TickData_analysis

October 7, 2022

[170]:
```
import pandas as pd
import stumpy
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.dates as dates
from matplotlib.patches import Rectangle
import datetime as dt
from functools import reduce
import time
```

[171]:
```
#loading data
executed = pd.read_excel("P:\\Boyan Davidov\\QuantResearch\\TickDataBHM.xlsx",␣
 ↪sheet_name="Executed")
executed = executed.set_index('Dates')
```

[172]:
```
executed.head()
```

[172]:

Dates	Price_of_Execution	Executed_Size
2020-05-05 10:05:29	4.25	50000
2020-05-05 10:06:37	4.28	1000
2020-05-05 10:14:31	4.25	5000
2020-05-05 10:14:31	4.25	10000
2020-05-05 10:14:31	4.25	5000

[173]:
```
#bid
bid = pd.read_excel("P:\\Boyan Davidov\\QuantResearch\\TickDataBHM.xlsx",␣
 ↪sheet_name="Bid")
bid = bid.set_index('Dates')
#offer
offer = pd.read_excel("P:\\Boyan Davidov\\QuantResearch\\TickDataBHM.xlsx",␣
 ↪sheet_name="Offer")
offer = offer.set_index('Dates')
#volume
volume = pd.read_excel("P:\\Boyan Davidov\\QuantResearch\\TickDataBHM.xlsx",␣
 ↪sheet_name="Volume")
volume = volume.set_index('Dates')
```

This is not one-to-one data, there could be bid but not ask data for certain time. To allow easier anaylsis we group by time, sum all executed sizes and average bids/asks in case of different values for same timestamp

[174]:
```
##### Grouping by time, averaging price and summing sizes

execc = (executed.groupby(executed.index)
       .agg({'Executed_Size':'sum', 'Price_of_Execution':'mean'}))

bid_m = (bid.groupby(bid.index)
       .agg({'Size_at_Bid':'sum', 'Bid':'mean'}))

offer_m = (offer.groupby(offer.index)
       .agg({'Size_at_Ask':'sum', 'Ask':'mean'}))
```

For instance, at timestamp 05/05/2020 10:28:44 when the second block was executed we see:

[175]:
```
execc[execc.index == '05/05/2020  10:28:44']
```

[175]:
```
                     Executed_Size  Price_of_Execution
Dates
2020-05-05 10:28:44          28353                 4.2
```

As next step we group the all parts of data (executed,bid,ask) matching on timestamp

[176]:
```
##### Grouping by time, averaging price and summing sizes
data_frames = [execc, bid_m, offer_m]

df_merged_agg = reduce(lambda left,right: pd.merge(left,right,on=['Dates'],
                                            how='outer'), data_frames)

df_merged_agg.head()
```

[176]:
```
                     Executed_Size  Price_of_Execution  Size_at_Bid       Bid  \
Dates
2020-05-05 10:05:29        50000.0                4.25          NaN       NaN
2020-05-05 10:06:37         1000.0                4.28      10000.0  4.220000
2020-05-05 10:14:31        20000.0                4.25          NaN       NaN
2020-05-05 10:14:53        10000.0                4.25          NaN       NaN
2020-05-05 10:15:23        96413.0                4.23     160084.0  4.226667

                     Size_at_Ask   Ask
Dates
2020-05-05 10:05:29      20000.0  4.29
2020-05-05 10:06:37       9000.0  4.28
2020-05-05 10:14:31     115000.0  4.25
2020-05-05 10:14:53      25000.0  4.25
2020-05-05 10:15:23      13545.0  4.23
```

To match with the volume data we need to modify the timestamps since volume arrivals are in format HH:MM without seconds. For example:

[177]:
```
volume.index[1]
```

[177]:
```
Timestamp('2020-05-05 10:06:00')
```

So let's add a new column to the bid/ask data on which we can merge with the volume (having same format)

[178]:
```
#modify timestap of bid/ask data to match that of volume
def time(rows):
    return (pd.Timestamp(rows.year, rows.month,
                         rows.day, rows.hour, rows.minute))

#time(df_merged.index[1]) == volume.index[1]
df_merged_agg['volume_time'] = df_merged_agg.index.to_series().apply(time)
```

The new column is called volume_time

[179]:
```
df_merged_agg.head()
```

[179]:

Dates	Executed_Size	Price_of_Execution	Size_at_Bid	Bid	Size_at_Ask	Ask	volume_time
2020-05-05 10:05:29	50000.0	4.25	NaN	NaN	20000.0	4.29	2020-05-05 10:05:00
2020-05-05 10:06:37	1000.0	4.28	10000.0	4.220000	9000.0	4.28	2020-05-05 10:06:00
2020-05-05 10:14:31	20000.0	4.25	NaN	NaN	115000.0	4.25	2020-05-05 10:14:00
2020-05-05 10:14:53	10000.0	4.25	NaN	NaN	25000.0	4.25	2020-05-05 10:14:00
2020-05-05 10:15:23	96413.0	4.23	160084.0	4.226667	13545.0	4.23	2020-05-05 10:15:00

[180]:
```
volume.head()
```

[180]:

Dates	Volume	Cumulative Volume
2020-05-05 10:05:00	50000	NaN
2020-05-05 10:06:00	1000	51000.0
2020-05-05 10:14:00	30000	81000.0
2020-05-05 10:15:00	96413	177413.0
2020-05-05 10:16:00	30042	207455.0

Now merge to get all data matched in one frame

[229]:
```
merged = pd.merge(df_merged_agg, volume, right_index=True,␣
↪left_on='volume_time')
```

[228]:
```
merged.head()
```

[228]:

Dates	Executed_Size	Price_of_Execution	Size_at_Bid	Bid	Size_at_Ask	Ask	volume_time	Volume	Cumulative Volume
2020-05-05 10:05:29	50000.0	4.25	NaN	NaN	20000.0	4.29	2020-05-05 10:05:00	50000	NaN
2020-05-05 10:05:51	NaN	NaN	1000.0	4.28	NaN	NaN	2020-05-05 10:05:00	50000	NaN
2020-05-05 10:06:37	1000.0	4.28	10000.0	4.22	9000.0	4.28	2020-05-05 10:06:00	1000	51000.0
2020-05-05 10:06:45	NaN	NaN	20000.0	4.18	NaN	NaN	2020-05-05 10:06:00	1000	51000.0
2020-05-05 10:14:31	20000.0	4.25	NaN	NaN	115000.0	4.25	2020-05-05 10:14:00	30000	81000.0

We don't need columns where no execution occured (i.e. NaN data).

[227]:
```
merged_clean = merged.dropna(subset=['Executed_Size'])
```

Creating a new column to monitor for bid/ask spread

[226]:
```
%%capture
merged_clean['Spread'] = merged_clean['Ask'] - merged_clean['Bid']
```

This is how our final dataframe looks:

[225]:
```
merged_clean.head()
```

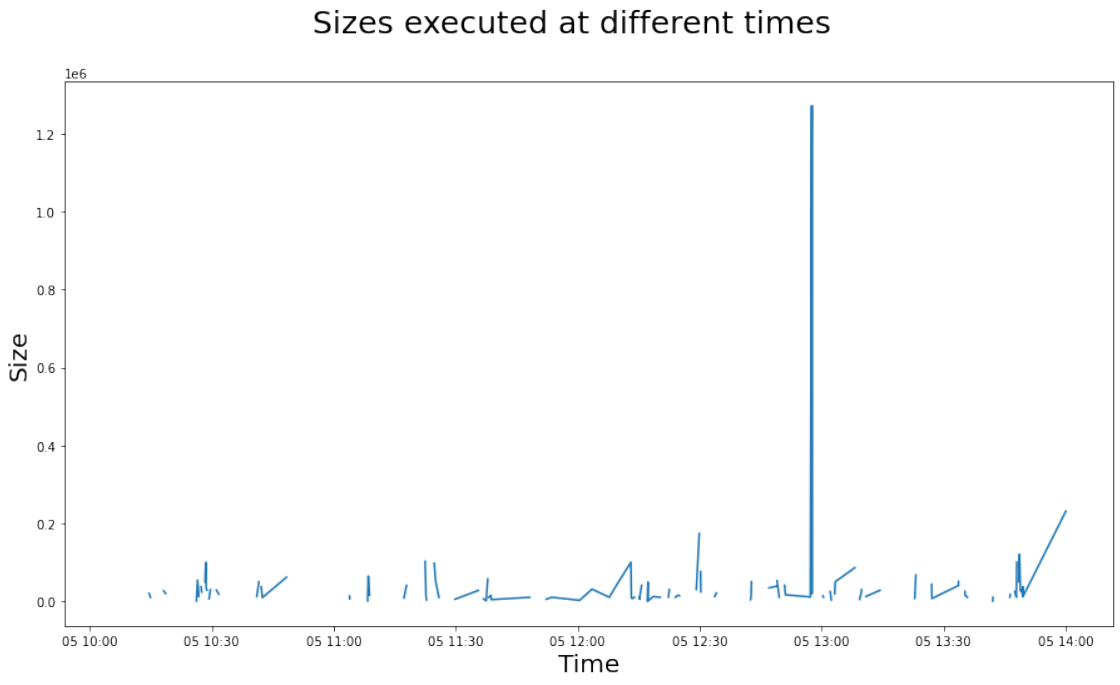
[225]:

Dates	Executed_Size	Price_of_Execution	Size_at_Bid	Bid	Size_at_Ask	Ask	volume_time	Volume	Cumulative Volume	Spread
2020-05-05 10:05:29	50000.0	4.25	NaN	NaN	20000.0	4.29	2020-05-05 10:05:00	50000	NaN	0.29
2020-05-05 10:06:37	1000.0	4.28	10000.0	4.220000	9000.0	4.28	2020-05-05 10:06:00	1000	51000.0	0.06
2020-05-05 10:14:31	20000.0	4.25	NaN	NaN	115000.0	4.25	2020-05-05 10:14:00	30000	81000.0	0.00
2020-05-05 10:14:53	10000.0	4.25	NaN	NaN	115000.0	4.25	2020-05-05 10:14:00	30000	81000.0	0.00
2020-05-05 10:15:23	96413.0	4.23	160084.0	4.226667	115000.0	4.25	2020-05-05 10:14:00	30000	81000.0	0.02

```
                     Size_at_Ask    Ask          volume_time  Volume  \
Dates
2020-05-05 10:05:29      20000.0  4.29 2020-05-05 10:05:00   50000
2020-05-05 10:06:37       9000.0  4.28 2020-05-05 10:06:00    1000
2020-05-05 10:14:31     115000.0  4.25 2020-05-05 10:14:00   30000
2020-05-05 10:14:53      25000.0  4.25 2020-05-05 10:14:00   30000
2020-05-05 10:15:23      13545.0  4.23 2020-05-05 10:15:00   96413

                     Cumulative Volume    Spread
Dates
2020-05-05 10:05:29                NaN       NaN
2020-05-05 10:06:37            51000.0  0.060000
2020-05-05 10:14:31            81000.0       NaN
2020-05-05 10:14:53            81000.0       NaN
2020-05-05 10:15:23           177413.0  0.003333
```

Now that we have matched and cleaned data - let's analyse. Our aim is to spot approximately repeated subsequences. Firstly we check whether there is any relationship between time and executed size (to assess whether twap algo could be useful).

[224]:
```
#search for motif based on time
plt.rcParams['figure.figsize'] = [15, 8]
plt.suptitle('Sizes executed at different times', fontsize='25')
plt.xlabel('Time', fontsize ='20')
plt.ylabel('Size', fontsize='20')
plt.plot(merged.index, merged['Executed_Size'].values)
plt.show()
```

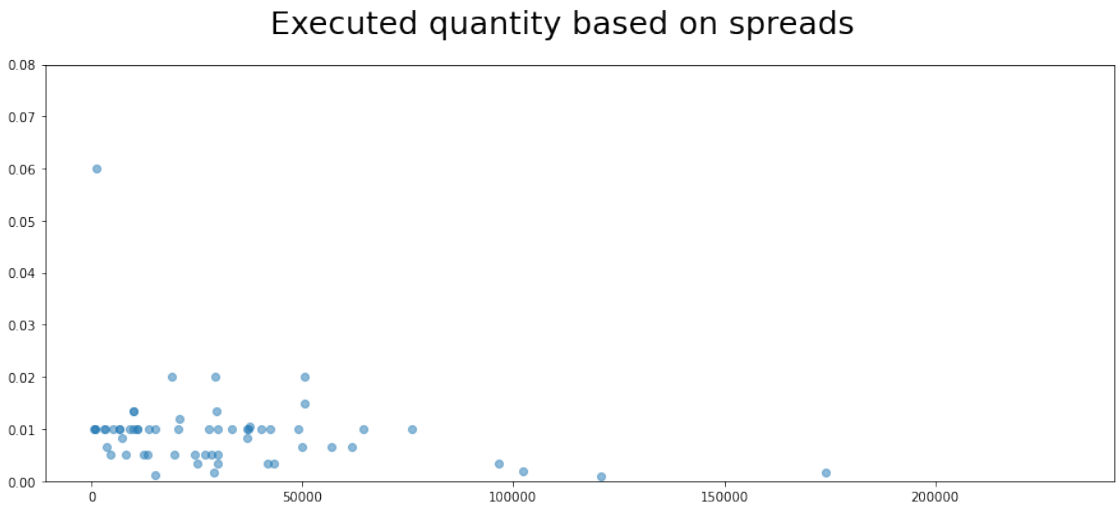


There is no particular relationship from the plot. There is a spilke when the afternoon auction starts and one particular at 13:00 o'clock. But nothing significant to conclude from.

Next, we check if any correlation between bid/ask spread and executed sizes:

[223]:
```
#search for motif based on bid/ask spread
plt.rcParams['figure.figsize'] = [15, 6]
plt.suptitle('Executed quantity based on spreads', fontsize='25')
plt.scatter(merged_clean['Executed_Size'], merged_clean['Spread'], alpha=0.5)
plt.ylim(0, 0.08)
```

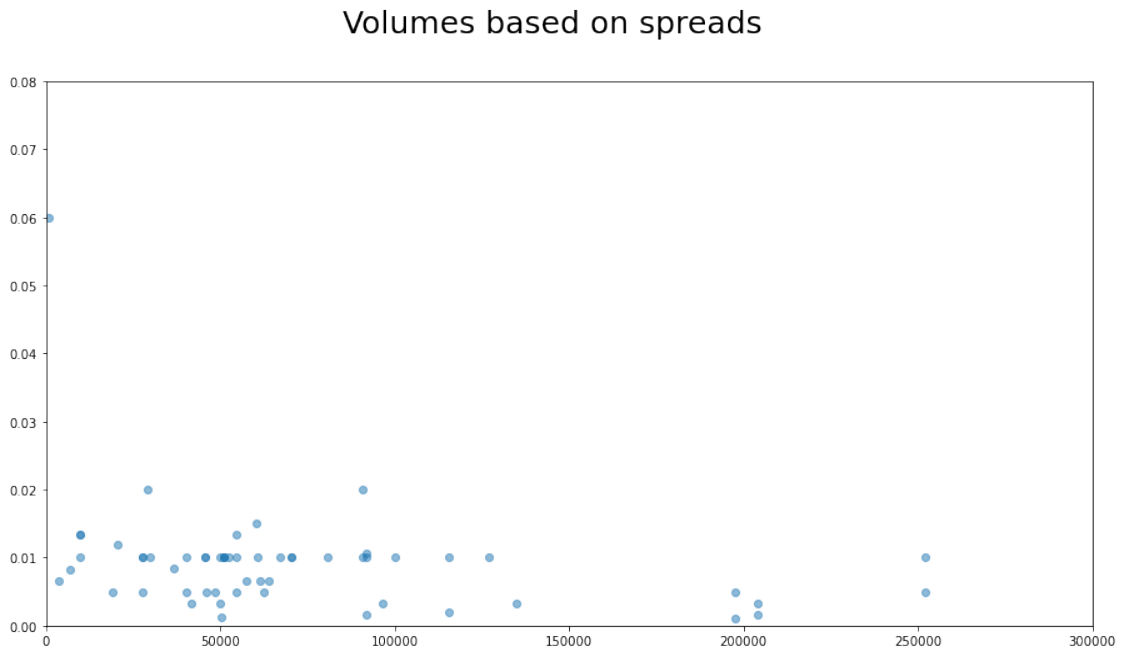
[223]: (0.0, 0.08)



We can see from the plot that most of the executed trades occured when spread was 0.01

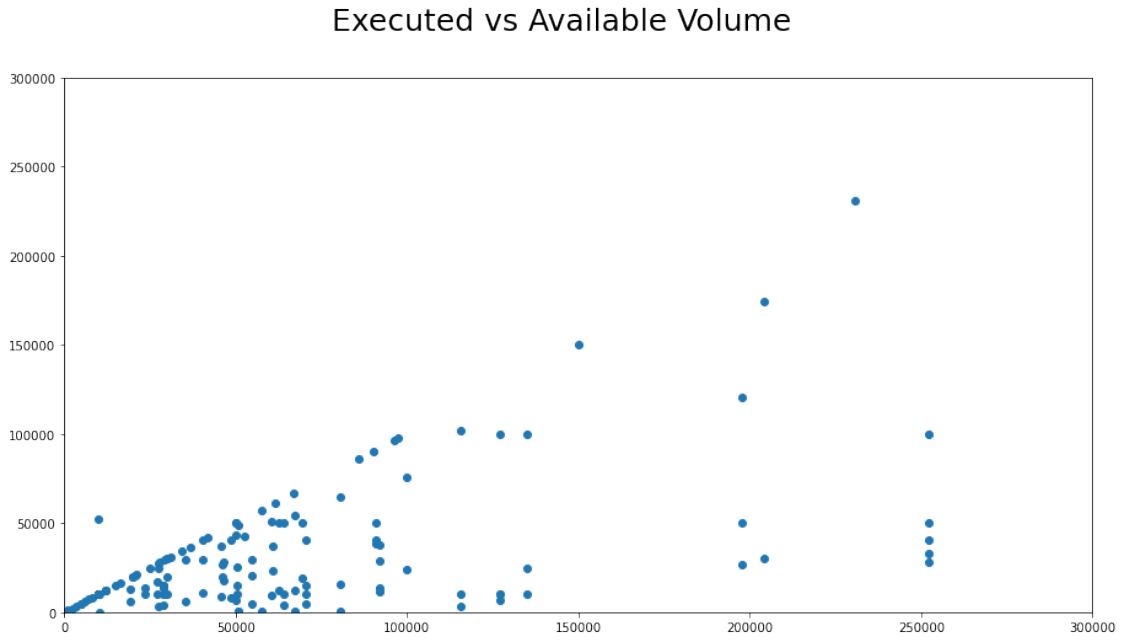
[222]:
```
#volume
plt.suptitle('Volumes based on spreads', fontsize='25')
plt.scatter(merged_clean['Volume'], merged_clean['Spread'], alpha=0.5)
plt.ylim(0, 0.08)
plt.xlim(0, 300000)
```

[222]: (0.0, 300000.0)



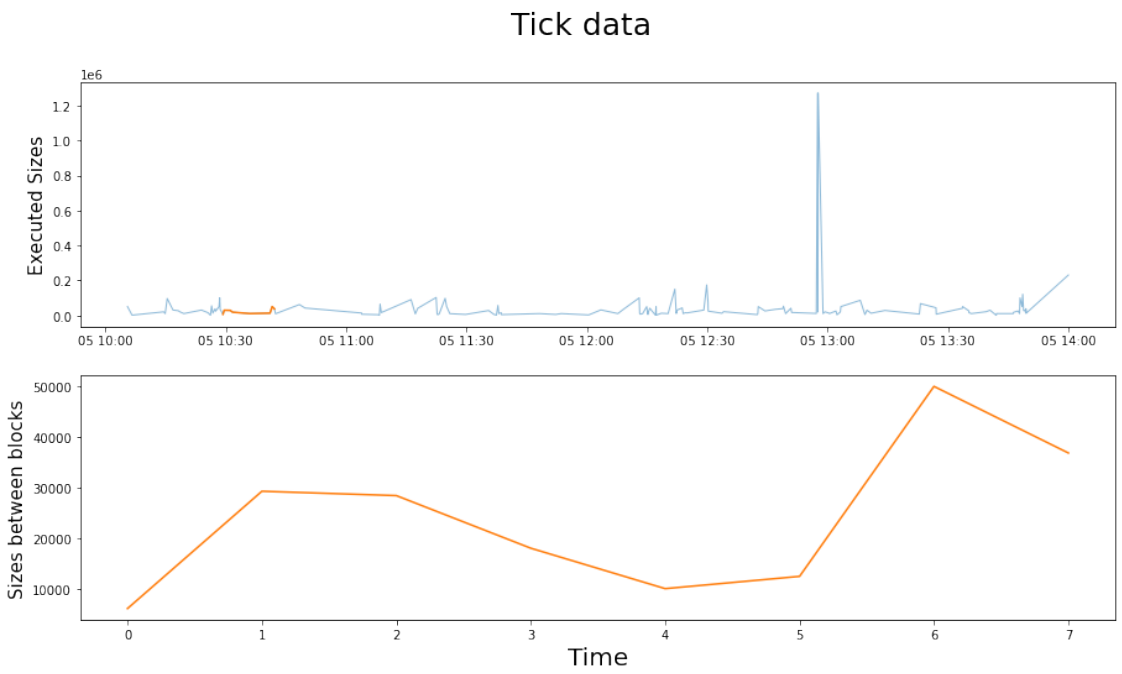
[221]:
```
#search for motif based on volume
plt.suptitle('Executed vs Available Volume', fontsize='25')
plt.scatter(merged_clean['Volume'], merged_clean['Executed_Size'])
plt.ylim(0, 300000)
plt.xlim(0,300000)
```

[221]: (0.0, 300000.0)



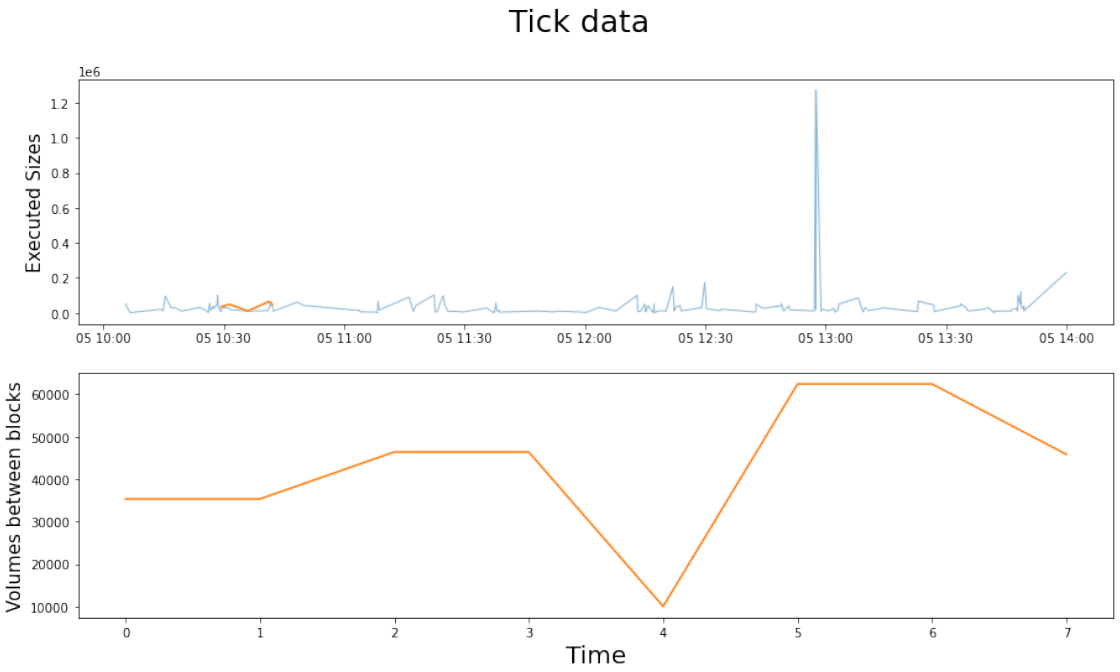
These plots give some idea about the data and the relationships but to find some real motif we can try using stumpy package analyzing windows with sizes equal to the time between the blocks occured

[220]:
```
m = 8
fig, axs = plt.subplots(2)
plt.suptitle('Tick data', fontsize='25')
axs[0].set_ylabel("Executed Sizes", fontsize='15')
axs[0].plot(merged_clean['Executed_Size'], alpha=0.5, linewidth=1)
axs[0].plot(merged_clean['Executed_Size'].iloc[21:21+m])
rect = Rectangle((21, 0), m, 20000000, facecolor='blue')
#axs[0].add_patch(rect)
axs[1].set_xlabel("Time", fontsize='20')
axs[1].set_ylabel("Sizes between blocks", fontsize='15')
axs[1].plot(merged_clean['Executed_Size'].values[21:21+m], color='C1')
plt.show()
```



[219]:
```
m = 8
fig, axs = plt.subplots(2)
plt.suptitle('Tick data', fontsize='25')
axs[0].set_ylabel("Executed Sizes", fontsize='15')
axs[0].plot(merged_clean['Executed_Size'], alpha=0.5, linewidth=1)
axs[0].plot(merged_clean['Volume'].iloc[21:21+m])
```

```
rect = Rectangle((21, 0), m, 20000000, facecolor='blue')
#axs[0].add_patch(rect)
axs[1].set_xlabel("Time", fontsize='20')
axs[1].set_ylabel("Volumes between blocks", fontsize='15')
axs[1].plot(merged_clean['Volume'].values[21:21+m], color='C1')
plt.show()
```



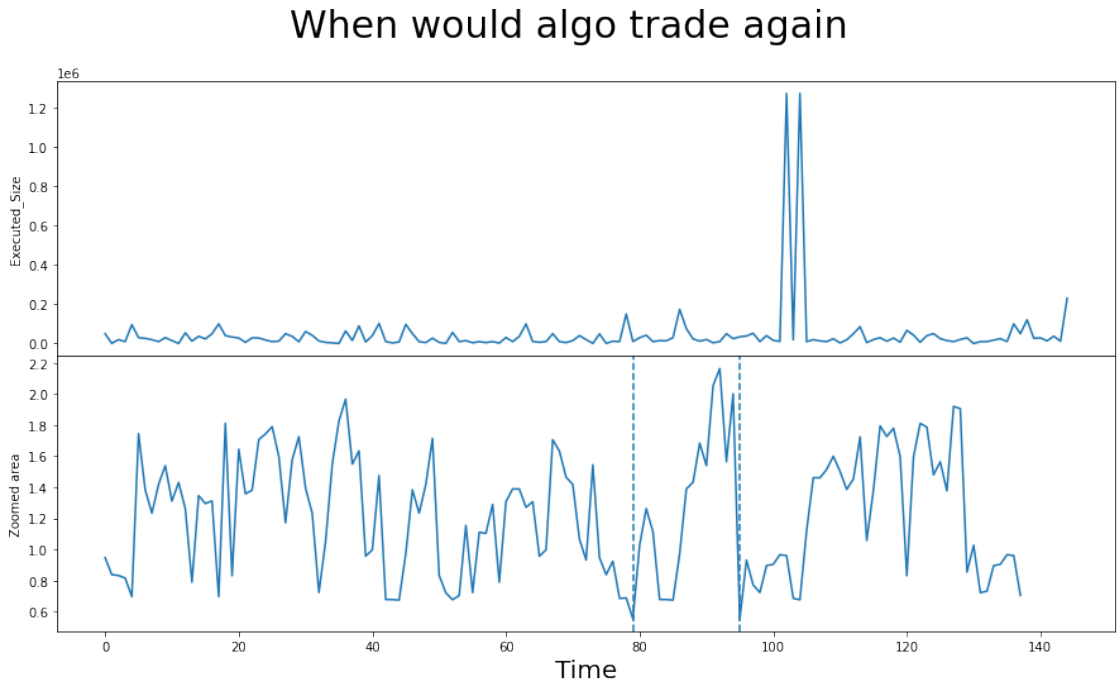
Clearly, this is VWAP algo.

We can try using stumpy package to detect patterns (stumpy is comparing pairwise z-normalized Euclidean distances in time series). Firstly, we check via executed volume

[218]:
```
#finding motif via stumpy package
m = 8
mp = stumpy.stump(merged_clean['Executed_Size'], m)


motif_idx = np.argsort(mp[:, 0])[0]
print(f"The motif is located at index {motif_idx}")


nearest_neighbor_idx = mp[motif_idx, 1]
print(f"The nearest neighbor is located at index {nearest_neighbor_idx}")
```

```
The motif is located at index 79
The nearest neighbor is located at index 95
```

[193]:
```
plt.rcParams['figure.figsize'] = [15, 8]
fig, axs = plt.subplots(2, sharex=True, gridspec_kw={'hspace': 0})
plt.suptitle('When would algo trade again', fontsize='30')
axs[0].plot(merged_clean['Executed_Size'].values)
axs[0].set_ylabel('Executed_Size', fontsize='10')
rect = Rectangle((motif_idx, 0), m, 40, facecolor='lightgrey')
axs[0].add_patch(rect)
rect = Rectangle((nearest_neighbor_idx, 0), m, 40, facecolor='lightgrey')
axs[0].add_patch(rect)
axs[1].set_xlabel('Time', fontsize ='20')
axs[1].set_ylabel('Zoomed area', fontsize='10')
axs[1].axvline(x=motif_idx, linestyle="dashed")
axs[1].axvline(x=nearest_neighbor_idx, linestyle="dashed")
axs[1].plot(mp[:, 0])
plt.show()
```



[217]:
```
merged_clean[merged_clean.index==merged_clean.index[79]]
```

[217]:

Dates	Executed_Size	Price_of_Execution	Size_at_Bid	Bid	Size_at_Ask	Ask	volume_time	Volume
2020-05-05 12:22:17	10678.0	4.15	72000.0	4.14	22630.0	4.15	2020-05-05 12:22:00	40461

```
                     Cumulative Volume  Spread
Dates
2020-05-05 12:22:17          2276651.0    0.01
```

[216]:
```
merged_clean[merged_clean.index==merged_clean.index[95]]
```

[216]:
```
                     Executed_Size  Price_of_Execution  Size_at_Bid   Bid  \
Dates
2020-05-05 12:47:02        34300.0                4.14     127700.0  4.14

                     Size_at_Ask  Ask         volume_time  Volume  \
Dates
2020-05-05 12:47:02          NaN  NaN 2020-05-05 12:47:00   34300

                     Cumulative Volume  Spread
Dates
2020-05-05 12:47:02          2818383.0     NaN
```

Apparently, executed size is not enough to conclude. Even though it flagged two 'local' minimums this is not saying much why we should buy there.

Let's try to see with VWAP

[215]:
```
def vwap(df):
    q = df.Volume.values
    p = df.Ask.values
    l = df['Cumulative Volume']
    return df.assign(vwap=(p * q).cumsum() / l)
```

[214]:
```
merged_clean_final = merged_clean.dropna(subset=['Ask'])
```

[213]:
```
merged_clean_vwap = merged_clean_final.groupby(merged_clean_final.index.date,␣
↪group_keys=False).apply(vwap)
```

[199]:
```
merged_clean_vwap.head()
```

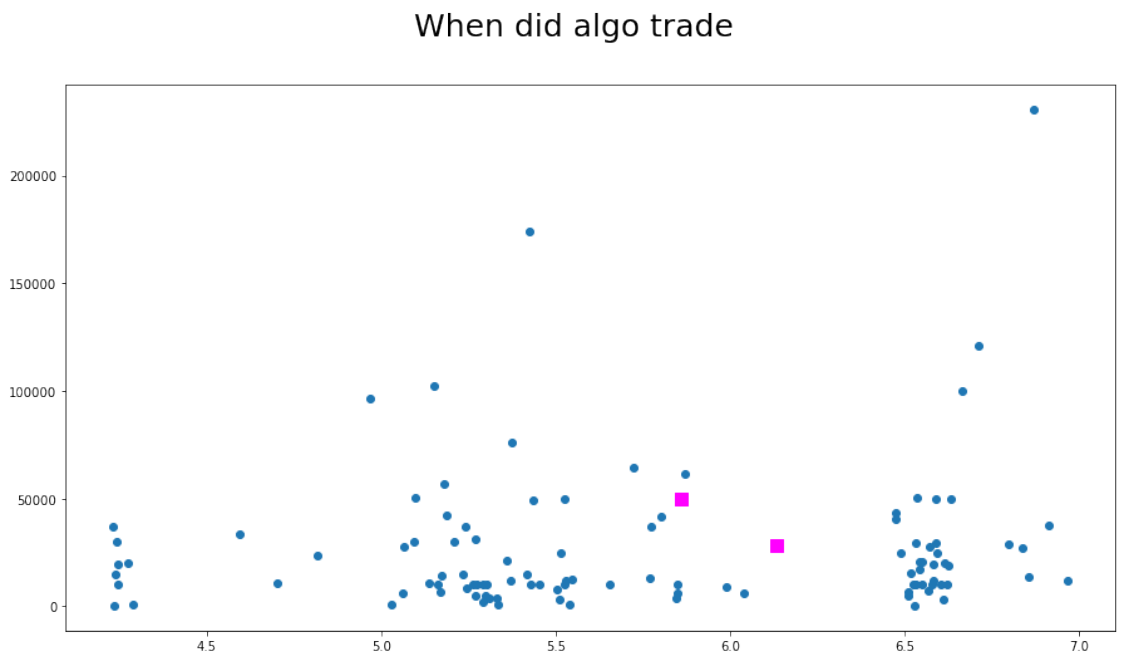
[199]:
```
                     Executed_Size  Price_of_Execution  Size_at_Bid       Bid  \
Dates
2020-05-05 10:05:29        50000.0                4.25          NaN       NaN
2020-05-05 10:06:37         1000.0                4.28      10000.0  4.220000
2020-05-05 10:14:31        20000.0                4.25          NaN       NaN
2020-05-05 10:14:53        10000.0                4.25          NaN       NaN
2020-05-05 10:15:23        96413.0                4.23     160084.0  4.226667

                     Size_at_Ask   Ask         volume_time  Volume  \
Dates
2020-05-05 10:05:29      20000.0  4.29 2020-05-05 10:05:00   50000
```

```
2020-05-05 10:06:37       9000.0  4.28 2020-05-05 10:06:00    1000
2020-05-05 10:14:31     115000.0  4.25 2020-05-05 10:14:00   30000
2020-05-05 10:14:53      25000.0  4.25 2020-05-05 10:14:00   30000
2020-05-05 10:15:23      13545.0  4.23 2020-05-05 10:15:00   96413

                     Cumulative Volume    Spread      vwap
Dates
2020-05-05 10:05:29                NaN       NaN       NaN
2020-05-05 10:06:37            51000.0  0.060000  4.289804
2020-05-05 10:14:31            81000.0       NaN  4.275062
2020-05-05 10:14:53            81000.0       NaN  5.849136
2020-05-05 10:15:23           177413.0  0.003333  4.969236
```

The higlighted in purple squares is where the algo traded.

[212]:
```
plt.suptitle('When did algo trade', fontsize='25')
plt.scatter(merged_clean_vwap['vwap'], merged_clean_vwap['Executed_Size'])
plt.scatter(merged_clean_vwap['vwap'][merged_clean_vwap.index == '05/05/2020 ␣
↪10:28:44'],merged_clean_vwap['Executed_Size'][merged_clean_vwap.index == '05/
↪05/2020  10:28:44'],  color="fuchsia", marker='s', s = 100)
plt.scatter(merged_clean_vwap['vwap'][merged_clean_vwap.index == '05/05/2020 ␣
↪10:41:33'],merged_clean_vwap['Executed_Size'][merged_clean_vwap.index == '05/
↪05/2020  10:41:33'],  color="fuchsia", marker='s', s = 100)
```

[212]:
```
<matplotlib.collections.PathCollection at 0x1d183744460>
```



[ ]:

The VWAPs at that moment resp. were:

[203]:
```
merged_clean_vwap[merged_clean_vwap.index == '05/05/2020  10:28:44']
```

[203]:
```
                     Executed_Size  Price_of_Execution  Size_at_Bid    Bid  \
Dates
2020-05-05 10:28:44        28353.0                 4.2     205919.0  4.195

                     Size_at_Ask  Ask         volume_time  Volume  \
Dates
2020-05-05 10:28:44      81547.0  4.2 2020-05-05 10:28:00  252013

                     Cumulative Volume  Spread      vwap
Dates
2020-05-05 10:28:44           688666.0   0.005  6.132606
```

[204]:
```
merged_clean_vwap[merged_clean_vwap.index == '05/05/2020  10:41:33']
```

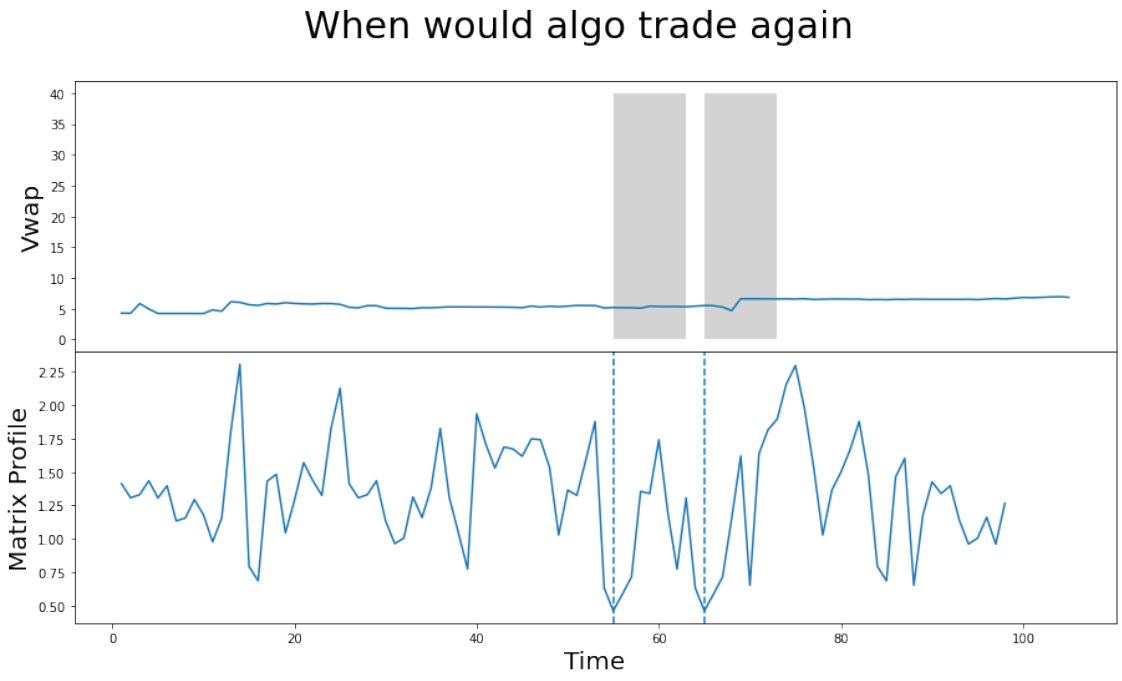
[204]:
```
                     Executed_Size  Price_of_Execution  Size_at_Bid  Bid  \
Dates
2020-05-05 10:41:33        50000.0                 4.2          NaN  NaN

                     Size_at_Ask  Ask         volume_time  Volume  \
Dates
2020-05-05 10:41:33     353836.0  4.2 2020-05-05 10:41:00   62426

                     Cumulative Volume  Spread     vwap
Dates
2020-05-05 10:41:33           842815.0     NaN  5.85851
```

Now, let's try running the stumpy procedure again.

[209]:
```
#finding motif via stumpy package for vwap
m = 8
mp = stumpy.stump(merged_clean_vwap['vwap'], m)


motif_idx = np.argsort(mp[:, 0])[0]
print(f"The motif is located at index {motif_idx}")


nearest_neighbor_idx = mp[motif_idx, 1]
print(f"The nearest neighbor is located at index {nearest_neighbor_idx}")

fig, axs = plt.subplots(2, sharex=True, gridspec_kw={'hspace': 0})
plt.suptitle('When would algo trade again', fontsize='30')
```

```
axs[0].plot(merged_clean_vwap['vwap'].values)
axs[0].set_ylabel('Vwap', fontsize='20')
rect = Rectangle((motif_idx, 0), m, 40, facecolor='lightgrey')
axs[0].add_patch(rect)
rect = Rectangle((nearest_neighbor_idx, 0), m, 40, facecolor='lightgrey')
axs[0].add_patch(rect)
axs[1].set_xlabel('Time', fontsize ='20')
axs[1].set_ylabel('Matrix Profile', fontsize='20')
axs[1].axvline(x=motif_idx, linestyle="dashed")
axs[1].axvline(x=nearest_neighbor_idx, linestyle="dashed")
axs[1].plot(mp[:, 0])
plt.show()
```

```
The motif is located at index 65
The nearest neighbor is located at index 55
```



[210]:
```
merged_clean_vwap[merged_clean_vwap.index == merged_clean_vwap.index[55]]
```

[210]:

Dates	Executed_Size	Price_of_Execution	Size_at_Bid	Bid	\
2020-05-05 12:22:30	29783.0	4.15	20217.0	4.15	

Dates	Size_at_Ask	Ask	volume_time	Volume	\

```
2020-05-05 12:22:30      26090.0  4.155 2020-05-05 12:22:00   40461

                     Cumulative Volume  Spread      vwap
Dates
2020-05-05 12:22:30          2276651.0   0.005  5.209298
```

[208]:
```
merged_clean_vwap[merged_clean_vwap.index == merged_clean_vwap.index[65]]
```

[208]:
```
                     Executed_Size  Price_of_Execution  Size_at_Bid    Bid  \
Dates
2020-05-05 12:42:43        50000.0                4.15      77421.0  4.145

                     Size_at_Ask       Ask         volume_time  Volume  \
Dates
2020-05-05 12:42:43     185223.0  4.151667 2020-05-05 12:42:00   64000

                     Cumulative Volume    Spread      vwap
Dates
2020-05-05 12:42:43          2759083.0  0.006667  5.525013
```

As we can see these blocks are very similar to the ones indicated as executed by the algo but at better VWAPs (5.209 and 5.52 compared to 6.13 and 5.85 earlier). In the plot marked as green diamonds are the suggested blocks.

[211]:
```
plt.suptitle('When would algo trade again', fontsize='30')
plt.scatter(merged_clean_vwap['vwap'], merged_clean_vwap['Executed_Size'])
plt.scatter(merged_clean_vwap['vwap'][merged_clean_vwap.index ==␣
 ↪merged_clean_vwap.
 ↪index[65]],merged_clean_vwap['Executed_Size'][merged_clean_vwap.index ==␣
 ↪merged_clean_vwap.index[65]],  color="lime", s=80, marker='D')
plt.scatter(merged_clean_vwap['vwap'][merged_clean_vwap.index ==␣
 ↪merged_clean_vwap.
 ↪index[55]],merged_clean_vwap['Executed_Size'][merged_clean_vwap.index ==␣
 ↪merged_clean_vwap.index[55]],  color="lime", s=80, marker='D')
plt.scatter(merged_clean_vwap['vwap'][merged_clean_vwap.index == '05/05/2020 ␣
 ↪10:28:44'],merged_clean_vwap['Executed_Size'][merged_clean_vwap.index == '05/
 ↪05/2020  10:28:44'],  color="fuchsia", marker='s', s = 100)
plt.scatter(merged_clean_vwap['vwap'][merged_clean_vwap.index == '05/05/2020 ␣
 ↪10:41:33'],merged_clean_vwap['Executed_Size'][merged_clean_vwap.index == '05/
 ↪05/2020  10:41:33'],  color="fuchsia", marker='s', s = 100)
plt.text(merged_clean_vwap['vwap'][merged_clean_vwap.index == merged_clean_vwap.
 ↪index[65]]-0.2,merged_clean_vwap['Executed_Size'][merged_clean_vwap.index ==␣
 ↪merged_clean_vwap.index[65]]+10000,"Algo trades here", fontsize=12)
plt.text(merged_clean_vwap['vwap'][merged_clean_vwap.index == merged_clean_vwap.
 ↪index[55]]-0.2,merged_clean_vwap['Executed_Size'][merged_clean_vwap.index ==␣
 ↪merged_clean_vwap.index[55]]+10000,"Algo trades here", fontsize=12)
```

[211]: Text(Dates
2020-05-05 12:22:30   5.009298
Name: vwap, dtype: float64, Dates
2020-05-05 12:22:30   39783.0
Name: Executed_Size, dtype: float64, 'Algo trades here')