classifier

March 13, 2019

```
In [44]: import pandas as pd
         import numpy as np
         import matplotlib.pyplot as plt
         import matplotlib.path as mpath
         plt.rcParams['figure.figsize'] = [17, 5]

         from sklearn.linear_model import LogisticRegression
         from sklearn.ensemble import RandomForestClassifier
         from sklearn.model_selection import train_test_split, cross_val_score
         from sklearn.grid_search import GridSearchCV
         from sklearn.metrics import precision_recall_curve, average_precision_score
```

```
In [45]: # load data
         df_sub1 = pd.read_csv('./labeled_data/sub1label.csv')
         df_sub2 = pd.read_csv('./labeled_data/sub1label.csv')

         # drop unneccessary columns
         df_sub1.drop('Unnamed: 0', axis=1, inplace=True)
         df_sub2.drop('Unnamed: 0', axis=1, inplace=True)

         df_sub1.head(10)
```

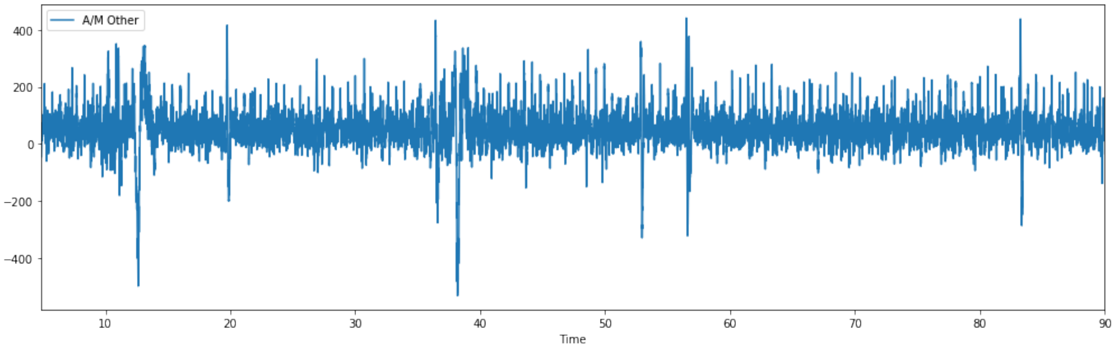
```
Out[45]:        Time  A/M Other   A/M  delta     theta  low_alpha  high_alpha  \
         0  4.880859      -44.0  51.0   74.0  567109.0    74006.0     38310.0
         1  4.882812      -38.0  51.0   74.0  567109.0    74006.0     38310.0
         2  4.884766      -27.0  51.0   74.0  567109.0    74006.0     38310.0
         3  4.886719      -25.0  51.0   74.0  567109.0    74006.0     38310.0
         4  4.888672      -19.0  51.0   74.0  567109.0    74006.0     38310.0
         5  4.890625      -22.0  51.0   74.0  567109.0    74006.0     38310.0
         6  4.892578      -21.0  51.0   74.0  567109.0    74006.0     38310.0
         7  4.894531       -8.0  51.0   74.0  567109.0    74006.0     38310.0
         8  4.896484        4.0  51.0   74.0  567109.0    74006.0     38310.0
         9  4.898438        7.0  51.0   74.0  567109.0    74006.0     38310.0

            low_beta  high_beta  low_gamma  mid_gamma  blink_stimulation  \
         0    6806.0     9837.0    10228.0     1916.0              849.0
         1    6806.0     9837.0    10228.0     1916.0              849.0
         2    6806.0     9837.0    10228.0     1916.0              849.0
```

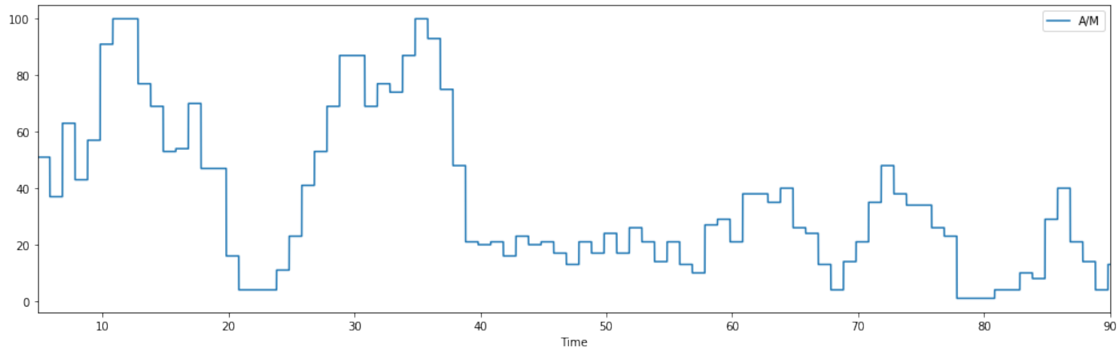
```
3    6806.0     9837.0    10228.0     1916.0                 849.0
4    6806.0     9837.0    10228.0     1916.0                 849.0
5    6806.0     9837.0    10228.0     1916.0                 849.0
6    6806.0     9837.0    10228.0     1916.0                 849.0
7    6806.0     9837.0    10228.0     1916.0                 849.0
8    6806.0     9837.0    10228.0     1916.0                 849.0
9    6806.0     9837.0    10228.0     1916.0                 849.0

   blink_strength  label
0    3.783506e-44      0
1    4.764415e-43      0
2    3.363116e-44      0
3    4.203895e-44      0
4    0.000000e+00      0
5    1.386716e-38      0
6    4.049753e-43      0
7    1.191104e-43      0
8    3.783506e-44      0
9    4.764415e-43      0
```

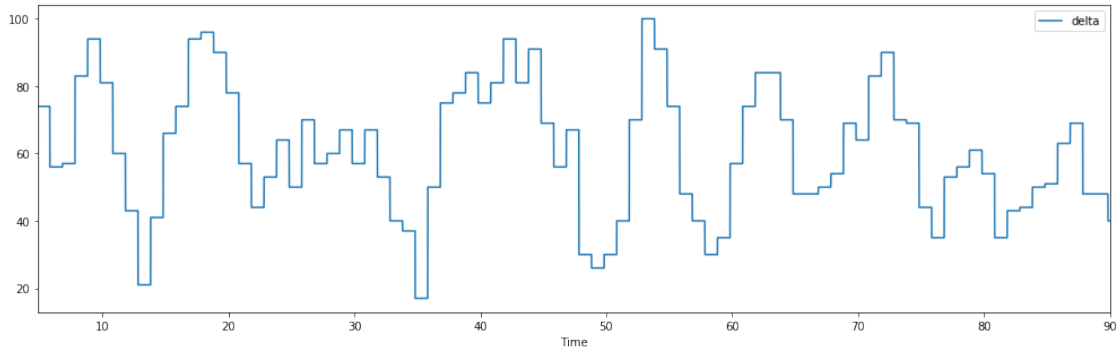
```
In [46]: print(df_sub1.shape)
```

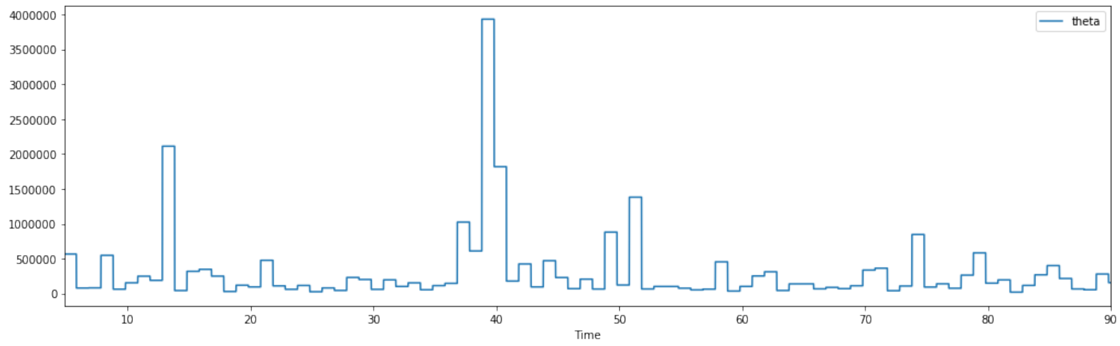
```
(43574, 14)
```

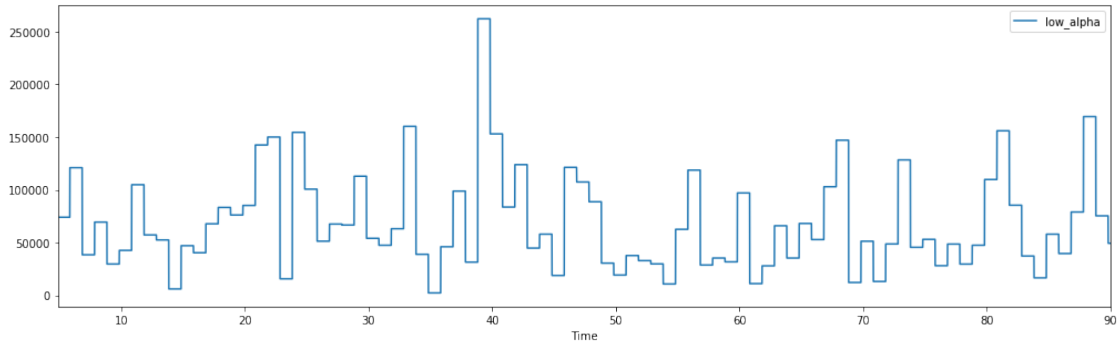
```
In [47]: # plot all features vs time
         cols = list(df_sub1)
         for c in cols:
             if (c != "Time"):
                 df_sub1.plot.line(x='Time', y=c)
         plt.show()
```

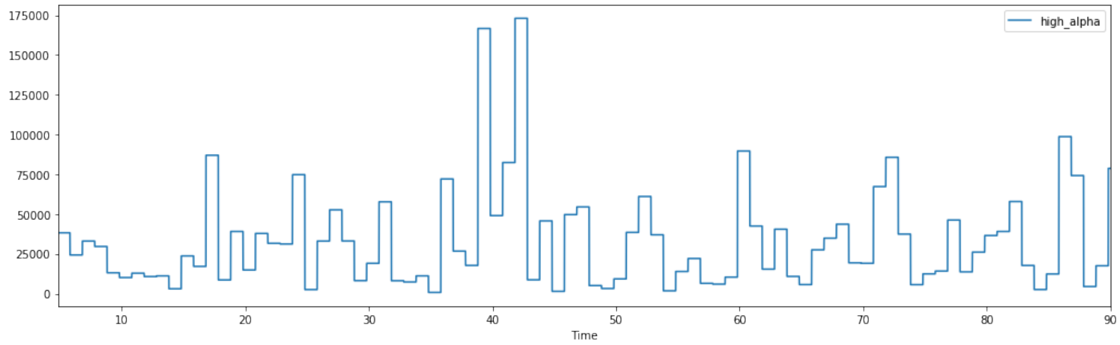


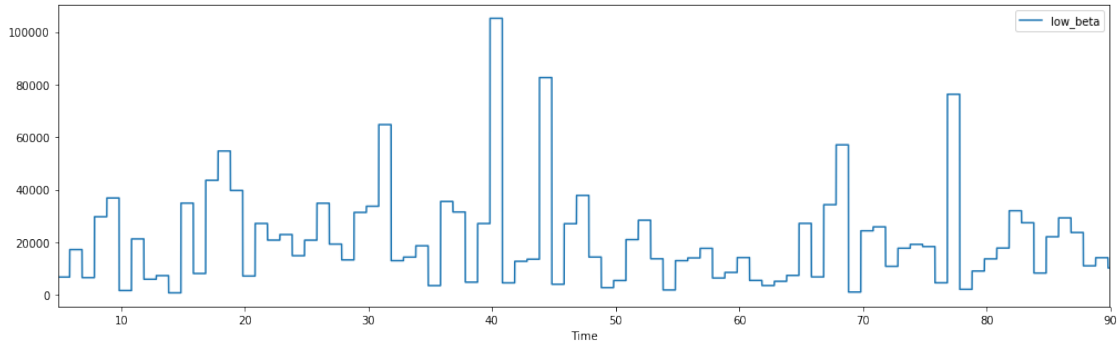

A/M
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
Time

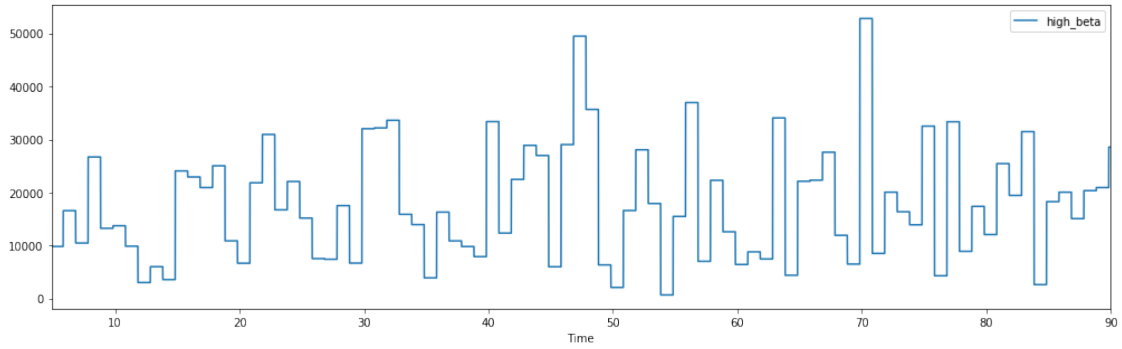

delta
100
80
60
40
20
10
20
30
40
50
60
70
80
90
Time

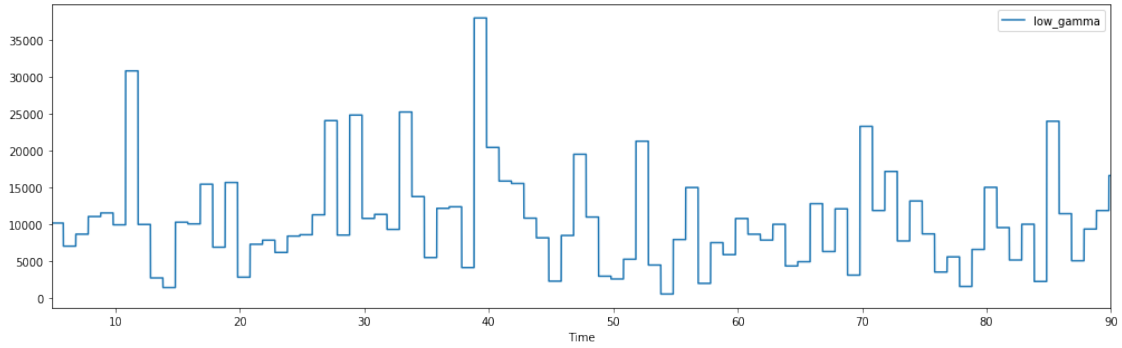

theta
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
10
20
30
40
50
60
70
80
90
Time

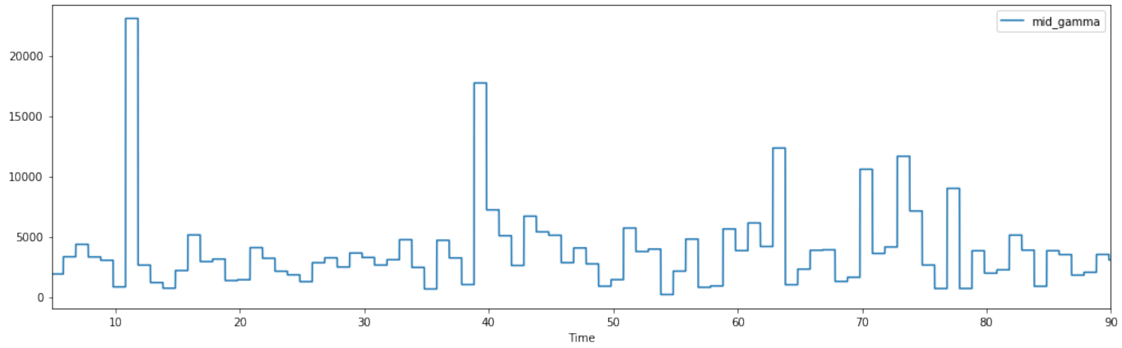

low_alpha
250000
200000
150000
100000
50000
0
10
20
30
40
50
60
70
80
90
Time

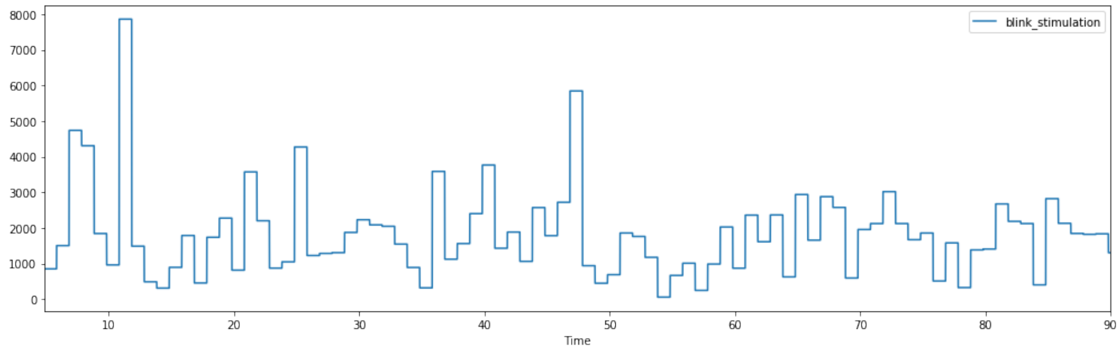

high_alpha
175000
150000
125000
100000
75000
50000
25000
0
10
20
30
40
50
60
70
80
90
Time

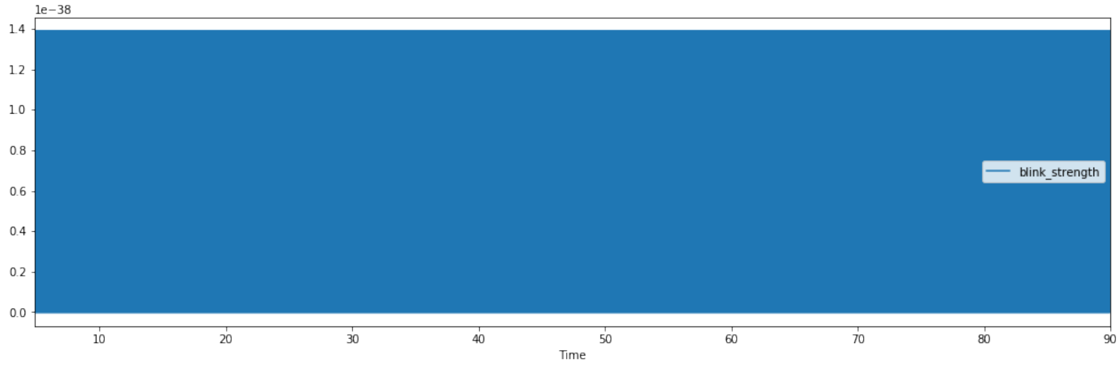

low_beta
100000
80000
60000
40000
20000
0
10
20
30
40
50
60
70
80
90
Time

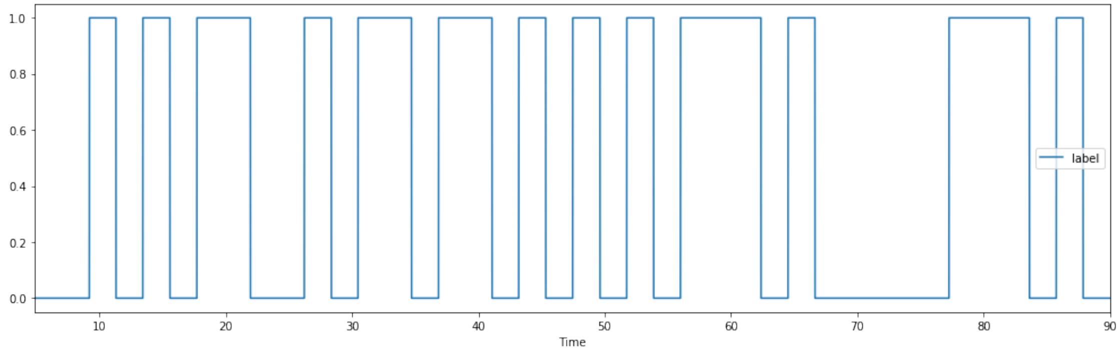

high_beta
50000
40000
30000
20000
10000
0
10
20
30
40
50
60
70
80
90
Time


low_gamma
35000
30000
25000
20000
15000
10000
5000
0
10
20
30
40
50
60
70
80
90
Time


mid_gamma
20000
15000
10000
5000
0
10
20
30
40
50
60
70
80
90
Time







```
In [48]: # remove time from dfs
         df_sub1.drop('Time', axis=1, inplace=True)
         df_sub2.drop('Time', axis=1, inplace=True)
         cols = list(df_sub1)
         df_sub1.head()
```

```
Out[48]:    A/M Other   A/M  delta     theta  low_alpha  high_alpha  low_beta  \
        0      -44.0  51.0   74.0  567109.0    74006.0     38310.0    6806.0
        1      -38.0  51.0   74.0  567109.0    74006.0     38310.0    6806.0
        2      -27.0  51.0   74.0  567109.0    74006.0     38310.0    6806.0
        3      -25.0  51.0   74.0  567109.0    74006.0     38310.0    6806.0
        4      -19.0  51.0   74.0  567109.0    74006.0     38310.0    6806.0

           high_beta  low_gamma  mid_gamma  blink_stimulation  blink_strength  label
        0     9837.0    10228.0     1916.0              849.0    3.783506e-44      0
        1     9837.0    10228.0     1916.0              849.0    4.764415e-43      0
        2     9837.0    10228.0     1916.0              849.0    3.363116e-44      0
        3     9837.0    10228.0     1916.0              849.0    4.203895e-44      0
        4     9837.0    10228.0     1916.0              849.0    0.000000e+00      0
```

```
In [49]: # correlation between features
         corr = df_sub1.corr()
         corr.style.background_gradient(cmap='coolwarm')
```

```
Out[49]: <pandas.io.formats.style.Styler at 0x1a12ea4978>
```

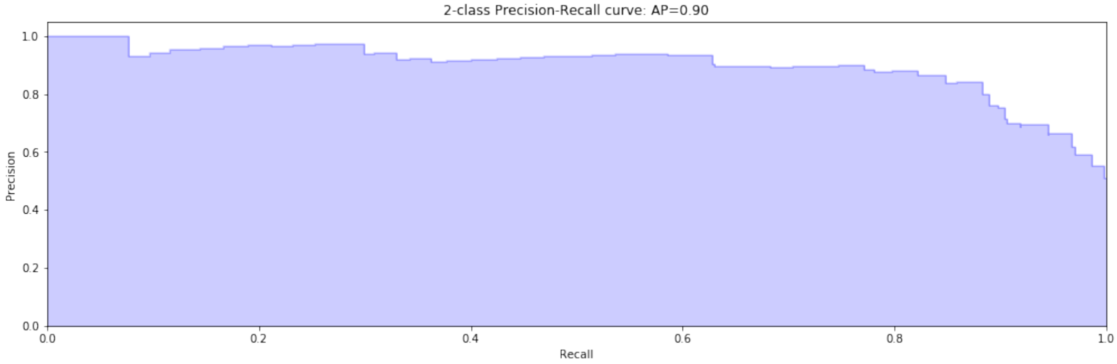
0.1 Random Forest

```
In [50]: # random forest
         train, test = train_test_split(df_sub1, test_size=0.2)
         X = train.values[:,0:12]
         Y = train.values[:,12]

         X_test = test.values[:,0:12]
         Y_test = test.values[:,12]
         clf = RandomForestClassifier(n_estimators=200, max_depth=2, random_state=0)
         clf.fit(X, Y)

         # feature importance
         for importance, feature in zip(clf.feature_importances_, cols):
             print(feature, importance)
```

```
A/M Other 0.0
A/M 0.11373261920096323
delta 0.04757553825490368
theta 0.06537066647588381
low_alpha 0.08278091284575494
high_alpha 0.10829649973755964
low_beta 0.08981303492901326
high_beta 0.2022986518637405
low_gamma 0.05447497226715841
mid_gamma 0.13663015040992754
blink_stimulation 0.09902695401509508
blink_strength 0.0
```

```
In [51]: # accuracy
         print("mean accuracy: ", clf.score(X_test, Y_test))
         Y_scores = []
         Y_scores = clf.predict_proba(X_test)[:,-1]
         #print(Y_scores)

         # cross validation
         scores = cross_val_score(clf, X, Y, cv=5)
         print("CV score:", scores)

         # precision recall
         precision, recall, thresholds = precision_recall_curve(Y_test, Y_scores)
         average_precision = average_precision_score(Y_test, Y_scores)

         plt.step(recall, precision, color='b', alpha=0.2,
                  where='post')
         plt.fill_between(recall, precision, step='post', alpha=0.2,
                          color='b')

         plt.xlabel('Recall')
         plt.ylabel('Precision')
         plt.ylim([0.0, 1.05])
         plt.xlim([0.0, 1.0])
         plt.title('2-class Precision-Recall curve: AP={0:0.2f}'.format(average_precision))
         plt.show()
```

```
mean accuracy:  0.8438324727481354
CV score: [0.80983795 0.85257421 0.82513269 0.82929278 0.83660881]
```



```
In [52]: # perform grid search for best hyperparams (DO NOT UNCOMMENT UNLESS GRID SEARCH IS NEED
         #param_grid = {
         #    'n_estimators': [200, 500, 800],
         #    'max_features': ['auto', 'sqrt', 'log2'],
         #     'max_depth': [1, 2, 3]
         #}
         #CV_rfc = GridSearchCV(estimator=clf, param_grid=param_grid, cv=5)
         #CV_rfc.fit(X, Y)
         #print(CV_rfc.best_params_)
```

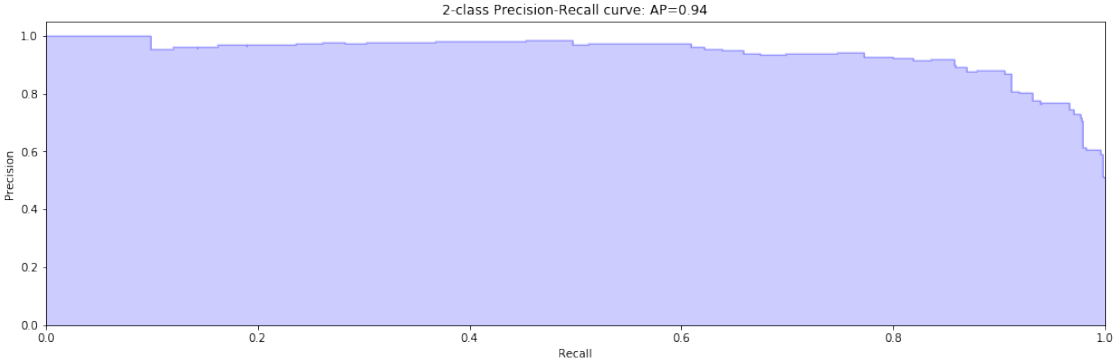
```
In [53]: # random forest with grid searched hyperparams
         clf = RandomForestClassifier(n_estimators=500, max_depth=3, max_features="auto", random
         clf.fit(X, Y)
         print("mean accuracy: ", clf.score(X_test, Y_test))

         # feature importance
         for importance, feature in zip(clf.feature_importances_, cols):
             print(feature, importance)
```

```
mean accuracy:  0.8882386689615606
A/M Other 0.00044221182517868664
A/M 0.10789110554145044
delta 0.07513773687476356
theta 0.0722319514512788
low_alpha 0.08869703499853694
high_alpha 0.09086522306666425
low_beta 0.10028891242252662
high_beta 0.13876202998324882
low_gamma 0.07589378980462765
mid_gamma 0.12011269175824656
blink_stimulation 0.12967731227347776
blink_strength 0.0
```

```
In [54]: # accuracy
         print("mean accuracy: ", clf.score(X_test, Y_test))
         Y_scores = []
         Y_scores = clf.predict_proba(X_test)[:,-1]
         #print(Y_scores)

         # cross validation
         scores = cross_val_score(clf, X, Y, cv=5)
         print("CV score:", scores)

         # precision recall
         precision, recall, thresholds = precision_recall_curve(Y_test, Y_scores)
         average_precision = average_precision_score(Y_test, Y_scores)

         plt.step(recall, precision, color='b', alpha=0.2,
                  where='post')
         plt.fill_between(recall, precision, step='post', alpha=0.2,
                          color='b')
```

```
        plt.xlabel('Recall')
        plt.ylabel('Precision')
        plt.ylim([0.0, 1.05])
        plt.xlim([0.0, 1.0])
        plt.title('2-class Precision-Recall curve: AP={0:0.2f}'.format(average_precision))
        plt.show()
```

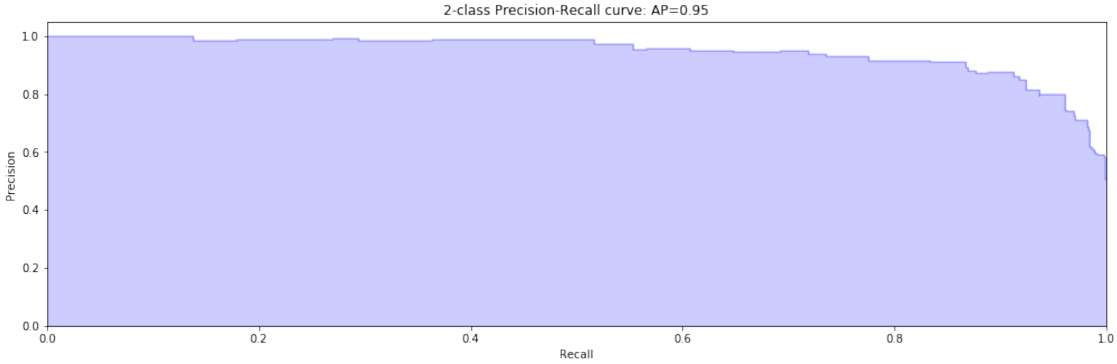
```
mean accuracy:  0.8882386689615606
CV score: [0.89043453 0.87638032 0.87878353 0.88394778 0.88853823]
```



```
In [55]: # testing on subject 2
         train2, test2 = train_test_split(df_sub2, test_size=0.2)
         X2 = train2.values[:,0:12]
         Y2 = train2.values[:,12]

         X_test2 = test2.values[:,0:12]
         Y_test2 = test2.values[:,12]

         clf.fit(X2, Y2)

         # accuracy
         print("mean accuracy: ", clf.score(X_test2, Y_test2))
         Y_scores2 = []
         Y_scores2 = clf.predict_proba(X_test2)[:,-1]
         #print(Y_scores)


         # cross validation
         scores = cross_val_score(clf, X, Y, cv=5)
         print("CV score:", scores)

         precision, recall, thresholds = precision_recall_curve(Y_test2, Y_scores2)
```

```
average_precision = average_precision_score(Y_test2, Y_scores2)

plt.step(recall, precision, color='b', alpha=0.2,
         where='post')
plt.fill_between(recall, precision, step='post', alpha=0.2,
                 color='b')

plt.xlabel('Recall')
plt.ylabel('Precision')
plt.ylim([0.0, 1.05])
plt.xlim([0.0, 1.0])
plt.title('2-class Precision-Recall curve: AP={0:0.2f}'.format(average_precision))
plt.show()
```

```
mean accuracy:  0.8772231784279977
CV score: [0.89043453 0.87638032 0.87878353 0.88394778 0.88853823]
```


2-class Precision-Recall curve: AP=0.95
Precision
Recall