判別異常交異的方法

(1)AutoEncoder,Predict 結果愈接近原本輸入的X,則loss愈低, 若差很多, 則loss愈高。
(2)對於異常交易(outlier), 使用AutoEncoder也難以表達其重要潛在特徵, 故autoencoder 的輸出X和原始資料X差異甚大。而正常交易
autoencoder 的輸出X和原始資料X差異會較小。此和使用PCA與InverPCA transform 的在判斷異常交易的道理相同。

Google Colab Setup

Only for users on Google Colab

In [1]:
```
# Define functions to connect to Google and change directories
def connectDrive():
    from google.colab import drive
    drive.mount('/content/drive', force_remount=True)

def changeDirectory(path):
    import os
    original_path = os.getcwd()
    os.chdir(path)
    new_path = os.getcwd()
    print("Original path: ",original_path)
    print("New path: ",new_path)

# Connect to Google Drive
#connectDrive()

# Change path
#changeDirectory("/content/drive/My Drive/github/handson-unsupervised-learni
```

Import Libraries

In [2]:
```
'''Main'''
import numpy as np
import pandas as pd
import os, time, re
import pickle, gzip

'''Data Viz'''
import matplotlib.pyplot as plt
import matplotlib as mpl
import seaborn as sns
color = sns.color_palette()
%matplotlib inline

'''Data Prep and Model Evaluation'''
from sklearn import preprocessing as pp
from sklearn.model_selection import train_test_split
from sklearn.model_selection import StratifiedKFold
from sklearn.metrics import log_loss
from sklearn.metrics import precision_recall_curve, average_precision_score
from sklearn.metrics import roc_curve, auc, roc_auc_score

'''Algos'''
import lightgbm as lgb

'''TensorFlow and Keras'''
import tensorflow as tf
from tensorflow import keras
K = keras.backend

from tensorflow.keras.models import Sequential, Model
from tensorflow.keras.layers import Activation, Dense, Dropout
from tensorflow.keras.layers import BatchNormalization, Input, Lambda
from tensorflow.keras import regularizers
from tensorflow.keras.losses import mse, binary_crossentropy
```

Check library versions & set seed

In [3]:
```
import sys, sklearn
print(f'sklearn    {sklearn.__version__}')
print(f'tensorflow {tf.__version__}')
print(f'keras      {keras.__version__}')
print(f'numpy      {np.__version__}')
```

```
sklearn    1.3.2
tensorflow 2.4.1
keras      2.4.0
numpy      1.20.0
```

In [4]:
```
# To make the output stable across runs
tf.random.set_seed(42)
np.random.seed(42)
```

In [5]:
```
# Check use of GPU
if tf.test.gpu_device_name():
    print('Default GPU Device: {}'.format(tf.test.gpu_device_name()))
else:
    print("Please install GPU version of TF, if GPU is available.")
```

```
Default GPU Device: /device:GPU:0
```

Data Preparation

Load the data

In [6]:
```
current_path = os.getcwd()
file = os.path.sep.join(['', 'datasets', 'credit_card_data', 'credit_card.cs
data = pd.read_csv(current_path + file)
```

In [7]:
```
dataX = data.copy().drop(['Class','Time'],axis=1)
dataY = data['Class'].copy()
```

Split into train and test

In [8]:
```
X_train, X_test, y_train, y_test = train_test_split(
                                    dataX, dataY, test_size=0.33,
                                    random_state=2018, stratify=dataY)
```

Scale the data

In [9]:
```
# Suppress warnings
pd.set_option('mode.chained_assignment', None)

featuresToScale = dataX.columns
sX = pp.StandardScaler()
X_train.loc[:,featuresToScale] = sX.fit_transform(X_train.loc[:,featuresToSc
X_test.loc[:,featuresToScale] = sX.transform(X_test.loc[:,featuresToScale])
```

In [10]:
```
X_train_AE, X_test_AE = X_train.copy(), X_test.copy()
```

Define evaluation function and plotting function

In [11]:
```
def anomalyScores(originalDF, reducedDF):
    loss = np.sum((np.array(originalDF) -
                   np.array(reducedDF))**2, axis=1)
    loss = pd.Series(data=loss,index=originalDF.index)
    loss = (loss-np.min(loss))/(np.max(loss)-np.min(loss))
    return loss
```

In [12]:
```
def plotResults(trueLabels, anomalyScores, returnPreds = False):
    preds = pd.concat([trueLabels, anomalyScores], axis=1)
    preds.columns = ['trueLabel', 'anomalyScore']
    precision, recall, thresholds = \
        precision_recall_curve(preds['trueLabel'],
                               preds['anomalyScore'])
    average_precision = average_precision_score(
                        preds['trueLabel'], preds['anomalyScore'])

    plt.step(recall, precision, color='k', alpha=0.7, where='post')
    plt.fill_between(recall, precision, step='post', alpha=0.3, color='k')

    plt.xlabel('Recall')
    plt.ylabel('Precision')
    plt.ylim([0.0, 1.05])
    plt.xlim([0.0, 1.0])

    plt.title('Precision-Recall curve: Average Precision = \
        {0:0.2f}'.format(average_precision))

    fpr, tpr, thresholds = roc_curve(preds['trueLabel'],
                                     preds['anomalyScore'])
    areaUnderROC = auc(fpr, tpr)

    plt.figure()
    plt.plot(fpr, tpr, color='r', lw=2, label='ROC curve')
    plt.plot([0, 1], [0, 1], color='k', lw=2, linestyle='--')
    plt.xlim([0.0, 1.0])
    plt.ylim([0.0, 1.05])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title('Receiver operating characteristic: Area under the \
        curve = {0:0.2f}'.format(areaUnderROC))
    plt.legend(loc="lower right")
    plt.show()

    if returnPreds==True:
        return preds, average_precision
```

Model One

Two layer overcomplete autoencoder with linear activation

In [13]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [14]:
```
# Call neural network API
model = Sequential()

# Apply linear activation function to input layer
# Generate hidden layer with 29 nodes, the same as the input layer
model.add(Dense(units=29, activation='linear',input_dim=29))

# Apply linear activation function to hidden layer
# Generate output layer with 29 nodes
model.add(Dense(units=29, activation='linear'))
```

In [15]:
```
# Compile the model
model.compile(optimizer='adam',
              loss='mean_squared_error',
              metrics=['accuracy'])
```

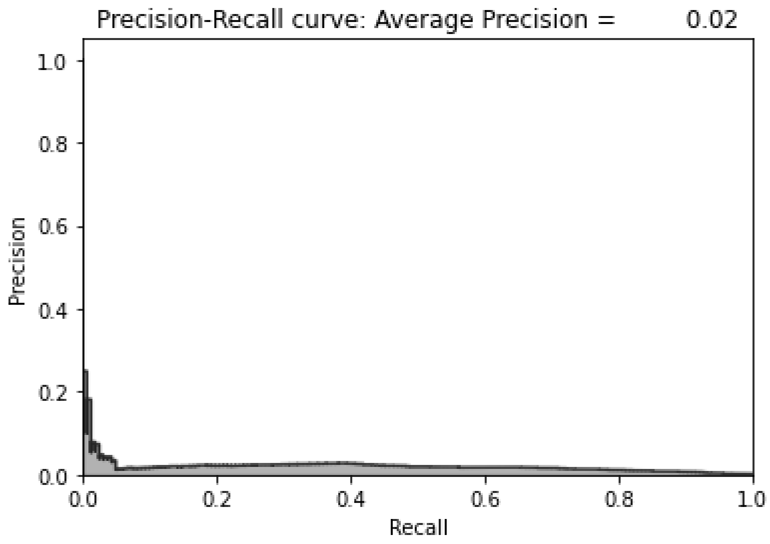
In [16]:
```
# Train the model
num_epochs = 10
batch_size = 32

history = model.fit(x=X_train_AE, y=X_train_AE,
                    epochs=num_epochs,
                    batch_size=batch_size,
                    shuffle=True,
                    validation_data=(X_train_AE, X_train_AE),
                    verbose=1)
```

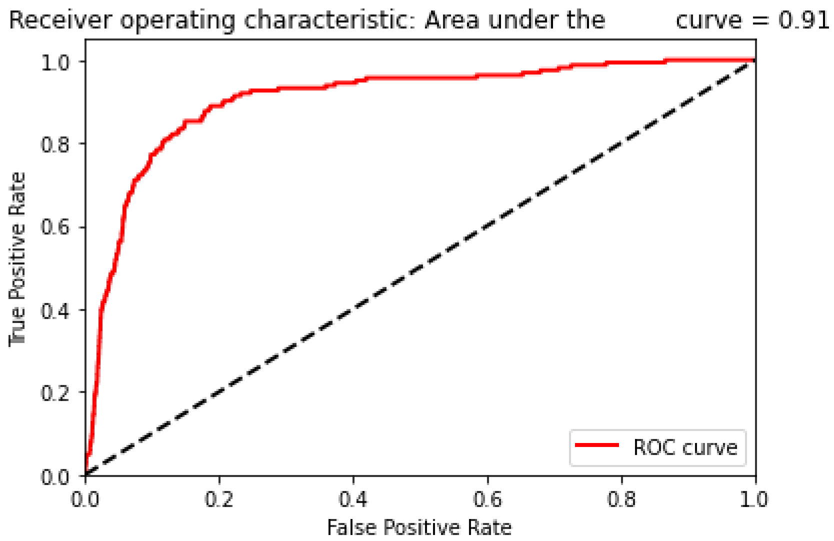
```
Epoch 1/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.2891 -
accuracy: 0.7103 - val_loss: 0.0011 - val_accuracy: 0.9836
Epoch 2/10
5964/5964 [==============================] - 35s 6ms/step - loss: 0.0014 -
accuracy: 0.9889 - val_loss: 5.0106e-06 - val_accuracy: 0.9990
Epoch 3/10
5964/5964 [==============================] - 35s 6ms/step - loss: 5.6253e-
04 - accuracy: 0.9940 - val_loss: 3.0691e-04 - val_accuracy: 0.9937
Epoch 4/10
5964/5964 [==============================] - 35s 6ms/step - loss: 4.6805e-
04 - accuracy: 0.9946 - val_loss: 8.5137e-06 - val_accuracy: 0.9988
Epoch 5/10
5964/5964 [==============================] - 36s 6ms/step - loss: 6.3032e-
04 - accuracy: 0.9929 - val_loss: 6.6694e-05 - val_accuracy: 0.9966
Epoch 6/10
5964/5964 [==============================] - 36s 6ms/step - loss: 3.0317e-
04 - accuracy: 0.9963 - val_loss: 5.9120e-04 - val_accuracy: 0.9883
Epoch 7/10
5964/5964 [==============================] - 36s 6ms/step - loss: 3.4278e-
04 - accuracy: 0.9957 - val_loss: 6.6711e-04 - val_accuracy: 0.9902
Epoch 8/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.0011 -
accuracy: 0.9929 - val_loss: 1.6144e-05 - val_accuracy: 0.9980
Epoch 9/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.0015 -
accuracy: 0.9945 - val_loss: 0.0017 - val_accuracy: 0.9867
Epoch 10/10
5964/5964 [==============================] - 36s 6ms/step - loss: 6.0522e-
04 - accuracy: 0.9929 - val_loss: 0.0033 - val_accuracy: 0.9766
```

Evaluate on Test Set

In [17]:
```
predictions = model.predict(X_test, verbose=1)
anomalyScoresAE = anomalyScores(X_test, predictions)
preds = plotResults(y_test, anomalyScoresAE, True)
model.reset_states()
```

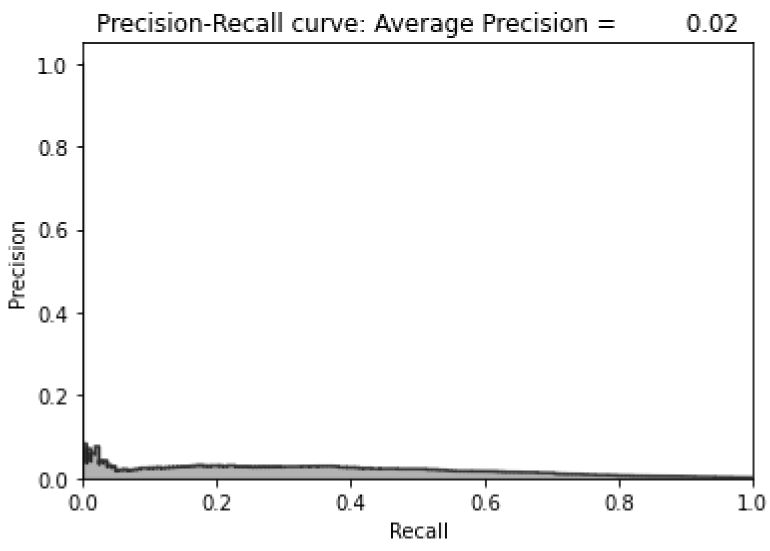
```
2938/2938 [==============================] - 3s 933us/step
```

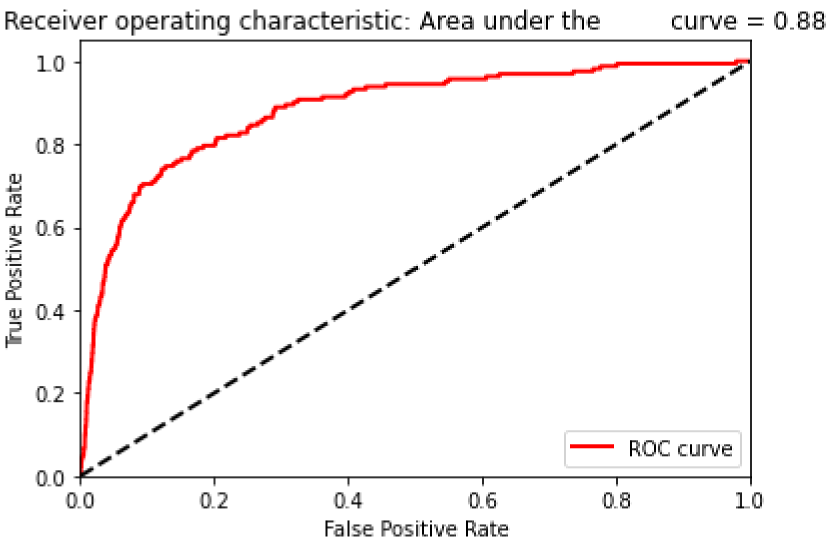




In [18]:
```python
# 10 runs - We will capture mean of average precision
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Apply linear activation function to input layer
    # Generate hidden layer with 29 nodes, the same as the input layer
    model.add(Dense(units=29, activation='linear',input_dim=29))

    # Apply linear activation function to hidden layer
    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f'Mean average precision over 10 runs: {np.mean(test_scores)}')
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.3308 -
accuracy: 0.6682 - val_loss: 0.0019 - val_accuracy: 0.9778
Epoch 2/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.0014 -
accuracy: 0.9886 - val_loss: 1.5908e-06 - val_accuracy: 0.9993
Epoch 3/10
5964/5964 [==============================] - 37s 6ms/step - loss: 5.9336e-
04 - accuracy: 0.9939 - val_loss: 4.2303e-04 - val_accuracy: 0.9930
Epoch 4/10
5964/5964 [==============================] - 37s 6ms/step - loss: 3.9920e-
04 - accuracy: 0.9953 - val_loss: 2.3430e-06 - val_accuracy: 0.9994
Epoch 5/10
5964/5964 [==============================] - 37s 6ms/step - loss: 4.5638e-
04 - accuracy: 0.9950 - val_loss: 1.6159e-04 - val_accuracy: 0.9947
Epoch 6/10
5964/5964 [==============================] - 38s 6ms/step - loss: 2.9407e-
04 - accuracy: 0.9961 - val_loss: 8.6358e-04 - val_accuracy: 0.9848
Epoch 7/10
5964/5964 [==============================] - 37s 6ms/step - loss: 2.4230e-
04 - accuracy: 0.9963 - val_loss: 5.4592e-04 - val_accuracy: 0.9916
Epoch 8/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.0018 -
accuracy: 0.9916 - val_loss: 5.8580e-05 - val_accuracy: 0.9967
Epoch 9/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.0020 -
accuracy: 0.9934 - val_loss: 0.0025 - val_accuracy: 0.9872
Epoch 10/10
5964/5964 [==============================] - 42s 7ms/step - loss: 6.5284e-
04 - accuracy: 0.9928 - val_loss: 0.0026 - val_accuracy: 0.9771
2938/2938 [==============================] - 3s 939us/step
```






```
Mean average precision over 10 runs: 0.019969338929891958
```

Out[18]:
```
[0.02]
```

In [19]:
```python
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.02
Coefficient of variation over 10 runs: 0.0
```

Out[19]:
```
[0.02]
```

Model Two

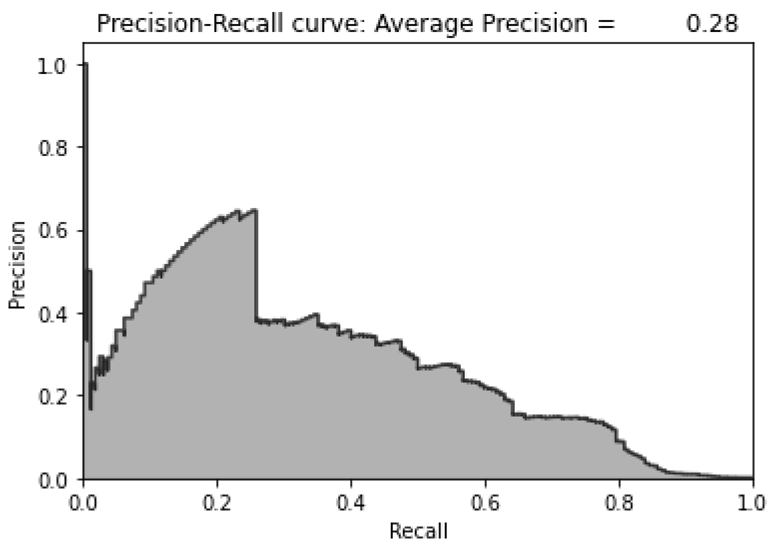
Two layer undercomplete autoencoder with linear activation

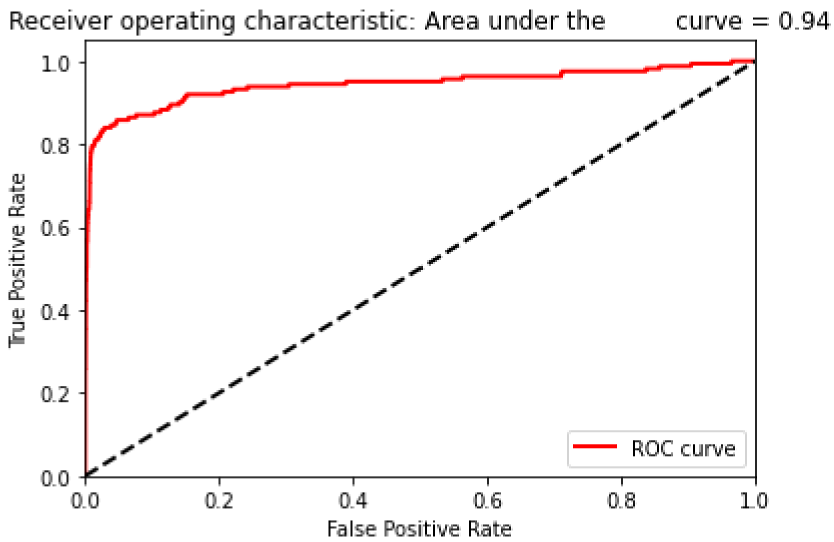
20 nodes in hidden layer

In [20]:
```python
tf.random.set_seed(42)
np.random.seed(42)
```

In [21]:
```python
# 10 runs - We will capture mean of average precision
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Apply linear activation function to input layer
    # Generate hidden layer with 20 nodes
    model.add(Dense(units=20, activation='linear',input_dim=29))

    # Apply linear activation function to hidden layer
    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)}
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.5200 -
accuracy: 0.4822 - val_loss: 0.2780 - val_accuracy: 0.6435
Epoch 2/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.2821 -
accuracy: 0.6348 - val_loss: 0.2753 - val_accuracy: 0.6338
Epoch 3/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.2869 -
accuracy: 0.6418 - val_loss: 0.2740 - val_accuracy: 0.6413
Epoch 4/10
5964/5964 [==============================] - 42s 7ms/step - loss: 0.2711 -
accuracy: 0.6485 - val_loss: 0.2744 - val_accuracy: 0.6533
Epoch 5/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.2784 -
accuracy: 0.6443 - val_loss: 0.2732 - val_accuracy: 0.6609
Epoch 6/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.2679 -
accuracy: 0.6644 - val_loss: 0.2735 - val_accuracy: 0.6584
Epoch 7/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.2713 -
accuracy: 0.6646 - val_loss: 0.2736 - val_accuracy: 0.6645
Epoch 8/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.2903 -
accuracy: 0.6659 - val_loss: 0.2737 - val_accuracy: 0.6753
Epoch 9/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.2982 -
accuracy: 0.6750 - val_loss: 0.2739 - val_accuracy: 0.6812
Epoch 10/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.2689 -
accuracy: 0.6813 - val_loss: 0.2739 - val_accuracy: 0.6793
2938/2938 [==============================] - 3s 967us/step
```






```
Mean average precision over 10 runs: 0.2799
```

Out[21]:
```
[0.2799]
```

Results

In [22]:
```
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.2799
Coefficient of variation over 10 runs: 0.0
```

Out[22]:
```
[0.2799]
```

Model Two v2

Two layer undercomplete autoencoder with linear activation

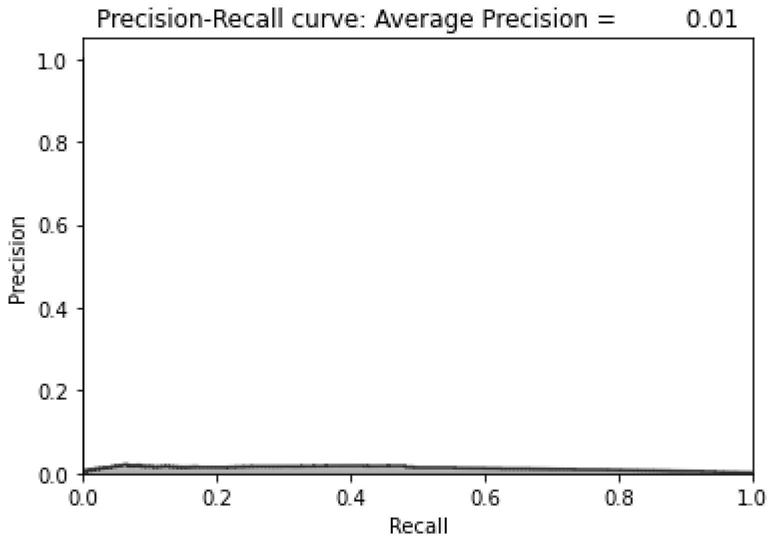
With 27 nodes this time

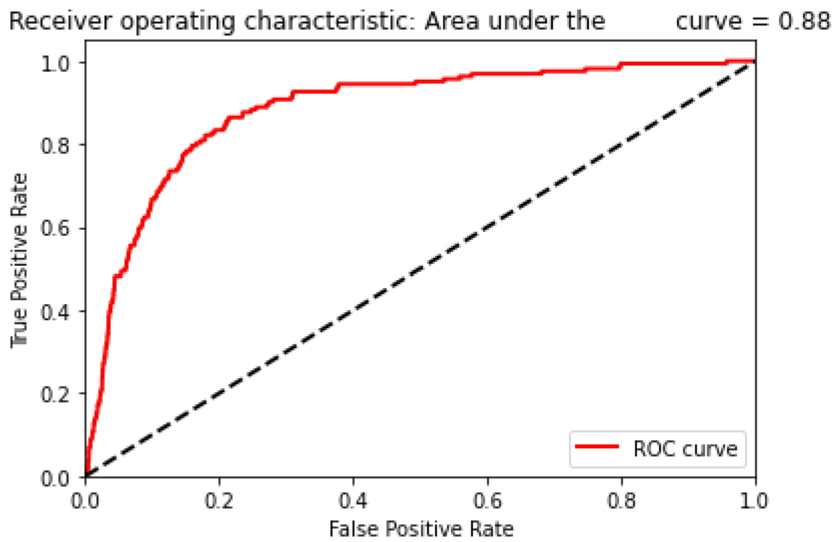
In [23]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [24]:

```python
# 10 runs - We will capture mean of average precision
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Apply linear activation function to input layer
    # Generate hidden layer with 27 nodes
    model.add(Dense(units=27, activation='linear',input_dim=29))

    # Apply linear activation function to hidden layer
    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)}
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.3209 -
accuracy: 0.6425 - val_loss: 0.0365 - val_accuracy: 0.8872
Epoch 2/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0368 -
accuracy: 0.8912 - val_loss: 0.0373 - val_accuracy: 0.9247
Epoch 3/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0474 -
accuracy: 0.9257 - val_loss: 0.0374 - val_accuracy: 0.9514
Epoch 4/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0393 -
accuracy: 0.9541 - val_loss: 0.0377 - val_accuracy: 0.9516
Epoch 5/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0382 -
accuracy: 0.9545 - val_loss: 0.0363 - val_accuracy: 0.9615
Epoch 6/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0360 -
accuracy: 0.9592 - val_loss: 0.0376 - val_accuracy: 0.9510
Epoch 7/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0352 -
accuracy: 0.9583 - val_loss: 0.0382 - val_accuracy: 0.9532
Epoch 8/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0547 -
accuracy: 0.9485 - val_loss: 0.0371 - val_accuracy: 0.9637
Epoch 9/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0572 -
accuracy: 0.9560 - val_loss: 0.0404 - val_accuracy: 0.9560
Epoch 10/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0329 -
accuracy: 0.9620 - val_loss: 0.0384 - val_accuracy: 0.9529
2938/2938 [==============================] - 3s 962us/step
```






```
Mean average precision over 10 runs: 0.0128
```

Out[24]: `[0.0128]`

Results

In [25]:
```
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.0128
Coefficient of variation over 10 runs: 0.0
```

Out[25]: `[0.0128]`

Model Three

Three layer undercomplete autoencoder with linear activation.

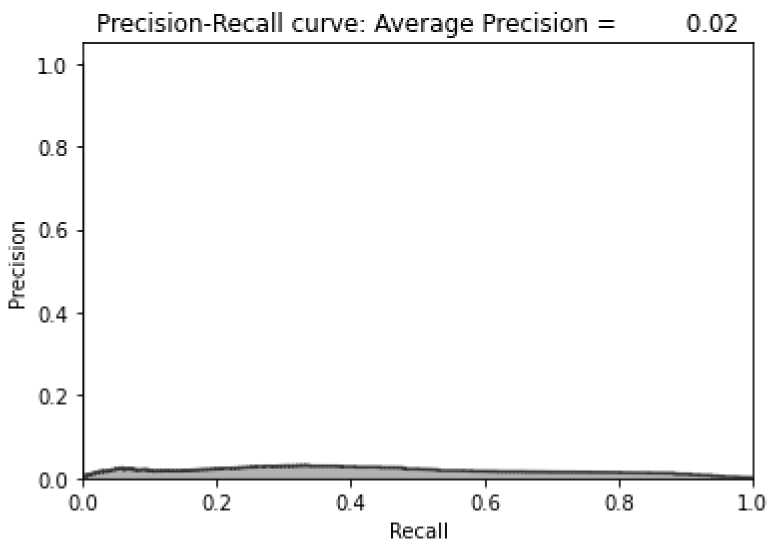
With 28 and 27 nodes in the two hidden layers, respectively

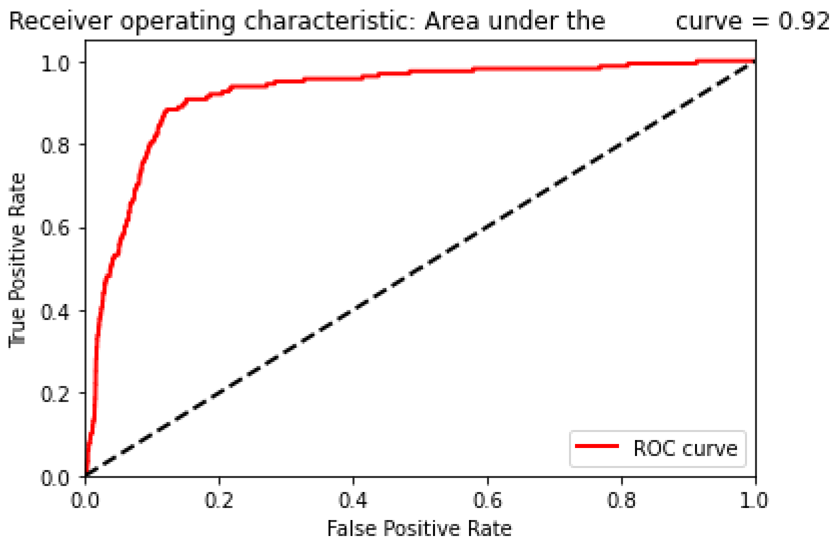
In [26]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [27]:

```
# 10 runs - We will capture mean of average precision
tf.random.set_seed(42)
np.random.seed(42)
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Apply linear activation function to input layer
    # Generate first hidden layer with 27 nodes
    # Generate second hidden layer with 28 nodes
    model.add(Dense(units=28, activation='linear',input_dim=29))
    model.add(Dense(units=27, activation='linear'))

    # Apply linear activation function to second hidden layer
    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)}
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 39s 7ms/step - loss: 0.3168 -
accuracy: 0.6229 - val_loss: 0.0369 - val_accuracy: 0.9341
Epoch 2/10
5964/5964 [==============================] - 40s 7ms/step - loss: 0.0412 -
accuracy: 0.9412 - val_loss: 0.0366 - val_accuracy: 0.9531
Epoch 3/10
5964/5964 [==============================] - 39s 7ms/step - loss: 0.0470 -
accuracy: 0.9534 - val_loss: 0.0393 - val_accuracy: 0.9610
Epoch 4/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0389 -
accuracy: 0.9632 - val_loss: 0.0384 - val_accuracy: 0.9571
Epoch 5/10
5964/5964 [==============================] - 39s 6ms/step - loss: 0.0397 -
accuracy: 0.9581 - val_loss: 0.0363 - val_accuracy: 0.9685
Epoch 6/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0370 -
accuracy: 0.9622 - val_loss: 0.0390 - val_accuracy: 0.9502
Epoch 7/10
5964/5964 [==============================] - 39s 6ms/step - loss: 0.0355 -
accuracy: 0.9587 - val_loss: 0.0373 - val_accuracy: 0.9603
Epoch 8/10
5964/5964 [==============================] - 39s 7ms/step - loss: 0.0553 -
accuracy: 0.9594 - val_loss: 0.0377 - val_accuracy: 0.9631
Epoch 9/10
5964/5964 [==============================] - 39s 7ms/step - loss: 0.0576 -
accuracy: 0.9580 - val_loss: 0.0392 - val_accuracy: 0.9564
Epoch 10/10
5964/5964 [==============================] - 40s 7ms/step - loss: 0.0333 -
accuracy: 0.9594 - val_loss: 0.0390 - val_accuracy: 0.9538
2938/2938 [==============================] - 3s 1ms/step
```






```
Mean average precision over 10 runs: 0.0189
```

Out[27]:
```
[0.0189]
```

Results

In [28]:
```
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.0189
Coefficient of variation over 10 runs: 0.0
```

Out[28]:
```
[0.0189]
```

Model Four

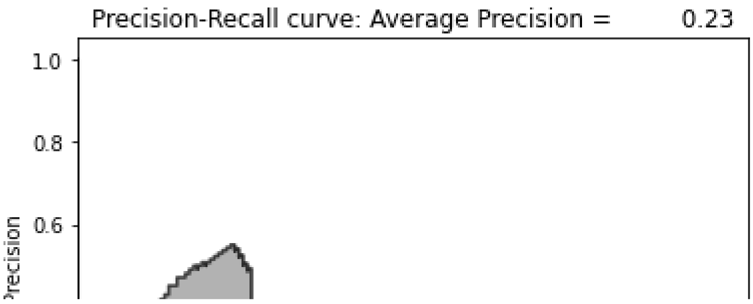
Four layer undercomplete autoencoder with ReLu activation

29 -> 27 -> 22 -> 27 -> 29

In [29]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [30]:
```python
# 10 runs - We will capture mean of average precision
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Apply ReLu throughout
    # Generate first hidden layer with 27 nodes
    # Generate second hidden layer with 22 nodes
    model.add(Dense(units=27, activation='relu',input_dim=29))
    model.add(Dense(units=22, activation='relu'))

    # Apply ReLu throughout
    # Generate third hidden layer with 27 nodes
    # Generate output layer with 29 nodes
    model.add(Dense(units=27, activation='relu'))
    model.add(Dense(units=29, activation='relu'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)}
[round(x,4) for x in test_scores]
```

```
Epoch 8/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.6328
- accuracy: 0.7420 - val_loss: 0.6181 - val_accuracy: 0.7356
Epoch 9/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.6366
- accuracy: 0.7344 - val_loss: 0.6164 - val_accuracy: 0.7540
Epoch 10/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.6180
- accuracy: 0.7451 - val_loss: 0.6339 - val_accuracy: 0.6888
2938/2938 [==============================] - 4s 1ms/step
```



Results

In [31]:
```
print(f'Mean average precision over 10 runs:    {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:    0.2292
Coefficient of variation over 10 runs: 0.0
```

Out[31]: [0.2292]

Model Five

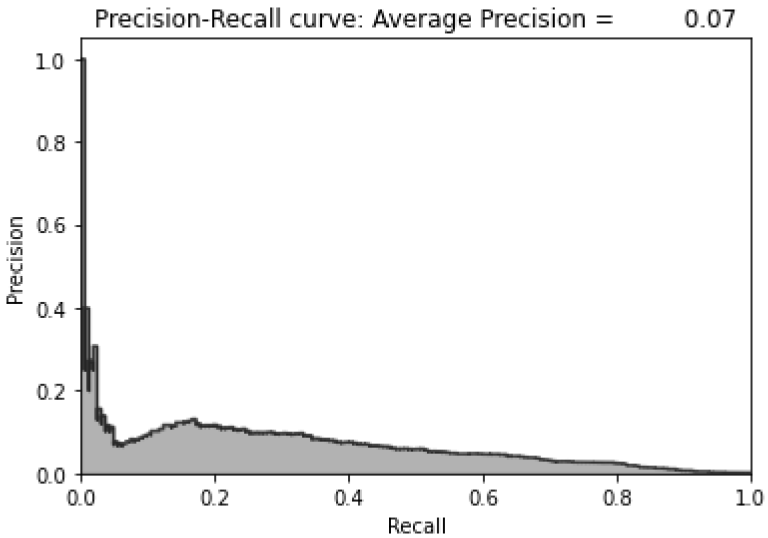
Two layer overcomplete autoencoder with linear activation

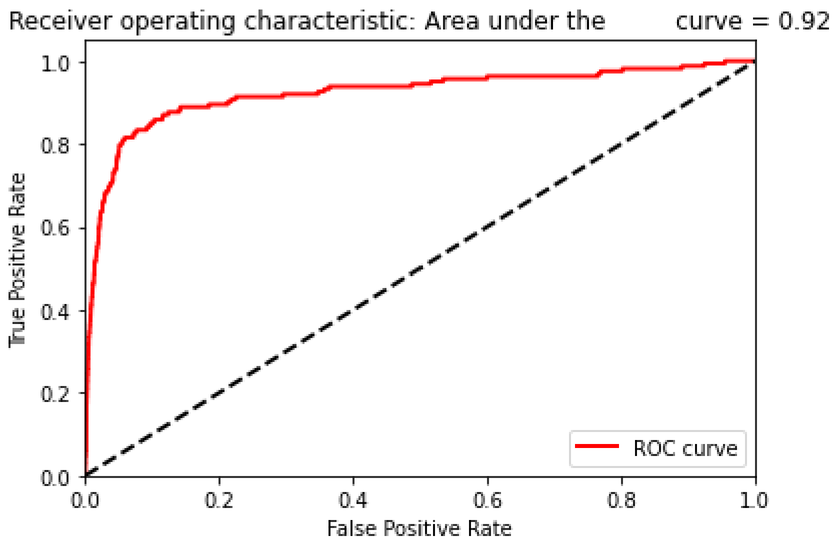
29 -> 40 -> 29

In [32]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [33]:
```python
# 10 runs - We will capture mean of average precision
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Apply linear activation function throughout
    # Generate first hidden layer with 40 nodes
    model.add(Dense(units=40, activation='linear',input_dim=29))

    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)}
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.2050 -
accuracy: 0.7910 - val_loss: 0.0011 - val_accuracy: 0.9762
Epoch 2/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0015 -
accuracy: 0.9896 - val_loss: 2.5041e-04 - val_accuracy: 0.9937
Epoch 3/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.0012 -
accuracy: 0.9926 - val_loss: 4.6329e-04 - val_accuracy: 0.9935
Epoch 4/10
5964/5964 [==============================] - 36s 6ms/step - loss: 3.9699e-
04 - accuracy: 0.9947 - val_loss: 4.5684e-04 - val_accuracy: 0.9959
Epoch 5/10
5964/5964 [==============================] - 37s 6ms/step - loss: 8.2627e-
04 - accuracy: 0.9920 - val_loss: 8.2839e-05 - val_accuracy: 0.9966
Epoch 6/10
5964/5964 [==============================] - 37s 6ms/step - loss: 3.1426e-
04 - accuracy: 0.9967 - val_loss: 0.0017 - val_accuracy: 0.9806
Epoch 7/10
5964/5964 [==============================] - 37s 6ms/step - loss: 4.6392e-
04 - accuracy: 0.9944 - val_loss: 9.3268e-04 - val_accuracy: 0.9903
Epoch 8/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.0020 -
accuracy: 0.9912 - val_loss: 8.9247e-05 - val_accuracy: 0.9966
Epoch 9/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0010 -
accuracy: 0.9938 - val_loss: 0.0059 - val_accuracy: 0.9791
Epoch 10/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0010 -
accuracy: 0.9911 - val_loss: 0.0069 - val_accuracy: 0.9656
2938/2938 [==============================] - 3s 1ms/step
```






```
Mean average precision over 10 runs: 0.0707
```

Out[33]: `[0.0707]`

Results

In [34]:
```
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.0707
Coefficient of variation over 10 runs: 0.0
```

Out[34]: `[0.0707]`

Model Six

Two layer overcomplete autoencoder with linear activation and dropout

29 -> 40 -> 29

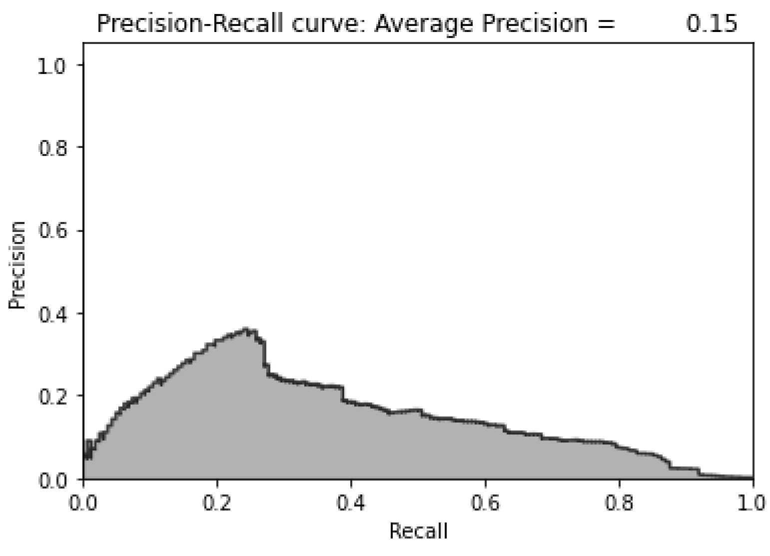
Dropout percentage: 10%

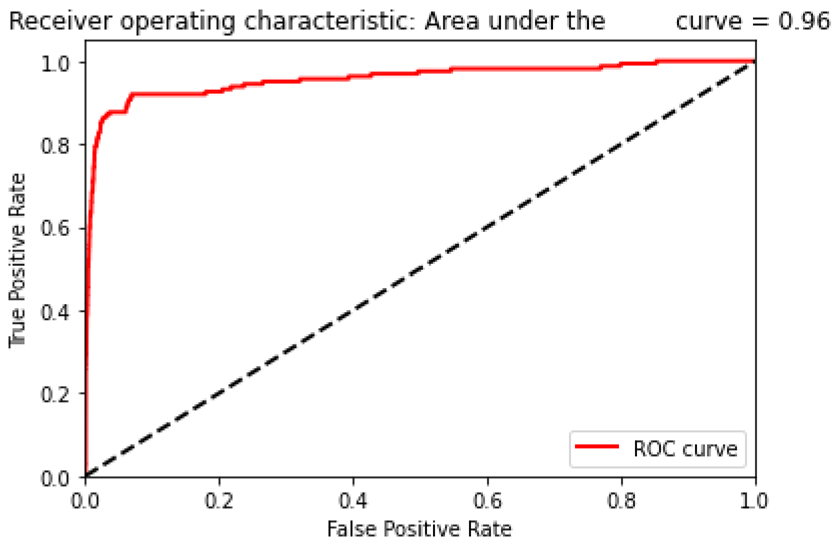
In [35]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [36]:

```
# 10 runs - We will capture mean of average precision
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    model.add(Dense(units=40, activation='linear',input_dim=29))
    model.add(Dropout(0.10))

    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)}
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.2984 -
accuracy: 0.6287 - val_loss: 0.0101 - val_accuracy: 0.9635
Epoch 2/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0771 -
accuracy: 0.7832 - val_loss: 0.0077 - val_accuracy: 0.9731
Epoch 3/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0773 -
accuracy: 0.7832 - val_loss: 0.0091 - val_accuracy: 0.9727
Epoch 4/10
5964/5964 [==============================] - 39s 7ms/step - loss: 0.0744 -
accuracy: 0.7827 - val_loss: 0.0091 - val_accuracy: 0.9688
Epoch 5/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0771 -
accuracy: 0.7835 - val_loss: 0.0075 - val_accuracy: 0.9739
Epoch 6/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0760 -
accuracy: 0.7846 - val_loss: 0.0074 - val_accuracy: 0.9721
Epoch 7/10
5964/5964 [==============================] - 39s 7ms/step - loss: 0.0757 -
accuracy: 0.7854 - val_loss: 0.0085 - val_accuracy: 0.9694
Epoch 8/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0895 -
accuracy: 0.7837 - val_loss: 0.0098 - val_accuracy: 0.9607
Epoch 9/10
5964/5964 [==============================] - 39s 6ms/step - loss: 0.0787 -
accuracy: 0.7856 - val_loss: 0.0090 - val_accuracy: 0.9687
Epoch 10/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0762 -
accuracy: 0.7847 - val_loss: 0.0123 - val_accuracy: 0.9678
2938/2938 [==============================] - 3s 944us/step
```






```
Mean average precision over 10 runs: 0.1539
```

Out[36]:
```
[0.1539]
```

Results

In [37]:
```python
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.1539
Coefficient of variation over 10 runs: 0.0
```

Out[37]:
```
[0.1539]
```

Model Seven

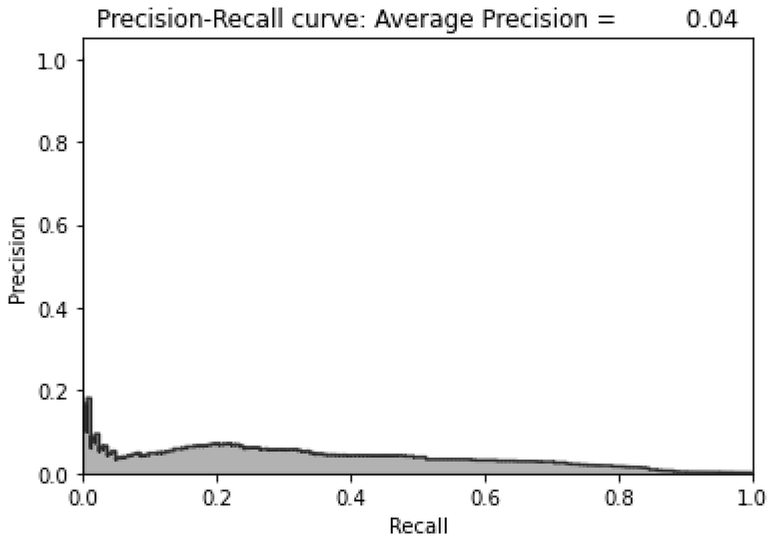
Two layer sparse overcomplete autoencoder with linear activation

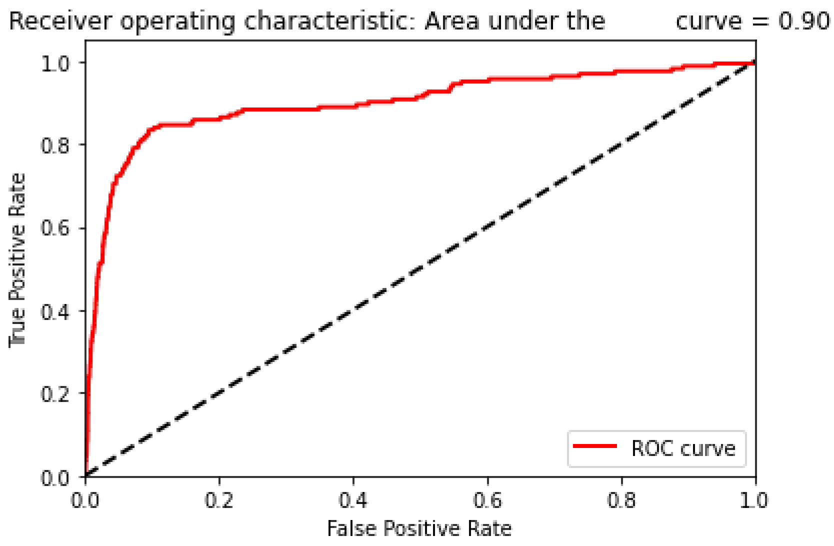
29 -> 40 -> 29

In [38]:
```python
tf.random.set_seed(42)
np.random.seed(42)
```

In [39]:
```python
# 10 runs - We will capture mean of average precision
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    model.add(Dense(units=40, activation='linear',  \
        activity_regularizer=regularizers.l1(10e-5), input_dim=29))

    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.2077 - accuracy: 0.7909 - val_loss: 0.0038 - val_accuracy: 0.9781
Epoch 2/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.0041 - accuracy: 0.9897 - val_loss: 0.0023 - val_accuracy: 0.9955
Epoch 3/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.0032 - accuracy: 0.9923 - val_loss: 0.0027 - val_accuracy: 0.9902
Epoch 4/10
5964/5964 [==============================] - 47s 8ms/step - loss: 0.0024 - accuracy: 0.9938 - val_loss: 0.0017 - val_accuracy: 0.9992
Epoch 5/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.0024 - accuracy: 0.9923 - val_loss: 0.0017 - val_accuracy: 0.9953
Epoch 6/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.0020 - accuracy: 0.9948 - val_loss: 0.0032 - val_accuracy: 0.9817
Epoch 7/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.0021 - accuracy: 0.9933 - val_loss: 0.0029 - val_accuracy: 0.9858
Epoch 8/10
5964/5964 [==============================] - 42s 7ms/step - loss: 0.0048 - accuracy: 0.9857 - val_loss: 0.0014 - val_accuracy: 0.9963
Epoch 9/10
5964/5964 [==============================] - 42s 7ms/step - loss: 0.0047 - accuracy: 0.9915 - val_loss: 0.0056 - val_accuracy: 0.9781
Epoch 10/10
5964/5964 [==============================] - 42s 7ms/step - loss: 0.0024 - accuracy: 0.9901 - val_loss: 0.0067 - val_accuracy: 0.9660
2938/2938 [==============================] - 3s 1ms/step
```






```
Mean average precision over 10 runs: 0.0385
```

Out[39]:
```
[0.0385]
```

Results

In [40]:
```
print(f'Mean average precision over 10 runs:    {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.0385
Coefficient of variation over 10 runs: 0.0
```

Out[40]:
```
[0.0385]
```

Model Eight

Two layer sparse overcomplete autoencoder with linear activation and dropout

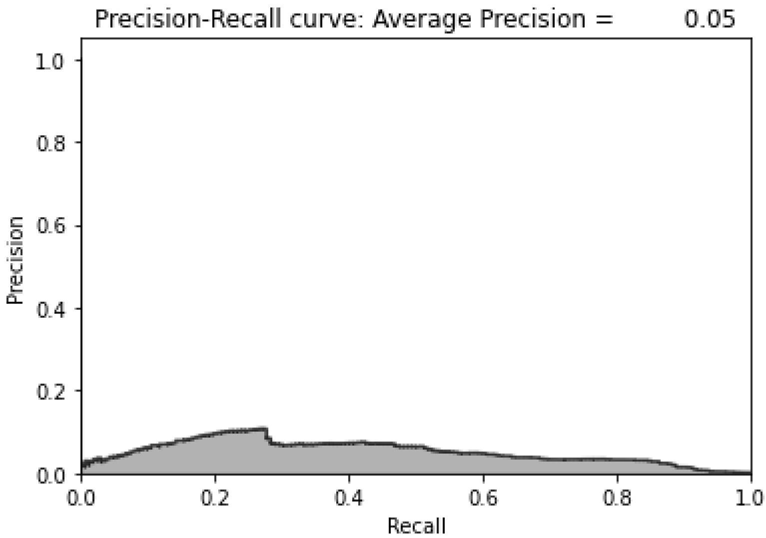
29 -> 40 -> 29

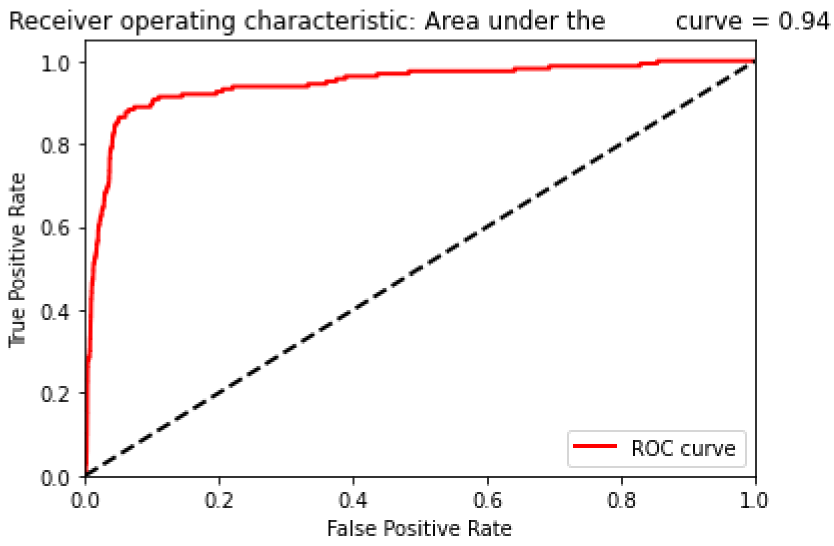
Dropout percentage: 5%

In [41]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [42]:
```
# 10 runs - We will capture mean of average precision
test_scores = []
for i in range(0,1):
    # Call neural network API
    model = Sequential()

    model.add(Dense(units=40, activation='linear',  \
        activity_regularizer=regularizers.l1(10e-5), input_dim=29))
    model.add(Dropout(0.05))

    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE, y=X_train_AE,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)}
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.2588 - accuracy: 0.6891 - val_loss: 0.0079 - val_accuracy: 0.9656
Epoch 2/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0412 - accuracy: 0.8589 - val_loss: 0.0051 - val_accuracy: 0.9793
Epoch 3/10
5964/5964 [==============================] - 45s 7ms/step - loss: 0.0398 - accuracy: 0.8616 - val_loss: 0.0061 - val_accuracy: 0.9774
Epoch 4/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0391 - accuracy: 0.8590 - val_loss: 0.0058 - val_accuracy: 0.9779
Epoch 5/10
5964/5964 [==============================] - 45s 7ms/step - loss: 0.0405 - accuracy: 0.8593 - val_loss: 0.0043 - val_accuracy: 0.9799
Epoch 6/10
5964/5964 [==============================] - 43s 7ms/step - loss: 0.0399 - accuracy: 0.8601 - val_loss: 0.0052 - val_accuracy: 0.9767
Epoch 7/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0394 - accuracy: 0.8627 - val_loss: 0.0050 - val_accuracy: 0.9758
Epoch 8/10
5964/5964 [==============================] - 45s 7ms/step - loss: 0.0450 - accuracy: 0.8597 - val_loss: 0.0074 - val_accuracy: 0.9649
Epoch 9/10
5964/5964 [==============================] - 45s 7ms/step - loss: 0.0428 - accuracy: 0.8590 - val_loss: 0.0053 - val_accuracy: 0.9781
Epoch 10/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0407 - accuracy: 0.8629 - val_loss: 0.0123 - val_accuracy: 0.9602
2938/2938 [==============================] - 3s 1ms/step
```






```
Mean average precision over 10 runs: 0.0522
```

Out[42]: [0.0522]

Results

In [43]:
```
print(f'Mean average precision over 10 runs:    {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.0522
Coefficient of variation over 10 runs: 0.0
```

Out[43]: [0.0522]

Model Nine

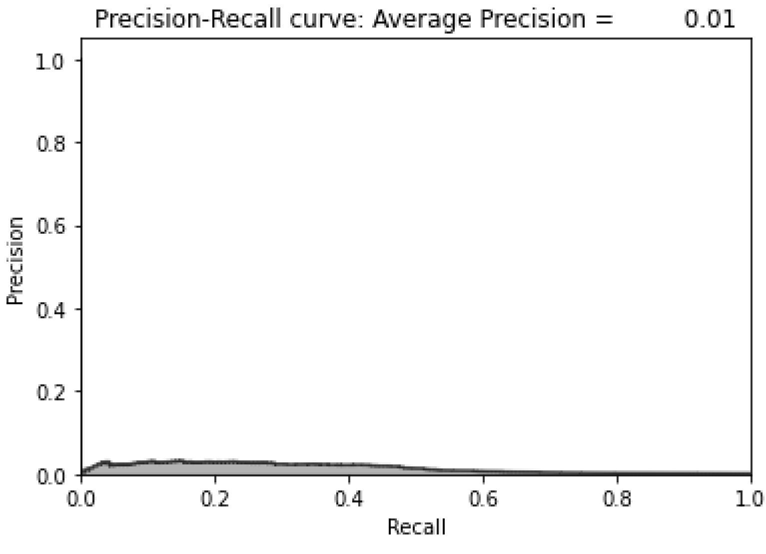
Two layer denoising undercomplete autoencoder with linear activation

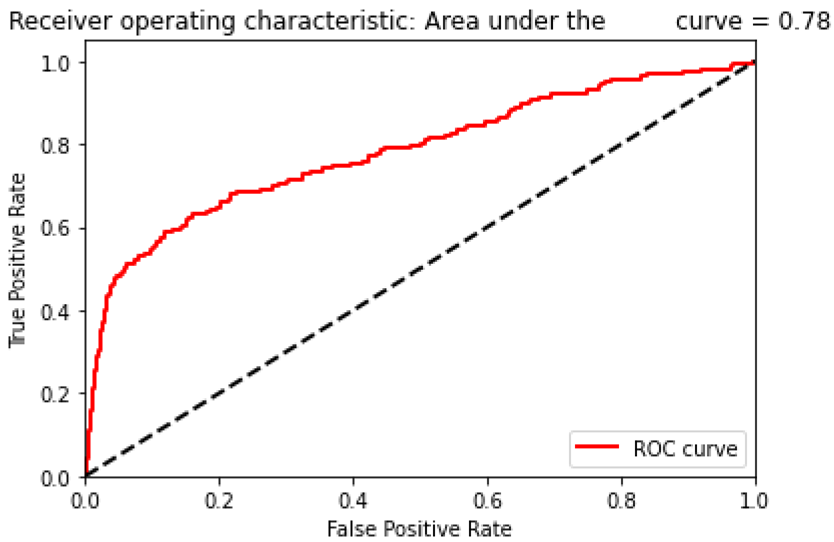
29 -> 27 -> 29

In [44]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [45]:
```python
# 10 runs - We will capture mean of average precision
test_scores = []

noise_factor = 0.50
X_train_AE_noisy = X_train_AE.copy() + noise_factor * \
 np.random.normal(loc=0.0, scale=1.0, size=X_train_AE.shape)
X_test_AE_noisy = X_test_AE.copy() + noise_factor * \
 np.random.normal(loc=0.0, scale=1.0, size=X_test_AE.shape)

for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Generate hidden layer with 27 nodes using linear activation
    model.add(Dense(units=27, activation='linear', input_dim=29))

    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE_noisy, y=X_train_AE_noisy,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test_AE_noisy, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)}
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.3727 -
accuracy: 0.6286 - val_loss: 0.0365 - val_accuracy: 0.8961
Epoch 2/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0556 -
accuracy: 0.8654 - val_loss: 0.0362 - val_accuracy: 0.9092
Epoch 3/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0575 -
accuracy: 0.8698 - val_loss: 0.0356 - val_accuracy: 0.8923
Epoch 4/10
5964/5964 [==============================] - 38s 6ms/step - loss: 0.0546 -
accuracy: 0.8712 - val_loss: 0.0365 - val_accuracy: 0.9097
Epoch 5/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0546 -
accuracy: 0.8823 - val_loss: 0.0362 - val_accuracy: 0.9192
Epoch 6/10
5964/5964 [==============================] - 36s 6ms/step - loss: 0.0544 -
accuracy: 0.8865 - val_loss: 0.0372 - val_accuracy: 0.9112
Epoch 7/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0525 -
accuracy: 0.8893 - val_loss: 0.0366 - val_accuracy: 0.9406
Epoch 8/10
5964/5964 [==============================] - 37s 6ms/step - loss: 0.0669 -
accuracy: 0.8968 - val_loss: 0.0369 - val_accuracy: 0.9551
Epoch 9/10
5964/5964 [==============================] - 39s 6ms/step - loss: 0.0743 -
accuracy: 0.9008 - val_loss: 0.0390 - val_accuracy: 0.9480
Epoch 10/10
5964/5964 [==============================] - 40s 7ms/step - loss: 0.0503 -
accuracy: 0.9078 - val_loss: 0.0384 - val_accuracy: 0.9457
2938/2938 [==============================] - 3s 990us/step
```






```
Mean average precision over 10 runs: 0.0148
```

Out[45]:
```
[0.0148]
```

Results

In [46]:
```
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.0148
Coefficient of variation over 10 runs: 0.0
```

Out[46]:
```
[0.0148]
```

Model Ten

Two layer denoising overcomplete autoencoder with linear activation

And sparsity regularizer and dropout

29 -> 40 -> 29

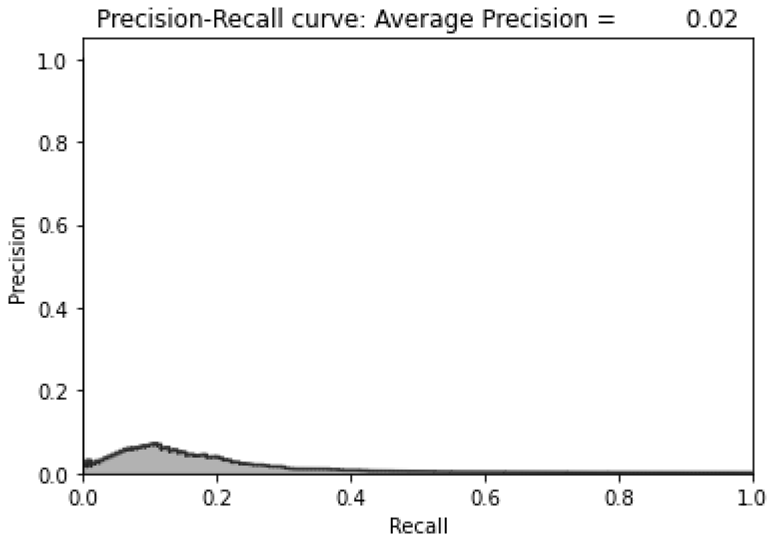
Dropout percentage: 5%

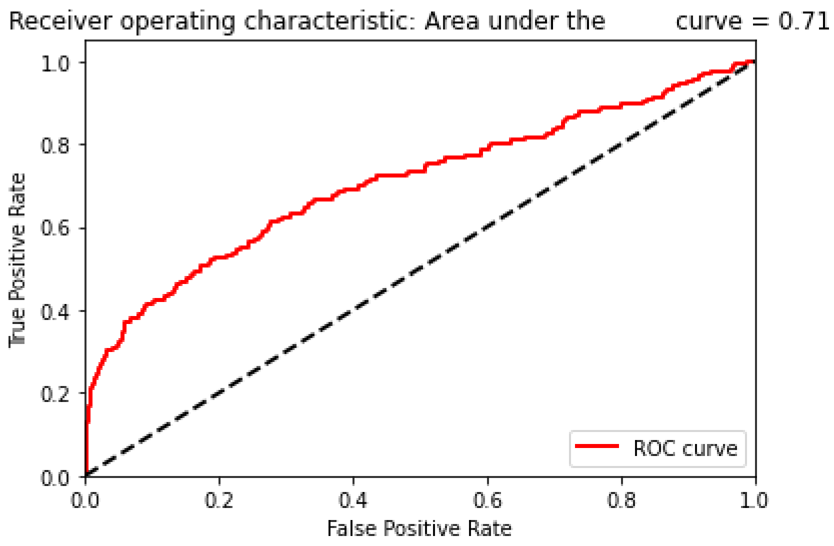
In [47]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [48]:

```
# 10 runs - We will capture mean of average precision
test_scores = []

noise_factor = 0.50
X_train_AE_noisy = X_train_AE.copy() + noise_factor * \
 np.random.normal(loc=0.0, scale=1.0, size=X_train_AE.shape)
X_test_AE_noisy = X_test_AE.copy() + noise_factor * \
 np.random.normal(loc=0.0, scale=1.0, size=X_test_AE.shape)

for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Generate hidden layer with 40 nodes using linear activation
    model.add(Dense(units=40, activation='linear',  \
        activity_regularizer=regularizers.l1(10e-5), input_dim=29))
    model.add(Dropout(0.05))

    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE_noisy, y=X_train_AE_noisy,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test_AE_noisy, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)]
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 45s 7ms/step - loss: 0.2963 -
accuracy: 0.6827 - val_loss: 0.0062 - val_accuracy: 0.9705
Epoch 2/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0508 -
accuracy: 0.8486 - val_loss: 0.0049 - val_accuracy: 0.9806
Epoch 3/10
5964/5964 [==============================] - 46s 8ms/step - loss: 0.0493 -
accuracy: 0.8456 - val_loss: 0.0053 - val_accuracy: 0.9807
Epoch 4/10
5964/5964 [==============================] - 45s 8ms/step - loss: 0.0489 -
accuracy: 0.8468 - val_loss: 0.0050 - val_accuracy: 0.9807
Epoch 5/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0502 -
accuracy: 0.8471 - val_loss: 0.0041 - val_accuracy: 0.9803
Epoch 6/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0499 -
accuracy: 0.8478 - val_loss: 0.0044 - val_accuracy: 0.9786
Epoch 7/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0490 -
accuracy: 0.8485 - val_loss: 0.0045 - val_accuracy: 0.9777
Epoch 8/10
5964/5964 [==============================] - 44s 7ms/step - loss: 0.0567 -
accuracy: 0.8471 - val_loss: 0.0065 - val_accuracy: 0.9686
Epoch 9/10
5964/5964 [==============================] - 45s 8ms/step - loss: 0.0539 -
accuracy: 0.8452 - val_loss: 0.0047 - val_accuracy: 0.9803
Epoch 10/10
5964/5964 [==============================] - 45s 8ms/step - loss: 0.0506 -
accuracy: 0.8469 - val_loss: 0.0084 - val_accuracy: 0.9671
2938/2938 [==============================] - 3s 990us/step
```






```
Mean average precision over 10 runs: 0.0155
```

Out[48]:
```
[0.0155]
```

Results

In [49]:
```
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.0155
Coefficient of variation over 10 runs: 0.0
```

Out[49]:
```
[0.0155]
```

Model Eleven

Two layer denoising overcomplete autoencoder with ReLU activation

And sparsity regularizer and dropout

29 -> 40 -> 29

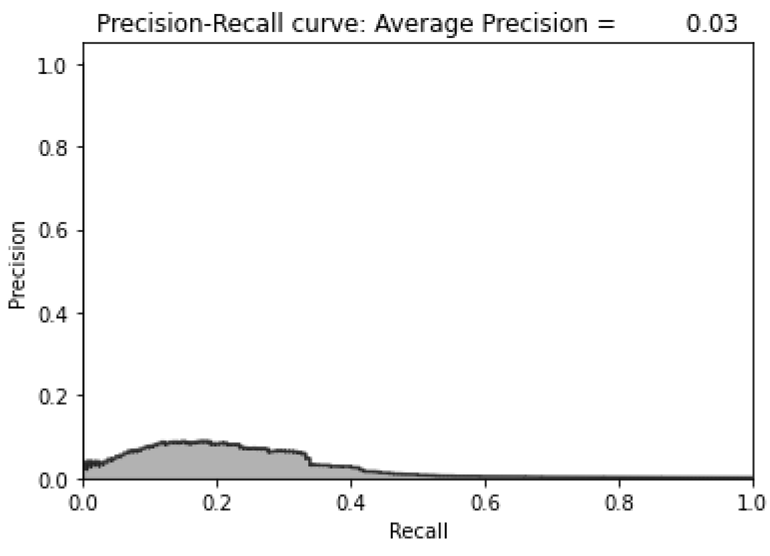
Dropout percentage: 5%

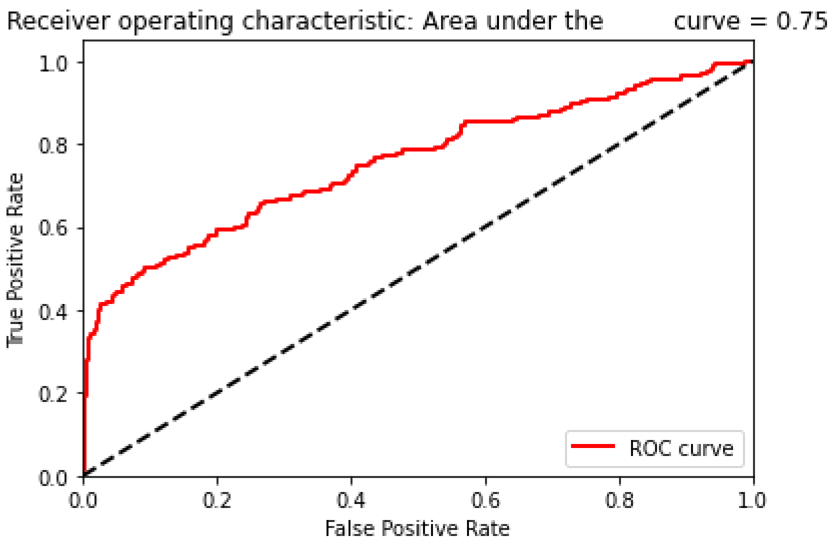
In [50]:
```
tf.random.set_seed(42)
np.random.seed(42)
```

In [51]:

```
# 10 runs - We will capture mean of average precision
test_scores = []

noise_factor = 0.50
X_train_AE_noisy = X_train_AE.copy() + noise_factor * \
 np.random.normal(loc=0.0, scale=1.0, size=X_train_AE.shape)
X_test_AE_noisy = X_test_AE.copy() + noise_factor * \
 np.random.normal(loc=0.0, scale=1.0, size=X_test_AE.shape)

for i in range(0,1):
    # Call neural network API
    model = Sequential()

    # Generate hidden layer with 40 nodes using linear activation
    model.add(Dense(units=40, activation='relu',  \
        activity_regularizer=regularizers.l1(10e-5), input_dim=29))
    model.add(Dropout(0.05))

    # Generate output layer with 29 nodes
    model.add(Dense(units=29, activation='linear'))

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

    # Train the model
    num_epochs = 10
    batch_size = 32

    history = model.fit(x=X_train_AE_noisy, y=X_train_AE_noisy,
                        epochs=num_epochs,
                        batch_size=batch_size,
                        shuffle=True,
                        validation_data=(X_train_AE, X_train_AE),
                        verbose=1)

    # Evaluate on test set
    predictions = model.predict(X_test_AE_noisy, verbose=1)
    anomalyScoresAE = anomalyScores(X_test, predictions)
    preds, avgPrecision = plotResults(y_test, anomalyScoresAE, True)
    test_scores.append(avgPrecision)
    model.reset_states()

print(f"Mean average precision over 10 runs: {round(np.mean(test_scores),4)
[round(x,4) for x in test_scores]
```

```
Epoch 1/10
5964/5964 [==============================] - 46s 8ms/step - loss: 0.4365 -
accuracy: 0.5372 - val_loss: 0.0228 - val_accuracy: 0.9172
Epoch 2/10
5964/5964 [==============================] - 46s 8ms/step - loss: 0.1360 -
accuracy: 0.7204 - val_loss: 0.0184 - val_accuracy: 0.9130
Epoch 3/10
5964/5964 [==============================] - 45s 7ms/step - loss: 0.1267 -
accuracy: 0.7291 - val_loss: 0.0152 - val_accuracy: 0.9225
Epoch 4/10
5964/5964 [==============================] - 46s 8ms/step - loss: 0.1177 -
accuracy: 0.7337 - val_loss: 0.0155 - val_accuracy: 0.9174
Epoch 5/10
5964/5964 [==============================] - 48s 8ms/step - loss: 0.1180 -
accuracy: 0.7330 - val_loss: 0.0128 - val_accuracy: 0.9232
Epoch 6/10
5964/5964 [==============================] - 46s 8ms/step - loss: 0.1175 -
accuracy: 0.7349 - val_loss: 0.0135 - val_accuracy: 0.9232
Epoch 7/10
5964/5964 [==============================] - 46s 8ms/step - loss: 0.1147 -
accuracy: 0.7361 - val_loss: 0.0129 - val_accuracy: 0.9232
Epoch 8/10
5964/5964 [==============================] - 47s 8ms/step - loss: 0.1165 -
accuracy: 0.7366 - val_loss: 0.0141 - val_accuracy: 0.9201
Epoch 9/10
5964/5964 [==============================] - 47s 8ms/step - loss: 0.1158 -
accuracy: 0.7392 - val_loss: 0.0125 - val_accuracy: 0.9235
Epoch 10/10
5964/5964 [==============================] - 46s 8ms/step - loss: 0.1092 -
accuracy: 0.7387 - val_loss: 0.0142 - val_accuracy: 0.9230
2938/2938 [==============================] - 3s 1ms/step
```






```
Mean average precision over 10 runs: 0.0289
```

Out[51]:
```
[0.0289]
```

Results

In [52]:
```
print(f'Mean average precision over 10 runs:   {round(np.mean(test_scores),4
print(f'Coefficient of variation over 10 runs: {round(np.std(test_scores)/np
[round(x,4) for x in test_scores]
```

```
Mean average precision over 10 runs:   0.0289
Coefficient of variation over 10 runs: 0.0
```

Out[52]:
```
[0.0289]
```

Conclusion

In [53]:
```
import datetime as dt
print("Completed: ", dt.datetime.now())
```

```
Completed:  2024-08-18 23:36:56.836364
```

結論:

Two layer undercomplete autoencoder with linear activation (20 nodes in one hidden layer) 的表現最好, 但也僅僅0.28. 次佳的是0.22, 使用 Four layer undercomplete autoencoder with ReLu activation (29 -> 27 -> 22 -> 27 -> 29)

In [ ]:
```
```

In [ ]:
```
```