Importing Libraries

In [528…

```
import os
os.getcwd()
```

Out[528…

```
'C:\\BigData\\~notebookJupyter'
```

In [529…

```
import requests
requests.packages.urllib3.disable_warnings()
```

In [530…

```
import plotly.plotly as py
import plotly.graph_objs as go
```

In [531…

```
import findspark
import pandas as pd
findspark.init("C:\BigData\Spark")
findspark.find()
```

Out[531…

```
'C:\\BigData\\Spark'
```

In [532…

```
import pyspark
from pyspark import SparkContext
from pyspark import SQLContext
from pyspark.sql import SparkSession
from pyspark.sql.functions import *
```

In [533…

```
spark.conf.set("spark.sql.excution.arrow.enabled","true")
```

In [534…

```
import seaborn as sns
import matplotlib.pyplot as plt
```

In [535…

```
sc = SparkContext.getOrCreate()
spark=SparkSession.builder.getOrCreate()
print(sc.version)
```

```
2.4.7
```

In [536…

```
from pyspark.sql.types import IntegerType
```

In [537…

```
plt.rcParams.update({'figure.figsize':(10,8), 'figure.dpi':100})
```

Loading Dataset

In [538…

```
%%time
orig_df = pd.read_csv("C:/Users/HP/Desktop/ECE552_final/ECE552_project/BitcoinHeistD
```

```
Wall time: 3.06 s
```

In [607…
```
orig_df.head()
orig_df.reset_index(drop=True, inplace=True)
```

converting into bitcoin

In [540…
```
orig_df['income'] = orig_df['income']/100000000
```

In [541…
```
orig_df=orig_df.dropna()
```

In [542…
```
orig_df.to_csv("C:/Users/HP/Desktop/ECE552_final/ECE552_project/BitcoinHeistData1.cs
```

reading data using spark

In [543…
```
%%time
df = spark.read.format("csv"). \
            option("header", "true").option("mode", "DROPMALFORMED").option("delimit
            option("ignoreLeadingWhiteSpace","true").option("ignoreTrailingWhiteSpac
            option("inferschema","true"). \
            load('C:/Users/HP/Desktop/ECE552_final/ECE552_project/BitcoinHeistData1.
```

```
Wall time: 3.98 s
```

In [544…
```
print(df.count())
df.printSchema()
```

```
1048575
root
 |-- _c0: integer (nullable = true)
 |-- address: string (nullable = true)
 |-- year: integer (nullable = true)
 |-- day: integer (nullable = true)
 |-- length: integer (nullable = true)
 |-- weight: double (nullable = true)
 |-- count: integer (nullable = true)
 |-- looped: integer (nullable = true)
 |-- neighbors: integer (nullable = true)
 |-- income: double (nullable = true)
 |-- label: string (nullable = true)
```

Writing paruet

In [545…
```
df.repartition(4).write.mode('overwrite').parquet('C:/Users/HP/Desktop/ECE552_final/
```

In [546…
```
%%time
spark=SparkSession.builder.appName("Python Spark dataframe").config("spark.some.conf
parquet_df=spark.read.parquet("C:/Users/HP/Desktop/ECE552_final/ECE552_project/Bitco
```

```
Wall time: 146 ms
```

In [547…
```
type(parquet_df)
```

Out[547…
```
pyspark.sql.dataframe.DataFrame
```

In [548…

```
parquet_df.show()
```

```
+------+--------------------+----+---+------+-----------+-----+------+---------+----
--------+---------------+
|   _c0|             address|year|day|length|     weight|count|looped|neighbors|
income|          label|
+------+--------------------+----+---+------+-----------+-----+------+---------+----
--------+---------------+
|207249|1EkNTexkRsMpgTE7a...|2011|176|   124|    2.98E-8|    2|     0|        2|
2.25|          white|
|121548|13JrBxWSJEjXtvAwa...|2011| 90|     6|       0.75|    3|     0|        2|
80.0|          white|
| 97738|18CRxe48uz1a3LWgd...|2011| 67|     0|        0.5|    1|     0|        2|
116.91|          white|
| 75564|17hFuRueNZAiPwDr1...|2011| 44|    16|    0.03125|    1|     0|        1|
0.3|          white|
| 72434|14XRZVVCi6j7aH6U9...|2011| 41|    22| 2.44141E-4|    1|     0|        2|
0.5|          white|
|210188|1JucwoRuVqAh4g7Lu...|2011|179|     0|        0.5|    1|     0|        1|
2.93118|          white|
| 84220|1Q4WQ7irizHbkt2fM...|2011| 53|    58|0.506404332|   51|     0|        2|
48.76|          white|
|132915|19L7TurgXprUJpN4v...|2011|102|    30|  1.2207E-4|    1|     0|        1|
58.38|          white|
|195332|1Pg3JkPdmTeSjLxJk...|2011|164|   114|    8.38E-9|    2|     0|        3|
2.92|          white|
| 93103|1AYZQFjKDvETaUP8w...|2011| 62|    16|0.001953125|    1|     0|        2|
11.33|          white|
|266715|153SRUhhVpfmnat3h...|2011|236|     6|        0.5|    1|     0|        2|
0.6|          white|
|137696|1271tY1rX2ihMocWF...|2011|106|     0|        0.5|    1|     0|        1|
1.01|          white|
|217213|1NDGzwDu9ADJdwoC1...|2011|186|    60|    1.53E-5|    1|     0|        1|
0.43|          white|
|161057|1ApE5DL1pL5NTqfBb...|2011|130|     0|        1.0|    1|     0|        2|
6.88|          white|
| 50877|1H8EvrtmCK6GUh8MN...|2011| 16|     6|       0.25|    1|     0|        2|
45.49|          white|
|275645|187rbGVNVw6MR5GPn...|2011|244|     2|        0.5|    1|     0|        2| 47.
50271007|          white|
|232600|1D88h6L5d47eqCwGX...|2011|201|    50|    4.11E-6|   28|     0|        1|
1.0|          white|
|162132|1BK47BchauWVHBHCj...|2011|131|     0|        1.0|    1|     0|        2|
2.11|          white|
|206442|1417eLt5Xu9GhqHxN...|2011|175|    34| 0.00390625|    1|     0|        2|563.
01393392|          white|
| 19473|1CweHaxHBhk7pt6VZ...|2015|265|   144| 0.11639657| 3544|  1115|        1|
3.13|paduaCryptoWall|
+------+--------------------+----+---+------+-----------+-----+------+---------+----
--------+---------------+
only showing top 20 rows
```

In [549…

```
print(parquet_df.count())
parquet_df.printSchema()
```

```
1048575
root
 |-- _c0: integer (nullable = true)
 |-- address: string (nullable = true)
 |-- year: integer (nullable = true)
 |-- day: integer (nullable = true)
 |-- length: integer (nullable = true)
 |-- weight: double (nullable = true)
 |-- count: integer (nullable = true)
 |-- looped: integer (nullable = true)
 |-- neighbors: integer (nullable = true)
 |-- income: double (nullable = true)
 |-- label: string (nullable = true)
```

In [550…

```
#import org.apache.spark.sql.types.IntegerType
#bitcoin_df["income"].astype("int64")
```

In [551…

```
print(parquet_df.schema["income"].dataType)
```

```
DoubleType
```

In [552…

```
parquet_df.select([count(when(col(c).isNull(), c)).alias(c) for c in parquet_df.colu
```

```
+---+-------+----+---+------+------+-----+------+---------+------+-----+
|_c0|address|year|day|length|weight|count|looped|neighbors|income|label|
+---+-------+----+---+------+------+-----+------+---------+------+-----+
|  0|      0|   0|  0|     0|     0|    0|     0|        0|     0|    0|
+---+-------+----+---+------+------+-----+------+---------+------+-----+
```

In [553…

```
parquet_df = parquet_df.na.drop()
```

In [554…

```
parquet_df.show()
```

```
+------+--------------------+----+---+------+-----------+-----+------+---------+----
--------+---------------+
|   _c0|             address|year|day|length|     weight|count|looped|neighbors|
income|          label|
+------+--------------------+----+---+------+-----------+-----+------+---------+----
--------+---------------+
|207249|1EkNTexkRsMpgTE7a...|2011|176|   124|    2.98E-8|    2|     0|        2|
2.25|          white|
|121548|13JrBxWSJEjXtvAwa...|2011| 90|     6|       0.75|    3|     0|        2|
80.0|          white|
| 97738|18CRxe48uz1a3LWgd...|2011| 67|     0|        0.5|    1|     0|        2|
116.91|          white|
| 75564|17hFuRueNZAiPwDr1...|2011| 44|    16|    0.03125|    1|     0|        1|
0.3|          white|
| 72434|14XRZVVCi6j7aH6U9...|2011| 41|    22| 2.44141E-4|    1|     0|        2|
0.5|          white|
|210188|1JucwoRuVqAh4g7Lu...|2011|179|     0|        0.5|    1|     0|        1|
2.93118|          white|
| 84220|1Q4WQ7irizHbkt2fM...|2011| 53|    58|0.506404332|   51|     0|        2|
48.76|          white|
|132915|19L7TurgXprUJpN4v...|2011|102|    30|  1.2207E-4|    1|     0|        1|
58.38|          white|
|195332|1Pg3JkPdmTeSjLxJk...|2011|164|   114|    8.38E-9|    2|     0|        3|
2.92|          white|
| 93103|1AYZQFjKDvETaUP8w...|2011| 62|    16|0.001953125|    1|     0|        2|
11.33|          white|
|266715|153SRUhhVpfmnat3h...|2011|236|     6|        0.5|    1|     0|        2|
0.6|          white|
|137696|1271tY1rX2ihMocWF...|2011|106|     0|        0.5|    1|     0|        1|
1.01|          white|
|217213|1NDGzwDu9ADJdwoC1...|2011|186|    60|    1.53E-5|    1|     0|         1|
0.43|          white|
|161057|1ApE5DL1pL5NTqfBb...|2011|130|     0|        1.0|    1|     0|         2|
6.88|          white|
| 50877|1H8EvrtmCK6GUh8MN...|2011| 16|     6|       0.25|    1|     0|         2|
45.49|          white|
|275645|187rbGVNVw6MR5GPn...|2011|244|     2|        0.5|    1|     0|         2| 47.
50271007|          white|
|232600|1D88h6L5d47eqCwGX...|2011|201|    50|    4.11E-6|   28|     0|         1|
1.0|          white|
|162132|1BK47BchauWVHBHCj...|2011|131|     0|        1.0|    1|     0|         2|
2.11|          white|
|206442|1417eLt5Xu9GhqHxN...|2011|175|    34| 0.00390625|    1|     0|         2|563.
01393392|          white|
| 19473|1CweHaxHBhk7pt6VZ...|2015|265|   144| 0.11639657| 3544|  1115|         1|
3.13|paduaCryptoWall|
+------+--------------------+----+---+------+-----------+-----+------+----------+----
--------+---------------+
only showing top 20 rows
```

In [ ]:

In [555…

```python
from pyspark.sql.functions import desc
```

In [556…

```python
parquet_df.createOrReplaceTempView("bc_data")
```

In [557…

```python
income_year = spark.sql("SELECT income,year from bc_data order by income desc")
```

Highest transaction from the data set and the year it occured

In [558…

```python
income_year.head(3) ##499643 will be highest
```

Out[558…

```
[Row(income=499643.98238996, year=2011),
 Row(income=498244.66601007, year=2011),
 Row(income=497976.31116927, year=2011)]
```

The Year wise transation count

In [559…

```python
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

In [ ]:

In [560…

```python
Year_txn=spark.sql("select year,count(year) as number_of_txn_per_year from bc_data w
```

In [561…

```python
Year_txn.show()
```

```
+----+----------------------+
|year|number_of_txn_per_year|
+----+----------------------+
|2012|                365714|
|2011|                355349|
|2013|                294372|
|2014|                 10319|
+----+----------------------+
```

In [562…

```
type(Year_txn)
```

Out[562…

```
pyspark.sql.dataframe.DataFrame
```

In [563…

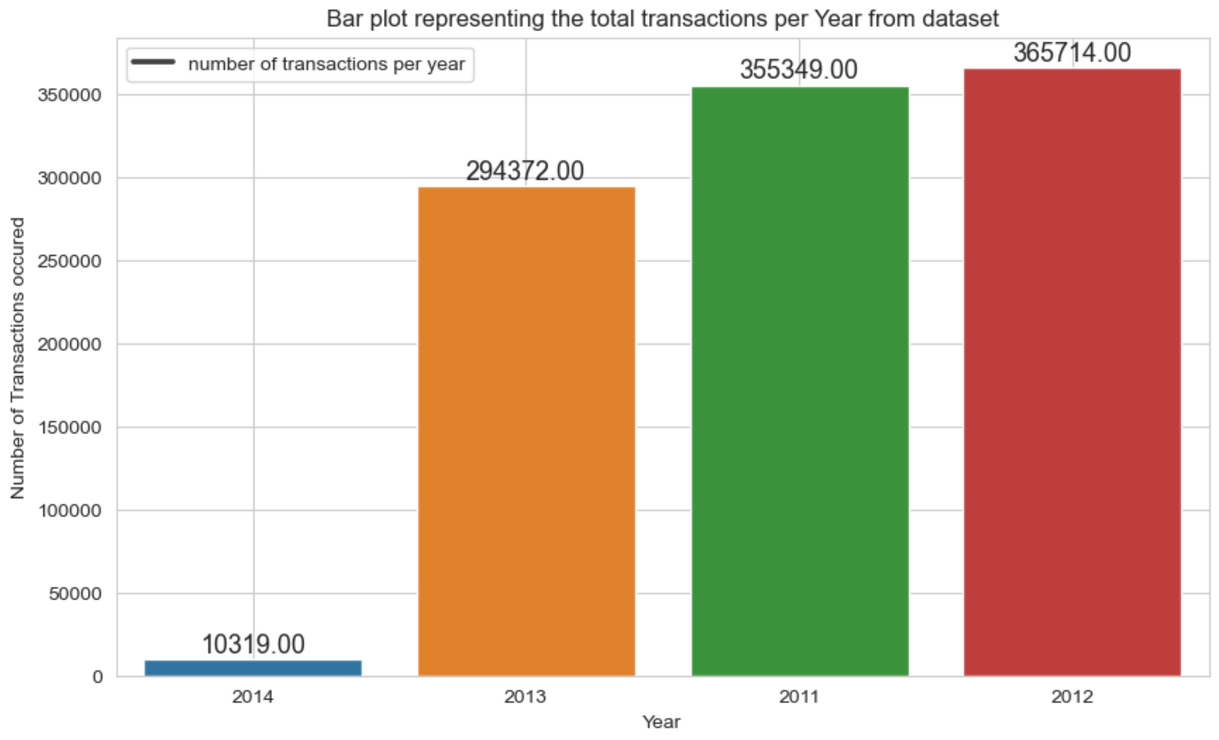
```
Year_txn=Year_txn.toPandas()
```

In [564…

```
temp1=Year_txn["year"]
temp=Year_txn["number_of_txn_per_year"]
```

In [565…

```
plt.figure(figsize=(10, 6))
plots = sns.barplot(x="year", y="number_of_txn_per_year", data=Year_txn,order=Year_t

# Iterrating over the bars one-by-one
for bar in plots.patches:

    plots.annotate(format(bar.get_height(), '.2f'),
                   (bar.get_x() + bar.get_width() / 2,
                    bar.get_height()), ha='center', va='center',
                   size=13, xytext=(0, 7),
                   textcoords='offset points')

# Creating the legend of the bars in the plot
plt.legend(labels = ['number of transactions per year'])
# Giving the tilte for the plot
plt.title("Bar plot representing the total transactions per Year from dataset")
# Namimg the x and y axis
plt.xlabel('Year')
plt.ylabel('Number of Transactions occured')
plt.grid(True)
```



In [ ]:

```

```

The Count of labels

In [566…

```
#minned minned label
parquet_df.select("label").distinct().show(truncate=False)
```

```
+---------------------------+
|label                      |
+---------------------------+
|paduaJigsaw                |
|montrealXLockerv5.0        |
|montrealJigSaw             |
|montrealCryptoTorLocker2015|
|montrealXTPLocker          |
|montrealAPT                |
|montrealRazy               |
|white                      |
|montrealNoobCrypt          |
|princetonCerber            |
|montrealEDA2               |
|paduaCryptoWall            |
|montrealGlobeImposter      |
|montrealCryptConsole       |
|montrealSamSam             |
|montrealSam                |
|montrealDMALockerv3        |
|montrealXLocker            |
|montrealVenusLocker        |
|montrealCryptoLocker       |
+---------------------------+
only showing top 20 rows
```

In [567…

```
label_df = spark.sql("select label, count(label) as label_count from bc_data group b
```

In [568…
```
label_df=label_df.na.drop()
```

In [569…
```
Newlabel_df=label_df.toPandas()
```

In [570…
```
Newlabel_df=Newlabel_df.head(6)
Newlabel_df
```

Out[570…

	label	label_count
0	white	1007162
1	paduaCryptoWall	12390
2	montrealCryptoLocker	9315
3	princetonCerber	9223
4	princetonLocky	6625
5	montrealCryptXXX	2419

White(1007162) which is not known to be ransomware

In [571…
```
print(type(label_df))
print(type(Newlabel_df))
x=Newlabel_df['label']
y=Newlabel_df["label_count"]
```

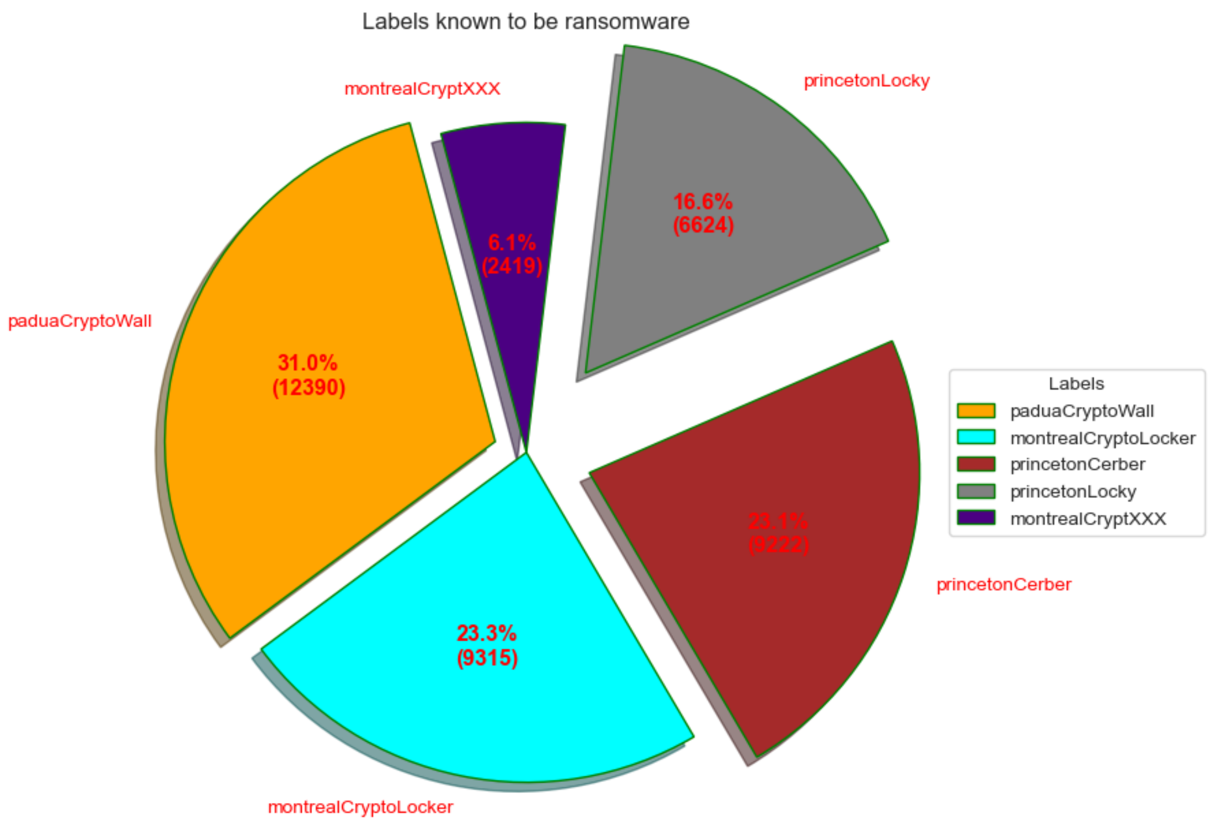
```
<class 'pyspark.sql.dataframe.DataFrame'>
<class 'pandas.core.frame.DataFrame'>
```

In [572…
```
Newlabel_df=Newlabel_df.drop([0])
x=Newlabel_df['label']
y=Newlabel_df["label_count"]
Newlabel_df
```

Out[572…

	label	label_count
1	paduaCryptoWall	12390
2	montrealCryptoLocker	9315
3	princetonCerber	9223
4	princetonLocky	6625
5	montrealCryptXXX	2419

In [573…
```
import numpy as np

l = Newlabel_df['label']
data = Newlabel_df["label_count"]


# Creating explode data
explode = (0.1, 0.0, 0.2, 0.3, 0.0)

# Creating color parameters
colors = ( "orange", "cyan", "brown",
          "grey", "indigo", "beige")

# Wedge properties
wp = { 'linewidth' : 1, 'edgecolor' : "green" }

# Creating autocpt arguments
def func(pct, allvalues):
    absolute = int(pct / 100.*np.sum(allvalues))
    #print(absolute)
    #return pct
    return "{:.1f}%\n({:d})".format(pct, absolute)

# Creating plot
fig, ax = plt.subplots(figsize =(10, 8))
wedges, texts, autotexts = ax.pie(y,
                                  autopct = lambda pct: func(pct, data),
                                  explode = explode,
                                  labels = x,
                                  shadow = True,
                                  colors = colors,
                                  startangle = 105,
                                  wedgeprops = wp,
                                  textprops = dict(color ="red"))

# Adding legend
ax.legend(wedges, l,
          title ="Labels",
          loc ="center left",
          bbox_to_anchor =(1, 0, 0.5, 1))

plt.setp(autotexts, size = 11.5, weight ="bold")
ax.set_title("Labels known to be ransomware")
# show plot
plt.show()
```



In [574…
```
#plt.pie(Newlabel_df['label'],labels = Newlabel_df['label_count'])
```

In [575…
```
income_year = spark.sql("SELECT income , year from bc_data where year = 2011 or year
```

In [576…
```
income_year.show()
```

```
+---------------+----+
|         income|year|
+---------------+----+
|499643.98238996|2011|
|498244.66601007|2011|
|497976.31116927|2011|
|497852.01883234|2011|
| 496785.7983011|2011|
|496766.69306791|2011|
|496651.52076174|2011|
|496324.31999242|2011|
|496150.15001557|2011|
|486752.21419529|2011|
|466023.66865338|2011|
|464548.09728703|2011|
|455501.30057744|2011|
|454856.92132679|2011|
|451523.24401692|2011|
|449111.17551607|2011|
|447785.59485753|2011|
|447427.86485753|2011|
|446573.52271277|2011|
|442561.65706485|2011|
+---------------+----+
only showing top 20 rows
```

In [ ]:

In [577…
```
income_year=income_year.toPandas()
```

In [578…
```
income_year.dtypes
```

Out[578…
```
income    float64
year        int32
dtype: object
```

In [579…
```
income_year.head(5)
```

Out[579…

	income	year
0	499643.982390	2011
1	498244.666010	2011
2	497976.311169	2011
3	497852.018832	2011
4	496785.798301	2011

In [580…

```
income_year.astype(int)
```

Out[580…

	income	year
0	499643	2011
1	498244	2011
2	497976	2011
3	497852	2011
4	496785	2011
...	...	...
649716	0	2013
649717	0	2013
649718	0	2013
649719	0	2013
649720	0	2013

649721 rows × 2 columns

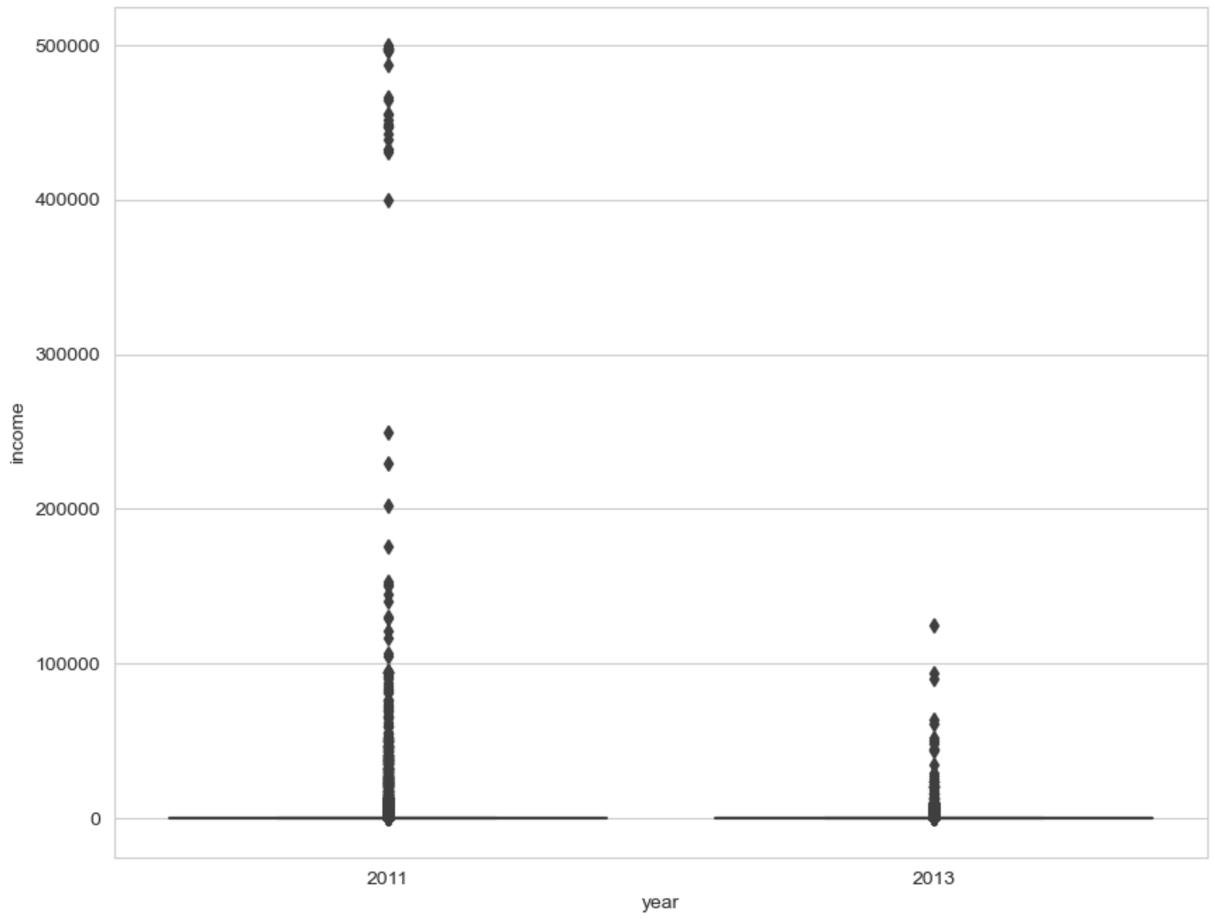
In [581…

```
income_year=income_year[income_year.income != 0]
```

boxplot

In [582…

```
ax = sns.boxplot(x="year", y="income", data=income_year)
```



In [ ]:
```
ax = sns.swarmplot(x="year", y="income", data=income_year, color=".25")
```

In [ ]:

In [583…
```
orig_df1 = orig_df[orig_df.length != 0]
```

In [584…
```
orig_df1.reset_index(drop=True, inplace=True)
```

In [585…
```
orig_df1.to_csv("C:/Users/HP/Desktop/ECE552_final/ECE552_project/BitcoinHeistData2.c
```

In [586…
```
house_df = spark.read.format("csv"). \
            option("header", "true").option("mode", "DROPMALFORMED").option("delimit
            option("ignoreLeadingWhiteSpace","true").option("ignoreTrailingWhiteSpac
            option("inferschema","true"). \
            load('C:/Users/HP/Desktop/ECE552_final/ECE552_project/BitcoinHeistData1.
```

In [ ]:

In [ ]:

In [587…
```
house_df.take(1)
```

Out[587…
```
[Row(_c0=0, address='111K8kZAEnJg245r2cM6y9zgJGHZtJPy6', year=2017, day=11, length=1
8, weight=0.008333333, count=1, looped=0, neighbors=2, income=1.0005, label='princet
onCerber')]
```

descriptive anallysis

In [588…
```
house_df.describe().toPandas().transpose()
```

Out[588…

	0	1	2	3	
summary	count	mean	stddev	min	
_c0	1048575	524287.0	302697.6735952888	0	
address	1048575	None	None	111111111111111111114oLvT2	3GbjoRZ
year	1048575	2012.0483856662613	1.005056531238343	2011	
day	1048575	173.52949383687385	100.14085576953202	1	
length	1048575	26.317415540137805	42.720042828726775	0	
weight	1048575	0.5406222223650033	2.9908459496285897	3.61E-94	
count	1048575	158.20701237393607	602.4127303067922	1	
looped	1048575	36.08665283837589	288.47339538256995	0	
neighbors	1048575	2.3242200128746155	18.623586560640728	1	
income	1048575	90.26239897843372	2555.8505269303614	0.3	

	0	1	2	3
label	1048575	None	None	montrealAPT

In [589...

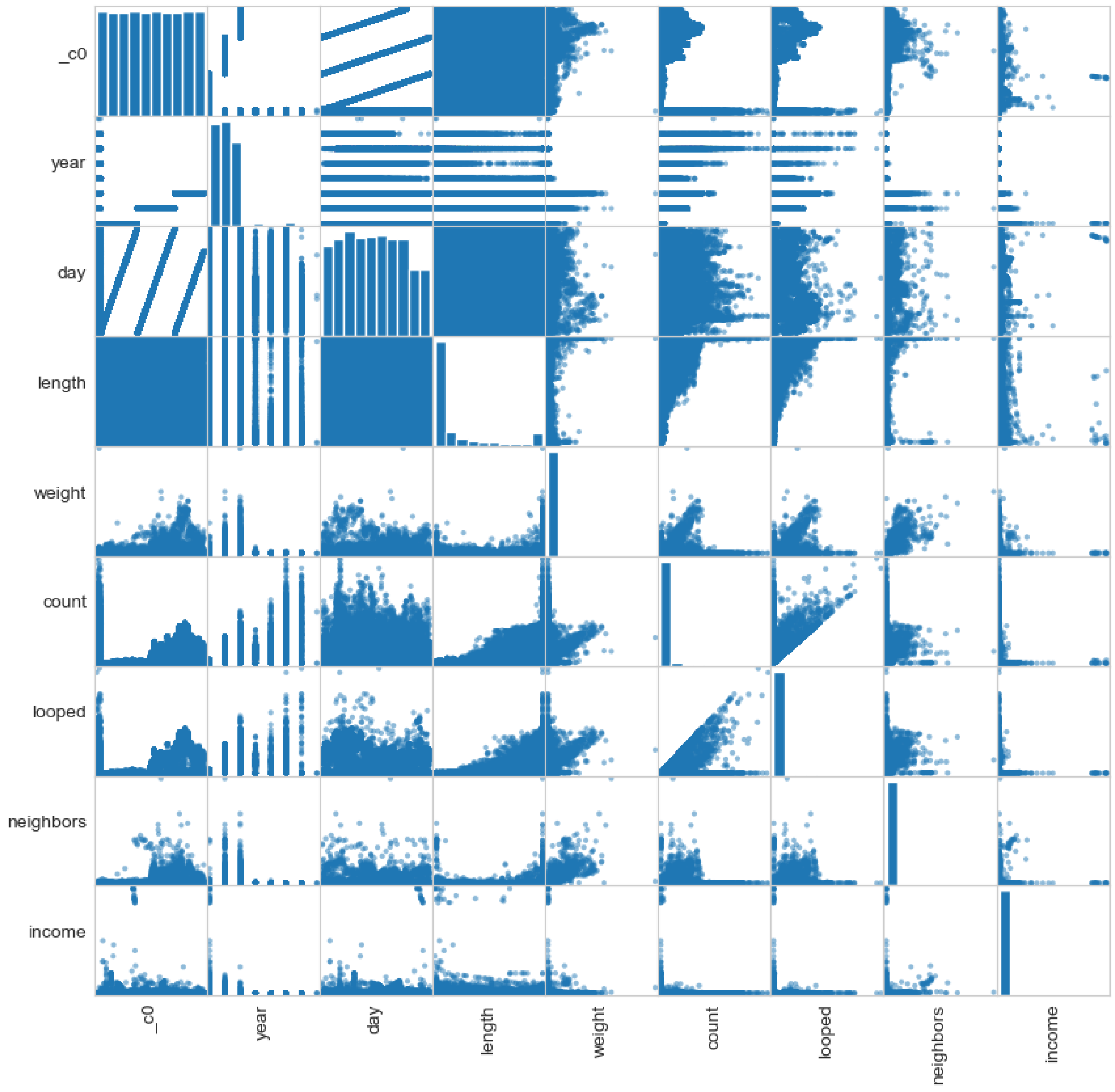
```
import pandas as pd
from pandas.plotting import scatter_matrix
```

In [590...

```
numeric_features = [t[0] for t in house_df.dtypes if t[1] == 'int' or t[1] == 'doubl
sampled_data = house_df.select(numeric_features).sample(False, 0.8).toPandas()
```

In [608...

```
axs = scatter_matrix(sampled_data, figsize=(10, 10))
#ax.set_title("Scatter matrix for linear correlation between multiple independent va
n = len(sampled_data.columns)
for i in range(n):
    v = axs[i, 0]
    v.yaxis.label.set_rotation(0)
    v.yaxis.label.set_ha('right')
    v.set_yticks(())
    h = axs[n-1, i]
    h.xaxis.label.set_rotation(90)
    h.set_xticks(())
```



Machine learning models

Linear regression model

In [592…

```
from pyspark.ml.feature import VectorAssembler
```

In [593…

```
house_df.printSchema()
```

```
root
 |-- _c0: integer (nullable = true)
 |-- address: string (nullable = true)
 |-- year: integer (nullable = true)
 |-- day: integer (nullable = true)
 |-- length: integer (nullable = true)
 |-- weight: double (nullable = true)
 |-- count: integer (nullable = true)
 |-- looped: integer (nullable = true)
 |-- neighbors: integer (nullable = true)
 |-- income: double (nullable = true)
 |-- label: string (nullable = true)
```

In [609…

```
import six
for i in house_df.columns:
    if not( isinstance(house_df.select(i).take(1)[0][0], six.string_types)):
        print( "Correlation to Length for ", i, house_df.stat.corr('length',i))
```

```
Correlation to Length for  _c0 0.046628208681509936
Correlation to Length for  year 0.09177169340486724
Correlation to Length for  day 0.04342247835202402
Correlation to Length for  length 1.0
Correlation to Length for  weight 0.060180331529211345
Correlation to Length for  count 0.6627173924217697
Correlation to Length for  looped 0.32688044270582417
Correlation to Length for  neighbors 0.08099163536800867
Correlation to Length for  income 0.009641611840837548
```

In [595…

```
vectorAssembler = VectorAssembler(inputCols = ['income', 'neighbors', 'looped', 'cou
vhouse_df = vectorAssembler.transform(house_df)
vhouse_df = vhouse_df.select(['features', 'length'])
vhouse_df.show(3)
```

```
+--------------------+------+
|            features|length|
+--------------------+------+
|[1.0005,2.0,0.0,1...|    18|
|[1.0,1.0,0.0,1.0,...|    44|
|[2.0,2.0,0.0,1.0,...|     0|
+--------------------+------+
only showing top 3 rows
```

Train and Test split

In [596…

```
splits = vhouse_df.randomSplit([0.7, 0.3])
train_df = splits[0]
test_df = splits[1]
```

In [597…

```
test_df.show()
```

```
+--------------------+------+
|            features|length|
+--------------------+------+
|[0.3,1.0,0.0,1.0,...|   130|
|[0.3,1.0,0.0,1.0,...|   114|
|[0.3,1.0,0.0,1.0,...|   118|
|[0.3,1.0,0.0,1.0,...|    66|
|[0.3,1.0,0.0,1.0,...|    90|
|[0.3,1.0,0.0,1.0,...|    62|
|[0.3,1.0,0.0,1.0,...|    70|
|[0.3,1.0,0.0,1.0,...|   104|
|[0.3,1.0,0.0,1.0,...|    64|
|[0.3,1.0,0.0,1.0,...|    84|
|[0.3,1.0,0.0,1.0,...|   108|
|[0.3,1.0,0.0,1.0,...|    50|
|[0.3,1.0,0.0,1.0,...|    50|
|[0.3,1.0,0.0,1.0,...|    56|
|[0.3,1.0,0.0,1.0,...|    38|
|[0.3,1.0,0.0,1.0,...|    42|
|[0.3,1.0,0.0,1.0,...|    28|
|[0.3,1.0,0.0,1.0,...|    28|
|[0.3,1.0,0.0,1.0,...|    38|
|[0.3,1.0,0.0,1.0,...|    44|
+--------------------+------+
only showing top 20 rows
```

In [ ]:

In [598…

```
from pyspark.ml.regression import LinearRegression
lr = LinearRegression(featuresCol = 'features', labelCol='length', maxIter=10, regPa
lr_model = lr.fit(train_df)
print("Coefficients: " + str(lr_model.coefficients))
print("Intercept: " + str(lr_model.intercept))
```

```
Coefficients: [0.0,0.0,0.0,0.0,0.0,0.9933528371493169]
Intercept: 0.1747814056096046
```

In [599…

```
trainingSummary = lr_model.summary
print("RMSE: %f" % trainingSummary.rootMeanSquaredError)
print("r2: %f" % trainingSummary.r2)
```

```
RMSE: 0.283893
r2: 0.999956
```

In [600…

```
train_df.describe().show()
```

```
+-------+-----------------+
|summary|           length|
+-------+-----------------+
|  count|           733966|
|   mean| 26.2941362406433|
| stddev|42.70898842474936|
|    min|                0|
|    max|              144|
+-------+-----------------+
```

In [601…

```
lr_predictions = lr_model.transform(test_df)
lr_predictions.select("prediction","length","features").show(5)
from pyspark.ml.evaluation import RegressionEvaluator
lr_evaluator = RegressionEvaluator(predictionCol="prediction", \
                 labelCol="length",metricName="r2")
print("R Squared (R2) on test data = %g" % lr_evaluator.evaluate(lr_predictions))
```

```
+------------------+------+--------------------+
|        prediction|length|            features|
+------------------+------+--------------------+
| 129.3106502350208|   130|[0.3,1.0,0.0,1.0,...|
|113.41700484063173|   114|[0.3,1.0,0.0,1.0,...|
|  117.390416189229|   118|[0.3,1.0,0.0,1.0,...|
| 65.73606865746453|    66|[0.3,1.0,0.0,1.0,...|
| 89.57653674904813|    90|[0.3,1.0,0.0,1.0,...|
+------------------+------+--------------------+
only showing top 5 rows

R Squared (R2) on test data = 0.999956
```

In [602…

```
test_result = lr_model.evaluate(test_df)
print("Root Mean Squared Error (RMSE) on test data = %g" % test_result.rootMeanSquar
```

```
Root Mean Squared Error (RMSE) on test data = 0.284139
```

In [603…

```
print("numIterations: %d" % trainingSummary.totalIterations)
print("objectiveHistory: %s" % str(trainingSummary.objectiveHistory))
trainingSummary.residuals.show()
```

```
numIterations: 11
objectiveHistory: [0.4999999999999999, 0.38122135545559316, 0.04948092617442175, 0.0
29621308549084034, 0.007708081762276442, 0.006428176910368608, 0.006297748096204369,
0.0062975373843313755, 0.006297411204998148, 0.006297335645781342, 0.006297290399106
494]
+--------------------+
|           residuals|
+--------------------+
|  0.5431121822641671|
|  0.6760554392778317|
| 0.46334622805596837|
|  0.3835802738477696|
|     0.5697008336669|
|  0.6095838107709994|
|  0.6627611135764653|
|  0.6760554392778317|
| 0.46334622805596837|
|   0.423463250951869|
|  0.5165235308614342|
|  0.5298178565628007|
|  0.5032292051600677|
|  0.5431121822641671|
|  0.3171086453409373|
|  0.6095838107709994|
|  0.3569916224450367|
|  0.2506370168341121|
| 0.33040297104230376|
|  0.5564065079655336|
+--------------------+
only showing top 20 rows
```

In [604…

```
predictions = lr_model.transform(test_df)
predictions.select("prediction","length","features").show()
```

```
+------------------+------+--------------------+
|        prediction|length|            features|
+------------------+------+--------------------+
| 129.3106502350208|   130|[0.3,1.0,0.0,1.0,...|
|113.41700484063173|   114|[0.3,1.0,0.0,1.0,...|
|  117.390416189229|   118|[0.3,1.0,0.0,1.0,...|
| 65.73606865746453|    66|[0.3,1.0,0.0,1.0,...|
| 89.57653674904813|    90|[0.3,1.0,0.0,1.0,...|
|61.762657308867254|    62|[0.3,1.0,0.0,1.0,...|
|  69.7094800060618|    70|[0.3,1.0,0.0,1.0,...|
|103.48347646913857|   104|[0.3,1.0,0.0,1.0,...|
| 63.74936298316589|    64|[0.3,1.0,0.0,1.0,...|
| 83.61641972615223|    84|[0.3,1.0,0.0,1.0,...|
|107.45688781773583|   108|[0.3,1.0,0.0,1.0,...|
| 49.84242326307545|    50|[0.3,1.0,0.0,1.0,...|
| 49.84242326307545|    50|[0.3,1.0,0.0,1.0,...|
|55.802540285971354|    56|[0.3,1.0,0.0,1.0,...|
| 37.92218921728365|    38|[0.3,1.0,0.0,1.0,...|
| 41.89560056588092|    42|[0.3,1.0,0.0,1.0,...|
|27.988660845790477|    28|[0.3,1.0,0.0,1.0,...|
|27.988660845790477|    28|[0.3,1.0,0.0,1.0,...|
| 37.92218921728365|    38|[0.3,1.0,0.0,1.0,...|
| 43.88230624017955|    44|[0.3,1.0,0.0,1.0,...|
+------------------+------+--------------------+
only showing top 20 rows
```

In [605…

```
test_df
```

Out[605…

```
DataFrame[features: vector, length: int]
```

In [606…

```
from pyspark.ml.regression import DecisionTreeRegressor
dt = DecisionTreeRegressor(featuresCol ='features', labelCol = 'length')
dt_model = dt.fit(train_df)
dt_predictions = dt_model.transform(test_df)
dt_evaluator = RegressionEvaluator(
    labelCol="length", predictionCol="prediction", metricName="rmse")
rmse = dt_evaluator.evaluate(dt_predictions)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse)
```

```
Root Mean Squared Error (RMSE) on test data = 2.39521
```

In [ ]:

In [ ]: