Machine Learning – Final Increment (Project)

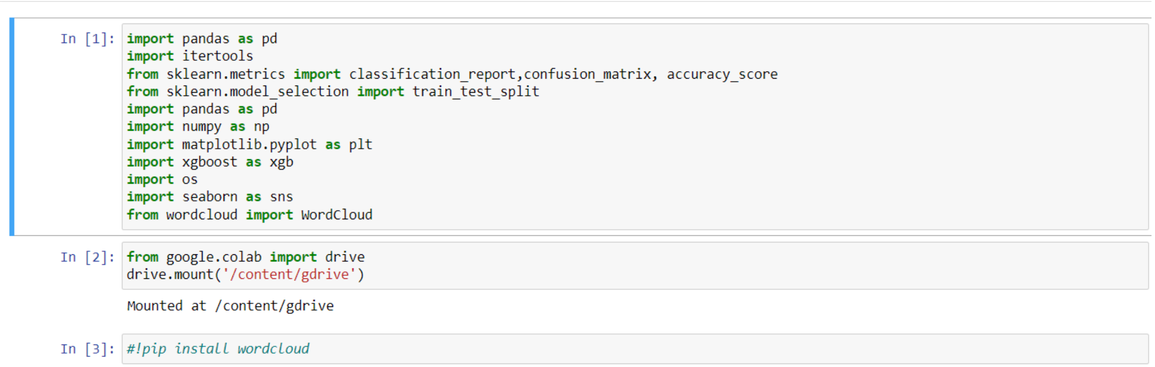
CS 5710 (CRN 22002)

Project Title: A Comparison of Machine Learning Algorithms on Detection of Phishing Websites

Team Members:

1. Kamala Ramesh – 700745451
2. Madhuri Vedulla – 700741625
3. Priyanka Bojja – 700739528
4. Sai Priyanka Narra – 700741613

Please find below the screenshots of the implementation

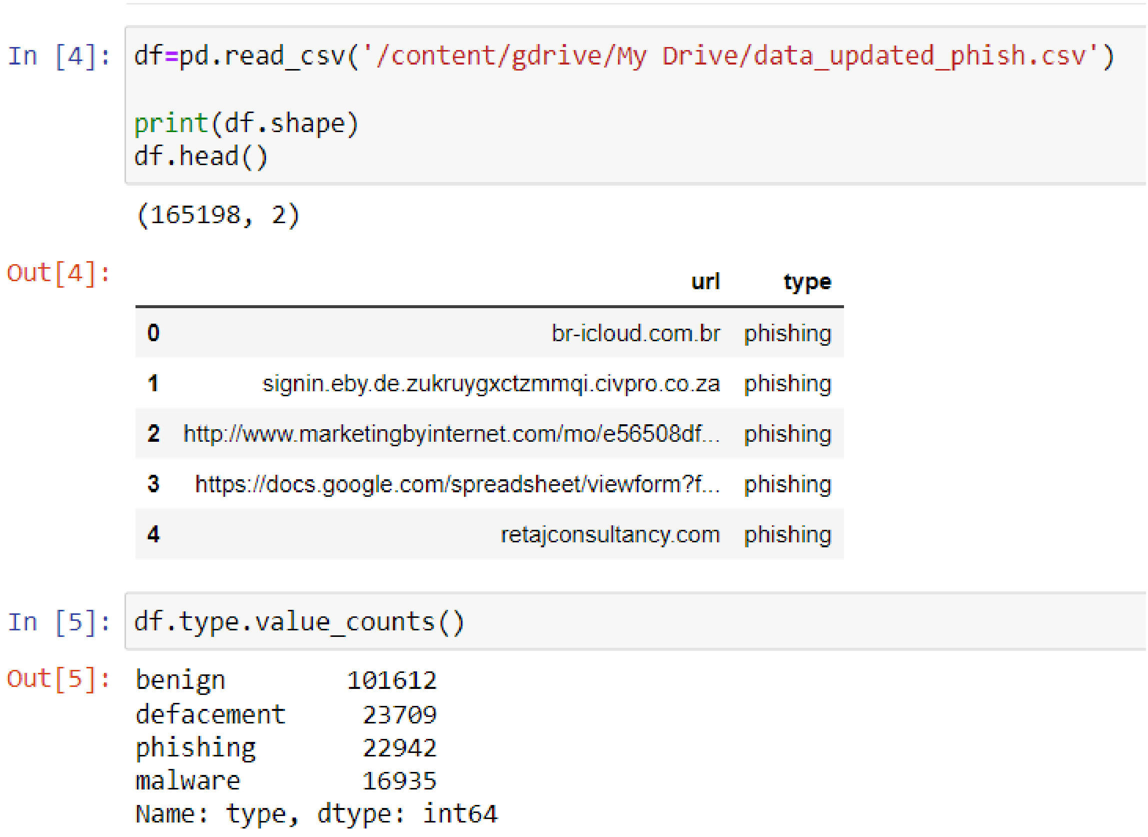


In [1]:
```
import pandas as pd
import itertools
from sklearn.metrics import classification_report,confusion_matrix, accuracy_score
from sklearn.model_selection import train_test_split
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import xgboost as xgb
import os
import seaborn as sns
from wordcloud import WordCloud
```

In [2]:
```
from google.colab import drive
drive.mount('/content/gdrive')
```

```
Mounted at /content/gdrive
```

In [3]:
```
#!pip install wordcloud
```



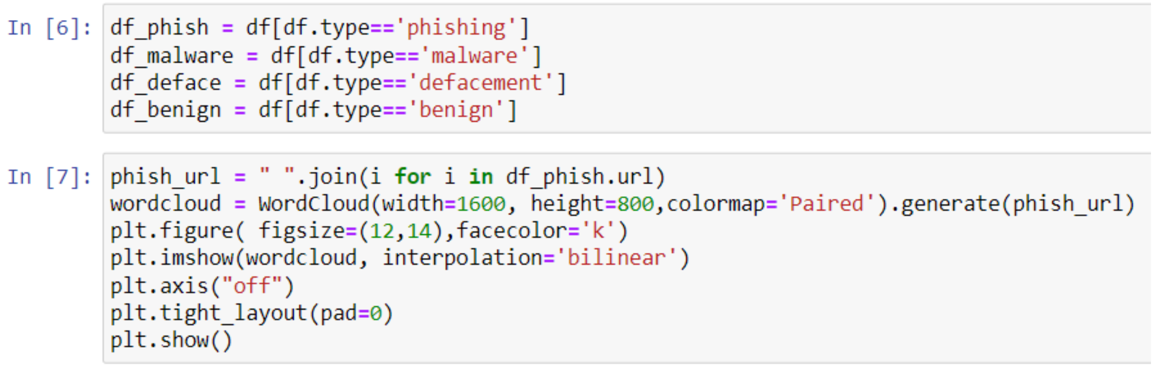
```
In [4]: df=pd.read_csv('/content/gdrive/My Drive/data_updated_phish.csv')

        print(df.shape)
        df.head()

        (165198, 2)
```

Out[4]:

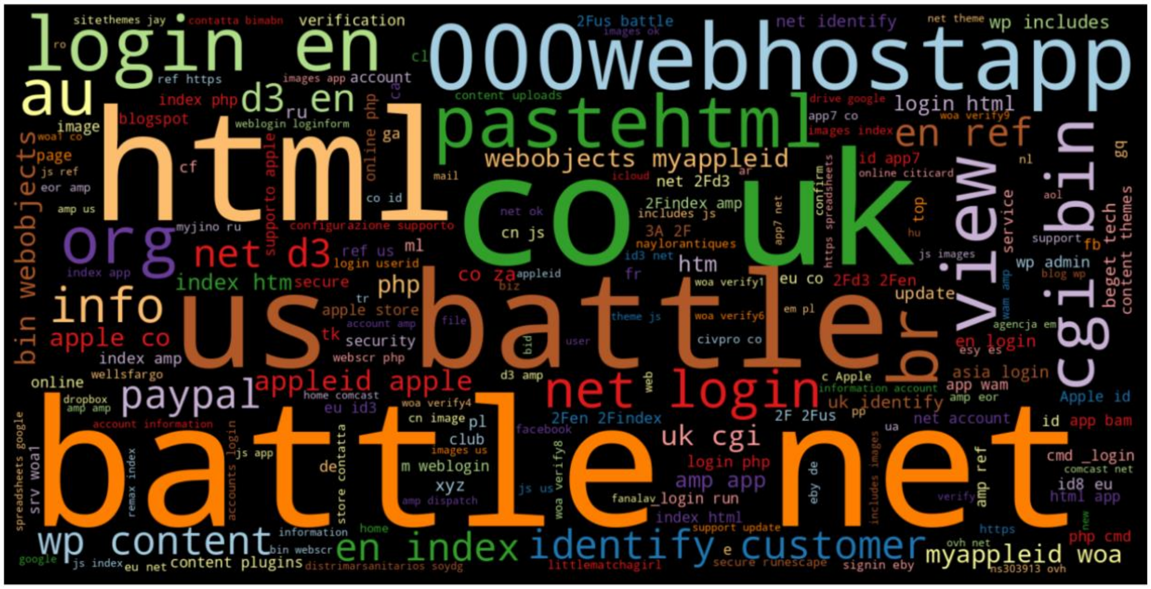
	url	type
0	br-icloud.com.br	phishing
1	signin.eby.de.zukruygxctzmmqi.civpro.co.za	phishing
2	http://www.marketingbyinternet.com/mo/e56508df...	phishing
3	https://docs.google.com/spreadsheet/viewform?f...	phishing
4	retajconsultancy.com	phishing

```
In [5]: df.type.value_counts()

Out[5]: benign        101612
        defacement     23709
        phishing       22942
        malware        16935
        Name: type, dtype: int64
```

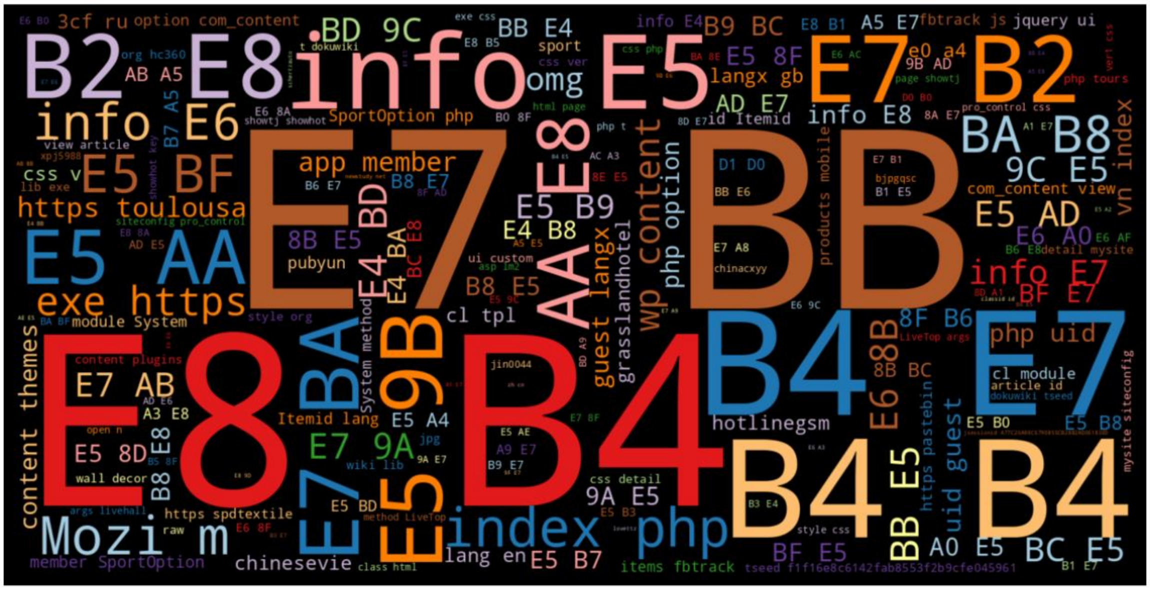
Word Cloud



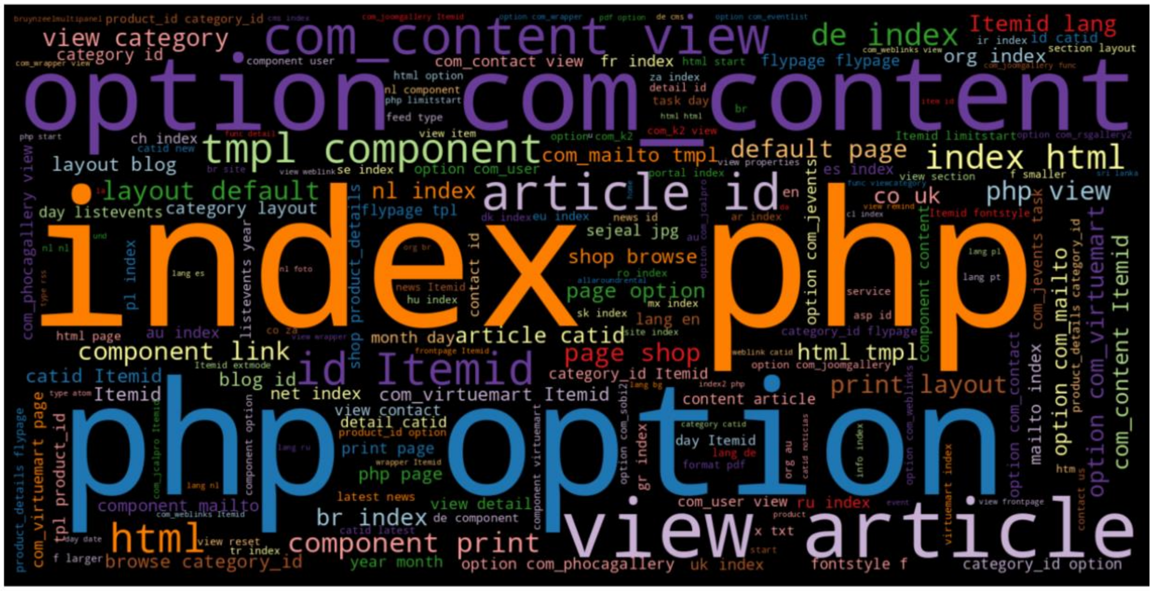
```
In [6]: df_phish = df[df.type=='phishing']
        df_malware = df[df.type=='malware']
        df_deface = df[df.type=='defacement']
        df_benign = df[df.type=='benign']

In [7]: phish_url = " ".join(i for i in df_phish.url)
        wordcloud = WordCloud(width=1600, height=800,colormap='Paired').generate(phish_url)
        plt.figure( figsize=(12,14),facecolor='k')
        plt.imshow(wordcloud, interpolation='bilinear')
        plt.axis("off")
        plt.tight_layout(pad=0)
        plt.show()
```



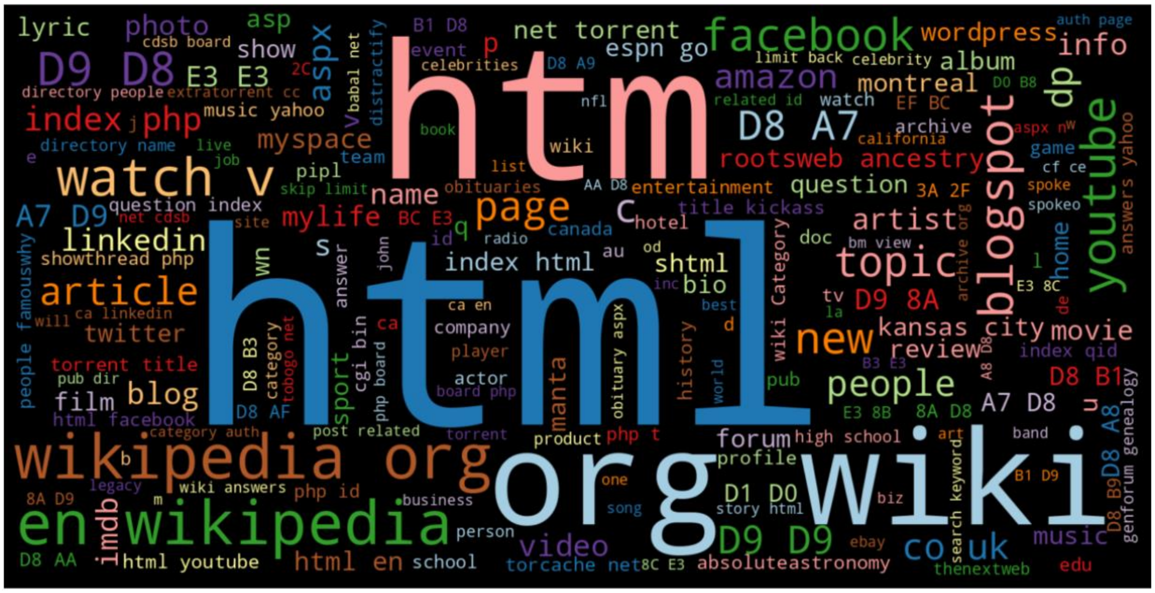
```
In [8]: malware_url = " ".join(i for i in df_malware.url)
        wordcloud = WordCloud(width=1600, height=800,colormap='Paired').generate(malware_url)
        plt.figure( figsize=(12,14),facecolor='k')
        plt.imshow(wordcloud, interpolation='bilinear')
        plt.axis("off")
        plt.tight_layout(pad=0)
        plt.show()
```

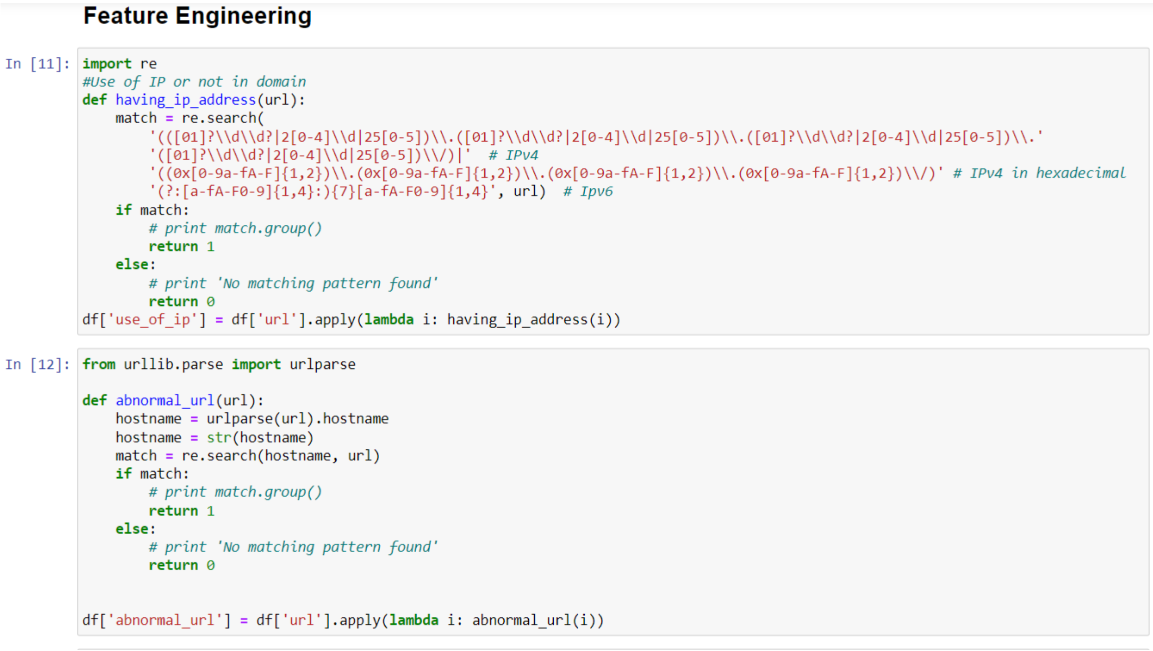


```
In [9]: deface_url = " ".join(i for i in df_deface.url)
        wordcloud = WordCloud(width=1600, height=800,colormap='Paired').generate(deface_url)
        plt.figure( figsize=(12,14),facecolor='k')
        plt.imshow(wordcloud, interpolation='bilinear')
        plt.axis("off")
        plt.tight_layout(pad=0)
        plt.show()
```



```
In [10]: benign_url = " ".join(i for i in df_benign.url)
         wordcloud = WordCloud(width=1600, height=800,colormap='Paired').generate(benign_url)
         plt.figure( figsize=(12,14),facecolor='k')
         plt.imshow(wordcloud, interpolation='bilinear')
         plt.axis("off")
         plt.tight_layout(pad=0)
         plt.show()
```

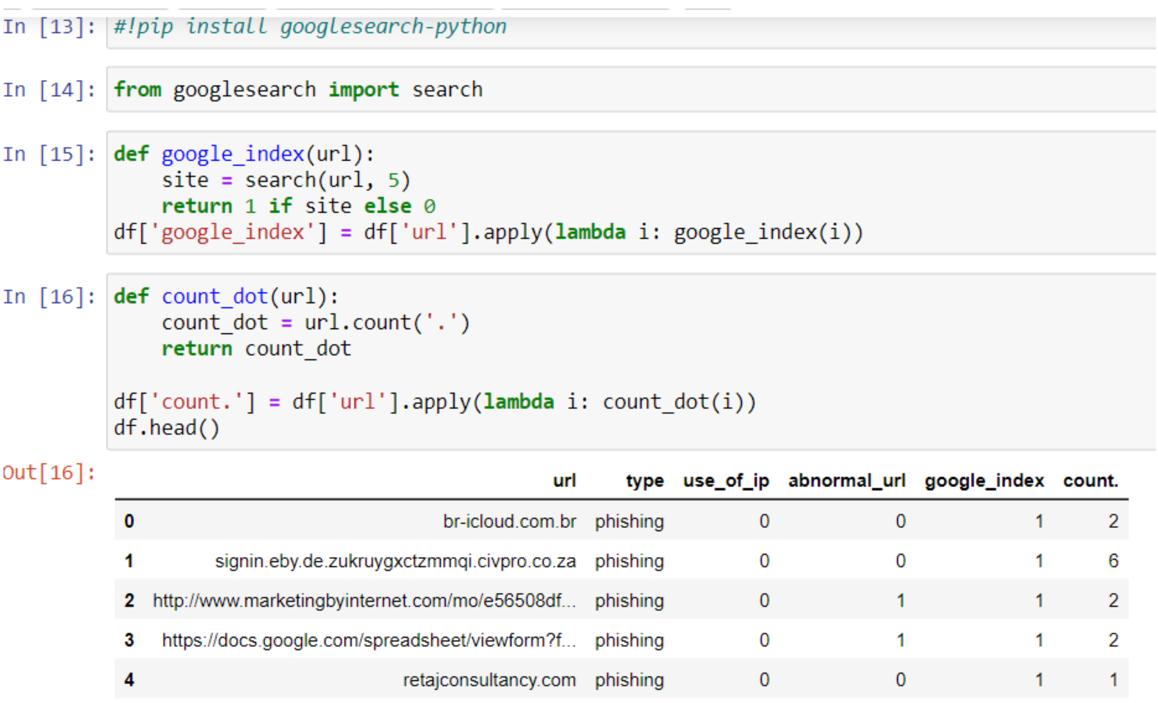




Feature Engineering

In [11]:
```
import re
#Use of IP or not in domain
def having_ip_address(url):
    match = re.search(
        '(([01]?\\d\\d?|2[0-4]\\d|25[0-5])\\.([01]?\\d\\d?|2[0-4]\\d|25[0-5])\\.([01]?\\d\\d?|2[0-4]\\d|25[0-5])\\.'
        '([01]?\\d\\d?|2[0-4]\\d|25[0-5])\\/)|'  # IPv4
        '((0x[0-9a-fA-F]{1,2})\\.(0x[0-9a-fA-F]{1,2})\\.(0x[0-9a-fA-F]{1,2})\\.(0x[0-9a-fA-F]{1,2})\\/)' # IPv4 in hexadecimal
        '(?:[a-fA-F0-9]{1,4}:){7}[a-fA-F0-9]{1,4}', url)  # Ipv6
    if match:
        # print match.group()
        return 1
    else:
        # print 'No matching pattern found'
        return 0
df['use_of_ip'] = df['url'].apply(lambda i: having_ip_address(i))
```

In [12]:
```
from urllib.parse import urlparse

def abnormal_url(url):
    hostname = urlparse(url).hostname
    hostname = str(hostname)
    match = re.search(hostname, url)
    if match:
        # print match.group()
        return 1
    else:
        # print 'No matching pattern found'
        return 0


df['abnormal_url'] = df['url'].apply(lambda i: abnormal_url(i))
```



In [13]:
```
#!pip install googlesearch-python
```

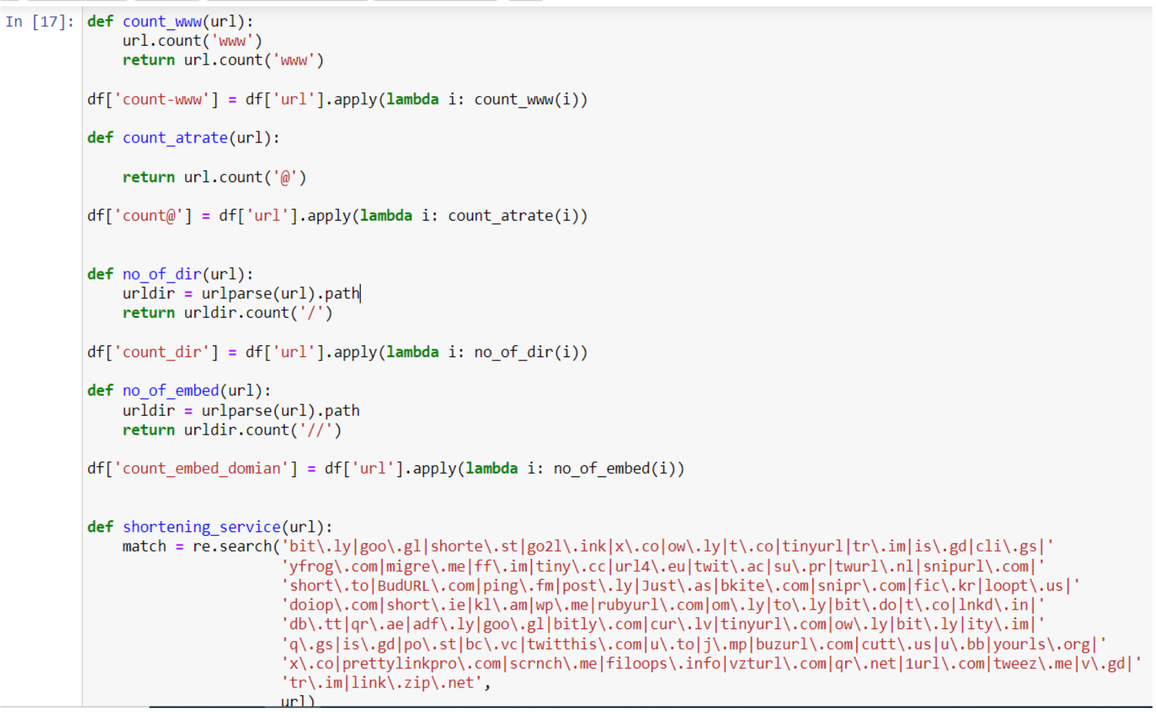
In [14]:
```
from googlesearch import search
```

In [15]:
```
def google_index(url):
    site = search(url, 5)
    return 1 if site else 0
df['google_index'] = df['url'].apply(lambda i: google_index(i))
```

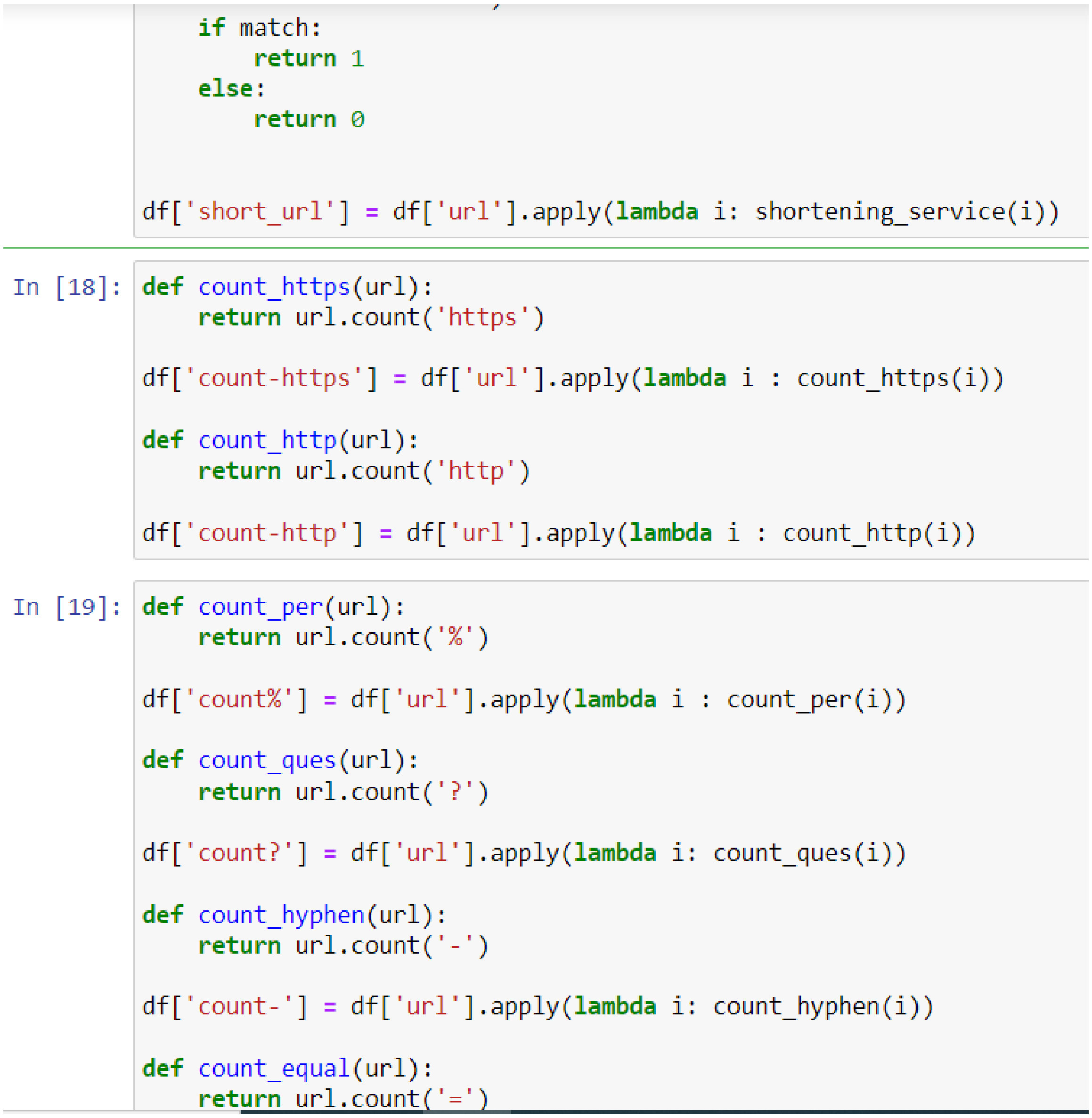
In [16]:
```
def count_dot(url):
    count_dot = url.count('.')
    return count_dot

df['count.'] = df['url'].apply(lambda i: count_dot(i))
df.head()
```

Out[16]:

	url	type	use_of_ip	abnormal_url	google_index	count.
0	br-icloud.com.br	phishing	0	0	1	2
1	signin.eby.de.zukruygxctzmmqi.civpro.co.za	phishing	0	0	1	6
2	http://www.marketingbyinternet.com/mo/e56508df...	phishing	0	1	1	2
3	https://docs.google.com/spreadsheet/viewform?f...	phishing	0	1	1	2
4	retajconsultancy.com	phishing	0	0	1	1



```
In [17]: def count_www(url):
             url.count('www')
             return url.count('www')

         df['count-www'] = df['url'].apply(lambda i: count_www(i))

         def count_atrate(url):

             return url.count('@')

         df['count@'] = df['url'].apply(lambda i: count_atrate(i))


         def no_of_dir(url):
             urldir = urlparse(url).path
             return urldir.count('/')

         df['count_dir'] = df['url'].apply(lambda i: no_of_dir(i))

         def no_of_embed(url):
             urldir = urlparse(url).path
             return urldir.count('//')

         df['count_embed_domian'] = df['url'].apply(lambda i: no_of_embed(i))


         def shortening_service(url):
             match = re.search('bit\.ly|goo\.gl|shorte\.st|go2l\.ink|x\.co|ow\.ly|t\.co|tinyurl|tr\.im|is\.gd|cli\.gs|'
                               'yfrog\.com|migre\.me|ff\.im|tiny\.cc|url4\.eu|twit\.ac|su\.pr|twurl\.nl|snipurl\.com|'
                               'short\.to|BudURL\.com|ping\.fm|post\.ly|Just\.as|bkite\.com|snipr\.com|fic\.kr|loopt\.us|'
                               'doiop\.com|short\.ie|kl\.am|wp\.me|rubyurl\.com|om\.ly|to\.ly|bit\.do|t\.co|lnkd\.in|'
                               'db\.tt|qr\.ae|adf\.ly|goo\.gl|bitly\.com|cur\.lv|tinyurl\.com|ow\.ly|bit\.ly|ity\.im|'
                               'q\.gs|is\.gd|po\.st|bc\.vc|twitthis\.com|u\.to|j\.mp|buzurl\.com|cutt\.us|u\.bb|yourls\.org|'
                               'x\.co|prettylinkpro\.com|scrnch\.me|filoops\.info|vzturl\.com|qr\.net|1url\.com|tweez\.me|v\.gd|'
                               'tr\.im|link\.zip\.net',
                               url)
```



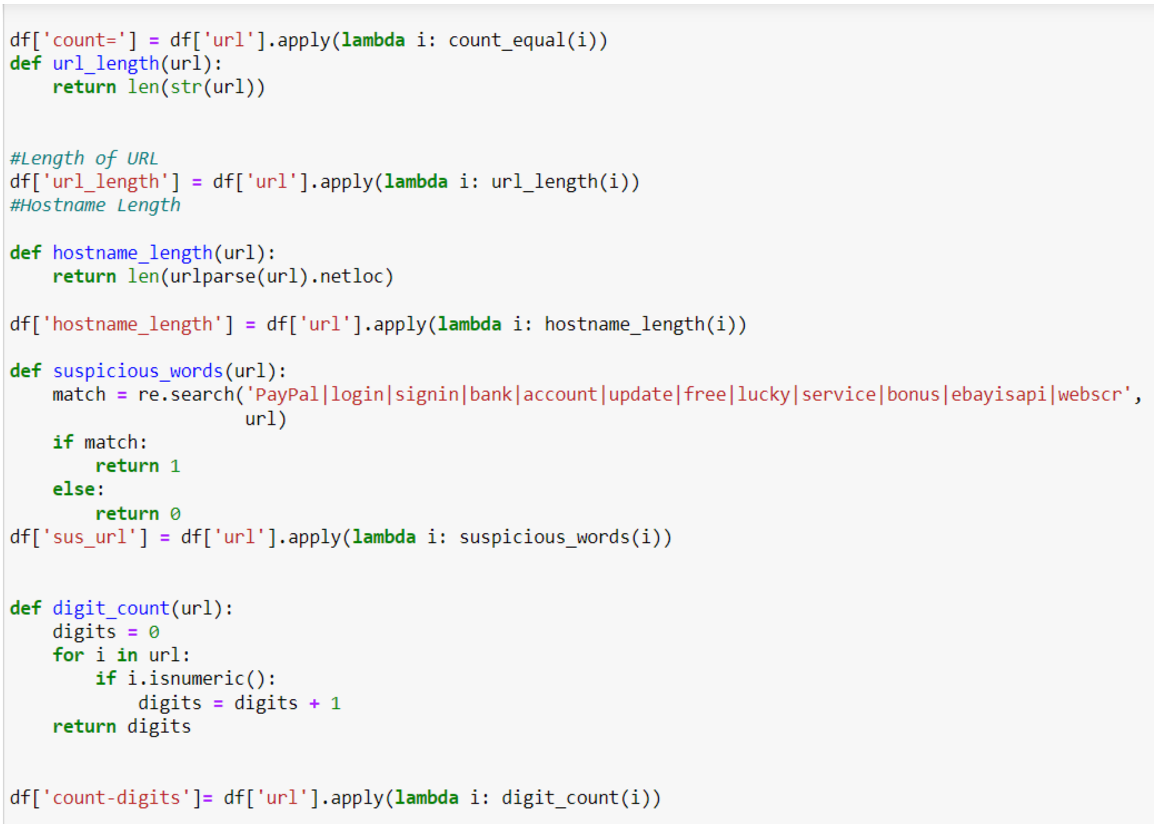
```
    if match:
        return 1
    else:
        return 0


df['short_url'] = df['url'].apply(lambda i: shortening_service(i))
```

In [18]:

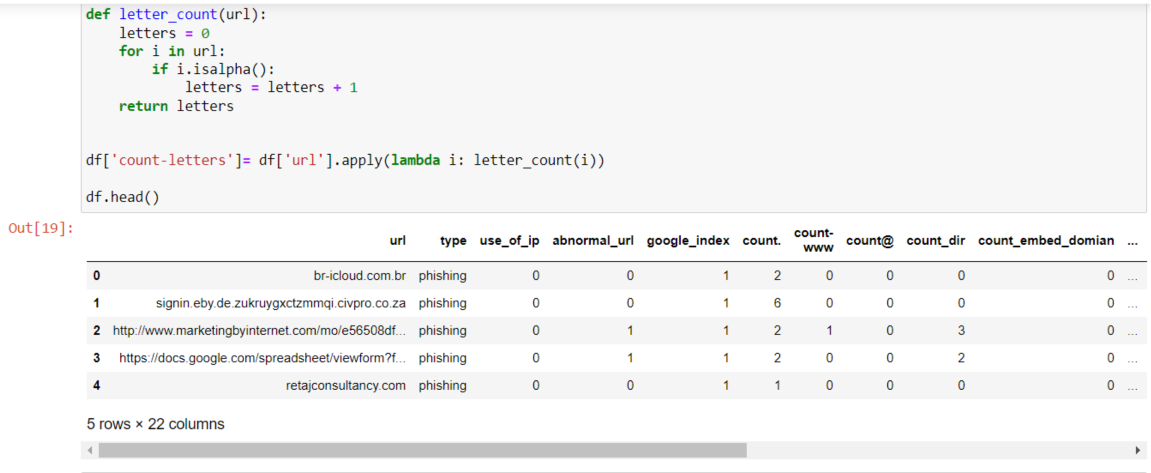
```
def count_https(url):
    return url.count('https')

df['count-https'] = df['url'].apply(lambda i : count_https(i))

def count_http(url):
    return url.count('http')

df['count-http'] = df['url'].apply(lambda i : count_http(i))
```

In [19]:

```
def count_per(url):
    return url.count('%')

df['count%'] = df['url'].apply(lambda i : count_per(i))

def count_ques(url):
    return url.count('?')

df['count?'] = df['url'].apply(lambda i: count_ques(i))

def count_hyphen(url):
    return url.count('-')

df['count-'] = df['url'].apply(lambda i: count_hyphen(i))

def count_equal(url):
    return url.count('=')
```



```
df['count='] = df['url'].apply(lambda i: count_equal(i))
def url_length(url):
    return len(str(url))


#Length of URL
df['url_length'] = df['url'].apply(lambda i: url_length(i))
#Hostname Length

def hostname_length(url):
    return len(urlparse(url).netloc)

df['hostname_length'] = df['url'].apply(lambda i: hostname_length(i))

def suspicious_words(url):
    match = re.search('PayPal|login|signin|bank|account|update|free|lucky|service|bonus|ebayisapi|webscr',
                      url)
    if match:
        return 1
    else:
        return 0
df['sus_url'] = df['url'].apply(lambda i: suspicious_words(i))


def digit_count(url):
    digits = 0
    for i in url:
        if i.isnumeric():
            digits = digits + 1
    return digits


df['count-digits']= df['url'].apply(lambda i: digit_count(i))
```

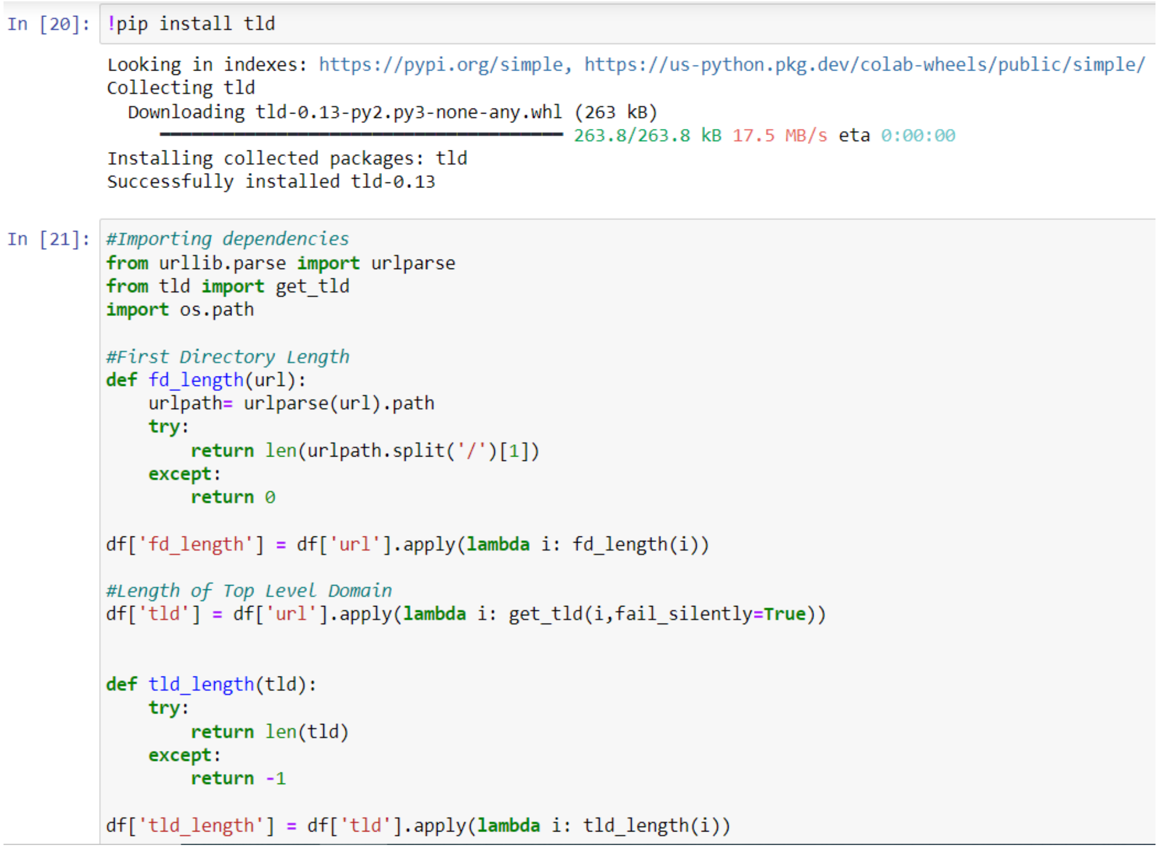


```
def letter_count(url):
    letters = 0
    for i in url:
        if i.isalpha():
            letters = letters + 1
    return letters


df['count-letters']= df['url'].apply(lambda i: letter_count(i))

df.head()
```

Out[19]:

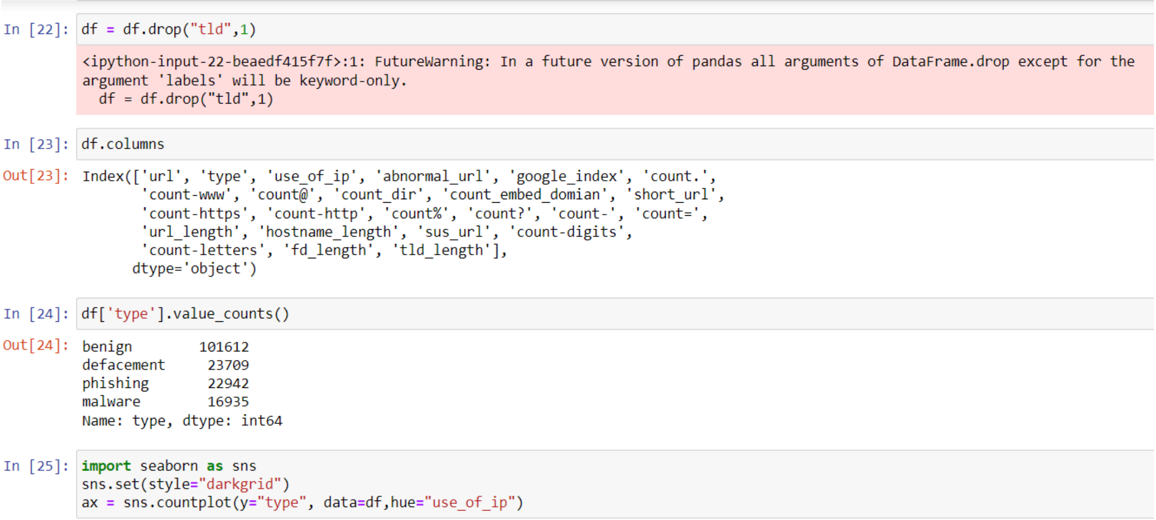
	url	type	use_of_ip	abnormal_url	google_index	count.	count-www	count@	count_dir	count_embed_domian	...
0	br-icloud.com.br	phishing	0	0	1	2	0	0	0	0	...
1	signin.eby.de.zukruygxctzmmqi.civpro.co.za	phishing	0	0	1	6	0	0	0	0	...
2	http://www.marketingbyinternet.com/mo/e56508df...	phishing	0	1	1	2	1	0	3	0	...
3	https://docs.google.com/spreadsheet/viewform?f...	phishing	0	1	1	2	0	0	2	0	...
4	retajconsultancy.com	phishing	0	0	1	1	0	0	0	0	...

5 rows × 22 columns



```
In [20]: !pip install tld

         Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
         Collecting tld
           Downloading tld-0.13-py2.py3-none-any.whl (263 kB)
              ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 263.8/263.8 kB 17.5 MB/s eta 0:00:00
         Installing collected packages: tld
         Successfully installed tld-0.13
```

```
In [21]: #Importing dependencies
         from urllib.parse import urlparse
         from tld import get_tld
         import os.path

         #First Directory Length
         def fd_length(url):
             urlpath= urlparse(url).path
             try:
                 return len(urlpath.split('/')[1])
             except:
                 return 0

         df['fd_length'] = df['url'].apply(lambda i: fd_length(i))

         #Length of Top Level Domain
         df['tld'] = df['url'].apply(lambda i: get_tld(i,fail_silently=True))


         def tld_length(tld):
             try:
                 return len(tld)
             except:
                 return -1

         df['tld_length'] = df['tld'].apply(lambda i: tld_length(i))
```

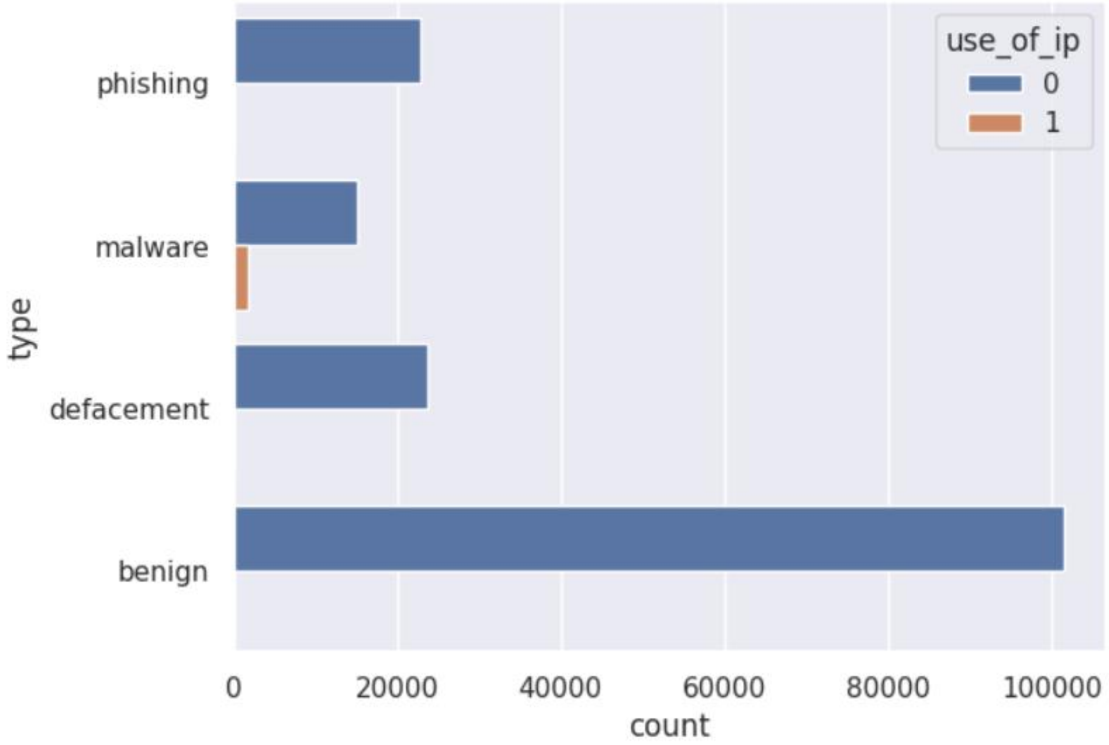


```
In [22]: df = df.drop("tld",1)

         <ipython-input-22-beaedf415f7f>:1: FutureWarning: In a future version of pandas all arguments of DataFrame.drop except for the
         argument 'labels' will be keyword-only.
           df = df.drop("tld",1)
```

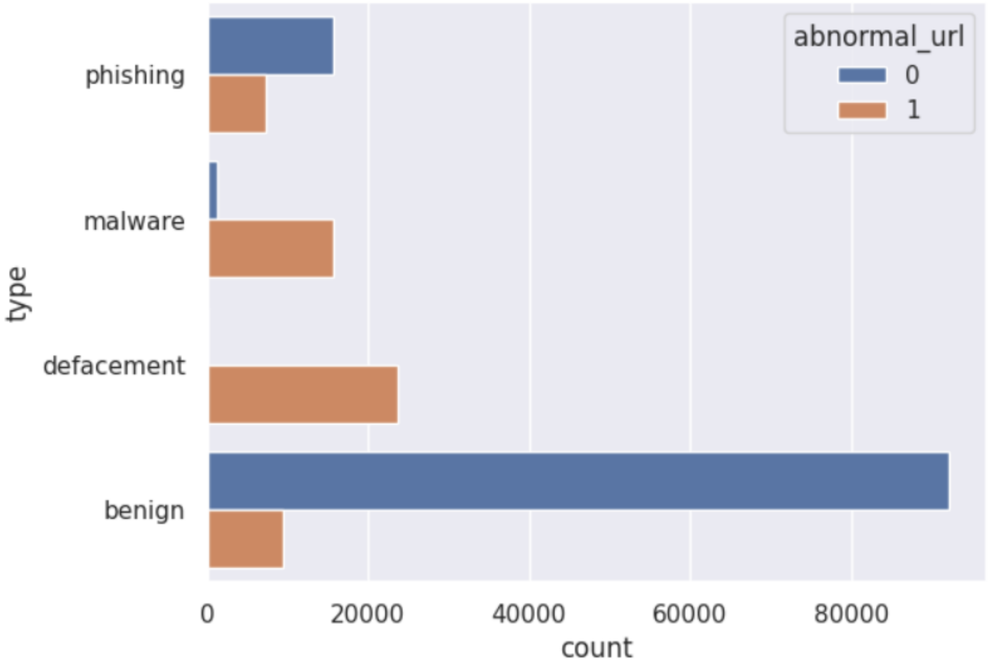
```
In [23]: df.columns

Out[23]: Index(['url', 'type', 'use_of_ip', 'abnormal_url', 'google_index', 'count.',
                'count-www', 'count@', 'count_dir', 'count_embed_domian', 'short_url',
                'count-https', 'count-http', 'count%', 'count?', 'count-', 'count=',
                'url_length', 'hostname_length', 'sus_url', 'count-digits',
                'count-letters', 'fd_length', 'tld_length'],
               dtype='object')
```

```
In [24]: df['type'].value_counts()

Out[24]: benign        101612
         defacement     23709
         phishing       22942
         malware        16935
         Name: type, dtype: int64
```

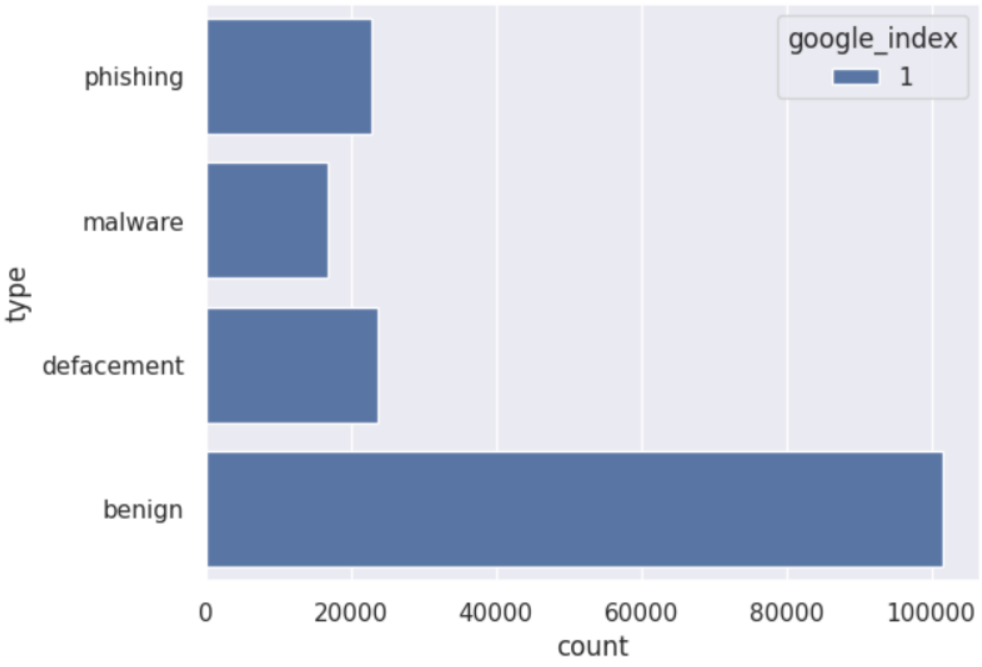
```
In [25]: import seaborn as sns
         sns.set(style="darkgrid")
         ax = sns.countplot(y="type", data=df,hue="use_of_ip")
```



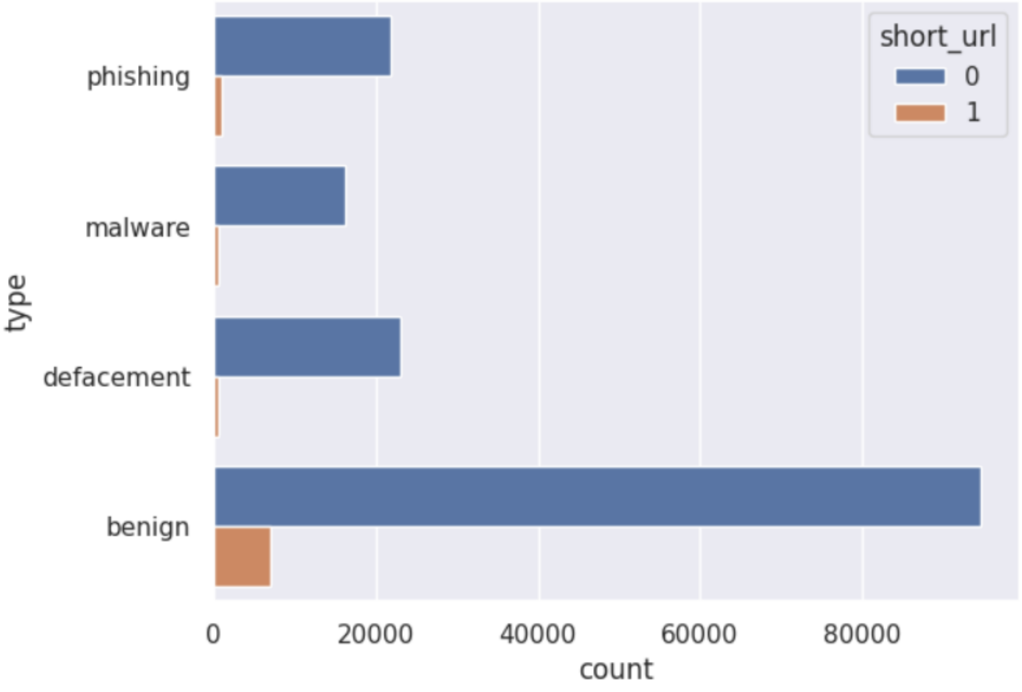
```
In [26]: sns.set(style="darkgrid")
         ax = sns.countplot(y="type", data=df,hue="abnormal_url")
```



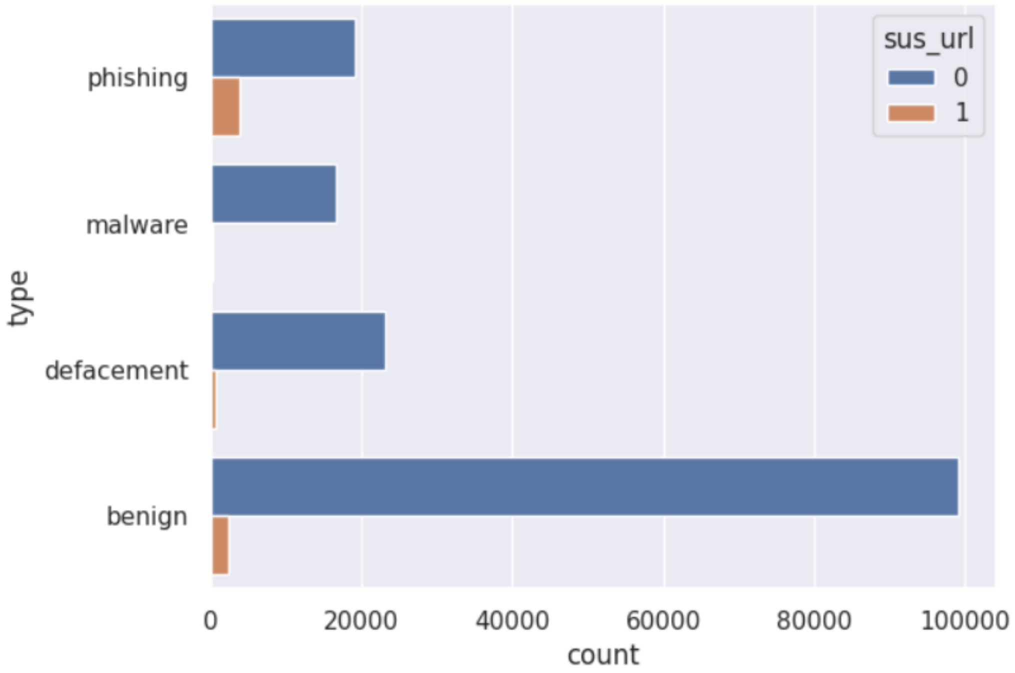
```
In [27]: sns.set(style="darkgrid")
         ax = sns.countplot(y="type", data=df,hue="google_index")
```

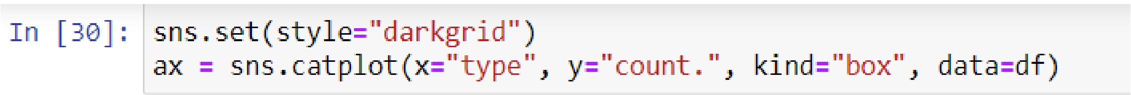


```
In [28]: sns.set(style="darkgrid")
         ax = sns.countplot(y="type", data=df,hue="short_url")
```

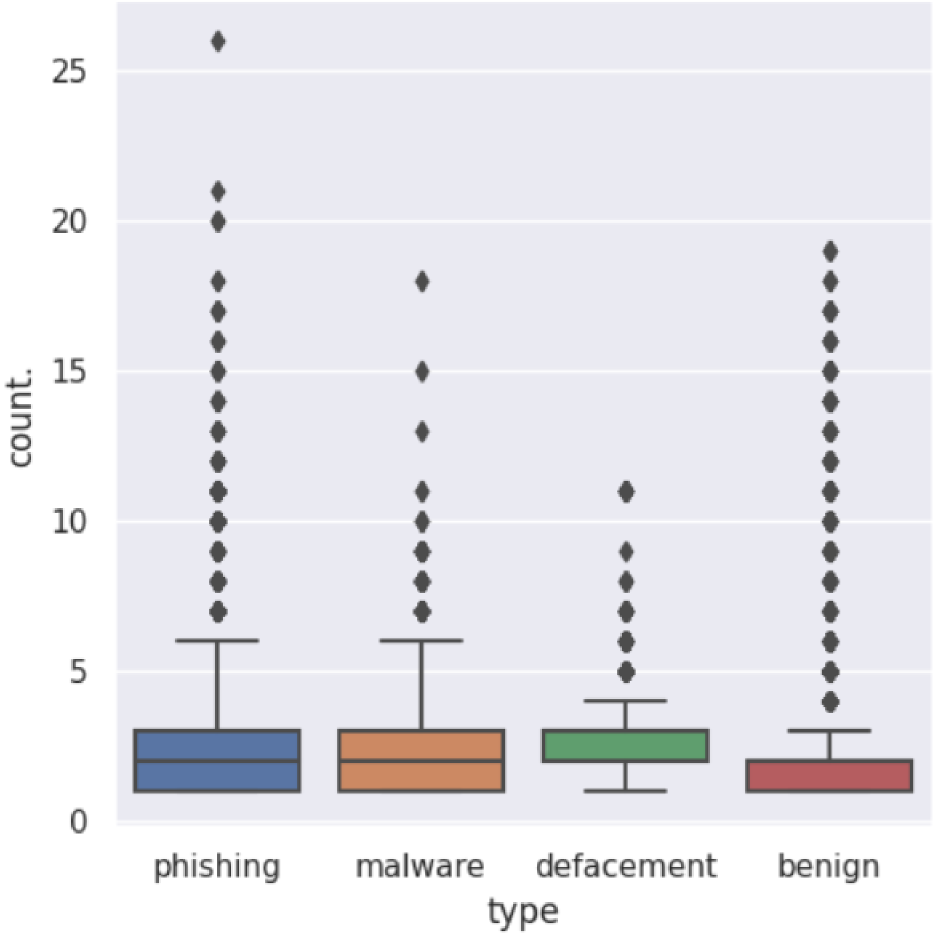


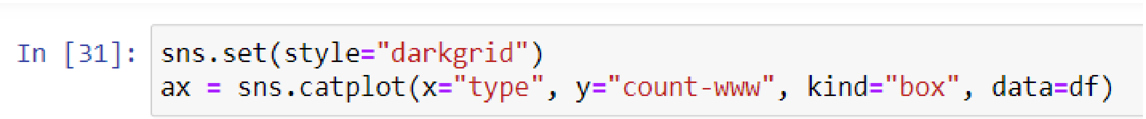
```
In [29]: sns.set(style="darkgrid")
         ax = sns.countplot(y="type", data=df,hue="sus_url")
```



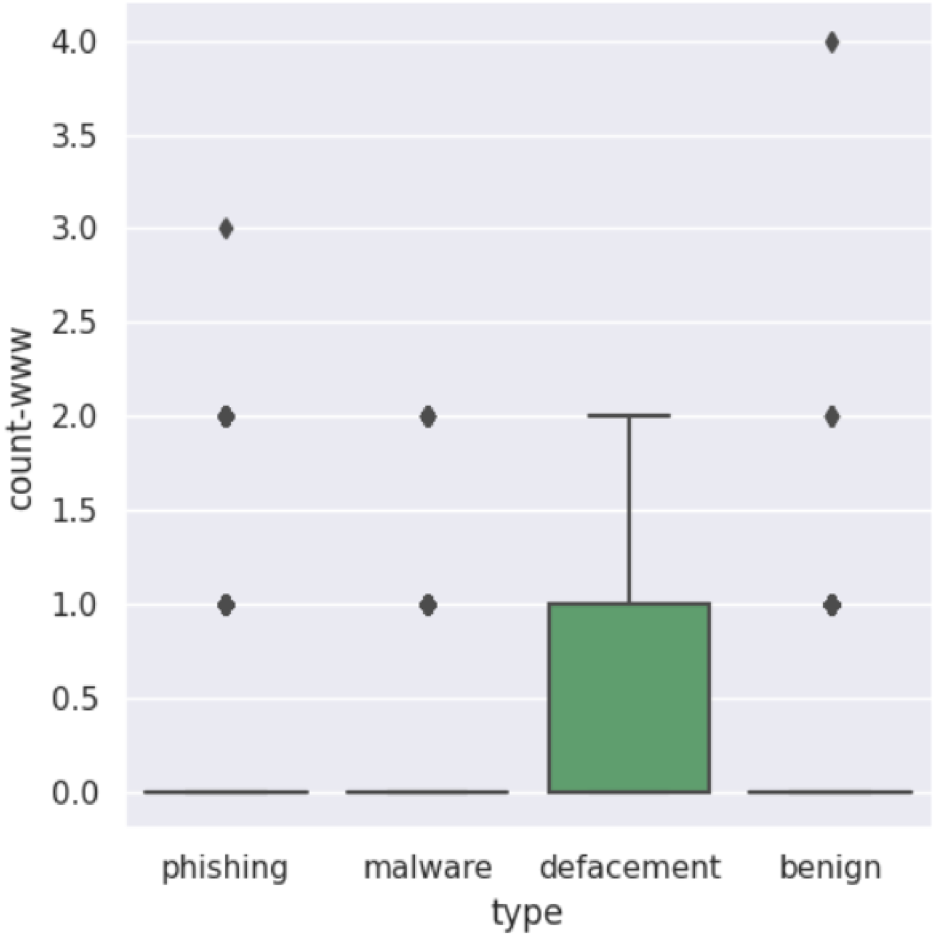


```
In [30]: sns.set(style="darkgrid")
         ax = sns.catplot(x="type", y="count.", kind="box", data=df)
```



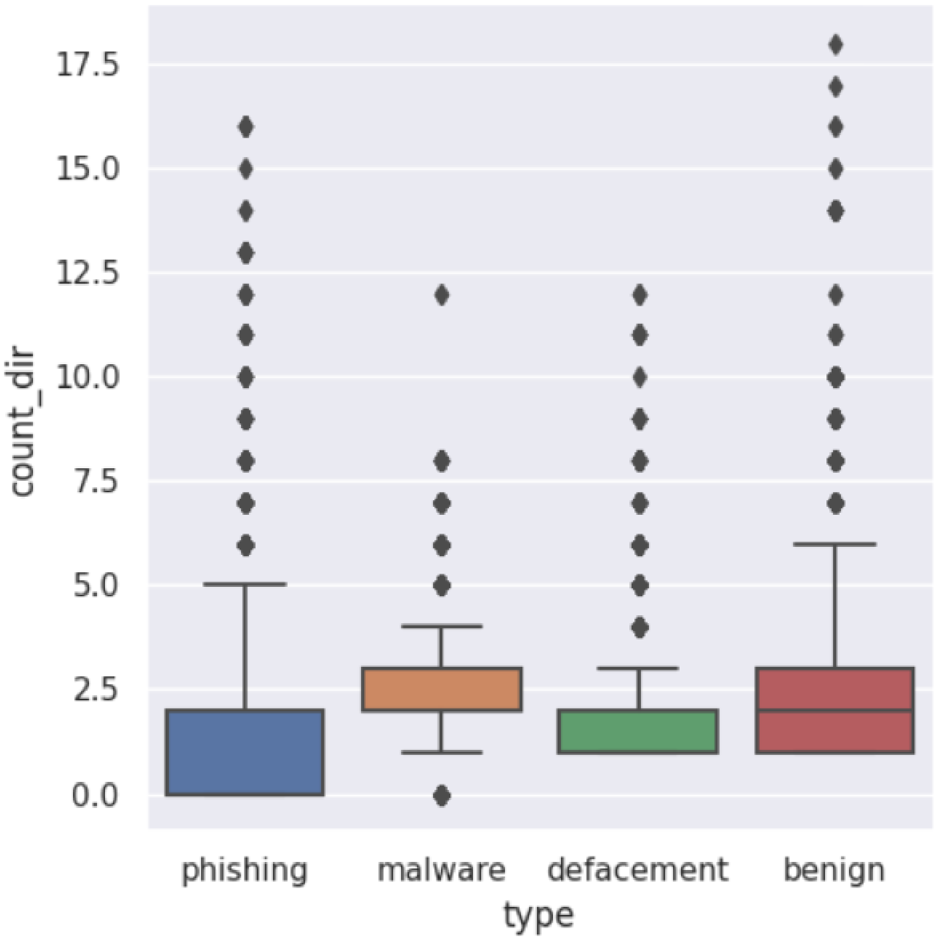


```
In [31]: sns.set(style="darkgrid")
         ax = sns.catplot(x="type", y="count-www", kind="box", data=df)
```

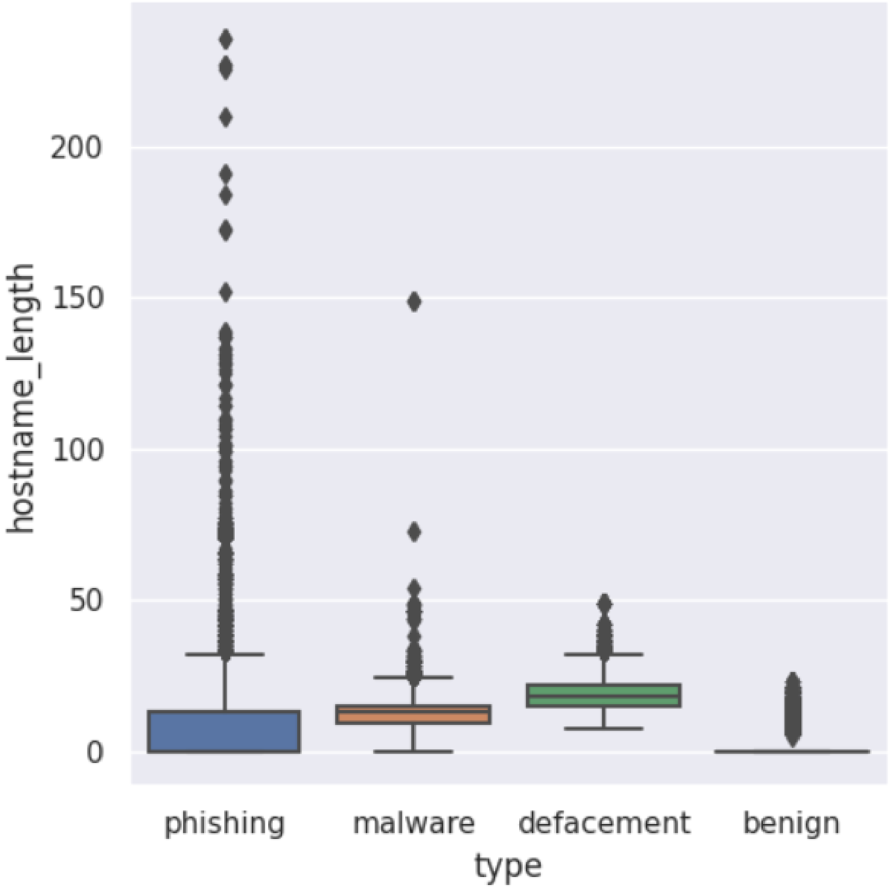


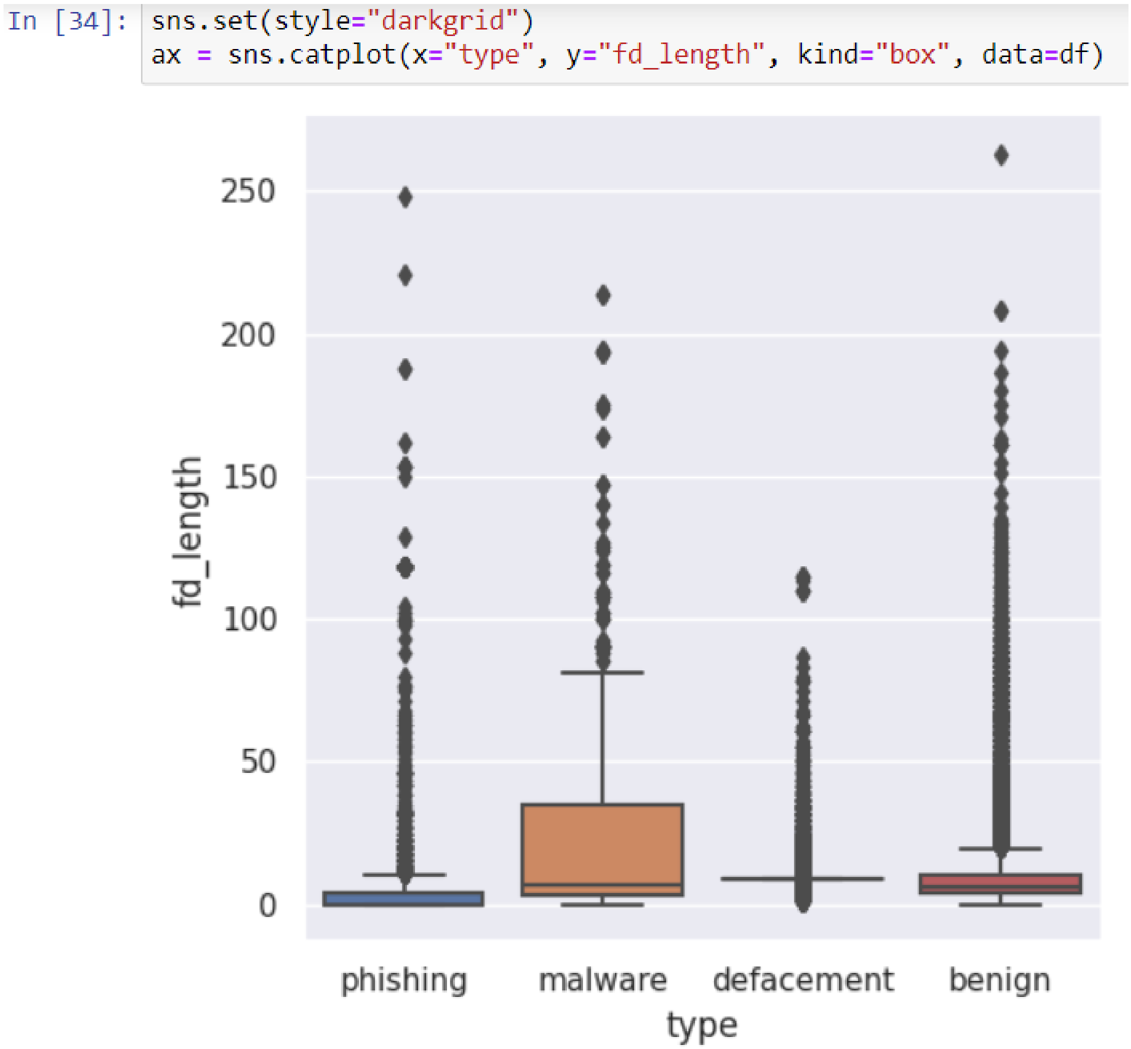
In [32]:

```
sns.set(style="darkgrid")
ax = sns.catplot(x="type", y="count_dir", kind="box", data=df)
```



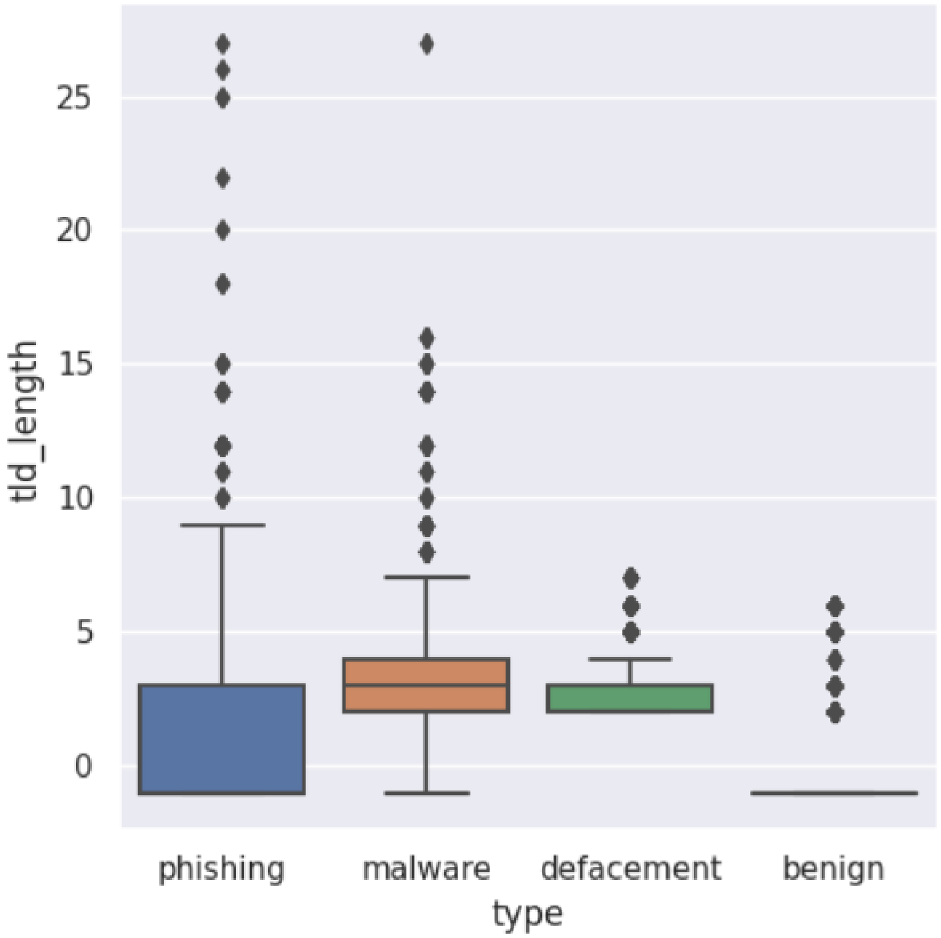
```
In [33]: sns.set(style="darkgrid")
         ax = sns.catplot(x="type", y="hostname_length", kind="box", data=df)
```





```
In [34]: sns.set(style="darkgrid")
         ax = sns.catplot(x="type", y="fd_length", kind="box", data=df)
```

```
In [35]: sns.set(style="darkgrid")
         ax = sns.catplot(x="type", y="tld_length", kind="box", data=df)
```



Target Encoding

```
In [36]: from sklearn.preprocessing import LabelEncoder

         lb_make = LabelEncoder()
         df["type_code"] = lb_make.fit_transform(df["type"])
         df["type_code"].value_counts()

Out[36]: 0    101612
         1     23709
         3     22942
         2     16935
         Name: type_code, dtype: int64
```

Test Train split

```
In [37]: #Predictor Variables
         # filtering out google_index and use of IP as it has only 1 value
         X = df[['use_of_ip','abnormal_url', 'count.', 'count-www', 'count@',
                'count_dir', 'count_embed_domian', 'short_url', 'count-https',
                'count-http', 'count%', 'count?', 'count-', 'count=', 'url_length',
                'hostname_length', 'sus_url', 'fd_length', 'tld_length', 'count-digits',
                'count-letters']]

         #Target Variable
         y = df['type_code']
```

```
In [38]: X.head()
```

Out[38]:

	use_of_ip	abnormal_url	count.	count-www	count@	count_dir	count_embed_domian	short_url	count-https	count-http	...	count?	count-	count=	url_length	hostnan
0	0	0	2	0	0	0	0	0	0	0	...	0	1	0	16	
1	0	0	6	0	0	0	0	0	0	0	...	0	0	0	42	
2	0	1	2	1	0	3	0	1	0	1	...	0	0	0	71	
3	0	1	2	0	0	2	0	0	1	1	...	1	0	1	87	
4	0	0	1	0	0	0	0	0	0	0	...	0	0	0	20	

5 rows × 21 columns

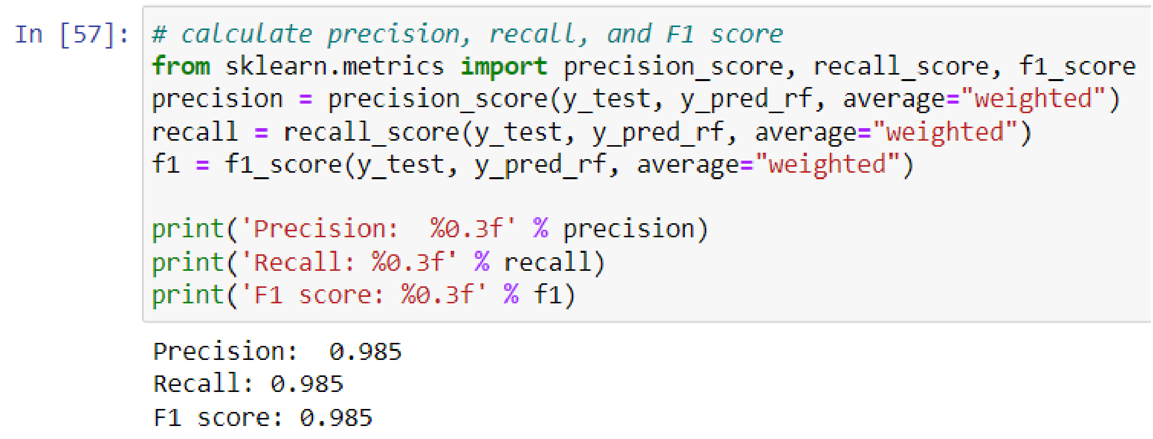
```
In [39]: X.columns

Out[39]: Index(['use_of_ip', 'abnormal_url', 'count.', 'count-www', 'count@',
                'count_dir', 'count_embed_domian', 'short_url', 'count-https',
                'count-http', 'count%', 'count?', 'count-', 'count=', 'url_length',
                'hostname_length', 'sus_url', 'fd_length', 'tld_length', 'count-digits',
                'count-letters'],
               dtype='object')
```

```
In [40]: X_train, X_test, y_train, y_test = train_test_split(X, y, stratify=y, test_size=0.2,shuffle=True, random_state=5)
```

```
In [41]: print(X_train.shape)
         print(X_test.shape)

         (132158, 21)
         (33040, 21)
```

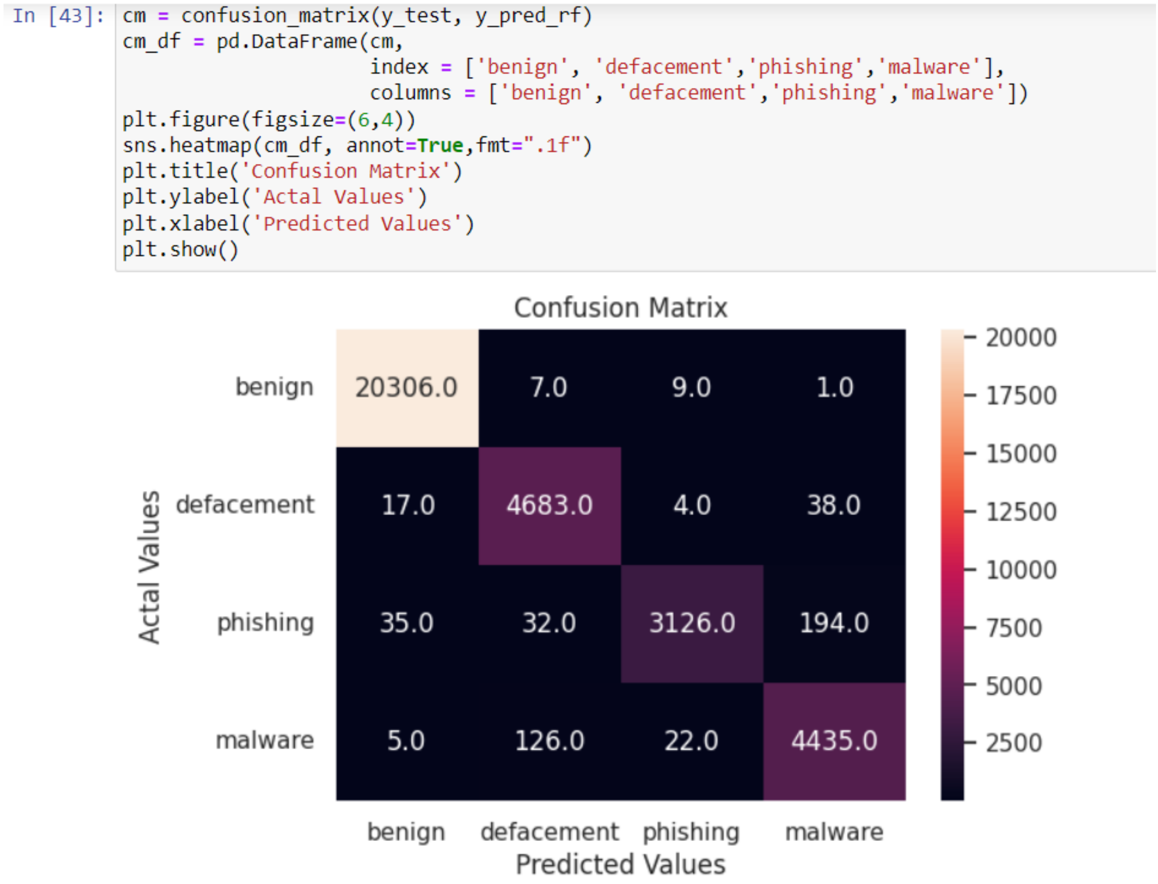
Random Forest

```
In [42]: from sklearn.ensemble import RandomForestClassifier
         rf = RandomForestClassifier(n_estimators=100,max_features='sqrt')
         rf.fit(X_train,y_train)
         y_pred_rf = rf.predict(X_test)
         print(classification_report(y_test,y_pred_rf,target_names=['benign', 'defacement','phishing','malware']))

         score = accuracy_score(y_test, y_pred_rf)
         print("accuracy:   %0.3f" % score)

                       precision    recall  f1-score   support

               benign       1.00      1.00      1.00     20323
           defacement       0.97      0.99      0.98      4742
             phishing       0.99      0.92      0.95      3387
              malware       0.95      0.97      0.96      4588

             accuracy                           0.99     33040
            macro avg       0.98      0.97      0.97     33040
         weighted avg       0.99      0.99      0.99     33040

         accuracy:   0.985
```



```
In [57]: # calculate precision, recall, and F1 score
         from sklearn.metrics import precision_score, recall_score, f1_score
         precision = precision_score(y_test, y_pred_rf, average="weighted")
         recall = recall_score(y_test, y_pred_rf, average="weighted")
         f1 = f1_score(y_test, y_pred_rf, average="weighted")

         print('Precision:  %0.3f' % precision)
         print('Recall: %0.3f' % recall)
         print('F1 score: %0.3f' % f1)
```

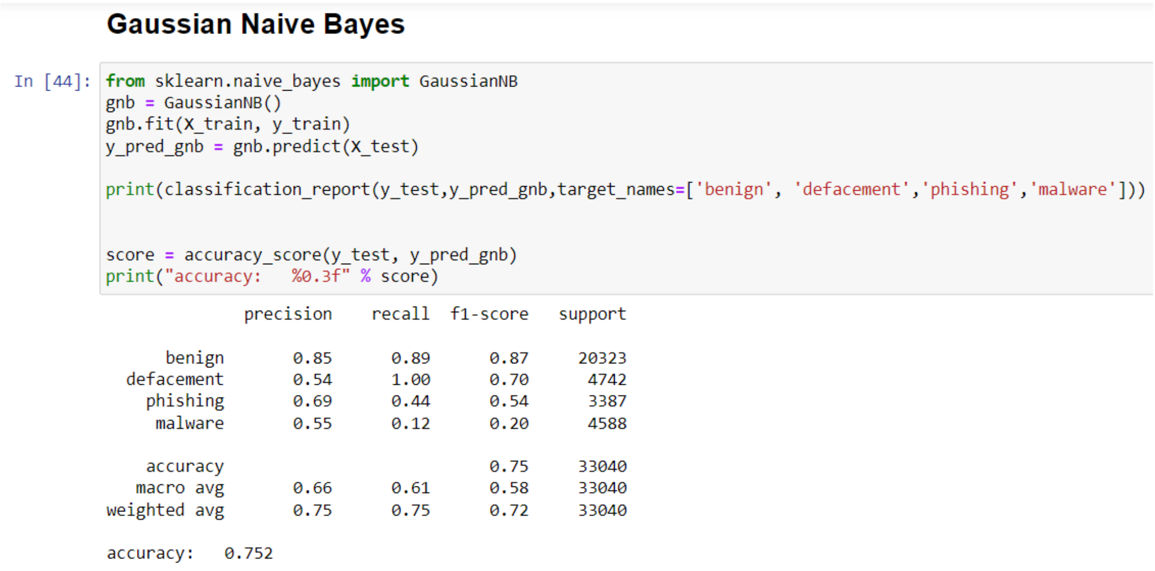
```
Precision:  0.985
Recall: 0.985
F1 score: 0.985
```



```
In [43]: cm = confusion_matrix(y_test, y_pred_rf)
         cm_df = pd.DataFrame(cm,
                              index = ['benign', 'defacement','phishing','malware'],
                              columns = ['benign', 'defacement','phishing','malware'])
         plt.figure(figsize=(6,4))
         sns.heatmap(cm_df, annot=True,fmt=".1f")
         plt.title('Confusion Matrix')
         plt.ylabel('Actal Values')
         plt.xlabel('Predicted Values')
         plt.show()
```

Confusion Matrix

Actal Values \ Predicted Values	benign	defacement	phishing	malware
benign	20306.0	7.0	9.0	1.0
defacement	17.0	4683.0	4.0	38.0
phishing	35.0	32.0	3126.0	194.0
malware	5.0	126.0	22.0	4435.0

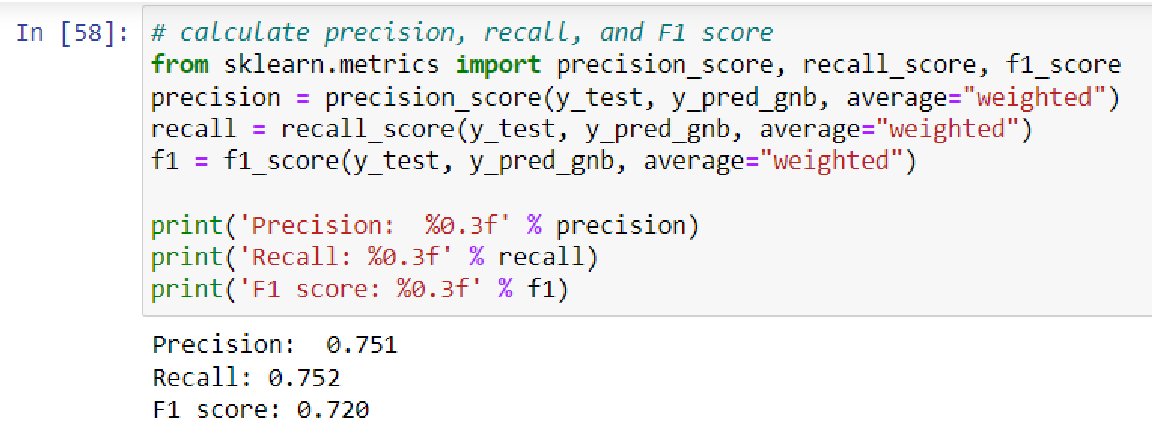


Gaussian Naive Bayes

In [44]:

```
from sklearn.naive_bayes import GaussianNB
gnb = GaussianNB()
gnb.fit(X_train, y_train)
y_pred_gnb = gnb.predict(X_test)

print(classification_report(y_test,y_pred_gnb,target_names=['benign', 'defacement','phishing','malware']))


score = accuracy_score(y_test, y_pred_gnb)
print("accuracy:   %0.3f" % score)
```

```
              precision    recall  f1-score   support

      benign       0.85      0.89      0.87     20323
  defacement       0.54      1.00      0.70      4742
    phishing       0.69      0.44      0.54      3387
     malware       0.55      0.12      0.20      4588

    accuracy                           0.75     33040
   macro avg       0.66      0.61      0.58     33040
weighted avg       0.75      0.75      0.72     33040

accuracy:   0.752
```

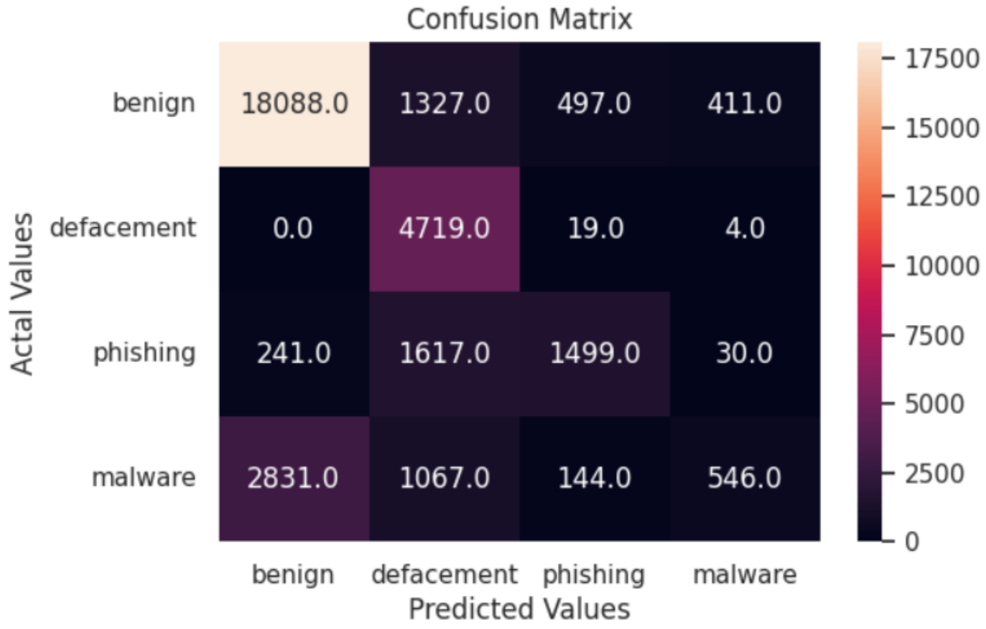


In [58]:

```
# calculate precision, recall, and F1 score
from sklearn.metrics import precision_score, recall_score, f1_score
precision = precision_score(y_test, y_pred_gnb, average="weighted")
recall = recall_score(y_test, y_pred_gnb, average="weighted")
f1 = f1_score(y_test, y_pred_gnb, average="weighted")

print('Precision:  %0.3f' % precision)
print('Recall: %0.3f' % recall)
print('F1 score: %0.3f' % f1)
```

```
Precision:  0.751
Recall: 0.752
F1 score: 0.720
```

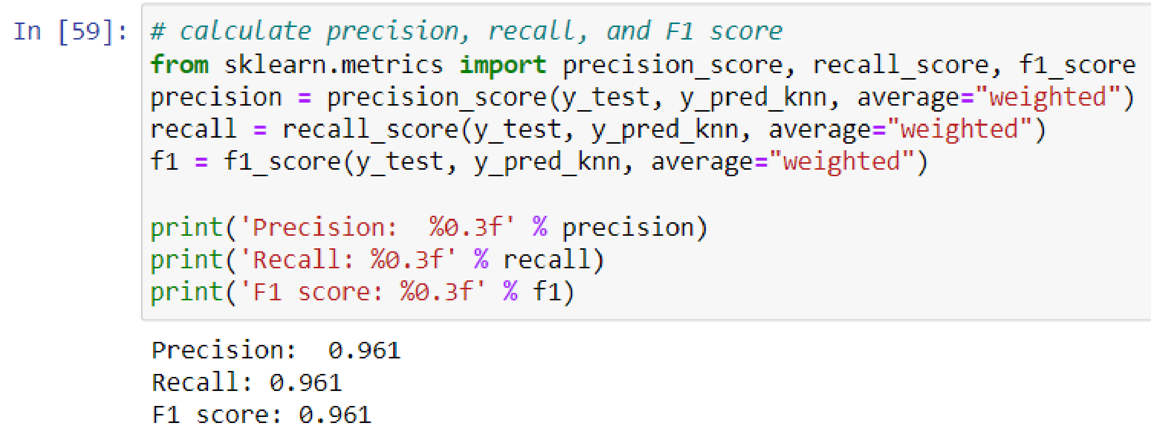
```
In [45]: cm = confusion_matrix(y_test, y_pred_gnb)
         cm_df = pd.DataFrame(cm,
                              index = ['benign', 'defacement','phishing','malware'],
                              columns = ['benign', 'defacement','phishing','malware'])
         plt.figure(figsize=(6,4))
         sns.heatmap(cm_df, annot=True,fmt=".1f")
         plt.title('Confusion Matrix')
         plt.ylabel('Actal Values')
         plt.xlabel('Predicted Values')
         plt.show()
```



K Nearest Neighbors

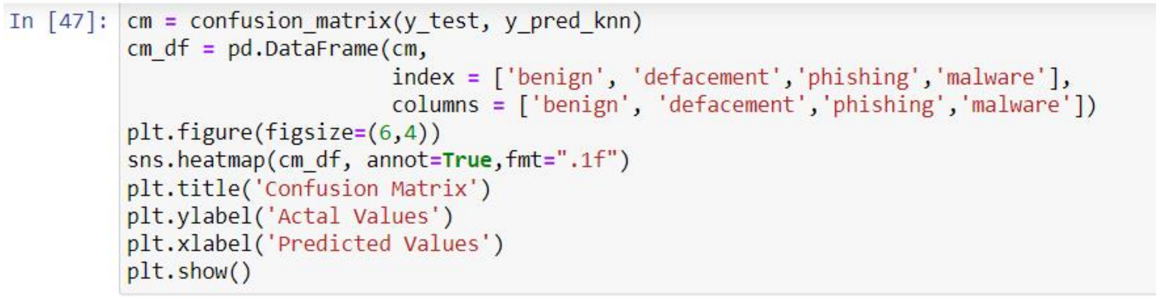
```
In [46]: from sklearn.neighbors import KNeighborsClassifier
         knn = KNeighborsClassifier(n_neighbors=7)
         knn.fit(X_train, y_train)

         y_pred_knn = knn.predict(X_test)

         print(classification_report(y_test,y_pred_knn,target_names=['benign', 'defacement','phishing','malware']))


         score = accuracy_score(y_test, y_pred_knn)
         print("accuracy:   %0.3f" % score)
```

```
              precision    recall  f1-score   support

      benign       0.99      0.99      0.99     20323
  defacement       0.90      0.95      0.92      4742
    phishing       0.93      0.87      0.90      3387
     malware       0.92      0.89      0.91      4588

    accuracy                           0.96     33040
   macro avg       0.94      0.93      0.93     33040
weighted avg       0.96      0.96      0.96     33040

accuracy:   0.961
```

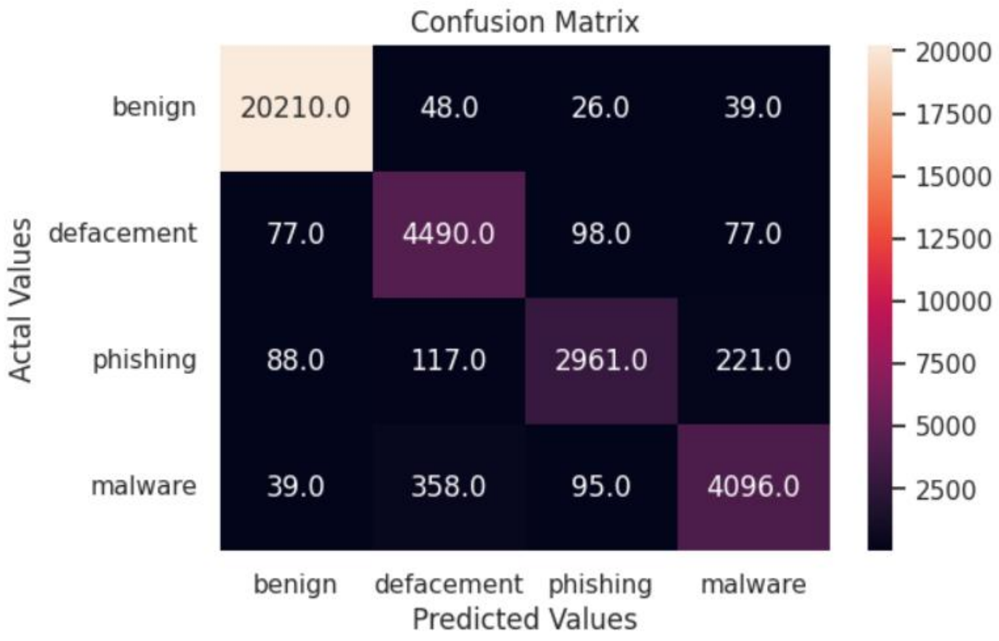


```
In [59]: # calculate precision, recall, and F1 score
         from sklearn.metrics import precision_score, recall_score, f1_score
         precision = precision_score(y_test, y_pred_knn, average="weighted")
         recall = recall_score(y_test, y_pred_knn, average="weighted")
         f1 = f1_score(y_test, y_pred_knn, average="weighted")

         print('Precision:  %0.3f' % precision)
         print('Recall: %0.3f' % recall)
         print('F1 score: %0.3f' % f1)
```

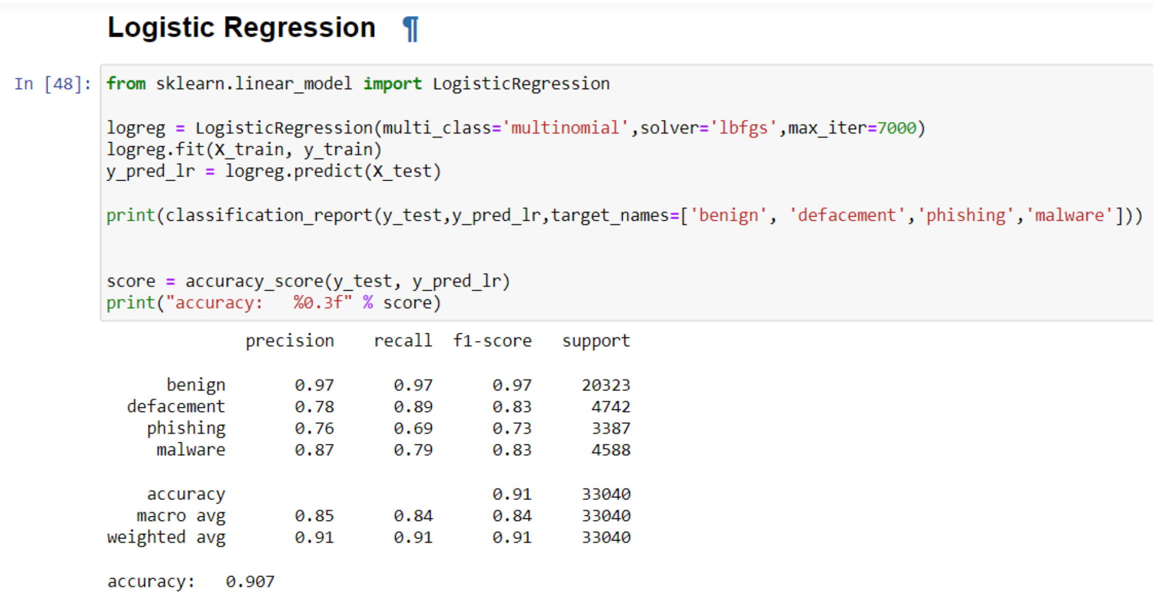
```
Precision:  0.961
Recall: 0.961
F1 score: 0.961
```



```
In [47]: cm = confusion_matrix(y_test, y_pred_knn)
         cm_df = pd.DataFrame(cm,
                              index = ['benign', 'defacement','phishing','malware'],
                              columns = ['benign', 'defacement','phishing','malware'])
         plt.figure(figsize=(6,4))
         sns.heatmap(cm_df, annot=True,fmt=".1f")
         plt.title('Confusion Matrix')
         plt.ylabel('Actal Values')
         plt.xlabel('Predicted Values')
         plt.show()
```



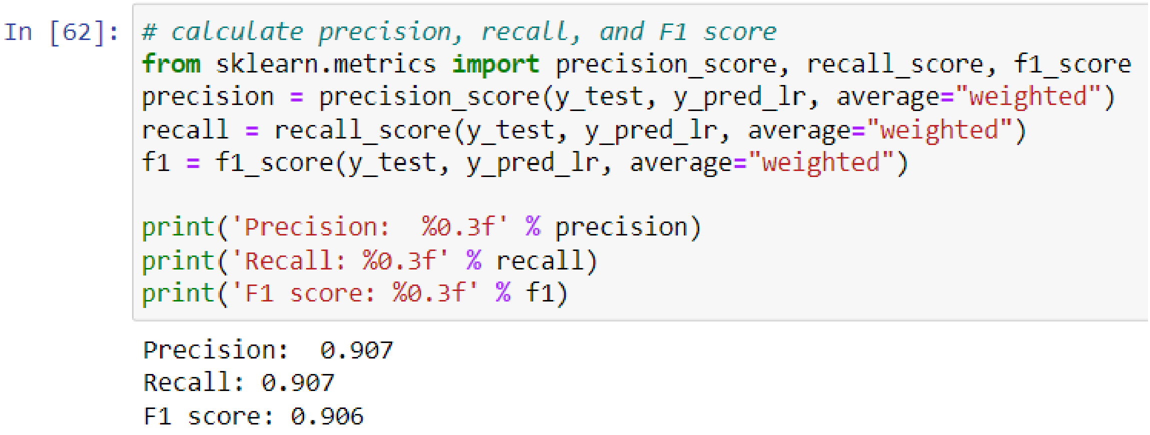
	benign	defacement	phishing	malware
benign	20210.0	48.0	26.0	39.0
defacement	77.0	4490.0	98.0	77.0
phishing	88.0	117.0	2961.0	221.0
malware	39.0	358.0	95.0	4096.0



Logistic Regression ¶

In [48]:
```
from sklearn.linear_model import LogisticRegression

logreg = LogisticRegression(multi_class='multinomial',solver='lbfgs',max_iter=7000)
logreg.fit(X_train, y_train)
y_pred_lr = logreg.predict(X_test)

print(classification_report(y_test,y_pred_lr,target_names=['benign', 'defacement','phishing','malware']))


score = accuracy_score(y_test, y_pred_lr)
print("accuracy:   %0.3f" % score)
```

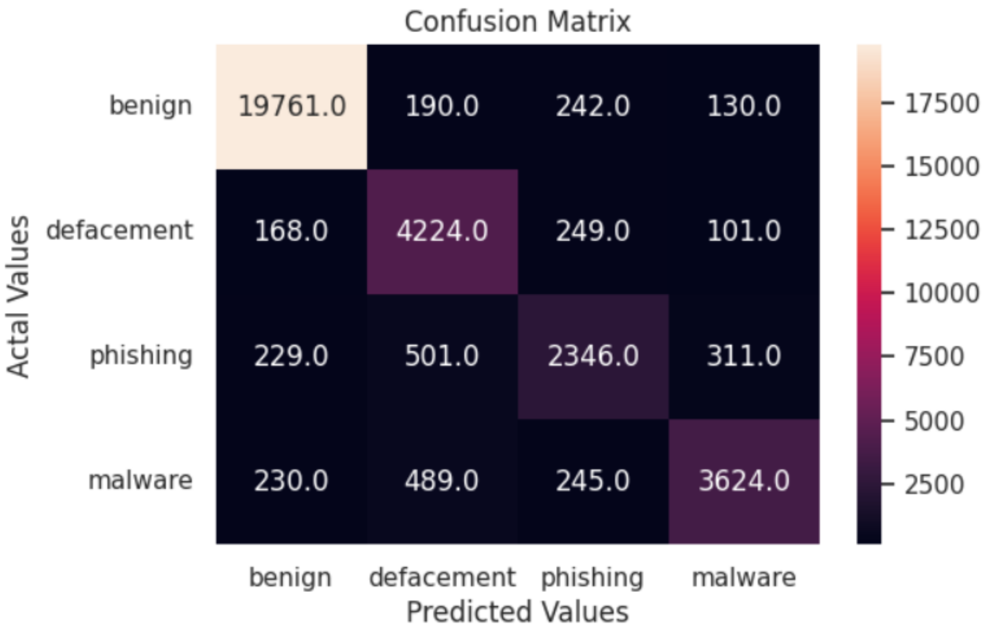
```
              precision    recall  f1-score   support

      benign       0.97      0.97      0.97     20323
  defacement       0.78      0.89      0.83      4742
    phishing       0.76      0.69      0.73      3387
     malware       0.87      0.79      0.83      4588

    accuracy                           0.91     33040
   macro avg       0.85      0.84      0.84     33040
weighted avg       0.91      0.91      0.91     33040

accuracy:   0.907
```



In [62]:
```
# calculate precision, recall, and F1 score
from sklearn.metrics import precision_score, recall_score, f1_score
precision = precision_score(y_test, y_pred_lr, average="weighted")
recall = recall_score(y_test, y_pred_lr, average="weighted")
f1 = f1_score(y_test, y_pred_lr, average="weighted")

print('Precision:  %0.3f' % precision)
print('Recall: %0.3f' % recall)
print('F1 score: %0.3f' % f1)
```

```
Precision:  0.907
Recall: 0.907
F1 score: 0.906
```

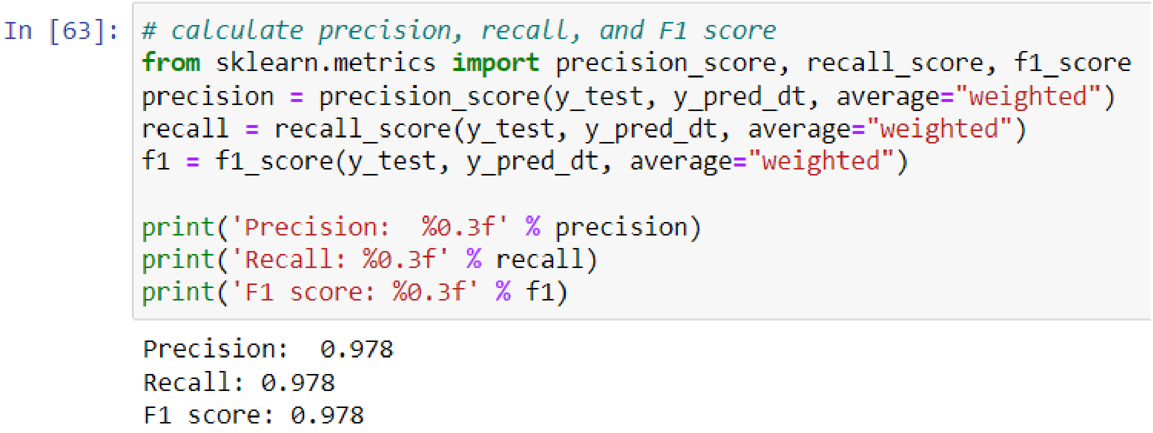
```
In [49]: cm = confusion_matrix(y_test, y_pred_lr)
         cm_df = pd.DataFrame(cm,
                              index = ['benign', 'defacement','phishing','malware'],
                              columns = ['benign', 'defacement','phishing','malware'])
         plt.figure(figsize=(6,4))
         sns.heatmap(cm_df, annot=True,fmt=".1f")
         plt.title('Confusion Matrix')
         plt.ylabel('Actal Values')
         plt.xlabel('Predicted Values')
         plt.show()
```



Decision Tree

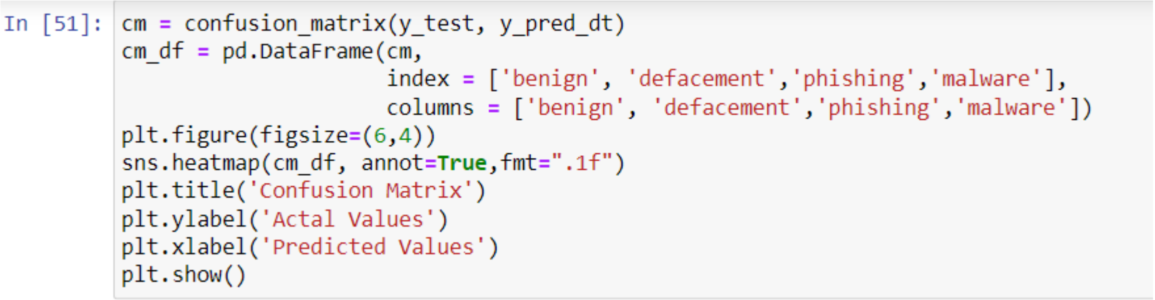
```
In [50]: from sklearn.tree import DecisionTreeClassifier
         dt = DecisionTreeClassifier()
         dt.fit(X_train, y_train)
         y_pred_dt = dt.predict(X_test)

         print(classification_report(y_test,y_pred_dt,target_names=['benign', 'defacement','phishing','malware']))


         score = accuracy_score(y_test, y_pred_dt)
         print("accuracy:   %0.3f" % score)
```

```
              precision    recall  f1-score   support

      benign       1.00      1.00      1.00     20323
  defacement       0.96      0.97      0.96      4742
    phishing       0.95      0.92      0.94      3387
     malware       0.93      0.95      0.94      4588

    accuracy                           0.98     33040
   macro avg       0.96      0.96      0.96     33040
weighted avg       0.98      0.98      0.98     33040

accuracy:   0.978
```

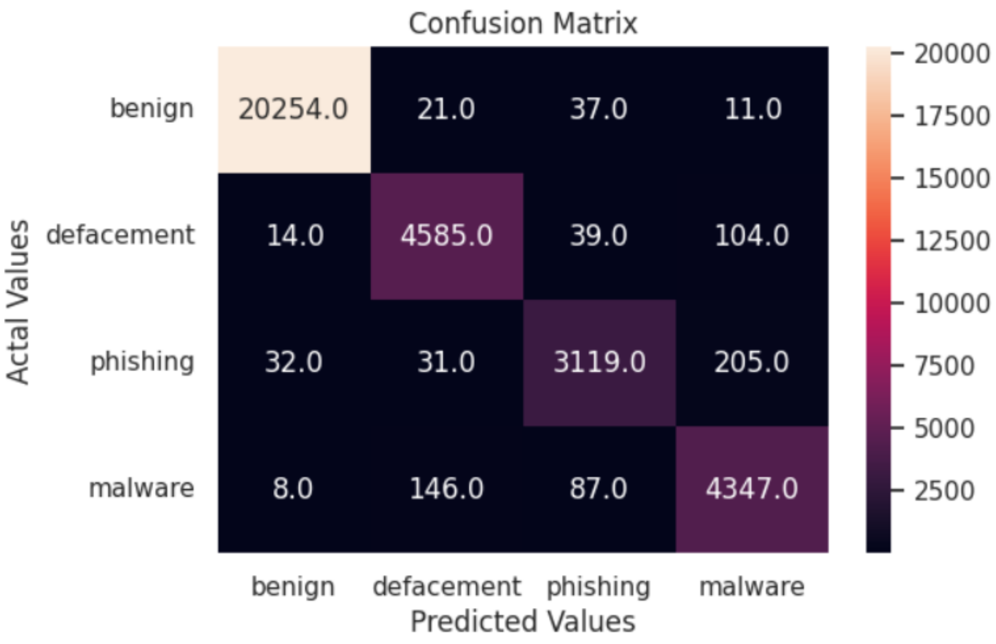


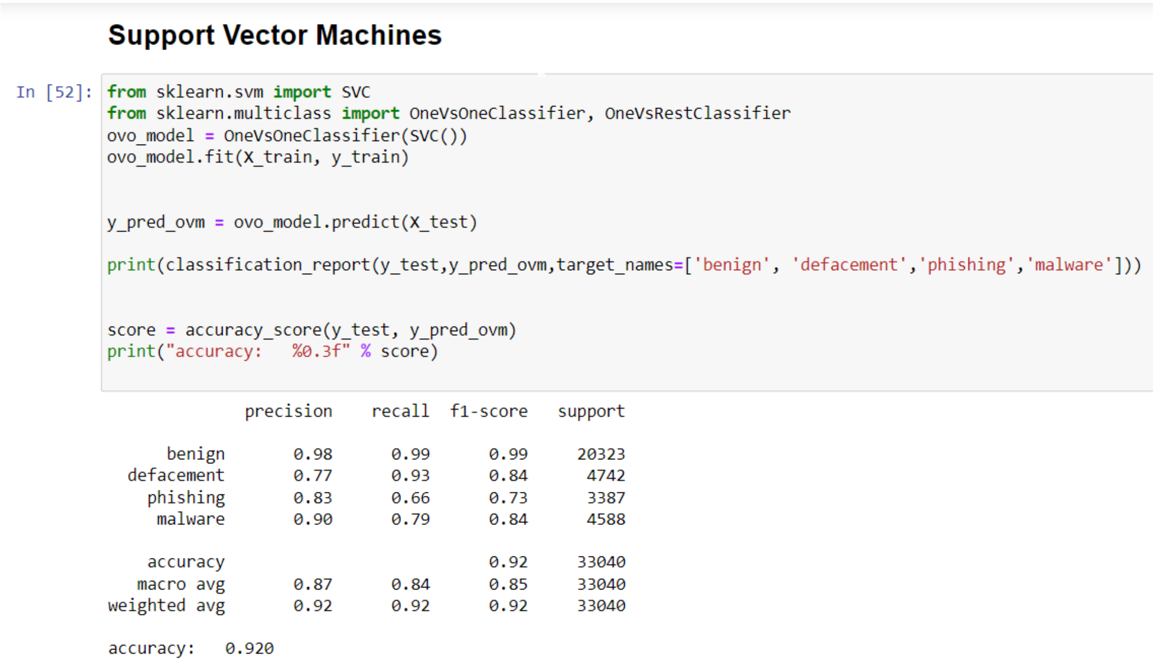
```
In [63]: # calculate precision, recall, and F1 score
         from sklearn.metrics import precision_score, recall_score, f1_score
         precision = precision_score(y_test, y_pred_dt, average="weighted")
         recall = recall_score(y_test, y_pred_dt, average="weighted")
         f1 = f1_score(y_test, y_pred_dt, average="weighted")

         print('Precision:  %0.3f' % precision)
         print('Recall: %0.3f' % recall)
         print('F1 score: %0.3f' % f1)
```

```
Precision:  0.978
Recall: 0.978
F1 score: 0.978
```



```
In [51]: cm = confusion_matrix(y_test, y_pred_dt)
         cm_df = pd.DataFrame(cm,
                              index = ['benign', 'defacement','phishing','malware'],
                              columns = ['benign', 'defacement','phishing','malware'])
         plt.figure(figsize=(6,4))
         sns.heatmap(cm_df, annot=True,fmt=".1f")
         plt.title('Confusion Matrix')
         plt.ylabel('Actal Values')
         plt.xlabel('Predicted Values')
         plt.show()
```



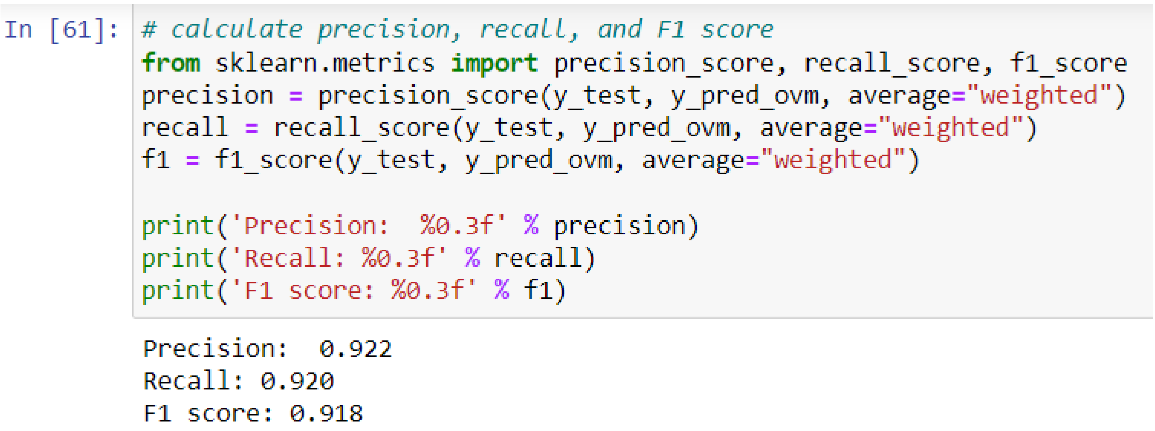


Support Vector Machines

In [52]:

```
from sklearn.svm import SVC
from sklearn.multiclass import OneVsOneClassifier, OneVsRestClassifier
ovo_model = OneVsOneClassifier(SVC())
ovo_model.fit(X_train, y_train)


y_pred_ovm = ovo_model.predict(X_test)

print(classification_report(y_test,y_pred_ovm,target_names=['benign', 'defacement','phishing','malware']))


score = accuracy_score(y_test, y_pred_ovm)
print("accuracy:   %0.3f" % score)
```

```
              precision    recall  f1-score   support

      benign       0.98      0.99      0.99     20323
  defacement       0.77      0.93      0.84      4742
    phishing       0.83      0.66      0.73      3387
     malware       0.90      0.79      0.84      4588

    accuracy                           0.92     33040
   macro avg       0.87      0.84      0.85     33040
weighted avg       0.92      0.92      0.92     33040

accuracy:   0.920
```

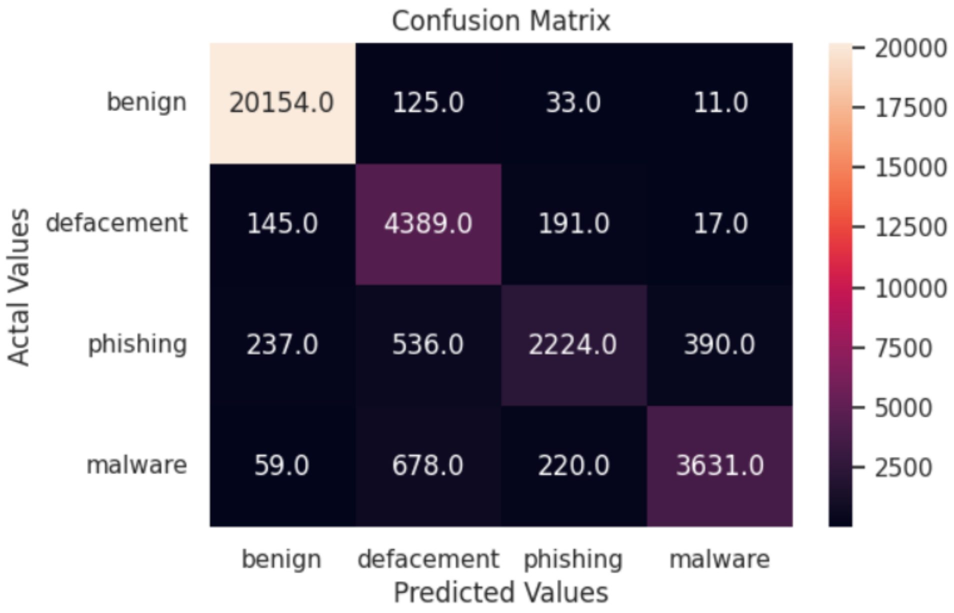


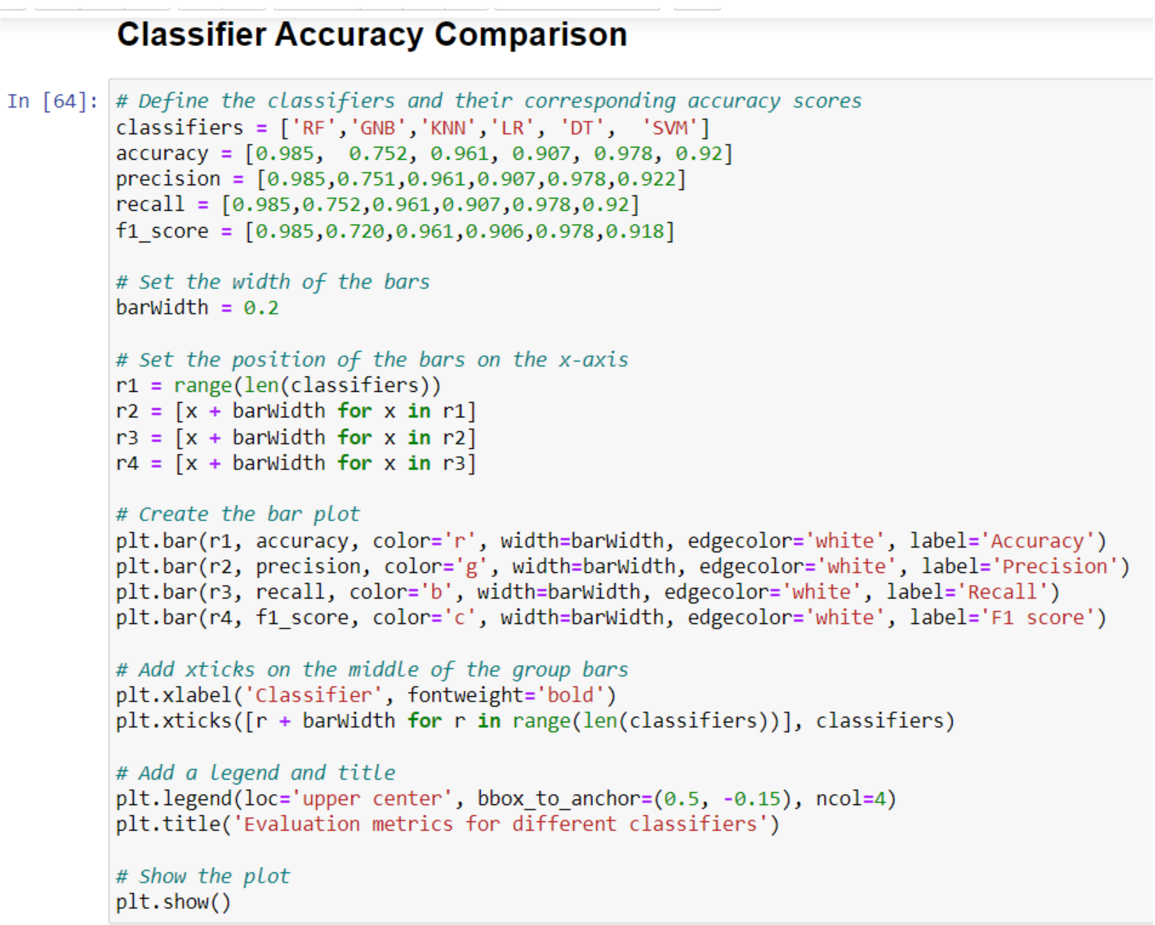
In [61]:

```
# calculate precision, recall, and F1 score
from sklearn.metrics import precision_score, recall_score, f1_score
precision = precision_score(y_test, y_pred_ovm, average="weighted")
recall = recall_score(y_test, y_pred_ovm, average="weighted")
f1 = f1_score(y_test, y_pred_ovm, average="weighted")

print('Precision:  %0.3f' % precision)
print('Recall: %0.3f' % recall)
print('F1 score: %0.3f' % f1)
```

```
Precision:  0.922
Recall: 0.920
F1 score: 0.918
```

```
In [53]: cm = confusion_matrix(y_test, y_pred_ovm)
         cm_df = pd.DataFrame(cm,
                              index = ['benign', 'defacement','phishing','malware'],
                              columns = ['benign', 'defacement','phishing','malware'])
         plt.figure(figsize=(6,4))
         sns.heatmap(cm_df, annot=True,fmt=".1f")
         plt.title('Confusion Matrix')
         plt.ylabel('Actal Values')
         plt.xlabel('Predicted Values')
         plt.show()
```

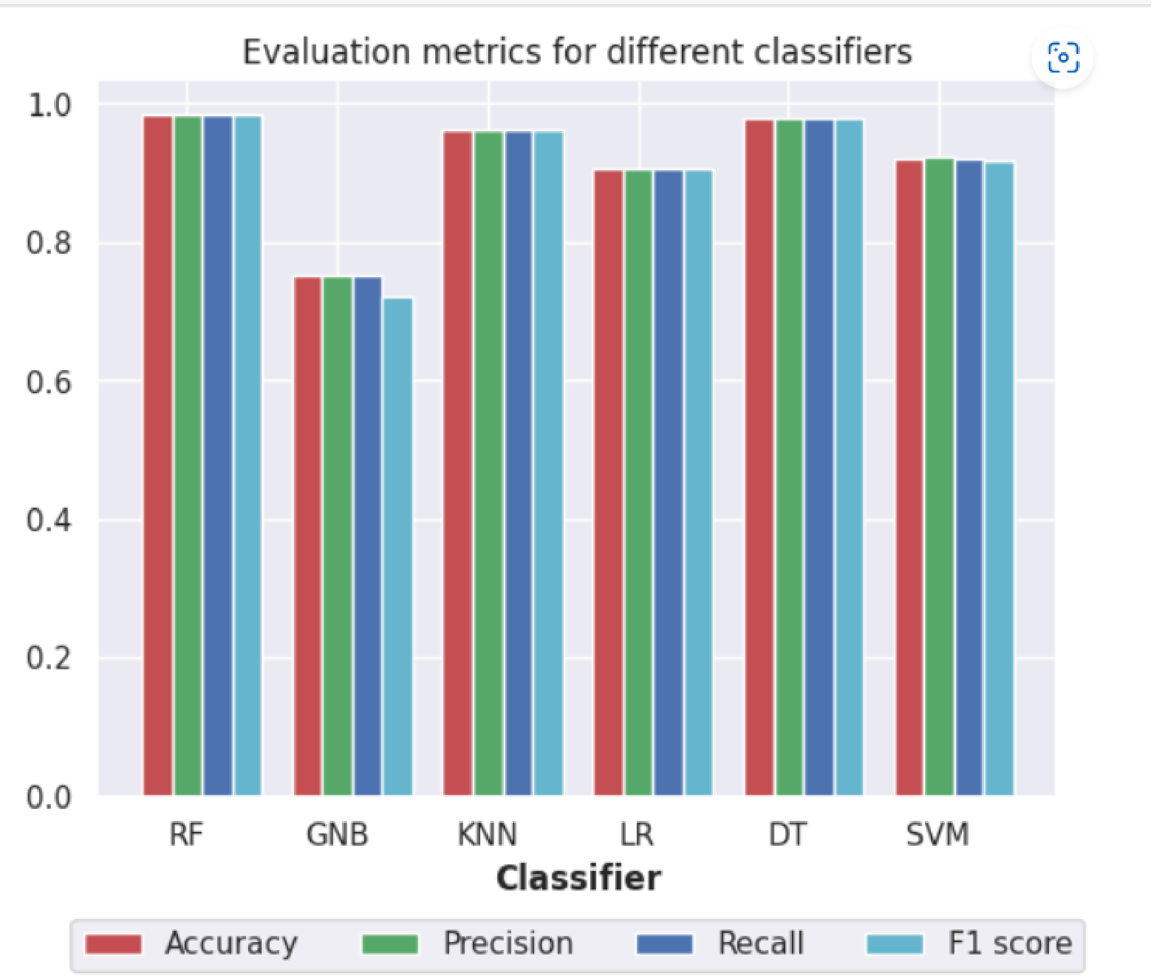




Classifier Accuracy Comparison

In [64]:

```
# Define the classifiers and their corresponding accuracy scores
classifiers = ['RF','GNB','KNN','LR', 'DT',  'SVM']
accuracy = [0.985,  0.752, 0.961, 0.907, 0.978, 0.92]
precision = [0.985,0.751,0.961,0.907,0.978,0.922]
recall = [0.985,0.752,0.961,0.907,0.978,0.92]
f1_score = [0.985,0.720,0.961,0.906,0.978,0.918]

# Set the width of the bars
barWidth = 0.2

# Set the position of the bars on the x-axis
r1 = range(len(classifiers))
r2 = [x + barWidth for x in r1]
r3 = [x + barWidth for x in r2]
r4 = [x + barWidth for x in r3]

# Create the bar plot
plt.bar(r1, accuracy, color='r', width=barWidth, edgecolor='white', label='Accuracy')
plt.bar(r2, precision, color='g', width=barWidth, edgecolor='white', label='Precision')
plt.bar(r3, recall, color='b', width=barWidth, edgecolor='white', label='Recall')
plt.bar(r4, f1_score, color='c', width=barWidth, edgecolor='white', label='F1 score')

# Add xticks on the middle of the group bars
plt.xlabel('Classifier', fontweight='bold')
plt.xticks([r + barWidth for r in range(len(classifiers))], classifiers)

# Add a legend and title
plt.legend(loc='upper center', bbox_to_anchor=(0.5, -0.15), ncol=4)
plt.title('Evaluation metrics for different classifiers')

# Show the plot
plt.show()
```



Evaluation metrics for different classifiers