AnomalyDetection_3_Problem_1

September 29, 2020

1 AnomalyDetection_3_Problem_1

Updates from parent notebook: - this notebook follows the problem definition laid out in AnomalyDetection_2_DefiningProblem - this notebook deals with the possible solutions presented there

1.1 Libraries and Configuration

[1]:
```
""" 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

[2]:
```
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

[3]:
```
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))
```

[4]:
```
dfs[0].head()
```

[4]:

	date	accX	accY	accZ	gyrX	gyrY	gyrZ	files	accTotal	gyrTotal
220	2020-09-14 19:19:26	0.01	0.02	0.00	3.62	1.04	1.38	1	0.022361	4.011284
319	2020-09-14 19:20:39	0.09	0.16	0.14	36.11	25.84	67.85	1	0.230868	81.087978
320	2020-09-14 19:20:40	0.09	0.16	0.09	22.98	15.43	16.45	1	0.204450	32.198879
321	2020-09-14 19:20:41	0.05	0.07	0.09	22.98	15.43	16.45	1	0.124499	32.198879
322	2020-09-14 19:20:42	0.12	0.07	0.07	29.44	39.83	27.27	1	0.155563	56.540210

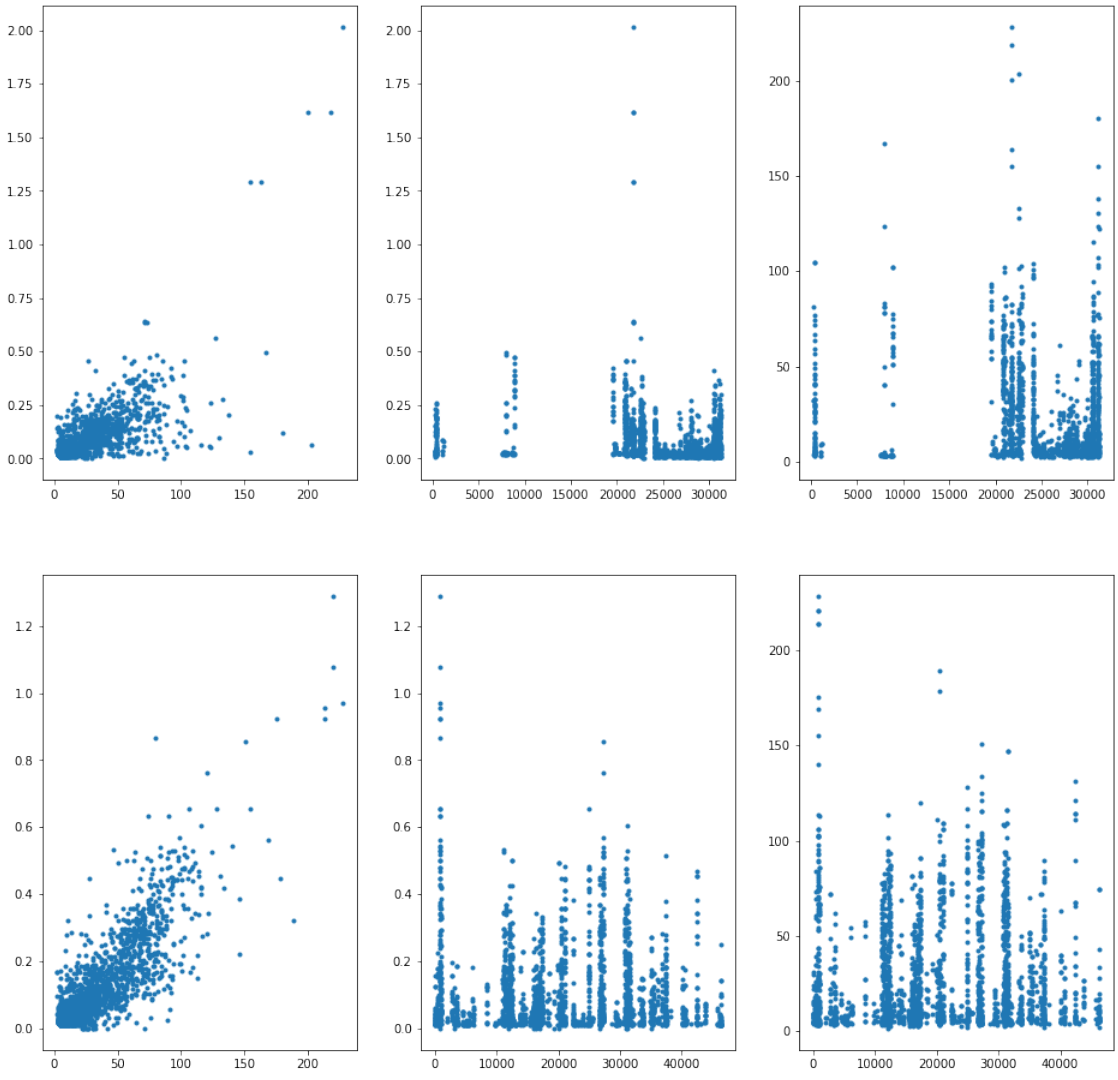
[5]:
```
dfs[1].head()
```

[5]:

	date	accX	accY	accZ	gyrX	gyrY	gyrZ	files	accTotal	gyrTotal
0	2020-09-13 17:09:25	0.02	0.12	0.03	1.47	3.32	2.22	1	0.125300	4.255784
1	2020-09-13 17:09:26	0.02	0.12	0.03	1.47	3.32	2.22	1	0.125300	4.255784
2	2020-09-13 17:09:27	0.01	0.01	0.00	7.43	6.82	10.10	1	0.014142	14.273307
12	2020-09-13 17:09:34	0.01	0.01	0.00	6.64	7.07	12.45	1	0.014142	15.782173
13	2020-09-13 17:09:34	0.01	0.01	0.00	4.12	3.61	5.81	1	0.014142	7.985149

[6]:
```
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
```



1.4 Moving Average Method

[87]:
```
df_train = dfs[1].reset_index()
df_test = dfs[0].reset_index()

df_train.date = pd.to_datetime(df_train.date)
df_test.date = pd.to_datetime(df_test.date)
df_train = seasonality(df_train,seasonality = 'month').find_seasonal_trends()
df_test = seasonality(df_test,seasonality = 'month').find_seasonal_trends()
```

[19]:
```
df_train.head()
```

[19]:

	index	date	accX	accY	accZ	gyrX	gyrY	gyrZ	files	\
0	0	2020-09-13 17:09:25	0.02	0.12	0.03	1.47	3.32	2.22	1	
1	1	2020-09-13 17:09:26	0.02	0.12	0.03	1.47	3.32	2.22	1	
2	2	2020-09-13 17:09:27	0.01	0.01	0.00	7.43	6.82	10.10	1	
3	12	2020-09-13 17:09:34	0.01	0.01	0.00	6.64	7.07	12.45	1	
4	13	2020-09-13 17:09:34	0.01	0.01	0.00	4.12	3.61	5.81	1	

	accTotal	gyrTotal	seasonality_month	times
0	0.125300	4.255784	9	61765.0
1	0.125300	4.255784	9	61766.0
2	0.014142	14.273307	9	61767.0
3	0.014142	15.782173	9	61774.0
4	0.014142	7.985149	9	61774.0

[20]:
```
df_test.head()

# seasonality class not working too well...
```

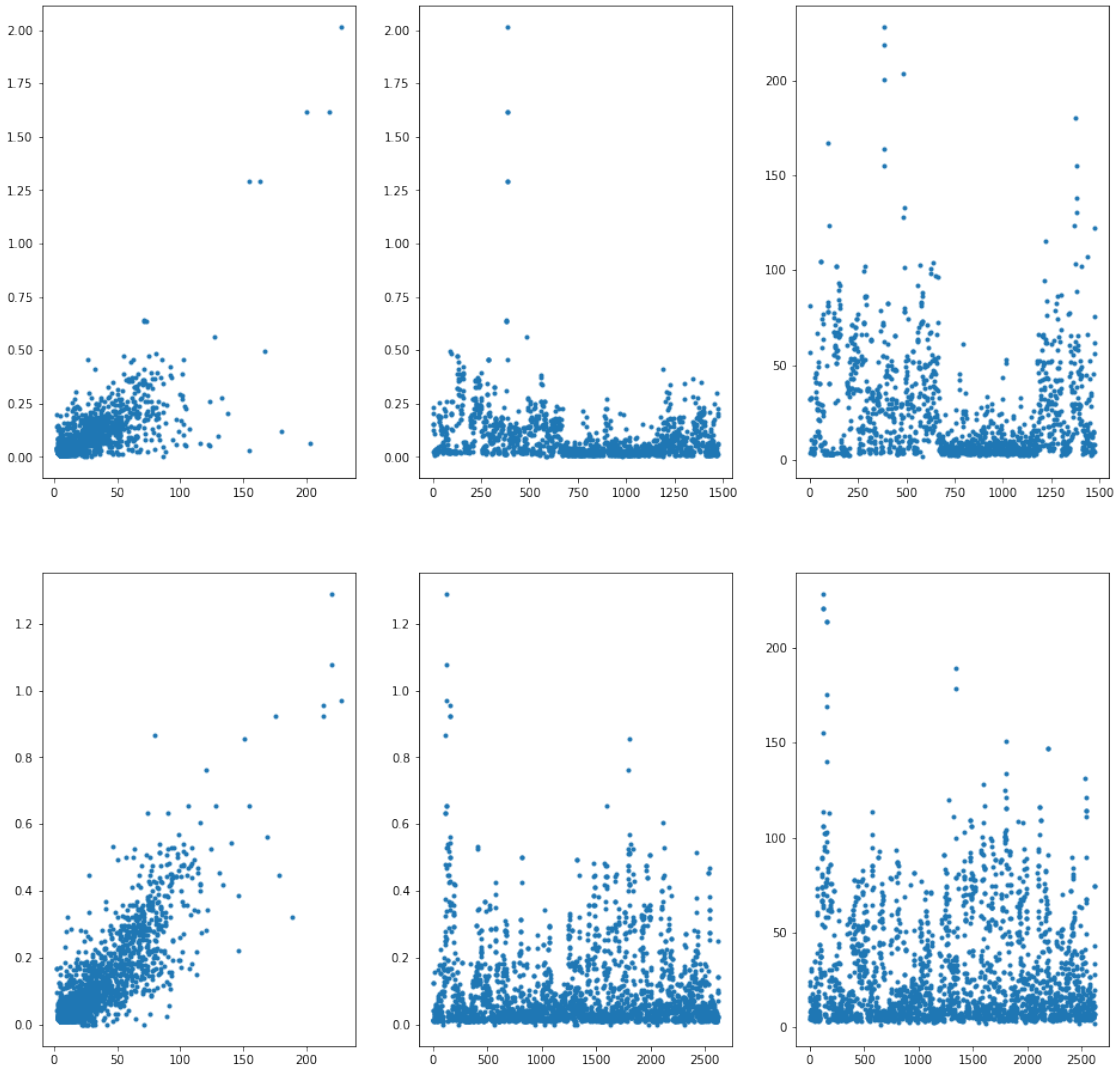
[20]:

	index	date	accX	accY	accZ	gyrX	gyrY	gyrZ	files	\
0	220	2020-09-14 19:19:26	0.01	0.02	0.00	3.62	1.04	1.38	1	
1	319	2020-09-14 19:20:39	0.09	0.16	0.14	36.11	25.84	67.85	1	
2	320	2020-09-14 19:20:40	0.09	0.16	0.09	22.98	15.43	16.45	1	
3	321	2020-09-14 19:20:41	0.05	0.07	0.09	22.98	15.43	16.45	1	
4	322	2020-09-14 19:20:42	0.12	0.07	0.07	29.44	39.83	27.27	1	

	accTotal	gyrTotal	seasonality_month	times
0	0.022361	4.011284	9	69566.0
1	0.230868	81.087978	9	69639.0
2	0.204450	32.198879	9	69640.0
3	0.124499	32.198879	9	69641.0
4	0.155563	56.540210	9	69642.0

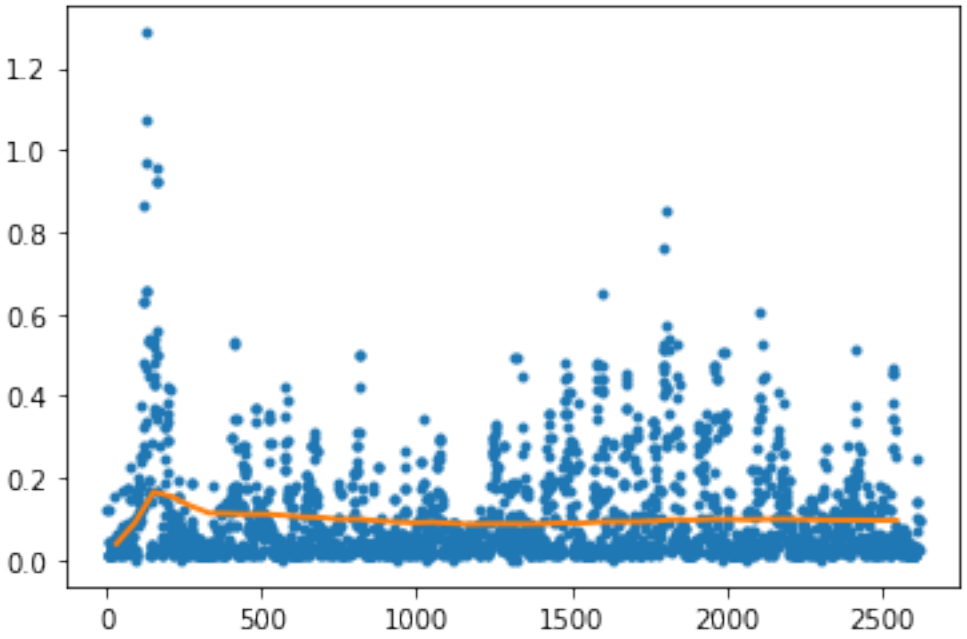
[22]:
```
dfs = [df_test,df_train]

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
```

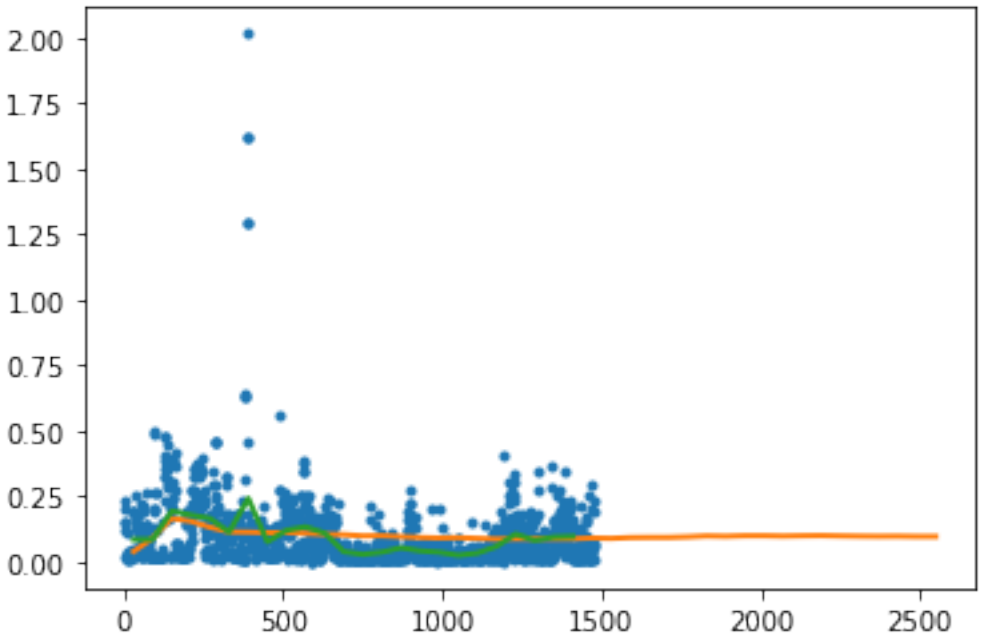


[158]:
```
time_window = 1 # this is the number of hours for the moving average time window
time_index = time_window*60 # note that each index represents a 'second' of␣
 ↪registered movements. So it doesn't actually have a
# physical meaning

count = time_index
averages = []
x = []
while count < df_train.shape[0]:
    df_temp = df_train.iloc[:count]
    averages.append([df_temp.accTotal.mean(),df_temp.gyrTotal.mean()])
    x.append(count-time_index/2)


    count+= time_index
    #print(count,df_train.shape[0])

averages = np.asarray(averages).reshape(-2,2)

plt.plot(df_train.index,df_train.accTotal,'.')
plt.plot(x,averages[:,0],linewidth = 2)

plt.show()

plt.plot(df_test.index,df_test.accTotal,'.')
plt.plot(x,averages[:,0],linewidth = 2)

count = time_index
averages = []
x = []
prev_count = 0
while count < df_test.shape[0]:
    df_temp = df_test.iloc[prev_count:count]
    averages.append([df_temp.accTotal.mean(),df_temp.gyrTotal.mean()])
    x.append(count-time_index/2)

    prev_count = count
    count+= time_index
    #print(count,df_train.shape[0])
averages = np.asarray(averages).reshape(-2,2)


plt.plot(x,averages[:,0],linewidth = 2)


# based on primitive testing, the average method does NOT seem suitable here...
```

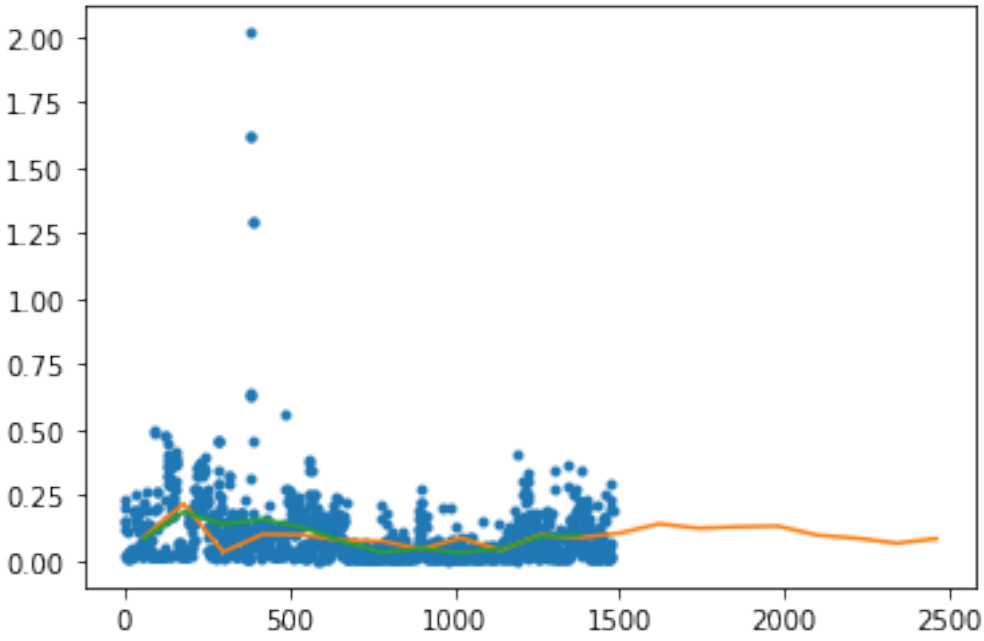
```
# I believe this is because of how right skewed the data is... Not sure I like␣
↪this method at all...
```



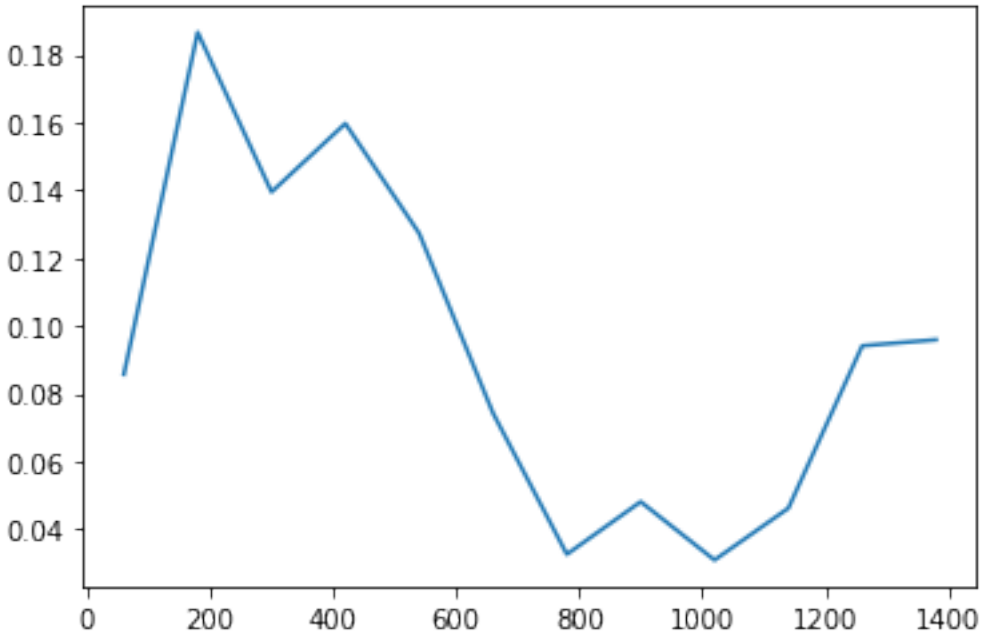
[158]: [<matplotlib.lines.Line2D at 0x1290b85d0>]



[210]:
```
class moving_avg:

    def __init__(self,df,time_index = 60,weight = 0):
        # note: would like to change class such that later, time_index could be␣
 ↪calculated from datetime
        self.df = df
        self.time_index = time_index
        self.weight = weight #for right skewed data, gives a weight to values␣
 ↪greater than the median

    def average(self):
        count = self.time_index
        averages = []
        x = []
        index = 0
        prev_count = 0
        while count < self.df.shape[0]:
            df_temp = self.df.iloc[prev_count:count]
            averages.append([df_temp.accTotal.mean(),df_temp.gyrTotal.mean()])
            x.append(count-self.time_index/2)

            index+=1
            prev_count = count
            count+= self.time_index

        averages = np.asarray(averages).reshape(-2,2)
        return x,averages



# not convinced of this method? You can't even measure hours because the data␣
 ↪that you have is less than 1 hr rn..

average = moving_avg(df_train,time_index = 120)
x,Y = average.average()

plt.plot(df_test.index,df_test.accTotal,'.')
plt.plot(x,Y[:,0])

average = moving_avg(df_test,time_index = 120)
x,Y = average.average()
plt.plot(x,Y[:,0])

plt.show()

plt.plot(x,Y[:,0])
```



[210]: [<matplotlib.lines.Line2D at 0x142c81690>]



1.5 Power of the singal

[214]:
```
from scipy import signal

fs = 1 # sampling frequency
x = df_train.accTotal
x = ifft(x)
f, Pxx_den = signal.periodogram(x, fs)
plt.show()

plt.semilogy(f, Pxx_den,'b.')

x = df_test.accTotal
x = ifft(x)
f, Pxx_den = signal.periodogram(x, fs)

plt.semilogy(f, Pxx_den,'r.')
#plt.show()

# this shows some more promise...
# at least very large movements can be captured


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

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

for file in df_testing.files.unique():
    x = df_testing.accTotal[df_testing.files == 9]
    x = ifft(x)
    f, Pxx_den = signal.periodogram(x, fs)
    plt.semilogy(f, Pxx_den,'.')
print(files)

plt.show()

# not convinced if power works either...
# need to look into what the power function is actually doing ?
```

```
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1812: UserWarning: Input data is complex,
switching to return_onesided=False
  warnings.warn('Input data is complex, switching to '
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1812: UserWarning: Input data is complex,
switching to return_onesided=False
  warnings.warn('Input data is complex, switching to '
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
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/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
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  warnings.warn('Input data is complex, switching to '
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1812: UserWarning: Input data is complex,
switching to return_onesided=False
  warnings.warn('Input data is complex, switching to '
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
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switching to return_onesided=False
  warnings.warn('Input data is complex, switching to '
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1812: UserWarning: Input data is complex,
switching to return_onesided=False
  warnings.warn('Input data is complex, switching to '
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1812: UserWarning: Input data is complex,
switching to return_onesided=False
  warnings.warn('Input data is complex, switching to '
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1812: UserWarning: Input data is complex,
switching to return_onesided=False
  warnings.warn('Input data is complex, switching to '
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1812: UserWarning: Input data is complex,
switching to return_onesided=False
  warnings.warn('Input data is complex, switching to '
```

```
/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/
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/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
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/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
/Users/yousefnami/KinKeepers/ProjectAI/Kin-Keepers/Data/TestData/
['adjusting-seating-position', 'falling', 'crossing-arms', 'walking', 'crossing-
legs', 'fetching-remote', 'sitting-down', 'lifting-leg', 'lying-down']
```
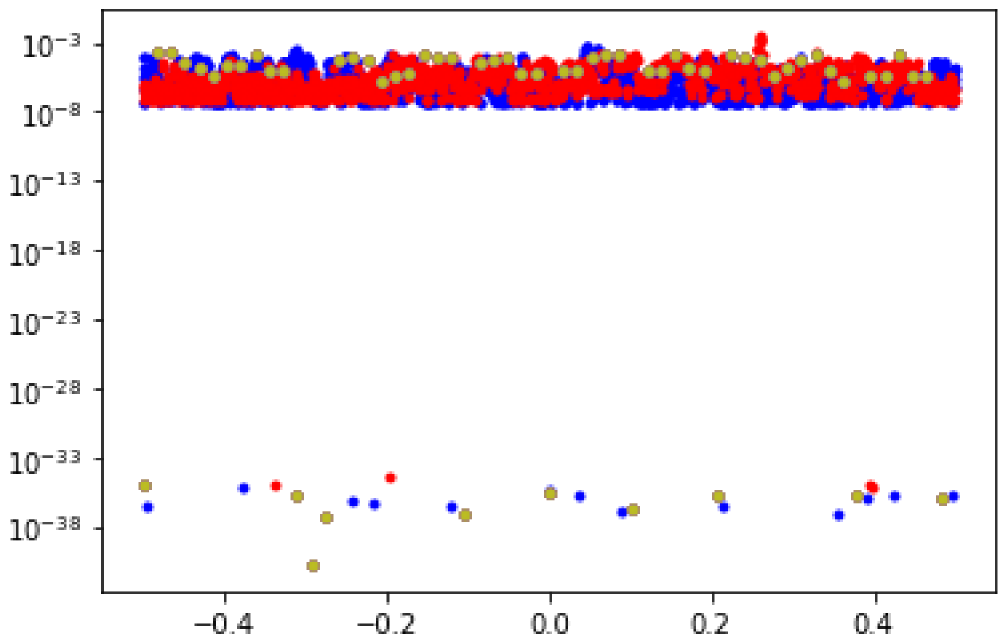
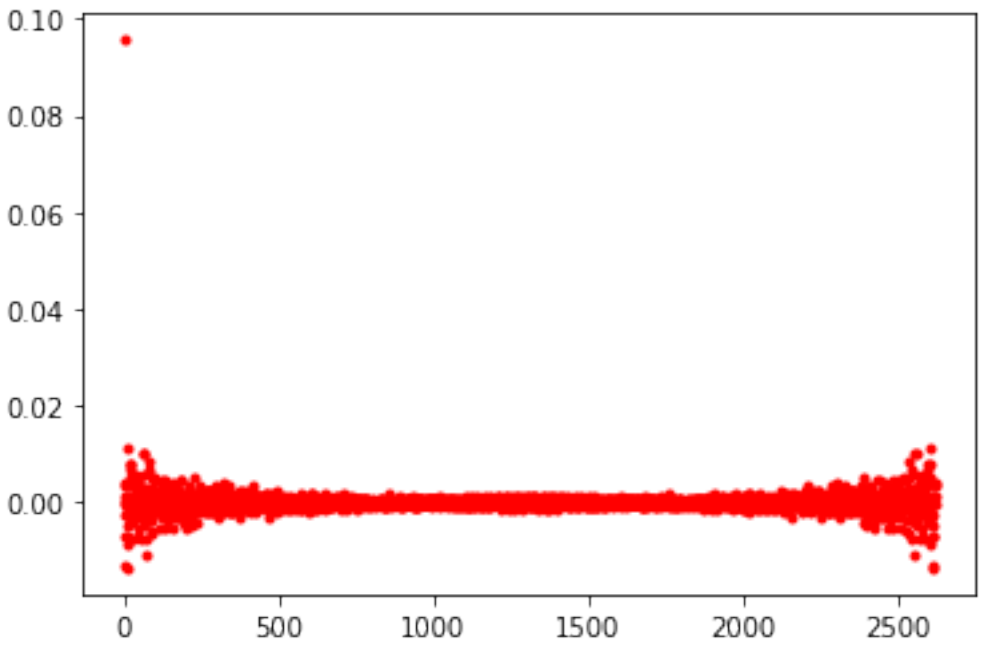



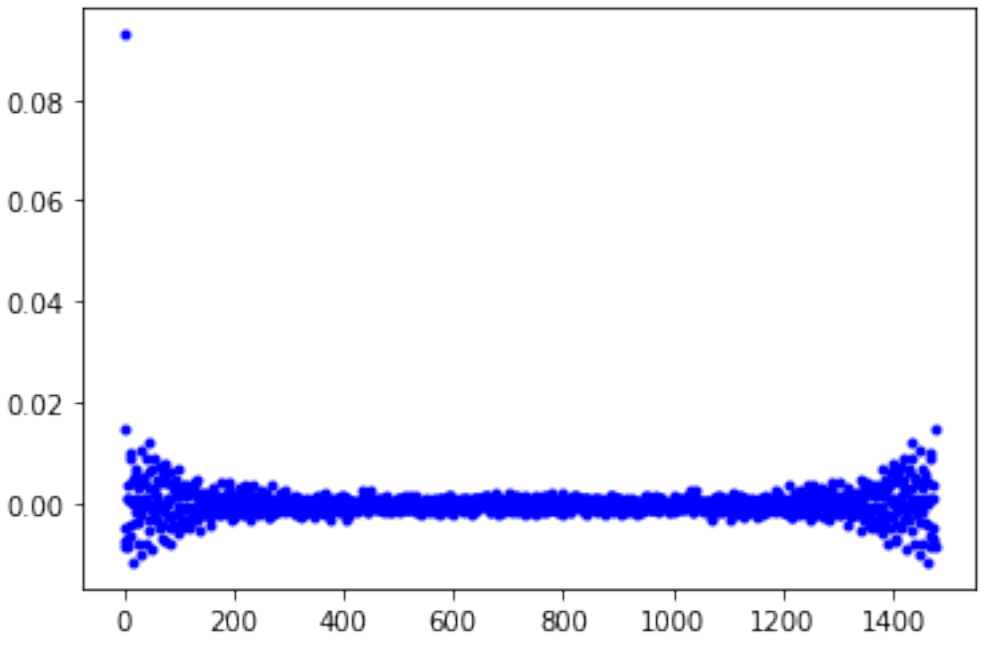
[212]:
```
x = df_train.accTotal
x = ifft(x)
plt.plot(df_train.index,x,'r.')
plt.show()
x = df_test.accTotal
x = ifft(x)
plt.plot(df_test.index,x,'b.')
```

```
/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)
```

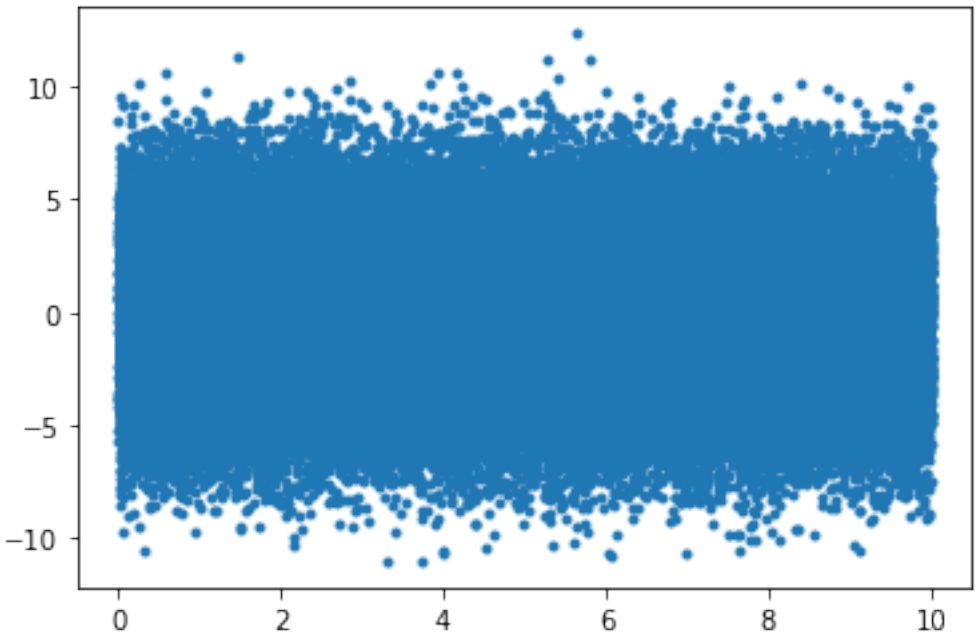


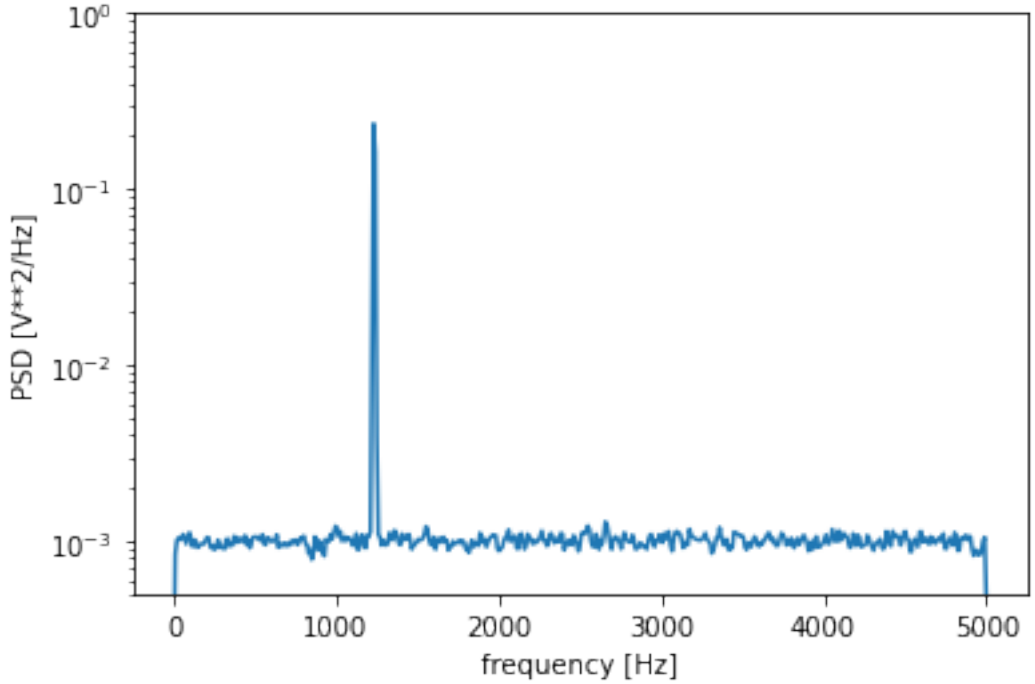

```
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/numpy/core/_asarray.py:83: ComplexWarning: Casting complex values to
real discards the imaginary part
  return array(a, dtype, copy=False, order=order)
```

[212]: `[<matplotlib.lines.Line2D at 0x129e85b50>]`



[144]:
```
fs = 10e3
N = 1e5
amp = 2*np.sqrt(2)
freq = 1234.0
noise_power = 0.001 * fs / 2
time = np.arange(N) / fs
x = amp*np.sin(2*np.pi*freq*time)
x += np.random.normal(scale=np.sqrt(noise_power), size=time.shape)

plt.plot(time,x,'.')
plt.show()

f, Pxx_den = signal.welch(x, fs, nperseg=1024)
plt.semilogy(f, Pxx_den)
plt.ylim([0.5e-3, 1])
plt.xlabel('frequency [Hz]')
plt.ylabel('PSD [V**2/Hz]')
plt.show()
```

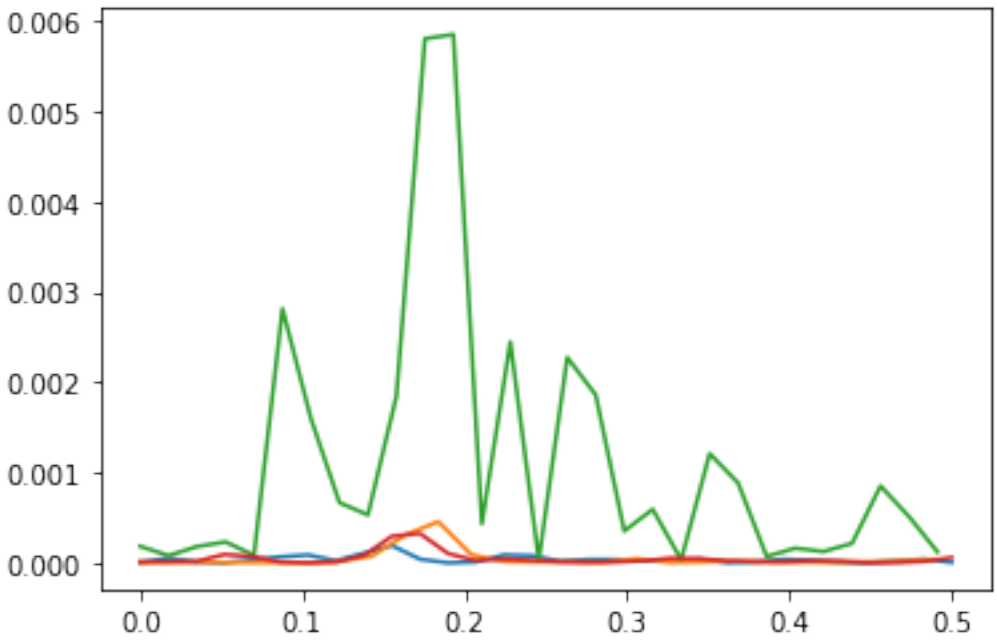




[215]:
```
df_walk = df_testing[df_testing.files == 4]
x = df_walk.accTotal
f, Pxx_den = signal.periodogram(x, 1)
f, Pxx_den = signal.welch(x, 1, nperseg=1024)
plt.plot(f,Pxx_den/58)



df_walk = df_testing[df_testing.files == 5]
x = df_walk.accTotal
f, Pxx_den = signal.periodogram(x, 1)
f, Pxx_den = signal.welch(x, 1, nperseg=1024)
plt.plot(f,Pxx_den/49)



df_walk = df_testing[df_testing.files == 2]
x = df_walk.accTotal
f, Pxx_den = signal.periodogram(x, 1)
f, Pxx_den = signal.welch(x, 1, nperseg=1024)
plt.plot(f,Pxx_den/57)
```

```
"""df_walk = df_testing[df_testing.files == 1]
x = df_walk.accTotal
f, Pxx_den = signal.periodogram(x, 1)
f, Pxx_den = signal.welch(x, 1, nperseg=1024)
plt.plot(f,Pxx_den/53)
"""


df_walk = df_testing[df_testing.files == 9]
x = df_walk.accTotal
f, Pxx_den = signal.periodogram(x, 1)
f, Pxx_den = signal.welch(x, 1, nperseg=1024)
plt.plot(f,Pxx_den/53)


plt.show()
```

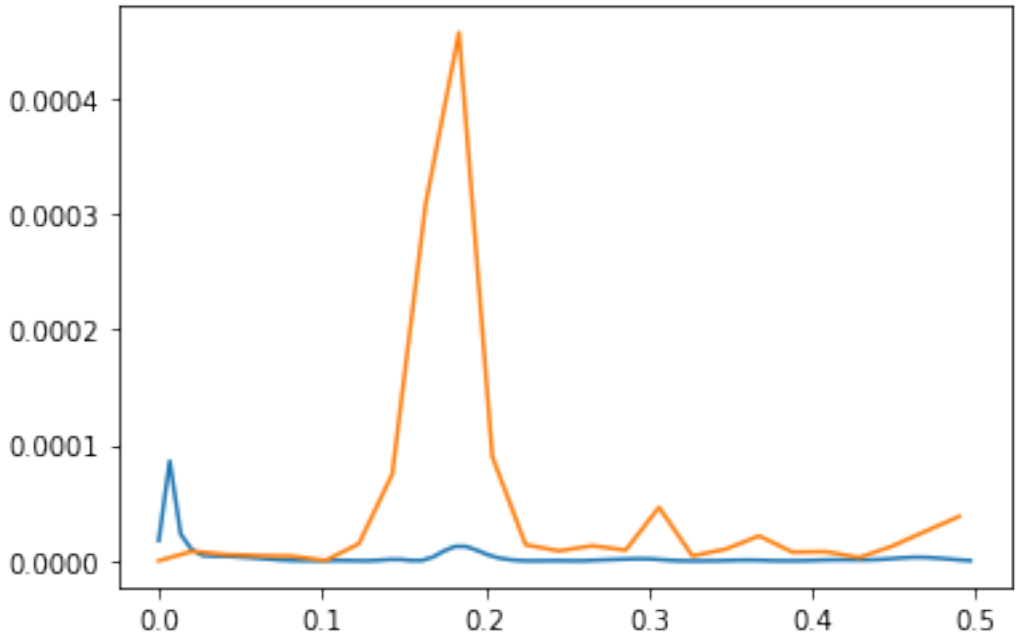
```
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1963: UserWarning: nperseg = 1024 is greater
than input length  = 58, using nperseg = 58
  .format(nperseg, input_length))
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1963: UserWarning: nperseg = 1024 is greater
than input length  = 49, using nperseg = 49
  .format(nperseg, input_length))
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1963: UserWarning: nperseg = 1024 is greater
than input length  = 57, using nperseg = 57
  .format(nperseg, input_length))
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1963: UserWarning: nperseg = 1024 is greater
than input length  = 58, using nperseg = 58
  .format(nperseg, input_length))
```



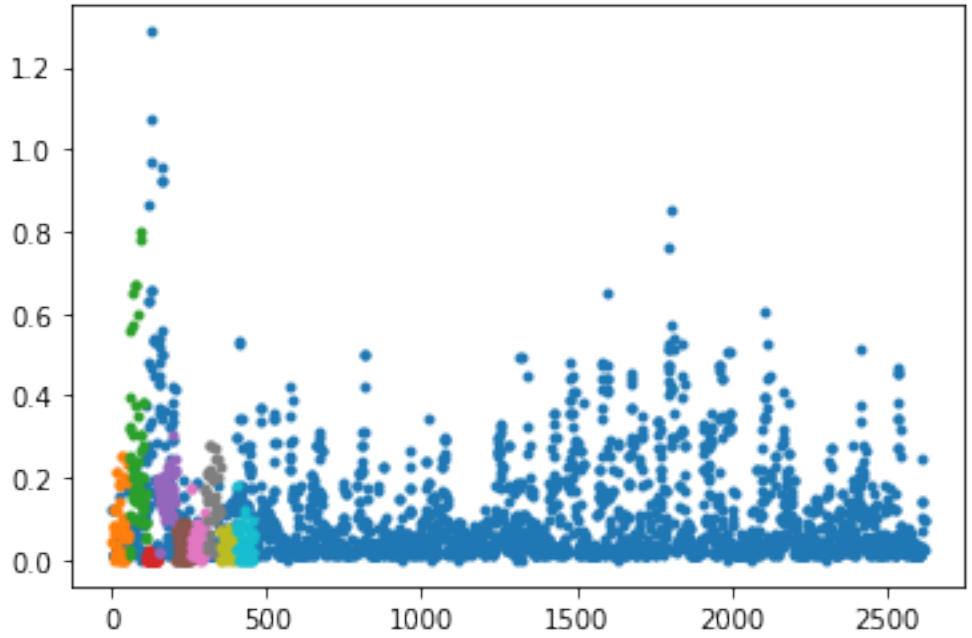
[208]:
```
df_walk = df_testing[df_testing.files == 5]
x = df_walk.accTotal.values.tolist()
for i in range(100):
    x.append(0)
f, Pxx_den = signal.periodogram(x, 1)
f, Pxx_den = signal.welch(x, 1, nperseg=1024)
plt.plot(f,Pxx_den/149)


df_walk = df_testing[df_testing.files == 5]
x = df_walk.accTotal.values.tolist()
f, Pxx_den = signal.periodogram(x, 1)
f, Pxx_den = signal.welch(x, 1, nperseg=1024)
plt.plot(f,Pxx_den/49)
```

```
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1963: UserWarning: nperseg = 1024 is greater
than input length  = 149, using nperseg = 149
  .format(nperseg, input_length))
/Users/yousefnami/python_environments/KinKeepers_AI/lib/python3.7/site-
packages/scipy/signal/spectral.py:1963: UserWarning: nperseg = 1024 is greater
than input length  = 49, using nperseg = 49
  .format(nperseg, input_length))
```

[208]:
```
[<matplotlib.lines.Line2D at 0x128daa1d0>]
```



[190]:
```
plt.plot(df_train.index,df_train.accTotal,'.')

for file in df_testing.files.unique():
    df_temp = df_testing[df_testing.files == file]
    plt.plot(df_temp.index,df_temp.accTotal,'.')
```



2 Conclusion

Power seems to be a much better indicator than moving average… I am still not convinced by that. Why? Here are my concerns: 1. What do you choose as the time interval? This cannot actually be based on time, must be based on a number of points. If so, then since you've lost the DoF of time, then for one set of movement data, you might be capturing data over 1 min, or over 2 hrs, for the 1 min, the movement may not even be finished yet, but for the 2 hrs, it may have captured too many different movements? 2. The averages don't change that much, because of the data being right skewed. That said, there might need to be some sort of 'weighting' given to values that are greater than the upper quartile. What would this weighting be? 3. The second point does not fix the first point 4. Not sure how to combine acceleration and gyration?

Need to perhaps also understand how the Movement detection API works.

Another idea… what if you randomly sample the data for a set period (i.e. 1 hr for example), and then based on those results, calculate the power of the signal, and store it. Then you can train a neural network based on the power within the data, and then see if your result is anomalous or not? This would be interesting eh?