ML_SP22_Project_3 (CNN)

Due Date: 5/16 23:59 pm

In [107…

```
import sys
import os
import platform
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
```

In [108…

```
from tensorflow import keras
from tensorflow.keras import layers
from tensorflow.keras.utils import image_dataset_from_directory
from tensorflow.keras.preprocessing import image
```

The goal for this Project is to practice running CNN using a set of dog and cat image

Make sure you fill in the blank inside the TODO section and try at least two different choices for the following parameters. Summarize your findings briefly at the end of the notebook

1. Define a first model, try two epoch choices and two batch size.
2. Add dropout to the first model to see if it helps or not, pick one of the epoch and batch size you had before
3. Try a second model with slighly different model arhitecture
4. Summarize your findings

Loading the datasets

In [109…

```
# download the dogsvscats.zip, save it under your notebook directory
# or somewhere else, change base_dir to where you save the datasets
base_dir = "./dogsvscats"
```

In [110…

```
train_dataset = image_dataset_from_directory(
         os.path.join(base_dir, "train"),
        image_size=(180, 180),
        batch_size=32)
```

```
Found 2000 files belonging to 2 classes.
```

In [111…

```
validation_dataset = image_dataset_from_directory(
        os.path.join(base_dir, "validation"),
        image_size=(180, 180),
        batch_size=32)
```

```
Found 1000 files belonging to 2 classes.
```

In [112…

```
test_dataset = image_dataset_from_directory(
        os.path.join(base_dir, "test"),
        image_size=(180, 180),
        batch_size=1000)
```

```
Found 1000 files belonging to 2 classes.
```

In [113…

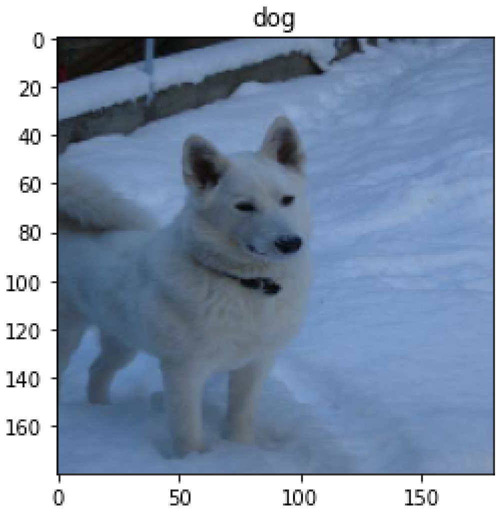
```
images, labels = list(train_dataset.take(1))[0]
class_names = train_dataset.class_names
```

In [114…

```
idx = 2
plt.imshow(images[idx].numpy().astype("uint8"))
plt.title(class_names[labels[idx].numpy()])
```

Out[114…

```
Text(0.5, 1.0, 'dog')
```



In [115…

```
plt.figure(figsize=(10, 10))
for images, labels in train_dataset.take(1):
  for i in range(32):
    ax = plt.subplot(6, 6, i + 1)
    plt.imshow(images[i].numpy().astype("uint8"))
    plt.title(class_names[labels[i].numpy()])
    plt.axis("off")

# Plotting the images
plt.show()
```

Define your first CNN model

In [11]:

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import BatchNormalization
from tensorflow.keras.layers import Conv2D
from tensorflow.keras.layers import MaxPooling2D
from tensorflow.keras.layers import Activation
from tensorflow.keras.layers import Dropout
from tensorflow.keras.layers import Dense
from tensorflow.keras.layers import Flatten
from tensorflow.keras.layers import Input
from tensorflow.keras.models import Model
```

In [93]:

```
# TODO: fill in the blank
inputs = keras.Input(shape=(180, 180, 3))

x = layers.Rescaling(1./255)(inputs)
x = layers.BatchNormalization()(x)

x = Conv2D(filters=32, kernel_size=3, activation="relu")(x)
x = MaxPooling2D(pool_size=2)(x)
x = Conv2D(filters=64, kernel_size=3, activation="relu")(x)
x = MaxPooling2D(pool_size=2)(x)
x = Conv2D(filters=128, kernel_size=3, activation="relu")(x)

x = layers.Flatten()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)

model = keras.Model(inputs=inputs, outputs=outputs)
```

In [94]:

```
from keras.datasets import mnist
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()
train_images = train_images.reshape((60000, 28, 28, 1))
train_images = train_images.astype("float32") / 255
test_images = test_images.reshape((10000, 28, 28, 1))
test_images = test_images.astype("float32") / 255
train_images.shape
```

Out[94]:

```
(60000, 28, 28, 1)
```

Comiple the model

In [95]:

```
# TODO: fill in the blank
model.compile(optimizer="rmsprop",
    loss="binary_crossentropy",
    metrics=["accuracy"])
model.summary()
```

```
Model: "model_8"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_10 (InputLayer)       [(None, 180, 180, 3)]     0

 rescaling_9 (Rescaling)     (None, 180, 180, 3)       0

 batch_normalization_9 (Batc  (None, 180, 180, 3)      12
 hNormalization)

 conv2d_27 (Conv2D)          (None, 178, 178, 32)      896

 max_pooling2d_18 (MaxPoolin  (None, 89, 89, 32)       0
 g2D)

 conv2d_28 (Conv2D)          (None, 87, 87, 64)        18496

 max_pooling2d_19 (MaxPoolin  (None, 43, 43, 64)       0
 g2D)

 conv2d_29 (Conv2D)          (None, 41, 41, 128)       73856

 flatten_11 (Flatten)        (None, 215168)            0

 dense_9 (Dense)             (None, 1)                 215169

=================================================================
Total params: 308,429
Trainable params: 308,423
Non-trainable params: 6
_________________________________________________________________
```

Running the first model

In [81]:

```
# increase epochs
history = model.fit(
    train_dataset,
    epochs=20,
    validation_data=validation_dataset)
```

```
Epoch 1/20
63/63 [==============================] - 30s 455ms/step - loss: 1.1047 - accuracy: 0.5585 - val_loss: 0.6898 - val_accura
cy: 0.5490
```

```
Epoch 2/20
63/63 [==============================] - 28s 446ms/step - loss: 0.6328 - accuracy: 0.6540 - val_loss: 0.6250 - val_accura
cy: 0.6520
Epoch 3/20
63/63 [==============================] - 28s 447ms/step - loss: 0.5199 - accuracy: 0.7445 - val_loss: 0.5931 - val_accura
cy: 0.7000
Epoch 4/20
63/63 [==============================] - 28s 446ms/step - loss: 0.4098 - accuracy: 0.8270 - val_loss: 0.5877 - val_accura
cy: 0.7000
Epoch 5/20
63/63 [==============================] - 28s 449ms/step - loss: 0.2883 - accuracy: 0.8855 - val_loss: 0.7424 - val_accura
cy: 0.6560
Epoch 6/20
63/63 [==============================] - 28s 445ms/step - loss: 0.1732 - accuracy: 0.9375 - val_loss: 0.7335 - val_accura
cy: 0.7010
Epoch 7/20
63/63 [==============================] - 28s 448ms/step - loss: 0.1105 - accuracy: 0.9655 - val_loss: 0.9225 - val_accura
cy: 0.6970
Epoch 8/20
63/63 [==============================] - 28s 451ms/step - loss: 0.0511 - accuracy: 0.9890 - val_loss: 1.3454 - val_accura
cy: 0.6840
Epoch 9/20
63/63 [==============================] - 28s 452ms/step - loss: 0.0446 - accuracy: 0.9855 - val_loss: 1.5448 - val_accura
cy: 0.6820
Epoch 10/20
63/63 [==============================] - 28s 449ms/step - loss: 0.0150 - accuracy: 0.9955 - val_loss: 2.2560 - val_accura
cy: 0.6850
Epoch 11/20
63/63 [==============================] - 28s 444ms/step - loss: 0.0450 - accuracy: 0.9915 - val_loss: 2.0842 - val_accura
cy: 0.6810
Epoch 12/20
63/63 [==============================] - 28s 445ms/step - loss: 0.0654 - accuracy: 0.9890 - val_loss: 2.0194 - val_accura
cy: 0.6840
Epoch 13/20
63/63 [==============================] - 28s 445ms/step - loss: 0.0273 - accuracy: 0.9915 - val_loss: 2.2777 - val_accura
cy: 0.6860
Epoch 14/20
63/63 [==============================] - 28s 446ms/step - loss: 0.0264 - accuracy: 0.9945 - val_loss: 2.4137 - val_accura
cy: 0.6920
Epoch 15/20
63/63 [==============================] - 28s 448ms/step - loss: 0.0256 - accuracy: 0.9935 - val_loss: 2.5007 - val_accura
cy: 0.6770
Epoch 16/20
63/63 [==============================] - 28s 445ms/step - loss: 0.0222 - accuracy: 0.9930 - val_loss: 2.5095 - val_accura
cy: 0.6810
```

```
Epoch 17/20
63/63 [==============================] - 28s 448ms/step - loss: 0.0143 - accuracy: 0.9950 - val_loss: 2.9525 - val_accura
cy: 0.6570
Epoch 18/20
63/63 [==============================] - 28s 446ms/step - loss: 0.0275 - accuracy: 0.9920 - val_loss: 3.0863 - val_accura
cy: 0.6710
Epoch 19/20
63/63 [==============================] - 28s 446ms/step - loss: 0.0016 - accuracy: 0.9990 - val_loss: 3.0933 - val_accura
cy: 0.6870
Epoch 20/20
63/63 [==============================] - 28s 448ms/step - loss: 0.0373 - accuracy: 0.9920 - val_loss: 3.2103 - val_accura
cy: 0.7030
```

Now, look at the testing dataset

In [82]:

```python
test_images, test_labels = list(test_dataset.take(1))[0]
```

In [83]:

```python
class_names
```

Out[83]:

```
['cat', 'dog']
```

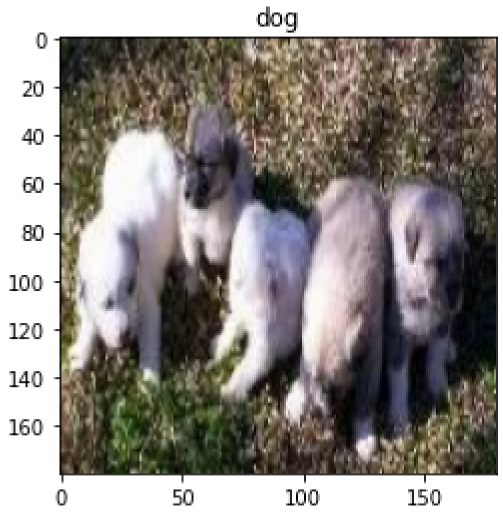
Predict one image at a time

In [84]:

```python
idx = 50
plt.imshow(test_images[idx].numpy().astype("uint8"))
plt.title(class_names[test_labels[idx].numpy()])
```

Out[84]:

```
Text(0.5, 1.0, 'dog')
```



In [85]:

```
img = test_images[idx]
img_array = image.img_to_array(img)
img_batch = np.expand_dims(img_array, axis=0)
```

In [86]:

```
print(img_array.shape)
print(img_batch.shape)
```

```
(180, 180, 3)
(1, 180, 180, 3)
```

In [87]:

```
prediction = model.predict(img_batch)
```

In [88]:

```
print(prediction)
```

```
[[0.8381897]]
```

Evaluate your first model out-of-sample

In [89]:

```
# TODO fill-in the blank here
test_loss, test_acc = model.evaluate(test_images, test_labels)
print(f"Test accuracy: {test_acc:.3f}")
```

```
32/32 [==============================] - 2s 65ms/step - loss: 3.6269 - accuracy: 0.6630
Test accuracy: 0.663
```

66.3% accuracy. Not bad, but we may use Dropout to improve performance

In [90]:

```
inputs = keras.Input(shape=(180, 180, 3))

x = layers.Rescaling(1./255)(inputs)
x = layers.BatchNormalization()(x)

x = Conv2D(filters=32, kernel_size=3, activation="relu")(x)
x = MaxPooling2D(pool_size=2)(x)
x = Conv2D(filters=64, kernel_size=3, activation="relu")(x)
x = MaxPooling2D(pool_size=2)(x)
x = Conv2D(filters=128, kernel_size=3, activation="relu")(x)
x = Dropout(0.2)(x)

x = layers.Flatten()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)

model2 = keras.Model(inputs=inputs, outputs=outputs)

model2.compile(
    loss='binary_crossentropy',
    optimizer='adam',
    metrics=['accuracy']
)
model2.summary()
```

```
Model: "model_7"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 input_9 (InputLayer)        [(None, 180, 180, 3)]     0         
                                                                 
 rescaling_8 (Rescaling)     (None, 180, 180, 3)       0         
                                                                 
 batch_normalization_8 (Batc  (None, 180, 180, 3)      12        
 hNormalization)                                                 
                                                                 
 conv2d_24 (Conv2D)          (None, 178, 178, 32)      896       
                                                                 
 max_pooling2d_16 (MaxPoolin  (None, 89, 89, 32)       0         
 g2D)                                                            
 conv2d_25 (Conv2D)          (None, 87, 87, 64)        18496

 max_pooling2d_17 (MaxPoolin  (None, 43, 43, 64)       0
 g2D)

 conv2d_26 (Conv2D)          (None, 41, 41, 128)       73856

 dropout_1 (Dropout)         (None, 41, 41, 128)       0

 flatten_10 (Flatten)        (None, 215168)            0

 dense_8 (Dense)             (None, 1)                 215169

=================================================================
Total params: 308,429
Trainable params: 308,423
Non-trainable params: 6
_________________________________________________________________
```

In [91]:

```python
history = model2.fit(
    train_dataset,
    epochs=20,
    validation_data=validation_dataset)
```

```
Epoch 1/20
63/63 [==============================] - 30s 474ms/step - loss: 0.7936 - accuracy: 0.5140 - val_loss: 0.6901 - val_accura
cy: 0.5430
Epoch 2/20
63/63 [==============================] - 30s 471ms/step - loss: 0.6463 - accuracy: 0.5930 - val_loss: 0.6813 - val_accura
cy: 0.5530
Epoch 3/20
63/63 [==============================] - 30s 476ms/step - loss: 0.6237 - accuracy: 0.6355 - val_loss: 0.6317 - val_accura
cy: 0.6240
Epoch 4/20
63/63 [==============================] - 30s 475ms/step - loss: 0.5530 - accuracy: 0.7110 - val_loss: 0.5957 - val_accura
cy: 0.6810
Epoch 5/20
63/63 [==============================] - 31s 485ms/step - loss: 0.4864 - accuracy: 0.7605 - val_loss: 0.5790 - val_accura
cy: 0.6960
Epoch 6/20
63/63 [==============================] - 30s 472ms/step - loss: 0.4033 - accuracy: 0.8140 - val_loss: 0.7790 - val_accura
cy: 0.6550
Epoch 7/20
```

```
63/63 [==============================] - 30s 477ms/step - loss: 0.3232 - accuracy: 0.8600 - val_loss: 0.8131 - val_accura
cy: 0.6790
Epoch 8/20
63/63 [==============================] - 30s 474ms/step - loss: 0.2801 - accuracy: 0.8780 - val_loss: 0.8232 - val_accura
cy: 0.7040
Epoch 9/20
63/63 [==============================] - 30s 476ms/step - loss: 0.2044 - accuracy: 0.9245 - val_loss: 0.9740 - val_accura
cy: 0.6730
Epoch 10/20
63/63 [==============================] - 30s 474ms/step - loss: 0.1249 - accuracy: 0.9570 - val_loss: 1.1982 - val_accura
cy: 0.6790
Epoch 11/20
63/63 [==============================] - 30s 475ms/step - loss: 0.0752 - accuracy: 0.9770 - val_loss: 1.3764 - val_accura
cy: 0.6890
Epoch 12/20
63/63 [==============================] - 30s 472ms/step - loss: 0.0686 - accuracy: 0.9725 - val_loss: 1.4874 - val_accura
cy: 0.6730
Epoch 13/20
63/63 [==============================] - 30s 470ms/step - loss: 0.0517 - accuracy: 0.9860 - val_loss: 1.5559 - val_accura
cy: 0.6990
Epoch 14/20
63/63 [==============================] - 30s 481ms/step - loss: 0.0412 - accuracy: 0.9890 - val_loss: 1.6638 - val_accura
cy: 0.6910
Epoch 15/20
63/63 [==============================] - 30s 480ms/step - loss: 0.0167 - accuracy: 0.9965 - val_loss: 1.8648 - val_accura
cy: 0.6880
Epoch 16/20
63/63 [==============================] - 30s 477ms/step - loss: 0.0116 - accuracy: 0.9995 - val_loss: 2.0126 - val_accura
cy: 0.6920
Epoch 17/20
63/63 [==============================] - 30s 475ms/step - loss: 0.0106 - accuracy: 0.9975 - val_loss: 2.1429 - val_accura
cy: 0.6920
Epoch 18/20
63/63 [==============================] - 30s 478ms/step - loss: 0.0157 - accuracy: 0.9960 - val_loss: 2.1807 - val_accura
cy: 0.6700
Epoch 19/20
63/63 [==============================] - 30s 470ms/step - loss: 0.0177 - accuracy: 0.9940 - val_loss: 2.2102 - val_accura
cy: 0.6810
Epoch 20/20
63/63 [==============================] - 30s 470ms/step - loss: 0.0178 - accuracy: 0.9950 - val_loss: 2.4069 - val_accura
cy: 0.6810
```

In [92]:

```
test_images, test_labels = list(test_dataset.take(1))[0]
test_loss, test_acc = model2.evaluate(test_images, test_labels)
print(f"Test accuracy: {test_acc:.3f}")
```

```
32/32 [==============================] - 2s 65ms/step - loss: 2.5483 - accuracy: 0.6790
Test accuracy: 0.679
```

Using Dropout, our accuracy slightly increased to 67.9%

Try different choices of epoch, batch size for your first model

In [96]:

```
# Type your code here
train_dataset = image_dataset_from_directory(
         os.path.join(base_dir, "train"),
        image_size=(180, 180),
        batch_size=16)

validation_dataset = image_dataset_from_directory(
        os.path.join(base_dir, "validation"),
        image_size=(180, 180),
        batch_size=16)

history = model.fit(
    train_dataset,
    epochs=8,
    validation_data=validation_dataset)
```

```
Found 2000 files belonging to 2 classes.
Found 1000 files belonging to 2 classes.
Epoch 1/8
125/125 [==============================] - 30s 236ms/step - loss: 0.8629 - accuracy: 0.5995 - val_loss: 0.6488 - val_accu
racy: 0.6260
Epoch 2/8
125/125 [==============================] - 30s 237ms/step - loss: 0.6107 - accuracy: 0.6720 - val_loss: 0.5963 - val_accu
racy: 0.6760
Epoch 3/8
125/125 [==============================] - 29s 236ms/step - loss: 0.4985 - accuracy: 0.7615 - val_loss: 0.6369 - val_accu
racy: 0.6900
Epoch 4/8
125/125 [==============================] - 29s 235ms/step - loss: 0.3527 - accuracy: 0.8435 - val_loss: 0.6552 - val_accu
racy: 0.7060
Epoch 5/8
125/125 [==============================] - 30s 237ms/step - loss: 0.2049 - accuracy: 0.9165 - val_loss: 1.0567 - val_accu
racy: 0.6760
Epoch 6/8
125/125 [==============================] - 30s 237ms/step - loss: 0.1140 - accuracy: 0.9575 - val_loss: 1.6088 - val_accu
```

```
racy: 0.6590
Epoch 7/8
125/125 [==============================] - 30s 237ms/step - loss: 0.0709 - accuracy: 0.9745 - val_loss: 1.6531 - val_accu
racy: 0.6990
Epoch 8/8
125/125 [==============================] - 30s 239ms/step - loss: 0.0617 - accuracy: 0.9790 - val_loss: 1.7955 - val_accu
racy: 0.6970
```

In [97]:

```
test_images, test_labels = list(test_dataset.take(1))[0]
test_loss, test_acc = model.evaluate(test_images, test_labels)
print(f"Test accuracy: {test_acc:.3f}")
```

```
32/32 [==============================] - 2s 67ms/step - loss: 1.9084 - accuracy: 0.6810
Test accuracy: 0.681
```

Changing the epoch and batch size increased the accuracy further to 68.1%

Try a second model with slightly different architecture (no need to be very complicated)

We will implement a model without MaxPooling

In [116…

```
# Type your code here
#
inputs = keras.Input(shape=(180, 180, 3))

x = layers.Rescaling(1./255)(inputs)
x = layers.BatchNormalization()(x)

x = Conv2D(filters=32, kernel_size=3, activation="relu")(x)
x = Conv2D(filters=64, kernel_size=3, activation="relu")(x)
x = Conv2D(filters=128, kernel_size=3, activation="relu")(x)

x = layers.Flatten()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)

model = keras.Model(inputs=inputs, outputs=outputs)
model.summary()
```

```
Model: "model_11"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_13 (InputLayer)       [(None, 180, 180, 3)]     0

 rescaling_12 (Rescaling)    (None, 180, 180, 3)       0

 batch_normalization_12 (Bat  (None, 180, 180, 3)      12
 chNormalization)

 conv2d_36 (Conv2D)          (None, 178, 178, 32)      896

 conv2d_37 (Conv2D)          (None, 176, 176, 64)      18496

 conv2d_38 (Conv2D)          (None, 174, 174, 128)     73856

 flatten_14 (Flatten)        (None, 3875328)           0

 dense_12 (Dense)            (None, 1)                 3875329

=================================================================
Total params: 3,968,589
Trainable params: 3,968,583
Non-trainable params: 6
_________________________________________________________________
```

In [119…

```
model.compile(optimizer="rmsprop",
    loss="binary_crossentropy",
    metrics=["accuracy"])
history = model.fit(
    train_dataset,
    epochs=5,
    validation_data=validation_dataset)
```

```
Epoch 1/5
63/63 [==============================] - 115s 2s/step - loss: 1.6251 - accuracy: 0.5555 - val_loss: 0.7085 - val_accurac
y: 0.5230
Epoch 2/5
63/63 [==============================] - 112s 2s/step - loss: 0.9124 - accuracy: 0.6580 - val_loss: 0.6579 - val_accurac
y: 0.5940
Epoch 3/5
63/63 [==============================] - 112s 2s/step - loss: 0.4445 - accuracy: 0.8250 - val_loss: 0.6700 - val_accurac
y: 0.6410
Epoch 4/5
63/63 [==============================] - 112s 2s/step - loss: 0.2245 - accuracy: 0.9430 - val_loss: 0.8818 - val_accurac
y: 0.6640
Epoch 5/5
```

```
63/63 [==============================] - 111s 2s/step - loss: 0.0383 - accuracy: 0.9915 - val_loss: 1.2913 - val_accurac
y: 0.6610
```

In [120…

```
# TODO test your second model on out-of-sample data
test_images, test_labels = list(test_dataset.take(1))[0]
test_loss, test_acc = model2.evaluate(test_images, test_labels)
print(f"Test accuracy: {test_acc:.3f}")
```

```
32/32 [==============================] - 2s 65ms/step - loss: 2.5483 - accuracy: 0.6790
Test accuracy: 0.679
```

The model without MaxPooling provided an accuracy of 67.9%

Summarize your findings below

In [ ]:

```
# Type your answers and comments here
```

In this project, many things were uncovered about the neural network. For the first model, I have learned that adding a dropout layer can improve accuracy of the neural network. This is because dropout layers decrease the risk of overfitting to the data that it is given.

We have also learned that decreasing the epoch and batch size can increase the neural networks accuracy. We can conclude that a small batch size allows our network to train better, with less variability.

Lastly, with our last model without MaxPooling, I have found out that model fitting took significantly longer than the model without it. From this, we can see that pooling is faster to compute than convolutions