Introduction

This is the code portion of the Udacity UD120 Introduction To Machine Learning MOOC. The MOOC covers Algorithms (Naive Bayes, Support Vector Machine, Random Forest, AdaBoost, Word Tokenization), feature selection and validation.

In [327]:
```
import pickle
import sys
import pandas as pd
sys.path.append("../tools/")
from feature_format import featureFormat, targetFeatureSplit
data_dict = pickle.load(open("../final_project/final_project_dataset.pkl", "r") )
data_dict[data_dict.keys()[1]]
```

Out[327]:
```
{'bonus': 1200000,
 'deferral_payments': 1295738,
 'deferred_income': -1386055,
 'director_fees': 'NaN',
 'email_address': 'NaN',
 'exercised_stock_options': 6680544,
 'expenses': 11200,
 'from_messages': 'NaN',
 'from_poi_to_this_person': 'NaN',
 'from_this_person_to_poi': 'NaN',
 'loan_advances': 'NaN',
 'long_term_incentive': 1586055,
 'other': 2660303,
 'poi': False,
 'restricted_stock': 3942714,
 'restricted_stock_deferred': 'NaN',
 'salary': 267102,
 'shared_receipt_with_poi': 'NaN',
 'to_messages': 'NaN',
 'total_payments': 5634343,
 'total_stock_value': 10623258}
```

Data Exploration

total number of data points allocation across classes (POI/non-POI) number of features used are there features with many missing values? etc.

In [2]:
```
#The first step is to take a look at the data provided.
#A couple issues pop out immediately: there are a large number of features, and many of the values will be missing
#We also have a relatively small number of records - 145 and 20 features to choose from
#Overfitting could be a problem
print(len(data_dict))
data_dict.items()[2]
#This last line is a spot check here to see that there are many missing values in the data.
```

```
146
```

Out[2]:
```
('ELLIOTT STEVEN',
 {'bonus': 350000,
  'deferral_payments': 'NaN',
  'deferred_income': -400729,
  'director_fees': 'NaN',
  'email_address': 'steven.elliott@enron.com',
  'exercised_stock_options': 4890344,
  'expenses': 78552,
  'from_messages': 'NaN',
  'from_poi_to_this_person': 'NaN',
  'from_this_person_to_poi': 'NaN',
  'loan_advances': 'NaN',
  'long_term_incentive': 'NaN',
  'other': 12961,
  'poi': False,
  'restricted_stock': 1788391,
  'restricted_stock_deferred': 'NaN',
  'salary': 170941,
  'shared_receipt_with_poi': 'NaN',
  'to_messages': 'NaN',
  'total_payments': 211725,
  'total_stock_value': 6678735})
```

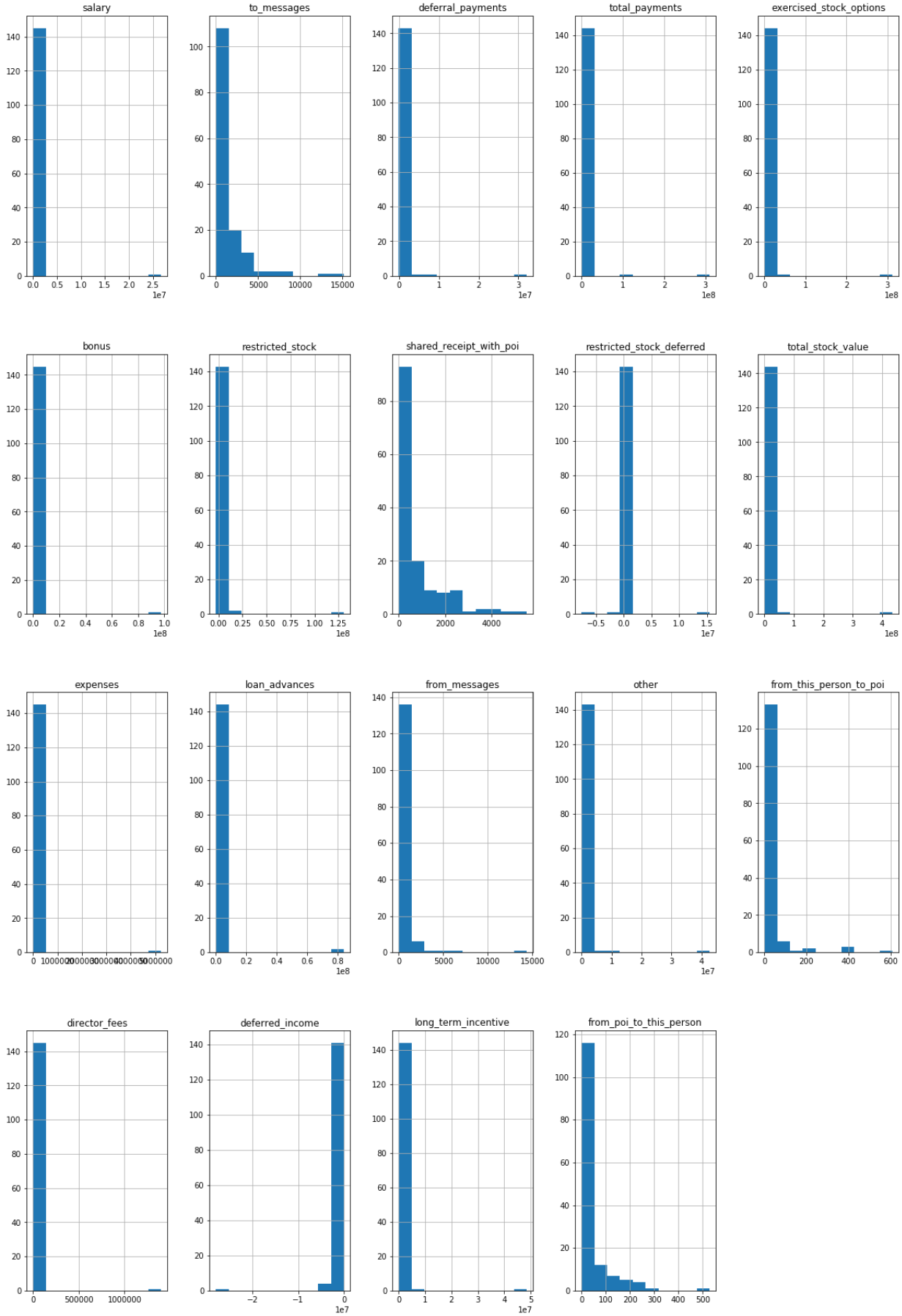
In [3]:
```
#Reformat data into an easier to use pandas data structure
df = pd.DataFrame.from_dict(data_dict,orient="index")
#Now answer some key questions about the data
#total number of data points
print 'Total number of people in data set: ', len(df.index)
print 'Total number of persons not of interest/of interest: ', df["poi
"].value_counts()
print 'Number of features(including poi metric): ', len(df.columns.val
ues)
#Next we will look for outliers and do any cleaning required

nan_count = 0
total_count = 0
for name, values in df.iteritems():
    for v in values:
        total_count += 1
        if v=='NaN':
            nan_count += 1
print 'Total NaN points: ', nan_count
print 'Total count: ', total_count
```

```
Total number of people in data set:  146
Total number of persons not of interest/of interest:  False    128
True      18
Name: poi, dtype: int64
Number of features(including poi metric):  21
Total NaN points:  1358
Total count:  3066
```

In [4]:
```
#
#Missing value by label
#
for name, values in df.iteritems():
    nan_count =0
    for v in values:
        if v=='NaN':
            nan_count += 1
    print name, ': ',nan_count
```

```
salary :  51
to_messages :  60
deferral_payments :  107
total_payments :  21
exercised_stock_options :  44
bonus :  64
restricted_stock :  36
shared_receipt_with_poi :  60
restricted_stock_deferred :  128
total_stock_value :  20
expenses :  51
loan_advances :  142
from_messages :  60
other :  53
from_this_person_to_poi :  60
poi :  0
director_fees :  129
deferred_income :  97
long_term_incentive :  80
email_address :  35
from_poi_to_this_person :  60
```

In [5]:
```
#Now we can look for outliers
#NaN values will be replaced with zero for the purposes of plotting on
ly
import matplotlib.pyplot as plt
# multiple box plots on one figure
df_cleaned = df.replace(to_replace='NaN', value=0)
plt.clf()
plt.cla()
plt.close()
columns = ['salary', 'to_messages', 'deferral_payments', 'total_paymen
ts',
       'exercised_stock_options', 'bonus', 'restricted_stock',
       'shared_receipt_with_poi', 'restricted_stock_deferred',
       'total_stock_value', 'expenses', 'loan_advances', 'from_message
s',
       'other', 'from_this_person_to_poi', 'director_fees',
       'deferred_income', 'long_term_incentive',
       'from_poi_to_this_person']
fig = plt.figure(figsize=(20, 30))
i=1
for column in columns:
    ax = fig.add_subplot(4, 5, i)
    #print(column)
    df_cleaned.hist(column=column,ax=ax)
    #plt.xticks(rotation=90)
    i+=1
plt.show()
```


salary
to_messages
deferral_payments
total_payments
exercised_stock_options
bonus
restricted_stock
shared_receipt_with_poi
restricted_stock_deferred
total_stock_value
expenses
loan_advances
from_messages
other
from_this_person_to_poi
director_fees
deferred_income
long_term_incentive
from_poi_to_this_person

Data Exploration - Outliers

In this section there is a check for suspect values, either very large or very small.

Two things stand out: 1: There is a total column that should be removed 2: Ken Lay has financial metrics that are so far above everyone else that his record will cause problems if we choose a machine learning algorithm that is sensitive to outliers. For now, Ken Lay will stay in.

In [6]:
```
#
# Check the high fliers
#
for column in columns:
    df_large = df_cleaned.nlargest(4,column)
    print column.ljust(30) ,': ',str(df_large.index.values).strip('[]'
)
    print column.ljust(30) ,': ',str(df_large[column].tolist()).strip(
'[]')
```

```
salary                         :  'TOTAL' 'SKILLING JEFFREY K' 'LAY
KENNETH L' 'FREVERT MARK A'
salary                         :  26704229, 1111258, 1072321, 106093
2
to_messages                    :  'SHAPIRO RICHARD S' 'KEAN STEVEN J
' 'KITCHEN LOUISE' 'BELDEN TIMOTHY N'
to_messages                    :  15149, 12754, 8305, 7991
deferral_payments              :  'TOTAL' 'FREVERT MARK A' 'HORTON S
TANLEY C' 'HUMPHREY GENE E'
deferral_payments              :  32083396, 6426990, 3131860, 296450
6
total_payments                 :  'TOTAL' 'LAY KENNETH L' 'FREVERT M
ARK A' 'BHATNAGAR SANJAY'
total_payments                 :  309886585, 103559793, 17252530, 15
456290
exercised_stock_options        :  'TOTAL' 'LAY KENNETH L' 'HIRKO JOS
EPH' 'RICE KENNETH D'
exercised_stock_options        :  311764000, 34348384, 30766064, 197
94175
bonus                          :  'TOTAL' 'LAVORATO JOHN J' 'LAY KEN
NETH L' 'SKILLING JEFFREY K'
bonus                          :  97343619, 8000000, 7000000, 560000
0
restricted_stock               :  'TOTAL' 'LAY KENNETH L' 'WHITE JR
THOMAS E' 'PAI LOU L'
restricted_stock               :  130322299, 14761694, 13847074, 845
3763
shared_receipt_with_poi        :  'BELDEN TIMOTHY N' 'SHAPIRO RICHAR
```

```
D S' 'LAVORATO JOHN J'
 'WHALLEY LAWRENCE G'
shared_receipt_with_poi        :  5521, 4527, 3962, 3920
restricted_stock_deferred      :  'BHATNAGAR SANJAY' 'BELFER ROBERT'
'BADUM JAMES P' 'BAXTER JOHN C'
restricted_stock_deferred      :  15456290, 44093, 0, 0
total_stock_value              :  'TOTAL' 'LAY KENNETH L' 'HIRKO JOS
EPH' 'SKILLING JEFFREY K'
total_stock_value              :  434509511, 49110078, 30766064, 260
93672
expenses                       :  'TOTAL' 'MCCLELLAN GEORGE' 'URQUHA
RT JOHN A' 'SHANKMAN JEFFREY A'
expenses                       :  5235198, 228763, 228656, 178979
loan_advances                  :  'TOTAL' 'LAY KENNETH L' 'FREVERT M
ARK A' 'PICKERING MARK R'
loan_advances                  :  83925000, 81525000, 2000000, 40000
0
from_messages                  :  'KAMINSKI WINCENTY J' 'KEAN STEVEN
J' 'BECK SALLY W' 'DELAINEY DAVID W'
from_messages                  :  14368, 6759, 4343, 3069
other                          :  'TOTAL' 'LAY KENNETH L' 'FREVERT M
ARK A' 'MARTIN AMANDA K'
other                          :  42667589, 10359729, 7427621, 28184
54
from_this_person_to_poi        :  'DELAINEY DAVID W' 'LAVORATO JOHN
J' 'KEAN STEVEN J' 'BECK SALLY W'
from_this_person_to_poi        :  609, 411, 387, 386
director_fees                  :  'TOTAL' 'BHATNAGAR SANJAY' 'SAVAGE
FRANK' 'GRAMM WENDY L'
director_fees                  :  1398517, 137864, 125034, 119292
deferred_income                :  'BADUM JAMES P' 'BAZELIDES PHILIP
J' 'BECK SALLY W' 'BELFER ROBERT'
deferred_income                :  0, 0, 0, 0
long_term_incentive            :  'TOTAL' 'MARTIN AMANDA K' 'LAY KEN
NETH L' 'ECHOLS JOHN B'
long_term_incentive            :  48521928, 5145434, 3600000, 223477
4
from_poi_to_this_person        :  'LAVORATO JOHN J' 'DIETRICH JANET
R' 'KITCHEN LOUISE' 'FREVERT MARK A'
from_poi_to_this_person        :  528, 305, 251, 242
```

In [7]:
```
#
#Check for low fliers
#
for column in columns:
    df_small = df_cleaned.nsmallest(4,column)
    print column.ljust(30) ,': ',str(df_small.index.values).strip('[]'
)
    print column.ljust(30) ,': ',str(df_small[column].tolist()).strip(
'[]')
```

```
salary                         :  'BADUM JAMES P' 'BELFER ROBERT' 'B
HATNAGAR SANJAY' 'BLAKE JR. NORMAN P'
salary                         :  0, 0, 0, 0
to_messages                    :  'BADUM JAMES P' 'BAXTER JOHN C' 'B
AY FRANKLIN R' 'BAZELIDES PHILIP J'
to_messages                    :  0, 0, 0, 0
deferral_payments              :  'BELFER ROBERT' 'BANNANTINE JAMES
M' 'BECK SALLY W' 'BERBERIAN DAVID'
deferral_payments              :  -102500, 0, 0, 0
total_payments                 :  'CHAN RONNIE' 'CHRISTODOULOU DIOME
DES' 'CLINE KENNETH W'
 'CORDES WILLIAM R'
total_payments                 :  0, 0, 0, 0
exercised_stock_options        :  'BAY FRANKLIN R' 'BECK SALLY W' 'B
ERGSIEKER RICHARD P'
 'BLAKE JR. NORMAN P'
exercised_stock_options        :  0, 0, 0, 0
bonus                          :  'BADUM JAMES P' 'BANNANTINE JAMES
M' 'BAZELIDES PHILIP J' 'BELFER ROBERT'
bonus                          :  0, 0, 0, 0
restricted_stock               :  'BHATNAGAR SANJAY' 'BADUM JAMES P'
'BAZELIDES PHILIP J' 'BELFER ROBERT'
restricted_stock               :  -2604490, 0, 0, 0
shared_receipt_with_poi        :  'BADUM JAMES P' 'BAXTER JOHN C' 'B
AY FRANKLIN R' 'BAZELIDES PHILIP J'
shared_receipt_with_poi        :  0, 0, 0, 0
restricted_stock_deferred      :  'TOTAL' 'DERRICK JR. JAMES V' 'BAN
NANTINE JAMES M' 'CLINE KENNETH W'
restricted_stock_deferred      :  -7576788, -1787380, -560222, -4725
68
total_stock_value              :  'BELFER ROBERT' 'BHATNAGAR SANJAY'
'BLAKE JR. NORMAN P' 'BROWN MICHAEL'
total_stock_value              :  -44093, 0, 0, 0
expenses                       :  'BAZELIDES PHILIP J' 'BELFER ROBER
T' 'BHATNAGAR SANJAY' 'BUY RICHARD B'
expenses                       :  0, 0, 0, 0
loan_advances                  :  'ALLEN PHILLIP K' 'BADUM JAMES P'
'BANNANTINE JAMES M' 'BAXTER JOHN C'
loan_advances                  :  0, 0, 0, 0
```

```
from_messages                  :  'BADUM JAMES P' 'BAXTER JOHN C' 'B
AY FRANKLIN R' 'BAZELIDES PHILIP J'
from_messages                  :  0, 0, 0, 0
other                          :  'BADUM JAMES P' 'BELFER ROBERT' 'B
ERBERIAN DAVID' 'BLAKE JR. NORMAN P'
other                          :  0, 0, 0, 0
from_this_person_to_poi        :  'BADUM JAMES P' 'BANNANTINE JAMES
M' 'BAXTER JOHN C' 'BAY FRANKLIN R'
from_this_person_to_poi        :  0, 0, 0, 0
director_fees                  :  'ALLEN PHILLIP K' 'BADUM JAMES P'
'BANNANTINE JAMES M' 'BAXTER JOHN C'
director_fees                  :  0, 0, 0, 0
deferred_income                :  'TOTAL' 'RICE KENNETH D' 'FREVERT
MARK A' 'HANNON KEVIN P'
deferred_income                :  -27992891, -3504386, -3367011, -31
17011
long_term_incentive            :  'BADUM JAMES P' 'BANNANTINE JAMES
M' 'BAY FRANKLIN R' 'BECK SALLY W'
long_term_incentive            :  0, 0, 0, 0
from_poi_to_this_person        :  'BADUM JAMES P' 'BAXTER JOHN C' 'B
AY FRANKLIN R' 'BAZELIDES PHILIP J'
from_poi_to_this_person        :  0, 0, 0, 0
```

In [8]:
```
#
#Sanity check all names
#'THE TRAVEL AGENCY IN THE PARK' does not belong!
df.index.values
```

Out[8]:
```
array(['ALLEN PHILLIP K', 'BADUM JAMES P', 'BANNANTINE JAMES M',
       'BAXTER JOHN C', 'BAY FRANKLIN R', 'BAZELIDES PHILIP J',
       'BECK SALLY W', 'BELDEN TIMOTHY N', 'BELFER ROBERT',
       'BERBERIAN DAVID', 'BERGSIEKER RICHARD P', 'BHATNAGAR SANJAY'
,
       'BIBI PHILIPPE A', 'BLACHMAN JEREMY M', 'BLAKE JR. NORMAN P',
       'BOWEN JR RAYMOND M', 'BROWN MICHAEL', 'BUCHANAN HAROLD G',
       'BUTTS ROBERT H', 'BUY RICHARD B', 'CALGER CHRISTOPHER F',
       'CARTER REBECCA C', 'CAUSEY RICHARD A', 'CHAN RONNIE',
       'CHRISTODOULOU DIOMEDES', 'CLINE KENNETH W', 'COLWELL WESLEY'
,
       'CORDES WILLIAM R', 'COX DAVID', 'CUMBERLAND MICHAEL S',
       'DEFFNER JOSEPH M', 'DELAINEY DAVID W', 'DERRICK JR. JAMES V'
,
       'DETMERING TIMOTHY J', 'DIETRICH JANET R', 'DIMICHELE RICHARD
G',
       'DODSON KEITH', 'DONAHUE JR JEFFREY M', 'DUNCAN JOHN H',
       'DURAN WILLIAM D', 'ECHOLS JOHN B', 'ELLIOTT STEVEN',
       'FALLON JAMES B', 'FASTOW ANDREW S', 'FITZGERALD JAY L',
       'FOWLER PEGGY', 'FOY JOE', 'FREVERT MARK A', 'FUGH JOHN L',
       'GAHN ROBERT S', 'GARLAND C KEVIN', 'GATHMANN WILLIAM D',
       'GIBBS DANA R', 'GILLIS JOHN', 'GLISAN JR BEN F', 'GOLD JOSEP
```

```
H',
       'GRAMM WENDY L', 'GRAY RODNEY', 'HAEDICKE MARK E', 'HANNON KE
VIN P',
       'HAUG DAVID L', 'HAYES ROBERT E', 'HAYSLETT RODERICK J',
       'HERMANN ROBERT J', 'HICKERSON GARY J', 'HIRKO JOSEPH',
       'HORTON STANLEY C', 'HUGHES JAMES A', 'HUMPHREY GENE E',
       'IZZO LAWRENCE L', 'JACKSON CHARLENE R', 'JAEDICKE ROBERT',
       'KAMINSKI WINCENTY J', 'KEAN STEVEN J', 'KISHKILL JOSEPH G',
       'KITCHEN LOUISE', 'KOENIG MARK E', 'KOPPER MICHAEL J',
       'LAVORATO JOHN J', 'LAY KENNETH L', 'LEFF DANIEL P',
       'LEMAISTRE CHARLES', 'LEWIS RICHARD', 'LINDHOLM TOD A',
       'LOCKHART EUGENE E', 'LOWRY CHARLES P', 'MARTIN AMANDA K',
       'MCCARTY DANNY J', 'MCCLELLAN GEORGE', 'MCCONNELL MICHAEL S',
       'MCDONALD REBECCA', 'MCMAHON JEFFREY', 'MENDELSOHN JOHN',
       'METTS MARK', 'MEYER JEROME J', 'MEYER ROCKFORD G',
       'MORAN MICHAEL P', 'MORDAUNT KRISTINA M', 'MULLER MARK S',
       'MURRAY JULIA H', 'NOLES JAMES L', 'OLSON CINDY K',
       'OVERDYKE JR JERE C', 'PAI LOU L', 'PEREIRA PAULO V. FERRAZ',
       'PICKERING MARK R', 'PIPER GREGORY F', 'PIRO JIM', 'POWERS WI
LLIAM',
       'PRENTICE JAMES', 'REDMOND BRIAN L', 'REYNOLDS LAWRENCE',
       'RICE KENNETH D', 'RIEKER PAULA H', 'SAVAGE FRANK',
       'SCRIMSHAW MATTHEW', 'SHANKMAN JEFFREY A', 'SHAPIRO RICHARD S
',
       'SHARP VICTORIA T', 'SHELBY REX', 'SHERRICK JEFFREY B',
       'SHERRIFF JOHN R', 'SKILLING JEFFREY K', 'STABLER FRANK',
       'SULLIVAN-SHAKLOVITZ COLLEEN', 'SUNDE MARTIN', 'TAYLOR MITCHE
LL S',
       'THE TRAVEL AGENCY IN THE PARK', 'THORN TERENCE H',
       'TILNEY ELIZABETH A', 'TOTAL', 'UMANOFF ADAM S', 'URQUHART JO
HN A',
       'WAKEHAM JOHN', 'WALLS JR ROBERT H', 'WALTERS GARETH W',
       'WASAFF GEORGE', 'WESTFAHL RICHARD K', 'WHALEY DAVID A',
       'WHALLEY LAWRENCE G', 'WHITE JR THOMAS E', 'WINOKUR JR. HERBE
RT S',
       'WODRASKA JOHN', 'WROBEL BRUCE', 'YEAGER F SCOTT', 'YEAP SOON
'], dtype=object)
```

In [9]:
```
# Last step of the outlier investigation - create a cleaned data set w
ithout the totals included
df_clean = df.drop("TOTAL")
df_clean = df_clean.drop('THE TRAVEL AGENCY IN THE PARK')
df_clean
```

Out[9]:

	salary	to_messages	deferral_payments	total_payments	exerci
ALLEN PHILLIP K	201955	2902	2869717	4484442	17295
BADUM JAMES P	NaN	NaN	178980	182466	25781

BANNANTINE JAMES M	477	566	NaN	916197	40461
BAXTER JOHN C	267102	NaN	1295738	5634343	66805
BAY FRANKLIN R	239671	NaN	260455	827696	NaN
BAZELIDES PHILIP J	80818	NaN	684694	860136	15996
BECK SALLY W	231330	7315	NaN	969068	NaN
BELDEN TIMOTHY N	213999	7991	2144013	5501630	95313
BELFER ROBERT	NaN	NaN	-102500	102500	3285
BERBERIAN DAVID	216582	NaN	NaN	228474	16243
BERGSIEKER RICHARD P	187922	383	NaN	618850	NaN
BHATNAGAR SANJAY	NaN	523	NaN	15456290	26044
BIBI PHILIPPE A	213625	1607	NaN	2047593	14657
BLACHMAN JEREMY M	248546	2475	NaN	2014835	76531
BLAKE JR. NORMAN P	NaN	NaN	NaN	1279	NaN
BOWEN JR RAYMOND M	278601	1858	NaN	2669589	NaN
BROWN MICHAEL	NaN	1486	NaN	49288	NaN
BUCHANAN HAROLD G	248017	1088	NaN	1054637	82546
BUTTS ROBERT H	261516	NaN	NaN	1271582	NaN
BUY RICHARD B	330546	3523	649584	2355702	25428
CALGER CHRISTOPHER F	240189	2598	NaN	1639297	NaN
CARTER REBECCA C	261809	312	NaN	477557	NaN
CAUSEY	415189	1892	NaN	1868758	NaN

RICHARD A					
CHAN RONNIE	NaN	NaN	NaN	NaN	NaN
CHRISTODOULOU DIOMEDES	NaN	NaN	NaN	NaN	51271
CLINE KENNETH W	NaN	NaN	NaN	NaN	NaN
COLWELL WESLEY	288542	1758	27610	1490344	NaN
CORDES WILLIAM R	NaN	764	NaN	NaN	65185
COX DAVID	314288	102	NaN	1101393	11755
CUMBERLAND MICHAEL S	184899	NaN	NaN	807956	NaN
...	...	...	...	...	...
SAVAGE FRANK	NaN	NaN	NaN	3750	NaN
SCRIMSHAW MATTHEW	NaN	NaN	NaN	NaN	75955
SHANKMAN JEFFREY A	304110	3221	NaN	3038702	14418
SHAPIRO RICHARD S	269076	15149	NaN	1057548	60783
SHARP VICTORIA T	248146	3136	187469	1576511	28107
SHELBY REX	211844	225	NaN	2003885	16243
SHERRICK JEFFREY B	NaN	613	NaN	NaN	14264
SHERRIFF JOHN R	428780	3187	NaN	4335388	18355
SKILLING JEFFREY K	1111258	3627	NaN	8682716	19250
STABLER FRANK	239502	NaN	NaN	1112087	NaN
SULLIVAN-SHAKLOVITZ COLLEEN	162779	NaN	181993	999356	13623

SUNDE MARTIN	257486	2647	NaN	1545059	NaN
TAYLOR MITCHELL S	265214	533	227449	1092663	31812
THORN TERENCE H	222093	266	16586	911453	44524
TILNEY ELIZABETH A	247338	460	NaN	399393	59125
UMANOFF ADAM S	288589	111	NaN	1130461	NaN
URQUHART JOHN A	NaN	NaN	NaN	228656	NaN
WAKEHAM JOHN	NaN	NaN	NaN	213071	NaN
WALLS JR ROBERT H	357091	671	NaN	1798780	43465
WALTERS GARETH W	NaN	NaN	53625	87410	10303
WASAFF GEORGE	259996	400	831299	1034395	16682
WESTFAHL RICHARD K	63744	NaN	NaN	762135	NaN
WHALEY DAVID A	NaN	NaN	NaN	NaN	98718
WHALLEY LAWRENCE G	510364	6019	NaN	4677574	32829
WHITE JR THOMAS E	317543	NaN	NaN	1934359	12970
WINOKUR JR. HERBERT S	NaN	NaN	NaN	84992	NaN
WODRASKA JOHN	NaN	NaN	NaN	189583	NaN
WROBEL BRUCE	NaN	NaN	NaN	NaN	13913
YEAGER F SCOTT	158403	NaN	NaN	360300	83085
YEAP SOON	NaN	NaN	NaN	55097	19275

144 rows × 21 columns

Feature Selection And Engineering

A first step is to balance the data out by adding multiples of each POI. This will help prevent achieving a high accuracy score through always predicting a person is not a POI.

The next first step is to determine what to do with the missing data values. Engineered features are added to flag missing values in each column, then the missing values in the original column are replaced with zeros.

For feature selection, univariate selection is used.

In [10]:
```
import numpy as np
df_selection = df_clean.copy()
new_columns = list(columns)
for column in columns:
    df_selection[column+'_IsMissing'] = np.where(df_selection[column]=
='NaN', 1, 0)
    new_columns.append(column+'_IsMissing')
df_selection = df_selection.replace(to_replace='NaN', value=0)
#POI_data = df_selection.loc[df_clean['poi'] == True]
#6 copies will get close to 50-50 split
#df_selection_aug=df_selection.append(POI_data,ignore_index=True)
#df_selection_aug=df_selection_aug.append(POI_data,ignore_index=True)
#df_selection_aug=df_selection_aug.append(POI_data,ignore_index=True)
#df_selection_aug=df_selection_aug.append(POI_data,ignore_index=True)
#df_selection_aug=df_selection_aug.append(POI_data,ignore_index=True)
#df_selection_aug.shape
df_selection.head()
```

Out[10]:

	salary	to_messages	deferral_payments	total_payments	exercised_s
ALLEN PHILLIP K	201955	2902	2869717	4484442	1729541
BADUM JAMES P	0	0	178980	182466	257817
BANNANTINE JAMES M	477	566	0	916197	4046157
BAXTER JOHN C	267102	0	1295738	5634343	6680544
BAY FRANKLIN R	239671	0	260455	827696	0

5 rows × 40 columns

In [11]:
```
#Univariate feature selection
# This next one is based on linear regression, so the presence of outi
ers like Ken Lay may be a problem
#
from sklearn.feature_selection import SelectPercentile, f_classif
Labels = df_selection["poi"].values
Features = df_selection[new_columns].values
selector = SelectPercentile(f_classif)
selector.fit(Features,Labels)
importances = selector.pvalues_
order = np.argsort(importances)
for i in order:
    print importances[i],new_columns[i]
```

```
1.59454384636e-06 exercised_stock_options
2.10580664901e-06 total_stock_value
9.70247434123e-06 bonus
3.03379610753e-05 salary
0.000454828852105 other_IsMissing
0.0008254654141 expenses_IsMissing
0.00085980314392 deferred_income
0.00184543514661 long_term_incentive
0.00265163145541 bonus_IsMissing
0.00266996113932 restricted_stock
0.003403426653 total_payments
0.00363440202436 shared_receipt_with_poi
0.00523055321107 salary_IsMissing
0.00729417704421 deferred_income_IsMissing
0.00797381626057 loan_advances
0.0136731508754 expenses
0.0222207279608 from_poi_to_this_person
0.0411643516562 other
0.0478154062078 restricted_stock_IsMissing
0.0502053203569 long_term_incentive_IsMissing
0.0615896650858 total_payments_IsMissing
0.0779822264099 total_stock_value_IsMissing
0.0962596265407 from_poi_to_this_person_IsMissing
0.0962596265407 to_messages_IsMissing
0.0962596265407 from_this_person_to_poi_IsMissing
0.0962596265407 from_messages_IsMissing
0.0962596265407 shared_receipt_with_poi_IsMissing
0.098350630937 restricted_stock_deferred_IsMissing
0.110318833089 director_fees_IsMissing
0.121524339837 from_this_person_to_poi
0.148769495273 director_fees
0.194551114875 to_messages
0.273365600776 loan_advances_IsMissing
0.642003894038 deferral_payments
0.6859607079 from_messages
0.73296130846 exercised_stock_options_IsMissing
0.799153556703 restricted_stock_deferred
0.887326927357 deferral_payments_IsMissing
```

In [12]:
```
#More that 3 features was found to cause overfitting
selected_features_univariate = ['exercised_stock_options','total_stock
_value','bonus']
```

In [13]:
```
#
#Try the same thing with a decision tree and recursive feature elimina
tion
from sklearn.feature_selection import RFE
from sklearn import tree
clf = tree.DecisionTreeClassifier(min_samples_split=2)
rfe = RFE(estimator=clf, n_features_to_select=1, step=1)
rfe.fit(Features, Labels)
rfe.ranking_
for i in range(0,len(rfe.ranking_)):
    print rfe.ranking_[i],new_columns[i]
```

```
38 salary
37 to_messages
36 deferral_payments
3 total_payments
2 exercised_stock_options
4 bonus
5 restricted_stock
9 shared_receipt_with_poi
16 restricted_stock_deferred
15 total_stock_value
1 expenses
18 loan_advances
6 from_messages
8 other
7 from_this_person_to_poi
26 director_fees
28 deferred_income
30 long_term_incentive
32 from_poi_to_this_person
34 salary_IsMissing
35 to_messages_IsMissing
33 deferral_payments_IsMissing
31 total_payments_IsMissing
29 exercised_stock_options_IsMissing
27 bonus_IsMissing
25 restricted_stock_IsMissing
14 shared_receipt_with_poi_IsMissing
13 restricted_stock_deferred_IsMissing
12 total_stock_value_IsMissing
11 expenses_IsMissing
10 loan_advances_IsMissing
17 from_messages_IsMissing
19 other_IsMissing
20 from_this_person_to_poi_IsMissing
21 director_fees_IsMissing
22 deferred_income_IsMissing
23 long_term_incentive_IsMissing
24 from_poi_to_this_person_IsMissing
```

In [14]:
```
#More that 3 features was found to cause overfitting
selected_features_multivariate = ['exercised_stock_options','restricte
d_stock','total_payments']
```

In [15]:
```
#
# One more time using feature importances are repprted by a Random for
est classifier
#Results are unstable
from sklearn.ensemble import RandomForestClassifier
clf = RandomForestClassifier()
clf.fit(Features, Labels)
clf.feature_importances_
for i in range(0,len(clf.feature_importances_)):
    print clf.feature_importances_[i],new_columns[i]
```

```
0.0290122201394 salary
0.0376467986448 to_messages
0.00126315789474 deferral_payments
0.0401382521162 total_payments
0.127099456518 exercised_stock_options
0.068699443071 bonus
0.086909141826 restricted_stock
0.0877851483261 shared_receipt_with_poi
0.0131559942697 restricted_stock_deferred
0.0761599146017 total_stock_value
0.0623710563236 expenses
0.0 loan_advances
0.0377896651815 from_messages
0.0464779335777 other
0.052128204993 from_this_person_to_poi
0.0 director_fees
0.0871950994772 deferred_income
0.0180738744015 long_term_incentive
0.0385480780981 from_poi_to_this_person
0.0 salary_IsMissing
0.00432404605263 to_messages_IsMissing
0.00224243752925 deferral_payments_IsMissing
0.0 total_payments_IsMissing
0.0124667064202 exercised_stock_options_IsMissing
0.00971429053217 bonus_IsMissing
0.0 restricted_stock_IsMissing
0.0 shared_receipt_with_poi_IsMissing
0.00909473684211 restricted_stock_deferred_IsMissing
0.0 total_stock_value_IsMissing
0.00413277204176 expenses_IsMissing
0.0 loan_advances_IsMissing
0.01004648735 from_messages_IsMissing
0.00667560755182 other_IsMissing
0.00140023417789 from_this_person_to_poi_IsMissing
0.000122358175751 director_fees_IsMissing
0.0251935407611 deferred_income_IsMissing
0.00413334310499 long_term_incentive_IsMissing
0.0 from_poi_to_this_person_IsMissing
```

In [16]:
```
#More that 3 features was found to cause overfitting
selected_features_rf = ['expenses','exercised_stock_options','bonus']
```

In [17]:
```
#
#Let's add one more for fun.  This is based on human intuition that mo
ney and communication are key
#The total number of features needs to be kept low to prevent overfitt
ing
#
#
selected_features_human= ['exercised_stock_options','expenses','from_t
his_person_to_poi']
selected_features_human_plus = ['exercised_stock_options','restricted_
stock','total_payments','from_this_person_to_poi']
```

Algorithm selection and tuning

Two common algorithms will be optimized and the best selected

A decision tree will be used - this does not require feature scaling, but will not be negatively impacted by scaling.

An SVM will be used. It does require feature scaling.

Both algorithms will be tested on scaled data.

In [309]:
```
#
# Try the next few cells with different classifiers and features
#
from sklearn import tree
from sklearn.naive_bayes import GaussianNB
#clf = GaussianNB()
clf = tree.DecisionTreeClassifier(min_samples_split=5)
test_features = selected_features_rf
#For tuning
parameters = {}
#parameters = {'min_samples_split':[2,5,10,20,40,80]}
#parameters = {'min_samples_split':[2,5,10,20,40,80], 'min_samples_lea
f':[2,5,10,20,40,80]}
#selected_features_rf = ['expenses','exercised_stock_options','bonus']
#selected_features_univariate = ['exercised_stock_options','total_stoc
k_value','bonus']
#selected_features_multivariate = ['exercised_stock_options','restrict
ed_stock','total_payments']
#selected_features_human= ['exercised_stock_options','expenses','from_
this_person_to_poi']
#selected_features_human_plus = ['exercised_stock_options','restricted
_stock','total_payments','from_this_person_to_poi'
```

In [310]:
```
from sklearn.preprocessing import MinMaxScaler

Labels = df_selection["poi"].values
Features = df_selection[test_features].values

#Scale
scaler = MinMaxScaler()
scaler.fit(Features)
Features - scaler.transform(Features)


from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(Features, Labels,
test_size=0.3, random_state=42)
clf.fit(X_train,y_train)
```

Out[310]:
```
DecisionTreeClassifier(class_weight=None, criterion='gini', max_dept
h=None,
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=5,
            min_weight_fraction_leaf=0.0, presort=False, random_stat
e=None,
            splitter='best')
```

In [311]:
```
#Quick test of the classifier
from sklearn.metrics import accuracy_score
predictions_test = clf.predict(X_test)
predictions_train = clf.predict(X_train)
print 'Test set: ',accuracy_score(predictions_test,y_test)
print 'Train set: ',accuracy_score(predictions_train,y_train)
```

```
Test set:  0.795454545455
Train set:  0.98
```

In [312]:
```
#Optimization
#Optimization can be performed on the entire data set
from sklearn.model_selection import GridSearchCV
optimizer = GridSearchCV(clf, parameters,return_train_score=False)
optimizer.fit(Features, Labels)
optimizer.best_params_
```

Out[312]:
```
{}
```

In [313]:
```
#We now have the following feature sets, tuning parameters, and test-s
et accuracy scores (tree, GNB)
#selected_features_rf {'min_samples_split': 5} 0.8409, 0.8181
#selected_features_univariate {'min_samples_split': 5} 0.8181, 0.8181
#selected_features_multivariate {'min_samples_split': 80} 0.8181, 0.79
54
#selected_features_human {'min_samples_split': 80} 0.0, 0.909
#selected_features_human_plus {'min_samples_split': 80} 0.8181, 0.7954
```

Algorithm Validation

In this section we will evaluate precision and recall using the included test script provided by Udacity.

In [314]:
```
import tester as ud120test
import feature_format as ff
```

In [315]:
```
labels_save = list(test_features)
labels_save.insert(0,'poi')
print(labels_save)
ud120test.dump_classifier_and_data(clf, df_selection[labels_save].to_d
ict(orient='index'), labels_save)
```

```
['poi', 'expenses', 'exercised_stock_options', 'bonus']
```

In [316]:
```
ud120test.main()
```

```
DecisionTreeClassifier(class_weight=None, criterion='gini', max_dept
h=None,
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=5,
            min_weight_fraction_leaf=0.0, presort=False, random_stat
e=None,
            splitter='best')
        Accuracy: 0.82636       Precision: 0.39100      Recall: 0.38
650     F1: 0.38874     F2: 0.38739
        Total predictions: 14000        True positives:  773
False positives: 1204   False negatives: 1227   True negatives: 1079
6
```

In [317]:
```
#We now have the following feature sets, tuning parameters, and test-s
et accuracy scores (train, test) (precision,recall)
#selected_features_rf dt {'min_samples_split': 5} (0.8409, 0.8181) (.3
9223, .3850)
#selected_features_rf nb (0.8638, 0.860) (0.482, 0.28850)
#selected_features_univariate dt {'min_samples_split': 5} (0.8181, 0.8
181) (0.35564,0.33771)
#selected_features_univariate nb (0.886 0.87) (0.48581, 0.351)
#selected_features_multivariate dt {'min_samples_split': 80} (0.8181,
0.7954) (0.75244, 0.19300)
#selected_features_multivariate nb (0.87 0.8636) (0.387, 0.179)
#selected_features_human dt {'min_samples_split': 80} (0.90, 0.909) (0
.75966, 0.177)
#selected_features_human nb (0.87 0.909) (0.56397 0.2755)
```

In [318]:
```
import graphviz
dot_data = tree.export_graphviz(clf, out_file=None,
                         feature_names=test_features,
                         class_names=[ 'Innocent','POI'],
                         filled=True, rounded=True,
                         special_characters=True)
graph = graphviz.Source(dot_data)
graphviz.Source(dot_data)
graph
```

Out[318]:


bonus ≤ 1225000.0
gini = 0.226
samples = 100
value = [87, 13]
class = Innocent
True
False
expenses ≤ 117234.5
gini = 0.11
samples = 86
value = [81, 5]
class = Innocent
expenses ≤ 11564.5
gini = 0.49
samples = 14
value = [6, 8]
class = POI
exercised_stock_options ≤ 825015.5
gini = 0.048
samples = 81
value = [79, 2]
class = Innocent
expenses ≤ 177836.5
gini = 0.48
samples = 5
value = [2, 3]
class = POI
gini = 0.0
samples = 2
value = [2, 0]
class = Innocent
expenses ≤ 56879.5
gini = 0.444
samples = 12
value = [4, 8]
class = POI
bonus ≤ 925000.0
gini = 0.025
samples = 78
value = [77, 1]
class = Innocent
gini = 0.444
samples = 3
value = [2, 1]
class = Innocent
gini = 0.0
samples = 3
value = [0, 3]
class = POI
gini = 0.0
samples = 2
value = [2, 0]
class = Innocent
gini = 0.0
samples = 6
value = [0, 6]
class = POI
bonus ≤ 1675000.0
gini = 0.444
samples = 6
value = [4, 2]
class = Innocent
gini = 0.0
samples = 72
value = [72, 0]
class = Innocent
exercised_stock_options ≤ 304375.0
gini = 0.278
samples = 6
value = [5, 1]
class = Innocent
gini = 0.0
samples = 1
value = [0, 1]
class = POI
bonus ≤ 5000000.0
gini = 0.32
samples = 5
value = [4, 1]
class = Innocent
gini = 0.5
samples = 2
value = [1, 1]
class = Innocent
gini = 0.0
samples = 4
value = [4, 0]
class = Innocent
gini = 0.0
samples = 4
value = [4, 0]
class = Innocent
gini = 0.0
samples = 1
value = [0, 1]
class = POI