AnomalyDetection_2_DefiningProblem

September 29, 2020

1 AnomalyDetection_2_DefiningProblem

Updates from old notebook: - Data has been filtered (after adding the thresholds) - The data is quite sparse and has lots of gaps in between, this raises one main problem: 1. Forecasting methods cannot be used to find anomalies in the data 2. Is the model robust? Will it work the same for different users or does one require training for each user? - Recall the purpose of this anomaly detection module: 1. Detect when the movements are lower "on average" (this is analogous to 'overflow' from the fluid detection module, i.e. a tap that is left open and thus the flow is higher, on average) 2. Adapt to the fact that the average movements will be decreasing as a function of time (because the person is getting older) 3. Detect that there is an overall decrease in daily activity (as measured by how 'strong' the activity is, how frequent naps are) 4. Detect that there is a high lack of motion (i.e. if the person removed their device or is critically ill), and detect the opposite, when there is a high amount of motion that is abnormal (if the device is attached to a dog) 5. Detect irregular movements (i.e. movements that don't have the same pattern that one would expect)

Based on this, it is likely that there is no 'one model' to solve all solution. Each of the above problems might require a different model. We just need to be smart about how we model it to a) make the solution simple and thus robust, and b) integrate it with the raspberry such that it does not take up too much memory / computational time.

1.1 Libraries and Configuration

[28]:

```python
""" Libraries """

#file / system libraries
import os
import datetime as dt

# mathematical

from numpy.fft import ifft
from numpy.fft import fft
import numpy as np

# data exploration

import pandas as pd
```

```
# data visualization

import matplotlib.pyplot as plt

""" Configuration """

# pandas

pd.set_option('display.max_columns', None)
```

1.2 Functions

[16]:

```
def polynomial(x):
    """ takes an array and returns it after our polynomial function has been␣
 ↪applied to it"""
    C = [0.7741697399557282,-0.15839741967042406,0.09528795099596377,-0.
 ↪004279871380772796]
    y = C[0]*np.power(x,4)+C[1]*np.power(x,2)+C[2]*x+C[3]
    return y

def directory_to_df(paths, exclude = [None], filetype = '.csv',ignore_index =␣
 ↪True, exception = '_repet'):
    """ concatenates all files in a directory into a dataframe
    components:
    path: path to the directory (must end with /)
    exclude: array of directories to excludes from the treatment
    filetype: a string of the file extension (must include .)
    ignore_index: boolean that tells pandas to ignore the index or not
    exception: takes a string. Any time a filename includes this string it is␣
 ↪treated differently (for cases when you have
    more than one )
    """
    filenames = []
    file_column = []
    frames = []
    test_index = 1

    for path in paths:
        for filename in os.listdir(path):
            print(path)
            if filetype in filename and filename not in exclude:
                if exception in filename:
                    curr_df = pd.read_csv(path+filename)
                    curr_df = special_treatment(curr_df)
                else:
                    curr_df = pd.read_csv(path+filename)
                frames.append(curr_df)
                filenames.append(filename.replace(filetype,''))
                for i in range(curr_df.shape[0]):
                    file_column.append(test_index)
                test_index+=1

    df = pd.concat(frames,ignore_index = ignore_index)
    df['files'] = file_column
    return df, filenames


def special_treatment(df):
    """ performs a custom operation on a dataframe
    components:
    df: dataframe to play on
    """
    columns = df.columns.values.tolist()
    columns.remove('date')
    df.drop('gyrZ',inplace = True, axis = 1)
    df.columns = columns
    df.reset_index(inplace = True)
    df.rename(columns= {'index':'date'},inplace = True)
    return df

class seasonality():
    """ takes in a dataframe, outputting it with two extra columns: seasonality␣
↪(but column name = seasonality
    inputted) and times, where 'times' is a plottable version of date with␣
↪reference to a prespecified start time
    (day_start)
    Components:
    df: the dataframe, must have the dates column as 'date' and in np.
↪datetime64 timeformat
    seasonality (optional): defaults to 'day'. This is the criteria for␣
↪splitting the data
    day_start (optional): this signifies what is the 'start time' of the day (i.
↪e. the 0 point on the x axis). Defaults
    for midnight.
    time_delta (optional): this defines the units for the time delta between␣
↪data points. Defaults to seconds.
    EDIT THIS MSG
    NEED TO FIX THIS
    """
    def __init__(self,df,seasonality='day',day_start = '00:00:00', time_delta =␣
↪'s'):

        if seasonality not in ['hour','day','month','year']:
            raise ValueError("you can only input the following for seasonality:␣
↪'day', 'month', or 'year'")
        self.df = df
        self.seasonality = 'seasonality_{}'.format(seasonality)
        try:
            self.day_start = dt.datetime.strptime(day_start,'%H:%M:%S')
        except:
            raise ValueError('Please enter your day_start in the correct format:
↪ "HH:MM:SS". "{}" is not acceptable'\
                             .format(day_start))
        self.time_delta = time_delta

    def find_seasonal_trends(self):
        if 'hour' in self.seasonality:
            self.df[self.seasonality] = self.df.date.dt.hour
        elif 'day' in self.seasonality:
            self.df[self.seasonality] = self.df.date.dt.day
        elif 'month' in self.seasonality:
            self.df[self.seasonality] = self.df.date.dt.month
        else:
            self.df[self.seasonality] = self.df.date.dt.year

        self.create_times()


        return self.df

    def create_times(self):
        times = []
        for season in self.df[self.seasonality].unique():
            temp_dates = self.df.date[self.df[self.seasonality] == season].
↪values
            date = dt.datetime.strptime(str(temp_dates[0])[:-3], '%Y-%m-%dT%H:
↪%M:%S.%f')
            # 'date' is wrong: this will not work for when you have a lower␣
↪order seasonality.
            # it needs to adapt such that it starts recording when the␣
↪beginning of the year
            start_day = dt.datetime(date.year,
                                    date.month,
                                    date.day,
                                    self.day_start.hour,
                                    self.day_start.minute,
                                    self.day_start.second)
            start_day = np.datetime64(start_day)

            for index, date in enumerate(temp_dates):
                times.append((date - start_day)/np.timedelta64(1, self.
↪time_delta))
        self.df['times'] = times
```

1.3 Data

[21]:
```
base = '/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/{}'
names = ['rohan','ignacio']
end_labels = ['_filtered.csv']
dfs = []

for index,name in enumerate(names):
    dfs.append(pd.read_csv(base.format(names[index]+end_labels[0]),index_col =␣
↪0))
```

[22]:
```
dfs[0].head()
```

[22]:
```
                    date  accX  accY  accZ   gyrX   gyrY   gyrZ  files  \
220  2020-09-14 19:19:26  0.01  0.02  0.00   3.62   1.04   1.38      1
319  2020-09-14 19:20:39  0.09  0.16  0.14  36.11  25.84  67.85      1
320  2020-09-14 19:20:40  0.09  0.16  0.09  22.98  15.43  16.45      1
321  2020-09-14 19:20:41  0.05  0.07  0.09  22.98  15.43  16.45      1
322  2020-09-14 19:20:42  0.12  0.07  0.07  29.44  39.83  27.27      1

     accTotal   gyrTotal
220  0.022361   4.011284
319  0.230868  81.087978
320  0.204450  32.198879
321  0.124499  32.198879
322  0.155563  56.540210
```

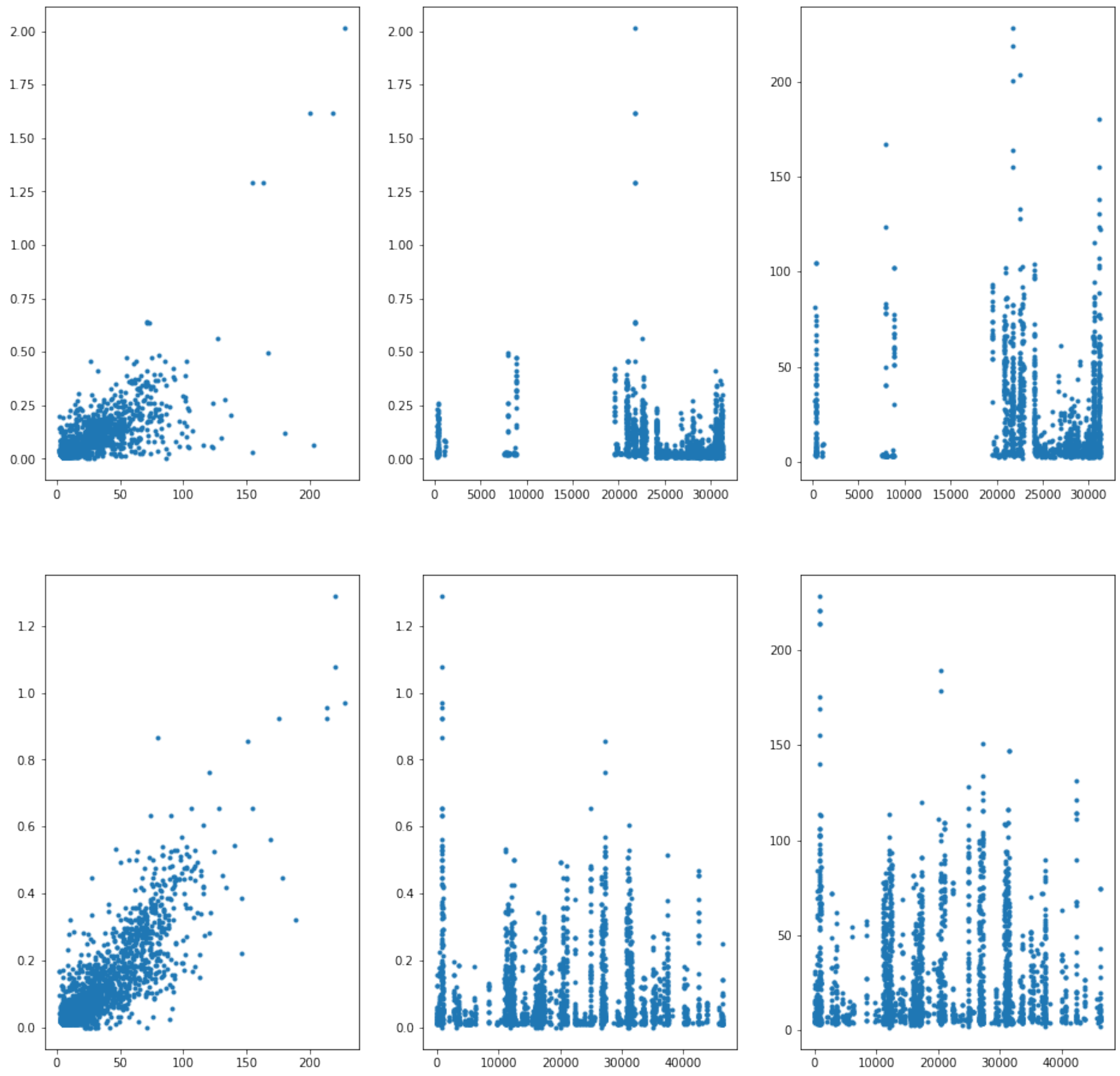
[23]:
```
dfs[1].head()
```

[23]:
```
                   date  accX  accY  accZ  gyrX  gyrY   gyrZ  files  accTotal  \
0   2020-09-13 17:09:25  0.02  0.12  0.03  1.47  3.32   2.22      1  0.125300
1   2020-09-13 17:09:26  0.02  0.12  0.03  1.47  3.32   2.22      1  0.125300
2   2020-09-13 17:09:27  0.01  0.01  0.00  7.43  6.82  10.10      1  0.014142
12  2020-09-13 17:09:34  0.01  0.01  0.00  6.64  7.07  12.45      1  0.014142
13  2020-09-13 17:09:34  0.01  0.01  0.00  4.12  3.61   5.81      1  0.014142

     gyrTotal
```

```
0    4.255784
1    4.255784
2   14.273307
12  15.782173
13   7.985149
```

[25]:

```python
fig = plt.figure(figsize = (16,16))
i = 1
for df in dfs:
    fig.add_subplot(len(dfs),3,i)
    plt.plot(df.gyrTotal,df.accTotal,'.')
    i+=1

    fig.add_subplot(len(dfs),3,i)
    plt.plot(df.index,df.accTotal,'.')
    i+=1

    fig.add_subplot(len(dfs),3,i)
    plt.plot(df.index,df.gyrTotal,'.')
    i+=1
```



[ ]:

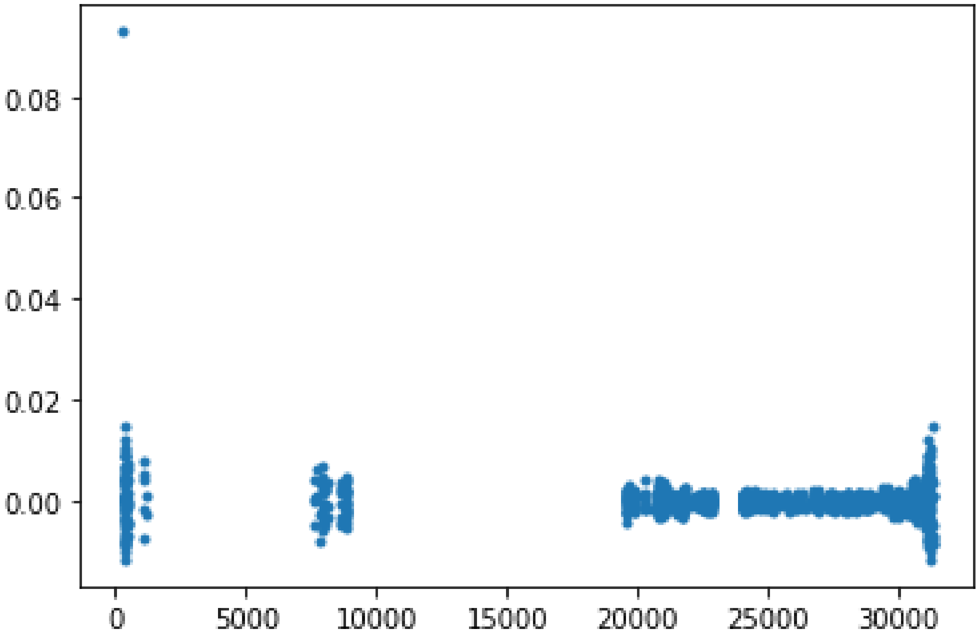
[61]:

```
x = dfs[0].index
Y = dfs[0].accTotal

y = ifft(Y)
plt.plot(x,y,'.')

# fourier seems to give us a 'nicer' curve but no information as to what is represents. Perhaps it's worth exploring
# this with the test data (i.e. the specific movements)
```

```
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/numpy/core/_asarray.py:83: ComplexWarning: Casting complex values to
```

```
real discards the imaginary part
  return array(a, dtype, copy=False, order=order)
```

```
[61]: [<matplotlib.lines.Line2D at 0x121e2f1d0>]
```



1.4 Test Data

```
[64]: path = ['/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/']

df_test, files = directory_to_df(path, ignore_index = False)
columns = df_test.columns.values.tolist()
columns.remove('date')
df_test.drop('gyrZ',inplace = True, axis = 1)
df_test.columns = columns
df_test['accTotal'] = np.sqrt(np.power(df_test[['accX','accY','accZ']],2).
 ↪sum(axis = 1))
df_test['gyrTotal'] = np.sqrt(np.power(df_test[['gyrX','gyrY','gyrZ']],2).
 ↪sum(axis = 1))
df_test.reset_index(inplace = True)
df_test.head()
```

```
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
```

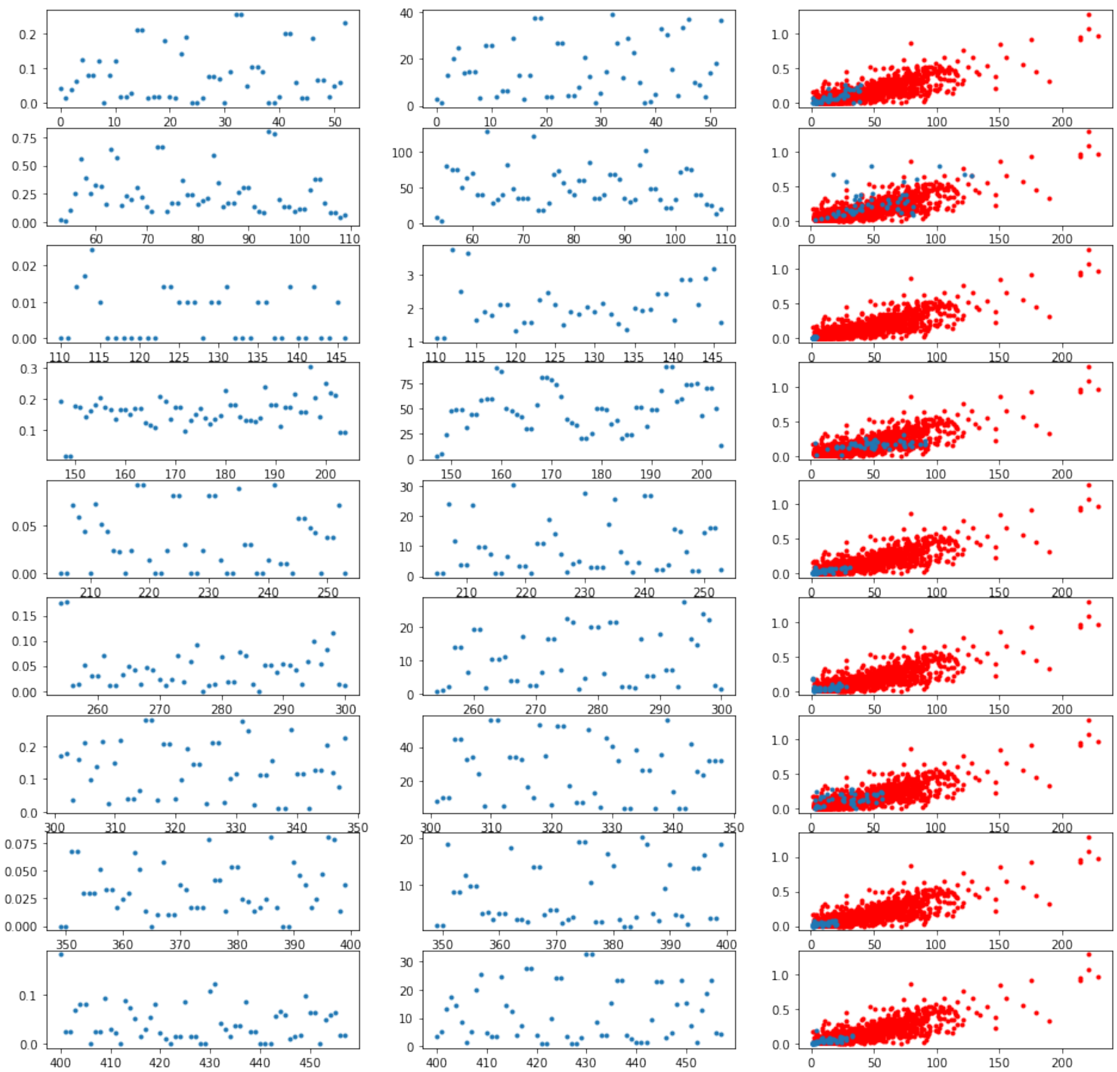
```
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
```

[64]:

```
                 index  accX  accY  accZ   gyrX   gyrY   gyrZ  files  \
0  2020-09-11 18:38:55  0.03  0.03  0.00   2.64   1.00   0.26      1
1  2020-09-11 18:38:56  0.01  0.01  0.00   0.85   1.00   0.26      1
2  2020-09-11 18:38:57  0.01  0.02  0.03   5.10   9.25   7.77      1
3  2020-09-11 18:38:58  0.05  0.02  0.03   5.10  13.47  14.31      1
4  2020-09-11 18:38:58  0.05  0.07  0.09  15.22  13.47  14.31      1

   accTotal   gyrTotal
0  0.042426   2.834996
1  0.014142   1.337946
2  0.037417  13.112795
3  0.061644  20.303374
4  0.124499  24.856898
```

[73]:

```python
fig = plt.figure(figsize=(16,16))
i= 1
for file in df_test.files.unique():
    df_temp = df_test[df_test.files == file]




    fig.add_subplot(len(df_test.files.unique()),3,i)
    i+=1
    plt.plot(df_temp.index,df_temp.accTotal,'.')

    fig.add_subplot(len(df_test.files.unique()),3,i)
    i+=1
    plt.plot(df_temp.index,df_temp.gyrTotal,'.')

    fig.add_subplot(len(df_test.files.unique()),3,i)
    i+=1
    plt.plot(df.gyrTotal,df.accTotal,'r.')
    plt.plot(df_temp.gyrTotal,df_temp.accTotal,'.')
```



1.5 1. Detecting when movements are smaller 'on average'

Definition: The solution to this detect movements that are smaller on average for a pre-defined time window (i.e. like a moving average). So every 5 hours, a moving average is taken, and if it has a lower threshold then an alarm is triggered.

Ideas: 1. Energy of a signal for every 5 hours 2. A moving average

1.6 2. Adapt to the fact that the seniors movements will be decreasing, on average, as a function of time

Definition:

Ideas: - can you use Fluid Mechanics (Turbulence) ideas? On how statistically stationary your movements are? Do you need more data on this?

1.7 3. Detecting if there is an ‘overall’ decrease in daily activity (as measured totally by how many naps there are, how strong the movements are)

Definition: Movements are defined on

Ideas: - can you convert gyration and acceleration into an ‘energy’ parameter and count it?

1.8 4. Detecting if there are large ‘gaps’ in data (i.e. long naps) or if there are spikes in continuous large movements

Definition: Movements are defined on

1.9 5. Detect irregular movements

2 Conclusion

Having discussed this with the team, it seems that Problem 1, 3 are the most important

[ ]:

```
```