Microsoft Malaware Data Challenge

As one part of their overall strategy for doing so, Microsoft is challenging the data science community to develop techniques to predict if a machine will soon be hit with malware.

https://www.kaggle.com/c/microsoft-malware-prediction (https://www.kaggle.com/c/microsoft-malware-prediction)

In [168]:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.pyplot import figure
import seaborn as sns
```

1 Data Setup and Exploration

1.1 Loading MSFT Data

In [169]:

```
# referred https://www.kaggle.com/theoviel/load-the-totality-of-the-data
dtypes = {
        'MachineIdentifier':                                    'category',
        'ProductName':                                          'category',
        'EngineVersion':                                        'category',
        'AppVersion':                                           'category',
        'AvSigVersion':                                         'category',
        'IsBeta':                                               'int8',
        'RtpStateBitfield':                                     'float16',
        'IsSxsPassiveMode':                                     'int8',
        'DefaultBrowsersIdentifier':                            'float32',
        'AVProductStatesIdentifier':                            'float32',
        'AVProductsInstalled':                                  'float16',
        'AVProductsEnabled':                                    'float16',
        'HasTpm':                                               'int8',
        'CountryIdentifier':                                    'int16',
        'CityIdentifier':                                       'float32',
        'OrganizationIdentifier':                               'float16',
        'GeoNameIdentifier':                                    'float16',
        'LocaleEnglishNameIdentifier':                          'int16',
        'Platform':                                             'category',
        'Processor':                                            'category',
        'OsVer':                                                'category',
        'OsBuild':                                              'int16',
        'OsSuite':                                              'int16',
        'OsPlatformSubRelease':                                 'category',
        'OsBuildLab':                                           'category',
        'SkuEdition':                                           'category',
        'IsProtected':                                          'float16',
        'AutoSampleOptIn':                                      'int8',
        'PuaMode':                                              'category',
        'SMode':                                                'float16',
        'IeVerIdentifier':                                      'float16',
        'SmartScreen':                                          'category',
        'Firewall':                                             'float16',
        'UacLuaenable':                                         'float32',
        'UacLuaenable':                                         'float64',
        'Census_MDC2FormFactor':                                'category',
        'Census_DeviceFamily':                                  'category',
        'Census_OEMNameIdentifier':                             'float32',
        'Census_OEMModelIdentifier':                            'float32',
        'Census_ProcessorCoreCount':                            'float16',
        'Census_ProcessorManufacturerIdentifier':               'float16',
        'Census_ProcessorModelIdentifier':                      'float32',
        'Census_ProcessorClass':                                'category',
        'Census_PrimaryDiskTotalCapacity':                      'float64',
        'Census_PrimaryDiskTypeName':                           'category',
        'Census_SystemVolumeTotalCapacity':                     'float64',
        'Census_HasOpticalDiskDrive':                           'int8',
        'Census_TotalPhysicalRAM':                              'float32',
        'Census_ChassisTypeName':                               'category',
        'Census_InternalPrimaryDiagonalDisplaySizeInInches':    'float32',
        'Census_InternalPrimaryDisplayResolutionHorizontal':    'float32',
        'Census_InternalPrimaryDisplayResolutionVertical':      'float32',
        'Census_PowerPlatformRoleName':                         'category',
        'Census_InternalBatteryType':                           'category',
        'Census_InternalBatteryNumberOfCharges':                'float64',
        'Census_OSVersion':                                     'category',
        'Census_OSArchitecture':                                'category',
        'Census_OSBranch':                                      'category',
        'Census_OSBuildNumber':                                 'int16',
        'Census_OSBuildRevision':                               'int32',
        'Census_OSEdition':                                     'category',
        'Census_OSSkuName':                                     'category',
        'Census_OSInstallTypeName':                             'category',
        'Census_OSInstallLanguageIdentifier':                   'float16',
        'Census_OSUILocaleIdentifier':                          'int16',
        'Census_OSWUAutoUpdateOptionsName':                     'category',
        'Census_IsPortableOperatingSystem':                     'int8',
        'Census_GenuineStateName':                              'category',
        'Census_ActivationChannel':                             'category',
        'Census_IsFlightingInternal':                           'float16',
        'Census_IsFlightsDisabled':                             'float16',
        'Census_FlightRing':                                    'category',
        'Census_ThresholdOptIn':                                'float16',
        'Census_FirmwareManufacturerIdentifier':                'float16',
        'Census_FirmwareVersionIdentifier':                     'float32',
        'Census_IsSecureBootEnabled':                           'int8',
        'Census_IsWIMBootEnabled':                              'float16',
        'Census_IsVirtualDevice':                               'float16',
        'Census_IsTouchEnabled':                                'int8',
        'Census_IsPenCapable':                                  'int8',
        'Census_IsAlwaysOnAlwaysConnectedCapable':              'float16',
        'Wdft_IsGamer':                                         'float16',
        'Wdft_RegionIdentifier':                                'float16',
        'HasDetections':                                        'int8'
}
```

In [279]:

```
train = pd.read_csv('MSFT_DATA/train_sample_50k.csv', dtype=dtypes)
```

1.2 Data Exploration

In [280]:

```
print("%d Columns" % (len(train.columns)))
print("%d Rows" % (len(train)))
train.head()
```

```
83 Columns
50000 Rows
```

Out[280]:

	MachineIdentifier	ProductName	EngineVersion	AppVersion	AvSigVersion
0	0000028988387b115f69f31a3bf04f09	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1735.0
1	000007535c3f730efa9ea0b7ef1bd645	win8defender	1.1.14600.4	4.13.17134.1	1.263.48.0
2	000007905a28d863f6d0d597892cd692	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1341.0
3	00000b11598a75ea8ba1beea8459149f	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1527.0
4	000014a5f00daa18e76b81417eeb99fc	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1379.0

5 rows × 83 columns

In [281]:

```
sum([True in i for i in train.isnull().values])
```

Out[281]:

```
50000
```

In [282]:

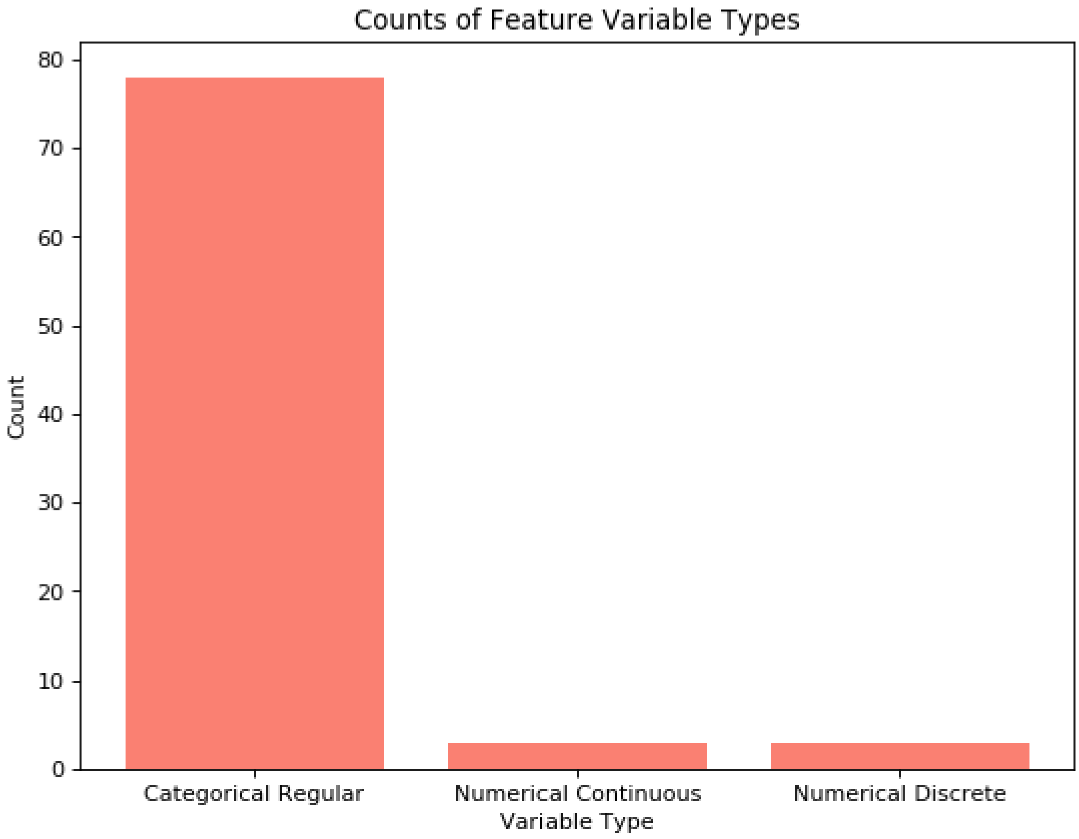
```
sum(['nan' in i for i in train.values])
```

Out[282]:

```
0
```

In [283]:

```
figure(num=None, figsize=(8, 6), dpi=80, facecolor='w', edgecolor='k')

plt.bar(["Categorical Regular", "Numerical Continuous", "Numerical Discrete

plt.title('Counts of Feature Variable Types')
plt.xlabel('Variable Type')
plt.ylabel('Count')

plt.savefig('Var-Type-Bar.png')

plt.show()
```



2 Feature Engineering

2.1 Missing Entries

In [284]:

```
bad_features = []
```

In [285]:

```
# List of percentage of null values...
(train.isnull().sum()/train.shape[0]).sort_values(ascending=False)
```

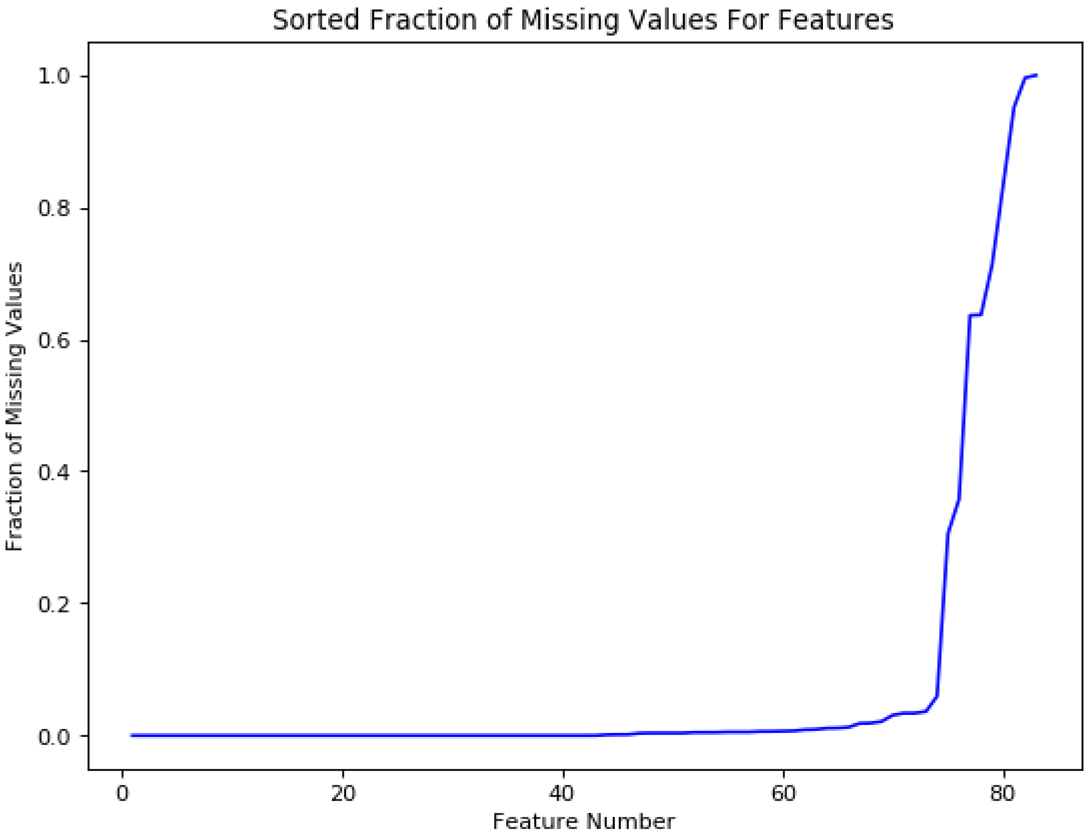
```
Census_IsTouchEnabled                                       0.0000
Census_IsSecureBootEnabled                                  0.0000
Census_FlightRing                                           0.0000
Census_ActivationChannel                                    0.0000
Census_GenuineStateName                                     0.0000
Census_IsPortableOperatingSystem                            0.0000
Census_OSWUAutoUpdateOptionsName                            0.0000
Census_OSUILocaleIdentifier                                 0.0000
Census_OSInstallTypeName                                    0.0000
Census_OSSkuName                                            0.0000
Census_OSEdition                                            0.0000
Census_OSBuildRevision                                      0.0000
Census_OSBuildNumber                                        0.0000
Census_OSBranch                                             0.0000
Census_OSArchitecture                                       0.0000
Census_OSVersion                                            0.0000
Census_PowerPlatformRoleName                                0.0000
Census_HasOpticalDiskDrive                                  0.0000
Census_DeviceFamily                                         0.0000
Census_MDC2FormFactor                                       0.0000
```

In [286]:

```
missing_vals = (train.isnull().sum()/train.shape[0]).sort_values(ascending=
```

In [287]:

```
figure(num=None, figsize=(8, 6), dpi=80, facecolor='w', edgecolor='k')

plt.plot(list(range(1, len(missing_vals) + 1, 1)), missing_vals, color='blu

# Plot text
plt.title('Sorted Fraction of Missing Values For Features')
plt.xlabel('Feature Number')
plt.ylabel('Fraction of Missing Values')

plt.savefig('Missing_Features.png', dpi=420)
plt.show()
```



In [288]:

```
bad_features.append('PuaMode')
bad_features.append('Census_ProcessorClass')
```

2.2 Skewed Features

For categorical data, extremely skewed data means most of the datapoints belong to a particular category for that feature.

i.e. House color but all the houses in the data are red. (Just remove house color)

In [289]:

```
pd.options.display.float_format = '{:,.4f}'.format

sk_df = pd.DataFrame([{'column': c, 'uniq': train[c].nunique(),
                       'skewness': train[c].value_counts(normalize=True)
                       .values[0]} for c in train.columns])

# Skewness
sk_df = sk_df.sort_values('skewness', ascending=False)
sk_df.head()
```

Out[289]:

	column	skewness	uniq
27	AutoSampleOptIn	1.0000	1
28	PuaMode	1.0000	1
69	Census_IsFlightsDisabled	1.0000	1
5	IsBeta	1.0000	1
75	Census_IsWIMBootEnabled	1.0000	1

In [290]:

```
sk_df
```

Out[290]:

	column	skewness	uniq
27	AutoSampleOptIn	1.0000	1
28	PuaMode	1.0000	1
69	Census_IsFlightsDisabled	1.0000	1
5	IsBeta	1.0000	1
75	Census_IsWIMBootEnabled	1.0000	1
68	Census_IsFlightingInternal	1.0000	1
71	Census_ThresholdOptIn	0.9998	2
29	SMode	0.9996	2
65	Census_IsPortableOperatingSystem	0.9992	2
35	Census_DeviceFamily	0.9987	2
33	UacLuaenable	0.9936	3
76	Census_IsVirtualDevice	0.9932	2
1	ProductName	0.9888	2
12	HasTpm	0.9874	2
7	IsSxsPassiveMode	0.9823	2
32	Firewall	0.9772	2
11	AVProductsEnabled	0.9748	5
6	RtpStateBitfield	0.9734	6
20	OsVer	0.9679	8
18	Platform	0.9666	4
78	Census_IsPenCapable	0.9624	2
26	IsProtected	0.9464	2
79	Census_IsAlwaysOnAlwaysConnectedCapable	0.9420	2
70	Census_FlightRing	0.9360	7
45	Census_HasOpticalDiskDrive	0.9241	2
19	Processor	0.9098	3
55	Census_OSArchitecture	0.9098	3
66	Census_GenuineStateName	0.8837	4
39	Census_ProcessorManufacturerIdentifier	0.8816	3
77	Census_IsTouchEnabled	0.8737	2
...	...	...	...
57	Census_OSBuildNumber	0.4503	31
64	Census_OSWUAutoUpdateOptionsName	0.4407	6

	column	skewness	uniq
21	OsBuild	0.4392	33
23	OsPlatformSubRelease	0.4392	9
30	IeVerIdentifier	0.4385	132
2	EngineVersion	0.4331	38
24	OsBuildLab	0.4110	316
59	Census_OSEdition	0.3885	18
60	Census_OSSkuName	0.3885	16
62	Census_OSInstallLanguageIdentifier	0.3586	39
63	Census_OSUILocaleIdentifier	0.3554	55
48	Census_InternalPrimaryDiagonalDisplaySizeInInches	0.3416	304
42	Census_PrimaryDiskTotalCapacity	0.3171	318
72	Census_FirmwareManufacturerIdentifier	0.3123	136
61	Census_OSInstallTypeName	0.2945	9
17	LocaleEnglishNameIdentifier	0.2330	171
81	Wdft_RegionIdentifier	0.2086	15
16	GeoNameIdentifier	0.1720	226
58	Census_OSBuildRevision	0.1561	209
54	Census_OSVersion	0.1561	241
36	Census_OEMNameIdentifier	0.1448	640
8	DefaultBrowsersIdentifier	0.1096	203
13	CountryIdentifier	0.0445	216
37	Census_OEMModelIdentifier	0.0344	10800
40	Census_ProcessorModelIdentifier	0.0324	1509
4	AvSigVersion	0.0116	3105
14	CityIdentifier	0.0115	10423
73	Census_FirmwareVersionIdentifier	0.0107	8930
44	Census_SystemVolumeTotalCapacity	0.0056	26255
0	MachineIdentifier	0.0000	50000

83 rows × 3 columns

In [291]:

```
skew_thresh = .99

bad_features.extend(sk_df[sk_df.skewness > skew_thresh].column.tolist())
bad_features = list(set(bad_features))
bad_features
```

Out[291]:

```
['Census_IsVirtualDevice',
 'Census_ProcessorClass',
 'AutoSampleOptIn',
 'Census_IsFlightingInternal',
 'UacLuaenable',
 'Census_IsPortableOperatingSystem',
 'Census_IsFlightsDisabled',
 'Census_IsWIMBootEnabled',
 'Census_ThresholdOptIn',
 'SMode',
 'Census_DeviceFamily',
 'PuaMode',
 'IsBeta']
```

In [292]:

```
# Updating our train data
train.drop(bad_features, axis=1, inplace=True)
```

In [293]:

```
# Machine ID shouldn't help and only adds noise since theres too many
train.drop('MachineIdentifier', axis=1, inplace=True)
```

2.3 Purifiy Missing Data

In [294]:

```
sum([True in i for i in train.isnull().values])
```

Out[294]:

```
49540
```

In [295]:

```
# Fill in the numerical data
train = train.fillna(train.median())
```

In [296]:

```
train.head()
```

Out[296]:

	ProductName	EngineVersion	AppVersion	AvSigVersion	RtpStateBitfield	IsSxsPassiveMode
0	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1735.0	7.0000	0
1	win8defender	1.1.14600.4	4.13.17134.1	1.263.48.0	7.0000	0
2	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1341.0	7.0000	0
3	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1527.0	7.0000	0
4	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1379.0	7.0000	0

5 rows × 69 columns

In [297]:

```
# Fill in the categorical data
train = train.fillna(train.mode().iloc[0])
```

In [298]:

```
train.head()
```

Out[298]:

	ProductName	EngineVersion	AppVersion	AvSigVersion	RtpStateBitfield	IsSxsPassiveMode
0	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1735.0	7.0000	0
1	win8defender	1.1.14600.4	4.13.17134.1	1.263.48.0	7.0000	0
2	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1341.0	7.0000	0
3	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1527.0	7.0000	0
4	win8defender	1.1.15100.1	4.18.1807.18075	1.273.1379.0	7.0000	0

5 rows × 69 columns

2.4 Correlated Features

In [299]:

```
from sklearn.preprocessing import LabelEncoder

train['SmartScreen'] = train.SmartScreen.astype('category')
train['Census_InternalBatteryType'] = train.Census_InternalBatteryType.asty

cate_cols = train.select_dtypes(include='category').columns.tolist()

le = LabelEncoder()

for col in cate_cols:
    train[col] = le.fit_transform(train[col])
```

from sklearn.preprocessing import LabelEncoder category_cols = [(train[c].dtype == 'O' or train[c].dtype == 'int64') for c in train.columns] le = LabelEncoder()

train['IsBeta'] = le.fit_transform(train['IsBeta'].astype('category'))

for col in train.columns[category_cols]: try: train[col] = le.fit_transform(train[col].astype('category')) except: print(col)

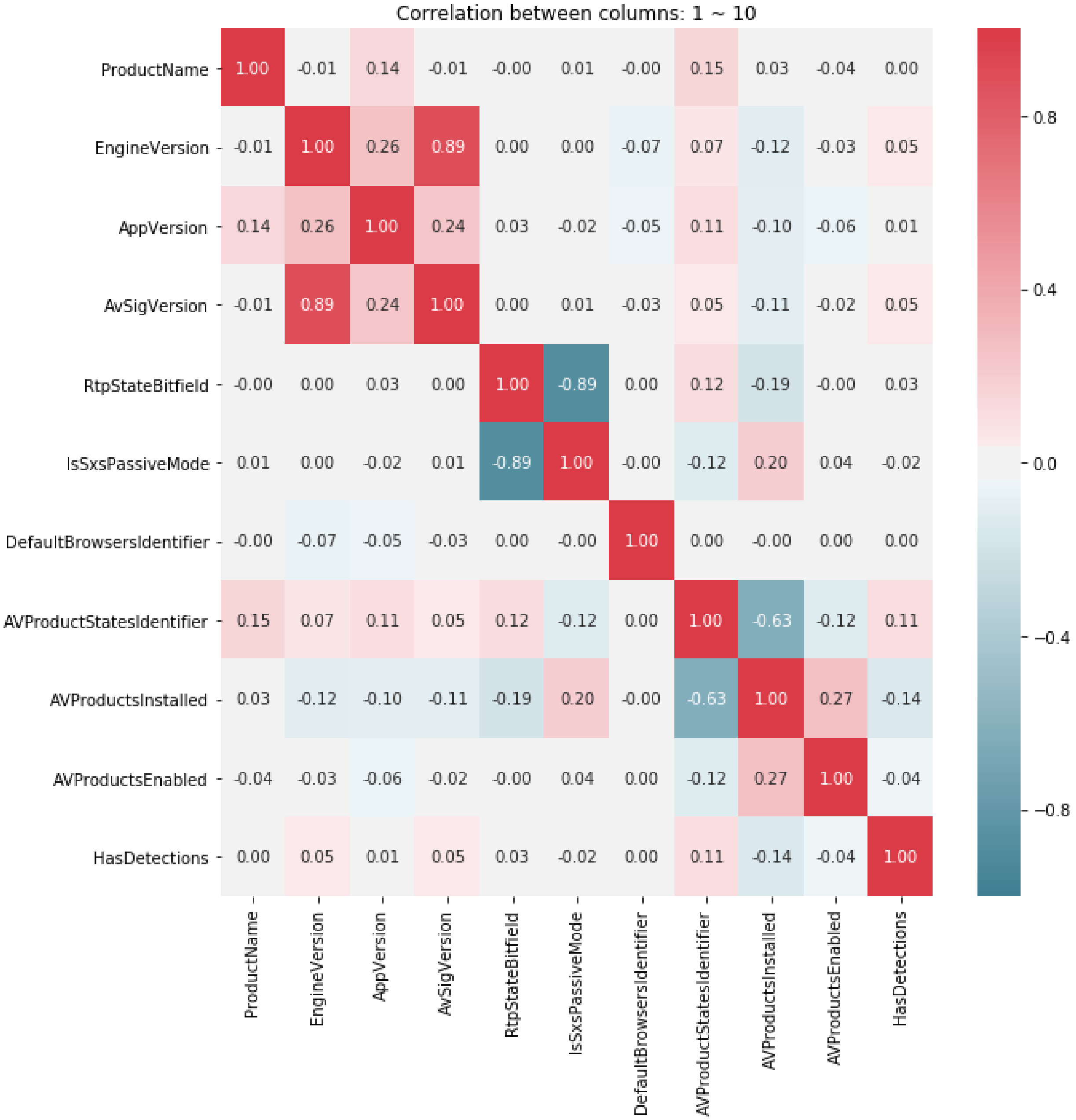
In [300]:
```
train[train.columns[0:10]].corr()
```

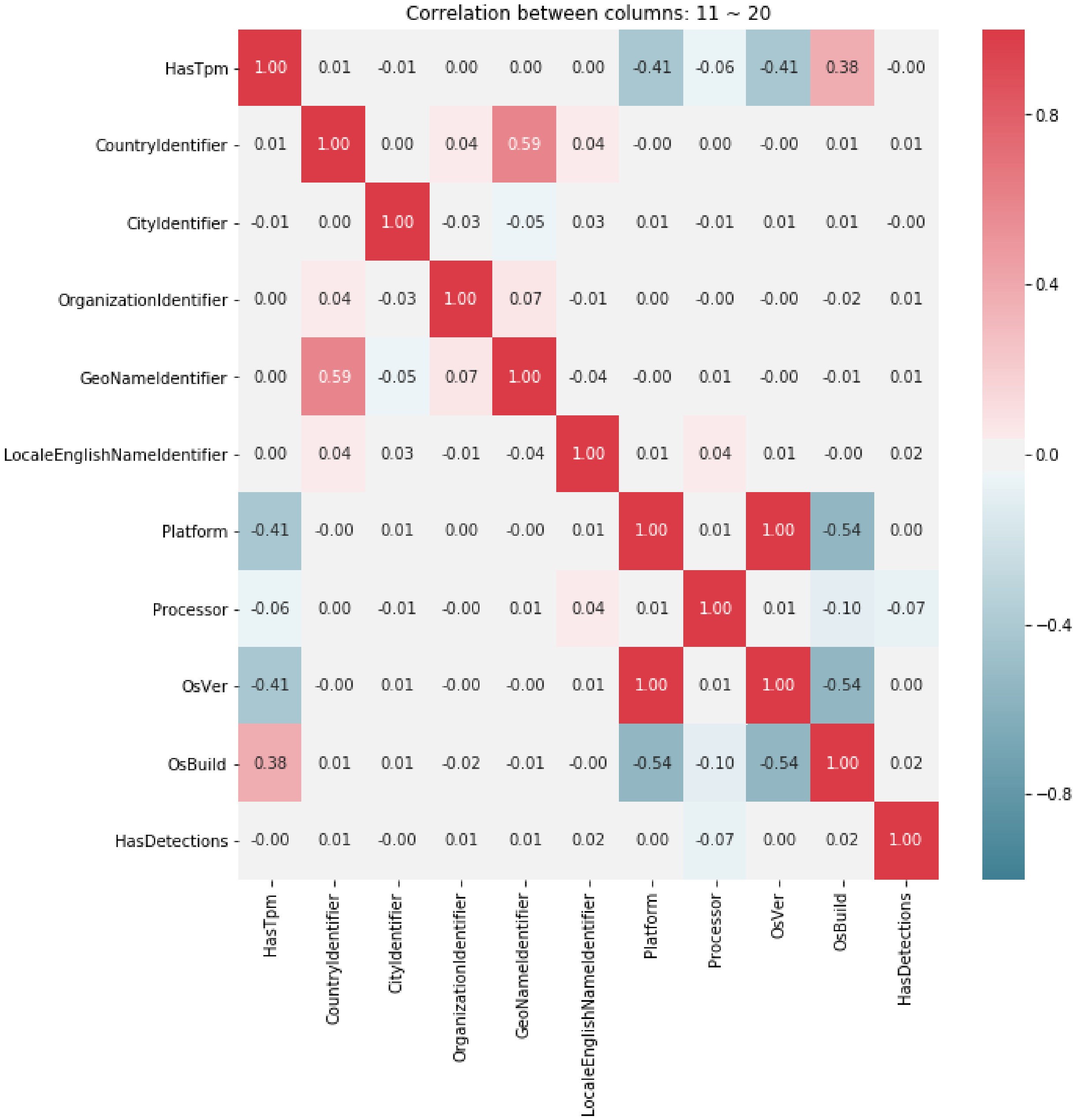
Out[300]:

	ProductName	EngineVersion	AppVersion	AvSigVersion	RtpStateBitfield	I
ProductName	1.0000	-0.0128	0.1423	-0.0120	-0.0045	
EngineVersion	-0.0128	1.0000	0.2581	0.8894	0.0045	
AppVersion	0.1423	0.2581	1.0000	0.2398	0.0319	
AvSigVersion	-0.0120	0.8894	0.2398	1.0000	0.0013	
RtpStateBitfield	-0.0045	0.0045	0.0319	0.0013	1.0000	
IsSxsPassiveMode	0.0143	0.0005	-0.0208	0.0074	-0.8897	
DefaultBrowsersIdentifier	-0.0014	-0.0680	-0.0535	-0.0310	0.0018	
AVProductStatesIdentifier	0.1531	0.0658	0.1108	0.0503	0.1175	
AVProductsInstalled	0.0317	-0.1161	-0.1012	-0.1055	-0.1887	
AVProductsEnabled	-0.0386	-0.0273	-0.0596	-0.0236	-0.0041	

In [301]:

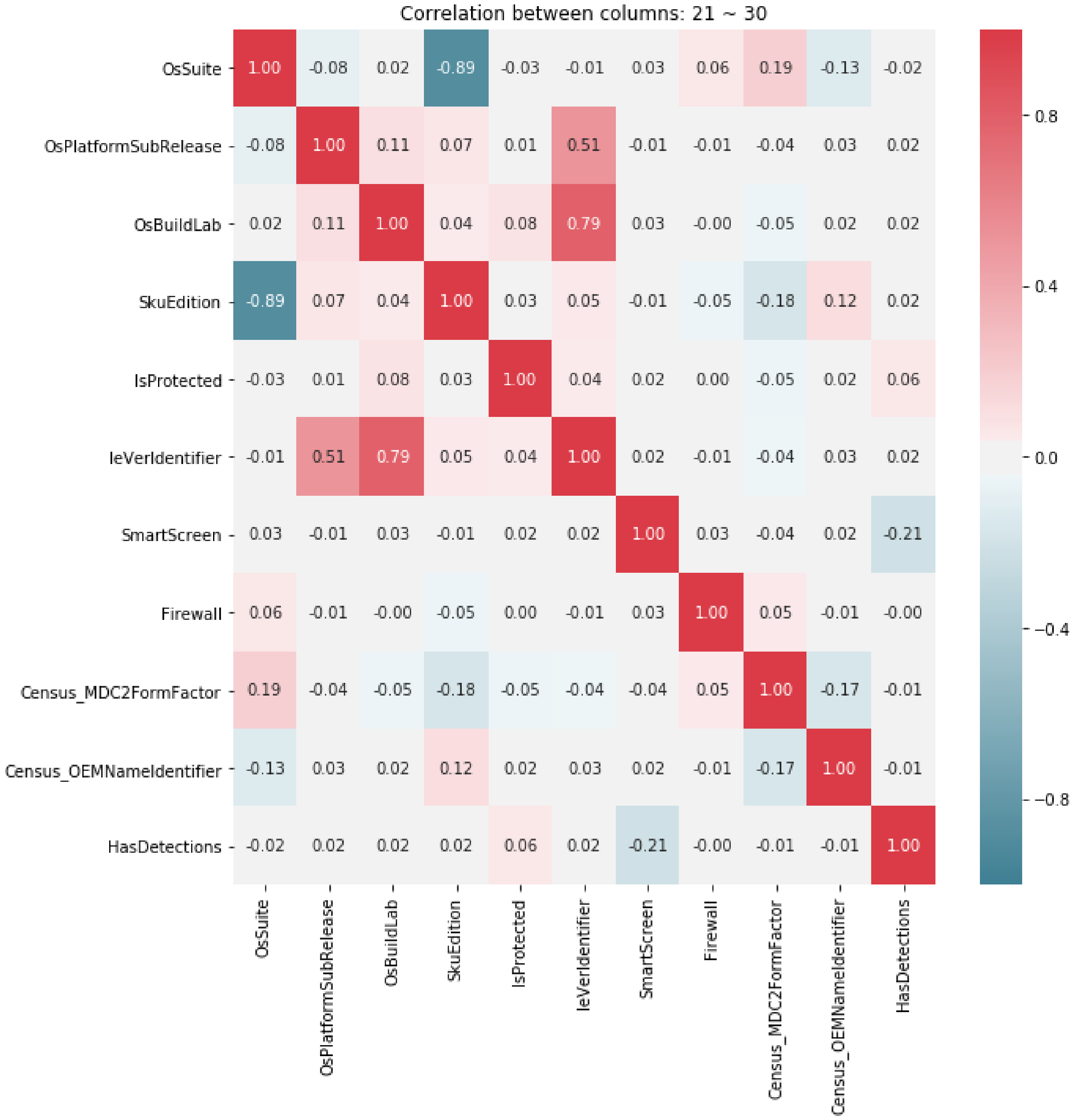
```
# Display correlation heat maps

cols = train.columns
for i in range(0, len(cols), 10):
    co_cols = cols[i:i+10].tolist() + ['HasDetections']
    #co_cols.append(pd.Index()'HasDetections')
    plt.figure(figsize=(10,10))
    colormap = sns.diverging_palette(220, 10, as_cmap=True)
    #Generate Heat Map, allow annotations and place floats in map
    sns.heatmap(train[co_cols].corr(), cmap=colormap, annot=True, fmt=".2f"

    plt.title('Correlation between columns: %d ~ %d' % (i+1, i+10))
    title = 'corr_' + str(i+1)
    plt.savefig(title, dpi=420, )
    plt.show()
```



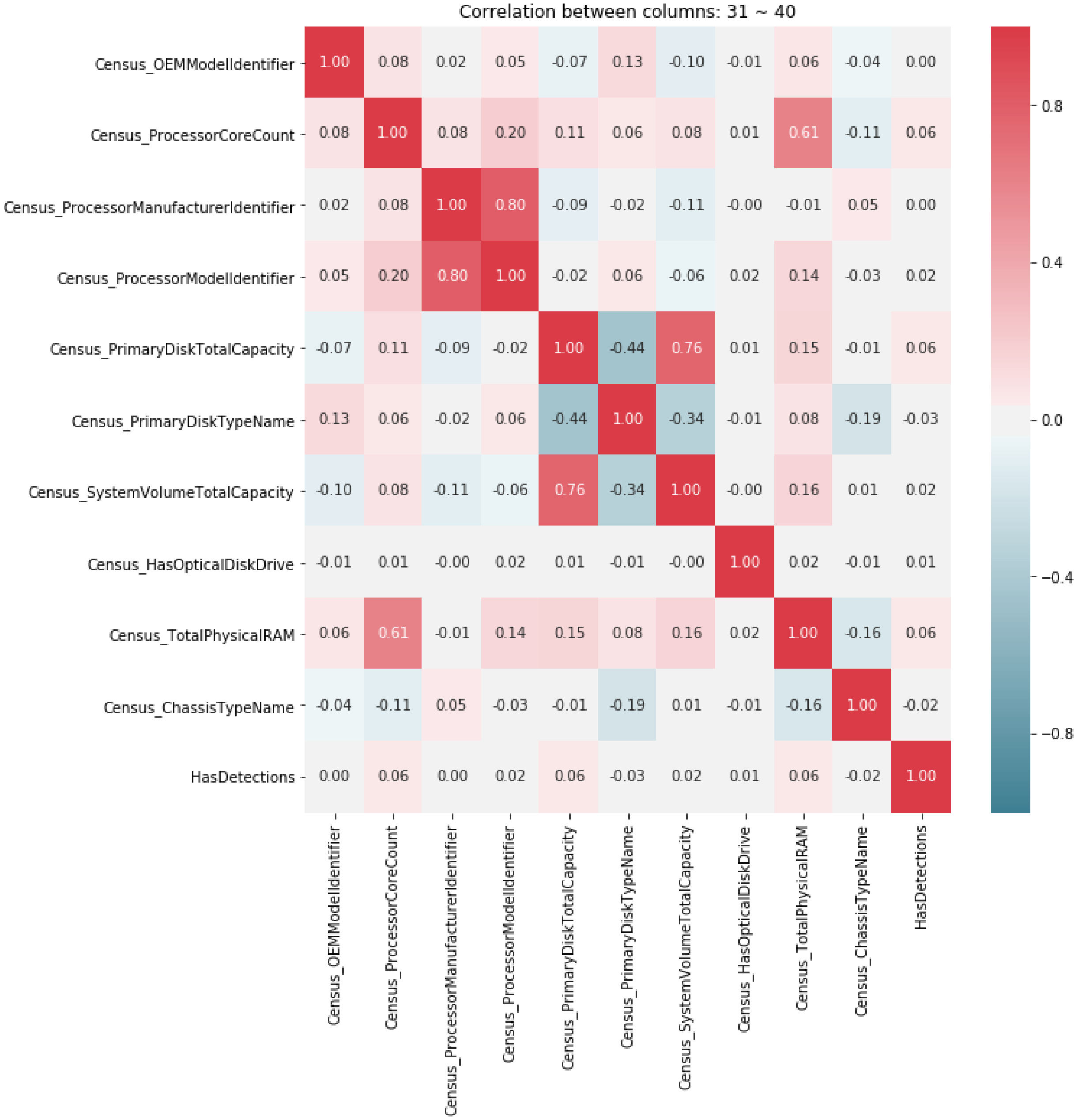


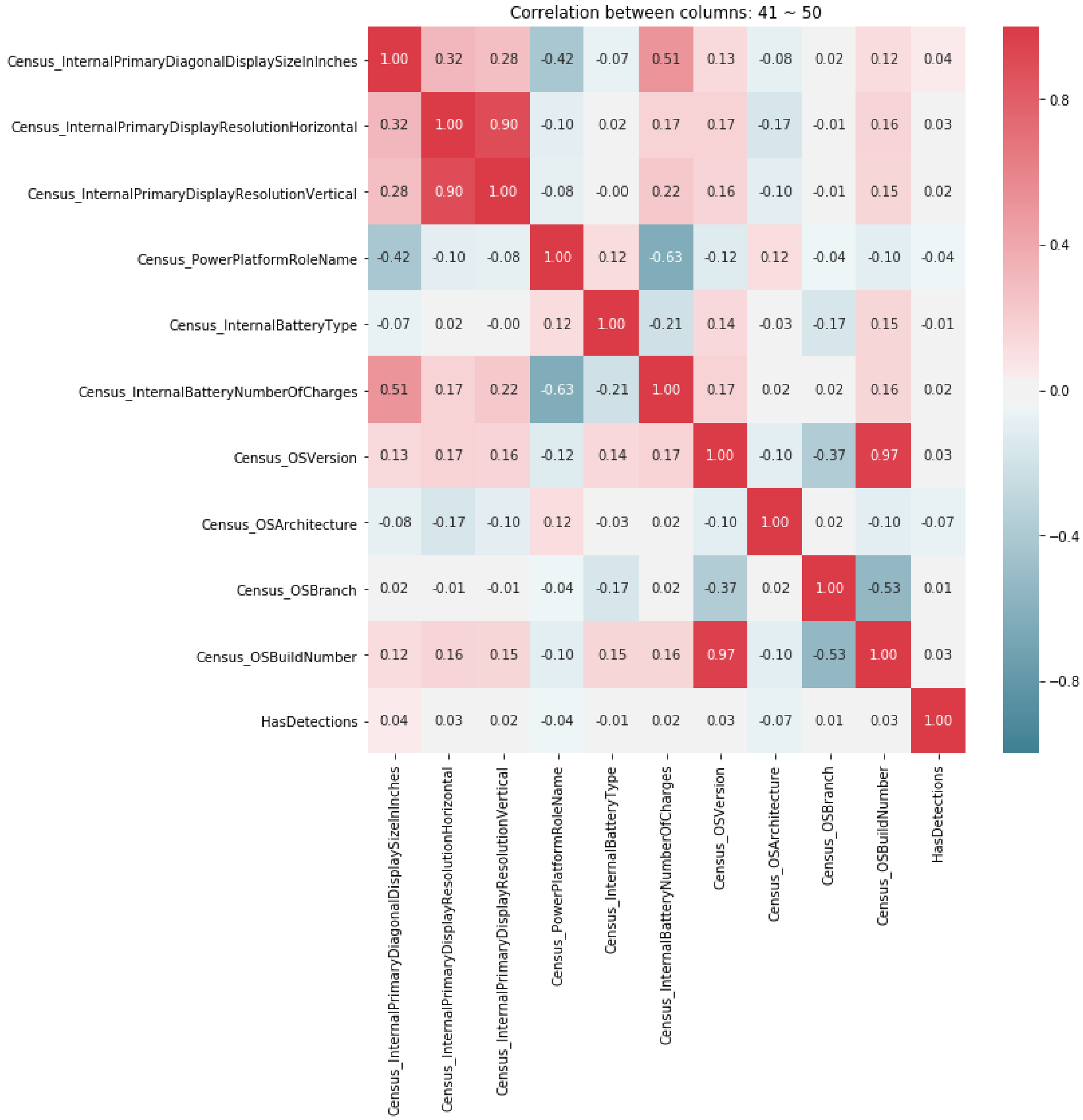
Correlation between columns: 11 ~ 20

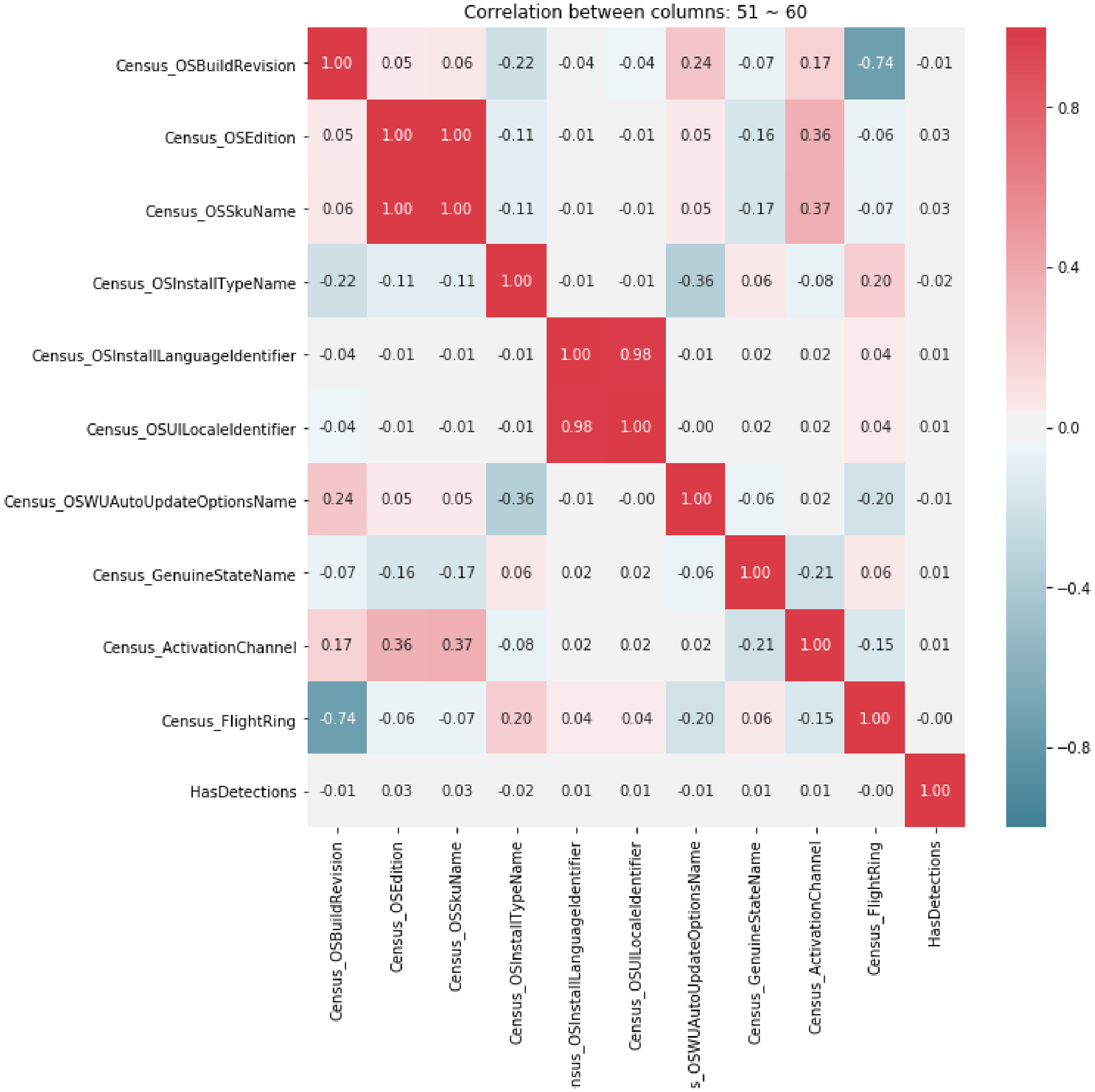
	HasTpm	CountryIdentifier	CityIdentifier	OrganizationIdentifier	GeoNameIdentifier	LocaleEnglishNameIdentifier	Platform	Processor	OsVer	OsBuild	HasDetections
HasTpm	1.00	0.01	-0.01	0.00	0.00	0.00	-0.41	-0.06	-0.41	0.38	-0.00
CountryIdentifier	0.01	1.00	0.00	0.04	0.59	0.04	-0.00	0.00	-0.00	0.01	0.01
CityIdentifier	-0.01	0.00	1.00	-0.03	-0.05	0.03	0.01	-0.01	0.01	0.01	-0.00
OrganizationIdentifier	0.00	0.04	-0.03	1.00	0.07	-0.01	0.00	-0.00	-0.00	-0.02	0.01
GeoNameIdentifier	0.00	0.59	-0.05	0.07	1.00	-0.04	-0.00	0.01	-0.00	-0.01	0.01
LocaleEnglishNameIdentifier	0.00	0.04	0.03	-0.01	-0.04	1.00	0.01	0.04	0.01	-0.00	0.02
Platform	-0.41	-0.00	0.01	0.00	-0.00	0.01	1.00	0.01	1.00	-0.54	0.00
Processor	-0.06	0.00	-0.01	-0.00	0.01	0.04	0.01	1.00	0.01	-0.10	-0.07
OsVer	-0.41	-0.00	0.01	-0.00	-0.00	0.01	1.00	0.01	1.00	-0.54	0.00
OsBuild	0.38	0.01	0.01	-0.02	-0.01	-0.00	-0.54	-0.10	-0.54	1.00	0.02
HasDetections	-0.00	0.01	-0.00	0.01	0.01	0.02	0.00	-0.07	0.00	0.02	1.00

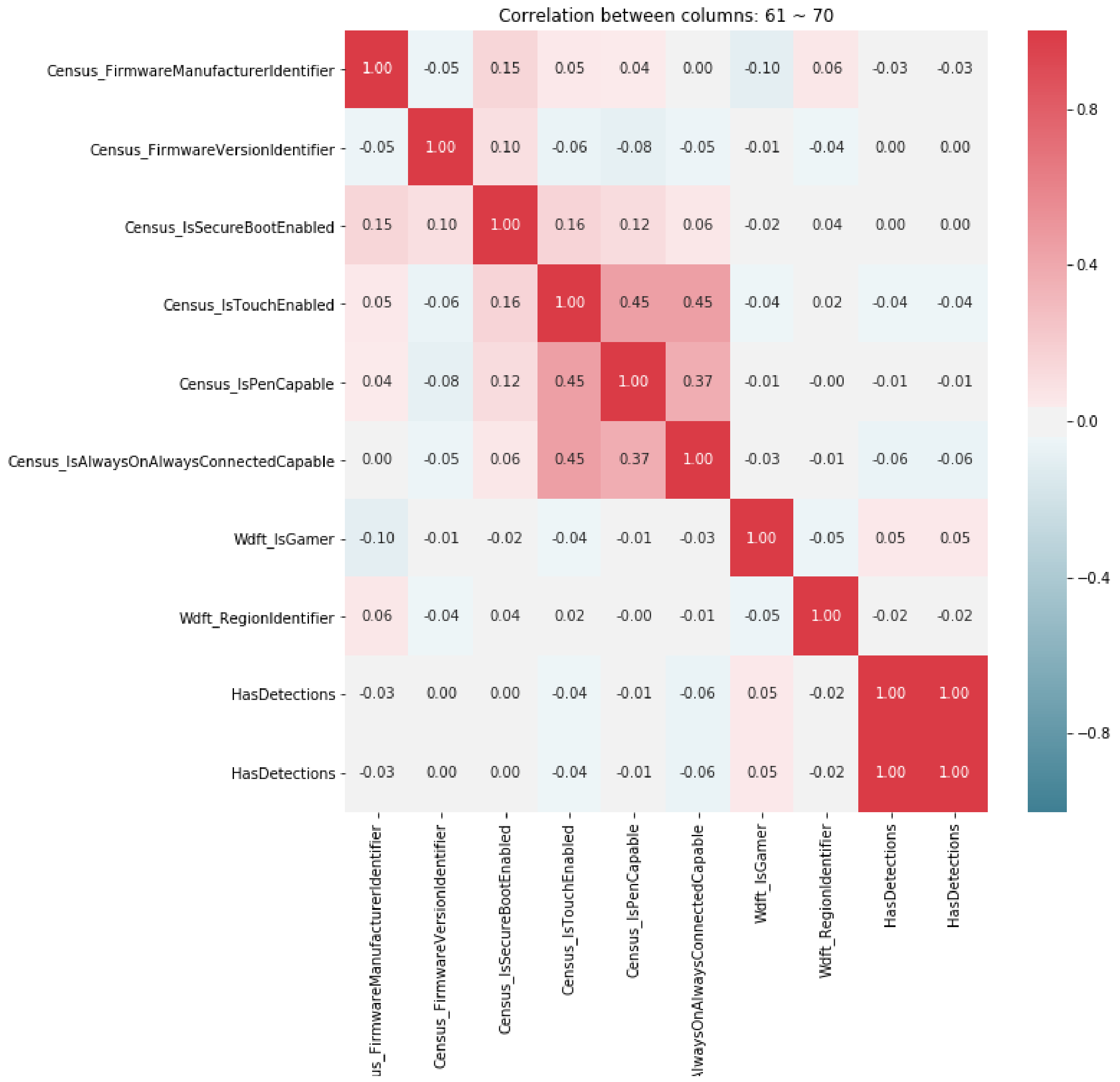


	OsSuite	OsPlatformSubRelease	OsBuildLab	SkuEdition	IsProtected	IeVerIdentifier	SmartScreen	Firewall	Census_MDC2FormFactor	Census_OEMNameIdentifier	HasDetections
OsSuite	1.00	-0.08	0.02	-0.89	-0.03	-0.01	0.03	0.06	0.19	-0.13	-0.02
OsPlatformSubRelease	-0.08	1.00	0.11	0.07	0.01	0.51	-0.01	-0.01	-0.04	0.03	0.02
OsBuildLab	0.02	0.11	1.00	0.04	0.08	0.79	0.03	-0.00	-0.05	0.02	0.02
SkuEdition	-0.89	0.07	0.04	1.00	0.03	0.05	-0.01	-0.05	-0.18	0.12	0.02
IsProtected	-0.03	0.01	0.08	0.03	1.00	0.04	0.02	0.00	-0.05	0.02	0.06
IeVerIdentifier	-0.01	0.51	0.79	0.05	0.04	1.00	0.02	-0.01	-0.04	0.03	0.02
SmartScreen	0.03	-0.01	0.03	-0.01	0.02	0.02	1.00	0.03	-0.04	0.02	-0.21
Firewall	0.06	-0.01	-0.00	-0.05	0.00	-0.01	0.03	1.00	0.05	-0.01	-0.00
Census_MDC2FormFactor	0.19	-0.04	-0.05	-0.18	-0.05	-0.04	-0.04	0.05	1.00	-0.17	-0.01
Census_OEMNameIdentifier	-0.13	0.03	0.02	0.12	0.02	0.03	0.02	-0.01	-0.17	1.00	-0.01
HasDetections	-0.02	0.02	0.02	0.02	0.06	0.02	-0.21	-0.00	-0.01	-0.01	1.00


Correlation between columns: 31 ~ 40
Census_OEMModelIdentifier 1.00 0.08 0.02 0.05 -0.07 0.13 -0.10 -0.01 0.06 -0.04 0.00
Census_ProcessorCoreCount 0.08 1.00 0.08 0.20 0.11 0.06 0.08 0.01 0.61 -0.11 0.06
Census_ProcessorManufacturerIdentifier 0.02 0.08 1.00 0.80 -0.09 -0.02 -0.11 -0.00 -0.01 0.05 0.00
Census_ProcessorModelIdentifier 0.05 0.20 0.80 1.00 -0.02 0.06 -0.06 0.02 0.14 -0.03 0.02
Census_PrimaryDiskTotalCapacity -0.07 0.11 -0.09 -0.02 1.00 -0.44 0.76 0.01 0.15 -0.01 0.06
Census_PrimaryDiskTypeName 0.13 0.06 -0.02 0.06 -0.44 1.00 -0.34 -0.01 0.08 -0.19 -0.03
Census_SystemVolumeTotalCapacity -0.10 0.08 -0.11 -0.06 0.76 -0.34 1.00 -0.00 0.16 0.01 0.02
Census_HasOpticalDiskDrive -0.01 0.01 -0.00 0.02 0.01 -0.01 -0.00 1.00 0.02 -0.01 0.01
Census_TotalPhysicalRAM 0.06 0.61 -0.01 0.14 0.15 0.08 0.16 0.02 1.00 -0.16 0.06
Census_ChassisTypeName -0.04 -0.11 0.05 -0.03 -0.01 -0.19 0.01 -0.01 -0.16 1.00 -0.02
HasDetections 0.00 0.06 0.00 0.02 0.06 -0.03 0.02 0.01 0.06 -0.02 1.00
Census_OEMModelIdentifier
Census_ProcessorCoreCount
Census_ProcessorManufacturerIdentifier
Census_ProcessorModelIdentifier
Census_PrimaryDiskTotalCapacity
Census_PrimaryDiskTypeName
Census_SystemVolumeTotalCapacity
Census_HasOpticalDiskDrive
Census_TotalPhysicalRAM
Census_ChassisTypeName
HasDetections
0.8
0.4
0.0
−0.4
−0.8


Correlation between columns: 41 ~ 50
Census_InternalPrimaryDiagonalDisplaySizeInInches 1.00 0.32 0.28 -0.42 -0.07 0.51 0.13 -0.08 0.02 0.12 0.04
Census_InternalPrimaryDisplayResolutionHorizontal 0.32 1.00 0.90 -0.10 0.02 0.17 0.17 -0.17 -0.01 0.16 0.03
Census_InternalPrimaryDisplayResolutionVertical 0.28 0.90 1.00 -0.08 -0.00 0.22 0.16 -0.10 -0.01 0.15 0.02
Census_PowerPlatformRoleName -0.42 -0.10 -0.08 1.00 0.12 -0.63 -0.12 0.12 -0.04 -0.10 -0.04
Census_InternalBatteryType -0.07 0.02 -0.00 0.12 1.00 -0.21 0.14 -0.03 -0.17 0.15 -0.01
Census_InternalBatteryNumberOfCharges 0.51 0.17 0.22 -0.63 -0.21 1.00 0.17 0.02 0.02 0.16 0.02
Census_OSVersion 0.13 0.17 0.16 -0.12 0.14 0.17 1.00 -0.10 -0.37 0.97 0.03
Census_OSArchitecture -0.08 -0.17 -0.10 0.12 -0.03 0.02 -0.10 1.00 0.02 -0.10 -0.07
Census_OSBranch 0.02 -0.01 -0.01 -0.04 -0.17 0.02 -0.37 0.02 1.00 -0.53 0.01
Census_OSBuildNumber 0.12 0.16 0.15 -0.10 0.15 0.16 0.97 -0.10 -0.53 1.00 0.03
HasDetections 0.04 0.03 0.02 -0.04 -0.01 0.02 0.03 -0.07 0.01 0.03 1.00
Census_InternalPrimaryDiagonalDisplaySizeInInches
Census_InternalPrimaryDisplayResolutionHorizontal
Census_InternalPrimaryDisplayResolutionVertical
Census_PowerPlatformRoleName
Census_InternalBatteryType
Census_InternalBatteryNumberOfCharges
Census_OSVersion
Census_OSArchitecture
Census_OSBranch
Census_OSBuildNumber
HasDetections
0.8
0.4
0.0
−0.4
−0.8


Correlation between columns: 51 ~ 60
Census_OSBuildRevision 1.00 0.05 0.06 -0.22 -0.04 -0.04 0.24 -0.07 0.17 -0.74 -0.01
Census_OSEdition 0.05 1.00 1.00 -0.11 -0.01 -0.01 0.05 -0.16 0.36 -0.06 0.03
Census_OSSkuName 0.06 1.00 1.00 -0.11 -0.01 -0.01 0.05 -0.17 0.37 -0.07 0.03
Census_OSInstallTypeName -0.22 -0.11 -0.11 1.00 -0.01 -0.01 -0.36 0.06 -0.08 0.20 -0.02
Census_OSInstallLanguageIdentifier -0.04 -0.01 -0.01 -0.01 1.00 0.98 -0.01 0.02 0.02 0.04 0.01
Census_OSUILocaleIdentifier -0.04 -0.01 -0.01 -0.01 0.98 1.00 -0.00 0.02 0.02 0.04 0.01
Census_OSWUAutoUpdateOptionsName 0.24 0.05 0.05 -0.36 -0.01 -0.00 1.00 -0.06 0.02 -0.20 -0.01
Census_GenuineStateName -0.07 -0.16 -0.17 0.06 0.02 0.02 -0.06 1.00 -0.21 0.06 0.01
Census_ActivationChannel 0.17 0.36 0.37 -0.08 0.02 0.02 0.02 -0.21 1.00 -0.15 0.01
Census_FlightRing -0.74 -0.06 -0.07 0.20 0.04 0.04 -0.20 0.06 -0.15 1.00 -0.00
HasDetections -0.01 0.03 0.03 -0.02 0.01 0.01 -0.01 0.01 0.01 -0.00 1.00
Census_OSBuildRevision
Census_OSEdition
Census_OSSkuName
Census_OSInstallTypeName
nsus_OSInstallLanguageIdentifier
Census_OSUILocaleIdentifier
s_OSWUAutoUpdateOptionsName
Census_GenuineStateName
Census_ActivationChannel
Census_FlightRing
HasDetections
0.8
0.4
0.0
−0.4
−0.8



Display correlation heat maps (Correlation all together)

cols = train.columns

#for i in range(0, len(cols), 10): co_cols = cols

#co_cols.append(pd.Index()'HasDetections') plt.figure(figsize=(10,10)) sns.heatmap(train[co_cols].corr(), cmap='RdBu_r', annot=True, center=0.0) plt.title('Correlation between columns: %d ~ %d' % (i, i+10)) plt.show()

In [302]:

```
# Remove highly correlated data

corr_thresh = .99
cols = train.columns
corr = train.corr()
new_bad = []

for i in range(0, corr.shape[1]):
    for j in range(0, i):
        # Remove highly correlated features
        if (abs(corr.iloc[i, j]) >= corr_thresh):
            # Remove the feature with less information
            if(train[cols[i]].nunique() > train[cols[j]].nunique()):
                new_bad.append(cols[j])
            else:
                new_bad.append(cols[i])
```

In [303]:

```
if ('HasDetections' in new_bad):
    new_bad.remove('HasDetections')

len(new_bad)
```

Out[303]:

```
2
```

In [304]:

```
train.drop(new_bad, axis=1, inplace=True)
```

In [305]:

```
bad_features.extend(new_bad)
bad_features = list(set(bad_features))
```

2.4 (alternative) Modified Tree Algorithm

3 Prediction

Testing trees and logistic regression with different regularizers. Then hypertuning each to select the best model.

In [306]:

```
bad_features
```

Out[306]:

```
['Census_ProcessorClass',
 'AutoSampleOptIn',
 'Census_IsFlightingInternal',
 'PuaMode',
 'UacLuaenable',
 'Census_IsPortableOperatingSystem',
 'Platform',
 'Census_IsFlightsDisabled',
 'Census_IsWIMBootEnabled',
 'Census_ThresholdOptIn',
 'SMode',
 'Census_DeviceFamily',
 'Census_OSSkuName',
 'Census_IsVirtualDevice',
 'IsBeta']
```

In [307]:

```
train.columns
```

Out[307]:

```
Index(['ProductName', 'EngineVersion', 'AppVersion', 'AvSigVersion',
       'RtpStateBitfield', 'IsSxsPassiveMode', 'DefaultBrowsersIdentifie
r',
       'AVProductStatesIdentifier', 'AVProductsInstalled', 'AVProductsEna
bled',
       'HasTpm', 'CountryIdentifier', 'CityIdentifier',
       'OrganizationIdentifier', 'GeoNameIdentifier',
       'LocaleEnglishNameIdentifier', 'Processor', 'OsVer', 'OsBuild',
       'OsSuite', 'OsPlatformSubRelease', 'OsBuildLab', 'SkuEdition',
       'IsProtected', 'IeVerIdentifier', 'SmartScreen', 'Firewall',
       'Census_MDC2FormFactor', 'Census_OEMNameIdentifier',
       'Census_OEMModelIdentifier', 'Census_ProcessorCoreCount',
       'Census_ProcessorManufacturerIdentifier',
       'Census_ProcessorModelIdentifier', 'Census_PrimaryDiskTotalCapacit
y',
       'Census_PrimaryDiskTypeName', 'Census_SystemVolumeTotalCapacity',
       'Census_HasOpticalDiskDrive', 'Census_TotalPhysicalRAM',
       'Census_ChassisTypeName',
       'Census_InternalPrimaryDiagonalDisplaySizeInInches',
       'Census_InternalPrimaryDisplayResolutionHorizontal',
       'Census_InternalPrimaryDisplayResolutionVertical',
       'Census_PowerPlatformRoleName', 'Census_InternalBatteryType',
       'Census_InternalBatteryNumberOfCharges', 'Census_OSVersion',
       'Census_OSArchitecture', 'Census_OSBranch', 'Census_OSBuildNumbe
r',
       'Census_OSBuildRevision', 'Census_OSEdition',
       'Census_OSInstallTypeName', 'Census_OSInstallLanguageIdentifier',
       'Census_OSUILocaleIdentifier', 'Census_OSWUAutoUpdateOptionsName',
       'Census_GenuineStateName', 'Census_ActivationChannel',
       'Census_FlightRing', 'Census_FirmwareManufacturerIdentifier',
       'Census_FirmwareVersionIdentifier', 'Census_IsSecureBootEnabled',
       'Census_IsTouchEnabled', 'Census_IsPenCapable',
       'Census_IsAlwaysOnAlwaysConnectedCapable', 'Wdft_IsGamer',
       'Wdft_RegionIdentifier', 'HasDetections'],
      dtype='object')
```

In [308]:
```
len(train.columns)
```

Out[308]:
```
67
```

In [309]:
```
# Setting up variables
UB = 8000
UB1 = 9000


X = train.drop('HasDetections', axis=1).values[:UB]
y = train['HasDetections'].tolist()[:UB]

X_val = train.drop('HasDetections', axis=1).values[UB:UB1]
y_val = train['HasDetections'].tolist()[UB:UB1]

X_test = train.drop('HasDetections', axis=1).values[UB1:]
y_test = train['HasDetections'].tolist()[UB1:]
```

3.1 Decision Tree Classifier

In [310]:
```
from sklearn.tree import DecisionTreeClassifier
```

In [311]:
```
tree_clf = DecisionTreeClassifier()
tree_clf.fit(X, y)

print("Train Acc %.3f" % (np.sum([tree_clf.predict(X) == y], axis=1) / len(
print("Val  Acc %.3f" % (np.sum([tree_clf.predict(X_val) == y_val], axis=1)
```

```
Train Acc 1.000
Val  Acc 0.520
```

In [312]:
```
for x,i in enumerate([10,10,10]):
    print(x,i)
```

```
0 10
1 10
2 10
```

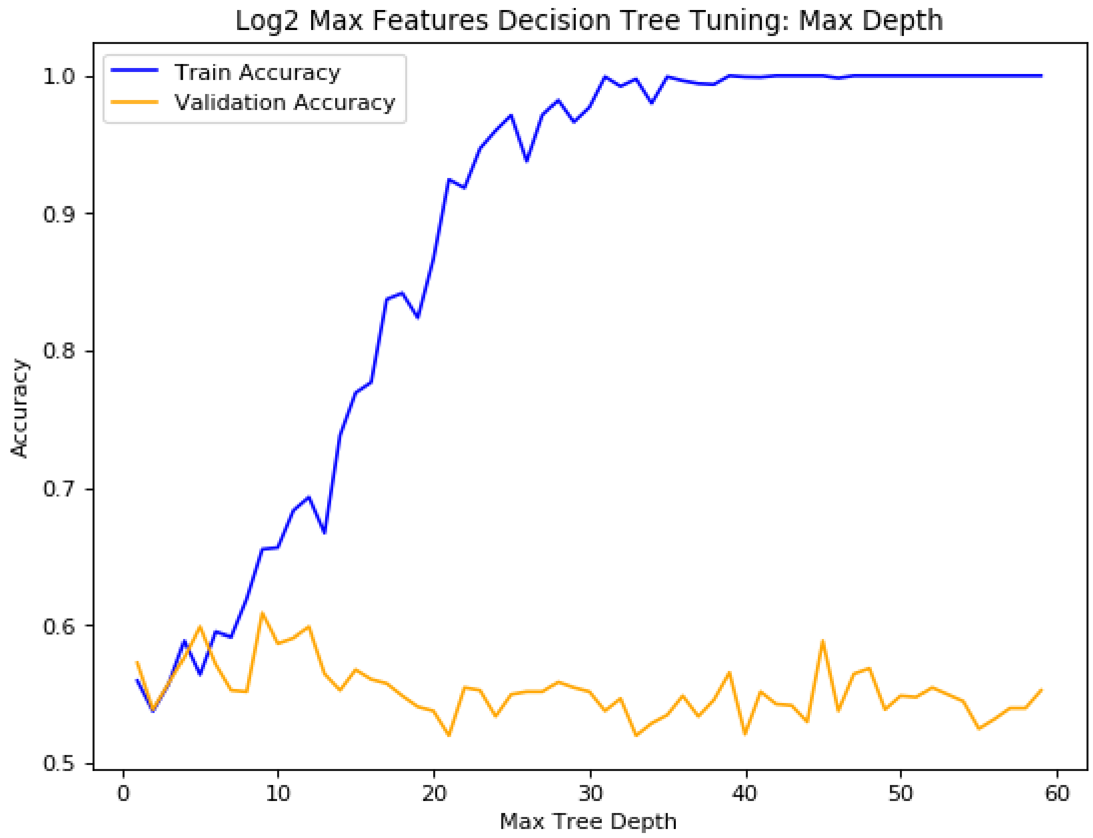
3.1.2 Decision Tree: Max log2 Features

In [333]:

```
# Find best decision tree with log2 max features
max_lens = list(range(1,60,1)) #[5, 10, 15, 20, 25, 30, 35, 40]
tree_log2_models = []

for i, m_len  in enumerate(max_lens):
    tree_log2_clf = DecisionTreeClassifier(max_depth=m_len, max_features='l
    tree_log2_clf.fit(X, y)

    # Prediction acc
    train_acc = np.sum([tree_log2_clf.predict(X) == y], axis=1) / len(y)
    val_acc = np.sum([tree_log2_clf.predict(X_val) == y_val], axis=1) / len
    test_acc = np.sum([tree_log2_clf.predict(X_test) == y_test], axis=1) /

    # Save model and acc
    tree_log2_models.append((tree_log2_clf, train_acc[0], val_acc[0], test_
```

In [334]:

```
xaxis_data = max_lens
yaxis_data_train = [i[1] for i in tree_log2_models]
yaxis_data_val = [i[2] for i in tree_log2_models]

figure(num=None, figsize=(8, 6), dpi=80, facecolor='w', edgecolor='k')

plt.plot(xaxis_data, yaxis_data_train, color='blue', label='Train Accuracy'
plt.plot(xaxis_data, yaxis_data_val, color='orange', label="Validation Accu

# Plot text
plt.legend()
plt.title('Log2 Max Features Decision Tree Tuning: Max Depth')
plt.xlabel('Max Tree Depth')
plt.ylabel('Accuracy')

plt.savefig('Log2-CV.png', dpi=420)
plt.show()
```



In [335]:

```
max([i[2] for i in tree_log2_models])
```

Out[335]:

```
0.609
```

In [336]:

```
tree_log2_models
```

Out[336]:

```
[(DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=
1,
               max_features='log2', max_leaf_nodes=None,
               min_impurity_decrease=0.0, min_impurity_split=None,
               min_samples_leaf=1, min_samples_split=2,
               min_weight_fraction_leaf=0.0, presort=False, random_state=N
one,
               splitter='best'), 0.56, 0.573, 0.5642926829268292),
 (DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=
2,
               max_features='log2', max_leaf_nodes=None,
               min_impurity_decrease=0.0, min_impurity_split=None,
               min_samples_leaf=1, min_samples_split=2,
               min_weight_fraction_leaf=0.0, presort=False, random_state=N
one,
               splitter='best'), 0.53775, 0.539, 0.5333658536585366),
 (DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=
3,
               max_features='log2', max_leaf_nodes=None,
```

In [337]:

```
feature_importance = list(tree_log2_models[6][0].feature_importances_)
arr = []
for i,j in zip(train.drop('HasDetections', axis=1).columns, feat_importance
    if j > 0:
        arr.append((i,j))
arr
```

Out[337]:

```
[('AppVersion', 0.005411327669183273),
 ('AvSigVersion', 0.12818671910397597),
 ('AVProductStatesIdentifier', 0.019625544389855067),
 ('AVProductsInstalled', 0.16069486380517994),
 ('HasTpm', 0.005490099761724008),
 ('CityIdentifier', 0.01065026768708279),
 ('OrganizationIdentifier', 0.002785002849290186),
 ('GeoNameIdentifier', 0.006808097717126339),
 ('OsBuildLab', 0.007049092326582092),
 ('SmartScreen', 0.5085008289759555),
 ('Census_OEMNameIdentifier', 0.021666999426615246),
 ('Census_ProcessorModelIdentifier', 0.015092964290409032),
 ('Census_PrimaryDiskTotalCapacity', 0.007871022064266582),
 ('Census_ChassisTypeName', 0.007338133670530459),
 ('Census_InternalPrimaryDiagonalDisplaySizeInInches', 0.07226169068088
93),
 ('Census_OSArchitecture', 0.004870194902264946),
 ('Census_OSBuildRevision', 0.004345916103615489),
 ('Census_FirmwareVersionIdentifier', 0.005744047032805019),
 ('Census_IsSecureBootEnabled', 0.005607187542648800)]
```

In [338]:

```
tree_log2_models[4]
```

Out[338]:

```
(DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=5,
             max_features='log2', max_leaf_nodes=None,
             min_impurity_decrease=0.0, min_impurity_split=None,
             min_samples_leaf=1, min_samples_split=2,
             min_weight_fraction_leaf=0.0, presort=False, random_state=No
ne,
             splitter='best'), 0.564375, 0.599, 0.5500731707317074)
```

In [318]:

```
feat_importance = tree_log2_models[4][0].feature_importances_
```

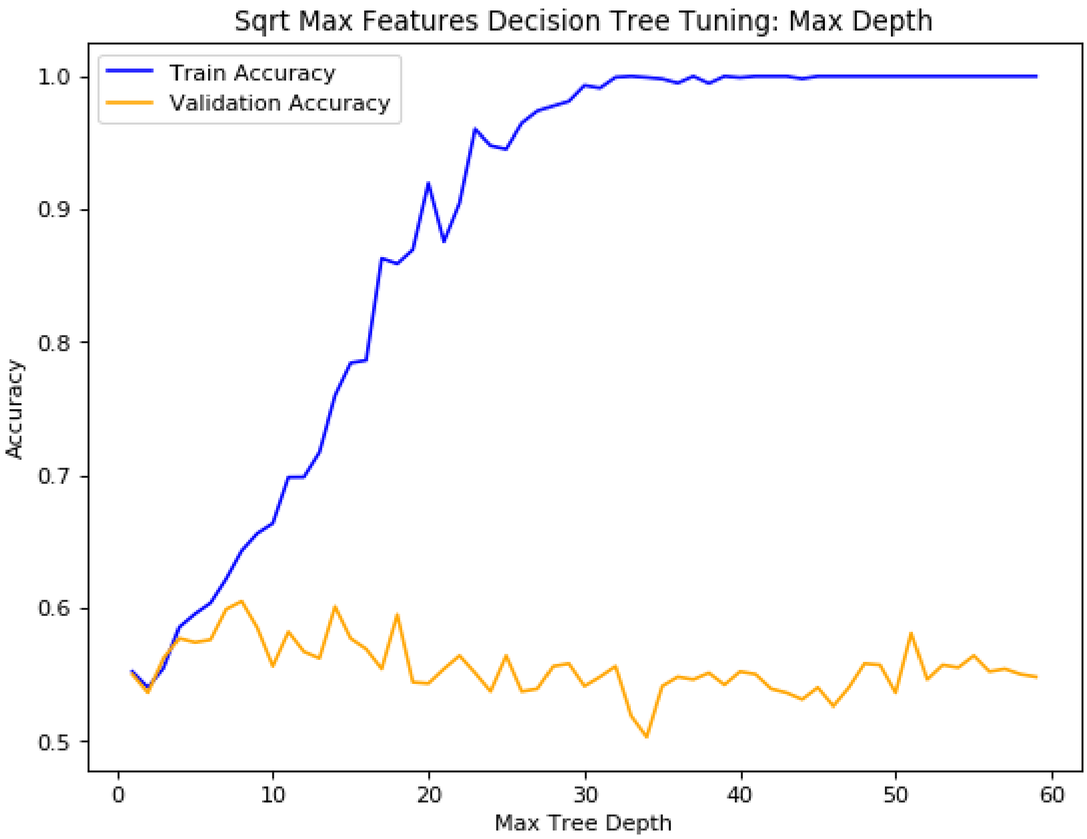
```
In [319]: arr = []
          for i,j in zip(train.drop('HasDetections', axis=1).columns, feat_importance
              arr.append((i,j))
          arr
```

```
Out[319]: [('ProductName', 0.0),
           ('EngineVersion', 0.0),
           ('AppVersion', 0.005411327669183273),
           ('AvSigVersion', 0.12818671910397597),
           ('RtpStateBitfield', 0.0),
           ('IsSxsPassiveMode', 0.0),
           ('DefaultBrowsersIdentifier', 0.0),
           ('AVProductStatesIdentifier', 0.019625544389855067),
           ('AVProductsInstalled', 0.16069486380517994),
           ('AVProductsEnabled', 0.0),
           ('HasTpm', 0.005490099761724008),
           ('CountryIdentifier', 0.0),
           ('CityIdentifier', 0.010650267687082 79),
           ('OrganizationIdentifier', 0.002785002849290186),
           ('GeoNameIdentifier', 0.006808097717126339),
           ('LocaleEnglishNameIdentifier', 0.0),
           ('Processor', 0.0),
           ('OsVer', 0.0),
           ('OsBuild', 0.0),
           ('OsSuite', 0.0),
           ('OsPlatformSubRelease', 0.0),
           ('OsBuildLab', 0.007049092326582092),
           ('SkuEdition', 0.0),
           ('IsProtected', 0.0),
           ('IeVerIdentifier', 0.0),
           ('SmartScreen', 0.5085008289759555),
           ('Firewall', 0.0),
           ('Census_MDC2FormFactor', 0.0),
           ('Census_OEMNameIdentifier', 0.021666999426615246),
           ('Census_OEMModelIdentifier', 0.0),
           ('Census_ProcessorCoreCount', 0.0),
           ('Census_ProcessorManufacturerIdentifier', 0.0),
           ('Census_ProcessorModelIdentifier', 0.015092964290409032),
           ('Census_PrimaryDiskTotalCapacity', 0.007871022064266582),
           ('Census_PrimaryDiskTypeName', 0.0),
           ('Census_SystemVolumeTotalCapacity', 0.0),
           ('Census_HasOpticalDiskDrive', 0.0),
           ('Census_TotalPhysicalRAM', 0.0),
           ('Census_ChassisTypeName', 0.007338133670530459),
           ('Census_InternalPrimaryDiagonalDisplaySizeInInches', 0.07226169068088 9
          3),
           ('Census_InternalPrimaryDisplayResolutionHorizontal', 0.0),
           ('Census_InternalPrimaryDisplayResolutionVertical', 0.0),
           ('Census_PowerPlatformRoleName', 0.0),
           ('Census_InternalBatteryType', 0.0),
           ('Census_InternalBatteryNumberOfCharges', 0.0),
           ('Census_OSVersion', 0.0),
           ('Census_OSArchitecture', 0.004870194902264946),
           ('Census_OSBranch', 0.0),
           ('Census_OSBuildNumber', 0.0),
           ('Census_OSBuildRevision', 0.004345916103615 4895),
           ('Census_OSEdition', 0.0),
           ('Census_OSInstallTypeName', 0.0),
           ('Census_OSInstallLanguageIdentifier', 0.0),
           ('Census_OSUILocaleIdentifier', 0.0),
           ('Census_OSWUAutoUpdateOptionsName', 0.0),
           ('Census_GenuineStateName', 0.0),
           ('Census_ActivationChannel', 0.0),
           ('Census_FlightRing', 0.0),
           ('Census_FirmwareManufacturerIdentifier', 0.0),
           ('Census_FirmwareVersionIdentifier', 0.0057440470328050195),
           ('Census_IsSecureBootEnabled', 0.0056071875426488005),
           ('Census_IsTouchEnabled', 0.0),
           ('Census_IsPenCapable', 0.0),
           ('Census_IsAlwaysOnAlwaysConnectedCapable', 0.0),
           ('Wdft_IsGamer', 0.0),
           ('Wdft_RegionIdentifier', 0.0)]
```

In [339]:

```
tree_sqrt_models = []

for i, m_len  in enumerate(max_lens):
    tree_sqrt_clf = DecisionTreeClassifier(max_depth=m_len, max_features='s
    tree_sqrt_clf.fit(X, y)

    # Prediction acc
    train_acc = np.sum([tree_sqrt_clf.predict(X) == y], axis=1) / len(y)
    val_acc = np.sum([tree_sqrt_clf.predict(X_val) == y_val], axis=1) / len
    test_acc = np.sum([tree_sqrt_clf.predict(X_test) == y_test], axis=1) /

    # Save model and acc
    tree_sqrt_models.append((tree_sqrt_clf, train_acc[0], val_acc[0], ))
```

In [340]:
```
xaxis_data = max_lens
yaxis_sqrt_train = [i[1] for i in tree_sqrt_models]
yaxis_sqrt_val = [i[2] for i in tree_sqrt_models]

figure(num=None, figsize=(8, 6), dpi=80, facecolor='w', edgecolor='k')

# Plot Data
plt.plot(xaxis_data, yaxis_sqrt_train, color='blue', label="Train Accuracy"
plt.plot(xaxis_data, yaxis_sqrt_val, color='orange', label="Validation Accu

# Plot text
plt.legend()
plt.title('Sqrt Max Features Decision Tree Tuning: Max Depth')
plt.xlabel('Max Tree Depth')
plt.ylabel('Accuracy')

plt.savefig('Sqrt-CV.png', dpi=420)

plt.show()
```



In [341]:
```
max([i[2] for i in tree_sqrt_models])
```

Out[341]:
```
0.605
```

In [342]:
```
tree_sqrt_models
```

Out[342]:
```
[(DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=
1,
                max_features='sqrt', max_leaf_nodes=None,
                min_impurity_decrease=0.0, min_impurity_split=None,
                min_samples_leaf=1, min_samples_split=2,
                min_weight_fraction_leaf=0.0, presort=False, random_state=N
one,
                splitter='best'), 0.552, 0.55),
 (DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=
2,
                max_features='sqrt', max_leaf_nodes=None,
                min_impurity_decrease=0.0, min_impurity_split=None,
                min_samples_leaf=1, min_samples_split=2,
                min_weight_fraction_leaf=0.0, presort=False, random_state=N
one,
                splitter='best'), 0.54, 0.536),
 (DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=
3,
                max_features='sqrt', max_leaf_nodes=None,
```

In [348]:
```
feat_importance = tree_sqrt_models[7][0].feature_importances_
```

```
In [349]: arr = []
          for i,j in zip(train.drop('HasDetections', axis=1).columns, feat_importance
              if j > 0:
                  arr.append((i,j))
          arr
```

```
Out[349]: [('EngineVersion', 0.09797331267045815),
           ('AppVersion', 0.019741279003257204),
           ('AvSigVersion', 0.019891061703133407),
           ('DefaultBrowsersIdentifier', 0.006459270871591631),
           ('AVProductStatesIdentifier', 0.011409068068357932),
           ('AVProductsInstalled', 0.11096245124235501),
           ('CountryIdentifier', 0.005484038520492168),
           ('CityIdentifier', 0.03340663155847973),
           ('OrganizationIdentifier', 0.0019450357932891949),
           ('GeoNameIdentifier', 0.04800244363364314),
           ('LocaleEnglishNameIdentifier', 0.0026040478507890078),
           ('OsPlatformSubRelease', 0.014639508082357158),
           ('OsBuildLab', 0.016157268405932613),
           ('SkuEdition', 0.0029373228699584317),
           ('IeVerIdentifier', 0.02244268049646621),
           ('SmartScreen', 0.12120814002527844),
           ('Census_MDC2FormFactor', 0.005270287488480066),
           ('Census_OEMNameIdentifier', 0.020963561943157140),
           ('Census_OEMModelIdentifier', 0.022358351731290510),
           ('Census_ProcessorCoreCount', 0.005456866808907994),
           ('Census_ProcessorModelIdentifier', 0.04760404814757409),
           ('Census_PrimaryDiskTotalCapacity', 0.06452195009038093),
           ('Census_SystemVolumeTotalCapacity', 0.019324901881132240),
           ('Census_HasOpticalDiskDrive', 0.004126664992184298),
           ('Census_TotalPhysicalRAM', 0.015183749728726431),
           ('Census_ChassisTypeName', 0.0051817671596256),
           ('Census_InternalPrimaryDiagonalDisplaySizeInInches', 0.0044002119285425
          625),
           ('Census_InternalPrimaryDisplayResolutionHorizontal', 0.0111801788093158
          13),
           ('Census_InternalPrimaryDisplayResolutionVertical', 0.0146950184896002
          7),
           ('Census_PowerPlatformRoleName', 0.001103013920531091),
           ('Census_InternalBatteryNumberOfCharges', 0.007947131097114965),
           ('Census_OSVersion', 0.016009741886231256),
           ('Census_OSBuildNumber', 0.003268189394166195),
           ('Census_OSBuildRevision', 0.02749003348825741),
           ('Census_OSEdition', 0.011651108734424376),
           ('Census_OSInstallTypeName', 0.03220100213366562),
           ('Census_OSInstallLanguageIdentifier', 0.007971386436886583),
           ('Census_OSUILocaleIdentifier', 0.010367284419974506),
           ('Census_OSWUAutoUpdateOptionsName', 0.005845636681005605),
           ('Census_ActivationChannel', 0.003075942959215241 4),
           ('Census_FlightRing', 0.003078914159211951 2),
           ('Census_FirmwareManufacturerIdentifier', 0.011815157621338591),
           ('Census_FirmwareVersionIdentifier', 0.022411707614850052),
           ('Census_IsSecureBootEnabled', 0.009152645071616523),
           ('Census_IsTouchEnabled', 0.015835613484674178),
           ('Wdft_IsGamer', 0.01588270317606865),
           ('Wdft_RegionIdentifier', 0.019361667726009172)]
```

In [354]:
```
arr.sort(key = lambda arr: arr[1])
```

In [355]:
```
arr
```

Out[355]:
```
[('Census_PowerPlatformRoleName', 0.001103013920531091),
 ('OrganizationIdentifier', 0.0019450357932891949),
 ('LocaleEnglishNameIdentifier', 0.0026040478507890078),
 ('SkuEdition', 0.0029373228699584317),
 ('Census_ActivationChannel', 0.0030759429592152414),
 ('Census_FlightRing', 0.0030789141592119512),
 ('Census_OSBuildNumber', 0.003268189394166195),
 ('Census_HasOpticalDiskDrive', 0.004126664992184298),
 ('Census_InternalPrimaryDiagonalDisplaySizeInInches', 0.0044002119285425
625),
 ('Census_ChassisTypeName', 0.0051817671596256),
 ('Census_MDC2FormFactor', 0.005270287488480066),
 ('Census_ProcessorCoreCount', 0.005456866808907994),
 ('CountryIdentifier', 0.005484038520492168),
 ('Census_OSWUAutoUpdateOptionsName', 0.005845636681005605),
 ('DefaultBrowsersIdentifier', 0.006459270871591631),
 ('Census_InternalBatteryNumberOfCharges', 0.007947131097114965),
 ('Census_OSInstallLanguageIdentifier', 0.007971386436886583),
 ('Census_IsSecureBootEnabled', 0.009152645071616523),
 ('Census_OSUILocaleIdentifier', 0.010367284419974506),
 ('Census_InternalPrimaryDisplayResolutionHorizontal', 0.0111801788093158
13),
 ('AVProductStatesIdentifier', 0.011409068068357932),
 ('Census_OSEdition', 0.011651108734424376),
 ('Census_FirmwareManufacturerIdentifier', 0.011815157621338591),
 ('OsPlatformSubRelease', 0.014639508082357158),
 ('Census_InternalPrimaryDisplayResolutionVertical', 0.0146950184896002
7),
 ('Census_TotalPhysicalRAM', 0.015183749728726431),
 ('Census_IsTouchEnabled', 0.015835613484674178),
 ('Wdft_IsGamer', 0.01588270317606865),
 ('Census_OSVersion', 0.016009741886231256),
 ('OsBuildLab', 0.016157268405932613),
 ('Census_SystemVolumeTotalCapacity', 0.01932490188113224),
 ('Wdft_RegionIdentifier', 0.019361667726009172),
 ('AppVersion', 0.019741279003257204),
 ('AvSigVersion', 0.019891061703133407),
 ('Census_OEMNameIdentifier', 0.02096356194315714),
 ('Census_OEMModelIdentifier', 0.02235835173129051),
 ('Census_FirmwareVersionIdentifier', 0.022411707614850052),
 ('IeVerIdentifier', 0.02244268049646621),
 ('Census_OSBuildRevision', 0.02749003348825741),
 ('Census_OSInstallTypeName', 0.03220100213366562),
 ('CityIdentifier', 0.03340663155847973),
 ('Census_ProcessorModelIdentifier', 0.04760404814757409),
 ('GeoNameIdentifier', 0.04800244363364314),
 ('Census_PrimaryDiskTotalCapacity', 0.06452195009038093),
 ('EngineVersion', 0.09797331267045815),
 ('AVProductsInstalled', 0.11096245124235501),
 ('SmartScreen', 0.12120814002527844)]
```

In [350]:

```
sum(i[1] for i in arr)
```

Out[350]:

```
0.9999999999999999
```

In [ ]:

```
[('AppVersion', 0.005411327669183273),
 ('AvSigVersion', 0.12818671910397597),
 ('AVProductStatesIdentifier', 0.019625544389855067),
 ('AVProductsInstalled', 0.16069486380517994),
 ('HasTpm', 0.005490099761724008),
 ('CityIdentifier', 0.01065026768708279),
 ('OrganizationIdentifier', 0.002785002849290186),
 ('GeoNameIdentifier', 0.006808097717126339),
 ('OsBuildLab', 0.007049092326582092),
 ('SmartScreen', 0.5085008289759555),
 ('Census_OEMNameIdentifier', 0.021666999426615246),
 ('Census_ProcessorModelIdentifier', 0.015092964290409032),
 ('Census_PrimaryDiskTotalCapacity', 0.007871022064266582),
 ('Census_ChassisTypeName', 0.007338133670530459),
 ('Census_InternalPrimaryDiagonalDisplaySizeInInches', 0.0722616906808893),
 ('Census_OSArchitecture', 0.004870194902264946),
 ('Census_OSBuildRevision', 0.0043459161036154895),
 ('Census_FirmwareVersionIdentifier', 0.0057440470328050195),
 ('Census_IsSecureBootEnabled', 0.0056071875426488005)]
```

In [217]:

```
tree_sqrt_models[8]
```

Out[217]:

```
(DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=9,
             max_features='sqrt', max_leaf_nodes=None,
             min_impurity_decrease=0.0, min_impurity_split=None,
             min_samples_leaf=1, min_samples_split=2,
             min_weight_fraction_leaf=0.0, presort=False, random_state=No
ne,
             splitter='best'), 0.65575, 0.584)
```

In [218]:

```
tree_sqrt_models[6]
```

Out[218]:

```
(DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=7,
             max_features='sqrt', max_leaf_nodes=None,
             min_impurity_decrease=0.0, min_impurity_split=None,
             min_samples_leaf=1, min_samples_split=2,
             min_weight_fraction_leaf=0.0, presort=False, random_state=No
ne,
             splitter='best'), 0.632625, 0.5795)
```

3.2 Logistic Regression

In [265]:

```
from sklearn.linear_model import LogisticRegression
```

In [266]:

```
ones = np.ones(X.shape[0]).reshape(-1, 1)
logit_X = np.append(X, ones, 1)

ones = np.ones(X_val.shape[0]).reshape(-1, 1)
logit_X_val = np.append(X_val, ones, 1)
```

In [267]:

```
lr = LogisticRegression(penalty='l2', solver='liblinear')
lr.fit(X, y)
print("Train Acc %.4f" % (np.sum([lr.predict(X) == y], axis=1) / len(y)))
print("Test  Acc %.4f" % (np.sum([lr.predict(X_val) == y_val], axis=1) / le
```

```
Train Acc 0.5270
Test  Acc 0.5360
```

3.2.1 L2 Regularized Logistic Regression

In [268]:

```
for i, c  in enumerate(C):
    print(i,c)
```

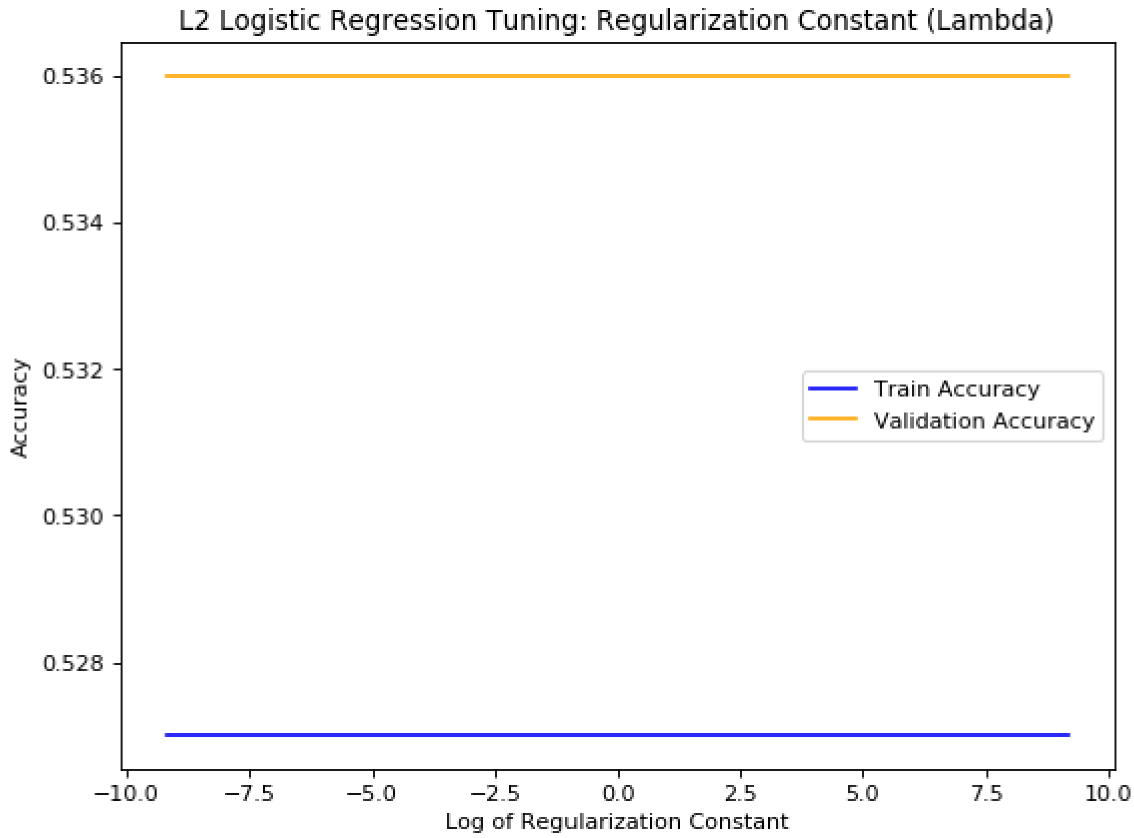
```
0 0.0001
1 0.001
2 0.005
3 0.01
4 1
5 10
6 100
7 500
8 1000
9 5000
10 10000
```

In [277]:

```
# Logistic regression with L2 regularization
C = [.0001, .00025, .0005, .00075, .001, .0025, .005, .0075, .01, 1, 10, 10
#C = [.000001, .01, 1, 10, 100, 1000000]

l2_logit_models = []

for i, c  in enumerate(C):
    lr = LogisticRegression(penalty='l2', C=c, solver='liblinear')
    lr.fit(X, y)

    # Prediction acc
    train_acc = np.sum([lr.predict(X) == y], axis=1) / len(y)
    val_acc = np.sum([lr.predict(X_val) == y_val], axis=1) / len(y_val)

    # Save model and acc
    l2_logit_models.append((lr, train_acc[0], val_acc[0], ))
```

In [278]:

```
xaxis_data = C
yaxis_l2_logit_train = [i[1] for i in l2_logit_models]
yaxis_l2_logit_val = [i[2] for i in l2_logit_models]

figure(num=None, figsize=(8, 6), dpi=80, facecolor='w', edgecolor='k')

# Plot Data
plt.plot(np.log(xaxis_data), yaxis_l2_logit_train, color='blue', label="Tra
plt.plot(np.log(xaxis_data), yaxis_l2_logit_val, color='orange', label="Val

# Plot text
plt.legend()
plt.title('L2 Logistic Regression Tuning: Regularization Constant (Lambda)'
plt.xlabel('Log of Regularization Constant')
plt.ylabel('Accuracy')

plt.show()
```



In [275]:

```
C
```

Out[275]:

```
[1e-06, 0.01, 1, 10, 100, 1000000]
```

3.2.1 L1 Regularized Logistic Regression

In [242]:

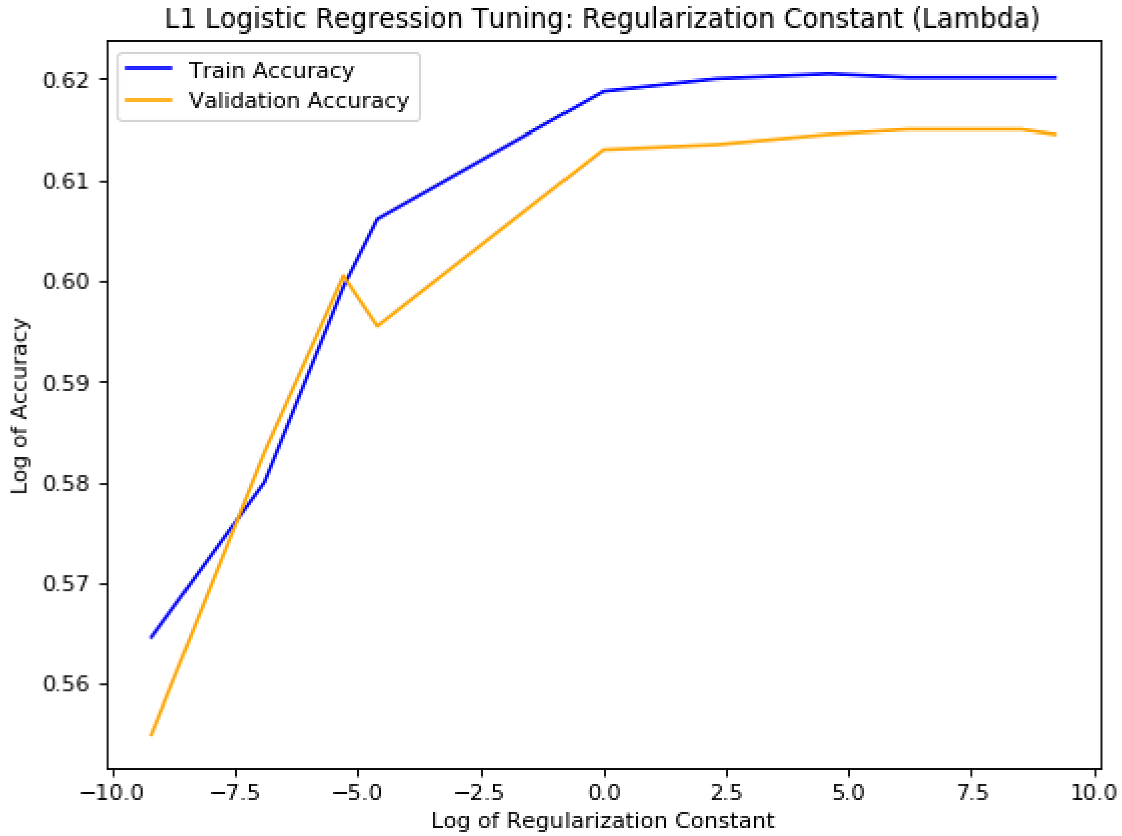
```
# Logistic regression with L1 regularization
C = [.0001, .001, .005, .01, 1, 10, 100, 500, 1000, 5000, 10000]

l1_logit_models = []

for i, c  in enumerate(C):
    lr = LogisticRegression(penalty='l1', C=c, solver='liblinear')
    lr.fit(logit_X, y)

    # Prediction acc
    train_acc = np.sum([lr.predict(logit_X) == y], axis=1) / len(y)
    val_acc = np.sum([lr.predict(logit_X_val) == y_val], axis=1) / len(y_va

    # Save model and acc
    l1_logit_models.append((lr, train_acc[0], val_acc[0], ))
```

```
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
/anaconda3/envs/py3-env/lib/python3.7/site-packages/sklearn/svm/base.py:9
```

```
31: ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  "the number of iterations.", ConvergenceWarning)
```

In [246]:

```
xaxis_data = C
yaxis_l1_logit_train = [i[1] for i in l1_logit_models]
yaxis_l1_logit_val = [i[2] for i in l1_logit_models]

figure(num=None, figsize=(8, 6), dpi=80, facecolor='w', edgecolor='k')

# Plot Data
plt.plot(np.log(xaxis_data), yaxis_l1_logit_train, color='blue', label="Tra
plt.plot(np.log(xaxis_data), yaxis_l1_logit_val, color='orange', label="Val

# Plot text
plt.legend()
plt.title('L1 Logistic Regression Tuning: Regularization Constant (Lambda)'
plt.xlabel('Log of Regularization Constant')
plt.ylabel('Log of Accuracy')

plt.savefig('L1-Logistic-CV.png', dpi=420)

plt.show()
```



In [248]:

```
max(i[2] for i in l1_logit_models)
```

Out[248]:

```
0.615
```

In [249]:
```
l1_logit_models
```

Out[249]:
```
[(LogisticRegression(C=0.0001, class_weight=None, dual=False,
             fit_intercept=True, intercept_scaling=1, max_iter=100,
             multi_class='warn', n_jobs=None, penalty='l1', random_state=N
one,
             solver='liblinear', tol=0.0001, verbose=0, warm_start=False),
  0.564625,
  0.555),
 (LogisticRegression(C=0.001, class_weight=None, dual=False, fit_intercep
t=True,
             intercept_scaling=1, max_iter=100, multi_class='warn',
             n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
             tol=0.0001, verbose=0, warm_start=False), 0.58, 0.583),
 (LogisticRegression(C=0.005, class_weight=None, dual=False, fit_intercep
t=True,
             intercept_scaling=1, max_iter=100, multi_class='warn',
             n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
             tol=0.0001, verbose=0, warm_start=False), 0.599375, 0.6005),
 (LogisticRegression(C=0.01, class_weight=None, dual=False, fit_intercept
=True,
             intercept_scaling=1, max_iter=100, multi_class='warn',
             n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
             tol=0.0001, verbose=0, warm_start=False), 0.606125, 0.5955),
 (LogisticRegression(C=1, class_weight=None, dual=False, fit_intercept=Tr
ue,
             intercept_scaling=1, max_iter=100, multi_class='warn',
             n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
             tol=0.0001, verbose=0, warm_start=False), 0.61875, 0.613),
 (LogisticRegression(C=10, class_weight=None, dual=False, fit_intercept=T
rue,
             intercept_scaling=1, max_iter=100, multi_class='warn',
             n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
             tol=0.0001, verbose=0, warm_start=False), 0.62, 0.6135),
 (LogisticRegression(C=100, class_weight=None, dual=False, fit_intercept=
True,
             intercept_scaling=1, max_iter=100, multi_class='warn',
             n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
             tol=0.0001, verbose=0, warm_start=False), 0.6205, 0.6145),
 (LogisticRegression(C=500, class_weight=None, dual=False, fit_intercept=
True,
             intercept_scaling=1, max_iter=100, multi_class='warn',
             n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
             tol=0.0001, verbose=0, warm_start=False), 0.620125, 0.615),
 (LogisticRegression(C=1000, class_weight=None, dual=False, fit_intercept
=True,
             intercept_scaling=1, max_iter=100, multi_class='warn',
             n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
             tol=0.0001, verbose=0, warm_start=False), 0.620125, 0.615),
 (LogisticRegression(C=5000, class_weight=None, dual=False, fit_intercept
=True,
            intercept_scaling=1, max_iter=100, multi_class='warn',
            n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
            tol=0.0001, verbose=0, warm_start=False), 0.620125, 0.615),
 (LogisticRegression(C=10000, class_weight=None, dual=False, fit_intercep
t=True,
            intercept_scaling=1, max_iter=100, multi_class='warn',
            n_jobs=None, penalty='l1', random_state=None, solver='libline
ar',
            tol=0.0001, verbose=0, warm_start=False), 0.620125, 0.6145)]
```

In [245]:

```
lr.coef_
```

```
         1.34071174e-01,  9.24543856e-01, -1.17283276e-04,
         1.25270217e-05, -3.73299198e-01, -4.12536719e-02,
        -1.12407945e-01, -1.01844009e-05, -1.07386681e-06,
         3.25142472e-03,  2.50192511e-04,  6.77801714e-04,
        -4.27973916e-01, -2.59649967e-01, -1.67193104e-04,
         6.36840642e-04,  1.90028855e-02,  3.93704222e-03,
        -6.52900240e-02,  7.55056988e-01, -1.13340979e-03,
        -3.55804477e-01,  6.40164038e-02, -1.72748133e-02,
        -6.60740940e-06,  9.02197758e-07,  2.15952515e-02,
        -6.86974590e-04, -3.60060366e-05,  4.30624027e-07,
         3.91146735e-03, -3.19348600e-07,  7.75166812e-02,
         1.28025299e-05, -1.72649144e-02,  6.85152009e-04,
         7.65999731e-05, -2.32659264e-04,  3.95148641e-02,
        -5.89359759e-02, -3.90924937e-11, -6.83265308e-03,
         1.77440627e-02,  4.73746292e-02,  2.39885697e-04,
        -2.13440920e-05,  6.25937763e-02, -1.44939411e-03,
         3.01828511e-03, -3.58398447e-04, -1.10869333e-02,
         2.72685975e-01, -2.81175681e-02, -4.54344232e-02,
         1.22789987e-04, -1.14171674e-07,  4.13567776e-02,
        -3.75129640e-01,  3.35626291e-01, -3.93827940e-01,
```

In [ ]:

```
print ("C = 100 is the best")
```

In [ ]:

In [ ]:

```
c = 100000
lr = LogisticRegression(penalty='l1', C=c, solver='liblinear')
lr.fit(logit_X, y)

# Prediction acc
train_acc = np.sum([lr.predict(logit_X) == y], axis=1) / len(y)
val_acc = np.sum([lr.predict(logit_X_val) == y_val], axis=1) / len(y_val)

# Save model and acc
l1_logit_models.append((lr, train_acc[0], val_acc[0], ))
```

In [ ]: