In [ ]:
```
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sns
from sklearn.metrics import confusion_matrix, classification_report
from collections import Counter
from sklearn.model_selection import train_test_split
from sklearn.ensemble import IsolationForest
```

Load Data

In [ ]:
```
# define the base path
base_path = "data/r4.2/"

# load each CSV file into a separate dataframe
device_df = pd.read_csv(base_path + "device.csv")
email_df = pd.read_csv(base_path + "email.csv")
file_df = pd.read_csv(base_path + "file.csv")
http_df = pd.read_csv(base_path + "http.csv")
logon_df = pd.read_csv(base_path + "logon.csv")
```

Data Exploration

Device.csv

In [ ]:
```
# view data
device_df.head()
```

Out[ ]:

	id	date	user	pc	activity
0	{J1S3-L9UU75BQ-7790ATPL}	01/02/2010 07:21:06	MOH0273	PC-6699	Connect
1	{N7B5-Y7BB27SI-2946PUJK}	01/02/2010 07:37:41	MOH0273	PC-6699	Disconnect
2	{U1V9-Z7XT67KV-5649MYHI}	01/02/2010 07:59:11	HPH0075	PC-2417	Connect
3	{H0Z7-E6GB57XZ-1603MOXD}	01/02/2010 07:59:49	IIW0249	PC-0843	Connect
4	{L7P2-G4PX02RX-7999GYOY}	01/02/2010 08:04:26	IIW0249	PC-0843	Disconnect

In [ ]:
```
# check for missing values
device_df.isnull().sum()
```

Out[ ]:
```
id          0
date        0
user        0
pc          0
activity    0
dtype: int64
```

In [ ]:
```
# data types for each column
device_df.dtypes
```

Out[ ]:
```
id          object
date        object
user        object
pc          object
activity    object
dtype: object
```

Email.csv

In [ ]:
```
# view data
email_df.head()
```

Out[ ]:

	id	date	user	pc	to	
0	{R3I7-S4TX96FG-8219JWFF}	01/02/2010 07:11:45	LAP0338	PC-5758	Dean.Flynn.Hines@dtaa.com;Wade_Harrison@lockhe...	Nathani
1	{R0R9-E4GL59IK-2907OSWJ}	01/02/2010 07:12:16	MOH0273	PC-6699	Odonnell-Gage@bellsouth.net	
2	{G2B2-A8XY58CP-2847ZJZL}	01/02/2010 07:13:00	LAP0338	PC-5758	Penelope_Colon@netzero.com	
3	{A3A9-F4TH89AA-8318GFGK}	01/02/2010 07:13:17	LAP0338	PC-5758	Judith_Hayden@comcast.net	
4	{E8B7-C8FZ88UF-2946RUQQ}	01/02/2010 07:13:28	MOH0273	PC-6699	Bond-Raymond@verizon.net;Alea_Ferrell@msn.com;...	

In [ ]:
```
# check for missing values
email_df.isnull().sum()
```

Out[ ]:
```
id                 0
date               0
user               0
pc                 0
to                 0
cc           1617054
bcc          2212977
from               0
size               0
attachments        0
content            0
dtype: int64
```

In [ ]:
```
# null values in cc and bcc, but this is normal, so lets just say there is "None" if a
email_df['cc'].fillna('None', inplace=True)
email_df['bcc'].fillna('None', inplace=True)
```

In [ ]:
```
# data types for each column
email_df.dtypes
```

Out[ ]:
```
id             object
date           object
user           object
pc             object
to             object
cc             object
bcc            object
from           object
size            int64
attachments     int64
content        object
dtype: object
```

File.csv

In [ ]:
```
# view data
file_df.head()
```

Out[ ]:

	id	date	user	pc	filename	content
0	{L9G8-J9QE34VM-2834VDPB}	01/02/2010 07:23:14	MOH0273	PC-6699	EYPC9Y08.doc	D0-CF-11-E0-A1-B1-1A-E1 during difficulty over...
1	{H0W6-L4FG38XG-9897XTEN}	01/02/2010 07:26:19	MOH0273	PC-6699	N3LTSU3O.pdf	25-50-44-46-2D carpenters 25 landed strait dis...
2	{M3Z0-O2KK89OX-5716MBIM}	01/02/2010 08:12:03	HPH0075	PC-2417	D3D3WC9W.doc	D0-CF-11-E0-A1-B1-1A-E1 union 24 declined impo...
3	{E1I4-S4QS61TG-3652YHKR}	01/02/2010 08:17:00	HPH0075	PC-2417	QCSW62YS.doc	D0-CF-11-E0-A1-B1-1A-E1 becoming period begin ...
4	{D4R7-E7JL45UX-0067XALT}	01/02/2010 08:24:57	HSB0196	PC-8001	AU75JV6U.jpg	FF-D8

In [ ]:
```
# check for missing values
file_df.isnull().sum()
```

Out[ ]:
```
id          0
date        0
user        0
pc          0
filename    0
content     0
dtype: int64
```

In [ ]:
```
# data types for each column
file_df.dtypes
```

Out[ ]:
```
id          object
date        object
user        object
pc          object
filename    object
content     object
dtype: object
```

Http.csv

In [ ]:
```
# view data
http_df.head()
```

Out[ ]:

	id	date	user	pc	url	co
0	{V1Y4-S2IR20QU-6154HFXJ}	01/02/2010 06:55:16	LRR0148	PC-4275	http://msn.com/The_Human_Centipede_First_Seque...	r represent cons concert a
1	{Q5R1-T3EF87UE-2395RWZS}	01/02/2010 07:00:13	NGF0157	PC-6056	http://urbanspoon.com/Plunketts_Creek_Loyalsoc...	festi north cong pa
2	{X9O1-O0XW52VO-5806RPHG}	01/02/2010 07:03:46	NGF0157	PC-6056	http://aa.com/Rhodocene/rhodocenium/fhaavatqrf...	long reorga baldwi busines
3	{G5S8-U5OG04TE-5299CCTU}	01/02/2010 07:05:26	IRM0931	PC-7188	http://groupon.com/Leonhard_Euler/leonhard/tne...	a g sc experin bec
4	{L0R4-A9DH29VP-4553AUWM}	01/02/2010 07:05:52	IRM0931	PC-7188	http://flickr.com/Inauguration_of_Barack_Obama...	kate cri 2008 hi 12 ir bc

In [ ]:
```
# check for missing values
http_df.isnull().sum()
```

Out[ ]:
```
id         0
date       0
user       0
pc         0
url        0
content    0
dtype: int64
```

In [ ]:
```
# data types for each column
http_df.dtypes
```

Out[ ]:
```
id         object
date       object
user       object
pc         object
url        object
content    object
dtype: object
```

Logon.csv

In [ ]:
```
# view data
logon_df.head()
```

Out[ ]:

	id	date	user	pc	activity
0	{X1D9-S0ES98JV-5357PWMI}	01/02/2010 06:49:00	NGF0157	PC-6056	Logon
1	{G2B3-L6EJ61GT-2222RKSO}	01/02/2010 06:50:00	LRR0148	PC-4275	Logon
2	{U6Q3-U0WE70UA-3770UREL}	01/02/2010 06:53:04	LRR0148	PC-4124	Logon
3	{I0N5-R7NA26TG-6263KNGM}	01/02/2010 07:00:00	IRM0931	PC-7188	Logon
4	{D1S0-N6FH62BT-5398KANK}	01/02/2010 07:00:00	MOH0273	PC-6699	Logon

In [ ]:
```
# check for missing values
logon_df.isnull().sum()
```

Out[ ]:
```
id          0
date        0
user        0
pc          0
activity    0
dtype: int64
```

In [ ]:
```
# data types for each column
logon_df.dtypes
```

Out[ ]:
```
id          object
date        object
user        object
pc          object
activity    object
dtype: object
```

Feature Engineering

In [ ]:
```
# converting date to datetime and extracting detailed time features
time_features = ['device_df', 'email_df', 'file_df', 'logon_df', 'http_df']
for df_name in time_features:
    df = globals()[df_name]
    df['datetime'] = pd.to_datetime(df['date'])
    df['date'] = df['datetime'].dt.date
    df['hour'] = df['datetime'].dt.hour
    df['weekday'] = df['datetime'].dt.weekday
```

In [ ]:
```
# define a feature mapping dictionary for different activities
feature_map = {
```

```
    'Connect_Normal': 0,
    'Connect_NonNormal': 1,
    'Disconnect': 2,
    'Email_In': 3,
    'Email_Out': 4,
    'File_exe': 5,
    'File_jpg': 6,
    'File_zip': 7,
    'File_txt': 8,
    'File_doc': 9,
    'File_pdf': 10,
    'Weekday_Logon_Normal': 11,
    'Weekday_Logon_After': 12,
    'Logoff': 13,
    'URL_Visit': 14
}
```

Device Dataframe Feature Engineering

In [ ]:
```
# create binary indicators for each device activity
device_df['Connect_Normal'] = ((device_df['activity'] == 'Connect') & (device_df['week
device_df['Connect_NonNormal'] = ((device_df['activity'] == 'Connect') & ((device_df['
device_df['Disconnect'] = (device_df['activity'] != 'Connect').astype(int)

# create a feature index based on the device activity
device_df['feature_index'] = device_df.apply(lambda row: feature_map['Connect_Normal']
                                             (feature_map['Connect_NonNormal'] if row[
                                              feature_map['Disconnect']), axis=1)

# aggregate features per user per day for device_df
device_features = device_df.groupby(['user', 'date']).agg({
    'Connect_Normal': 'sum',
    'Connect_NonNormal': 'sum',
    'Disconnect': 'sum',
    'feature_index': 'first'
}).reset_index()
```

Email Dataframe Feature Engineering

In [ ]:
```
# function to check for external emails
def is_external_email(addresses):
    return addresses.apply(lambda x: 0 if pd.isna(x) else int(any('@dtaa.com' not in a

# apply the function to 'to', 'cc', and 'bcc' columns for email_df
email_df['Email_Out'] = is_external_email(email_df['to']) | is_external_email(email_df
email_df['Email_In'] = ~email_df['Email_Out']

# boolean to int
email_df['Email_Out'] = email_df['Email_Out'].astype(int)
email_df['Email_In'] = email_df['Email_In'].astype(int)

# create a feature index based on whether it's an inbound or outbound email
email_df['feature_index'] = email_df.apply(lambda row: feature_map['Email_In'] if row[

# aggregate features per user per day for email_df
email_features = email_df.groupby(['user', 'date']).agg({
    'Email_In': 'sum',
    'Email_Out': 'sum',
```

```
    'feature_index': 'first'
}).reset_index()
```

File Dataframe Feature Engineering

In [ ]:
```
# create binary indicators for file types in file_df
file_types = ['.exe', '.jpg', '.zip', '.txt', '.doc', '.pdf']
for file_type in file_types:
    file_df['File' + file_type.replace('.', '_')] = file_df['filename'].str.lower().st

# create a feature index based on the file type
def map_file_feature(row):
    for file_type in ['File_exe', 'File_jpg', 'File_zip', 'File_txt', 'File_doc', 'Fil
        if row[file_type]:
            return feature_map[file_type]
    return feature_map['File_other']

file_df['feature_index'] = file_df.apply(map_file_feature, axis=1)

# aggregate features per user per day for file_df
file_features = file_df.groupby(['user', 'date']).agg({
    'File_exe': 'sum',
    'File_jpg': 'sum',
    'File_zip': 'sum',
    'File_txt': 'sum',
    'File_doc': 'sum',
    'File_pdf': 'sum',
    'feature_index': 'first'
}).reset_index()
```

Logon Dataframe Feature Engineering

In [ ]:
```
# create binary indicators for logon/logoff activities in logon_df
logon_df['Weekday_Logon_Normal'] = ((logon_df['activity'] == 'Logon') & (logon_df['wee
logon_df['Weekday_Logon_After'] = ((logon_df['activity'] == 'Logon') & ((logon_df['wee
logon_df['Logoff'] = (logon_df['activity'] != 'Logon').astype(int)

# create a feature index based on logon/logoff activities
logon_df['feature_index'] = logon_df.apply(lambda row: feature_map['Weekday_Logon_Norm
                                           (feature_map['Weekday_Logon_After'] if row[
                                            feature_map['Logoff']), axis=1)


# aggregate features per user per day for logon_df
logon_features = logon_df.groupby(['user', 'date']).agg({
    'Weekday_Logon_Normal': 'sum',
    'Weekday_Logon_After': 'sum',
    'Logoff': 'sum',
    'feature_index': 'first'
}).reset_index()
```

HTTP Dataframe Feature Engineering

In [ ]:
```
# create a binary indicator for URL visits in http_df
http_df['URL_Visit'] = 1

# set a feature index for http_df
```

```
http_df['feature_index'] = feature_map['URL_Visit']

# aggregate features per user per day for http_df
http_features = http_df.groupby(['user', 'date']).agg({
    'URL_Visit': 'sum',
    'feature_index': 'first'
}).reset_index()
```

Data Vectorization

In [ ]:
```
# combine aggregated features
all_features = [device_features, email_features, file_features, logon_features, http_f
combined_df = pd.concat(all_features)
```

In [ ]:
```
# sort by date and user
sorted_df = combined_df.sort_values(by=['user', 'date'])
```

In [ ]:
```
# define the time horizon
start_date = sorted_df['date'].min()
end_date = sorted_df['date'].max()
time_horizon = (end_date - start_date).days + 1

def vectorize_data(user_data):
    vector = np.zeros((len(feature_map), time_horizon))
    for _, row in user_data.iterrows():
        date_index = (row['date'] - start_date).days
        feature_index = row['feature_index']
        vector[feature_index, date_index] += 1
    return vector

# apply vectorization for each user
user_vectors = sorted_df.groupby('user').apply(vectorize_data)
```

Working With the Model

In [ ]:
```
# 'threat_actors' is a list of users who are considered threats (predefined)
threat_actors=["AAM0658","AJR0932","BDV0168","BIH0745","BLS0678","BTL0226","CAH0936","

X = np.array([vector for vector in user_vectors])

# define labels (y) based on whether a user is in 'threat_actors'
y = np.array([user in threat_actors for user in user_vectors.index])
```

Train-Test Split

In [ ]:
```
# split the data into training and testing sets (train 75% test 25%)
X_train, X_test, y_train, y_test = train_test_split(X, y, stratify=y)

print(X_train.shape)
print(y_train.shape)
print(X_test.shape)
print(y_test.shape)
```

```
(750, 15, 501)
(750,)
(250, 15, 501)
(250,)
```

Data Reshaping

In [ ]:
```
X_train_reshaped = X_train.reshape([X_train.shape[0], X_train.shape[1] * X_train.shape
X_test_reshaped = X_test.reshape([X_test.shape[0], X_test.shape[1] * X_test.shape[2]])

# separate normal and threat data in the training set
X_train_normal = X_train_reshaped[y_train == 0, :]
X_train_threat = X_train_reshaped[y_train == 1, :]
print(X_train_normal.shape)
print(X_train_threat.shape)

# separate normal and threat data in the testing set
X_test_normal = X_test_reshaped[y_test == 0, :]
X_test_threat = X_test_reshaped[y_test == 1, :]
print(X_test_normal.shape)
print(X_test_threat.shape)
```

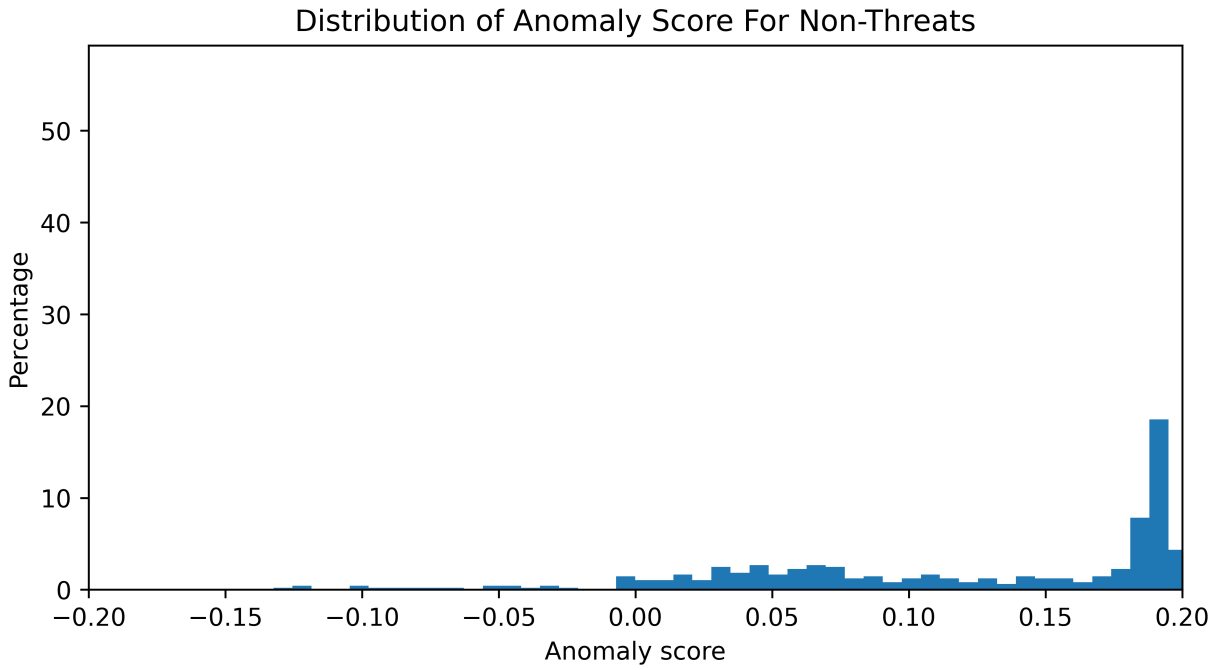
```
(697, 7515)
(53, 7515)
(233, 7515)
(17, 7515)
```

Anomaly Detection

In [ ]:
```
# initialize the Isolation Forest model
IF = IsolationForest(
    n_estimators=100, max_samples=256, contamination=0.035
)
```

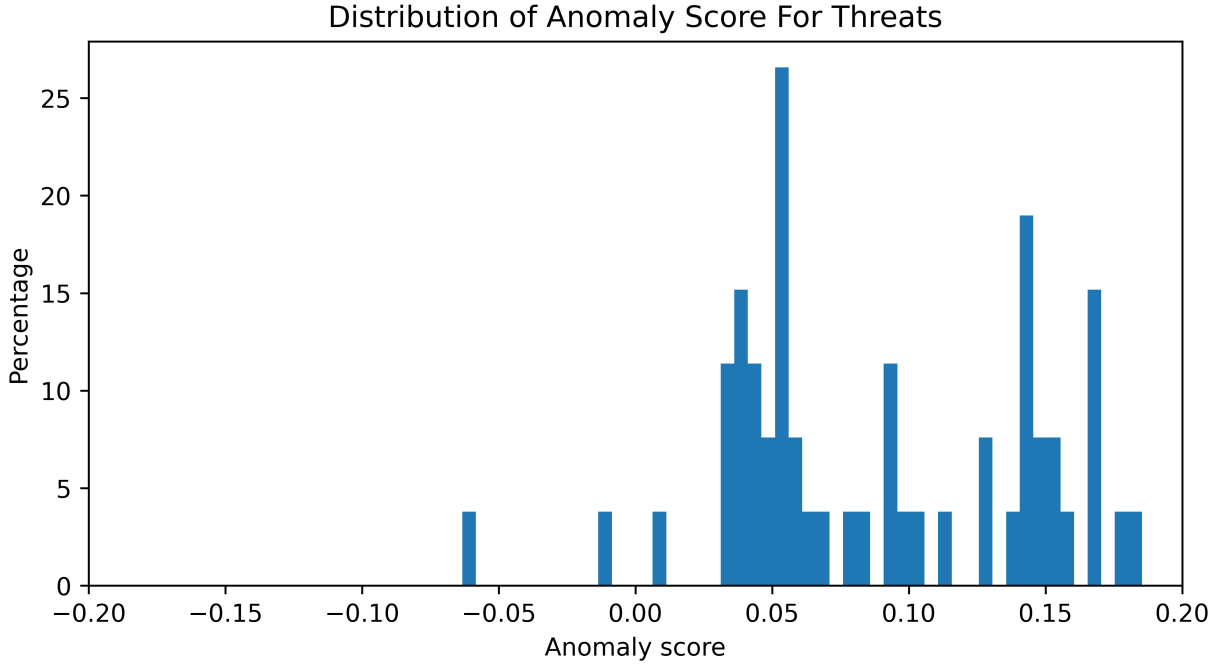
In [ ]:
```
# fit the model on the reshaped training data
IF.fit(X_train_reshaped)

# calculate anomaly scores for normal data in the training set
normal_scores = IF.decision_function(X_train_normal)

# plot the distribution of anomaly scores for normal data
fig = plt.figure(figsize=(8, 4), dpi=600, facecolor="w", edgecolor="k")
normal = plt.hist(normal_scores, 50, density=True)

plt.xlim((-0.2, 0.2))
plt.xlabel("Anomaly score")
plt.ylabel("Percentage")
plt.title("Distribution of Anomaly Score For Non-Threats")
```

Out[ ]:
```
Text(0.5, 1.0, 'Distribution of Anomaly Score For Non-Threats')
```

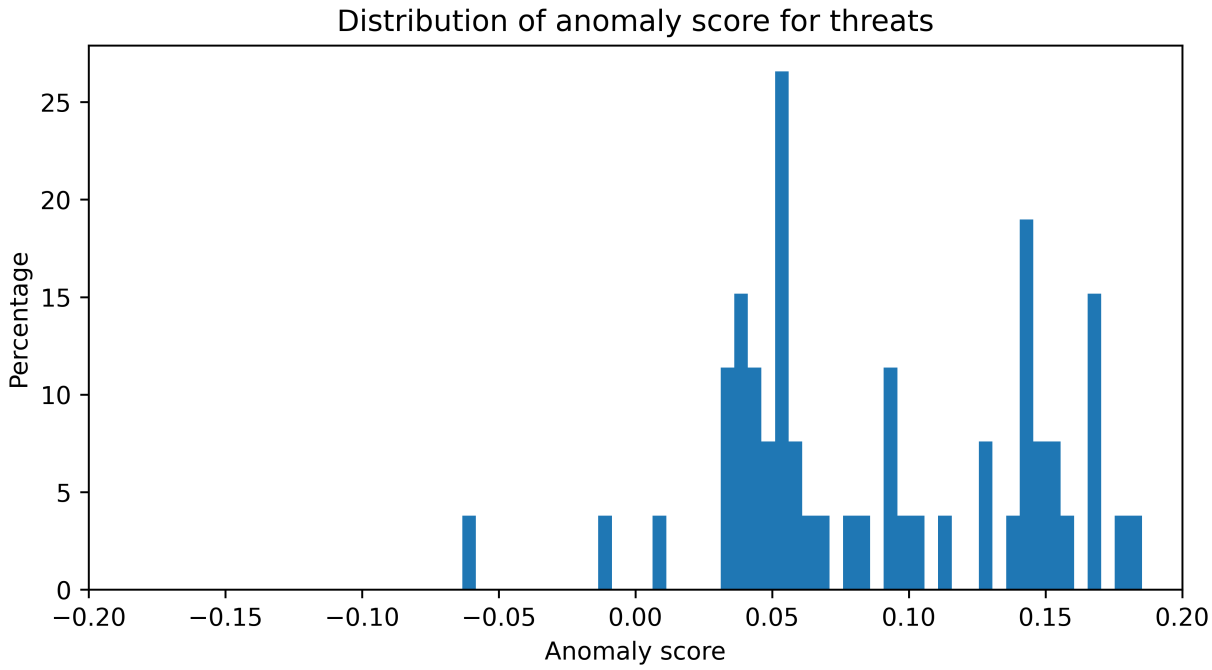


In [ ]:
```
# calculate anomaly scores for threat data in the training set
anomaly_scores = IF.decision_function(X_train_threat)

# plot the distribution of anomaly scores for threat data
fig = plt.figure(figsize=(8, 4), dpi=600, facecolor="w", edgecolor="k")
anomaly = plt.hist(anomaly_scores, 50, density=True)

plt.xlim((-0.2, 0.2))
plt.xlabel("Anomaly score")
plt.ylabel("Percentage")
plt.title("Distribution of Anomaly Score For Threats")
```

Out[ ]:
```
Text(0.5, 1.0, 'Distribution of Anomaly Score For Threats')
```



In [ ]:
```
# compute histogram
bin_count = 50
hist, bin_edges = np.histogram(anomaly_scores, bins=bin_count, density=True)

# maximum bin
max_bin_index = np.argmax(hist)
max_bin_value = hist[max_bin_index]
max_bin_center = (bin_edges[max_bin_index] + bin_edges[max_bin_index + 1]) / 2

plt.figure(figsize=(8, 4), dpi=600)
plt.hist(anomaly_scores, bins=bin_count, density=True)
plt.xlim((-0.2, 0.2))
plt.xlabel("Anomaly score")
plt.ylabel("Percentage")
plt.title("Distribution of anomaly score for threats")

plt.show()
```



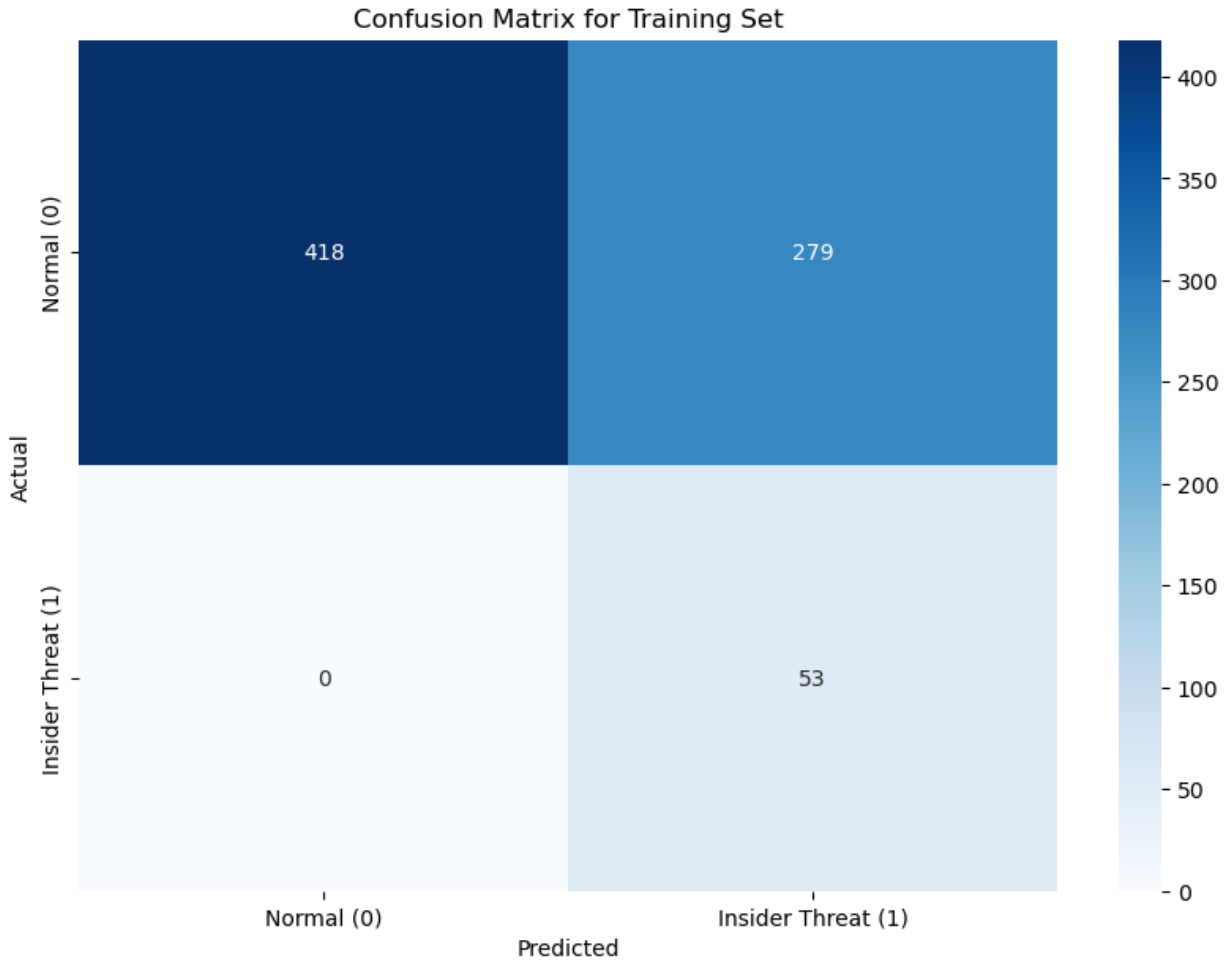
Analysis of Results

In [ ]:
```
# set a threshold for anomaly detection
cutoff = 0.19

# calculate anomaly scores for the training set
s = IF.decision_function(X_train_reshaped)
print("Training Results")
print(Counter(y_train[cutoff > s]))

# calculate anomaly scores for the testing set
s = IF.decision_function(X_test_reshaped)
print("Testing Results")
print(Counter(y_test[cutoff > s]))
```

```
Training Results
Counter({False: 279, True: 53})
Testing Results
Counter({False: 89, True: 17})
```

In [ ]:

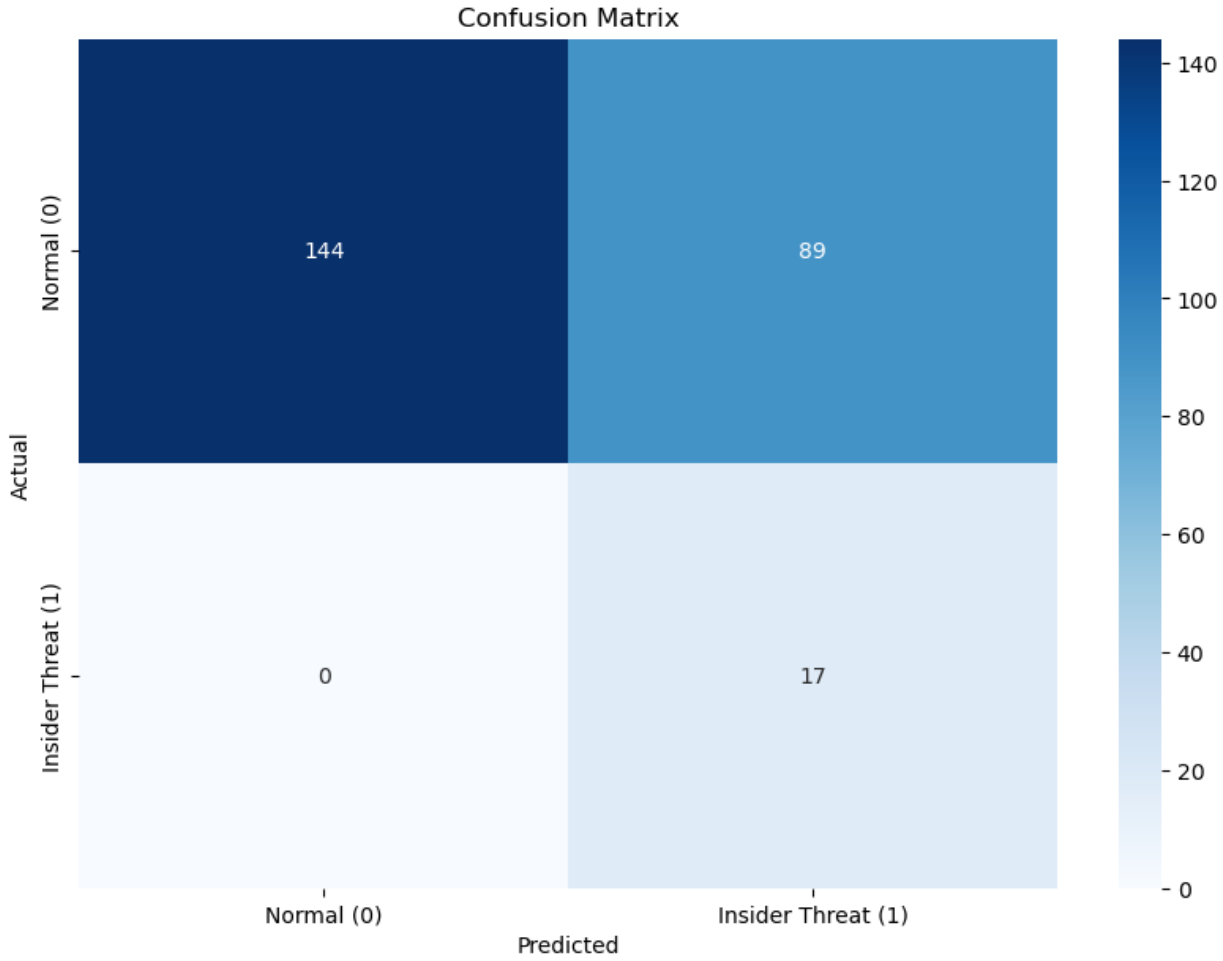
```
# predictions for training set
# if the anomaly score is greater than the cutoff, it's a normal case (0), otherwise,
training_predictions = (IF.decision_function(X_train_reshaped) < cutoff).astype(int)

# confusion matrix
training_cm = confusion_matrix(y_train, training_predictions)

# metrics
training_report = classification_report(y_train, training_predictions)

# labels
class_labels = ["Normal (0)", "Insider Threat (1)"]

# plot confusion matrix
plt.figure(figsize=(10, 7))
sns.heatmap(training_cm, annot=True, fmt='d', xticklabels=class_labels, yticklabels=cl
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.title('Confusion Matrix for Training Set')
plt.show()

# print metrics
print("Classification Report for Training Set:")
print(training_report)
```



```
Classification Report for Training Set:
              precision    recall  f1-score   support

       False       1.00      0.60      0.75       697
        True       0.16      1.00      0.28        53

    accuracy                           0.63       750
   macro avg       0.58      0.80      0.51       750
weighted avg       0.94      0.63      0.72       750
```

In [ ]:

```python
# predictions for training set
# if the anomaly score is greater than the cutoff, it's a normal case (0), otherwise,
test_predictions = (IF.decision_function(X_test_reshaped) < cutoff).astype(int)

# confusion matrix
test_cm = confusion_matrix(y_test, test_predictions)

# metrics
test_report = classification_report(y_test, test_predictions)

# labels
class_labels = ["Normal (0)", "Insider Threat (1)"]

# plot confusion matrix
plt.figure(figsize=(10, 7))
sns.heatmap(test_cm, annot=True, fmt='d', xticklabels=class_labels, yticklabels=class_
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.title('Confusion Matrix')
plt.show()

# print test metrics
print("Classification Report for Test Set:")
print(test_report)
```



Classification Report for Test Set:

	precision	recall	f1-score	support
False	1.00	0.62	0.76	233
True	0.16	1.00	0.28	17
accuracy			0.64	250
macro avg	0.58	0.81	0.52	250
weighted avg	0.94	0.64	0.73	250