In [132...

```
import numpy as np
from numpy import where
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from sklearn.svm import OneClassSVM
from sklearn.ensemble import IsolationForest
from sklearn.covariance import EllipticEnvelope
sns.set_style("darkgrid")
```

In [515...

```
general = pd.read_csv('General_Payments_2020.csv', parse_dates=['Date_of_Payment', 'Payment_Publication_Date'],
                      dtype={'Teaching_Hospital_CCN': np.float32,
                             'Teaching_Hospital_ID': np.float16,
                             'Physician_Profile_ID' : np.float32,
                             'Total_Amount_of_Payment_USDollars': np.float32,
                             'Number_of_Payments_in_Total_Amount': np.int16,
                             'Record_ID': np.int32})
```

```
/Users/marcusyeo/anaconda3/lib/python3.8/site-packages/IPython/core/interactiveshell.py:3457: DtypeWarning: Colum
ns (4,7,9,11,14,16,17,21,22,23,24,27,34,35,36,39,40,41,42,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,6
5,66,67,68,69,70) have mixed types.Specify dtype option on import or set low_memory=False.
  exec(code_obj, self.user_global_ns, self.user_ns)
```

In [485...

```
investments = pd.read_csv('Ownership_Investment_2020.csv')
```

In [486...

```
research = pd.read_csv('Research_Payments_2020.csv')
```

```
/Users/marcusyeo/anaconda3/lib/python3.8/site-packages/IPython/core/interactiveshell.py:3457: DtypeWarning: Colum
ns (2,5,7,8,9,10,17,18,19,20,21,22,23,24,32,33,38,39,43,44,45,46,51,52,53,59,60,61,95,100,101,102) have mixed typ
es.Specify dtype option on import or set low_memory=False.
  exec(code_obj, self.user_global_ns, self.user_ns)
```

General Dataset

In [516...

```
general_raw = general.copy()
general.head()
```

Out[516...

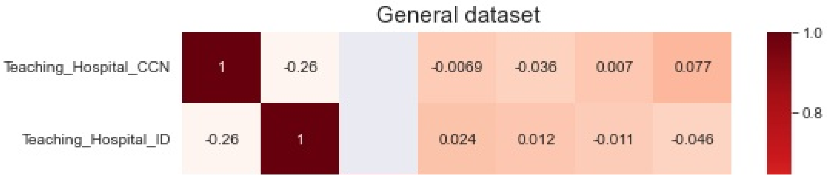
	Change_Type	Covered_Recipient_Type	Teaching_Hospital_CCN	Teaching_Hospital_ID	Teaching_Hospital_Name	Physician_Profile_ID	Physici
0	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	557946.0	
1	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	276936.0	
2	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	1275463.0	
3	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	268352.0	
4	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	904225.0	

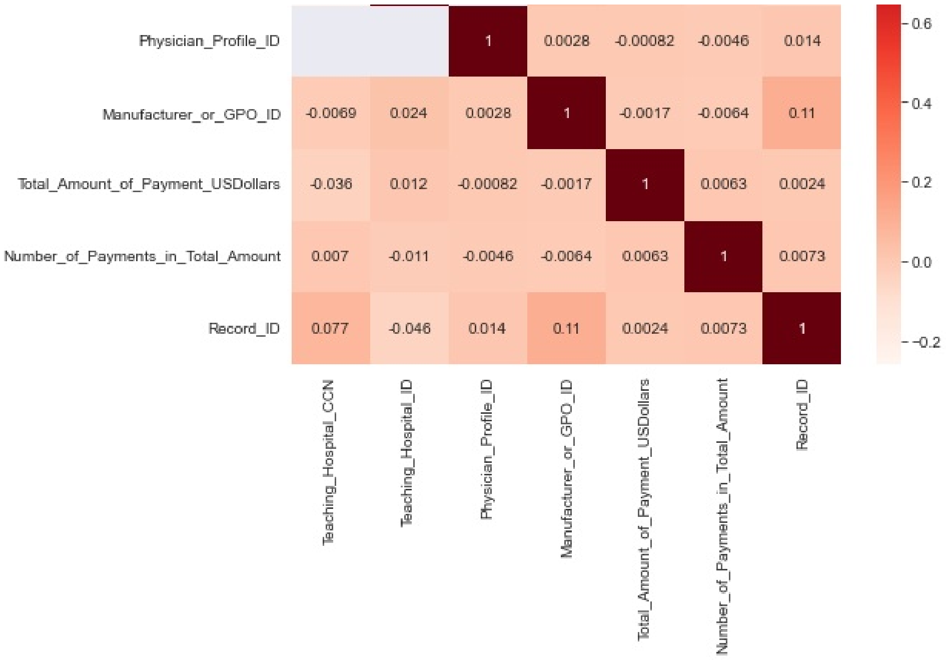
5 rows × 72 columns

Using Pearson Correlation to get a sensing of different features

In [488...

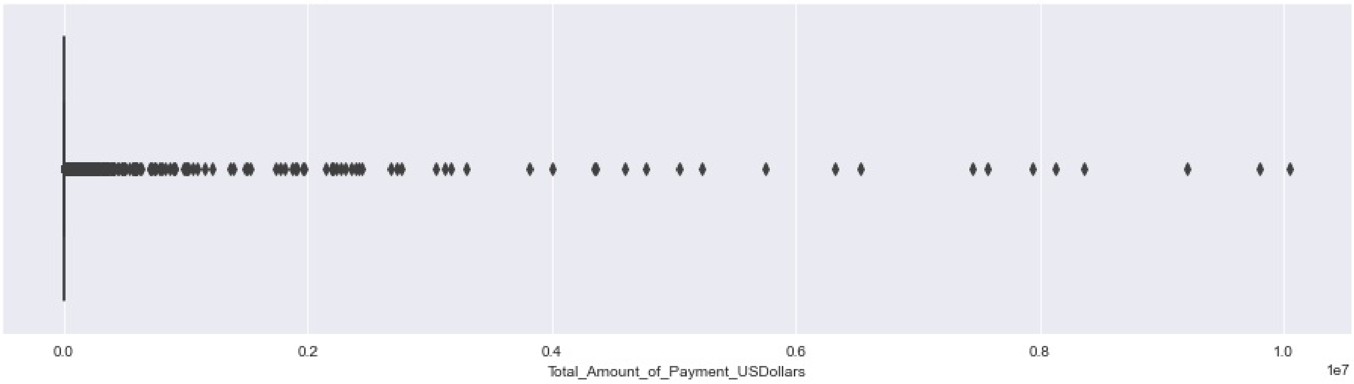
```
#Using Pearson Correlation
plt.figure(figsize=(8,6))
plt.title('General dataset',fontsize=15)
cor = general.corr()
sns.heatmap(cor, annot=True, cmap=plt.cm.Reds)
plt.show()
```





In [489…

```
plt.figure(figsize=(16,4))
sns.boxplot(data=df,x ='Total_Amount_of_Payment_USDollars')
plt.show()
```

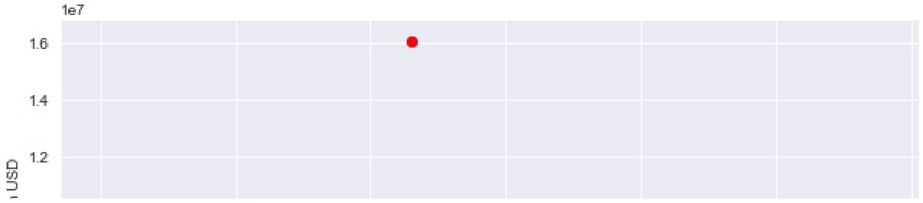


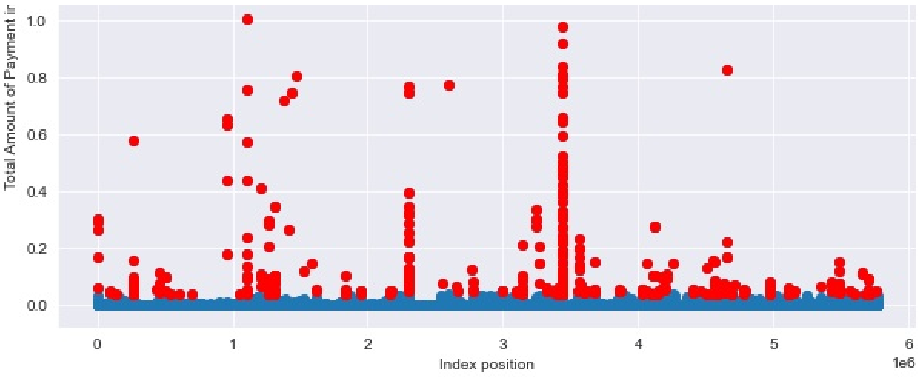
Anomaly Detection with Isolation Forests for Single Feature

In [490…

```
model = IsolationForest(contamination= 0.0001, random_state = 101)
model.fit(general[['Total_Amount_of_Payment_USDollars']])

general['index'] = general.index
general['scores'] = model.decision_function(general[['Total_Amount_of_Payment_USDollars']])
general['anomaly'] = model.predict(general[['Total_Amount_of_Payment_USDollars']])

print(general['anomaly'].value_counts())

outlier_index = where(general['anomaly'] == -1)
outlier_values = general.iloc[outlier_index]

plt.figure(figsize=(10,6))
plt.scatter(general['index'],general['Total_Amount_of_Payment_USDollars'])
plt.scatter(outlier_values['index'], outlier_values['Total_Amount_of_Payment_USDollars'], c = "r")
plt.title('With outliers',fontsize=18)
plt.ylabel('Total Amount of Payment in USD')
plt.xlabel('Index position')
plt.show()
```

```
/Users/marcusyeo/anaconda3/lib/python3.8/site-packages/sklearn/base.py:450: UserWarning: X does not have valid fe
ature names, but IsolationForest was fitted with feature names
  warnings.warn(
```





In [498…

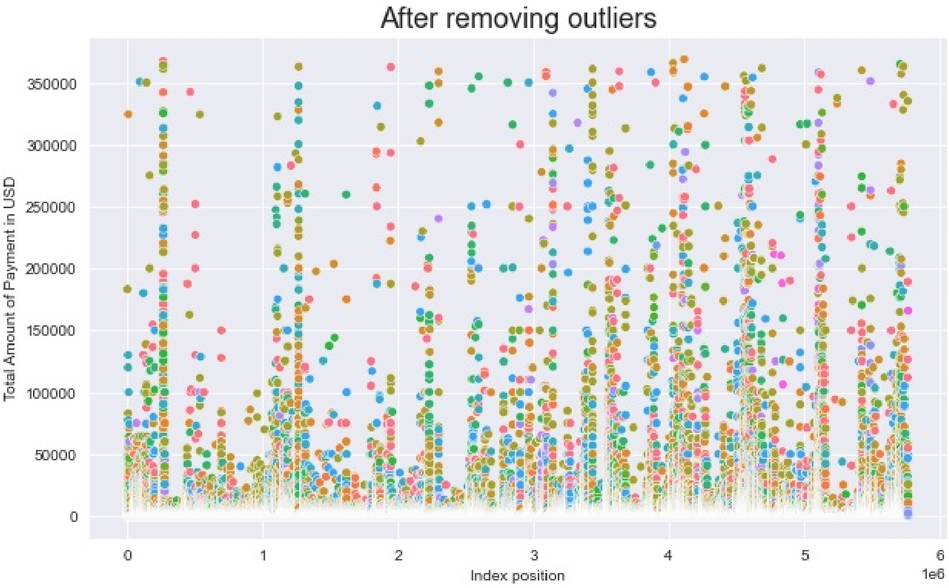
```
list_index = list(outlier_index[0])
```

In [499…

```
general.drop(list_index, axis=0, inplace=True)
```

In [505…

```
plt.figure(figsize=(10,6))
# plt.scatter(general['index'],general['Total_Amount_of_Payment_USDollars'])
sns.scatterplot(data=general,x='index',y='Total_Amount_of_Payment_USDollars',hue='Recipient_State',legend=False)
plt.title('After removing outliers',fontsize=18)
plt.ylabel('Total Amount of Payment in USD')
plt.xlabel('Index position')
plt.show()
```



Analysing Outliers for Total Payment in General Payment

In [399…

```
# outlier_values.columns
```

In [330…

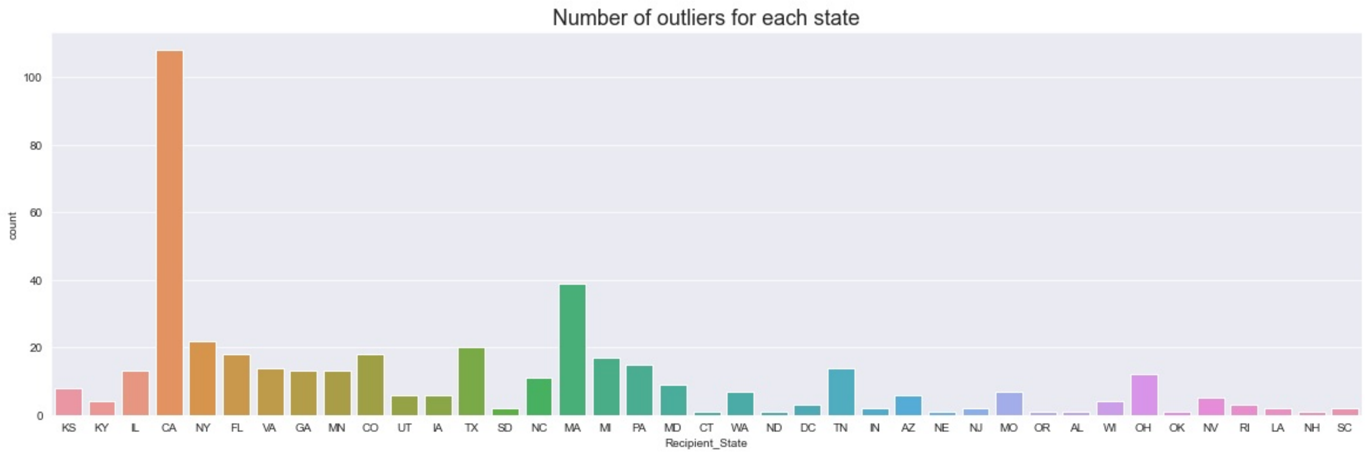
```
outlier_values.describe()
```

Out[330…

	Teaching_Hospital_CCN	Teaching_Hospital_ID	Physician_Profile_ID	Manufacturer_or_GPO_ID	Total_Amount_of_Payment_USDollars	Numb
count	160.00000	160.0	2.730000e+02	4.330000e+02	4.330000e+02	
mean	171417.15625	inf	5.547838e+05	1.000000e+11	1.404148e+06	
std	133656.78125	inf	1.108956e+06	9.456788e+04	1.892230e+06	
min	10033.00000	8632.0	1.618400e+04	1.000000e+11	3.716110e+05	
25%	50146.00000	9008.0	1.274990e+05	1.000000e+11	4.660606e+05	
50%	110010.00000	9672.0	2.528480e+05	1.000000e+11	5.866689e+05	
75%	230046.00000	9928.0	4.893040e+05	1.000000e+11	1.393243e+06	
max	460009.00000	9928.0	8.804061e+06	1.000008e+11	1.602908e+07	

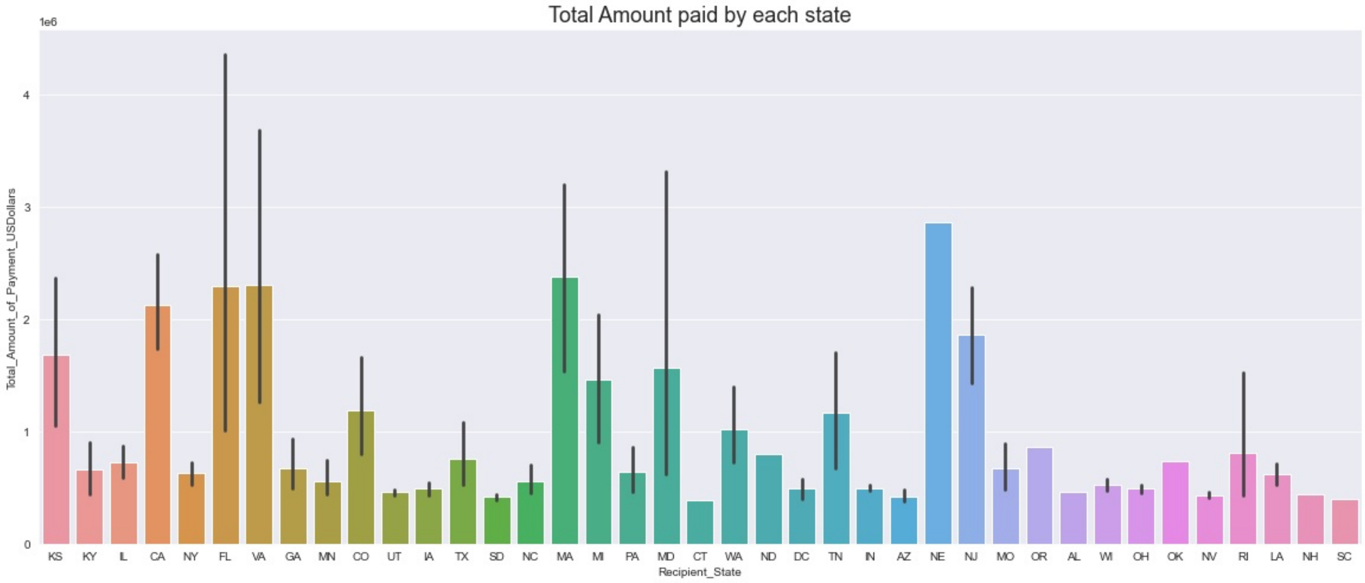
In [355…

```
plt.figure(figsize=(20,6))
sns.countplot(data=outlier_values,x='Recipient_State')
plt.title('Number of outliers for each state',fontsize=18)
plt.show()
```



In [357…

```
plt.figure(figsize=(20,8))
sns.barplot(data=outlier_values,x='Recipient_State',y='Total_Amount_of_Payment_USDollars',estimator=np.mean)
plt.title('Total Amount paid by each state',fontsize=18)
plt.show()
```



> Suspicious: FL, VA, MD, NE, NU

In [508…

```
NE = outlier_values[outlier_values['Recipient_State'] == 'NE']
NE
```

Out[508…

	Change_Type	Covered_Recipient_Type	Teaching_Hospital_CCN	Teaching_Hospital_ID	Teaching_Hospital_Name	Physician_Profile_ID
2299887	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	1008618.0

1 rows × 75 columns

In [507…

```
# for x in NE.iloc[0]:
#     print(x)
```

> Conclusion: NE's single payment related to the acquisition of Avenu Medical.

In [377…

```
FL = outlier_values[outlier_values['Recipient_State'] == 'FL']
```

In [395…

```
FL.head()
```

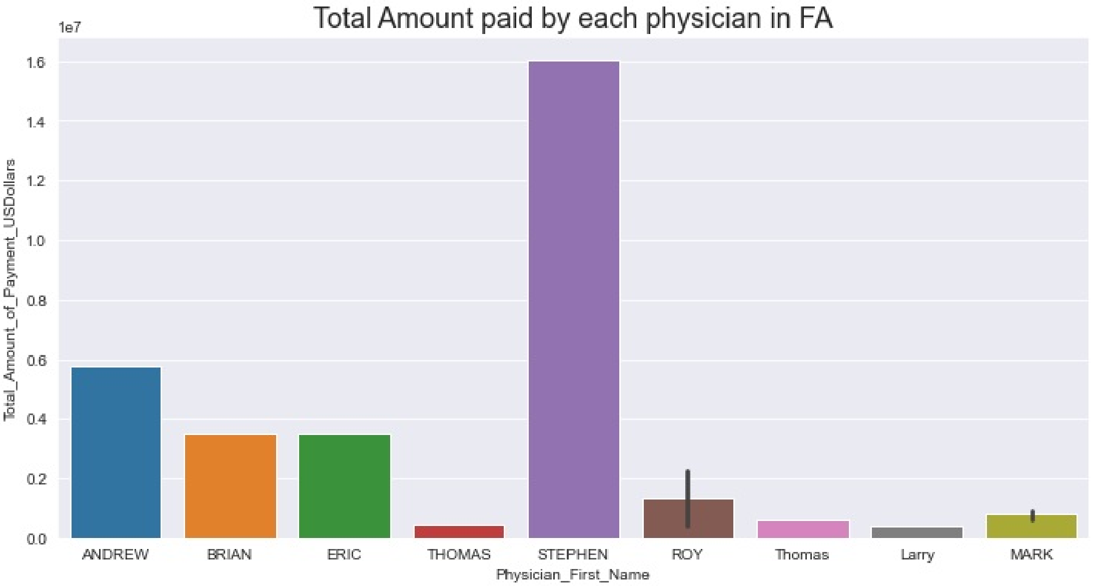
Out[395…

	Change_Type	Covered_Recipient_Type	Teaching_Hospital_CCN	Teaching_Hospital_ID	Teaching_Hospital_Name	Physician_Profile_ID	F
263886	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	258909.0	
1311817	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	5705128.0	
1311818	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	217494.0	
1312185	UNCHANGED	Covered Recipient Teaching Hospital	100079.0	9472.0	University Of Miami Hosp & Clinics	NaN	
1943614	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	231549.0	

5 rows × 75 columns

In [529…

```
plt.figure(figsize=(12,6))
sns.barplot(data=FL,x='Physician_First_Name',y='Total_Amount_of_Payment_USDollars',estimator=np.mean)
plt.title('Total Amount paid by each physician in FA',fontsize=18)
plt.show()
```



In [520…

```
# for x in general_raw.iloc[2299889]:
#     print(x)
```

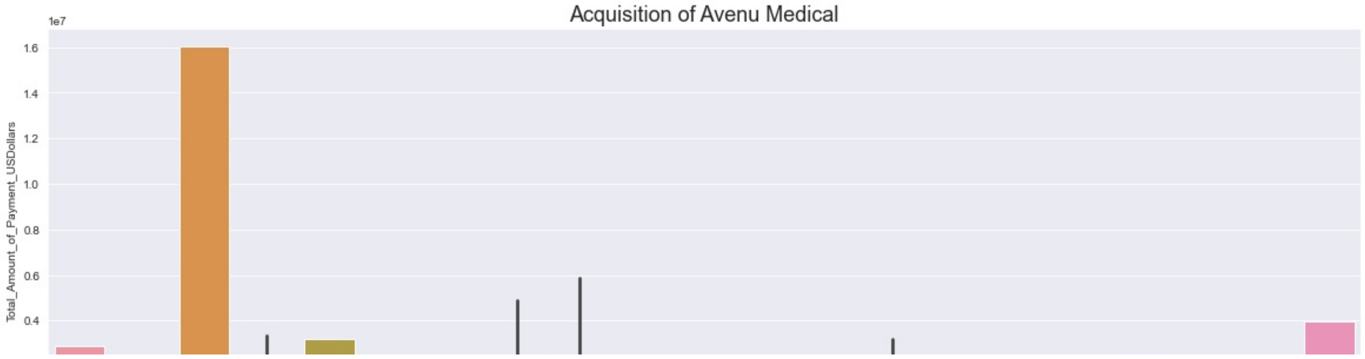
> Conclusion: Stephen's payment related to the acquisition of Avenu Medical.

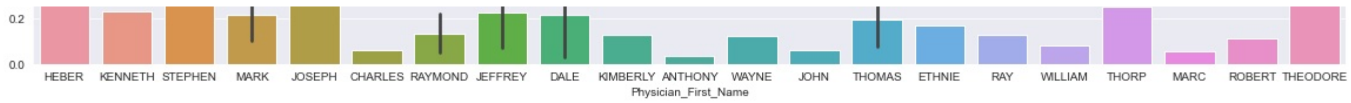
In [522…

```
acq = general_raw[general_raw['Contextual_Information'] == 'Payment related to the acquisition of Avenu Medical.'
```

In [526…

```
plt.figure(figsize=(20,6))
sns.barplot(data=acq,x='Physician_First_Name',y='Total_Amount_of_Payment_USDollars',estimator=np.mean)
plt.title('Acquisition of Avenu Medical',fontsize=18)
plt.show()
```





In [ ]:

In [ ]:

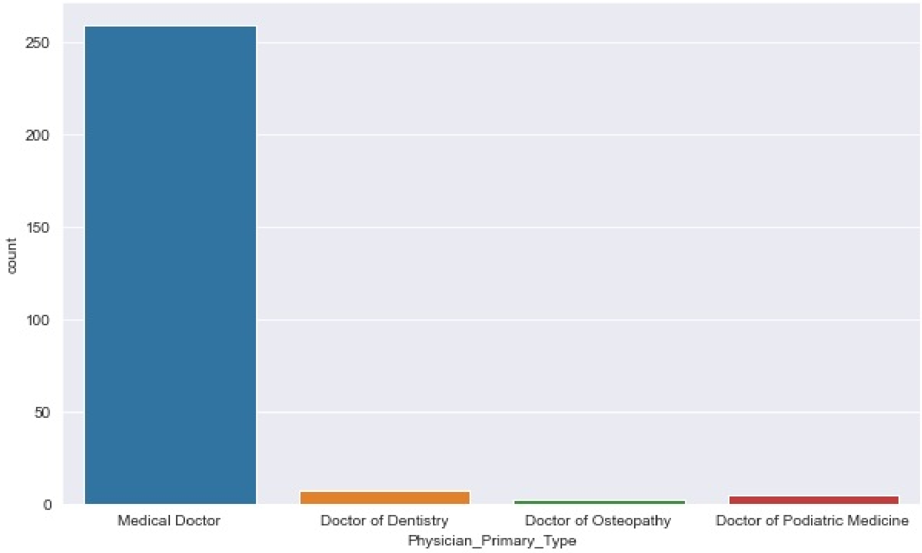
In [ ]:

In [ ]:

In [ ]:

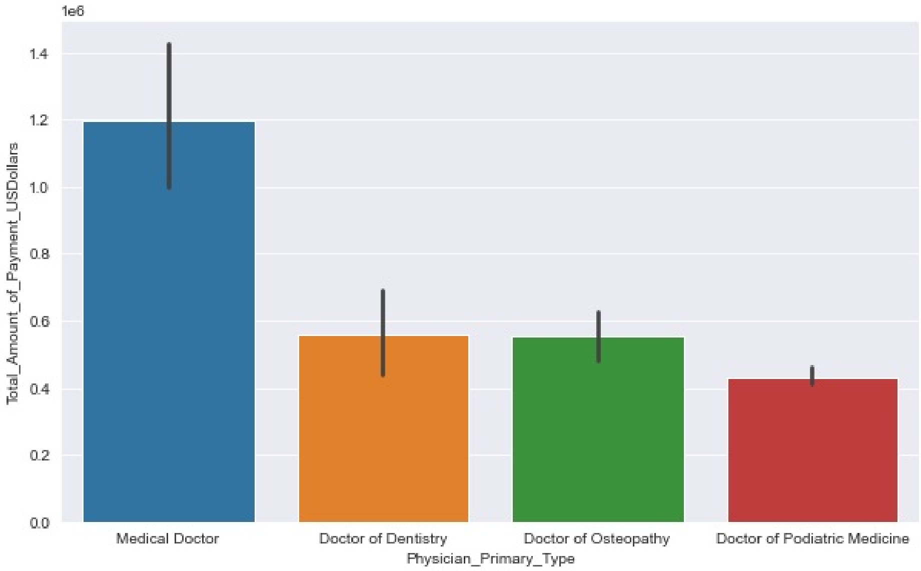
In [409…

```
plt.figure(figsize=(10,6))
sns.countplot(data=outlier_values,x='Physician_Primary_Type')
plt.show()
```



In [405…

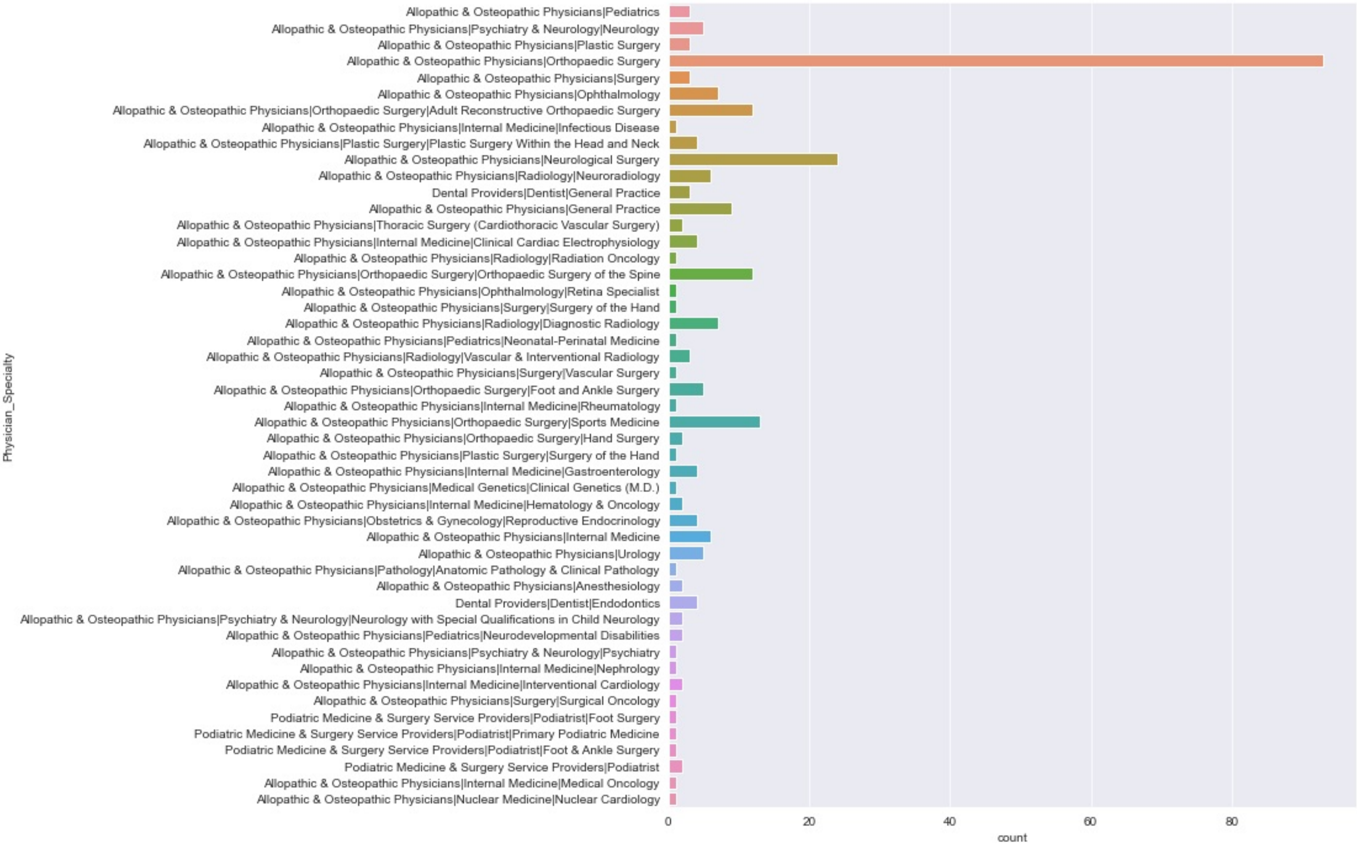
```
plt.figure(figsize=(10,6))
sns.barplot(data=outlier_values,x='Physician_Primary_Type',y='Total_Amount_of_Payment_USDollars',estimator=np.mea
plt.show()
```



In [347…

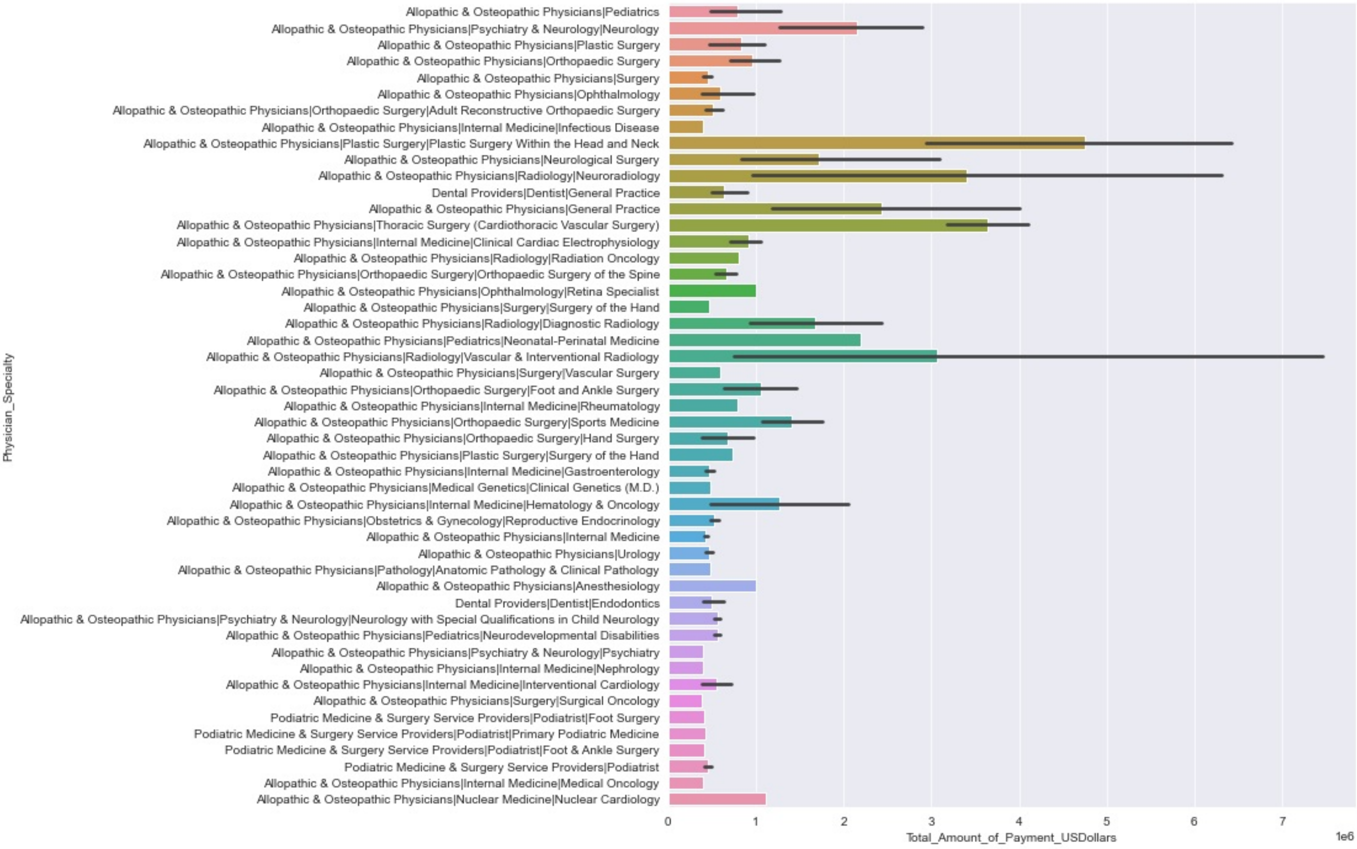
```
plt.figure(figsize=(10,12))
sns.countplot(data=outlier_values,y='Physician_Specialty')
```

```
plt.show()
```



In [404…

```
plt.figure(figsize=(10,12))
sns.barplot(data=outlier_values,y='Physician_Specialty',x='Total_Amount_of_Payment_USDollars',estimator=np.mean)
plt.show()
```



In [ ]:

```

```

In [ ]:

```

```

In [ ]:

```

```

In [ ]:

```

```

Investments Dataset

In [109…

```
investments.head()
```

Out[109…

	Change_Type	Physician_Profile_ID	Physician_First_Name	Physician_Middle_Name	Physician_Last_Name	Physician_Name_Suffix	Recipient_P
0	UNCHANGED	134335	Aysha	NaN	Khalid	NaN	
1	UNCHANGED	997719	Jamie	NaN	Koprivnikar	NaN	
2	UNCHANGED	32057	Peter	NaN	Kourlas	NaN	
3	UNCHANGED	887574	Gurpreet	NaN	Lamba	NaN	
4	UNCHANGED	138170	Craig	NaN	Lampert	NaN	

5 rows × 26 columns

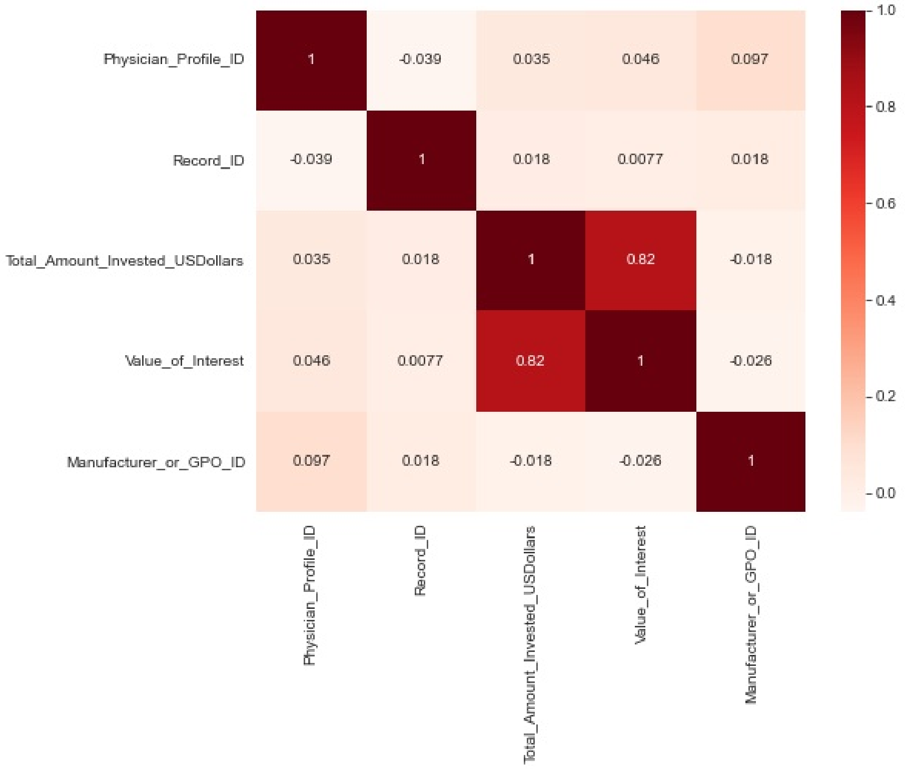
Using Pearson Correlation to get a sensing of different features

In [113…

```
investments_dropped = investments.drop('Recipient_Province',axis=1)
investments_dropped = investments_dropped.drop('Recipient_Postal_Code',axis=1)
```

In [417…

```
plt.figure(figsize=(8,6))
cor = investments_dropped.corr()
sns.heatmap(cor, annot=True, cmap=plt.cm.Reds)
plt.show()
```

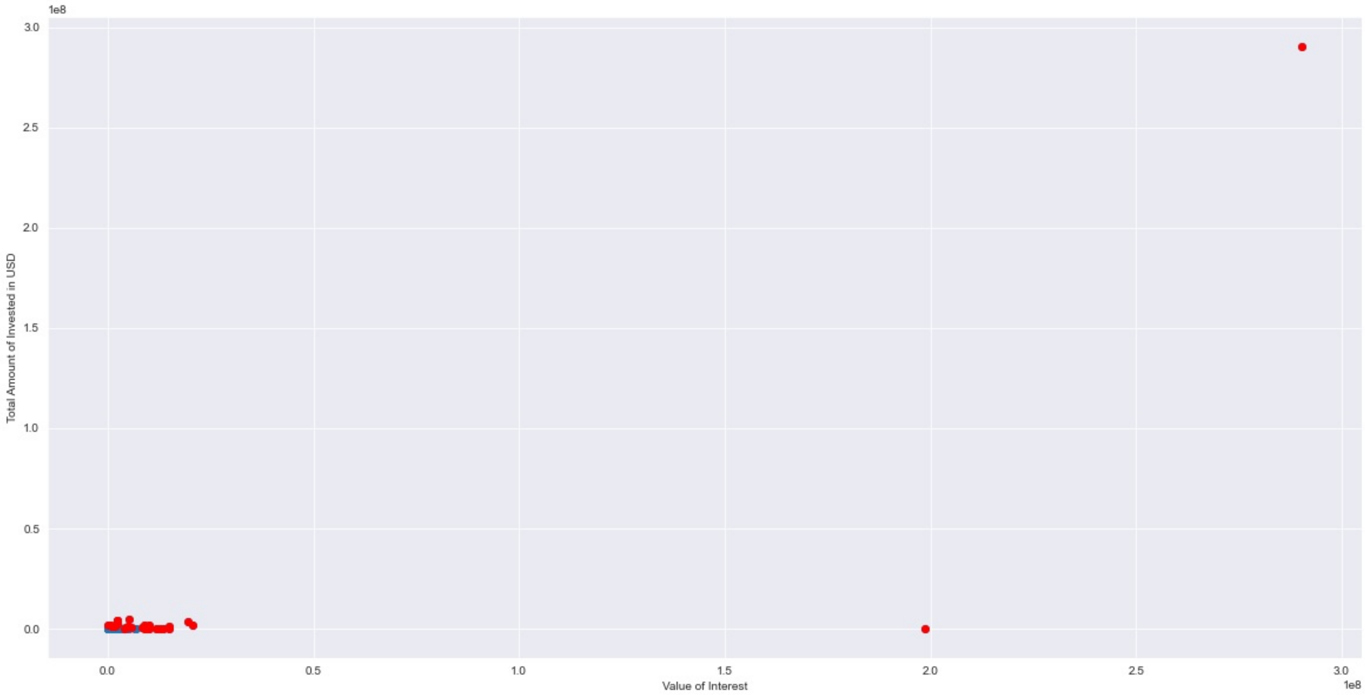


In [471…

```
model2 = IsolationForest(contamination= 0.01, random_state = 101)
model2.fit(investments[['Value_of_Interest','Total_Amount_Invested_USDollars']])

investments['index'] = investments.index
investments['scores'] = model2.decision_function(investments[['Value_of_Interest','Total_Amount_Invested_USDollar
investments['anomaly'] = model2.predict(investments[['Value_of_Interest','Total_Amount_Invested_USDollars']])
```

```
print(investments['anomaly'].value_counts())
outlier_index2 = where(investments['anomaly'] == -1)
outlier_values2 = investments.iloc[outlier_index2]

plt.figure(figsize=(20,10))
plt.scatter(investments['Value_of_Interest'],investments['Total_Amount_Invested_USDollars'])
plt.scatter(outlier_values2['Value_of_Interest'], outlier_values2['Total_Amount_Invested_USDollars'], c = "r")
plt.ylabel('Total Amount of Invested in USD')
plt.xlabel('Value of Interest')
plt.show()
```

```
/Users/marcusyeo/anaconda3/lib/python3.8/site-packages/sklearn/base.py:450: UserWarning: X does not have valid fe
ature names, but IsolationForest was fitted with feature names
  warnings.warn(
 1    3205
-1      33
Name: anomaly, dtype: int64
```



In [472…

```
outlier_index2
```

Out[472…

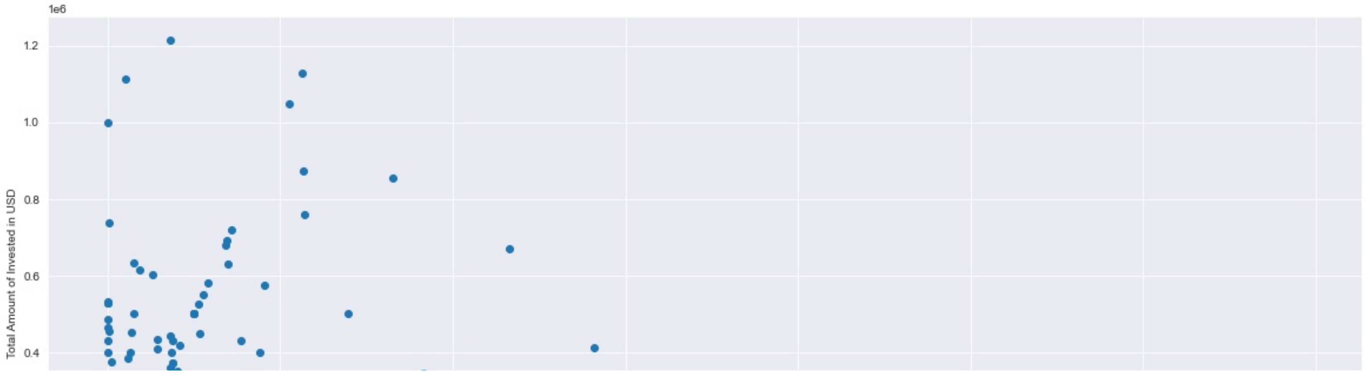
```
(array([ 261,  283,  349,  367,  376,  458,  459,  471,  738,  890, 1383,
        1387, 1625, 1878, 1879, 2001, 2002, 2003, 2005, 2171, 2224, 2291,
        2349, 2350, 2363, 2443, 2452, 2498, 2590, 2595, 2817, 2925, 2926]),)
```

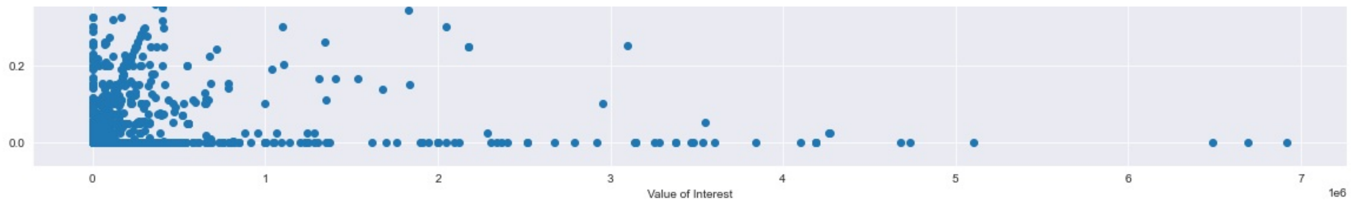
In [473…

```
investments.drop([ 261,  283,  349,  367,  376,  458,  459,  471,  738,  890, 1383,
                  1387, 1625, 1878, 1879, 2001, 2002, 2003, 2005, 2171, 2224, 2291,
                  2349, 2350, 2363, 2443, 2452, 2498, 2590, 2595, 2817, 2925, 2926], axis=0, inplace=True)
```

In [474…

```
plt.figure(figsize=(20,8))
plt.scatter(investments['Value_of_Interest'],investments['Total_Amount_Invested_USDollars'])
plt.ylabel('Total Amount of Invested in USD')
plt.xlabel('Value of Interest')
plt.show()
```





In [475…

```
investments['natural_log_voi'] = np.log(investments['Value_of_Interest'])
investments['natural_log_total'] = np.log(investments['Total_Amount_Invested_USDollars'])
```

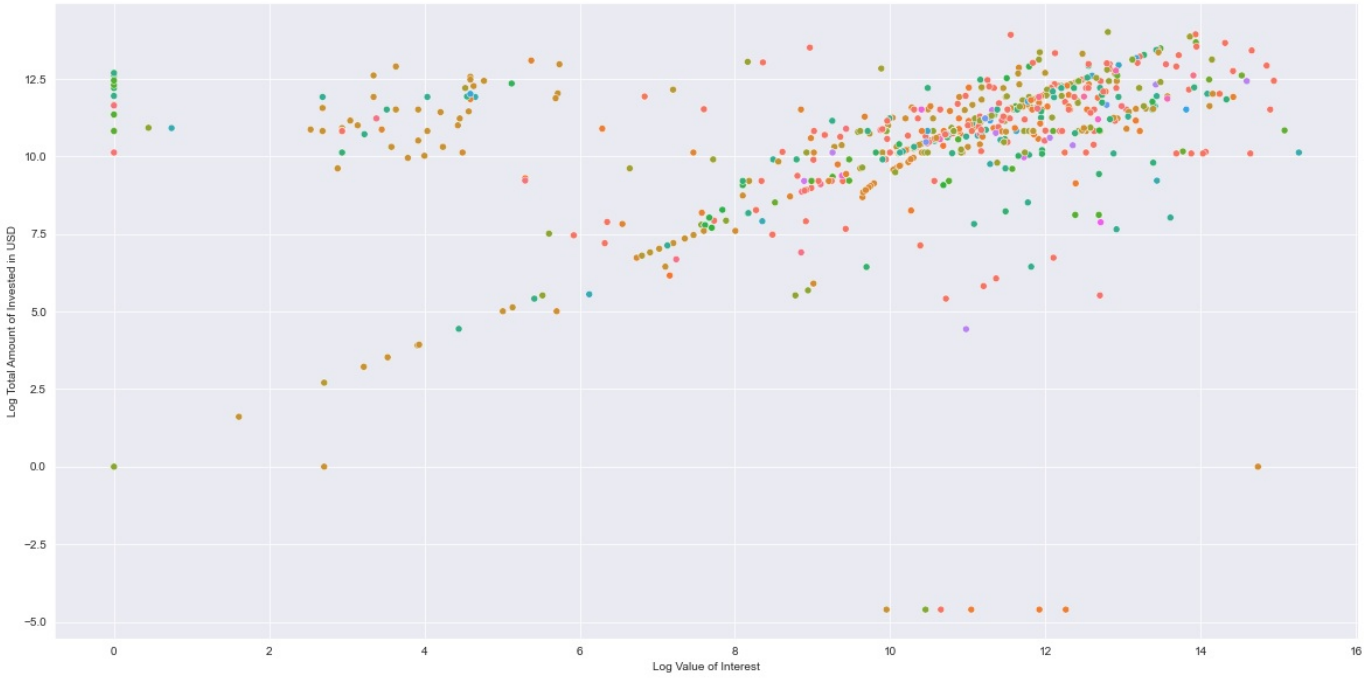
```
/Users/marcusyeo/anaconda3/lib/python3.8/site-packages/pandas/core/arraylike.py:364: RuntimeWarning: divide by ze
ro encountered in log
  result = getattr(ufunc, method)(*inputs, **kwargs)
```

In [476…

```
# plt.figure(figsize=(20,8))
# plt.scatter(data = investments,
#             x = 'natural_log_voi',
#             y = 'natural_log_total',
#             c = 'Physician_Specialty')
# plt.ylabel('Log Total Amount of Invested in USD')
# plt.xlabel('Log Value of Interest')
# plt.show()
```

In [477…

```
plt.figure(figsize=(20,10))
sns.scatterplot(data = investments,
                x = 'natural_log_voi',
                y = 'natural_log_total',
                hue = 'Physician_Specialty')
plt.ylabel('Log Total Amount of Invested in USD')
plt.xlabel('Log Value of Interest')
plt.legend([],[], frameon=False)
plt.show()
```



In [ ]:

In [437…

```
# model = OneClassSVM(kernel = 'rbf', gamma = 'auto', nu = 0.005).fit(df_investments)
```

In [438…

```
# y_pred = model.predict(df_investments)
# y_pred
```

In [439…

```
# # filter outlier index
# outlier_index = where(y_pred == -1)
# # filter outlier values
# outlier_values = df_investments.iloc[outlier_index]
# outlier_values
```

In [440…

```
# # visualize outputs
# plt.scatter(df_investments['Total_Amount_Invested_USDollars'], df_investments['Value_of_Interest'])
# plt.scatter(outlier_values['Total_Amount_Invested_USDollars'], outlier_values['Value_of_Interest'], c = "r")
# plt.show()
```

Research Dataset

In [447…

```
research.head()
```

Out[447…

	Change_Type	Covered_Recipient_Type	Noncovered_Recipient_Entity	Teaching_Hospital_CCN	Teaching_Hospital_ID	Teaching_Hospital_Name
0	UNCHANGED	Covered Recipient Teaching Hospital	NaN	220110.0	8641.0	Brigham And Womens Hospital
1	UNCHANGED	Covered Recipient Teaching Hospital	NaN	310001.0	8837.0	HACKENSACK UNIVERSITY MEDICAL CENTER
2	UNCHANGED	Covered Recipient Physician	NaN	NaN	NaN	NaN
3	UNCHANGED	Covered Recipient Teaching Hospital	NaN	50047.0	9847.0	CALIFORNIA PACIFIC MEDICAL CENTER
4	UNCHANGED	Covered Recipient Teaching Hospital	NaN	100258.0	9699.0	Delray Medical Center

5 rows × 97 columns

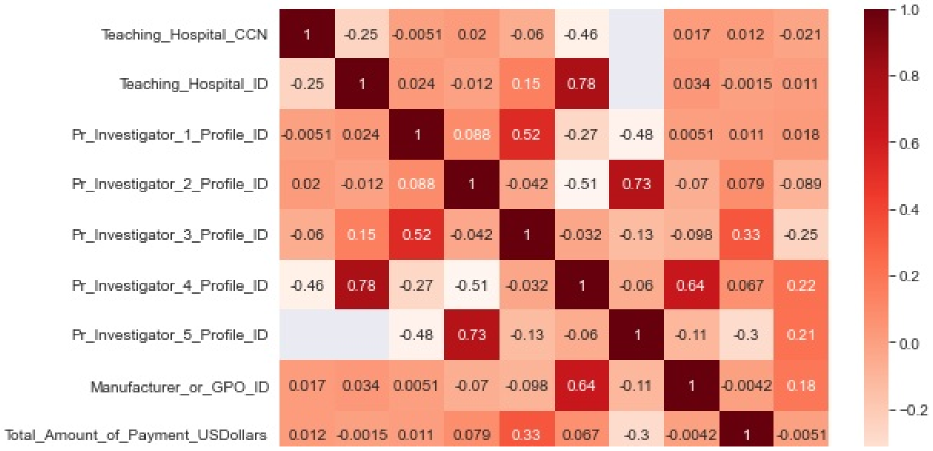
Using Pearson Correlation to get a sensing of different features

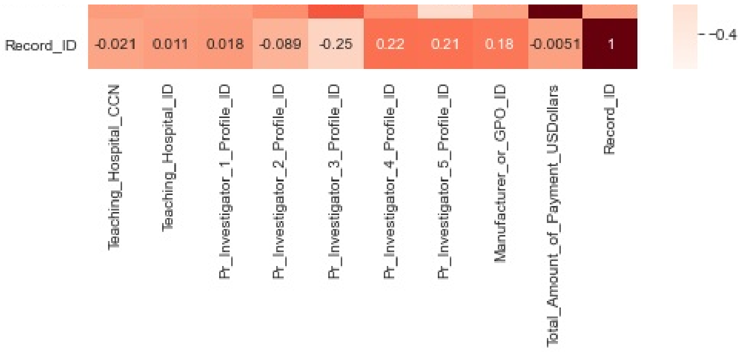
In [449…

```
to_drop = ['Physician_Profile_ID',
           'Physician_License_State_code5',
           'Pr_Investigator_2_License_State_code4',
           'Pr_Investigator_2_License_State_code5',
           'Pr_Investigator_3_License_State_code3',
           'Pr_Investigator_3_License_State_code4',
           'Pr_Investigator_3_License_State_code5',
           'Pr_Investigator_4_License_State_code2',
           'Pr_Investigator_4_License_State_code3',
           'Pr_Investigator_4_License_State_code4',
           'Pr_Investigator_4_License_State_code5',
           'Pr_Investigator_5_License_State_code2',
           'Pr_Investigator_5_License_State_code3',
           'Pr_Investigator_5_License_State_code4',
           'Pr_Investigator_5_License_State_code5',
           'Expenditure_Category5',
           'Expenditure_Category6']

research.drop(columns=to_drop,inplace=True)
```

In [451…

```
plt.figure(figsize=(8,6))
cor = research.corr()
sns.heatmap(cor, annot=True, cmap=plt.cm.Reds)
plt.show()
```





Loading [MathJax]/jax/output/CommonHTML/fonts/TeX/fontdata.js