**ENRON Final project**

**By Eric Rabaute**

# Introduction

This analysis is part of Udacity training.

The objective is to make a data analysis applying on Machine learning methods and tools.

# MachinE learning objective

The questions we want to answer in this study are:

* How can we identify with a good accurate result the persons of interest related to Enron Fraud? (ie.: wich available features are the most valuable?)
* How can we optimize this Person of Interest Identifier thanks to Machine learning methods and tools?

# Features selection

The first task is to choose among all available features the one that will helps us

**financial features**: ['salary', 'deferral\_payments', 'total\_payments', 'loan\_advances', 'bonus', 'restricted\_stock\_deferred', 'deferred\_income', 'total\_stock\_value', 'expenses', 'exercised\_stock\_options', 'other', 'long\_term\_incentive', 'restricted\_stock', 'director\_fees'] (all units are in US dollars)

**email features**: ['to\_messages', 'email\_address', 'from\_poi\_to\_this\_person', 'from\_messages', 'from\_this\_person\_to\_poi', 'shared\_receipt\_with\_poi'] (units are generally number of emails messages; notable exception is ‘email\_address’, which is a text string)

Number of persons on the sample:146

Number of poi on the sample:18 (0.12%)

First observations on data show a lot of features missed (ie. NaN value). I proposed to make a quantitative check on this value for all features first. Indeed, if a feature is miss for more than 50% absent of all data set, it could be not interesting to go further with it.

Hereafter the count of NaN for all features (max to min order) for a total of **146 persons**:

(1) loan\_advances:142

(2) director\_fees:129

(3) restricted\_stock\_deferred:128

(4) deferral\_payments:107

(5) deferred\_income:97

(6) long\_term\_incentive:80

(7) bonus:64

(8) to\_messages:60

(9) shared\_receipt\_with\_poi:60

(10) from\_poi\_to\_this\_person:60

(11) from\_messages:60

(12) from\_this\_person\_to\_poi:60

(13) other:53

(14) salary:51

(15) expenses:51

(16) exercised\_stock\_options:44

(17) restricted\_stock:36

(18) email\_address:35

(19) total\_payments:21

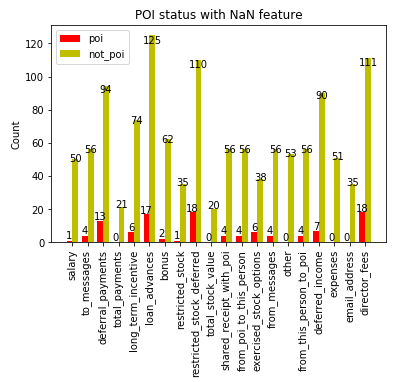
(20) total\_stock\_value:20

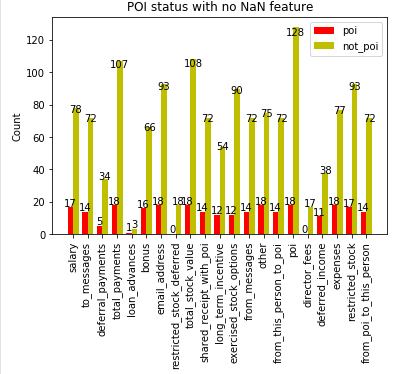
It is interesting to see that some features are more than 97% missing (loan advances). It could be explained by the fact the information is difficult to get that is not a very valuable information or this feature absence means something about the person (ex.: director fees means the person is a high ranking person and so likely a POI).

I propose to move forward this question by correlating the number of NaN and the POI status (ie. Have we got a higher POI status rate if NaN value is more or less present for one feature).

Hereafter two figures:

* The first one is number of POI and not POI persons according features equals to NaN value
* The second is the same with persons with value different of NaN





**Analysis**: At a first sight, no clear output is raised except that theory about ‘director fees’ is false, indeed, there is no ‘poi’ with director fees different from NaN. This is strange since we could expect to have mainly POI inside director committee.

I propose to go a last step further with the ratio between poi and not poi for none NaN value.

(1) loan\_advances: poi=0.25% (n=4)

(2) deferred\_income: poi=0.22% (n=49)

(3) bonus: poi=0.2% (n=82)

(4) other: poi=0.19% (n=93)

(5) expenses: poi=0.19% (n=95)

(6) salary: poi=0.18% (n=95)

(7) long\_term\_incentive: poi=0.18% (n=66)

(8) to\_messages: poi=0.16% (n=86)

(9) shared\_receipt\_with\_poi: poi=0.16% (n=86)

(10) from\_poi\_to\_this\_person: poi=0.16% (n=86)

(11) from\_messages: poi=0.16% (n=86)

(12) from\_this\_person\_to\_poi: poi=0.16% (n=86)

(13) email\_address: poi=0.16% (n=111)

(14) restricted\_stock: poi=0.15% (n=110)

(15) total\_payments: poi=0.14% (n=125)

(16) total\_stock\_value: poi=0.14% (n=126)

(17) deferral\_payments: poi=0.13% (n=39)

(18) exercised\_stock\_options: poi=0.12% (n=102)

(19) poi: poi=0.12% (n=146)

(20) restricted\_stock\_deferred: poi=0.0% (n=18)

(21) director\_fees: poi=0.0% (n=17)

**Analysis**: On first observations, we noticed the ratio between poi and not poi in the sample is 12% (18/146). We can assume the features we would like to select have the less NaN value to provide most information as possible and the poi sample mean different from sample mean.

I propose to exclude in a first step the features where NaN values are more than 50% (ie. 73), ie:

(1) loan\_advances: poi=0.25% (n=4)

(2) deferred\_income: poi=0.22% (n=49)

(7) long\_term\_incentive: poi=0.18% (n=66)

(17) deferral\_payments: poi=0.13% (n=39)

(20) restricted\_stock\_deferred: poi=0.0% (n=18)

(21) director\_fees: poi=0.0% (n=17)

Then I propose to get Three features per category (financial, email). I will prioritize features with n and ratio bigger as possible.

Consequently, I get:

(15) total\_payments: poi=0.14% (n=125)

(16) total\_stock\_value: poi=0.14% (n=126)

(18) exercised\_stock\_options: poi=0.12% (n=102)

(10) from\_poi\_to\_this\_person: poi=0.16% (n=86)

(12) from\_this\_person\_to\_poi: poi=0.16% (n=86)

(9) shared\_receipt\_with\_poi: poi=0.16% (n=86)

Consequently, I exclude for the moments following features (I could use it afterwards).

(14) restricted\_stock: poi=0.15% (n=110)

(3) bonus: poi=0.2% (n=82)

(4) other: poi=0.19% (n=93)

(5) expenses: poi=0.19% (n=95)

(6) salary: poi=0.18% (n=95)

(8) to\_messages: poi=0.16% (n=86)

(11) from\_messages: poi=0.16% (n=86)

# Remove outliers

The best way to remove outliers is to look for the maximum value for each feature (even those not selected for the machine learning algorithm).

Hereafter the results of the maximum value:

Maximum value for salary: (**'TOTAL'**, 26704229)

Maximum value for to\_messages: ('SHAPIRO RICHARD S', 15149)

Maximum value for deferral\_payments: (**'TOTAL'**, 32083396)

Maximum value for total\_payments: (**'TOTAL'**, 309886585)

Maximum value for exercised\_stock\_options: (**'TOTAL'**, 311764000)

Maximum value for bonus: (**'TOTAL'**, 97343619)

Maximum value for restricted\_stock: (**'TOTAL'**, 130322299)

Maximum value for shared\_receipt\_with\_poi: ('BELDEN TIMOTHY N', 5521)

Maximum value for restricted\_stock\_deferred: ('BHATNAGAR SANJAY', 15456290)

Maximum value for total\_stock\_value: (**'TOTAL'**, 434509511)

Maximum value for expenses: (**'TOTAL'**, 5235198)

Maximum value for loan\_advances: (**'TOTAL'**, 83925000)

Maximum value for from\_messages: ('KAMINSKI WINCENTY J', 14368)

Maximum value for other: (**'TOTAL'**, 42667589)

Maximum value for from\_this\_person\_to\_poi: ('DELAINEY DAVID W', 609)

Maximum value for poi: ('HANNON KEVIN P', True)

Maximum value for director\_fees: (**'TOTAL'**, 1398517)

Maximum value for deferred\_income: ('BOWEN JR RAYMOND M', -833)

Maximum value for long\_term\_incentive: (**'TOTAL'**, 48521928)

Maximum value for email\_address: ('COLWELL WESLEY', 'wes.colwell@enron.com')

Maximum value for from\_poi\_to\_this\_person: ('LAVORATO JOHN J', 528)

It is obvious that TOTAL person doesn’t exist. It is just an error in extracting the data from the dataset.

I propose to remove this “person” from the rest of analysis.

Hereafter the new results for maximum value:

Maximum value for salary: ('SKILLING JEFFREY K', 1111258)

Maximum value for to\_messages: ('SHAPIRO RICHARD S', 15149)

Maximum value for deferral\_payments: ('FREVERT MARK A', 6426990)

Maximum value for total\_payments: ('LAY KENNETH L', 103559793)

Maximum value for exercised\_stock\_options: ('LAY KENNETH L', 34348384)

Maximum value for bonus: ('LAVORATO JOHN J', 8000000)

Maximum value for restricted\_stock: ('LAY KENNETH L', 14761694)

Maximum value for shared\_receipt\_with\_poi: ('BELDEN TIMOTHY N', 5521)

Maximum value for restricted\_stock\_deferred: ('BHATNAGAR SANJAY', 15456290)

Maximum value for total\_stock\_value: ('LAY KENNETH L', 49110078)

Maximum value for expenses: ('MCCLELLAN GEORGE', 228763)

Maximum value for loan\_advances: ('LAY KENNETH L', 81525000)

Maximum value for from\_messages: ('KAMINSKI WINCENTY J', 14368)

Maximum value for other: ('LAY KENNETH L', 10359729)

Maximum value for from\_this\_person\_to\_poi: ('DELAINEY DAVID W', 609)

Maximum value for poi: ('HANNON KEVIN P', True)

Maximum value for director\_fees: ('BHATNAGAR SANJAY', 137864)

Maximum value for deferred\_income: ('BOWEN JR RAYMOND M', -833)

Maximum value for long\_term\_incentive: ('MARTIN AMANDA K', 5145434)

Maximum value for email\_address: ('COLWELL WESLEY', 'wes.colwell@enron.com')

Maximum value for from\_poi\_to\_this\_person: ('LAVORATO JOHN J', 528)

The result is far better.

Moreover, in the list of features I select, there are persons with NaN value, it could disturb the algorithms.

I propose to remove all persons from the list that have NaN value for all selected features.

It only concerns 2 people.

---> Delete: CHAN RONNIE

---> Delete: LOCKHART EUGENE E

# Rescale features

Thanks to min/max functions, we can observe that values are completely different as we compare millions of dollars and at best thousands of emails.

I propose to rescale all features thanks to Python *MinMaxScaler()*.

# CREATE NEW FEATURE

In “*chapter 3: Feature selection*”, We have chosen to select features with maximum non NAN values to get maximal information.

Now, we have to think about creating new more valuable features.

Regarding emails, my hypothesis is ratio between emails sent/received to/from poi would be far more accurate than absolute figures.

I propose consequently to add two features:

* ratio\_from\_poi\_email\_received
* ratio\_to\_poi\_email\_sent

In the same way, as the fraud has been characterized by a sudden sell of actions by persons involved in the fraud, I propose to add:

* ratio\_exer\_stock\_total

To check the benefits of those new features, I’m making a features selection according to the k highest scores (Python *SelectKBest*).

First, I’m checking the scores:

Scores for features:

(1) exercised\_stock\_options: 6.84550933503

(2) total\_stock\_value: 5.47661009929

(3) ratio\_exer\_stock\_total: 4.68313270573

(4) ratio\_to\_poi\_email\_sent: 4.64455528039

(5) total\_payments: 2.77918249429

(6) shared\_receipt\_with\_poi: 2.43221986514

(7) from\_poi\_to\_this\_person: 1.37005929223

(8) from\_this\_person\_to\_poi: 1.0008076418

(9) ratio\_from\_poi\_email\_received: 0.827769252139

Secondly, I’m making several classification tests thanks to provided test function with different value of k (selected features).

I’m using decision tree as algorithm with default settings but I could have used another one.

|  |  |  |  |
| --- | --- | --- | --- |
| k | Accuracy | Precision | Recall |
| 2 | 0.83267 | 0.35880 | 0.32400 |
| 4 |  |  |  |
| 6 |  |  |  |
| 8 |  |  |  |
| 10 (All) |  |  |  |