In [ ]:
```python
# imports
import os
import pandas as pd
import numpy as np

# load data
train = pd.read_csv('../data/processed/train_data_processed.csv')
test = pd.read_csv('../data/processed/test_data_processed.csv')
val = pd.read_csv('../data/processed/val_data_processed.csv')
```

In [ ]:
```python
# more feature engineering
# use encoder to encode OCCURRED_ON_DATE column
from sklearn.preprocessing import LabelEncoder
le = LabelEncoder()
train['OCCURRED_ON_DATE'] = le.fit_transform(train['OCCURRED_ON_DATE'])
test['OCCURRED_ON_DATE'] = le.transform(test['OCCURRED_ON_DATE'])
val['OCCURRED_ON_DATE'] = le.transform(val['OCCURRED_ON_DATE'])
```

In [ ]:
```python
# save le
import joblib
joblib.dump(le, '../models/datetime_encoder.pkl')
```

Out[ ]:
```
['../models/datetime_encoder.pkl']
```

In [ ]:
```python
#drop _id column

test = test.drop('_id', axis=1)
val = val.drop('_id', axis=1)
```

In [ ]:
```python
# define the target variable
y_train = train['Severe_crimes']
y_test = test['Severe_crimes']
y_val = val['Severe_crimes']

# define the features
X_train = train.drop(['Severe_crimes'], axis=1)
X_test = test.drop(['Severe_crimes'], axis=1)
X_val = val.drop(['Severe_crimes'], axis=1)
```

In [ ]:
```python
# build a CNN model
from keras.models import Sequential
from keras.layers import Dense, Dropout
from keras import regularizers

model = Sequential()
model.add(Dense(64, input_dim=7, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(32, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(1, activation='sigmoid'))

# compile the model
model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accuracy']

# fit the model
history = model.fit(X_train, y_train, epochs=50, batch_size=64, validation_data=
```

```
WARNING:tensorflow:From c:\Users\wangd\.conda\envs\BCAIML\Lib\site-packages\keras
\src\losses.py:2976: The name tf.losses.sparse_softmax_cross_entropy is deprecate
d. Please use tf.compat.v1.losses.sparse_softmax_cross_entropy instead.

WARNING:tensorflow:From c:\Users\wangd\.conda\envs\BCAIML\Lib\site-packages\keras
\src\backend.py:873: The name tf.get_default_graph is deprecated. Please use tf.c
ompat.v1.get_default_graph instead.

WARNING:tensorflow:From c:\Users\wangd\.conda\envs\BCAIML\Lib\site-packages\keras
\src\optimizers\__init__.py:309: The name tf.train.Optimizer is deprecated. Pleas
e use tf.compat.v1.train.Optimizer instead.

Epoch 1/50
WARNING:tensorflow:From c:\Users\wangd\.conda\envs\BCAIML\Lib\site-packages\keras
\src\utils\tf_utils.py:492: The name tf.ragged.RaggedTensorValue is deprecated. P
lease use tf.compat.v1.ragged.RaggedTensorValue instead.

WARNING:tensorflow:From c:\Users\wangd\.conda\envs\BCAIML\Lib\site-packages\keras
\src\engine\base_layer_utils.py:384: The name tf.executing_eagerly_outside_functi
ons is deprecated. Please use tf.compat.v1.executing_eagerly_outside_functions in
stead.

964/964 [==============================] - 3s 2ms/step - loss: 7.3420 - accuracy:
0.8907 - val_loss: 0.1911 - val_accuracy: 0.9365
Epoch 2/50
964/964 [==============================] - 2s 2ms/step - loss: 0.4153 - accuracy:
0.9285 - val_loss: 0.2043 - val_accuracy: 0.9365
Epoch 3/50
964/964 [==============================] - 1s 1ms/step - loss: 0.2689 - accuracy:
0.9308 - val_loss: 0.1859 - val_accuracy: 0.9365
Epoch 4/50
964/964 [==============================] - 1s 1ms/step - loss: 0.2309 - accuracy:
0.9316 - val_loss: 0.1817 - val_accuracy: 0.9365
Epoch 5/50
964/964 [==============================] - 2s 2ms/step - loss: 0.2206 - accuracy:
0.9319 - val_loss: 0.1768 - val_accuracy: 0.9365
Epoch 6/50
964/964 [==============================] - 1s 1ms/step - loss: 0.2080 - accuracy:
0.9336 - val_loss: 0.1753 - val_accuracy: 0.9365
Epoch 7/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1961 - accuracy:
0.9357 - val_loss: 0.1480 - val_accuracy: 0.9365
Epoch 8/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1767 - accuracy:
0.9387 - val_loss: 0.1255 - val_accuracy: 0.9365
Epoch 9/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1585 - accuracy:
0.9402 - val_loss: 0.1056 - val_accuracy: 0.9507
Epoch 10/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1417 - accuracy:
0.9438 - val_loss: 0.1009 - val_accuracy: 0.9522
Epoch 11/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1329 - accuracy:
0.9462 - val_loss: 0.1008 - val_accuracy: 0.9526
Epoch 12/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1250 - accuracy:
0.9485 - val_loss: 0.0979 - val_accuracy: 0.9615
Epoch 13/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1152 - accuracy:
0.9519 - val_loss: 0.0918 - val_accuracy: 0.9655
```

```
Epoch 14/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1128 - accuracy:
0.9559 - val_loss: 0.0925 - val_accuracy: 0.9622
Epoch 15/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1074 - accuracy:
0.9610 - val_loss: 0.0930 - val_accuracy: 0.9611
Epoch 16/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1046 - accuracy:
0.9637 - val_loss: 0.0863 - val_accuracy: 0.9722
Epoch 17/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1047 - accuracy:
0.9653 - val_loss: 0.1016 - val_accuracy: 0.9712
Epoch 18/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1021 - accuracy:
0.9656 - val_loss: 0.0829 - val_accuracy: 0.9746
Epoch 19/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1000 - accuracy:
0.9682 - val_loss: 0.0793 - val_accuracy: 0.9758
Epoch 20/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0965 - accuracy:
0.9687 - val_loss: 0.0794 - val_accuracy: 0.9769
Epoch 21/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0924 - accuracy:
0.9713 - val_loss: 0.0750 - val_accuracy: 0.9791
Epoch 22/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0913 - accuracy:
0.9711 - val_loss: 0.0735 - val_accuracy: 0.9781
Epoch 23/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0887 - accuracy:
0.9728 - val_loss: 0.0696 - val_accuracy: 0.9796
Epoch 24/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0869 - accuracy:
0.9734 - val_loss: 0.0704 - val_accuracy: 0.9775
Epoch 25/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0883 - accuracy:
0.9726 - val_loss: 0.0644 - val_accuracy: 0.9818
Epoch 26/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0871 - accuracy:
0.9729 - val_loss: 0.0680 - val_accuracy: 0.9827
Epoch 27/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0869 - accuracy:
0.9727 - val_loss: 0.0706 - val_accuracy: 0.9785
Epoch 28/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0882 - accuracy:
0.9708 - val_loss: 0.0672 - val_accuracy: 0.9808
Epoch 29/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0851 - accuracy:
0.9730 - val_loss: 0.0701 - val_accuracy: 0.9785
Epoch 30/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0863 - accuracy:
0.9719 - val_loss: 0.0667 - val_accuracy: 0.9845
Epoch 31/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0862 - accuracy:
0.9721 - val_loss: 0.0688 - val_accuracy: 0.9792
Epoch 32/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0859 - accuracy:
0.9729 - val_loss: 0.0735 - val_accuracy: 0.9780
Epoch 33/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0864 - accuracy:
0.9719 - val_loss: 0.0668 - val_accuracy: 0.9803
```

```
Epoch 34/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0852 - accuracy:
0.9729 - val_loss: 0.0709 - val_accuracy: 0.9774
Epoch 35/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0848 - accuracy:
0.9724 - val_loss: 0.0684 - val_accuracy: 0.9785
Epoch 36/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0861 - accuracy:
0.9721 - val_loss: 0.0612 - val_accuracy: 0.9847
Epoch 37/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0833 - accuracy:
0.9722 - val_loss: 0.0696 - val_accuracy: 0.9794
Epoch 38/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0830 - accuracy:
0.9743 - val_loss: 0.0661 - val_accuracy: 0.9788
Epoch 39/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0842 - accuracy:
0.9722 - val_loss: 0.0655 - val_accuracy: 0.9784
Epoch 40/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0837 - accuracy:
0.9733 - val_loss: 0.0745 - val_accuracy: 0.9769
Epoch 41/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0834 - accuracy:
0.9726 - val_loss: 0.0721 - val_accuracy: 0.9776
Epoch 42/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0813 - accuracy:
0.9754 - val_loss: 0.0616 - val_accuracy: 0.9847
Epoch 43/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0835 - accuracy:
0.9726 - val_loss: 0.0629 - val_accuracy: 0.9887
Epoch 44/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0826 - accuracy:
0.9736 - val_loss: 0.0647 - val_accuracy: 0.9787
Epoch 45/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0824 - accuracy:
0.9745 - val_loss: 0.0710 - val_accuracy: 0.9820
Epoch 46/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0866 - accuracy:
0.9722 - val_loss: 0.0676 - val_accuracy: 0.9803
Epoch 47/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0801 - accuracy:
0.9747 - val_loss: 0.0586 - val_accuracy: 0.9836
Epoch 48/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0788 - accuracy:
0.9755 - val_loss: 0.0570 - val_accuracy: 0.9822
Epoch 49/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0806 - accuracy:
0.9747 - val_loss: 0.0694 - val_accuracy: 0.9819
Epoch 50/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0838 - accuracy:
0.9728 - val_loss: 0.0604 - val_accuracy: 0.9804
```

In [ ]:

```python
# use the model on validation data and evaluate
y_pred = model.predict(X_val)
y_pred = (y_pred > 0.5)

# evaluate the model
from sklearn.metrics import accuracy_score, confusion_matrix
accuracy = accuracy_score(y_val, y_pred)
confusion = confusion_matrix(y_val, y_pred)
```

```
print('Accuracy:', accuracy)
print('Confusion Matrix:', confusion)

# f1 score
from sklearn.metrics import f1_score
f1 = f1_score(y_val, y_pred)
print('F1 Score:', f1)
```

```
484/484 [==============================] - 0s 768us/step
Accuracy: 0.9804137039431157
Confusion Matrix: [[14297   190]
 [  113   870]]
F1 Score: 0.8516886930983847
```

In [ ]:

```
# build a deeper CNN model
model_deeper = Sequential()
model_deeper.add(Dense(512, input_dim=7, activation='relu'))
model_deeper.add(Dropout(0.5))
model_deeper.add(Dense(256, activation='relu'))
model_deeper.add(Dropout(0.5))
model_deeper.add(Dense(128, activation='relu'))
model_deeper.add(Dropout(0.5))
model_deeper.add(Dense(64, activation='relu'))
model_deeper.add(Dropout(0.5))
model_deeper.add(Dense(32, activation='relu'))
model_deeper.add(Dropout(0.5))
model_deeper.add(Dense(1, activation='sigmoid'))




# compile the model
model_deeper.compile(loss='binary_crossentropy', optimizer='adam', metrics=['acc
model_deeper.summary()

# fit the model
history_deeper = model_deeper.fit(X_train, y_train, epochs=50, batch_size=64, va
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_3 (Dense)             (None, 512)               4096

 dropout_2 (Dropout)         (None, 512)               0

 dense_4 (Dense)             (None, 256)               131328

 dropout_3 (Dropout)         (None, 256)               0

 dense_5 (Dense)             (None, 128)               32896

 dropout_4 (Dropout)         (None, 128)               0

 dense_6 (Dense)             (None, 64)                8256

 dropout_5 (Dropout)         (None, 64)                0

 dense_7 (Dense)             (None, 32)                2080

 dropout_6 (Dropout)         (None, 32)                0

 dense_8 (Dense)             (None, 1)                 33

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_3 (Dense)             (None, 512)               4096

 dropout_2 (Dropout)         (None, 512)               0

 dense_4 (Dense)             (None, 256)               131328

 dropout_3 (Dropout)         (None, 256)               0

 dense_5 (Dense)             (None, 128)               32896

 dropout_4 (Dropout)         (None, 128)               0

 dense_6 (Dense)             (None, 64)                8256

 dropout_5 (Dropout)         (None, 64)                0

 dense_7 (Dense)             (None, 32)                2080

 dropout_6 (Dropout)         (None, 32)                0

 dense_8 (Dense)             (None, 1)                 33

=================================================================
Total params: 178689 (698.00 KB)
Trainable params: 178689 (698.00 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
Epoch 1/50
964/964 [==============================] - 5s 4ms/step - loss: 1.9188 - accuracy:
0.8950 - val_loss: 0.4700 - val_accuracy: 0.9365
Epoch 2/50
```

```
964/964 [==============================] - 4s 4ms/step - loss: 0.2627 - accuracy:
0.9248 - val_loss: 0.2639 - val_accuracy: 0.9365
Epoch 3/50
964/964 [==============================] - 3s 4ms/step - loss: 0.1983 - accuracy:
0.9303 - val_loss: 0.1985 - val_accuracy: 0.9365
Epoch 4/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1694 - accuracy:
0.9316 - val_loss: 0.1387 - val_accuracy: 0.9365
Epoch 5/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1524 - accuracy:
0.9316 - val_loss: 0.1390 - val_accuracy: 0.9365
Epoch 6/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1441 - accuracy:
0.9318 - val_loss: 0.1468 - val_accuracy: 0.9365
Epoch 7/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1361 - accuracy:
0.9532 - val_loss: 0.1064 - val_accuracy: 0.9741
Epoch 8/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1310 - accuracy:
0.9614 - val_loss: 0.1189 - val_accuracy: 0.9717
Epoch 9/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1303 - accuracy:
0.9641 - val_loss: 0.1212 - val_accuracy: 0.9751
Epoch 10/50
964/964 [==============================] - 3s 4ms/step - loss: 0.1228 - accuracy:
0.9658 - val_loss: 0.0937 - val_accuracy: 0.9741
Epoch 11/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1200 - accuracy:
0.9682 - val_loss: 0.1660 - val_accuracy: 0.9677
Epoch 12/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1216 - accuracy:
0.9682 - val_loss: 0.0875 - val_accuracy: 0.9749
Epoch 13/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1194 - accuracy:
0.9688 - val_loss: 0.0925 - val_accuracy: 0.9747
Epoch 14/50
964/964 [==============================] - 3s 4ms/step - loss: 0.1136 - accuracy:
0.9705 - val_loss: 0.1430 - val_accuracy: 0.9646
Epoch 15/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1137 - accuracy:
0.9708 - val_loss: 0.1352 - val_accuracy: 0.9560
Epoch 16/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1117 - accuracy:
0.9704 - val_loss: 0.0961 - val_accuracy: 0.9690
Epoch 17/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1125 - accuracy:
0.9706 - val_loss: 0.0984 - val_accuracy: 0.9696
Epoch 18/50
964/964 [==============================] - 3s 4ms/step - loss: 0.1138 - accuracy:
0.9710 - val_loss: 0.0939 - val_accuracy: 0.9732
Epoch 19/50
964/964 [==============================] - 3s 4ms/step - loss: 0.1101 - accuracy:
0.9709 - val_loss: 0.1437 - val_accuracy: 0.9702
Epoch 20/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1115 - accuracy:
0.9706 - val_loss: 0.0929 - val_accuracy: 0.9685
Epoch 21/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1097 - accuracy:
0.9712 - val_loss: 0.1954 - val_accuracy: 0.9531
Epoch 22/50
```

```
964/964 [==============================] - 3s 4ms/step - loss: 0.1105 - accuracy:
0.9707 - val_loss: 0.1240 - val_accuracy: 0.9725
Epoch 23/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1092 - accuracy:
0.9703 - val_loss: 0.1223 - val_accuracy: 0.9659
Epoch 24/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1063 - accuracy:
0.9722 - val_loss: 0.1017 - val_accuracy: 0.9714
Epoch 25/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1064 - accuracy:
0.9717 - val_loss: 0.2372 - val_accuracy: 0.9644
Epoch 26/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1080 - accuracy:
0.9711 - val_loss: 0.1997 - val_accuracy: 0.9628
Epoch 27/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1064 - accuracy:
0.9730 - val_loss: 0.1293 - val_accuracy: 0.9701
Epoch 28/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1055 - accuracy:
0.9725 - val_loss: 0.2187 - val_accuracy: 0.9704
Epoch 29/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1079 - accuracy:
0.9728 - val_loss: 0.1896 - val_accuracy: 0.9646
Epoch 30/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1095 - accuracy:
0.9715 - val_loss: 0.1236 - val_accuracy: 0.9655
Epoch 31/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1086 - accuracy:
0.9722 - val_loss: 0.0956 - val_accuracy: 0.9667
Epoch 32/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1083 - accuracy:
0.9711 - val_loss: 0.1136 - val_accuracy: 0.9703
Epoch 33/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1056 - accuracy:
0.9721 - val_loss: 0.1294 - val_accuracy: 0.9607
Epoch 34/50
964/964 [==============================] - 3s 4ms/step - loss: 0.1042 - accuracy:
0.9716 - val_loss: 0.0888 - val_accuracy: 0.9676
Epoch 35/50
964/964 [==============================] - 3s 4ms/step - loss: 0.1061 - accuracy:
0.9713 - val_loss: 0.0851 - val_accuracy: 0.9737
Epoch 36/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1048 - accuracy:
0.9708 - val_loss: 0.1579 - val_accuracy: 0.9379
Epoch 37/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1037 - accuracy:
0.9710 - val_loss: 0.1158 - val_accuracy: 0.9657
Epoch 38/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1035 - accuracy:
0.9720 - val_loss: 0.1255 - val_accuracy: 0.9703
Epoch 39/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1027 - accuracy:
0.9721 - val_loss: 0.2129 - val_accuracy: 0.9664
Epoch 40/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1004 - accuracy:
0.9722 - val_loss: 0.1353 - val_accuracy: 0.9654
Epoch 41/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1036 - accuracy:
0.9719 - val_loss: 0.1435 - val_accuracy: 0.9666
Epoch 42/50
```

```
964/964 [==============================] - 3s 4ms/step - loss: 0.1026 - accuracy:
0.9724 - val_loss: 0.0868 - val_accuracy: 0.9674
Epoch 43/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1007 - accuracy:
0.9722 - val_loss: 0.2084 - val_accuracy: 0.9253
Epoch 44/50
964/964 [==============================] - 3s 4ms/step - loss: 0.1049 - accuracy:
0.9712 - val_loss: 0.1997 - val_accuracy: 0.9510
Epoch 45/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1049 - accuracy:
0.9723 - val_loss: 0.1782 - val_accuracy: 0.9643
Epoch 46/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1000 - accuracy:
0.9716 - val_loss: 0.1358 - val_accuracy: 0.9691
Epoch 47/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1025 - accuracy:
0.9716 - val_loss: 0.0979 - val_accuracy: 0.9668
Epoch 48/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1030 - accuracy:
0.9714 - val_loss: 0.0848 - val_accuracy: 0.9673
Epoch 49/50
964/964 [==============================] - 3s 3ms/step - loss: 0.1031 - accuracy:
0.9724 - val_loss: 0.1239 - val_accuracy: 0.9567
Epoch 50/50
964/964 [==============================] - 4s 4ms/step - loss: 0.1072 - accuracy:
0.9715 - val_loss: 0.1146 - val_accuracy: 0.9654
```

In [ ]:

```python
# use the model on validation data and evaluate
y_pred = model_deeper.predict(X_val)
y_pred = (y_pred > 0.5)

# evaluate the model
from sklearn.metrics import accuracy_score, confusion_matrix
accuracy = accuracy_score(y_val, y_pred)
confusion = confusion_matrix(y_val, y_pred)

print('Accuracy:', accuracy)
print('Confusion Matrix:', confusion)

# f1 score
from sklearn.metrics import f1_score
f1 = f1_score(y_val, y_pred)
print('F1 Score:', f1)
```

```
484/484 [==============================] - 1s 1ms/step
Accuracy: 0.9654169360051713
Confusion Matrix: [[14023   464]
 [   71   912]]
F1 Score: 0.7732089868588384
```

In [ ]:

```python
# test different dropout rates
dropout_rates = [0.1, 0.2, 0.3, 0.4, 0.5]
f1_scores = []

for rate in dropout_rates:
    model = Sequential()
    model.add(Dense(64, input_dim=7, activation='relu'))
    model.add(Dropout(rate))
    model.add(Dense(32, activation='relu'))
    model.add(Dropout(rate))
```

```
    model.add(Dense(1, activation='sigmoid'))

    # compile the model
    model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accura

    # fit the model
    history = model.fit(X_train, y_train, epochs=50, batch_size=64, validation_d

    # use the model on validation data and evaluate
    y_pred = model.predict(X_val)
    y_pred = (y_pred > 0.5)

    # f1 score
    f1 = f1_score(y_val, y_pred)
    f1_scores.append(f1)

print(f1_scores)
```

```
Epoch 1/50
964/964 [==============================] - 2s 2ms/step - loss: 4.6706 - accuracy:
0.9069 - val_loss: 0.1600 - val_accuracy: 0.9491
Epoch 2/50
964/964 [==============================] - 2s 2ms/step - loss: 0.2398 - accuracy:
0.9280 - val_loss: 0.1171 - val_accuracy: 0.9456
Epoch 3/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1644 - accuracy:
0.9376 - val_loss: 0.1064 - val_accuracy: 0.9540
Epoch 4/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1337 - accuracy:
0.9473 - val_loss: 0.0994 - val_accuracy: 0.9613
Epoch 5/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1193 - accuracy:
0.9551 - val_loss: 0.0991 - val_accuracy: 0.9729
Epoch 6/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1115 - accuracy:
0.9629 - val_loss: 0.1022 - val_accuracy: 0.9739
Epoch 7/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1092 - accuracy:
0.9660 - val_loss: 0.0886 - val_accuracy: 0.9750
Epoch 8/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1026 - accuracy:
0.9683 - val_loss: 0.0886 - val_accuracy: 0.9732
Epoch 9/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0980 - accuracy:
0.9709 - val_loss: 0.0877 - val_accuracy: 0.9750
Epoch 10/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0945 - accuracy:
0.9725 - val_loss: 0.0867 - val_accuracy: 0.9751
Epoch 11/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0925 - accuracy:
0.9729 - val_loss: 0.0816 - val_accuracy: 0.9795
Epoch 12/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0902 - accuracy:
0.9740 - val_loss: 0.0784 - val_accuracy: 0.9763
Epoch 13/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0880 - accuracy:
0.9736 - val_loss: 0.0813 - val_accuracy: 0.9754
Epoch 14/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0885 - accuracy:
0.9746 - val_loss: 0.0811 - val_accuracy: 0.9772
Epoch 15/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0867 - accuracy:
0.9747 - val_loss: 0.0791 - val_accuracy: 0.9808
Epoch 16/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0857 - accuracy:
0.9750 - val_loss: 0.0774 - val_accuracy: 0.9775
Epoch 17/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0833 - accuracy:
0.9749 - val_loss: 0.0782 - val_accuracy: 0.9764
Epoch 18/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0836 - accuracy:
0.9762 - val_loss: 0.0791 - val_accuracy: 0.9747
Epoch 19/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0831 - accuracy:
0.9768 - val_loss: 0.0898 - val_accuracy: 0.9738
Epoch 20/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0799 - accuracy:
0.9773 - val_loss: 0.0689 - val_accuracy: 0.9798
```

```
Epoch 21/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0797 - accuracy:
0.9771 - val_loss: 0.0743 - val_accuracy: 0.9803
Epoch 22/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0775 - accuracy:
0.9781 - val_loss: 0.0728 - val_accuracy: 0.9803
Epoch 23/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0756 - accuracy:
0.9782 - val_loss: 0.0626 - val_accuracy: 0.9856
Epoch 24/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0745 - accuracy:
0.9786 - val_loss: 0.0634 - val_accuracy: 0.9780
Epoch 25/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0747 - accuracy:
0.9783 - val_loss: 0.0644 - val_accuracy: 0.9856
Epoch 26/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0736 - accuracy:
0.9788 - val_loss: 0.0671 - val_accuracy: 0.9827
Epoch 27/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0731 - accuracy:
0.9793 - val_loss: 0.0625 - val_accuracy: 0.9810
Epoch 28/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0700 - accuracy:
0.9803 - val_loss: 0.0647 - val_accuracy: 0.9869
Epoch 29/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0694 - accuracy:
0.9812 - val_loss: 0.0600 - val_accuracy: 0.9813
Epoch 30/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0678 - accuracy:
0.9809 - val_loss: 0.0538 - val_accuracy: 0.9873
Epoch 31/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0670 - accuracy:
0.9811 - val_loss: 0.0637 - val_accuracy: 0.9822
Epoch 32/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0648 - accuracy:
0.9822 - val_loss: 0.0574 - val_accuracy: 0.9836
Epoch 33/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0654 - accuracy:
0.9818 - val_loss: 0.0538 - val_accuracy: 0.9871
Epoch 34/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0688 - accuracy:
0.9809 - val_loss: 0.0689 - val_accuracy: 0.9879
Epoch 35/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0667 - accuracy:
0.9811 - val_loss: 0.0592 - val_accuracy: 0.9813
Epoch 36/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0646 - accuracy:
0.9822 - val_loss: 0.0572 - val_accuracy: 0.9875
Epoch 37/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0660 - accuracy:
0.9816 - val_loss: 0.0565 - val_accuracy: 0.9855
Epoch 38/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0623 - accuracy:
0.9838 - val_loss: 0.0537 - val_accuracy: 0.9904
Epoch 39/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0623 - accuracy:
0.9837 - val_loss: 0.0578 - val_accuracy: 0.9880
Epoch 40/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0604 - accuracy:
0.9847 - val_loss: 0.0528 - val_accuracy: 0.9883
```

```
Epoch 41/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0606 - accuracy:
0.9852 - val_loss: 0.0474 - val_accuracy: 0.9915
Epoch 42/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0610 - accuracy:
0.9853 - val_loss: 0.0453 - val_accuracy: 0.9927
Epoch 43/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0572 - accuracy:
0.9863 - val_loss: 0.0447 - val_accuracy: 0.9910
Epoch 44/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0661 - accuracy:
0.9812 - val_loss: 0.0534 - val_accuracy: 0.9895
Epoch 45/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0628 - accuracy:
0.9832 - val_loss: 0.0510 - val_accuracy: 0.9911
Epoch 46/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0602 - accuracy:
0.9841 - val_loss: 0.0522 - val_accuracy: 0.9868
Epoch 47/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0586 - accuracy:
0.9847 - val_loss: 0.0458 - val_accuracy: 0.9893
Epoch 48/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0564 - accuracy:
0.9858 - val_loss: 0.0420 - val_accuracy: 0.9932
Epoch 49/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0562 - accuracy:
0.9859 - val_loss: 0.0454 - val_accuracy: 0.9931
Epoch 50/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0543 - accuracy:
0.9863 - val_loss: 0.0442 - val_accuracy: 0.9917
484/484 [==============================] - 1s 930us/step
Epoch 1/50
964/964 [==============================] - 3s 2ms/step - loss: 4.2816 - accuracy:
0.8965 - val_loss: 0.1766 - val_accuracy: 0.9365
Epoch 2/50
964/964 [==============================] - 2s 2ms/step - loss: 0.2264 - accuracy:
0.9313 - val_loss: 0.1316 - val_accuracy: 0.9399
Epoch 3/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1672 - accuracy:
0.9347 - val_loss: 0.1111 - val_accuracy: 0.9423
Epoch 4/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1438 - accuracy:
0.9368 - val_loss: 0.0998 - val_accuracy: 0.9430
Epoch 5/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1310 - accuracy:
0.9410 - val_loss: 0.0960 - val_accuracy: 0.9599
Epoch 6/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1208 - accuracy:
0.9504 - val_loss: 0.0942 - val_accuracy: 0.9653
Epoch 7/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1133 - accuracy:
0.9567 - val_loss: 0.0933 - val_accuracy: 0.9718
Epoch 8/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1083 - accuracy:
0.9587 - val_loss: 0.0912 - val_accuracy: 0.9721
Epoch 9/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1066 - accuracy:
0.9586 - val_loss: 0.0881 - val_accuracy: 0.9690
Epoch 10/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1046 - accuracy:
```

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0.9598 - val_loss: 0.0856 - val_accuracy: 0.9704
Epoch 11/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1026 - accuracy:
0.9585 - val_loss: 0.0845 - val_accuracy: 0.9715
Epoch 12/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0996 - accuracy:
0.9622 - val_loss: 0.0812 - val_accuracy: 0.9729
Epoch 13/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1002 - accuracy:
0.9630 - val_loss: 0.0797 - val_accuracy: 0.9727
Epoch 14/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0997 - accuracy:
0.9621 - val_loss: 0.0805 - val_accuracy: 0.9713
Epoch 15/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0981 - accuracy:
0.9629 - val_loss: 0.0824 - val_accuracy: 0.9736
Epoch 16/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0961 - accuracy:
0.9651 - val_loss: 0.0814 - val_accuracy: 0.9753
Epoch 17/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0975 - accuracy:
0.9659 - val_loss: 0.0778 - val_accuracy: 0.9750
Epoch 18/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0944 - accuracy:
0.9678 - val_loss: 0.0737 - val_accuracy: 0.9754
Epoch 19/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0895 - accuracy:
0.9695 - val_loss: 0.0754 - val_accuracy: 0.9755
Epoch 20/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0880 - accuracy:
0.9709 - val_loss: 0.0786 - val_accuracy: 0.9758
Epoch 21/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0847 - accuracy:
0.9727 - val_loss: 0.0718 - val_accuracy: 0.9787
Epoch 22/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0847 - accuracy:
0.9736 - val_loss: 0.0797 - val_accuracy: 0.9752
Epoch 23/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0844 - accuracy:
0.9734 - val_loss: 0.0690 - val_accuracy: 0.9763
Epoch 24/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0867 - accuracy:
0.9707 - val_loss: 0.0823 - val_accuracy: 0.9766
Epoch 25/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0833 - accuracy:
0.9732 - val_loss: 0.0759 - val_accuracy: 0.9782
Epoch 26/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0836 - accuracy:
0.9740 - val_loss: 0.0706 - val_accuracy: 0.9765
Epoch 27/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0825 - accuracy:
0.9734 - val_loss: 0.0697 - val_accuracy: 0.9798
Epoch 28/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0791 - accuracy:
0.9757 - val_loss: 0.0898 - val_accuracy: 0.9577
Epoch 29/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0784 - accuracy:
0.9751 - val_loss: 0.0672 - val_accuracy: 0.9790
Epoch 30/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0772 - accuracy:
```

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0.9758 - val_loss: 0.0632 - val_accuracy: 0.9796
Epoch 31/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0752 - accuracy:
0.9767 - val_loss: 0.0618 - val_accuracy: 0.9816
Epoch 32/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0742 - accuracy:
0.9775 - val_loss: 0.0541 - val_accuracy: 0.9880
Epoch 33/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0737 - accuracy:
0.9774 - val_loss: 0.0588 - val_accuracy: 0.9810
Epoch 34/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0713 - accuracy:
0.9786 - val_loss: 0.0561 - val_accuracy: 0.9870
Epoch 35/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0756 - accuracy:
0.9745 - val_loss: 0.0502 - val_accuracy: 0.9916
Epoch 36/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0704 - accuracy:
0.9802 - val_loss: 0.0586 - val_accuracy: 0.9795
Epoch 37/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0717 - accuracy:
0.9801 - val_loss: 0.0586 - val_accuracy: 0.9836
Epoch 38/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0726 - accuracy:
0.9799 - val_loss: 0.1010 - val_accuracy: 0.9452
Epoch 39/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0734 - accuracy:
0.9786 - val_loss: 0.0529 - val_accuracy: 0.9904
Epoch 40/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0698 - accuracy:
0.9800 - val_loss: 0.0562 - val_accuracy: 0.9926
Epoch 41/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0677 - accuracy:
0.9810 - val_loss: 0.0484 - val_accuracy: 0.9919
Epoch 42/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0664 - accuracy:
0.9818 - val_loss: 0.0523 - val_accuracy: 0.9930
Epoch 43/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0665 - accuracy:
0.9815 - val_loss: 0.0519 - val_accuracy: 0.9854
Epoch 44/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0645 - accuracy:
0.9828 - val_loss: 0.0497 - val_accuracy: 0.9913
Epoch 45/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0640 - accuracy:
0.9831 - val_loss: 0.0535 - val_accuracy: 0.9864
Epoch 46/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0670 - accuracy:
0.9816 - val_loss: 0.0493 - val_accuracy: 0.9913
Epoch 47/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0655 - accuracy:
0.9818 - val_loss: 0.0606 - val_accuracy: 0.9794
Epoch 48/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0681 - accuracy:
0.9814 - val_loss: 0.0535 - val_accuracy: 0.9921
Epoch 49/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0656 - accuracy:
0.9822 - val_loss: 0.0453 - val_accuracy: 0.9917
Epoch 50/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0623 - accuracy:
```

```
0.9826 - val_loss: 0.0605 - val_accuracy: 0.9798
484/484 [==============================] - 0s 819us/step
Epoch 1/50
964/964 [==============================] - 2s 2ms/step - loss: 1.5521 - accuracy:
0.9166 - val_loss: 0.1926 - val_accuracy: 0.9365
Epoch 2/50
964/964 [==============================] - 1s 2ms/step - loss: 0.2234 - accuracy:
0.9320 - val_loss: 0.1702 - val_accuracy: 0.9365
Epoch 3/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1916 - accuracy:
0.9321 - val_loss: 0.1291 - val_accuracy: 0.9365
Epoch 4/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1557 - accuracy:
0.9362 - val_loss: 0.1103 - val_accuracy: 0.9458
Epoch 5/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1347 - accuracy:
0.9442 - val_loss: 0.1001 - val_accuracy: 0.9548
Epoch 6/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1200 - accuracy:
0.9500 - val_loss: 0.1030 - val_accuracy: 0.9630
Epoch 7/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1106 - accuracy:
0.9594 - val_loss: 0.0921 - val_accuracy: 0.9699
Epoch 8/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1052 - accuracy:
0.9650 - val_loss: 0.0920 - val_accuracy: 0.9721
Epoch 9/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1002 - accuracy:
0.9675 - val_loss: 0.0886 - val_accuracy: 0.9712
Epoch 10/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0997 - accuracy:
0.9688 - val_loss: 0.0889 - val_accuracy: 0.9714
Epoch 11/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0970 - accuracy:
0.9699 - val_loss: 0.0846 - val_accuracy: 0.9712
Epoch 12/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0967 - accuracy:
0.9710 - val_loss: 0.0840 - val_accuracy: 0.9718
Epoch 13/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0943 - accuracy:
0.9711 - val_loss: 0.0823 - val_accuracy: 0.9744
Epoch 14/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0938 - accuracy:
0.9716 - val_loss: 0.0796 - val_accuracy: 0.9768
Epoch 15/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0916 - accuracy:
0.9730 - val_loss: 0.0835 - val_accuracy: 0.9772
Epoch 16/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0902 - accuracy:
0.9736 - val_loss: 0.0804 - val_accuracy: 0.9742
Epoch 17/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0883 - accuracy:
0.9744 - val_loss: 0.0793 - val_accuracy: 0.9750
Epoch 18/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0870 - accuracy:
0.9743 - val_loss: 0.0756 - val_accuracy: 0.9778
Epoch 19/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0859 - accuracy:
0.9756 - val_loss: 0.0749 - val_accuracy: 0.9790
Epoch 20/50
```

```
964/964 [==============================] - 1s 2ms/step - loss: 0.0854 - accuracy:
0.9754 - val_loss: 0.0759 - val_accuracy: 0.9763
Epoch 21/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0823 - accuracy:
0.9755 - val_loss: 0.0754 - val_accuracy: 0.9776
Epoch 22/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0838 - accuracy:
0.9759 - val_loss: 0.0708 - val_accuracy: 0.9780
Epoch 23/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0815 - accuracy:
0.9765 - val_loss: 0.0777 - val_accuracy: 0.9778
Epoch 24/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0807 - accuracy:
0.9771 - val_loss: 0.0691 - val_accuracy: 0.9786
Epoch 25/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0804 - accuracy:
0.9773 - val_loss: 0.0659 - val_accuracy: 0.9802
Epoch 26/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0786 - accuracy:
0.9779 - val_loss: 0.0643 - val_accuracy: 0.9809
Epoch 27/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0773 - accuracy:
0.9783 - val_loss: 0.0723 - val_accuracy: 0.9745
Epoch 28/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0779 - accuracy:
0.9775 - val_loss: 0.0672 - val_accuracy: 0.9794
Epoch 29/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0768 - accuracy:
0.9782 - val_loss: 0.0692 - val_accuracy: 0.9787
Epoch 30/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0754 - accuracy:
0.9791 - val_loss: 0.0600 - val_accuracy: 0.9815
Epoch 31/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0753 - accuracy:
0.9792 - val_loss: 0.0624 - val_accuracy: 0.9829
Epoch 32/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0732 - accuracy:
0.9793 - val_loss: 0.0643 - val_accuracy: 0.9798
Epoch 33/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0729 - accuracy:
0.9801 - val_loss: 0.0630 - val_accuracy: 0.9794
Epoch 34/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0749 - accuracy:
0.9788 - val_loss: 0.0614 - val_accuracy: 0.9840
Epoch 35/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0745 - accuracy:
0.9784 - val_loss: 0.0584 - val_accuracy: 0.9820
Epoch 36/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0730 - accuracy:
0.9785 - val_loss: 0.0626 - val_accuracy: 0.9794
Epoch 37/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0711 - accuracy:
0.9793 - val_loss: 0.0629 - val_accuracy: 0.9820
Epoch 38/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0700 - accuracy:
0.9806 - val_loss: 0.0600 - val_accuracy: 0.9817
Epoch 39/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0695 - accuracy:
0.9793 - val_loss: 0.0626 - val_accuracy: 0.9798
Epoch 40/50
```

```
964/964 [==============================] - 2s 2ms/step - loss: 0.0727 - accuracy:
0.9794 - val_loss: 0.0620 - val_accuracy: 0.9800
Epoch 41/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0708 - accuracy:
0.9794 - val_loss: 0.0555 - val_accuracy: 0.9849
Epoch 42/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0708 - accuracy:
0.9798 - val_loss: 0.0596 - val_accuracy: 0.9842
Epoch 43/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0699 - accuracy:
0.9807 - val_loss: 0.0575 - val_accuracy: 0.9844
Epoch 44/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0684 - accuracy:
0.9803 - val_loss: 0.0567 - val_accuracy: 0.9868
Epoch 45/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0729 - accuracy:
0.9779 - val_loss: 0.0516 - val_accuracy: 0.9837
Epoch 46/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0689 - accuracy:
0.9800 - val_loss: 0.0520 - val_accuracy: 0.9830
Epoch 47/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0690 - accuracy:
0.9802 - val_loss: 0.0491 - val_accuracy: 0.9908
Epoch 48/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0690 - accuracy:
0.9803 - val_loss: 0.0529 - val_accuracy: 0.9824
Epoch 49/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0682 - accuracy:
0.9799 - val_loss: 0.0479 - val_accuracy: 0.9920
Epoch 50/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0697 - accuracy:
0.9798 - val_loss: 0.0593 - val_accuracy: 0.9915
484/484 [==============================] - 0s 829us/step
Epoch 1/50
964/964 [==============================] - 2s 2ms/step - loss: 6.2183 - accuracy:
0.8955 - val_loss: 0.2342 - val_accuracy: 0.9365
Epoch 2/50
964/964 [==============================] - 2s 2ms/step - loss: 0.3221 - accuracy:
0.9296 - val_loss: 0.1792 - val_accuracy: 0.9365
Epoch 3/50
964/964 [==============================] - 2s 2ms/step - loss: 0.2360 - accuracy:
0.9317 - val_loss: 0.1846 - val_accuracy: 0.9365
Epoch 4/50
964/964 [==============================] - 1s 2ms/step - loss: 0.2283 - accuracy:
0.9318 - val_loss: 0.1717 - val_accuracy: 0.9365
Epoch 5/50
964/964 [==============================] - 2s 2ms/step - loss: 0.2056 - accuracy:
0.9321 - val_loss: 0.1533 - val_accuracy: 0.9365
Epoch 6/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1795 - accuracy:
0.9322 - val_loss: 0.1251 - val_accuracy: 0.9365
Epoch 7/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1621 - accuracy:
0.9324 - val_loss: 0.1139 - val_accuracy: 0.9365
Epoch 8/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1396 - accuracy:
0.9323 - val_loss: 0.1018 - val_accuracy: 0.9365
Epoch 9/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1276 - accuracy:
0.9471 - val_loss: 0.1006 - val_accuracy: 0.9690
```

```
Epoch 10/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1236 - accuracy:
0.9602 - val_loss: 0.1017 - val_accuracy: 0.9688
Epoch 11/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1197 - accuracy:
0.9628 - val_loss: 0.0964 - val_accuracy: 0.9735
Epoch 12/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1147 - accuracy:
0.9641 - val_loss: 0.0955 - val_accuracy: 0.9736
Epoch 13/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1152 - accuracy:
0.9650 - val_loss: 0.0945 - val_accuracy: 0.9732
Epoch 14/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1107 - accuracy:
0.9663 - val_loss: 0.0940 - val_accuracy: 0.9736
Epoch 15/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1052 - accuracy:
0.9682 - val_loss: 0.0901 - val_accuracy: 0.9738
Epoch 16/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1040 - accuracy:
0.9688 - val_loss: 0.0889 - val_accuracy: 0.9730
Epoch 17/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1018 - accuracy:
0.9683 - val_loss: 0.0935 - val_accuracy: 0.9696
Epoch 18/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0998 - accuracy:
0.9689 - val_loss: 0.0929 - val_accuracy: 0.9741
Epoch 19/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0980 - accuracy:
0.9698 - val_loss: 0.0860 - val_accuracy: 0.9758
Epoch 20/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0974 - accuracy:
0.9702 - val_loss: 0.0836 - val_accuracy: 0.9744
Epoch 21/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0954 - accuracy:
0.9703 - val_loss: 0.0837 - val_accuracy: 0.9721
Epoch 22/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0966 - accuracy:
0.9693 - val_loss: 0.0840 - val_accuracy: 0.9749
Epoch 23/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0949 - accuracy:
0.9705 - val_loss: 0.0833 - val_accuracy: 0.9719
Epoch 24/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0955 - accuracy:
0.9703 - val_loss: 0.0790 - val_accuracy: 0.9752
Epoch 25/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0927 - accuracy:
0.9703 - val_loss: 0.0794 - val_accuracy: 0.9778
Epoch 26/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0916 - accuracy:
0.9708 - val_loss: 0.0738 - val_accuracy: 0.9747
Epoch 27/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0913 - accuracy:
0.9719 - val_loss: 0.0809 - val_accuracy: 0.9739
Epoch 28/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0889 - accuracy:
0.9736 - val_loss: 0.0777 - val_accuracy: 0.9761
Epoch 29/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0891 - accuracy:
0.9737 - val_loss: 0.0699 - val_accuracy: 0.9844
```

```
Epoch 30/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0848 - accuracy:
0.9745 - val_loss: 0.0707 - val_accuracy: 0.9761
Epoch 31/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0830 - accuracy:
0.9752 - val_loss: 0.0686 - val_accuracy: 0.9787
Epoch 32/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0813 - accuracy:
0.9758 - val_loss: 0.0701 - val_accuracy: 0.9816
Epoch 33/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0802 - accuracy:
0.9762 - val_loss: 0.0728 - val_accuracy: 0.9794
Epoch 34/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0825 - accuracy:
0.9750 - val_loss: 0.0677 - val_accuracy: 0.9776
Epoch 35/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0782 - accuracy:
0.9762 - val_loss: 0.0628 - val_accuracy: 0.9788
Epoch 36/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0793 - accuracy:
0.9757 - val_loss: 0.0624 - val_accuracy: 0.9842
Epoch 37/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0778 - accuracy:
0.9768 - val_loss: 0.0617 - val_accuracy: 0.9825
Epoch 38/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0761 - accuracy:
0.9781 - val_loss: 0.0655 - val_accuracy: 0.9795
Epoch 39/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0744 - accuracy:
0.9781 - val_loss: 0.0616 - val_accuracy: 0.9899
Epoch 40/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0730 - accuracy:
0.9782 - val_loss: 0.0560 - val_accuracy: 0.9856
Epoch 41/50
964/964 [==============================] - 1s 2ms/step - loss: 0.0732 - accuracy:
0.9786 - val_loss: 0.0697 - val_accuracy: 0.9790
Epoch 42/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0762 - accuracy:
0.9765 - val_loss: 0.0715 - val_accuracy: 0.9796
Epoch 43/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0741 - accuracy:
0.9777 - val_loss: 0.0595 - val_accuracy: 0.9793
Epoch 44/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0754 - accuracy:
0.9769 - val_loss: 0.0709 - val_accuracy: 0.9790
Epoch 45/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0755 - accuracy:
0.9769 - val_loss: 0.0577 - val_accuracy: 0.9860
Epoch 46/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0731 - accuracy:
0.9779 - val_loss: 0.0714 - val_accuracy: 0.9790
Epoch 47/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0735 - accuracy:
0.9779 - val_loss: 0.0539 - val_accuracy: 0.9860
Epoch 48/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0699 - accuracy:
0.9795 - val_loss: 0.0652 - val_accuracy: 0.9794
Epoch 49/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0716 - accuracy:
0.9788 - val_loss: 0.0689 - val_accuracy: 0.9792
```

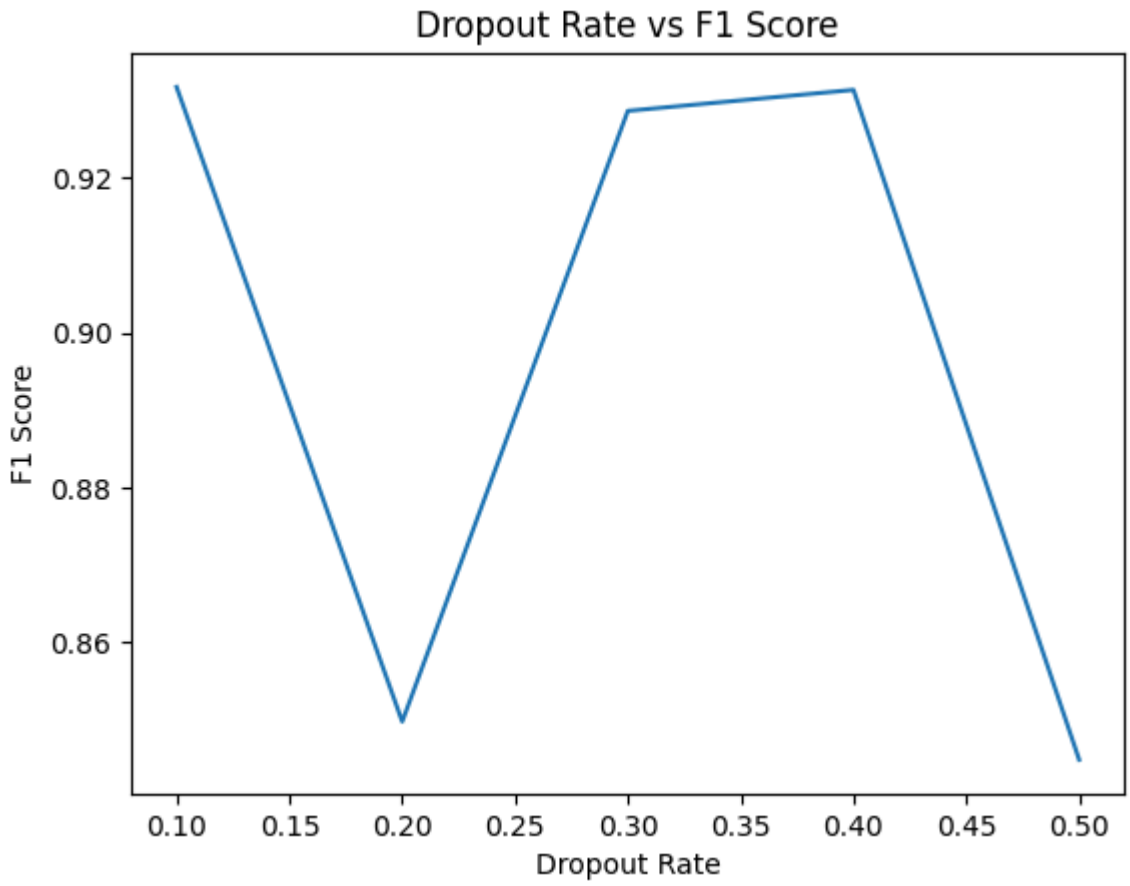
```
Epoch 50/50
964/964 [==============================] - 1s 1ms/step - loss: 0.0698 - accuracy:
0.9796 - val_loss: 0.0513 - val_accuracy: 0.9917
484/484 [==============================] - 0s 766us/step
Epoch 1/50
964/964 [==============================] - 2s 2ms/step - loss: 8.9372 - accuracy:
0.8954 - val_loss: 0.4041 - val_accuracy: 0.9365
Epoch 2/50
964/964 [==============================] - 1s 1ms/step - loss: 0.4608 - accuracy:
0.9281 - val_loss: 0.1946 - val_accuracy: 0.9365
Epoch 3/50
964/964 [==============================] - 1s 2ms/step - loss: 0.2660 - accuracy:
0.9313 - val_loss: 0.1852 - val_accuracy: 0.9365
Epoch 4/50
964/964 [==============================] - 1s 1ms/step - loss: 0.2292 - accuracy:
0.9319 - val_loss: 0.1856 - val_accuracy: 0.9365
Epoch 5/50
964/964 [==============================] - 1s 2ms/step - loss: 0.2215 - accuracy:
0.9322 - val_loss: 0.1752 - val_accuracy: 0.9365
Epoch 6/50
964/964 [==============================] - 2s 2ms/step - loss: 0.2025 - accuracy:
0.9322 - val_loss: 0.1565 - val_accuracy: 0.9365
Epoch 7/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1841 - accuracy:
0.9335 - val_loss: 0.1319 - val_accuracy: 0.9365
Epoch 8/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1635 - accuracy:
0.9393 - val_loss: 0.1141 - val_accuracy: 0.9392
Epoch 9/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1490 - accuracy:
0.9433 - val_loss: 0.1052 - val_accuracy: 0.9515
Epoch 10/50
964/964 [==============================] - 1s 2ms/step - loss: 0.1446 - accuracy:
0.9465 - val_loss: 0.1019 - val_accuracy: 0.9566
Epoch 11/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1360 - accuracy:
0.9488 - val_loss: 0.0979 - val_accuracy: 0.9599
Epoch 12/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1271 - accuracy:
0.9534 - val_loss: 0.0976 - val_accuracy: 0.9613
Epoch 13/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1240 - accuracy:
0.9547 - val_loss: 0.0927 - val_accuracy: 0.9687
Epoch 14/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1134 - accuracy:
0.9600 - val_loss: 0.0905 - val_accuracy: 0.9722
Epoch 15/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1116 - accuracy:
0.9604 - val_loss: 0.0858 - val_accuracy: 0.9711
Epoch 16/50
964/964 [==============================] - 1s 1ms/step - loss: 0.1064 - accuracy:
0.9632 - val_loss: 0.0872 - val_accuracy: 0.9717
Epoch 17/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1067 - accuracy:
0.9635 - val_loss: 0.0847 - val_accuracy: 0.9677
Epoch 18/50
964/964 [==============================] - 2s 2ms/step - loss: 0.1000 - accuracy:
0.9654 - val_loss: 0.0835 - val_accuracy: 0.9773
Epoch 19/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0980 - accuracy:
```

```
0.9677 - val_loss: 0.0767 - val_accuracy: 0.9806
Epoch 20/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0961 - accuracy:
0.9694 - val_loss: 0.0775 - val_accuracy: 0.9763
Epoch 21/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0929 - accuracy:
0.9703 - val_loss: 0.0764 - val_accuracy: 0.9775
Epoch 22/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0917 - accuracy:
0.9703 - val_loss: 0.0709 - val_accuracy: 0.9782
Epoch 23/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0894 - accuracy:
0.9713 - val_loss: 0.0698 - val_accuracy: 0.9797
Epoch 24/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0890 - accuracy:
0.9713 - val_loss: 0.0710 - val_accuracy: 0.9800
Epoch 25/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0861 - accuracy:
0.9731 - val_loss: 0.0670 - val_accuracy: 0.9794
Epoch 26/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0873 - accuracy:
0.9721 - val_loss: 0.0646 - val_accuracy: 0.9803
Epoch 27/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0845 - accuracy:
0.9734 - val_loss: 0.0646 - val_accuracy: 0.9813
Epoch 28/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0864 - accuracy:
0.9721 - val_loss: 0.0716 - val_accuracy: 0.9781
Epoch 29/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0859 - accuracy:
0.9721 - val_loss: 0.0735 - val_accuracy: 0.9774
Epoch 30/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0833 - accuracy:
0.9727 - val_loss: 0.0680 - val_accuracy: 0.9869
Epoch 31/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0841 - accuracy:
0.9727 - val_loss: 0.0651 - val_accuracy: 0.9784
Epoch 32/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0823 - accuracy:
0.9735 - val_loss: 0.0654 - val_accuracy: 0.9808
Epoch 33/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0828 - accuracy:
0.9737 - val_loss: 0.0708 - val_accuracy: 0.9771
Epoch 34/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0826 - accuracy:
0.9738 - val_loss: 0.0614 - val_accuracy: 0.9803
Epoch 35/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0809 - accuracy:
0.9755 - val_loss: 0.0553 - val_accuracy: 0.9860
Epoch 36/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0822 - accuracy:
0.9737 - val_loss: 0.0675 - val_accuracy: 0.9781
Epoch 37/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0839 - accuracy:
0.9731 - val_loss: 0.0606 - val_accuracy: 0.9795
Epoch 38/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0815 - accuracy:
0.9734 - val_loss: 0.0654 - val_accuracy: 0.9782
Epoch 39/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0798 - accuracy:
```

```
0.9756 - val_loss: 0.0619 - val_accuracy: 0.9793
Epoch 40/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0810 - accuracy:
0.9749 - val_loss: 0.0591 - val_accuracy: 0.9887
Epoch 41/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0804 - accuracy:
0.9755 - val_loss: 0.0672 - val_accuracy: 0.9785
Epoch 42/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0798 - accuracy:
0.9744 - val_loss: 0.0606 - val_accuracy: 0.9824
Epoch 43/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0810 - accuracy:
0.9749 - val_loss: 0.0616 - val_accuracy: 0.9820
Epoch 44/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0762 - accuracy:
0.9763 - val_loss: 0.0581 - val_accuracy: 0.9833
Epoch 45/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0800 - accuracy:
0.9753 - val_loss: 0.0597 - val_accuracy: 0.9836
Epoch 46/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0798 - accuracy:
0.9754 - val_loss: 0.0665 - val_accuracy: 0.9785
Epoch 47/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0792 - accuracy:
0.9751 - val_loss: 0.0598 - val_accuracy: 0.9813
Epoch 48/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0801 - accuracy:
0.9748 - val_loss: 0.0588 - val_accuracy: 0.9862
Epoch 49/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0796 - accuracy:
0.9746 - val_loss: 0.0567 - val_accuracy: 0.9847
Epoch 50/50
964/964 [==============================] - 2s 2ms/step - loss: 0.0794 - accuracy:
0.9750 - val_loss: 0.0636 - val_accuracy: 0.9793
484/484 [==============================] - 1s 1ms/step
[0.9317821258593338, 0.8497359577532405, 0.9286880783886772, 0.9314040728831725,
0.8448108632395733]
```

In [ ]:

```python
# draw the dropout rates vs f1 scores
import matplotlib.pyplot as plt
plt.plot(dropout_rates, f1_scores)
plt.xlabel('Dropout Rate')
plt.ylabel('F1 Score')
plt.title('Dropout Rate vs F1 Score')
plt.show()
```



In [ ]:
```
# final model, use a 0.15 dropout rate
model_final = Sequential()
model_final.add(Dense(1024, input_dim=7, activation='relu'))
model_final.add(Dropout(0.15))
model_final.add(Dense(512, activation='relu'))
model_final.add(Dropout(0.15))
model_final.add(Dense(256, activation='relu'))

model_final.add(Dropout(0.15))
model_final.add(Dense(128, activation='relu'))
model_final.add(Dropout(0.15))
model_final.add(Dense(64, activation='relu'))
model_final.add(Dropout(0.15))
model_final.add(Dense(32, activation='relu'))
model_final.add(Dropout(0.15))
model_final.add(Dense(1, activation='sigmoid'))

# compile the model
model_final.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accu
model_final.summary()
```

```
Model: "sequential_7"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_24 (Dense)            (None, 1024)              8192

 dropout_17 (Dropout)        (None, 1024)              0

 dense_25 (Dense)            (None, 512)               524800

 dropout_18 (Dropout)        (None, 512)               0

 dense_26 (Dense)            (None, 256)               131328

 dropout_19 (Dropout)        (None, 256)               0

 dense_27 (Dense)            (None, 128)               32896

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_24 (Dense)            (None, 1024)              8192

 dropout_17 (Dropout)        (None, 1024)              0

 dense_25 (Dense)            (None, 512)               524800

 dropout_18 (Dropout)        (None, 512)               0

 dense_26 (Dense)            (None, 256)               131328

 dropout_19 (Dropout)        (None, 256)               0

 dense_27 (Dense)            (None, 128)               32896

 dropout_20 (Dropout)        (None, 128)               0

 dense_28 (Dense)            (None, 64)                8256

 dropout_21 (Dropout)        (None, 64)                0

 dense_29 (Dense)            (None, 32)                2080

 dropout_22 (Dropout)        (None, 32)                0

 dense_30 (Dense)            (None, 1)                 33

=================================================================
Total params: 707585 (2.70 MB)
Trainable params: 707585 (2.70 MB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

In [ ]:
```
# fit the model
history_final = model_final.fit(X_train, y_train, epochs=50, batch_size=64, vali
```

```
Epoch 1/50
964/964 [==============================] - 8s 7ms/step - loss: 0.3484 - accuracy:
0.9327 - val_loss: 0.0961 - val_accuracy: 0.9605
Epoch 2/50
964/964 [==============================] - 7s 7ms/step - loss: 0.1085 - accuracy:
0.9619 - val_loss: 0.1580 - val_accuracy: 0.9597
Epoch 3/50
964/964 [==============================] - 7s 7ms/step - loss: 0.1029 - accuracy:
0.9675 - val_loss: 0.0991 - val_accuracy: 0.9679
Epoch 4/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0961 - accuracy:
0.9705 - val_loss: 0.0802 - val_accuracy: 0.9756
Epoch 5/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0926 - accuracy:
0.9724 - val_loss: 0.0854 - val_accuracy: 0.9747
Epoch 6/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0881 - accuracy:
0.9733 - val_loss: 0.0917 - val_accuracy: 0.9745
Epoch 7/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0844 - accuracy:
0.9749 - val_loss: 0.0735 - val_accuracy: 0.9773
Epoch 8/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0816 - accuracy:
0.9759 - val_loss: 0.0795 - val_accuracy: 0.9756
Epoch 9/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0795 - accuracy:
0.9772 - val_loss: 0.0704 - val_accuracy: 0.9831
Epoch 10/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0734 - accuracy:
0.9792 - val_loss: 0.0565 - val_accuracy: 0.9894
Epoch 11/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0730 - accuracy:
0.9789 - val_loss: 0.0607 - val_accuracy: 0.9797
Epoch 12/50
964/964 [==============================] - 6s 7ms/step - loss: 0.0735 - accuracy:
0.9790 - val_loss: 0.0724 - val_accuracy: 0.9778
Epoch 13/50
964/964 [==============================] - 6s 7ms/step - loss: 0.0711 - accuracy:
0.9793 - val_loss: 0.0569 - val_accuracy: 0.9822
Epoch 14/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0682 - accuracy:
0.9804 - val_loss: 0.0496 - val_accuracy: 0.9886
Epoch 15/50
964/964 [==============================] - 6s 6ms/step - loss: 0.0695 - accuracy:
0.9790 - val_loss: 0.0790 - val_accuracy: 0.9789
Epoch 16/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0612 - accuracy:
0.9829 - val_loss: 0.0582 - val_accuracy: 0.9819
Epoch 17/50
964/964 [==============================] - 6s 6ms/step - loss: 0.0625 - accuracy:
0.9826 - val_loss: 0.0634 - val_accuracy: 0.9790
Epoch 18/50
964/964 [==============================] - 6s 6ms/step - loss: 0.0694 - accuracy:
0.9797 - val_loss: 0.0583 - val_accuracy: 0.9800
Epoch 19/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0730 - accuracy:
0.9787 - val_loss: 0.0719 - val_accuracy: 0.9756
Epoch 20/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0739 - accuracy:
0.9795 - val_loss: 0.0833 - val_accuracy: 0.9754
```

```
Epoch 21/50
964/964 [==============================] - 6s 6ms/step - loss: 0.0685 - accuracy:
0.9819 - val_loss: 0.0495 - val_accuracy: 0.9866
Epoch 22/50
964/964 [==============================] - 6s 7ms/step - loss: 0.0659 - accuracy:
0.9829 - val_loss: 0.0858 - val_accuracy: 0.9758
Epoch 23/50
964/964 [==============================] - 6s 6ms/step - loss: 0.0816 - accuracy:
0.9746 - val_loss: 0.0713 - val_accuracy: 0.9757
Epoch 24/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0798 - accuracy:
0.9743 - val_loss: 0.0707 - val_accuracy: 0.9789
Epoch 25/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0730 - accuracy:
0.9794 - val_loss: 0.0509 - val_accuracy: 0.9891
Epoch 26/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0695 - accuracy:
0.9808 - val_loss: 0.0746 - val_accuracy: 0.9767
Epoch 27/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0685 - accuracy:
0.9815 - val_loss: 0.0716 - val_accuracy: 0.9769
Epoch 28/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0660 - accuracy:
0.9823 - val_loss: 0.0435 - val_accuracy: 0.9913
Epoch 29/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0706 - accuracy:
0.9804 - val_loss: 0.0542 - val_accuracy: 0.9884
Epoch 30/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0624 - accuracy:
0.9829 - val_loss: 0.0592 - val_accuracy: 0.9794
Epoch 31/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0702 - accuracy:
0.9790 - val_loss: 0.0726 - val_accuracy: 0.9787
Epoch 32/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0650 - accuracy:
0.9796 - val_loss: 0.0469 - val_accuracy: 0.9861
Epoch 33/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0609 - accuracy:
0.9812 - val_loss: 0.0745 - val_accuracy: 0.9789
Epoch 34/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0622 - accuracy:
0.9811 - val_loss: 0.0700 - val_accuracy: 0.9754
Epoch 35/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0698 - accuracy:
0.9777 - val_loss: 0.0404 - val_accuracy: 0.9926
Epoch 36/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0603 - accuracy:
0.9828 - val_loss: 0.0468 - val_accuracy: 0.9844
Epoch 37/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0697 - accuracy:
0.9789 - val_loss: 0.0471 - val_accuracy: 0.9916
Epoch 38/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0729 - accuracy:
0.9782 - val_loss: 0.0405 - val_accuracy: 0.9928
Epoch 39/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0919 - accuracy:
0.9697 - val_loss: 0.0655 - val_accuracy: 0.9795
Epoch 40/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0766 - accuracy:
0.9739 - val_loss: 0.0567 - val_accuracy: 0.9792
```

```
Epoch 41/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0652 - accuracy:
0.9819 - val_loss: 0.0423 - val_accuracy: 0.9923
Epoch 42/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0658 - accuracy:
0.9816 - val_loss: 0.0719 - val_accuracy: 0.9775
Epoch 43/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0629 - accuracy:
0.9825 - val_loss: 0.0733 - val_accuracy: 0.9798
Epoch 44/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0791 - accuracy:
0.9746 - val_loss: 0.0689 - val_accuracy: 0.9847
Epoch 45/50
964/964 [==============================] - 7s 8ms/step - loss: 0.0578 - accuracy:
0.9845 - val_loss: 0.0550 - val_accuracy: 0.9862
Epoch 46/50
964/964 [==============================] - 8s 9ms/step - loss: 0.0737 - accuracy:
0.9786 - val_loss: 0.0812 - val_accuracy: 0.9745
Epoch 47/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0736 - accuracy:
0.9780 - val_loss: 0.0916 - val_accuracy: 0.9794
Epoch 48/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0596 - accuracy:
0.9834 - val_loss: 0.0520 - val_accuracy: 0.9857
Epoch 49/50
964/964 [==============================] - 8s 8ms/step - loss: 0.0747 - accuracy:
0.9797 - val_loss: 0.0439 - val_accuracy: 0.9928
Epoch 50/50
964/964 [==============================] - 7s 7ms/step - loss: 0.0625 - accuracy:
0.9848 - val_loss: 0.1255 - val_accuracy: 0.9675
```

In [ ]:
```python
# f1 score
y_pred = model_final.predict(X_val)
y_pred = (y_pred > 0.5)
f1 = f1_score(y_val, y_pred)
print('F1 Score:', f1)
```

```
484/484 [==============================] - 1s 2ms/step
F1 Score: 0.7447995941146627
```

In [ ]:
```python
# accuracy
accuracy = accuracy_score(y_val, y_pred)
print('Accuracy:', accuracy)
```

```
Accuracy: 0.9674854557207498
```