

Linear Algebra

March 12, 2018

```
In [1]: import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
%matplotlib inline
```

```
In [2]: df=pd.read_csv('creditcard.csv')
```

```
In [4]: df.tail()
```

```
Out[4]:
```

	Time	V1	V2	V3	V4	V5	\
284802	172786.0	-11.881118	10.071785	-9.834783	-2.066656	-5.364473	
284803	172787.0	-0.732789	-0.055080	2.035030	-0.738589	0.868229	
284804	172788.0	1.919565	-0.301254	-3.249640	-0.557828	2.630515	
284805	172788.0	-0.240440	0.530483	0.702510	0.689799	-0.377961	
284806	172792.0	-0.533413	-0.189733	0.703337	-0.506271	-0.012546	

	V6	V7	V8	V9	...	V21	V22	\
284802	-2.606837	-4.918215	7.305334	1.914428	...	0.213454	0.111864	
284803	1.058415	0.024330	0.294869	0.584800	...	0.214205	0.924384	
284804	3.031260	-0.296827	0.708417	0.432454	...	0.232045	0.578229	
284805	0.623708	-0.686180	0.679145	0.392087	...	0.265245	0.800049	
284806	-0.649617	1.577006	-0.414650	0.486180	...	0.261057	0.643078	

	V23	V24	V25	V26	V27	V28	Amount	\
284802	1.014480	-0.509348	1.436807	0.250034	0.943651	0.823731	0.77	
284803	0.012463	-1.016226	-0.606624	-0.395255	0.068472	-0.053527	24.79	
284804	-0.037501	0.640134	0.265745	-0.087371	0.004455	-0.026561	67.88	
284805	-0.163298	0.123205	-0.569159	0.546668	0.108821	0.104533	10.00	
284806	0.376777	0.008797	-0.473649	-0.818267	-0.002415	0.013649	217.00	

	Class
284802	0
284803	0
284804	0
284805	0
284806	0

[5 rows x 31 columns]

```
In [5]: df.head()
```

```
Out[5]:
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	Time	V1	V2	V3	V4	V5	V6	V7	\
0	0.0	-1.359807	-0.072781	2.536347	1.378155	-0.338321	0.462388	0.239599	
1	0.0	1.191857	0.266151	0.166480	0.448154	0.060018	-0.082361	-0.078803	
2	1.0	-1.358354	-1.340163	1.773209	0.379780	-0.503198	1.800499	0.791461	
3	1.0	-0.966272	-0.185226	1.792993	-0.863291	-0.010309	1.247203	0.237609	
4	2.0	-1.158233	0.877737	1.548718	0.403034	-0.407193	0.095921	0.592941	

	V8	V9	...	V21	V22	V23	V24	\
0	0.098698	0.363787	...	-0.018307	0.277838	-0.110474	0.066928	
1	0.085102	-0.255425	...	-0.225775	-0.638672	0.101288	-0.339846	
2	0.247676	-1.514654	...	0.247998	0.771679	0.909412	-0.689281	
3	0.377436	-1.387024	...	-0.108300	0.005274	-0.190321	-1.175575	
4	-0.270533	0.817739	...	-0.009431	0.798278	-0.137458	0.141267	

	V25	V26	V27	V28	Amount	Class
0	0.128539	-0.189115	0.133558	-0.021053	149.62	0
1	0.167170	0.125895	-0.008983	0.014724	2.69	0
2	-0.327642	-0.139097	-0.055353	-0.059752	378.66	0
3	0.647376	-0.221929	0.062723	0.061458	123.50	0
4	-0.206010	0.502292	0.219422	0.215153	69.99	0

[5 rows x 31 columns]

```
In [7]: df['Class'].describe()
```

```
Out[7]:
```

count	284807.000000
mean	0.001727
std	0.041527
min	0.000000
25%	0.000000
50%	0.000000
75%	0.000000
max	1.000000

Name: Class, dtype: float64

```
In [14]: g=df.groupby('Class')
```

```
In [18]: for Class, Class_df in g:
          print(Class_df['Class'].describe())
          print('\n')
```

```
count    284315.0
mean       0.0
std        0.0
```

```

min          0.0
25%          0.0
50%          0.0
75%          0.0
max          0.0
Name: Class, dtype: float64

```

```

count      492.0
mean        1.0
std         0.0
min         1.0
25%         1.0
50%         1.0
75%         1.0
max         1.0
Name: Class, dtype: float64

```

```
In [20]: 284315//492
```

```
Out[20]: 577
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```
In [24]: 577*5
```

```
Out[24]: 2885
```

```

non_fraudulent : fraudulent :: 577 : 1
sample composition -
2885 non_fraudulent 5 fraudeulent transactions

```

```
In [71]: fraudulent_dataset=df[df['Class']==1][5:]
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```
In [72]: non_fraudulent_dataset=df[df['Class']==0][2885:]
```

```

In [73]: fraudulent_sample=df[df['Class']==1][:5]
         non_fraudulent_sample=df[df['Class']==0][:2885]

```

```
In [74]: source=pd.concat((fraudulent_sample, non_fraudulent_sample))
```

```
In [75]: target=pd.concat((fraudulent_dataset, non_fraudulent_dataset))
```

Now source has similar Class distribution as df and for each transaction in source we have to search for top 10 transactions in target with lowest similarity

$$similarity(v_i, v_j) = \cos^{-1} \frac{v_i \cdot v_j}{\|v_i\| \|v_j\|}$$

```

In [94]: source_matrix=source.as_matrix()
         target_matrix=target.as_matrix()

In [97]: ans=[]

         for sIndex, sample in zip(source.index,source_matrix):
             similarity_list=[]

             for tIndex, tVec in zip(target.index,target_matrix):
                 similarity_list.append((np.dot(sample, np.transpose(tVec))/(np.linalg.norm(sample)*np.linalg.norm(tVec))))

             print('sample' + str(sIndex))

             similarity_list=sorted(similarity_list, key=lambda x:x[0])
             similarity_list.reverse()
             ans.append((sIndex, similarity_list[:10]))

```

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```

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(0.9999793028609808, 3081)]),
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[(0.99999201214622158, 2943),
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(0.99998746307025577, 3790),
(0.9999871720004726, 7523),
(0.99998694024091384, 3142),
(0.99998692174133197, 4769),
(0.99998691990628541, 2974)]),
...]
```

1 Now let's do the EDA

1.1 Dataset description

284807 rows 31 features

Feature 1 is time elapsed between this transaction and first transaction in dataset Features 2 - 29 are Principle components of some unknown features Feature 30 in transaction amount
Class label in feature 31

1.2 Objective

Find the best features for classification

```
In [43]: df.describe().loc['std'].max()
```

```
Out[43]: 47488.145954565822
```

```
In [7]: df.describe()['Amount']
```

```
Out[7]: count      284807.000000  
       mean         88.349619  
       std         250.120109  
       min          0.000000  
       25%          5.600000  
       50%         22.000000  
       75%         77.165000  
       max        25691.160000  
       Name: Amount, dtype: float64
```

```
In [3]: fraudulent=df[df['Class']==1]  
       genuine=df[df['Class']==0]
```

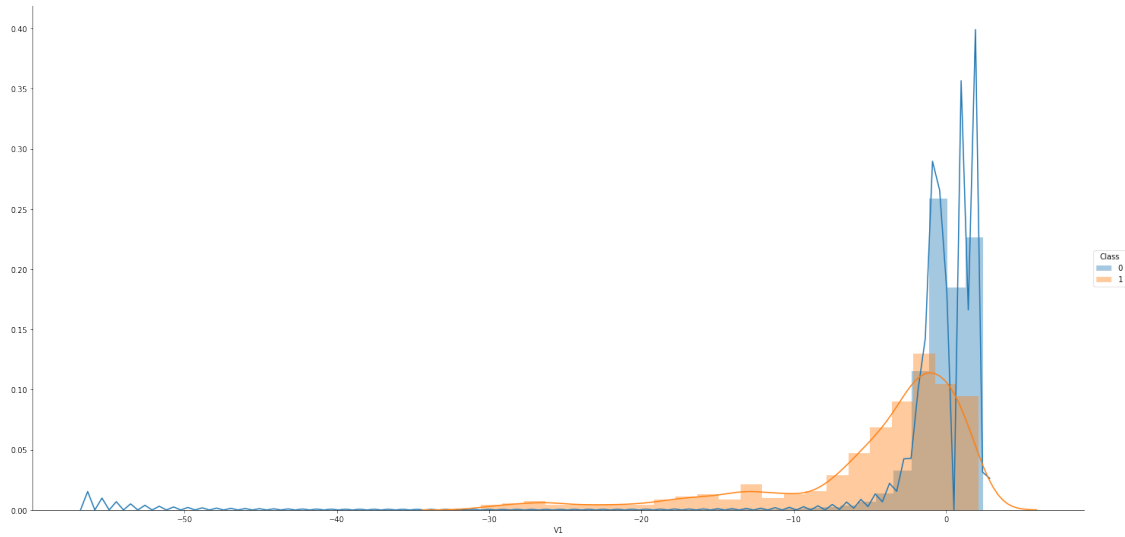
```
In [5]: from statsmodels import robust
```

```
In [6]: robust.mad(df['Amount'])
```

```
Out[6]: 29.97821685818327
```

Indicates presence of outliers

```
In [57]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \  
        .map(sns.distplot, "V1") \  
        .add_legend();
```

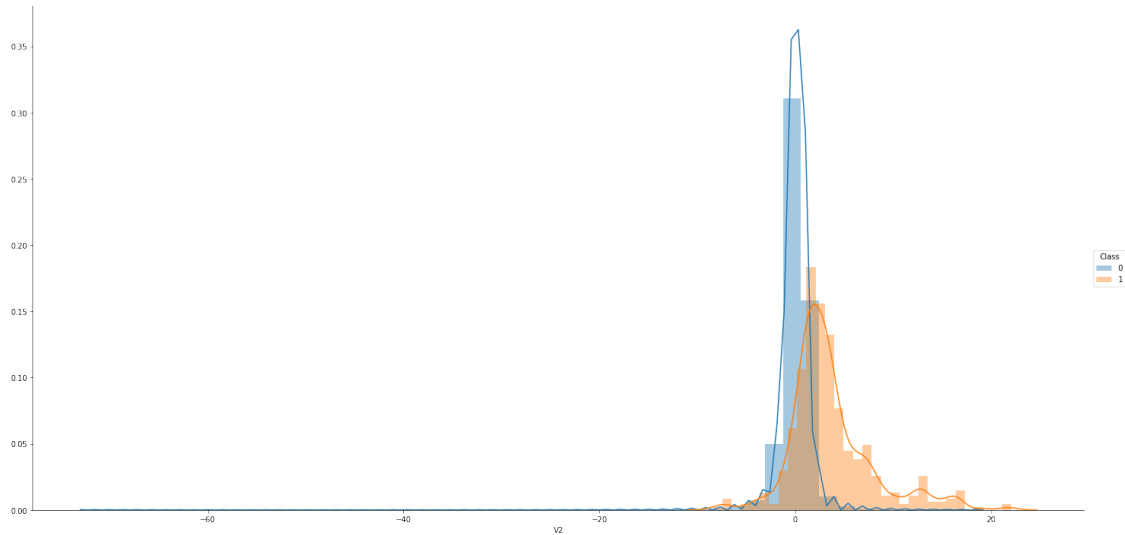


```
In [111]: print(np.percentile(fraudulent['V1'],q=[0,25,50,75,90,100]))
           print(np.percentile(genuine['V1'], q=[100,75,50,25,10,0, 40]))
```

```
[-30.55238004 -6.03606299 -2.34249745 -0.41920008  1.07523544
  2.13238602]
[ 2.45492999e+00  1.31621801e+00  2.00232859e-02 -9.17543591e-01
 -1.88472416e+00 -5.64075096e+01 -4.24916604e-01]
```

there is overlap between two pdfs however we can observe 75% fraudulent transactions have V1 less than -0.42 60% genuine transactions have V1 more than -0.42. This makes V1 a fairly feature for classification

```
In [58]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
         .map(sns.distplot, "V2") \
         .add_legend();
```

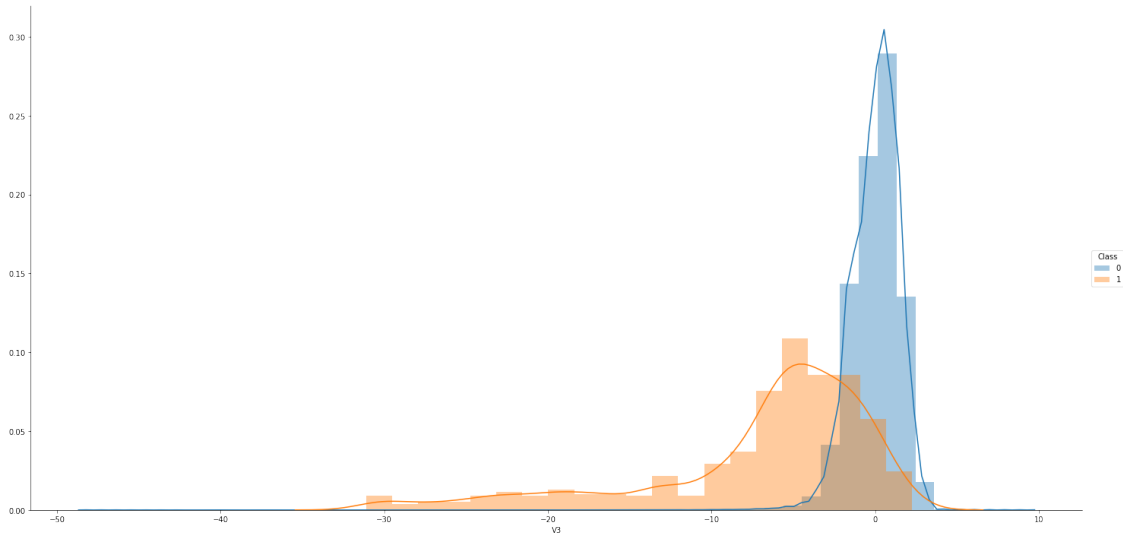


```
In [117]: print(np.percentile(fraudulent['V2'],q=[0,21,50,75,90,100]))
          print(np.percentile(genuine['V2'], q=[100,75,85,50,25,10,0]))
```

```
[ -8.40215368  1.06997849  2.7178686   4.97125732  8.76972245
 22.05772899]
[ 1.89024528e+01  8.00446405e-01  1.10659479e+00  6.40697590e-02
-5.99472583e-01 -1.36060501e+00 -7.27157276e+01]
```

At first glance pdfs seem to overlap a lot but careful analysis reveals that 85% of genuine transactions have V2 less than 1.1065 whereas 79% fraudulent transactions have V2 more than 1.1069. This makes V2 a very good choice for discrimination

```
In [59]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V3") \
        .add_legend();
```

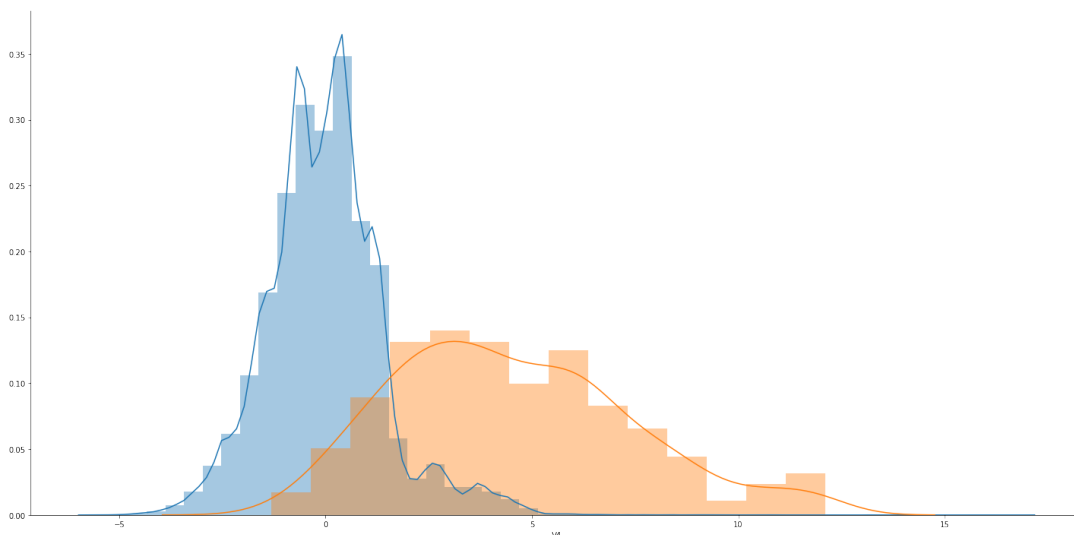



It can be seen visually that a large chunk of fraudulent transactions have V3 less than about -1 (intersection of two pdfs) and genuine ones have V3 greater than -1. A more detailed analysis reveals great results with 80% fraudulent transactions having V3 less than -1.67 and 80% genuine ones having V3 more than -1.16, a very good discriminant indeed.

```
In [121]: print(np.percentile(fraudulent['V3'],q=[80]))
          print(np.percentile(genuine['V3'], q=[20]))
```

```
[-1.67891456]
[-1.16267187]
```

```
In [60]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V4") \
        .add_legend();
```

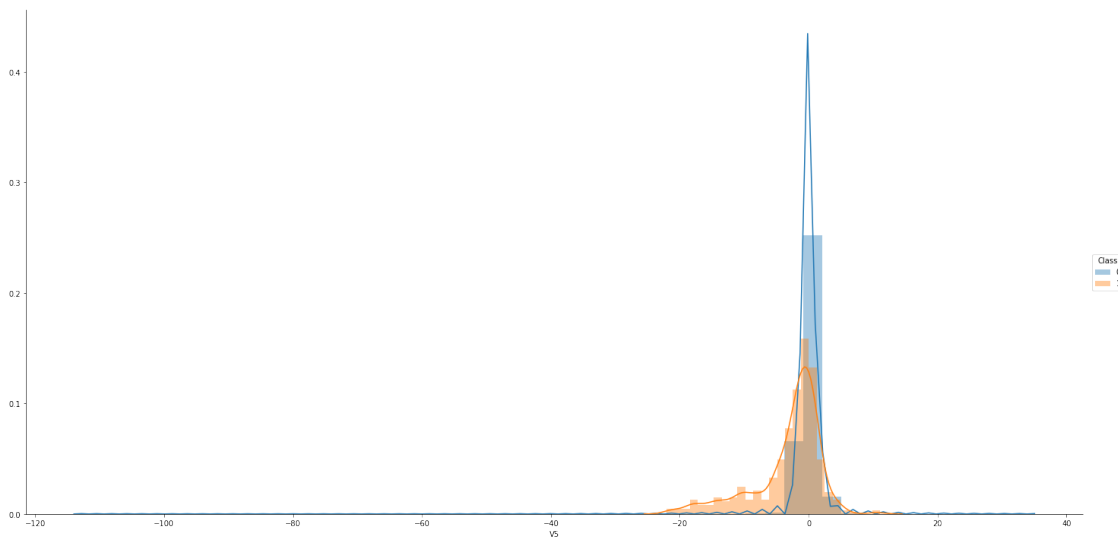


This pretty much resembles V3 and is indeed a great discriminating feature 85% fraudulent transactions have V4 more than 1.6 and 85% genuine transactions have V4 less than 1.2

```
In [126]: print(np.percentile(fraudulent['V4'],q=[15]))
          print(np.percentile(genuine['V4'], q=[85]))

[ 1.60192399]
[ 1.20808306]
```

```
In [61]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V5") \
        .add_legend();
```

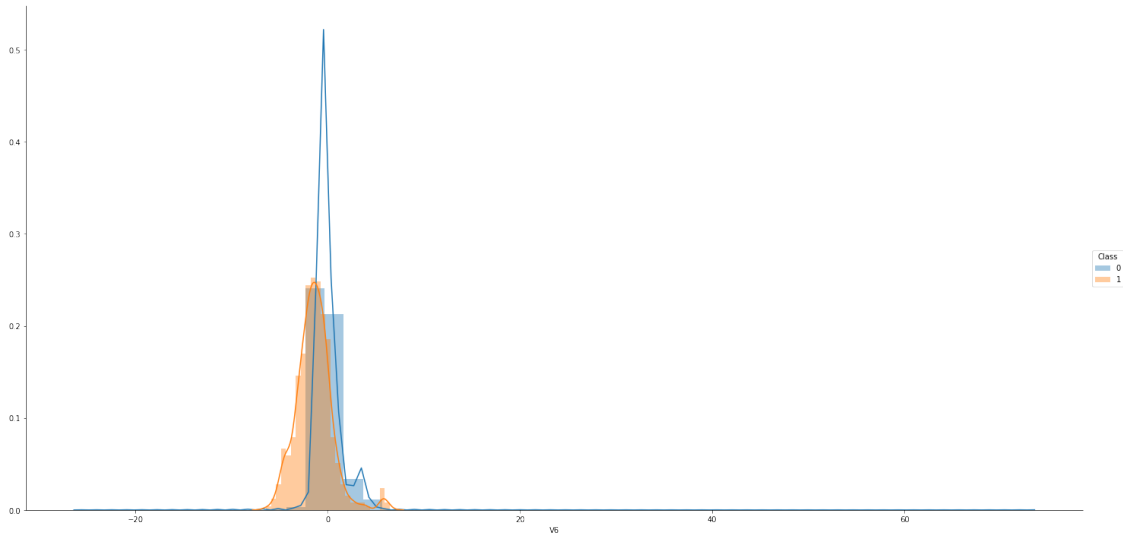


As compared to V4 and V3 this does not seem to be a very good feature 66% fraudulent transactions have V5 less than -0.417 and 66% genuine transactions have V5 more than -0.43

```
In [137]: print(np.percentile(fraudulent['V5'],q=[66]))
          print(np.percentile(genuine['V5'], q=[34]))

[-0.41771202]
[-0.43696705]
```

```
In [63]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V6") \
        .add_legend();
```

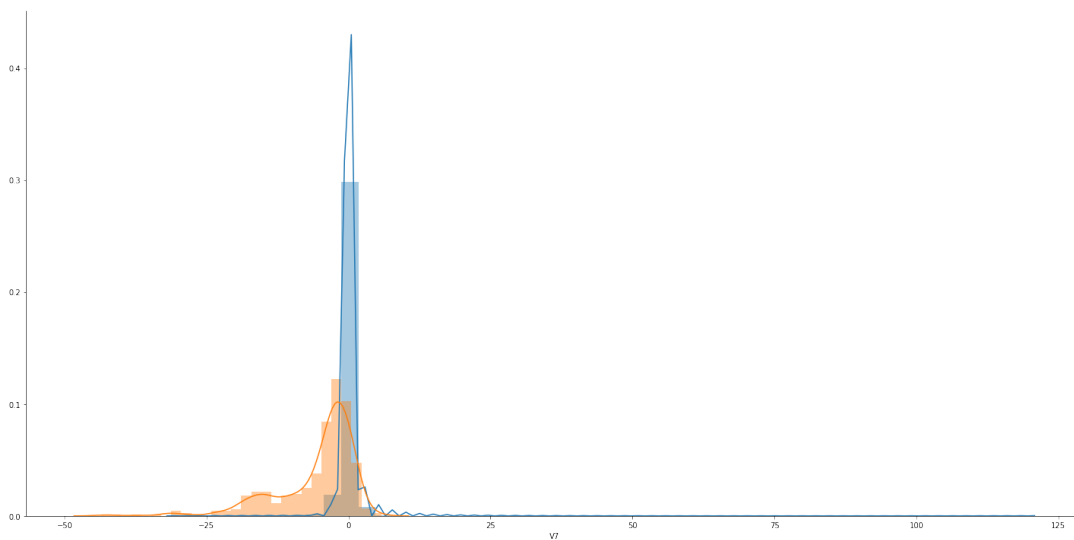


```
In [140]: print(np.percentile(fraudulent['V6'],q=[70]))
          print(np.percentile(genuine['V6'], q=[30]))
```

```
[-0.6244269]
[-0.66644016]
```

This is surely better than V5 as we can see there is a 70% fraudulent distinguished from 70% genuine transactions based on V6

```
In [64]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V7") \
        .add_legend();
```

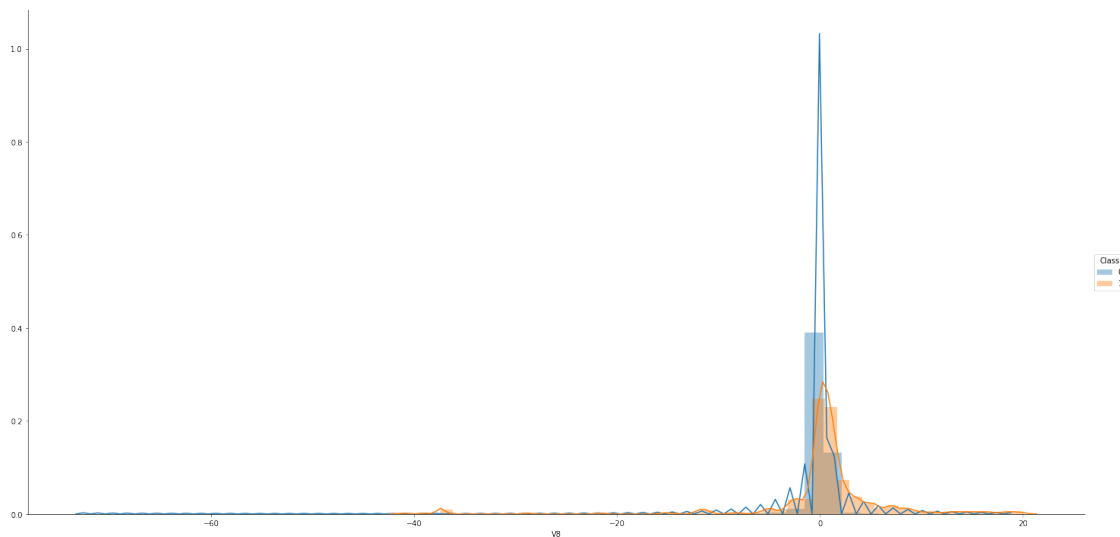


```
In [147]: print(np.percentile(fraudulent['V7'],q=[77]))
          print(np.percentile(genuine['V7'], q=[23]))
```

```
[-0.82341149]
[-0.60213432]
```

This feature is slightly better than V6 offering a 77% classification accuracy

```
In [65]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V8") \
        .add_legend();
```

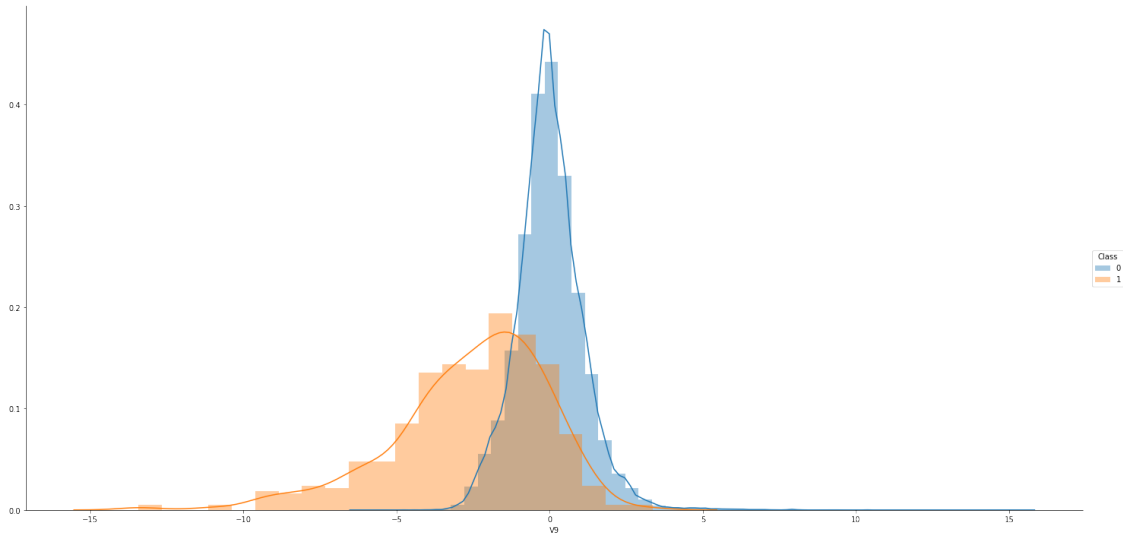


```
In [155]: print(np.percentile(fraudulent['V8'],q=[37]))
          print(np.percentile(genuine['V8'], q=[63]))
```

```
[ 0.1571183]
[ 0.15303342]
```

This feature offers a 63% classification accuracy and hence not a very good choice

```
In [66]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V9") \
        .add_legend();
```

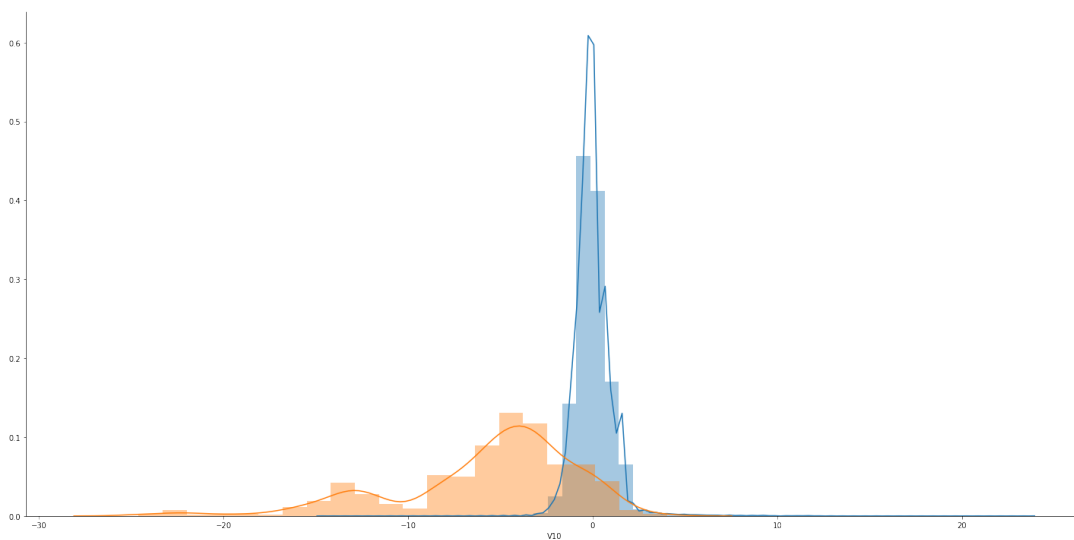


```
In [158]: print(np.percentile(fraudulent['V9'],q=[77]))
          print(np.percentile(genuine['V9'], q=[23]))

[-0.71721535]
[-0.7035978]
```

This is a fairly good feature offering a 77% classification accuracy

```
In [160]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
          .map(sns.distplot, "V10") \
          .add_legend();
```

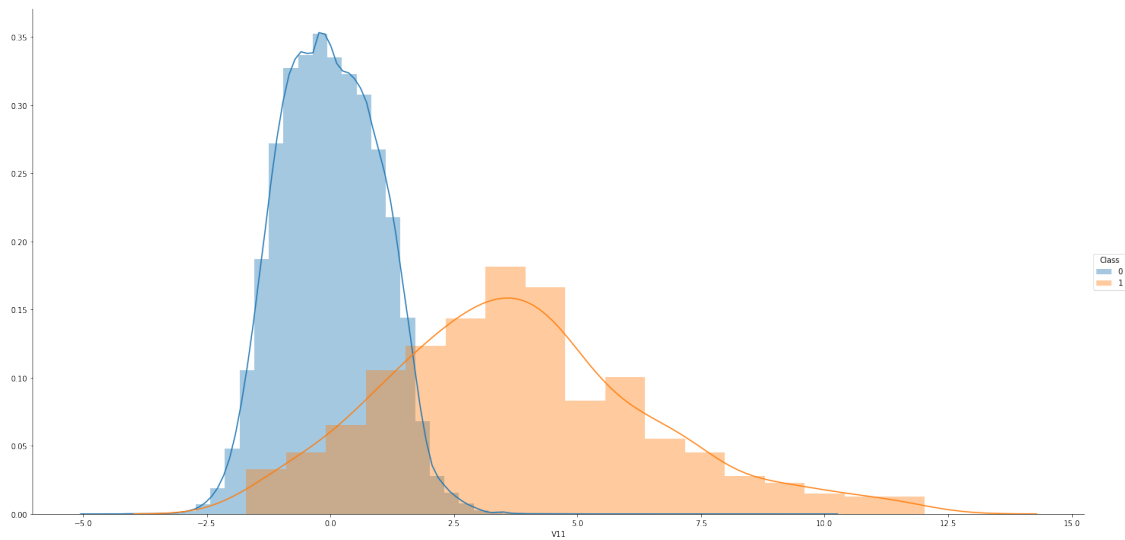


```
In [166]: print(np.percentile(fraudulent['V10'],q=[86]))
          print(np.percentile(genuine['V10'], q=[14]))
```

```
[-0.87019182]
[-0.86167548]
```

Visually one can tell this feature is a great one offering 86% classification accuracy

```
In [68]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V11") \
        .add_legend();
```

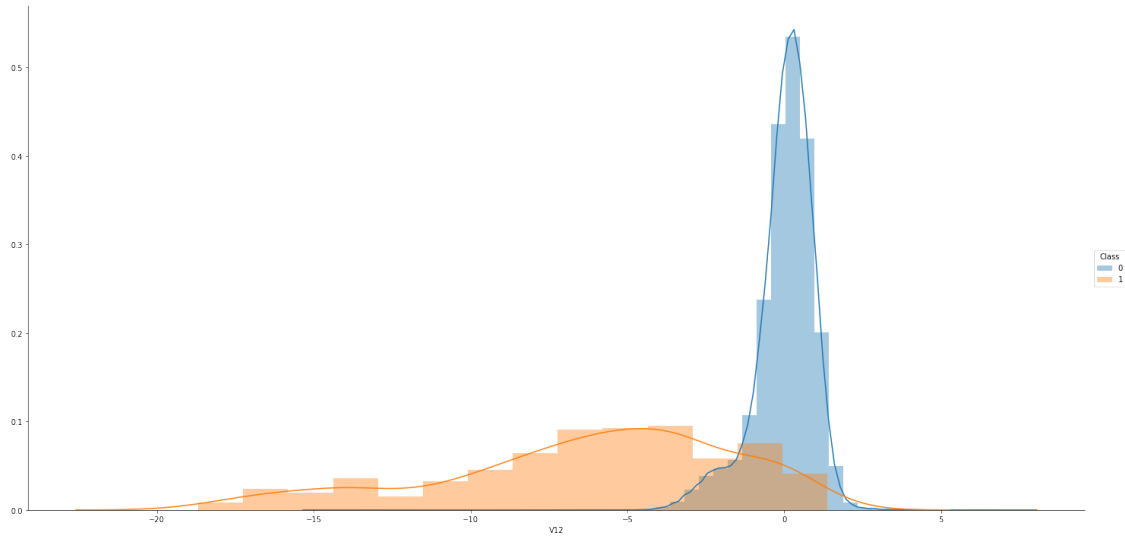


```
In [169]: print(np.percentile(fraudulent['V11'],q=[16]))
          print(np.percentile(genuine['V11'], q=[84]))
```

```
[ 1.17053386]
[ 1.05966576]
```

This is also a great feature offering an 84% accuracy

```
In [69]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V12") \
        .add_legend();
```



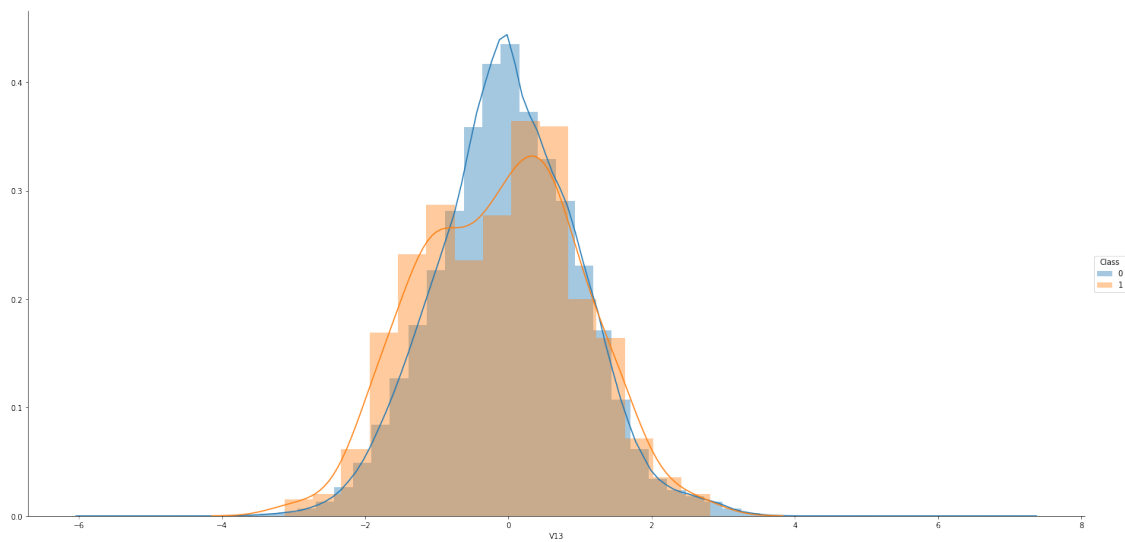
```
In [173]: print(np.percentile(fraudulent['V12'],q=[86]))
          print(np.percentile(genuine['V12'], q=[14]))
```

```
[-0.83130394]
```

```
[-0.8352217]
```

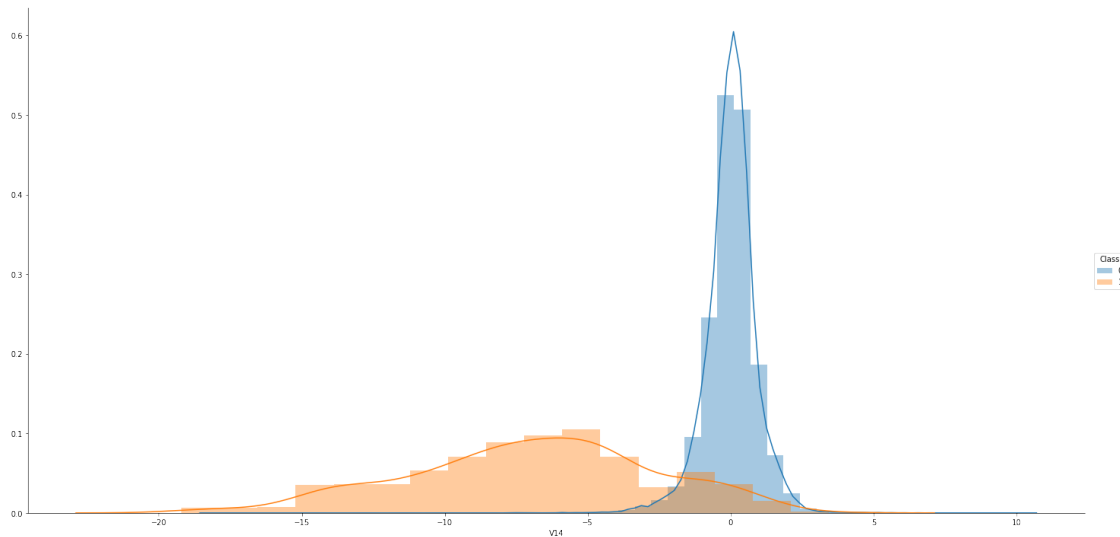
This is also a good feature offering roughly 86% accuracy

```
In [70]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V13") \
        .add_legend();
```



Clearly not a good feature

```
In [71]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V14") \
        .add_legend();
```



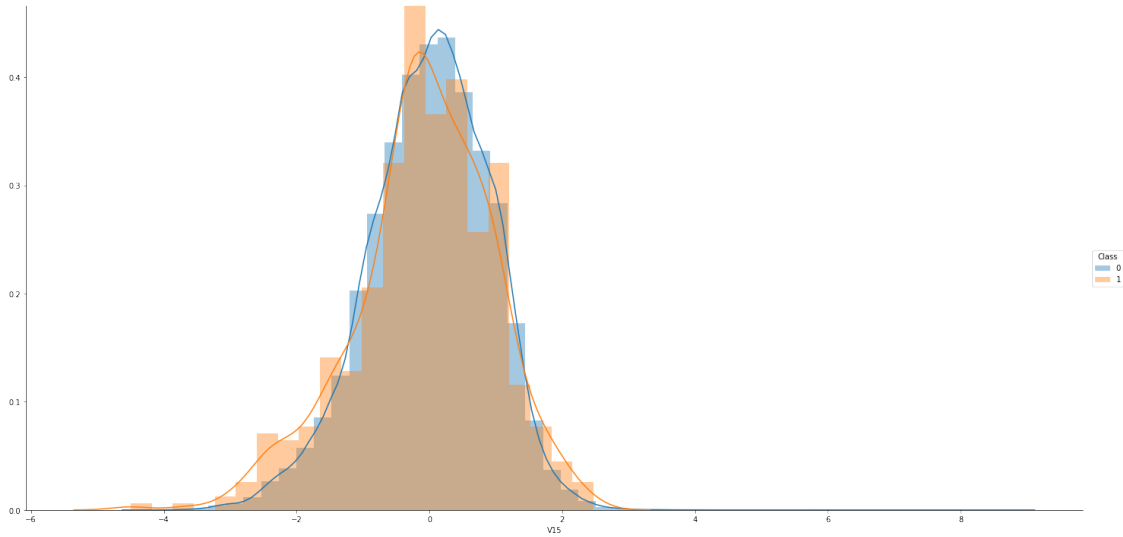
```
In [177]: print(np.percentile(fraudulent['V14'],q=[90]))
          print(np.percentile(genuine['V14'], q=[10]))
```

```
[-1.07836903]
```

```
[-0.99523233]
```

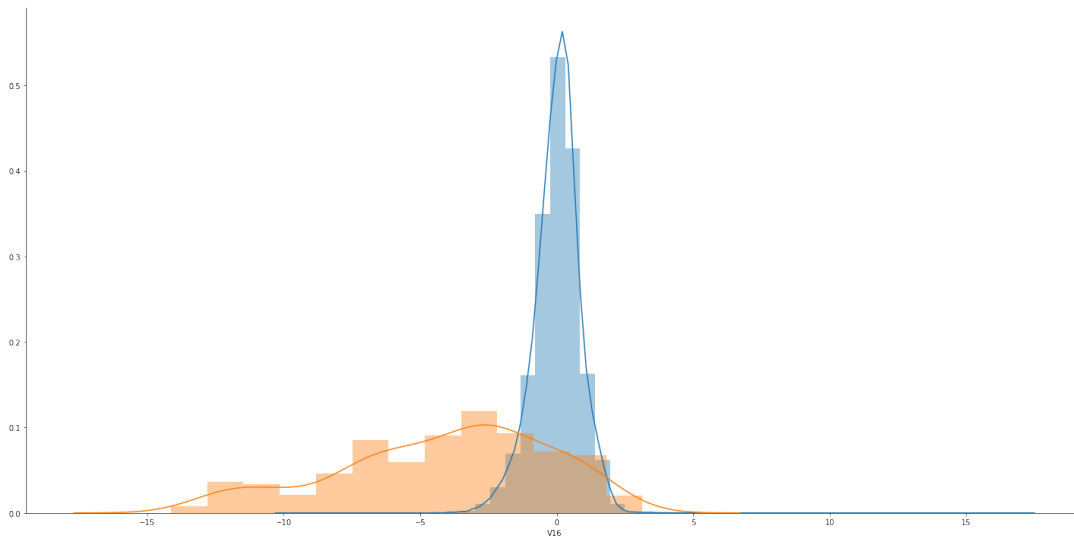
An astounding 90% sets this feature apart from others

```
In [72]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V15") \
        .add_legend();
```

Not a good feature again

```
In [73]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V16") \
        .add_legend();
```

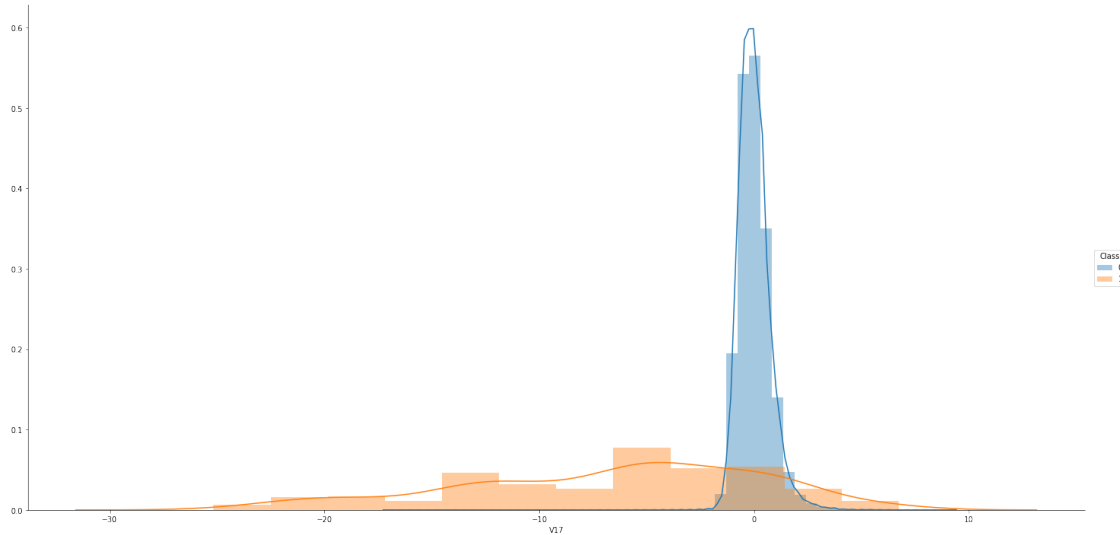


```
In [182]: print(np.percentile(fraudulent['V5'],q=[65]))
          print(np.percentile(genuine['V5'], q=[35]))
```

```
[-0.51484326]
[-0.41165364]
```

Fairly good feature with 65% success rate

```
In [74]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V17") \
        .add_legend();
```

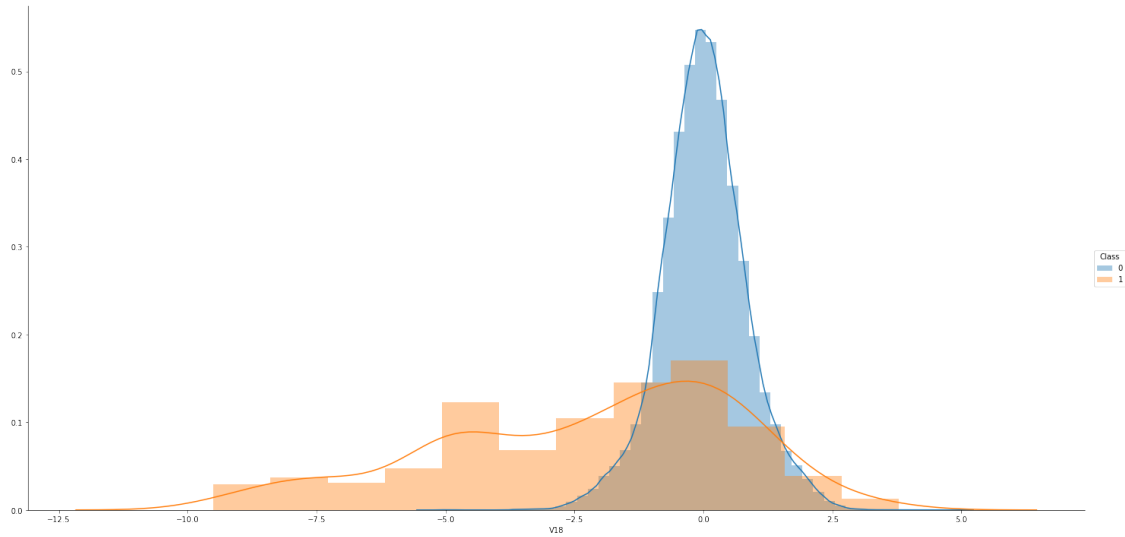


```
In [190]: print(np.percentile(fraudulent['V17'],q=[77]))
          print(np.percentile(genuine['V17'], q=[25,23,75]))

[-0.78197431]
[-0.48264388 -0.51722041  0.39992239]
```

One noticeable fact about this feature is large percentage of genuine transactions within the inter quartile range of -0.482 to 0.399

```
In [75]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V18") \
        .add_legend();
```

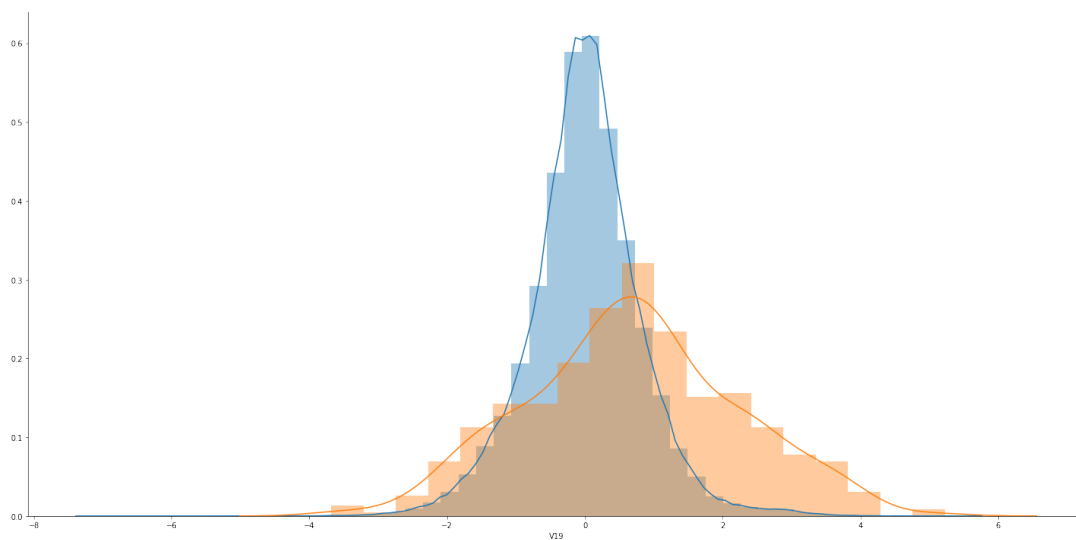


```
In [192]: print(np.percentile(fraudulent['V5'],q=[65]))
          print(np.percentile(genuine['V5'], q=[35]))
```

[-0.51484326]
[-0.41165364]

Fairly good feature with 65% success rate

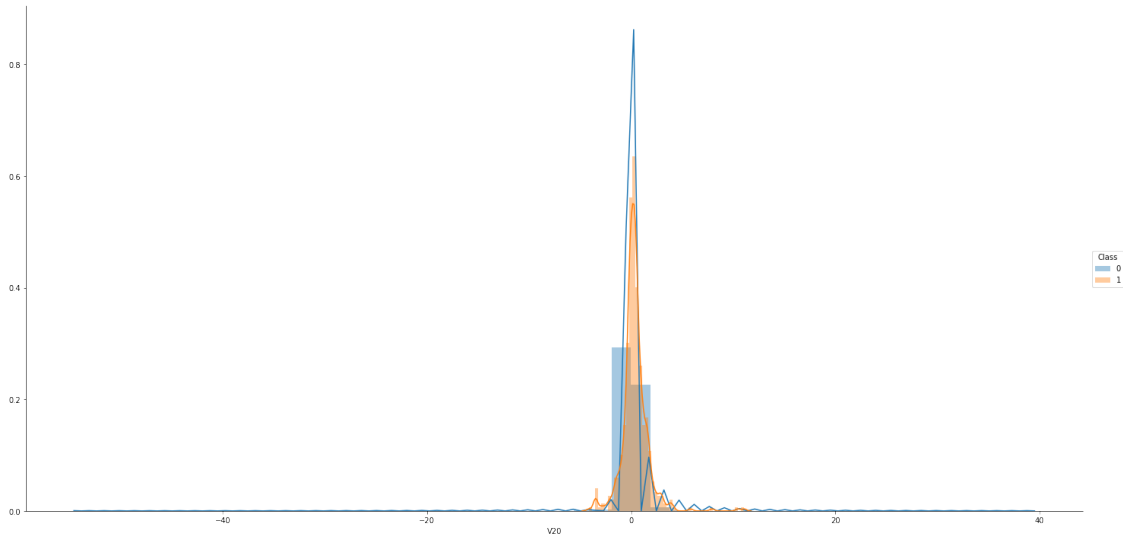
```
In [76]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V19") \
        .add_legend();
```



```
In [205]: print(np.percentile(fraudulent['V19'],q=[37]))
          print(np.percentile(genuine['V19'], q=[63]))

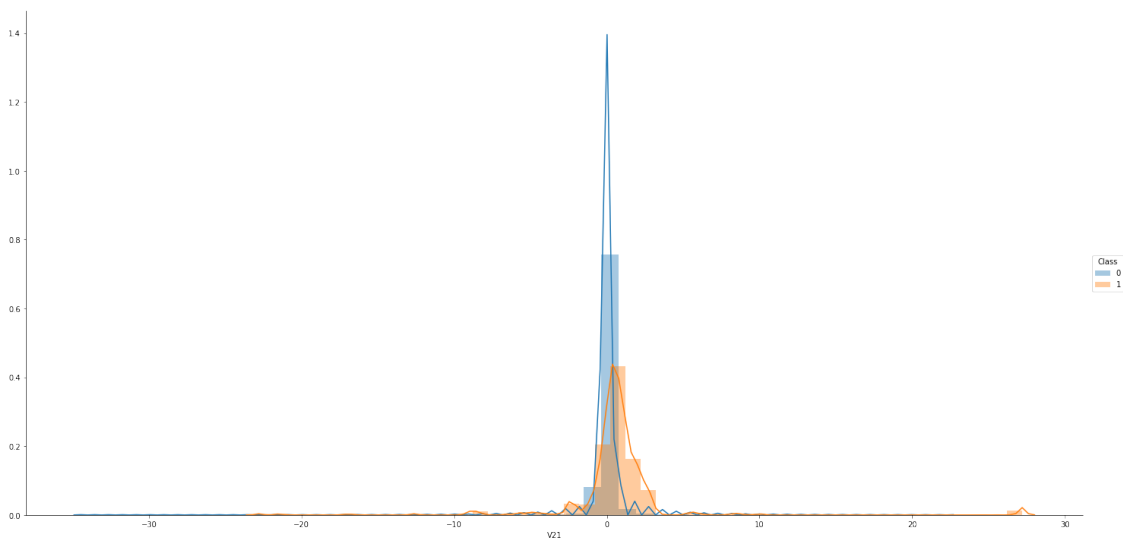
[ 0.23298149]
[ 0.21476089]
```

```
In [77]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V20") \
        .add_legend();
```



Clearly not a good feature

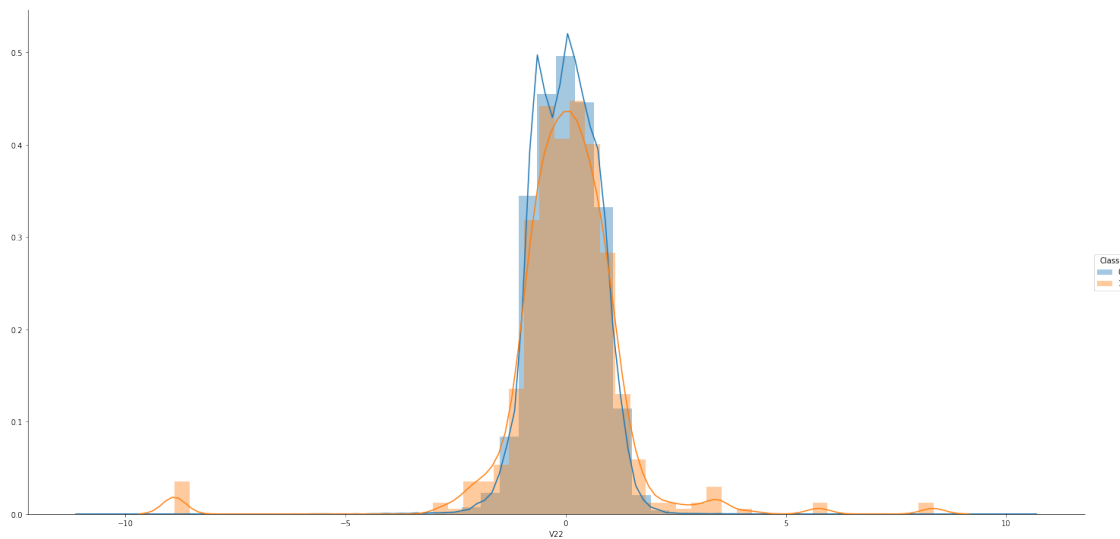
```
In [78]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V21") \
        .add_legend();
```



```
In [212]: print(np.percentile(fraudulent['V21'],q=[29]))
          print(np.percentile(genuine['V21'], q=[71]))
```

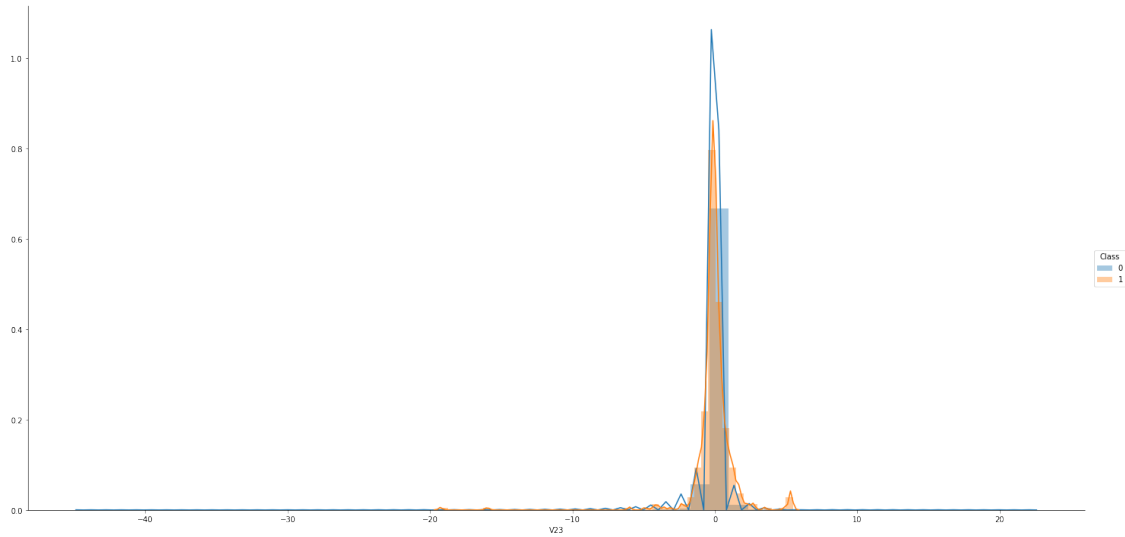
```
[ 0.15203493]
[ 0.14681008]
```

```
In [79]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V22") \
        .add_legend();
```



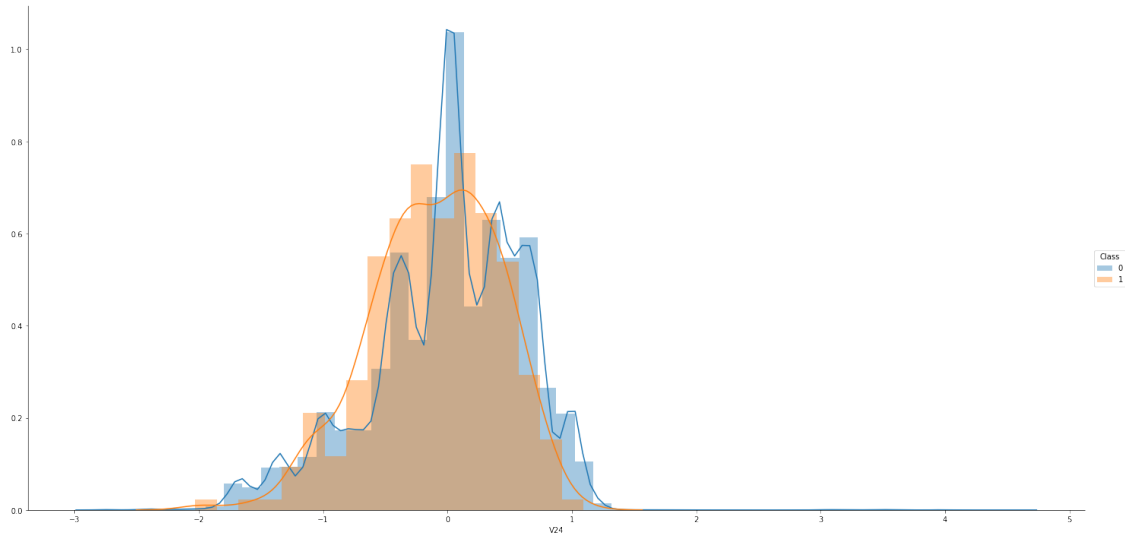
Again not a very good feature

```
In [80]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V23") \
        .add_legend();
```



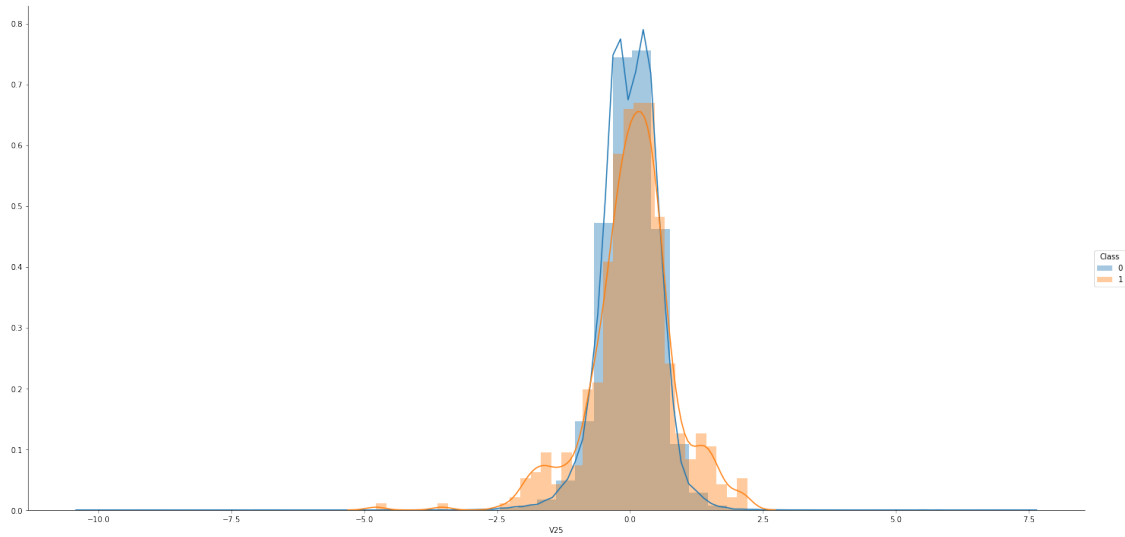
Massive overlap, not a good feature

```
In [81]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V24") \
        .add_legend();
```



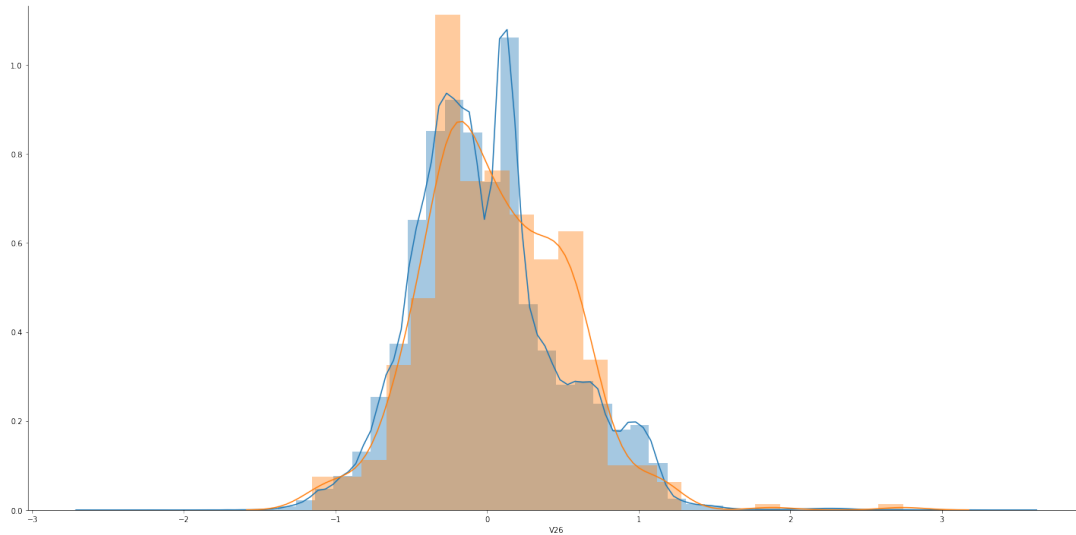
Not a good feature due to overlap

```
In [82]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V25") \
        .add_legend();
```



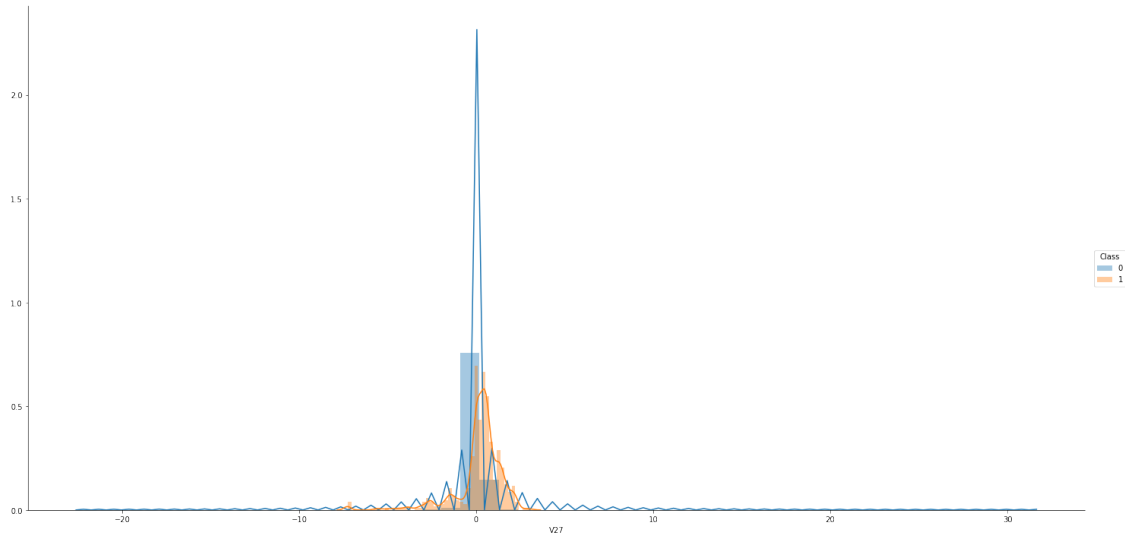
Not a good feature due to overlap

```
In [83]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V26") \
        .add_legend();
```



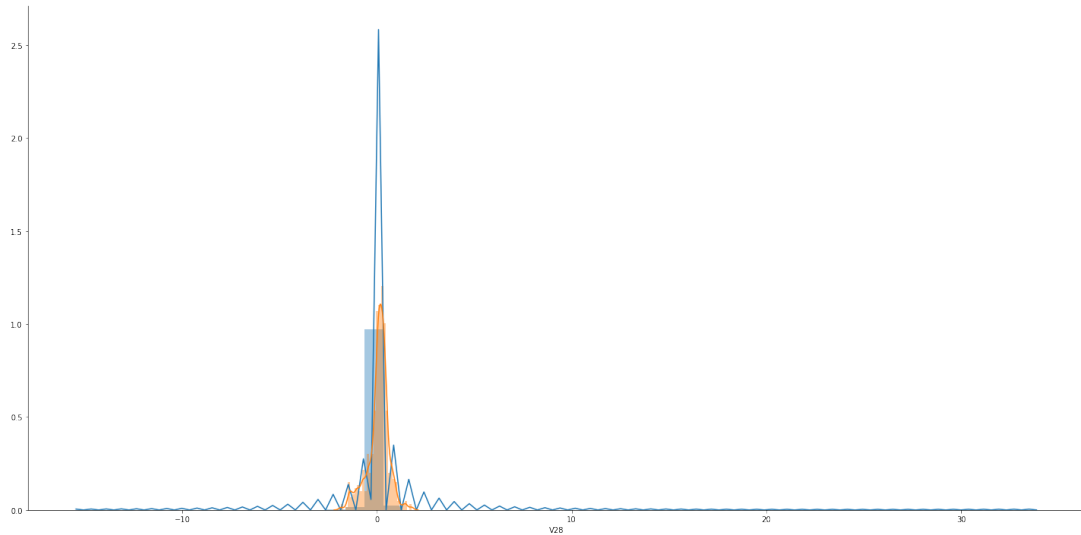
Not a good feature due to overlap

```
In [84]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V27") \
        .add_legend();
```



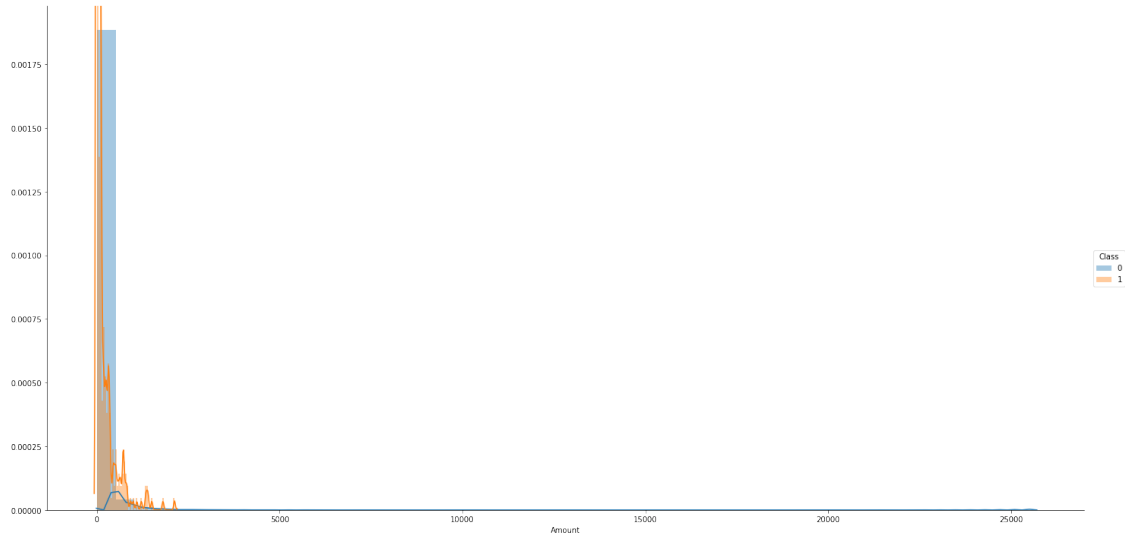
Not a good feature due to overlap

```
In [85]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "V28") \
        .add_legend();
```



Not a good feature due to overlap

```
In [86]: sns.FacetGrid(df, hue="Class", size=10, aspect=2) \
        .map(sns.distplot, "Amount") \
        .add_legend();
```

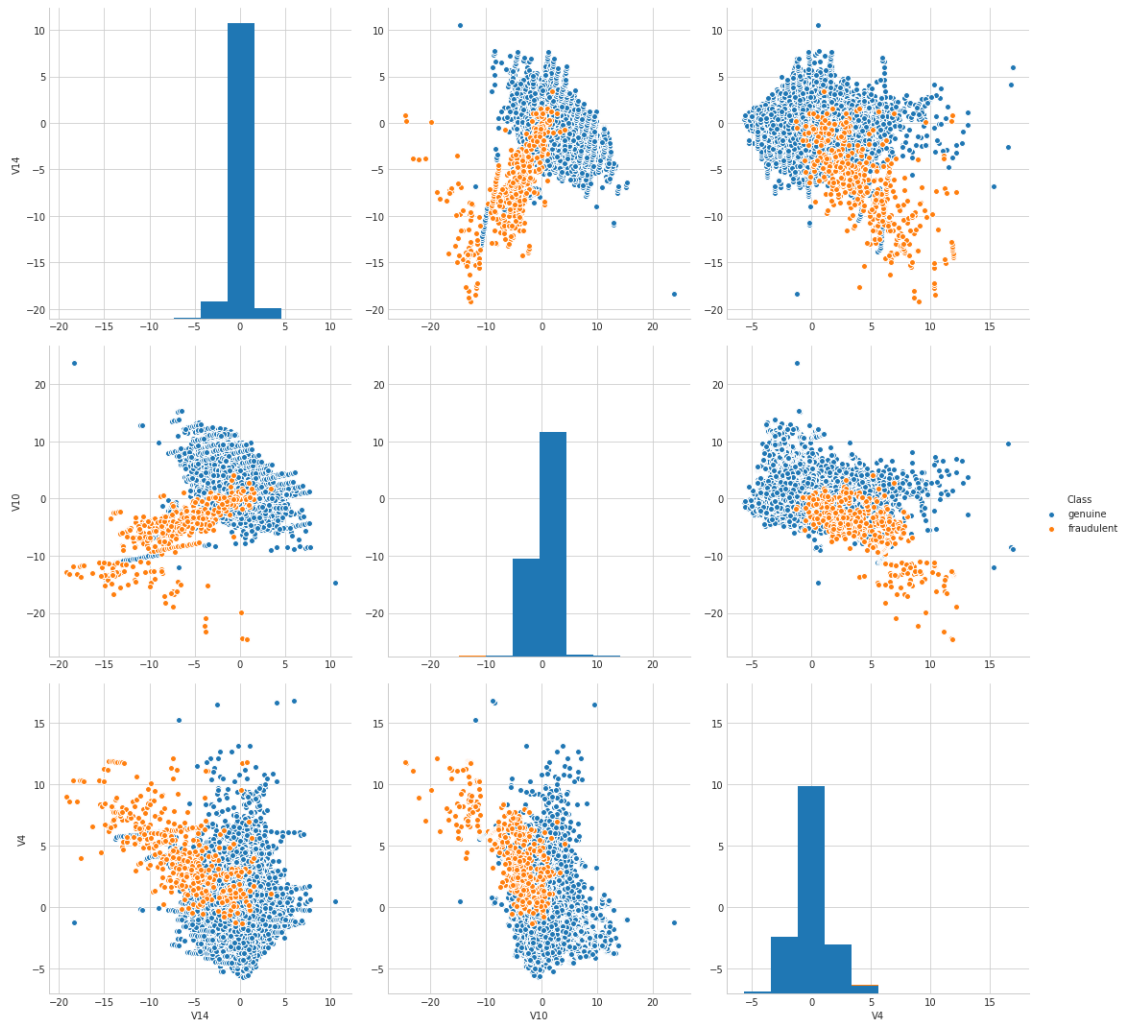
This again is not a good feature due to heavy overlap between 2 pdfs

1.3 List of good features

V14 > V10 > V12 > V4 > V11 > V3 > V2 > V9 > V7 > V6 > V1 > V5

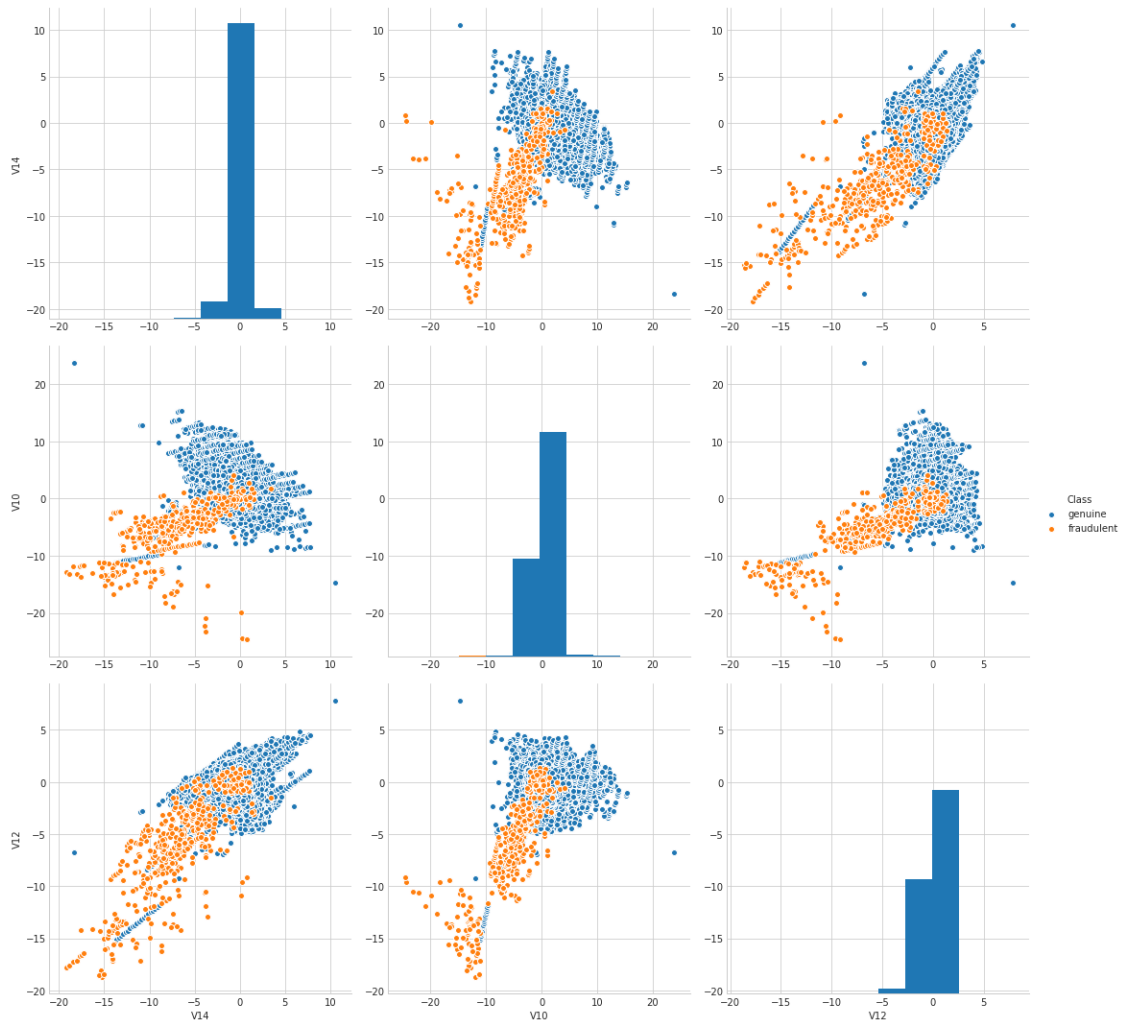
```
In [218]: trans_dict={0:'genuine', 1:'fraudulent'}
          df['Class']=df.Class.apply(lambda x:trans_dict[x])
```

```
In [220]: sns.set_style("whitegrid");
          sns.pairplot(df[['Class', 'V14', 'V10', 'V4']], hue="Class", size=5);
```



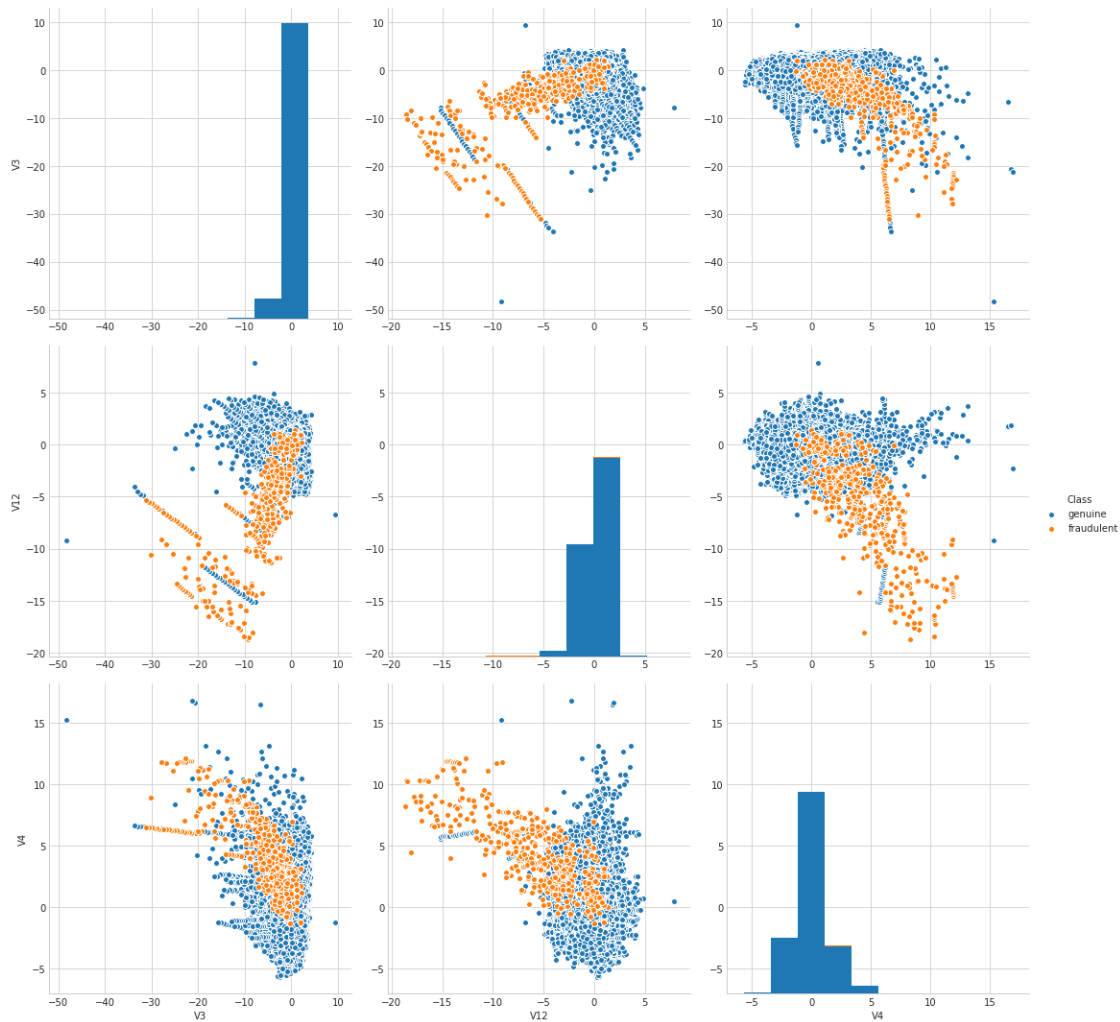
$(V14, V10) > (V14, V4) > (V10, V4)$

```
In [221]: sns.pairplot(df[['Class', 'V14', 'V10', 'V12']], hue="Class", size=5);
```



$(V14, V10) > (V14, V12) > (V10, V12)$

```
In [222]: sns.pairplot(df[['Class', 'V3', 'V12', 'V4']], hue="Class", size=5);
```



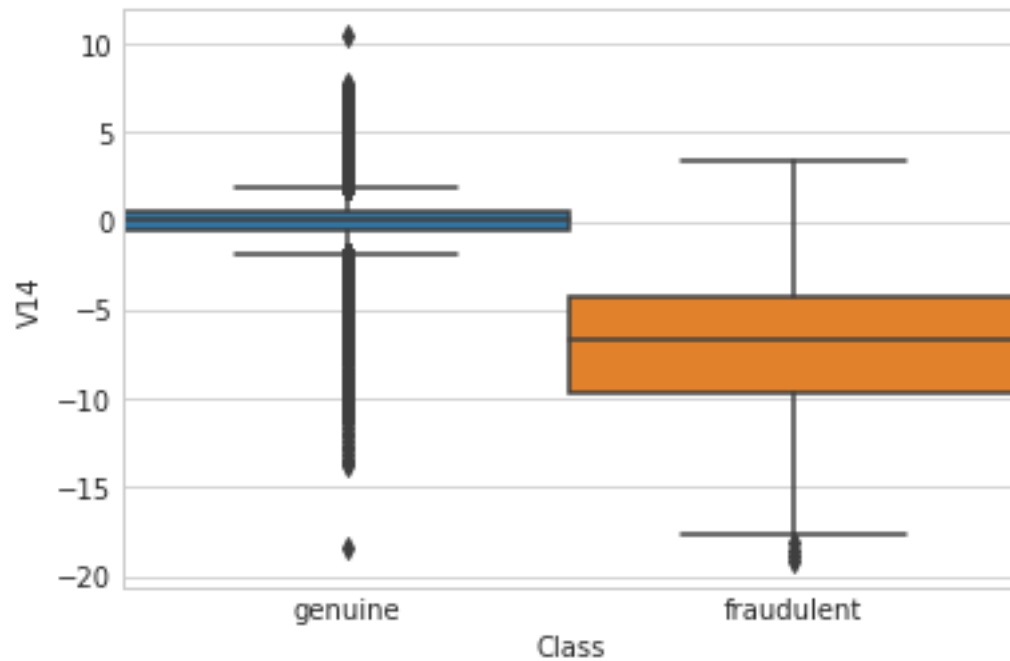
(V12, V3) > (V12, V4) > (V4, V3)

2 Univariate analysis using box plots

Although percentiles have been evaluated before, the best chosen features are evaluated here for better visualisation

```
In [223]: sns.boxplot(x='Class', y='V14', data=df, width=1)
```

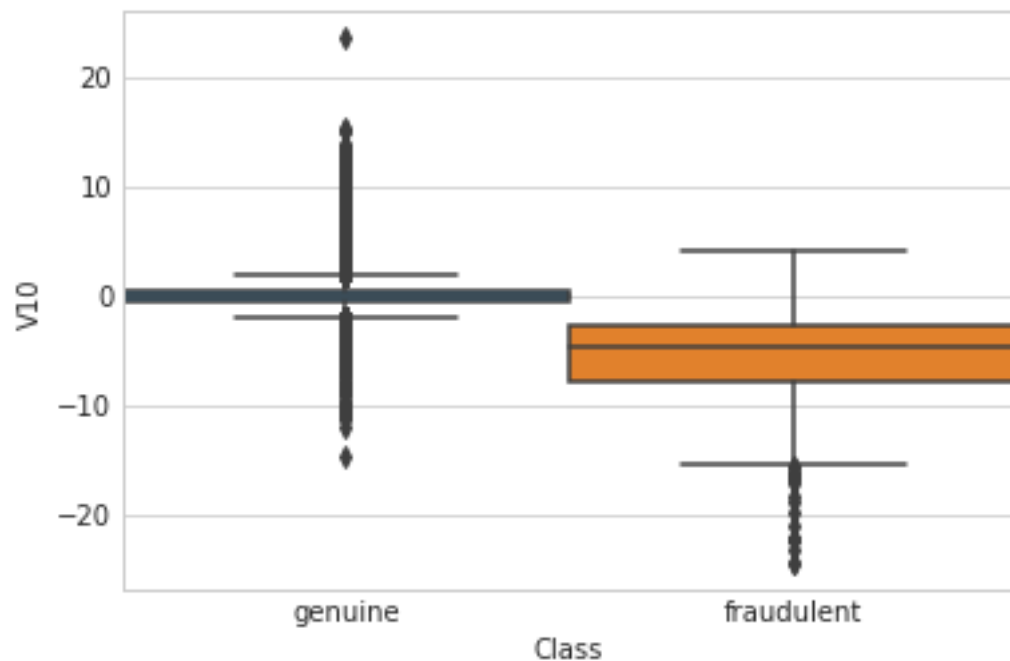
```
Out[223]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea303a3438>
```



Clearly 75% of fraudulent transactions have V14 less than -4 and 75% of genuine transactions have V14 more than about 0

```
In [224]: sns.boxplot(x='Class', y='V10', data=df, width=1)
```

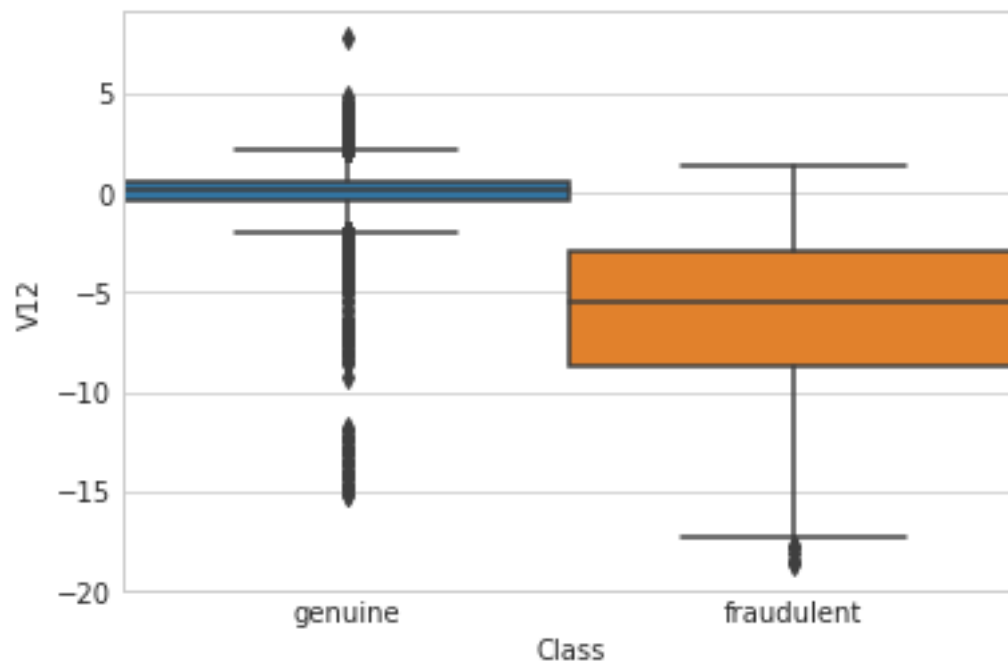
```
Out[224]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea30a14f28>
```



Similar trend can be observed for V10

```
In [225]: sns.boxplot(x='Class', y='V12', data=df, width=1)
```

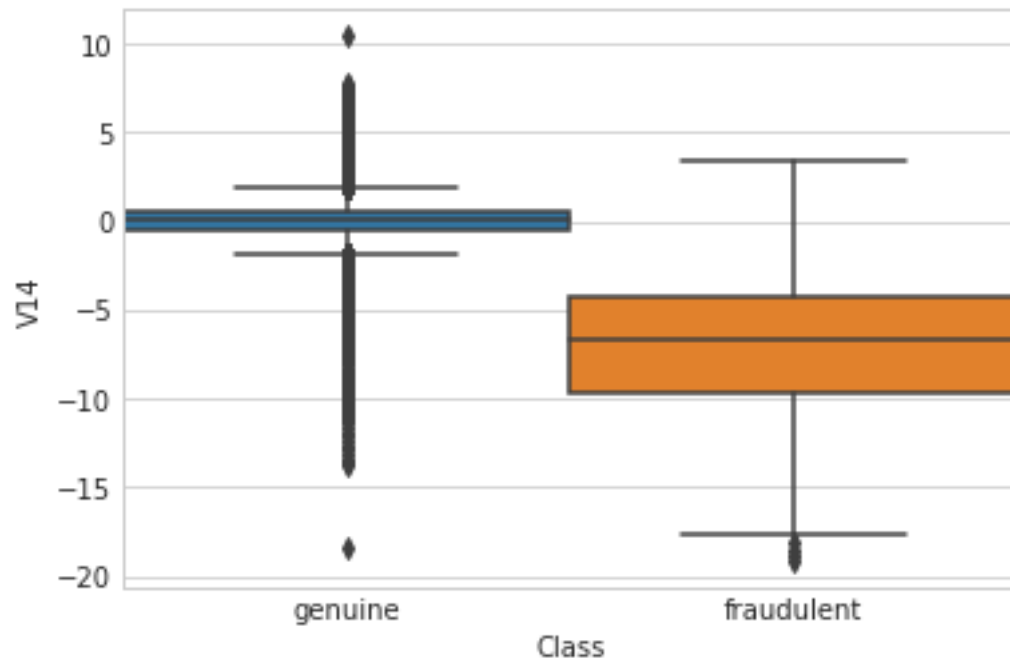
```
Out[225]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea30959b38>
```



and V12

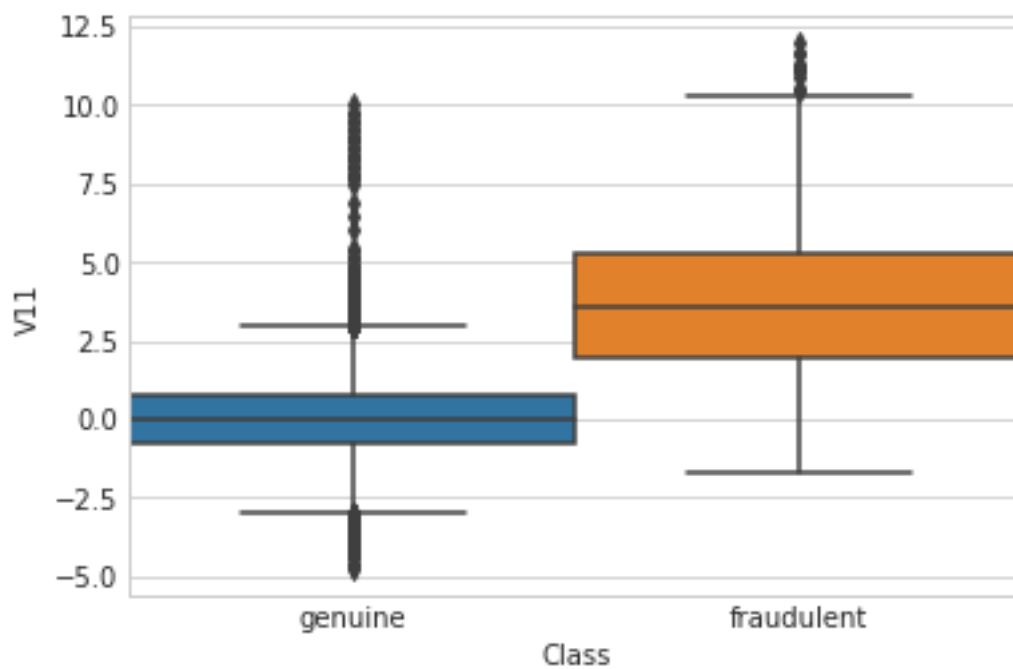
```
In [226]: sns.boxplot(x='Class', y='V14', data=df, width=1)
```

```
Out[226]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea30957860>
```



```
In [227]: sns.boxplot(x='Class', y='V11', data=df, width=1)
```

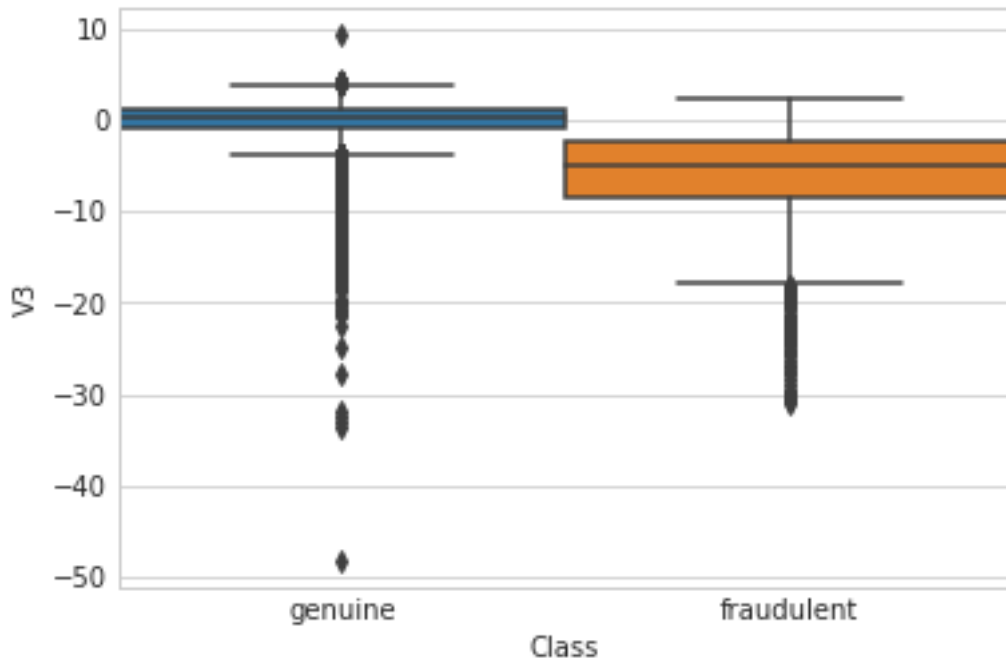
```
Out[227]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea30424f28>
```



More than 75% fraudulent transactions have V11 above 2.4 whereas more than 75% genuine transactions have V11 below 2.3

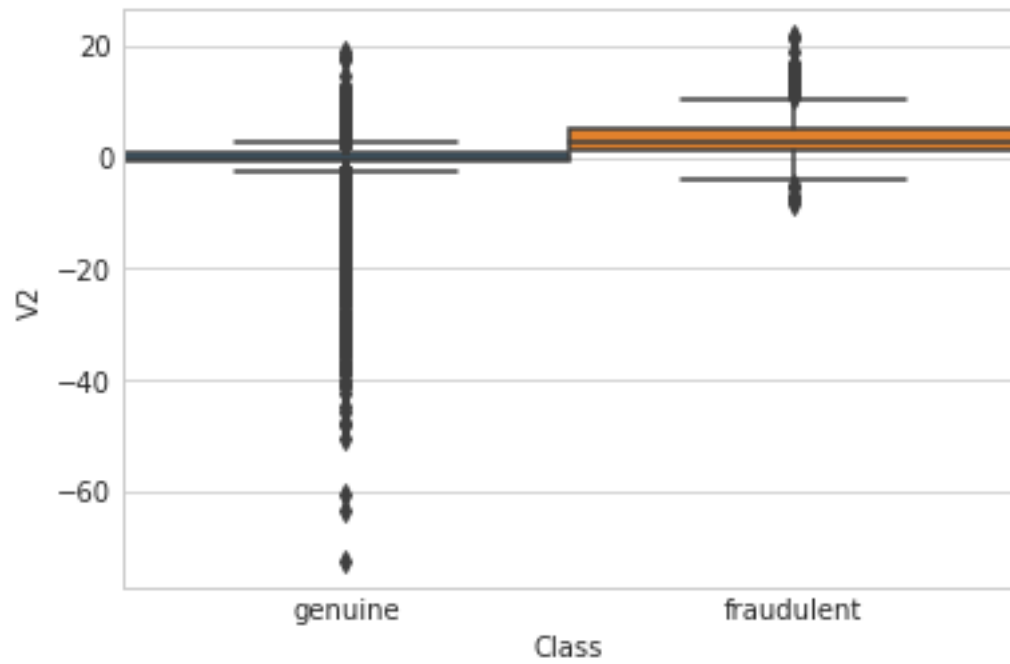
```
In [229]: sns.boxplot(x='Class', y='V3', data=df, width=1)
```

```
Out[229]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea2e806780>
```



```
In [230]: sns.boxplot(x='Class', y='V2', data=df, width=1)
```

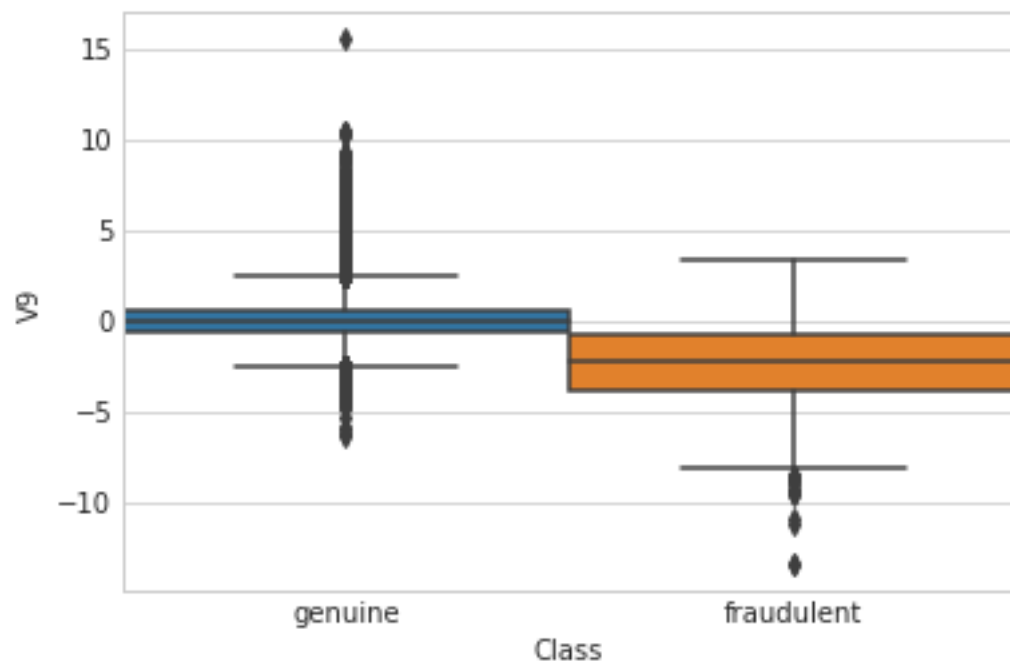
```
Out[230]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea3c360ba8>
```

Similar trend as V11

```
In [231]: sns.boxplot(x='Class', y='V9', data=df, width=1)
```

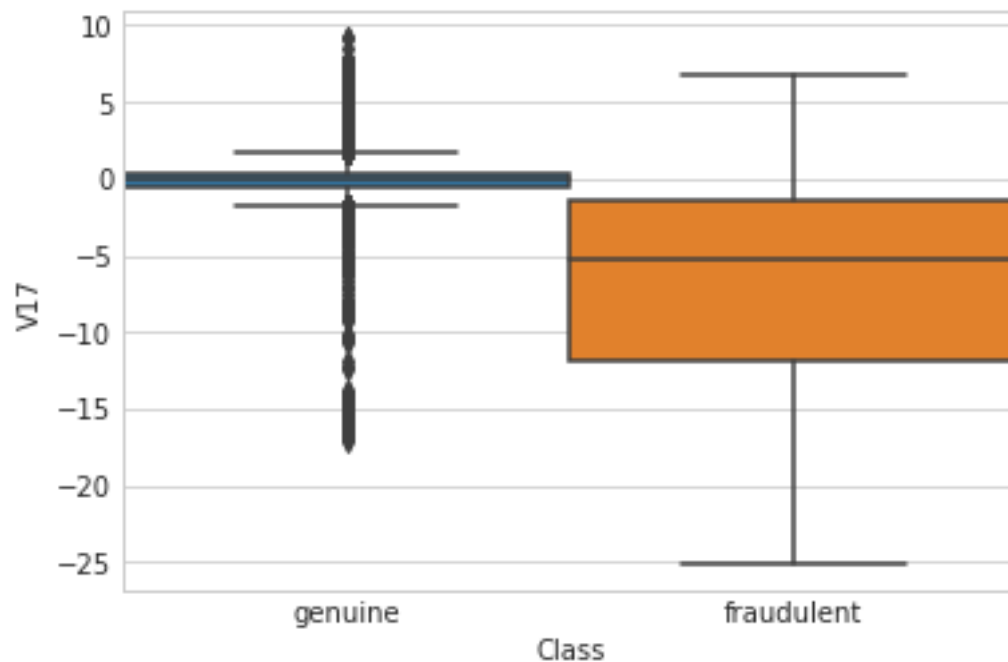
```
Out[231]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea2eac9908>
```



We can observe that moving down the order of relevance of features brings 25% value of one class closer to 75% value of the other

```
In [232]: sns.boxplot(x='Class', y='V17', data=df, width=1)
```

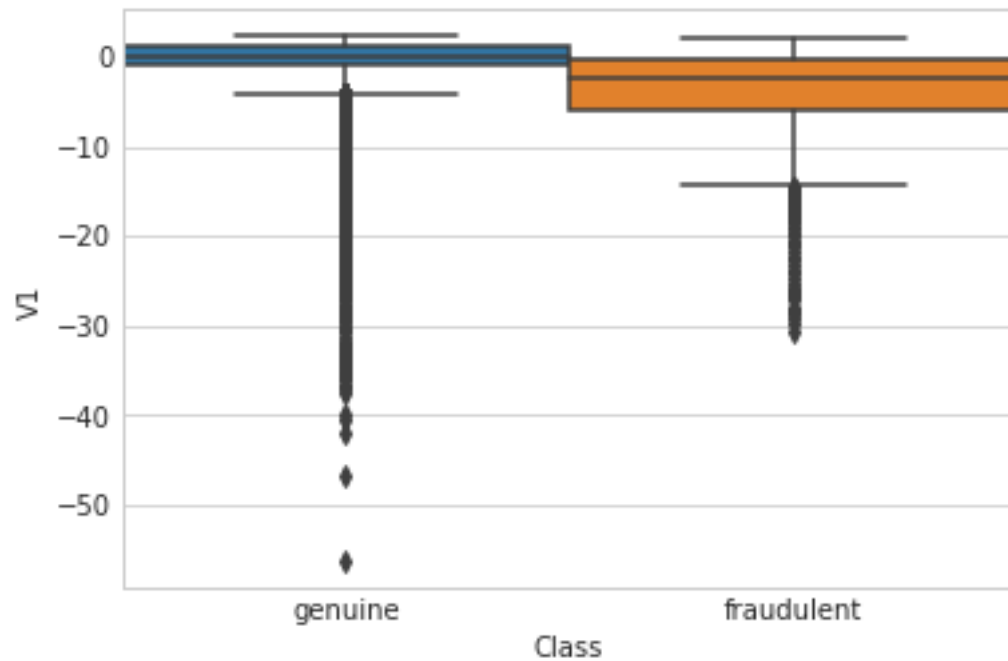
```
Out[232]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea2ea162b0>
```



Although it wasn't evident from pdf, box plots reveal that V17 separates 2 classes better than V9

```
In [240]: sns.boxplot(x='Class', y='V1', data=df, width=1)
```

```
Out[240]: <matplotlib.axes._subplots.AxesSubplot at 0x7fea3b122ba8>
```



3 Conclusion

The best 12 features have been enumerated for classification. Although it seems intuitive that transaction amount should count towards a valuable feature, it does not