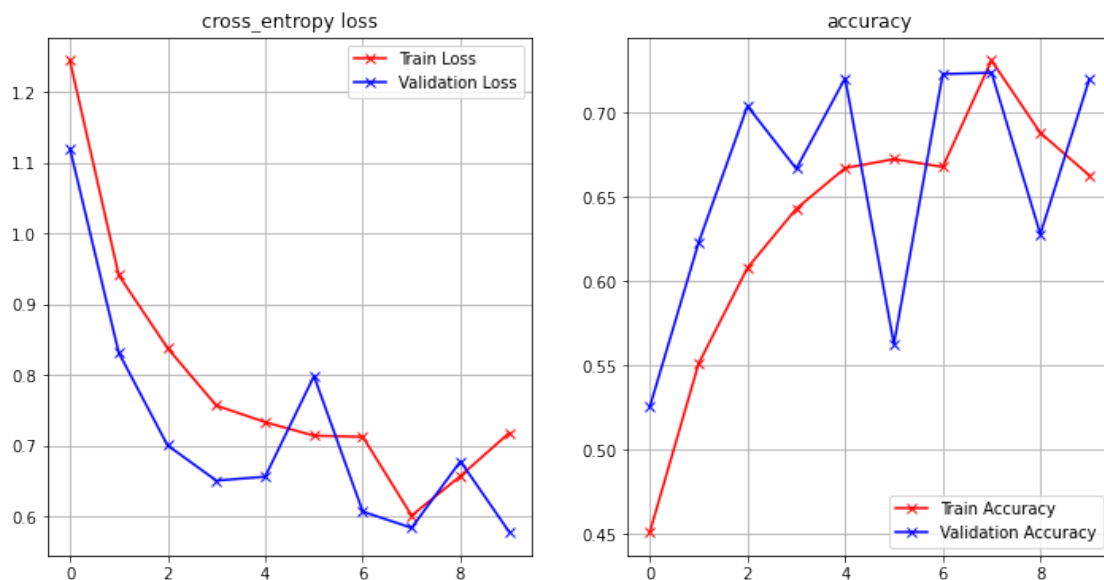
print('Test loss:', hist_combine.history["val_loss"][-1])
print('Test accuracy:', hist_combine.history["val_accuracy"][-1])
print('Train loss:', hist_combine.history["loss"][-1])
print('Train accuracy:', hist_combine.history["accuracy"][-1])
plot_loss_accuracy(hist_combine)

```

```

Test loss: 0.5785264372825623
Test accuracy: 0.7194719314575195
Train loss: 0.7184997797012329
Train accuracy: 0.6627700924873352

```



## ResNet50 version 2

- difference
    - changed the architecture of the user-created classifier layer
- 

- Test loss: 0.6851625442504883
- Test accuracy: 0.7095709443092346
- Train loss: 0.6683652997016907
- Train accuracy: 0.6971307396888733

```
model_combine_2 = Sequential()
model_combine_2.add(t_model)
model_combine_2.add(MaxPooling2D(pool_size=(2,2)))
model_combine_2.add(Flatten())
model_combine_2.add(Dense(64, activation="relu",
kernel_regularizer=regularizers.l2(0.0001)))
model_combine_2.add(Dense(32, activation="relu",
kernel_regularizer=regularizers.l2(0.0001)))
model_combine_2.add(Dense(3, activation="softmax"))

model_combine_2.compile(loss="categorical_crossentropy",
optimizer="adam",
metrics=["accuracy"])
```

```
hist_combine_2 = model_combine_2.fit(
    train_generator,
    # steps_per_epoch = 8,
    epochs=10,
    validation_data=test_generator)
```

Epoch 1/10

```
89/89 [=====] - 82s 814ms/step - loss: 1.1665
- accuracy: 0.3925 - val_loss: 0.9164 - val_accuracy: 0.6617
```

Epoch 2/10

```
89/89 [=====] - 67s 747ms/step - loss: 0.9750
- accuracy: 0.5225 - val_loss: 0.8668 - val_accuracy: 0.5875
```

Epoch 3/10

```
89/89 [=====] - 63s 712ms/step - loss: 0.8416
- accuracy: 0.6128 - val_loss: 0.7452 - val_accuracy: 0.6939
```

Epoch 4/10

```
89/89 [=====] - 61s 683ms/step - loss: 0.7736
- accuracy: 0.6560 - val_loss: 0.7331 - val_accuracy: 0.6485
```

Epoch 5/10

```
89/89 [=====] - 61s 690ms/step - loss: 0.7291
- accuracy: 0.6713 - val_loss: 0.7121 - val_accuracy: 0.6865
```

Epoch 6/10

```
89/89 [=====] - 64s 722ms/step - loss: 0.7294
- accuracy: 0.6688 - val_loss: 0.6685 - val_accuracy: 0.6840
```

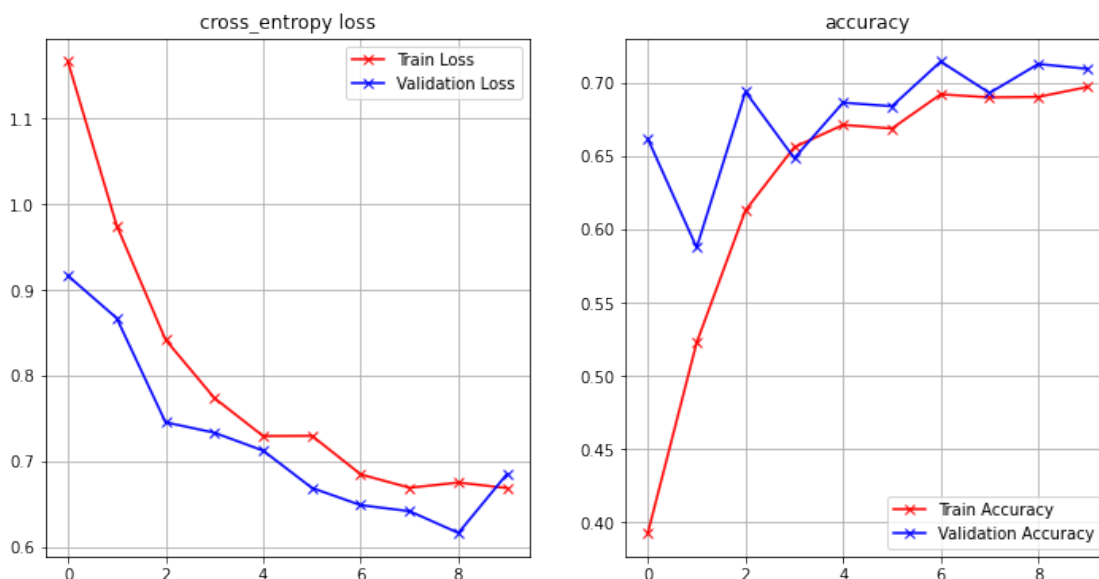
Epoch 7/10

```
89/89 [=====] - 61s 686ms/step - loss: 0.6843
```

```
- accuracy: 0.6922 - val_loss: 0.6484 - val_accuracy: 0.7145
Epoch 8/10
89/89 [=====] - 64s 717ms/step - loss: 0.6688
- accuracy: 0.6900 - val_loss: 0.6414 - val_accuracy: 0.6931
Epoch 9/10
89/89 [=====] - 62s 694ms/step - loss: 0.6749
- accuracy: 0.6904 - val_loss: 0.6160 - val_accuracy: 0.7129
Epoch 10/10
89/89 [=====] - 62s 702ms/step - loss: 0.6684
- accuracy: 0.6971 - val_loss: 0.6852 - val_accuracy: 0.7096
```

```
print('Test loss:', hist_combine_2.history["val_loss"][-1])
print('Test accuracy:', hist_combine_2.history["val_accuracy"][-1])
print('Train loss:', hist_combine_2.history["loss"][-1])
print('Train accuracy:', hist_combine_2.history["accuracy"][-1])
plot_loss_accuracy(hist_combine_2)
```

```
Test loss: 0.6851625442504883
Test accuracy: 0.7095709443092346
Train loss: 0.6683652997016907
Train accuracy: 0.6971307396888733
```



## ResNet without weights

- Test loss: 0.5426440238952637
- Test accuracy: 0.7648515105247498
- Train loss: 0.5997710824012756
- Train accuracy: 0.7364506125450134

```
t_model_3 = ResNet50(weights=None, input_shape=(224,224,3),
include_top=False)
t_model_3.trainable = False
```

```

model_combine_3 = Sequential()
model_combine_3.add(t_model_3)
model_combine_3.add(MaxPooling2D(pool_size=(2,2)))
model_combine_3.add(Flatten())
model_combine_3.add(Dense(64, activation="relu",
kernel_regularizer=regularizers.l2(0.0001)))
model_combine_3.add(Dense(3, activation="softmax"))

model_combine_3.compile(loss="categorical_crossentropy",
optimizer=Adam(lr=0.001),
metrics=["accuracy"])

hist_combine_3 = model_combine_3.fit(
train_generator,
# steps_per_epoch = 8,
epochs=10,
validation_data=test_generator)

Epoch 1/10
89/89 [=====] - 67s 705ms/step - loss: 0.9549
- accuracy: 0.5657 - val_loss: 0.7872 - val_accuracy: 0.6955
Epoch 2/10
89/89 [=====] - 62s 697ms/step - loss: 0.7452
- accuracy: 0.6897 - val_loss: 0.6612 - val_accuracy: 0.7434
Epoch 3/10
89/89 [=====] - 66s 740ms/step - loss: 0.6951
- accuracy: 0.7099 - val_loss: 0.6410 - val_accuracy: 0.7153
Epoch 4/10
89/89 [=====] - 62s 692ms/step - loss: 0.6790
- accuracy: 0.7074 - val_loss: 0.6424 - val_accuracy: 0.7129
Epoch 5/10
89/89 [=====] - 61s 689ms/step - loss: 0.6398
- accuracy: 0.7205 - val_loss: 0.5929 - val_accuracy: 0.7368
Epoch 6/10
89/89 [=====] - 61s 689ms/step - loss: 0.6246
- accuracy: 0.7294 - val_loss: 0.6239 - val_accuracy: 0.7475
Epoch 7/10
89/89 [=====] - 61s 685ms/step - loss: 0.6179
- accuracy: 0.7329 - val_loss: 0.5660 - val_accuracy: 0.7492
Epoch 8/10
89/89 [=====] - 62s 698ms/step - loss: 0.6099
- accuracy: 0.7389 - val_loss: 0.5554 - val_accuracy: 0.7706
Epoch 9/10
89/89 [=====] - 62s 691ms/step - loss: 0.6011
- accuracy: 0.7382 - val_loss: 0.5755 - val_accuracy: 0.7508
Epoch 10/10
89/89 [=====] - 64s 718ms/step - loss: 0.5998
- accuracy: 0.7365 - val_loss: 0.5426 - val_accuracy: 0.7649

```

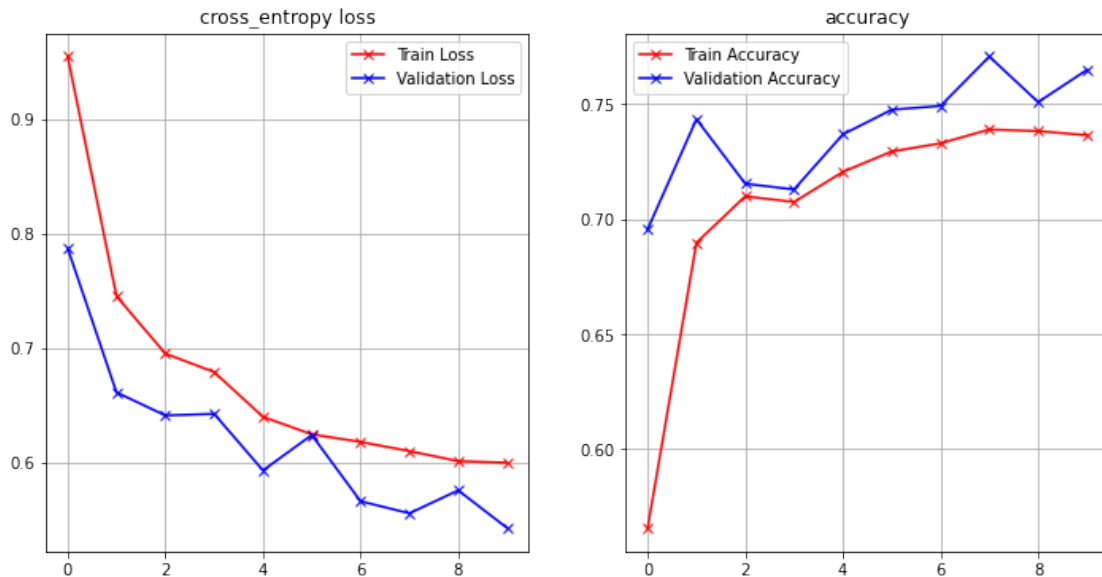


```

print('Test loss:', hist_combine_3.history["val_loss"][-1])
print('Test accuracy:', hist_combine_3.history["val_accuracy"][-1])
print('Train loss:', hist_combine_3.history["loss"][-1])
print('Train accuracy:', hist_combine_3.history["accuracy"][-1])
plot_loss_accuracy(hist_combine_3)

```

Test loss: 0.5426440238952637  
 Test accuracy: 0.7648515105247498  
 Train loss: 0.5997710824012756  
 Train accuracy: 0.7364506125450134



## VGG16 version 1

- Extending our model on top of VGG16
- no fine tuning
- **pre-trained weights are frozen**
  - Test loss: 0.21388743817806244
  - Test accuracy: **0.919966995716095**
  - Train loss: 0.1789405345916748
  - Train accuracy: 0.9341126680374146

```
from tensorflow.keras.applications import VGG16
```

```

t_model_4 = VGG16(weights='imagenet',
                    include_top=False,
                    input_shape=(224, 224, 3))

```

```
t_model_4.summary()
```

Downloading data from [https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16\\_weights\\_tf\\_dim\\_ordering\\_tf\\_kernels\\_notop.h5](https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5)

58892288/58889256 [=====] - 0s 0us/step  
58900480/58889256 [=====] - 0s 0us/step  
Model: "vgg16"

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	[(None, 224, 224, 3)]	0
block1_conv1 (Conv2D)	(None, 224, 224, 64)	1792
block1_conv2 (Conv2D)	(None, 224, 224, 64)	36928
block1_pool (MaxPooling2D)	(None, 112, 112, 64)	0
block2_conv1 (Conv2D)	(None, 112, 112, 128)	73856
block2_conv2 (Conv2D)	(None, 112, 112, 128)	147584
block2_pool (MaxPooling2D)	(None, 56, 56, 128)	0
block3_conv1 (Conv2D)	(None, 56, 56, 256)	295168
block3_conv2 (Conv2D)	(None, 56, 56, 256)	590080
block3_conv3 (Conv2D)	(None, 56, 56, 256)	590080
block3_pool (MaxPooling2D)	(None, 28, 28, 256)	0
block4_conv1 (Conv2D)	(None, 28, 28, 512)	1180160
block4_conv2 (Conv2D)	(None, 28, 28, 512)	2359808
block4_conv3 (Conv2D)	(None, 28, 28, 512)	2359808
block4_pool (MaxPooling2D)	(None, 14, 14, 512)	0
block5_conv1 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv2 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv3 (Conv2D)	(None, 14, 14, 512)	2359808
block5_pool (MaxPooling2D)	(None, 7, 7, 512)	0
=====		
Total params: 14,714,688		
Trainable params: 14,714,688		
Non-trainable params: 0		

*# freeze all trainable parameters, so weights of the pre-trained model won't get updated and lose*  
*# the weights it acquired when it was learning from images before.*  
*Essentially we will see what the*  
*# pretrained CNN will give us given all the images it's learned from.*

```
t_model_4.trainable = False
```

```
model_vgg16_1 = Sequential()  
model_vgg16_1.add(t_model_4)  
model_vgg16_1.add(Flatten())
```

*# add your custom dense layers. VGG16 has no dense layer on purpose, so us users can use it for multiclass or*  
*# binary classification purposes.*

```
model_vgg16_1.add(Dense(128, activation='relu')) # used to be 256  
model_vgg16_1.add(Dense(64, activation='relu')) # used to be 128  
model_vgg16_1.add(Dense(3, activation='softmax'))
```

```
model_vgg16_1.summary()
```

```
Model: "sequential_1"
```

Layer (type)	Output Shape	Param #
vgg16 (Functional)	(None, 7, 7, 512)	14714688
flatten_1 (Flatten)	(None, 25088)	0
dense_2 (Dense)	(None, 128)	3211392
dense_3 (Dense)	(None, 64)	8256
dense_4 (Dense)	(None, 3)	195

```
=====  
Total params: 17,934,531
```

```
Trainable params: 3,219,843
```

```
Non-trainable params: 14,714,688  
=====
```

```
model_vgg16_1.compile(loss='categorical_crossentropy',  
                      optimizer=RMSprop(lr=2e-5),  
                      metrics=['acc'])
```

```
hist_vgg16_1 = model_vgg16_1.fit_generator(  
    train_generator,  
    epochs=15,  
    validation_data=test_generator,  
    verbose=2)
```

```

/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/
rmsprop.py:130: UserWarning: The `lr` argument is deprecated, use
`learning_rate` instead.
    super(RMSprop, self).__init__(name, **kwargs)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:9:
UserWarning: `Model.fit_generator` is deprecated and will be removed
in a future version. Please use `Model.fit`, which supports
generators.
    if __name__ == '__main__':

```

```

Epoch 1/15
89/89 - 2074s - loss: 0.7088 - acc: 0.7428 - val_loss: 0.5244 -
val_acc: 0.8003 - 2074s/epoch - 23s/step
Epoch 2/15
89/89 - 2047s - loss: 0.4705 - acc: 0.8261 - val_loss: 0.3938 -
val_acc: 0.8523 - 2047s/epoch - 23s/step
Epoch 3/15
89/89 - 2037s - loss: 0.3826 - acc: 0.8495 - val_loss: 0.3402 -
val_acc: 0.8795 - 2037s/epoch - 23s/step
Epoch 4/15
89/89 - 2035s - loss: 0.3387 - acc: 0.8746 - val_loss: 0.3215 -
val_acc: 0.8746 - 2035s/epoch - 23s/step
Epoch 5/15
89/89 - 2035s - loss: 0.3124 - acc: 0.8842 - val_loss: 0.3443 -
val_acc: 0.8589 - 2035s/epoch - 23s/step
Epoch 6/15
89/89 - 2033s - loss: 0.2825 - acc: 0.8941 - val_loss: 0.2696 -
val_acc: 0.9002 - 2033s/epoch - 23s/step
Epoch 7/15
89/89 - 2038s - loss: 0.2666 - acc: 0.8962 - val_loss: 0.2894 -
val_acc: 0.8878 - 2038s/epoch - 23s/step
Epoch 8/15
89/89 - 2041s - loss: 0.2481 - acc: 0.9068 - val_loss: 0.2386 -
val_acc: 0.9175 - 2041s/epoch - 23s/step
Epoch 9/15
89/89 - 2036s - loss: 0.2338 - acc: 0.9157 - val_loss: 0.2378 -
val_acc: 0.9134 - 2036s/epoch - 23s/step
Epoch 10/15
89/89 - 2030s - loss: 0.2239 - acc: 0.9171 - val_loss: 0.2309 -
val_acc: 0.9117 - 2030s/epoch - 23s/step
Epoch 11/15

```

```

hist_vgg16_1.history.keys()

```

```

dict_keys(['loss', 'acc', 'val_loss', 'val_acc'])

```

```

def plot_loss_accuracy_vgg16(history):
    fig = plt.figure(figsize=(12, 6))
    ax = fig.add_subplot(1, 2, 1)
    ax.plot(history.history["loss"], 'r-x', label="Train Loss")
    ax.plot(history.history["val_loss"], 'b-x', label="Validation

```

```

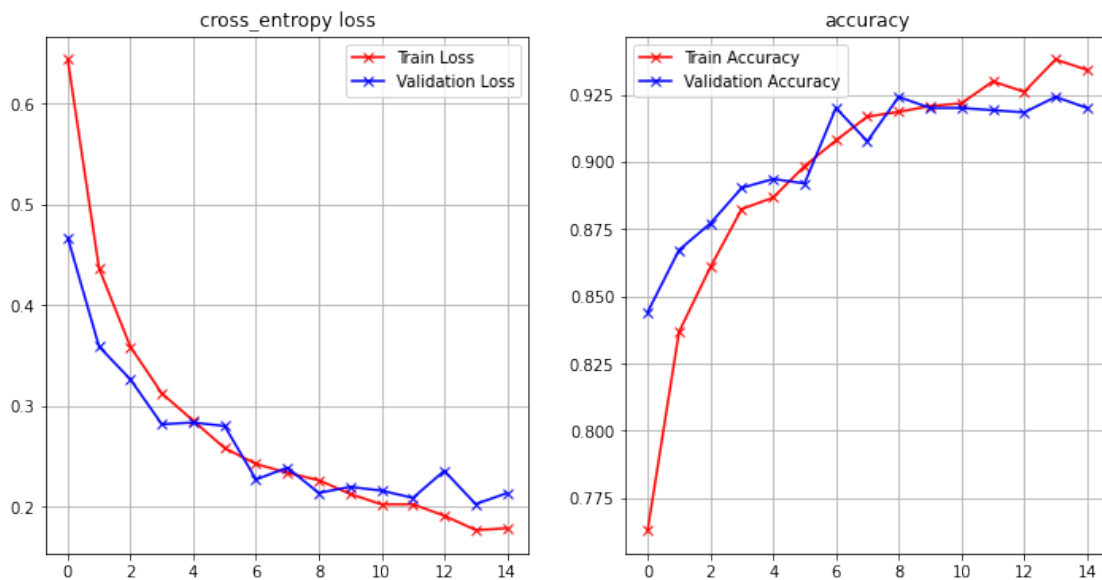
Loss")
    ax.legend()
    ax.set_title('cross_entropy loss')
    ax.grid(True)

    ax = fig.add_subplot(1, 2, 2)
    ax.plot(history.history["acc"], 'r-x', label="Train Accuracy")
    ax.plot(history.history["val_acc"], 'b-x', label="Validation
Accuracy")
    ax.legend()
    ax.set_title('accuracy')
    ax.grid(True)

print('Test loss:', hist_vgg16_1.history["val_loss"][-1])
print('Test accuracy:', hist_vgg16_1.history["val_acc"][-1])
print('Train loss:', hist_vgg16_1.history["loss"][-1])
print('Train accuracy:', hist_vgg16_1.history["acc"][-1])
plot_loss_accuracy_vgg16(hist_vgg16_1)

```

Test loss: 0.21388743817806244  
 Test accuracy: 0.919966995716095  
 Train loss: 0.1789405345916748  
 Train accuracy: 0.9341126680374146



## VGG16 version 2

- Using Feature Extraction
- Test loss: 0.28629744052886963
- Test accuracy: **0.9488449096679688**
- Train loss: 0.4090595245361328

- Train accuracy: 0.8292596340179443

```
from tensorflow.keras.applications import VGG16
```

```
t_model_5 = VGG16(weights='imagenet',
                      include_top=False,
                      input_shape=(224, 224, 3))
```

```
t_model_5.summary()
```

```
Model: "vgg16"
```

Layer (type)	Output Shape	Param #
=====		
input_9 (InputLayer)	[(None, 224, 224, 3)]	0
block1_conv1 (Conv2D)	(None, 224, 224, 64)	1792
block1_conv2 (Conv2D)	(None, 224, 224, 64)	36928
block1_pool (MaxPooling2D)	(None, 112, 112, 64)	0
block2_conv1 (Conv2D)	(None, 112, 112, 128)	73856
block2_conv2 (Conv2D)	(None, 112, 112, 128)	147584
block2_pool (MaxPooling2D)	(None, 56, 56, 128)	0
block3_conv1 (Conv2D)	(None, 56, 56, 256)	295168
block3_conv2 (Conv2D)	(None, 56, 56, 256)	590080
block3_conv3 (Conv2D)	(None, 56, 56, 256)	590080
block3_pool (MaxPooling2D)	(None, 28, 28, 256)	0
block4_conv1 (Conv2D)	(None, 28, 28, 512)	1180160
block4_conv2 (Conv2D)	(None, 28, 28, 512)	2359808
block4_conv3 (Conv2D)	(None, 28, 28, 512)	2359808
block4_pool (MaxPooling2D)	(None, 14, 14, 512)	0
block5_conv1 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv2 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv3 (Conv2D)	(None, 14, 14, 512)	2359808
block5_pool (MaxPooling2D)	(None, 7, 7, 512)	0

```
=====
Total params: 14,714,688
Trainable params: 14,714,688
Non-trainable params: 0
=====
```

---

```
datagen = ImageDataGenerator(rescale=1./255)
batch_size = 20
```

```
def extract_features(directory, sample_count):
    features = np.zeros(shape=(sample_count, 7, 7, 512))
    labels = np.zeros(shape=(sample_count))
    generator = datagen.flow_from_directory(
        directory,
        target_size=(224, 224),
        batch_size=batch_size,
        class_mode='binary')
    i = 0
    for inputs_batch, labels_batch in generator:
        features_batch = t_model_5.predict(inputs_batch)
        features[i * batch_size : (i + 1) * batch_size] =
features_batch
        labels[i * batch_size : (i + 1) * batch_size] = labels_batch
        i += 1
        if i * batch_size >= sample_count:
            # Note that since generators yield data indefinitely in a
loop,
            # we must 'break' after every image has been seen once.
            break
    return features, labels
```

```
train_features, train_labels = extract_features(train_path, 2823)
test_features, test_labels = extract_features(test_path, 1212)
```

```
Found 2823 images belonging to 3 classes.
Found 1212 images belonging to 3 classes.
```

```
train_features = np.reshape(train_features, (2823, 7 * 7 * 512))
test_features = np.reshape(test_features, (1212, 7 * 7 * 512))
```

```
model_vgg16_2 = Sequential()
model_vgg16_2.add(Dense(256, activation='relu', input_dim=7 * 7 *
512))
model_vgg16_2.add(Dropout(0.4))
model_vgg16_2.add(Dense(256, activation='relu'))
model_vgg16_2.add(Dropout(0.4))
model_vgg16_2.add(Dense(3, activation='softmax'))
```

```
model_vgg16_2.compile(optimizer='adam', loss =
```

```
tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True),  
        metrics=['acc'])
```

```
hist_vgg16_2 = model_vgg16_2.fit(train_features, train_labels,  
        epochs=40,  
        batch_size=20,  
        validation_data=(test_features, test_labels))
```

Epoch 1/40

```
142/142 [=====] - 2s 12ms/step - loss: 0.8125  
- acc: 0.7350 - val_loss: 0.2858 - val_acc: 0.8886
```

Epoch 2/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.3626  
- acc: 0.8495 - val_loss: 0.2336 - val_acc: 0.8952
```

Epoch 3/40

```
142/142 [=====] - 1s 9ms/step - loss: 0.3175  
- acc: 0.8704 - val_loss: 0.1933 - val_acc: 0.9356
```

Epoch 4/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2432  
- acc: 0.8973 - val_loss: 0.1465 - val_acc: 0.9488
```

Epoch 5/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2757  
- acc: 0.8856 - val_loss: 0.1795 - val_acc: 0.9365
```

Epoch 6/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2288  
- acc: 0.9047 - val_loss: 0.1905 - val_acc: 0.9422
```

Epoch 7/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.1924  
- acc: 0.9210 - val_loss: 0.1691 - val_acc: 0.9398
```

Epoch 8/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2953  
- acc: 0.8654 - val_loss: 0.1741 - val_acc: 0.9447
```

Epoch 9/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2546  
- acc: 0.8998 - val_loss: 0.1602 - val_acc: 0.9513
```

Epoch 10/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.3030  
- acc: 0.8859 - val_loss: 0.1819 - val_acc: 0.9571
```

Epoch 11/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2556  
- acc: 0.9001 - val_loss: 0.1491 - val_acc: 0.9513
```

Epoch 12/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2412  
- acc: 0.9068 - val_loss: 0.1377 - val_acc: 0.9587
```

Epoch 13/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2435  
- acc: 0.9036 - val_loss: 0.1491 - val_acc: 0.9513
```

Epoch 14/40

```
142/142 [=====] - 1s 10ms/step - loss: 0.2494  
- acc: 0.9036 - val_loss: 0.1603 - val_acc: 0.9513
```



Epoch 15/40  
142/142 [=====] - 1s 10ms/step - loss: 0.3023  
- acc: 0.8792 - val\_loss: 0.1792 - val\_acc: 0.9464  
Epoch 16/40  
142/142 [=====] - 1s 10ms/step - loss: 0.2369  
- acc: 0.9065 - val\_loss: 0.2191 - val\_acc: 0.9422  
Epoch 17/40  
142/142 [=====] - 1s 10ms/step - loss: 0.2422  
- acc: 0.9047 - val\_loss: 0.1485 - val\_acc: 0.9604  
Epoch 18/40  
142/142 [=====] - 1s 10ms/step - loss: 0.2832  
- acc: 0.8679 - val\_loss: 0.1660 - val\_acc: 0.9521  
Epoch 19/40  
142/142 [=====] - 1s 10ms/step - loss: 0.3211  
- acc: 0.8307 - val\_loss: 0.1705 - val\_acc: 0.9521  
Epoch 20/40  
142/142 [=====] - 1s 10ms/step - loss: 0.3455  
- acc: 0.8200 - val\_loss: 0.1611 - val\_acc: 0.9579  
Epoch 21/40  
142/142 [=====] - 1s 10ms/step - loss: 0.3222  
- acc: 0.8300 - val\_loss: 0.1990 - val\_acc: 0.9455  
Epoch 22/40  
142/142 [=====] - 1s 10ms/step - loss: 0.2957  
- acc: 0.8424 - val\_loss: 0.1928 - val\_acc: 0.9464  
Epoch 23/40  
142/142 [=====] - 1s 10ms/step - loss: 0.3003  
- acc: 0.8324 - val\_loss: 0.1872 - val\_acc: 0.9513  
Epoch 24/40  
142/142 [=====] - 1s 10ms/step - loss: 0.3845  
- acc: 0.7963 - val\_loss: 0.3343 - val\_acc: 0.9216  
Epoch 25/40  
142/142 [=====] - 1s 10ms/step - loss: 0.4161  
- acc: 0.8154 - val\_loss: 0.3278 - val\_acc: 0.9233  
Epoch 26/40  
142/142 [=====] - 1s 10ms/step - loss: 0.4107  
- acc: 0.8126 - val\_loss: 0.3486 - val\_acc: 0.9200  
Epoch 27/40  
142/142 [=====] - 1s 10ms/step - loss: 0.4180  
- acc: 0.8165 - val\_loss: 0.3142 - val\_acc: 0.9175  
Epoch 28/40  
142/142 [=====] - 1s 10ms/step - loss: 0.4108  
- acc: 0.8218 - val\_loss: 0.3635 - val\_acc: 0.9059  
Epoch 29/40  
142/142 [=====] - 1s 10ms/step - loss: 0.4652  
- acc: 0.7903 - val\_loss: 0.3135 - val\_acc: 0.9257  
Epoch 30/40  
142/142 [=====] - 1s 10ms/step - loss: 0.4161  
- acc: 0.8193 - val\_loss: 0.2978 - val\_acc: 0.9389  
Epoch 31/40  
142/142 [=====] - 1s 10ms/step - loss: 0.4116

```

- acc: 0.8179 - val_loss: 0.2721 - val_acc: 0.9488
Epoch 32/40
142/142 [=====] - 1s 10ms/step - loss: 0.3957
- acc: 0.8296 - val_loss: 0.3137 - val_acc: 0.9422
Epoch 33/40
142/142 [=====] - 1s 10ms/step - loss: 0.3776
- acc: 0.8395 - val_loss: 0.3630 - val_acc: 0.9307
Epoch 34/40
142/142 [=====] - 1s 9ms/step - loss: 0.4006
- acc: 0.8275 - val_loss: 0.3001 - val_acc: 0.9480
Epoch 35/40
142/142 [=====] - 2s 12ms/step - loss: 0.4019
- acc: 0.8296 - val_loss: 0.3345 - val_acc: 0.9348
Epoch 36/40
142/142 [=====] - 1s 9ms/step - loss: 0.4966
- acc: 0.8006 - val_loss: 0.3273 - val_acc: 0.9365
Epoch 37/40
142/142 [=====] - 1s 10ms/step - loss: 0.4532
- acc: 0.8183 - val_loss: 0.2950 - val_acc: 0.9398
Epoch 38/40
142/142 [=====] - 1s 10ms/step - loss: 0.4667
- acc: 0.8123 - val_loss: 0.3403 - val_acc: 0.9381
Epoch 39/40
142/142 [=====] - 1s 10ms/step - loss: 0.4657
- acc: 0.8073 - val_loss: 0.3168 - val_acc: 0.9472
Epoch 40/40
142/142 [=====] - 1s 10ms/step - loss: 0.4091
- acc: 0.8293 - val_loss: 0.2863 - val_acc: 0.9488

```

```

def plot_loss_accuracy_vgg16(history):
    fig = plt.figure(figsize=(12, 6))
    ax = fig.add_subplot(1, 2, 1)
    ax.plot(history.history["loss"], 'r-x', label="Train Loss")
    ax.plot(history.history["val_loss"], 'b-x', label="Validation
Loss")
    ax.legend()
    ax.set_title('cross_entropy loss')
    ax.grid(True)

    ax = fig.add_subplot(1, 2, 2)
    ax.plot(history.history["acc"], 'r-x', label="Train Accuracy")
    ax.plot(history.history["val_acc"], 'b-x', label="Validation
Accuracy")
    ax.legend()
    ax.set_title('accuracy')
    ax.grid(True)

```

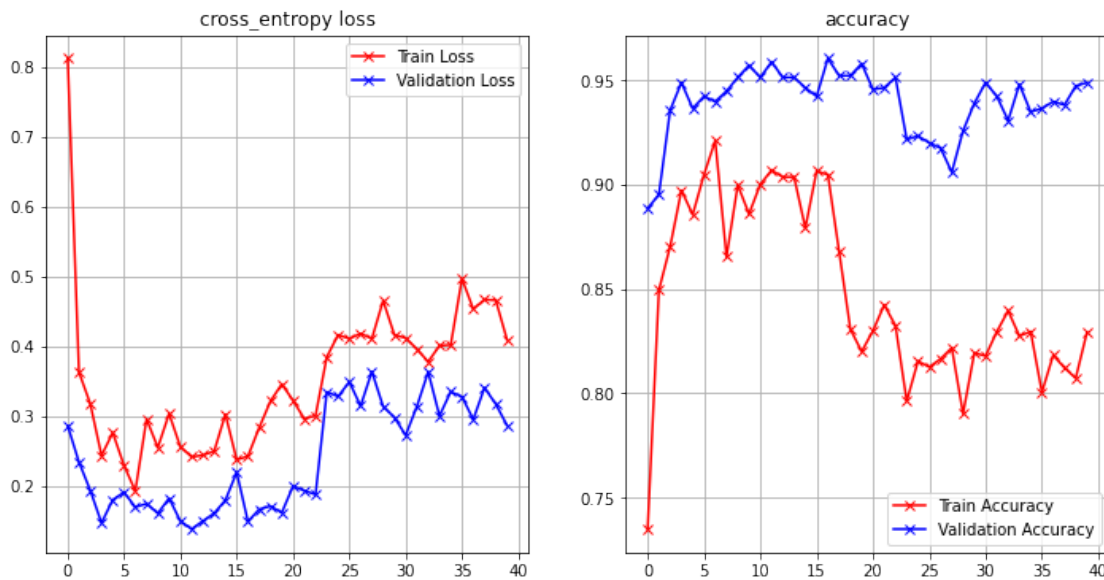
```

print('Test loss:', hist_vgg16_2.history["val_loss"][-1])
print('Test accuracy:', hist_vgg16_2.history["val_acc"][-1])

```

```
print('Train loss:', hist_vgg16_2.history["loss"][-1])
print('Train accuracy:', hist_vgg16_2.history['acc'][-1])
plot_loss_accuracy_vgg16(hist_vgg16_2)
```

Test loss: 0.28629744052886963  
 Test accuracy: 0.9488449096679688  
 Train loss: 0.4090595245361328  
 Train accuracy: 0.8292596340179443



### VGG16 version 3

- fine tuning the last 3 convolutional networks
- classification layer flattens the inputs and is passed through 3 Dense functions of size 64, 32, and 3--with the first 2 Density functions having an l2 regularizer with the value 0.0001

Test loss: 0.17993402481079102

Test accuracy: **0.9455445408821106**

Train loss: 0.11249853670597076

Train accuracy: 0.9649309515953064

```
from tensorflow.keras.applications import VGG16
from keras import regularizers
```

```
t_model_4 = VGG16(weights = "imagenet", include_top=False,
input_shape=(224, 224, 3))
```

```
t_model_4.summary()
```

Model: "vgg16"

Layer (type)	Output Shape	Param #
input_3 (InputLayer)	[(None, 224, 224, 3)]	0
block1_conv1 (Conv2D)	(None, 224, 224, 64)	1792
block1_conv2 (Conv2D)	(None, 224, 224, 64)	36928
block1_pool (MaxPooling2D)	(None, 112, 112, 64)	0
block2_conv1 (Conv2D)	(None, 112, 112, 128)	73856
block2_conv2 (Conv2D)	(None, 112, 112, 128)	147584
block2_pool (MaxPooling2D)	(None, 56, 56, 128)	0
block3_conv1 (Conv2D)	(None, 56, 56, 256)	295168
block3_conv2 (Conv2D)	(None, 56, 56, 256)	590080
block3_conv3 (Conv2D)	(None, 56, 56, 256)	590080
block3_pool (MaxPooling2D)	(None, 28, 28, 256)	0
block4_conv1 (Conv2D)	(None, 28, 28, 512)	1180160
block4_conv2 (Conv2D)	(None, 28, 28, 512)	2359808
block4_conv3 (Conv2D)	(None, 28, 28, 512)	2359808
block4_pool (MaxPooling2D)	(None, 14, 14, 512)	0
block5_conv1 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv2 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv3 (Conv2D)	(None, 14, 14, 512)	2359808
block5_pool (MaxPooling2D)	(None, 7, 7, 512)	0

=====  
Total params: 14,714,688  
Trainable params: 14,714,688  
Non-trainable params: 0

---

t\_model\_4.trainable = True

```

set_trainable = False
for layer in t_model_4.layers:
    if layer.name == 'block5_conv1':
        set_trainable = True
    if set_trainable:
        layer.trainable = True
    else:
        layer.trainable = False

```

```
t_model_4.summary()
```

Model: "vgg16"

Layer (type)	Output Shape	Param #
input_3 (InputLayer)	[(None, 224, 224, 3)]	0
block1_conv1 (Conv2D)	(None, 224, 224, 64)	1792
block1_conv2 (Conv2D)	(None, 224, 224, 64)	36928
block1_pool (MaxPooling2D)	(None, 112, 112, 64)	0
block2_conv1 (Conv2D)	(None, 112, 112, 128)	73856
block2_conv2 (Conv2D)	(None, 112, 112, 128)	147584
block2_pool (MaxPooling2D)	(None, 56, 56, 128)	0
block3_conv1 (Conv2D)	(None, 56, 56, 256)	295168
block3_conv2 (Conv2D)	(None, 56, 56, 256)	590080
block3_conv3 (Conv2D)	(None, 56, 56, 256)	590080
block3_pool (MaxPooling2D)	(None, 28, 28, 256)	0
block4_conv1 (Conv2D)	(None, 28, 28, 512)	1180160
block4_conv2 (Conv2D)	(None, 28, 28, 512)	2359808
block4_conv3 (Conv2D)	(None, 28, 28, 512)	2359808
block4_pool (MaxPooling2D)	(None, 14, 14, 512)	0
block5_conv1 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv2 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv3 (Conv2D)	(None, 14, 14, 512)	2359808

block5\_pool (MaxPooling2D) (None, 7, 7, 512) 0

```
=====
Total params: 14,714,688
Trainable params: 7,079,424
Non-trainable params: 7,635,264
=====
```

As we can see the only trainable parameters here are the convolutional layers at block5\_conv1, 2, and 3.

```
model_vgg16_3 = Sequential()
model_vgg16_3.add(t_model_4)
model_vgg16_3.add(Flatten())
model_vgg16_3.add(Dense(64,
activation='relu',kernel_regularizer=regularizers.l2(0.0001)))
model_vgg16_3.add(Dense(32,
activation='relu',kernel_regularizer=regularizers.l2(0.0001)))
model_vgg16_3.add(Dense(3, activation='softmax'))

model_vgg16_3.summary()
```

Model: "sequential\_3"

Layer (type)	Output Shape	Param #
vgg16 (Functional)	(None, 7, 7, 512)	14714688
flatten_1 (Flatten)	(None, 25088)	0
dense_6 (Dense)	(None, 64)	1605696
dense_7 (Dense)	(None, 32)	2080
dense_8 (Dense)	(None, 3)	99

```
=====
Total params: 16,322,563
Trainable params: 8,687,299
Non-trainable params: 7,635,264
=====
```

```
model_vgg16_3.compile(loss='categorical_crossentropy',
optimizer=Adam(lr=0.00001),
metrics=['acc'])
```

```
hist_vgg16_3 = model_vgg16_3.fit_generator(
train_generator,
epochs=15,
validation_data=test_generator)
```

```
/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/adam.py:105:
UserWarning: The `lr` argument is deprecated, use `learning_rate`
instead.
```

```
super(Adam, self).__init__(name, **kwargs)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:8:
UserWarning: `Model.fit_generator` is deprecated and will be removed
in a future version. Please use `Model.fit`, which supports
generators.
```

```
Epoch 1/15
89/89 [=====] - 326s 4s/step - loss: 0.6628 -
acc: 0.7506 - val_loss: 0.4059 - val_acc: 0.8482
Epoch 2/15
89/89 [=====] - 62s 696ms/step - loss: 0.3712
- acc: 0.8565 - val_loss: 0.2993 - val_acc: 0.8993
Epoch 3/15
89/89 [=====] - 62s 695ms/step - loss: 0.2889
- acc: 0.8948 - val_loss: 0.2714 - val_acc: 0.9109
Epoch 4/15
89/89 [=====] - 62s 692ms/step - loss: 0.2333
- acc: 0.9203 - val_loss: 0.2604 - val_acc: 0.9134
Epoch 5/15
89/89 [=====] - 62s 694ms/step - loss: 0.2054
- acc: 0.9330 - val_loss: 0.2002 - val_acc: 0.9340
Epoch 6/15
89/89 [=====] - 61s 687ms/step - loss: 0.1868
- acc: 0.9380 - val_loss: 0.2532 - val_acc: 0.9200
Epoch 7/15
89/89 [=====] - 62s 691ms/step - loss: 0.1790
- acc: 0.9394 - val_loss: 0.1907 - val_acc: 0.9389
Epoch 8/15
89/89 [=====] - 61s 689ms/step - loss: 0.1596
- acc: 0.9469 - val_loss: 0.3023 - val_acc: 0.9035
Epoch 9/15
89/89 [=====] - 61s 687ms/step - loss: 0.1597
- acc: 0.9486 - val_loss: 0.1901 - val_acc: 0.9398
Epoch 10/15
89/89 [=====] - 61s 685ms/step - loss: 0.1398
- acc: 0.9593 - val_loss: 0.1766 - val_acc: 0.9455
Epoch 11/15
89/89 [=====] - 61s 684ms/step - loss: 0.1336
- acc: 0.9571 - val_loss: 0.1991 - val_acc: 0.9307
Epoch 12/15
89/89 [=====] - 61s 682ms/step - loss: 0.1274
- acc: 0.9632 - val_loss: 0.1723 - val_acc: 0.9455
Epoch 13/15
89/89 [=====] - 61s 689ms/step - loss: 0.1159
- acc: 0.9667 - val_loss: 0.1742 - val_acc: 0.9447
Epoch 14/15
```

```
89/89 [=====] - 60s 678ms/step - loss: 0.1155
- acc: 0.9607 - val_loss: 0.2048 - val_acc: 0.9332
Epoch 15/15
89/89 [=====] - 61s 683ms/step - loss: 0.1125
- acc: 0.9649 - val_loss: 0.1799 - val_acc: 0.9455
```

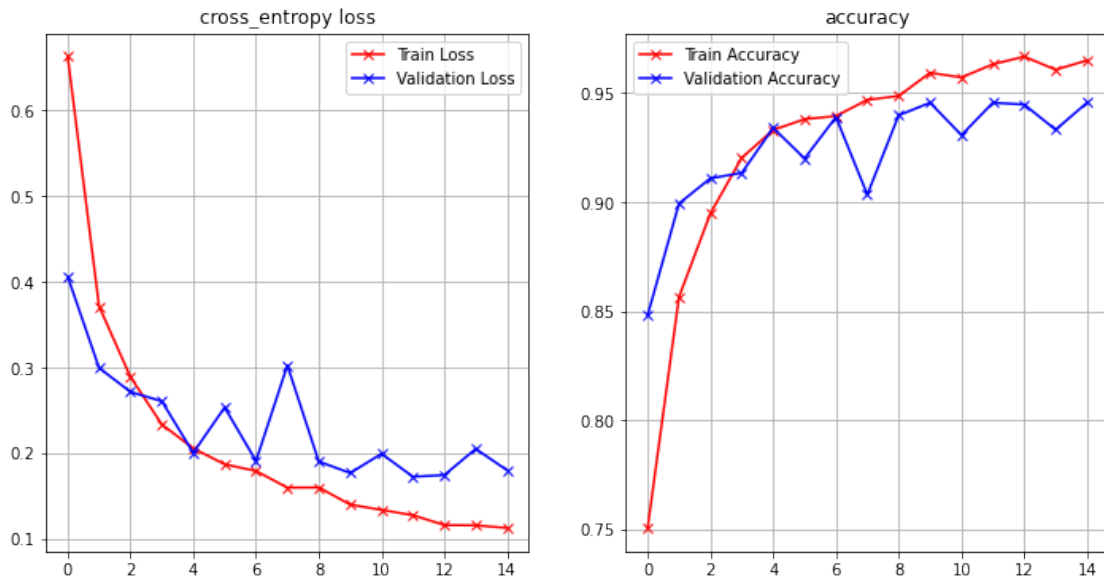
```
def plot_loss_accuracy_vgg16(history):
    fig = plt.figure(figsize=(12, 6))
    ax = fig.add_subplot(1, 2, 1)
    ax.plot(history.history["loss"], 'r-x', label="Train Loss")
    ax.plot(history.history["val_loss"], 'b-x', label="Validation
Loss")
    ax.legend()
    ax.set_title('cross_entropy loss')
    ax.grid(True)

    ax = fig.add_subplot(1, 2, 2)
    ax.plot(history.history["acc"], 'r-x', label="Train Accuracy")
    ax.plot(history.history["val_acc"], 'b-x', label="Validation
Accuracy")
    ax.legend()
    ax.set_title('accuracy')
    ax.grid(True)
```

```
print('Test loss:', hist_vgg16_3.history["val_loss"][-1])
print('Test accuracy:', hist_vgg16_3.history['val_acc'][-1])
print('Train loss:', hist_vgg16_3.history["loss"][-1])
print('Train accuracy:', hist_vgg16_3.history['acc'][-1])
plot_loss_accuracy_vgg16(hist_vgg16_3)
```

```
Test loss: 0.17993402481079102
Test accuracy: 0.9455445408821106
Train loss: 0.11249853670597076
Train accuracy: 0.9649309515953064
```





## Conclusion

For the CNN that was made from scratch, model 2 met the minimum requirement of test accuracy of 85% or above at 86.71%.

For the transfer learning method using a pre-trained CNN, we used VGG16 as the top CNN and then applied our own dense layers on top. In the experiments I have conducted with transfer learning, the method that uses feature extraction seemed to not only be the fastest at training, but also got the highest test accuracy score of 94.88%.

However, it is important to note that while model 3 (VGG16 version 3) got the 2nd highest test accuracy score of 94.55%, its training accuracy is also really high at 96.49%. Also model 3's loss scores are a lot lower than the loss scores of model 2 for both the test and train loss.

## Recommendation

I recommend combining all the test and train data into one training set and have model 2 from our from-scratch CNN as well as our model 3 transfer learning CNN (VGG16 version 3) be trained on them. Lastly, we should have a dataset for test images containing the remaining lung x-ray images we did not use which amounts to about 19,820 images. And then record the results.