DatathoanAI - Final Model

February 26, 2019

0.0.1 Problem:

A laboratory uses five highly sophisticated sensors to continuously capture atmospheric data. T
random interval over a long period of time automatically. There is an event recorder which reco
(basically a parameter) at random interval. There is a mathematical relationship between the da
sensors & the event recorded by the recorder

You are provided a training set of sensor data & its corresponding event value. You need to use
predict the atmospheric events value using another set of test sensor data. You are basically g
to learn the relationship between sensor data & recorded atmospheric event. Then you are going
predict future atmospheric event using a set of test data from the same sensors

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

In [2]:
```
mode = 'Training'
#mode = 'Test'
```

In [3]:
```
if (mode == 'Training'):
    # Training Data
    SensorFilename = 'DatathonAI2018\data\DatathoanAISensordataTrng.csv'
    EventFilename = 'DatathonAI2018\data\DatathoanAIEventdataTrng.csv'
else:
    # Test Data
    SensorFilename = 'DatathonAI2018\data\DatathoanAISensordataTest.csv'
    EventFilename = 'DatathonAI2018\data\DatathoanAIEventdataTest.csv'
```

In [4]:
```
DS_Sensor = pd.read_csv(SensorFilename)
DS_Sensor.head()
```

Out[4]:

	Time	S1	S2	S3	S4	S5	Unnamed: 6	Unnamed: 7
0	0:09:54.303	2.511536	6.195190	6.600372	6.878428	3.988469	NaN	
1	0:09:54.368	1.958466	6.599808	6.539322	6.878428	3.988469	NaN	
2	0:09:54.375	1.355133	7.016403	6.212509	6.878428	3.988469	NaN	
3	0:09:54.379	1.328796	7.343216	6.048508	6.878428	3.988469	NaN	
4	0:09:54.388	1.221054	8.217102	6.684174	6.878428	3.988469	NaN	

```
0         NaN
1         NaN
2         NaN
3         NaN
4         NaN
```

In [5]:
```
if (mode == 'Training'):
    # Training Data
    DS_Sensor = pd.read_csv(SensorFilename).drop(['Unnamed: 6','Unnamed: 7'],1)
else:
    DS_Sensor = pd.read_csv(SensorFilename).drop(['Unnamed: 6'],1)
```

In [6]:
```
##DS_Sensor = pd.read_csv(SensorFilename).drop(['Unnamed: 6','Unnamed: 7'],1)
#DS_Sensor = pd.read_csv(SensorFilename).drop(['Unnamed: 6'],1)
DS_Sensor.head()
```

Out[6]:

	Time	S1	S2	S3	S4	S5
0	0:09:54.303	2.511536	6.195190	6.600372	6.878428	3.988469
1	0:09:54.368	1.958466	6.599808	6.539322	6.878428	3.988469
2	0:09:54.375	1.355133	7.016403	6.212509	6.878428	3.988469
3	0:09:54.379	1.328796	7.343216	6.048508	6.878428	3.988469
4	0:09:54.388	1.221054	8.217102	6.684174	6.878428	3.988469

In [7]:
```
print(DS_Sensor.shape)
DS_Sensor = DS_Sensor.dropna()
print(DS_Sensor.shape)
```

```
(64629, 6)
(62606, 6)
```

In [8]:
```
#DS_Sensor['Event_val']=-999
```

In [9]:
```
DS_Event = pd.read_csv(EventFilename).drop('Unnamed: 2',1)
DS_Event.head()
```

Out[9]:

	Time	Event_val
0	0:09:54.303	0.000000
1	0:09:58.737	12.276000
2	0:09:59.725	9.252000
3	0:10:00.745	12.276000
4	0:10:01.730	23.147999

In [10]:
```
if (mode == 'Training'):
    print(DS_Event.shape)
    DS_Event = DS_Event.dropna()
    print(DS_Event.shape)
```

```
(1023, 2)
(983, 2)
```

```
In [11]: DS_Event.shape

Out[11]: (983, 2)

In [12]: DS_Event['Event_val'].isna().any()

Out[12]: False

In [13]: DS_Event[DS_Event['Event_val'].isna()]

Out[13]: Empty DataFrame
         Columns: [Time, Event_val]
         Index: []

In [14]: # only for Test Data
         if (mode == 'Test'):
             DS_Event['Event_val'] = DS_Event['Event_val'].fillna(1000)

In [15]: DS_Event.head()

Out[15]:           Time  Event_val
         0  0:09:54.303   0.000000
         1  0:09:58.737  12.276000
         2  0:09:59.725   9.252000
         3  0:10:00.745  12.276000
         4  0:10:01.730  23.147999

In [16]: print(DS_Event.shape)
         DS_Event = DS_Event.dropna()
         print(DS_Event.shape)

(983, 2)
(983, 2)


In [17]: #DS_Event[DS_Event['Event_val']>99]
```

1 Training Dataset

```
In [18]: #trainingDS_Sensor = pd.read_csv('DatathonAI2018\data\DatathoanAISensordataTrng.csv')
         #trainingDS_Sensor.shape

In [19]: #trainingDS_Sensor = trainingDS_Sensor.dropna()
         #trainingDS_Sensor.shape

In [20]: #trainingDS_Event = pd.read_csv('DatathonAI2018\data\DatathoanAIEventdataTrng.csv').d
         #trainingDS_Event.head()

In [21]: #print(trainingDS_Event.shape)
         #trainingDS_Event = trainingDS_Event.dropna()
         #print(trainingDS_Event.shape)
```

1.0.1 Merge training - Sensor and event data

```
In [22]: dataset = pd.merge(DS_Sensor,DS_Event, on='Time',how='outer')
         dataset.shape
```

```
Out[22]: (63588, 7)
```

```
In [23]: dataset = dataset.sort_values('Time').reset_index(drop=True)
```

```
In [24]: dataset.tail()
```

```
Out[24]:              Time        S1        S2        S3        S4        S5  \
         63583  0:38:31.652  5.088882 -1.481812  8.550446  0.990970  0.933973
         63584  0:38:31.655  4.930878 -1.499786  8.017746  0.990951  0.933985
         63585  0:38:31.661  5.242111 -1.182541  8.386444  0.990913  0.934009
         63586  0:38:31.663  4.539413 -1.036499  7.819031  0.990900  0.934017
         63587  0:38:31.686  4.693848 -0.791092  7.890854  0.990753  0.934108

                Event_val
         63583        NaN
         63584        NaN
         63585        NaN
         63586        NaN
         63587        NaN
```

```
In [25]: dataset['Event_val'].notnull().value_counts()
```

```
Out[25]: False    62605
         True       983
         Name: Event_val, dtype: int64
```

```
In [26]: # function to calculate elapased time in millisecond - from 1st record
         def GetElapasedTime(df):
             df_copy =df.copy()
             import datetime
             ElapasedTime = []
             TimeElapased=0
             for i in range(len(df_copy)):
                 if (i==0):
                     t1=datetime.datetime.strptime(df_copy['Time'].iloc[i], "%H:%M:%S.%f")

                 t2 = datetime.datetime.strptime(df_copy['Time'].iloc[i], "%H:%M:%S.%f")
                 TimeElapased = TimeElapased + (t2-t1).total_seconds()*1000
                 #TimeElapased = (t2-t1).total_seconds()*1000
                 #print(t1)
                 #print(t2)
                 t1= t2
                 ElapasedTime.append(TimeElapased)
             df_copy['ElapasedTime'] = ElapasedTime
             return df_copy
```

```
In [27]: dataset = GetElapasedTime(dataset)

In [28]: dataset.tail()
```

Out[28]:

	Time	S1	S2	S3	S4	S5	\
63583	0:38:31.652	5.088882	-1.481812	8.550446	0.990970	0.933973	
63584	0:38:31.655	4.930878	-1.499786	8.017746	0.990951	0.933985	
63585	0:38:31.661	5.242111	-1.182541	8.386444	0.990913	0.934009	
63586	0:38:31.663	4.539413	-1.036499	7.819031	0.990900	0.934017	
63587	0:38:31.686	4.693848	-0.791092	7.890854	0.990753	0.934108	

	Event_val	ElapasedTime
63583	NaN	1717349.0
63584	NaN	1717352.0
63585	NaN	1717358.0
63586	NaN	1717360.0
63587	NaN	1717383.0

1.0.2 Plot

```
In [29]: def plotdata(df,filename):
             plotfilename = filename # 'DatathoanTraining'
             df_copy = df.copy()
             import matplotlib.pyplot as plt
             from matplotlib import cm
             import numpy as np

             fig = plt.figure(figsize=(20,10))

             x = df_copy['ElapasedTime']
             y1 = df_copy['S1']
             y2 = df_copy['S2']
             y3 = df_copy['S3']
             y4 = df_copy['S4']
             y5 = df_copy['S5']

             ax1 = fig.add_subplot(511)
             ax1.plot(x,y1,color='skyblue')
             ax1.set(title='S1')
             ax1.set_xticklabels([])
             #ax1.axis('off')

             ax2 = fig.add_subplot(512)
             ax2.plot(x,y2,color='seagreen')
             ax2.set(title='S2')
             ax2.set_xticklabels([])

             ax3 = fig.add_subplot(513)
```

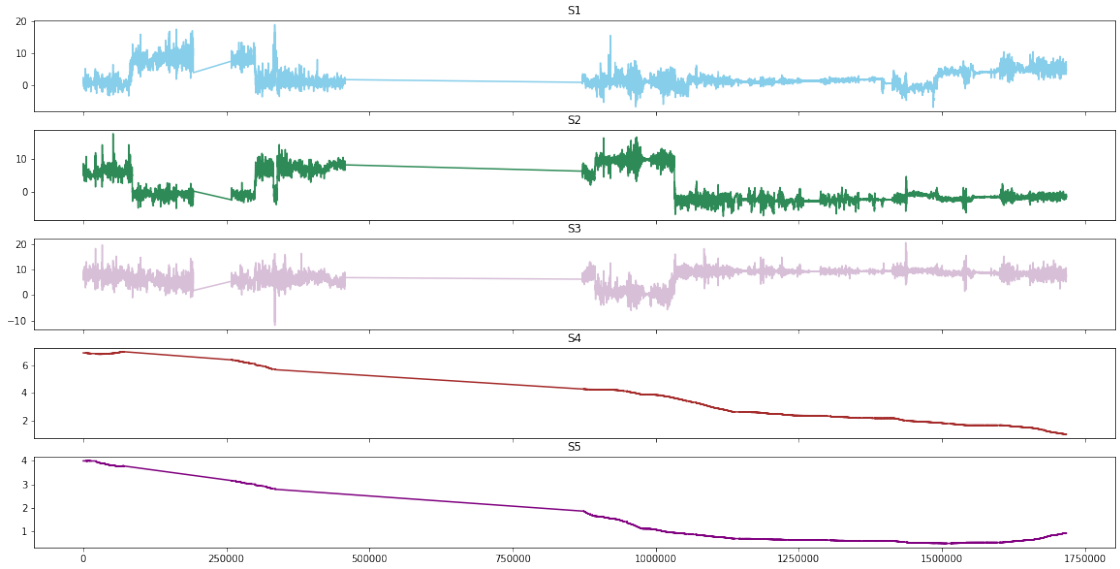
```
        ax3.plot(x,y3,color='thistle')
        ax3.set(title='S3')
        ax3.set_xticklabels([])

        ax4 = fig.add_subplot(514)
        ax4.plot(x,y4,color='brown')
        ax4.set(title='S4')
        ax4.set_xticklabels([])

        ax5 = fig.add_subplot(515)
        ax5.plot(x,y5,color='purple')
        ax5.set(title='S5')
        #ax5.set_xticklabels([])

        #plt.tight_layout()
        fig.savefig(filename, dpi=fig.dpi)
        plt.show()
```

In [30]:
```
if (mode == 'Training'):
    plotdata(dataset,'DatathoanTraining')
else:
    plotdata(dataset,'DatathoanTest')
```



In [31]:
```
dataset[dataset['Event_val'].isna()].head()
```

Out[31]:

	Time	S1	S2	S3	S4	S5	Event_val	\
1	0:09:54.368	1.958466	6.599808	6.539322	6.878428	3.988469	NaN	
2	0:09:54.375	1.355133	7.016403	6.212509	6.878428	3.988469	NaN	
3	0:09:54.379	1.328796	7.343216	6.048508	6.878428	3.988469	NaN	

```
4  0:09:54.388  1.221054  8.217102  6.684174  6.878428  3.988469        NaN
5  0:09:54.413  1.075012  8.525955  7.188156  6.878428  3.988469        NaN

   ElapasedTime
1          65.0
2          72.0
3          76.0
4          85.0
5         110.0
```

In [32]:
```
dataset['Event_val'] = dataset['Event_val'].fillna(-999)
```

In [33]:
```
def fillMissingData(df):
    df_copy = df.copy()
    MissingIndex = df_copy[df_copy['Event_val']>=0].index.values # >0
    for i in MissingIndex:
        previous = i-1
        current = i
        nextIndex = i+1

        while (df_copy.iloc[nextIndex].isnull()['S1']):
            nextIndex = nextIndex+1


        if (previous>=0):
            s1 = df_copy.iloc[previous]['S1'] + ((df_copy.iloc[nextIndex]['S1'] - df_
            s2 = df_copy.iloc[previous]['S2'] + ((df_copy.iloc[nextIndex]['S2'] - df_
            s3 = df_copy.iloc[previous]['S3'] + ((df_copy.iloc[nextIndex]['S3'] - df_
            s4 = df_copy.iloc[previous]['S4'] + ((df_copy.iloc[nextIndex]['S4'] - df_
            s5 = df_copy.iloc[previous]['S5'] + ((df_copy.iloc[nextIndex]['S5'] - df_

            df_copy.loc[current,'S1']= s1
            df_copy.loc[current,'S2']= s2
            df_copy.loc[current,'S3']= s3
            df_copy.loc[current,'S4']= s4
            df_copy.loc[current,'S5']= s5
    return df_copy
```

In [34]:
```
#dataset[dataset['Event_val']>=0]
dataset.dtypes
```

Out[34]:
```
Time            object
S1             float64
S2             float64
S3             float64
S4             float64
S5             float64
Event_val      float64
```

```
ElapasedTime    float64
dtype: object
```

```
In [35]: dataset = fillMissingData(dataset)
```

```
In [36]: dataset.head()
```

Out[36]:

	Time	S1	S2	S3	S4	S5	Event_val	ElapasedTime
0	0:09:54.303	2.511536	6.195190	6.600372	6.878428	3.988469	0.0	0.0
1	0:09:54.368	1.958466	6.599808	6.539322	6.878428	3.988469	-999.0	65.0
2	0:09:54.375	1.355133	7.016403	6.212509	6.878428	3.988469	-999.0	72.0
3	0:09:54.379	1.328796	7.343216	6.048508	6.878428	3.988469	-999.0	76.0
4	0:09:54.388	1.221054	8.217102	6.684174	6.878428	3.988469	-999.0	85.0

```
In [37]: dataset['S1'].isna().any(),dataset['S1'].notna().all()
```

```
Out[37]: (False, True)
```

```
In [38]: dataset.shape
```

```
Out[38]: (63588, 8)
```

```
In [39]: if (mode == 'Training'):
             dataset.to_csv('TrainingDataset.csv')
         else:
             dataset.to_csv('TestDataset.csv')
```

```
In [40]: #FinalDS = dataset[dataset['Event_val']!=-999].reset_index(drop=True)
```

```
In [41]: if (mode == 'Training'):
             FinalTrngDS = dataset[dataset['Event_val']!=-999].reset_index(drop=True)
         else:
             #FinalTestDS = FinalDS[FinalDS['Event_val']!=-999].reset_index(drop=True)
             FinalTestDS = dataset
```

```
In [42]: FinalTrngDS.tail()
```

Out[42]:

	Time	S1	S2	S3	S4	S5	Event_val
978	0:38:26.602	5.233952	-1.431107	7.408528	1.025671	0.917116	28.584000
979	0:38:27.691	4.249381	-1.156721	9.368759	1.017413	0.920567	31.104001
980	0:38:28.678	4.476321	-2.005435	9.619458	1.010383	0.923541	29.592001
981	0:38:29.576	4.575018	-1.615453	8.138397	1.003851	0.925565	28.872002
982	0:38:30.651	6.096842	-1.075211	7.128698	0.997355	0.929995	29.663999

```
     ElapasedTime
978     1712299.0
979     1713388.0
980     1714375.0
981     1715273.0
982     1716348.0
```

2 Build Model

In [43]:
```
# Correlation
```

In [44]:
```
corr = FinalTrngDS.loc[:,FinalTrngDS.columns !='ElapasedTime'].corr()
corr.style.background_gradient().set_precision(2)
```

Out[44]:
```
<pandas.io.formats.style.Styler at 0x1fe1f59cdd8>
```

In [45]:
```
FinalTrngDS['Event_val'].head()
```

Out[45]:
```
0     0.000000
1    12.276000
2     9.252000
3    12.276000
4    23.147999
Name: Event_val, dtype: float64
```

In [46]:
```
FinalTrngDS.columns
```

Out[46]:
```
Index(['Time', 'S1', 'S2', 'S3', 'S4', 'S5', 'Event_val', 'ElapasedTime'], dtype='obj
```

In [47]:
```
y = FinalTrngDS.iloc[:,6].values # 'Event_val'
#y
```

In [48]:
```
#FeatuesPredictors = ['S1', 'S3', 'S4', 'S5'] # 'S2'
#FeatuesPredictors = ['S1', 'S2', 'S3', 'S4', 'S5']
#FeatuesPredictors = ['S1', 'S2', 'S4', 'S5'] # 'S3' # Best So far
#FeatuesPredictors = ['S2', 'S4', 'S5'] #'S1',  'S3'

#FeatuesPredictors = ['S1','S2', 'S4'] #'S1',  'S3'

FeatuesPredictors = ['S2','S4', 'S5'] #'S2'   ######BESSSSSSSSSSSSSSSSSSSSSSSSSSSSST

#FeatuesPredictors = ['S4','S5'] #'S5'

X=FinalTrngDS[FeatuesPredictors].values
X
```

Out[48]:
```
array([[ 6.19519043,  6.8784279 ,  3.988469  ],
       [ 7.08083135,  6.87838518,  3.98847683],
```

```
                [ 3.3636049 ,  6.87010495,  3.98975564],
                ...,
                [-2.00543454,  1.01038331,  0.92354065],
                [-1.61545282,  1.00385092,  0.92556495],
                [-1.07521057,  0.9973554 ,  0.92999528]])
```

```
In [49]: X.shape,y.shape
```

```
Out[49]: ((983, 3), (983,))
```

```
In [50]: from sklearn.model_selection import train_test_split
         X_train,X_test,y_train,y_test = train_test_split(X,y,test_size=0.20, random_state=0)
```

3 Fitting Multiple Linear regression to training set

```
In [51]: from sklearn.linear_model import LinearRegression
         regressor_mlr = LinearRegression()
         regressor_mlr.fit(X_train,y_train)
```

```
Out[51]: LinearRegression(copy_X=True, fit_intercept=True, n_jobs=1, normalize=False)
```

```
In [52]: regressor_mlr.intercept_,regressor_mlr.coef_
```

```
Out[52]: (7.522903140218286, array([ 0.16034485,  5.10562587, -2.80940363]))
```

```
In [53]: y_pred_mlr = regressor_mlr.predict(X_test)
```

4 Fitting Polynoinal regression to training set

```
In [54]: from sklearn.preprocessing import PolynomialFeatures
         poly_reg = PolynomialFeatures(degree=4)
         X_poly = poly_reg.fit_transform(X_train)
         poly_reg.fit(X_poly,y_train)
         regressor_linPoly = LinearRegression()
         regressor_linPoly.fit(X_poly,y_train)
```

```
Out[54]: LinearRegression(copy_X=True, fit_intercept=True, n_jobs=1, normalize=False)
```

```
In [55]: #regressor_linPoly.intercept_,regressor_linPoly.coef_
```

```
In [56]: y_pred_poly = regressor_linPoly.predict(poly_reg.fit_transform(X_test))
```

5 Fitting Decision Tree regression to training set

```
In [57]: from sklearn.tree import DecisionTreeRegressor
         regressor_dt = DecisionTreeRegressor(random_state=0)
         regressor_dt.fit(X_train,y_train)
```

```
Out[57]: DecisionTreeRegressor(criterion='mse', max_depth=None, max_features=None,
                    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=0, splitter='best')

In [58]: y_pred_dt = regressor_dt.predict(X_test)
```

6 Fitting Random Forest regression to training set

```
In [59]: from sklearn.ensemble import RandomForestRegressor
         regressor_rf = RandomForestRegressor(n_estimators=300, random_state=0)
         regressor_rf.fit(X_train,y_train)

Out[59]: RandomForestRegressor(bootstrap=True, criterion='mse', max_depth=None,
                    max_features='auto', 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, n_estimators=300, n_jobs=1,
                    oob_score=False, random_state=0, verbose=0, warm_start=False)

In [60]: y_pred_rf = regressor_rf.predict(X_test)
```

7 Evaluate Model performance

```
In [61]: from sklearn.metrics import r2_score
         r2_score(y_test,y_pred_mlr),r2_score(y_test,y_pred_poly),r2_score(y_test,y_pred_dt),r

Out[61]: (0.12215890452961975,
          0.6214586253289226,
          0.9276480271239957,
          0.9570300572372749)

In [62]: from sklearn.metrics import mean_squared_error
         mean_squared_error(y_test,y_pred_mlr),mean_squared_error(y_test,y_pred_poly),mean_squa

Out[62]: (221.3312474155168, 95.44214219025594, 18.242199519081403, 10.834069038373276)

In [63]: Actuals = y_test.reshape(len(y_test),1)

         y_pred_mlr = y_pred_dt.reshape(len(y_pred_mlr),1)
         y_pred_poly = y_pred_dt.reshape(len(y_pred_poly),1)

         y_pred_dt = y_pred_dt.reshape(len(y_pred_dt),1)
         y_pred_rf = y_pred_rf.reshape(len(y_pred_rf),1)

         Columns = ['Actuals','MLR','Poly','DecisionTree','RandomForest']
```

```
FinalResult = pd.DataFrame(np.hstack((Actuals,y_pred_mlr,y_pred_poly,y_pred_dt,y_pred
#FinalResult = pd.DataFrame(Actuals)
FinalResult.head()
```

Out[63]:

	Actuals	MLR	Poly	DecisionTree	RandomForest
0	56.880001	60.120003	60.120003	60.120003	52.647362
1	4.140000	6.588000	6.588000	6.588000	5.344920
2	17.675999	19.763999	19.763999	19.763999	15.376080
3	0.000000	4.896000	4.896000	4.896000	1.886760
4	31.932000	31.572002	31.572002	31.572002	30.392760

8 ********** Selected Model **********

8.0.1 - RandomForest for prediction

In [64]:
```
TestDataset_final = pd.read_csv('DatathonAI2018\data\TestDataset_final.csv').drop(colu
TestDataset_final.head()
```

Out[64]:

	Time	S1	S2	S3	S4	S5	Event_val	\
0	38:31.7	4.121874	-0.708732	7.278171	0.990715	0.934132	1000	
1	38:31.7	4.382599	-0.785110	7.696915	0.990644	0.934168	-999	
2	38:31.7	4.856644	-0.923981	8.458267	0.990514	0.934234	-999	
3	38:31.8	4.486740	-1.374084	7.609528	0.990319	0.934332	-999	
4	38:31.8	5.060165	-1.381271	7.668182	0.990163	0.934411	-999	

	ElapasedTime
0	0
1	11
2	31
3	61
4	85

In [65]:
```
TestDataset_final.shape
```

Out[65]: (2063, 8)

In [66]:
```
TestDataset = TestDataset_final[TestDataset_final['Event_val']>0].reset_index(drop=Tru
TestDataset.shape
```

Out[66]: (40, 8)

In [67]:
```
FeatuesPredictors
```

Out[67]: ['S2', 'S4', 'S5']

In [68]:
```
#FeatuesPredictors = ['S2','S4', 'S5']

X_test_Final=TestDataset[FeatuesPredictors].values
#X_test_Final
```

```
In [69]: y_pred_rf_final = regressor_rf.predict(X_test_Final)

In [70]: y_pred_rf_final

Out[70]: array([29.34083952, 29.48987973, 29.56991951, 30.00660067, 29.56235966,
                28.8645596 , 29.56463974, 29.5683598 , 29.91708074, 28.77875959,
                29.48640022, 29.5066799 , 29.2164005 , 29.91708074, 29.55660103,
                29.5477197 , 29.56463974, 29.5477197 , 29.61792099, 29.5465197 ,
                29.57723966, 29.55479965, 29.55875965, 29.57507966, 29.55875965,
                29.55479965, 29.55479965, 29.56235966, 29.58995972, 29.57303977,
                29.56235966, 29.5957196 , 29.58720084, 29.00519958, 29.22251962,
                29.20919962, 29.19419962, 29.22251962, 29.4964799 , 29.17139963])

In [71]: #FinalPrediction = y_pred.reshape(len(y_pred),1)

         Columns = ['Event_val']

         FinalPrediction = pd.DataFrame(np.hstack((y_pred_rf_final)),columns = Columns)

         FinalPrediction.head()

Out[71]:    Event_val
         0  29.340840
         1  29.489880
         2  29.569920
         3  30.006601
         4  29.562360

In [72]: TestFile = pd.read_csv('DatathonAI2018\data\DatathoanAIEventdataTest.csv').drop(colum
         TestFile.head()

Out[72]:           Time
         0  0:38:31.692
         1  0:38:32.657
         2  0:38:33.672
         3  0:38:34.732
         4  0:38:35.606

In [73]: CaseStudy1_result = pd.concat([TestFile,FinalPrediction],axis=1)

In [74]: CaseStudy1_result.head()

Out[74]:           Time  Event_val
         0  0:38:31.692  29.340840
         1  0:38:32.657  29.489880
         2  0:38:33.672  29.569920
         3  0:38:34.732  30.006601
         4  0:38:35.606  29.562360

In [75]: CaseStudy1_result.to_csv('DatathonAI2018\data\CaseStudy1_result.csv',index=False)

In [76]: # ************************************************************************
```