It has been more than a year since my last post, I've been super busy with consulting assignments working on algorithmic/electronic trading. The workload is still heavy but I managed to find a few hours to write this post as I came across a new great tool: **LOBSTER** (and before anyone asks I've no link whatsoever with the company)

LOBSTER stands for: Limit Order Book System – The Efficient Reconstructor. This is an online limit order book data tool to provide easy-to-use, high-quality limit order book data. Since 2013 LOBSTER acts as a data provider for the academic community, giving access to reconstructed limit order book data for the entire universe of NASDAQ traded stocks

I really wanted to test the data and in a effort to sharpen my Python knowledge, I decided to translate the R code LOBSTER makes available on its website (here) into Python.

The data

LOBSTER provides 3 sample files: an '**orderbook**' file, a '**message**' file and a '**readme**' file summarizing the data's properties. All sample files are based on the official NASDAQ Historical **TotalView-ITCH** sample.

There is an 'orderbook' and a 'message' file for each active trading day of a selected ticker. The 'orderbook' file contains the evolution of the limit order book up to the requested number of levels (up to 50). The 'message' file contains indicators for the type of event causing an update of the limit order book in the requested price range. All events are timestamped to seconds after midnight, with decimal precision of at least milliseconds and up to nanoseconds depending on the requested period.

Both the 'message' and 'orderbook' files are provided in the .CSV format and can easily be red with any statistical software package. The detailed structure of the message and orderbook files are described on LOBSTER website

The code

I adapted the code found on LOBSTER website and in some cases I had to do some adjustments. In particular I downloaded the data manually for a specific date from LOBSTER website (I wanted to focus on the analysis). Overall both R and Python implementations are very similar i.e. they both create an almost identical output.

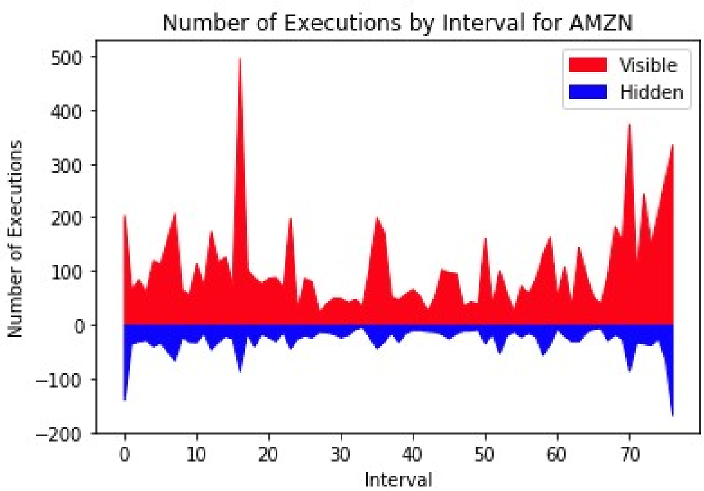
```
"""
Test on LOBSTER data
Convert LOBSTER R demo code into python (https://lobsterdata.com)

Dec. 2019 - thertrader@gmail.com
"""
import pandas as pd
from matplotlib import pyplot as plt
import os
import itertools as it

# change the current directory
os.chdir(r"/home/arno/work/research/lobster")

# Message file information:
# ----------------------------------------------------------
#
#   - Dimension:    (NumberEvents x 6)
#
#   - Structure:    Each row:
#                   Time stamp (sec after midnight with decimal
#                   precision of at least milliseconds and
#                   up to nanoseconds depending on the period),
#                   Event type, Order ID, Size (# of shares),
#                   Price, Direction
```

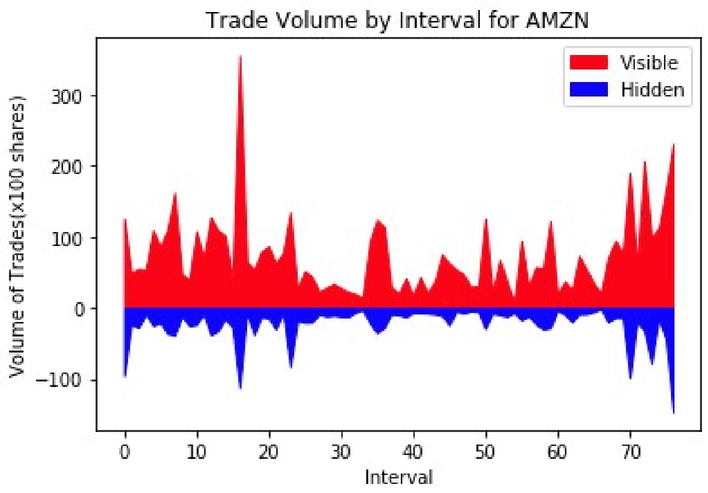
```
#
#                   Event types:
#                       - '1'   Submission new limit order
#                       - '2'   Cancellation (partial)
#                       - '3'   Deletion (total order)
#                       - '4'   Execution of a visible limit order
#                       - '5'   Execution of a hidden limit order
#                       - '7'   Trading Halt (Detailed information below)
#
#                   Direction:
#                       - '-1'  Sell limit order
#                       - '-2'  Buy limit order
#                       - NOTE: Execution of a sell (buy)
#                               limit order corresponds to
#                               a buyer-(seller-) initiated
#                               trade, i.e. a BUY (SELL) trade.
#
# ------------------------------------------------------------
ticker = 'AMZN'

theMessageBookFileName = "AMZN_2012-06-21_34200000_57600000_message_10.csv"

theMessageBook = pd.read_csv(theMessageBookFileName, names = ['Time','Type','OrderID',
Size','Price','TradeDirection'])

startTrad = 9.5*60*60       # 9:30:00.000 in ms after midnight
endTrad = 16*60*60        # 16:00:00.000 in ms after midnight

theMessageBookFiltered = theMessageBook[theMessageBook['Time'] >= startTrad]
theMessageBookFiltered = theMessageBookFiltered[theMessageBookFiltered['Time'] <=
endTrad]


# Note: As the rows of the message and orderbook file correspond to each other, the ti
index of
# the message file can also be used to 'cut' the orderbook file.

# Check for trading halts code (left untouched for now)
# ------------------------------------------------------------
tradingHaltIdx = theMessageBookFiltered.index[(theMessageBookFiltered.Type == 7) &
(theMessageBookFiltered.TradeDirection == -1)]

tradeQuoteIdx = theMessageBookFiltered.index[(theMessageBookFiltered.Type == 7) &
(theMessageBookFiltered.TradeDirection == 0)]

tradeResumeIdx = theMessageBookFiltered.index[(theMessageBookFiltered.Type == 7) &
(theMessageBookFiltered.TradeDirection == 1)]


if (len(tradingHaltIdx) == 0 | len(tradeQuoteIdx) == 0  | len(tradeResumeIdx) == 0):
    print("No trading halts detected.")

if(len(tradingHaltIdx) != 0):
        print("Data contains trading halt! at time stamp(s): ");
print(list(tradingHaltIdx))

if(len(tradeQuoteIdx) != 0):
```

```
        print(" Data contains quoting message! at time stamp(s)");
print(list(tradeQuoteIdx))

if(len(tradeResumeIdx) != 0):
        print(" Data resumes trading! at time stamp(s) "); print(list(tradeResumeIdx))


# -----------------------------------------------------------
#               When trading halts, a message of type '7' is written into the
#               'message' file. The corresponding price and trade direction
#               are set to '-1' and all other properties are set to '0'.
#               Should the resume of quoting be indicated by an additional
#               message in NASDAQ's Historical TotalView-ITCH files, another
#               message of type '7' with price '0' is added to the 'message'
#               file. Again, the trade direction is set to '-1' and all other
#               fields are set to '0'.
#               When trading resumes a message of type '7' and
#               price '1' (Trade direction '-1' and all other
#               entries '0') is written to the 'message' file. For messages
#               of type '7', the corresponding order book rows contain a
#               duplication of the preceding order book state. The reason
#               for the trading halt is not included in the output.
#
#               Example: Stylized trading halt messages in 'message'
file.
#
#               Halt:                   36023   | 7 | 0 | 0 | -1 | -1
#
...
#               Quoting:                36323   | 7 | 0 | 0 | 0  | -1
#
...
#               Resume Trading:         36723   | 7 | 0 | 0 | 1  | -1
#
...
#               The vertical bars indicate the different columns in the
#               message file.

# Set Bounds for Intraday Intervals
# -----------------------------------------------------------

# Define interval length
freq = 5 * 60   # Interval length in ms 5 minutes

# Number of intervals from 9:30 to 4:00
noint = int((endTrad-startTrad)/freq)
theMessageBookFiltered.index = range(0,len(theMessageBookFiltered),1)

# Variables for 'for' loop
j = 0
l = 0
bound = []                # Variable for inverval bound
visible_count = []         # visible_count calculates the number of visible trades in a
interval of 5 min
hidden_count = []          # hidden_count calculates the number of visible trades in an
interval of 5 min
visible_size = []          # Total volume of visible trades in an interval of 5 minutes
```

```
hidden_size = []          # Total volume of hidden trades in an interval of 5 minutes

# Set Bounds for Intraday Intervals
bound = []
for j in range(0,noint):
    bound.append(startTrad + j * freq)

#______________________________________________________________________________
#
# Plot - Number of Executions and Trade Volume by Interval
#______________________________________________________________________________

# Note: Difference between trades and executions
#
#    The LOBSTER output records limit order executions
#    and not what one might intuitively consider trades.
#
#    Imagine a volume of 1000 is posted at the best ask
#    price. Further, an incoming market buy order of
#    volume 1000 is executed against the quote.
#
#    The LOBSTER output of this trade depends on the
#    composition of the volume at the best ask price.
#    Take the following two scenarios with the best ask
#        volume consisting of ...
#       (a) 1 sell limit order with volume 1000
#       (b) 5 sell limit orders with volume 200 each
#               (ordered according to time of submission)
#
#     The LOBSTER output for case ...
#       (a) shows one execution of volume 1000. If the
#           incoming market order is matched with one
#           standing limit order, execution and trade
#           coincide.
#       (b) shows 5 executions of volume 200 each with the
#           same time stamp. The incoming order is matched
#           with 5 standing limit orders and triggers 5
#           executions.
#
#       Bottom line:
#       LOBSTER records the exact limit orders against
#       which incoming market orders are executed. What
#       might be called 'economic' trade size has to be
#       inferred from the executions.


# Logic to calculate number of visible/hidden trades and their volume
for l in range(1,noint):
    visible_count.append(len(theMessageBookFiltered[(theMessageBookFiltered.Time >
bound[l-1]) & (theMessageBookFiltered.Time < bound[l]) & (theMessageBookFiltered.Type =
4)]))
    visible_size.append(sum(theMessageBookFiltered['Size'][(theMessageBookFiltered.Time
> bound[l-1]) & (theMessageBookFiltered.Time < bound[l]) & (theMessageBookFiltered.Type
== 4)])/100)

    hidden_count.append(len(theMessageBookFiltered[(theMessageBookFiltered.Time >
bound[l-1]) & (theMessageBookFiltered.Time < bound[l]) & (theMessageBookFiltered.Type =
```

```
5)]))
    hidden_size.append(sum(theMessageBookFiltered['Size'][(theMessageBookFiltered.Time
bound[l-1]) & (theMessageBookFiltered.Time < bound[l]) & (theMessageBookFiltered.Type =
5)])/100)


# First plot : Number of Execution by Interval (Visible + Hidden)
plt.title('Number of Executions by Interval for ' + ticker)
plt.fill_between(range(0,len(visible_count)),
                 visible_count,
                 color = '#fc0417',
                 label = 'Visible')
plt.ylabel('Number of Executions')
plt.xlabel('Interval')
plt.legend()

plt.fill_between(range(0,len(visible_count)),
         [x * (-1) for x in hidden_count],
         color = '#0c04fc',
         label = 'Hidden')
plt.legend()
plt.show()

# Second plot : Trade Volume by Interval (Visible + Hidden)
plt.title('Trade Volume by Interval for ' + ticker)
plt.fill_between(range(0,len(visible_size)),
                 visible_size,
                 color = '#fc0417',
                 label = 'Visible')
plt.ylabel('Volume of Trades(x100 shares)')
plt.xlabel('Interval')
plt.legend()

plt.fill_between(range(0,len(visible_size)),
         [x * (-1) for x in hidden_size],
         color = '#0c04fc',
         label = 'Hidden')
plt.legend()
plt.show()
```

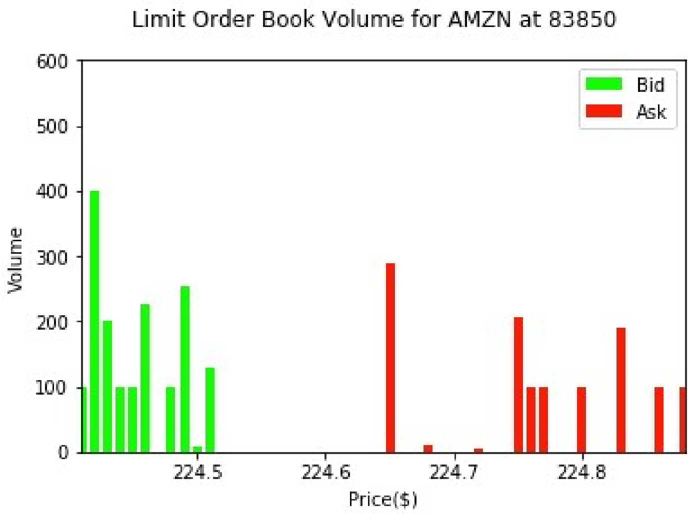




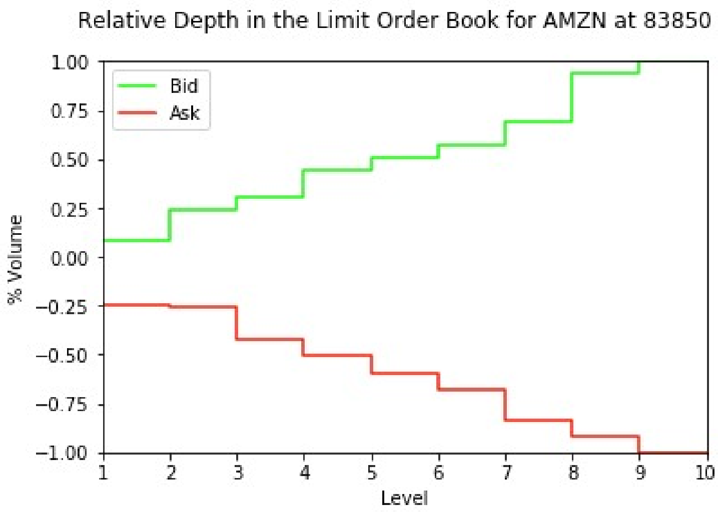

```
#______________________________________________________________________________
#
# Load Order Book File
#______________________________________________________________________________
nlevels = 10

# Load data
theOrderBookFileName = "AMZN_2012-06-21_34200000_57600000_orderbook_10.csv"

col = ['Ask Price ','Ask Size ','Bid Price ','Bid Size ']

theNames = []
for i in range(1, nlevels + 1):
    for j in col:
        theNames.append(str(j) + str(i))

theOrderBook = pd.read_csv(theOrderBookFileName, names = theNames)

# Orderbook file information:
# ----------------------------------------------------------
#
#   - Dimension:    (NumberEvents x (NumberLevels*4))
#
#   - Structure:    Each row:
#                   Ask price 1, Ask volume 1, Bid price 1,
#                   Bid volume 1, Ask price 2, Ask volume 2,
#                   Bid price 2, Bid volume 2, ...
#
#   - Note:         Unoccupied bid (ask) price levels are
#                   set to -9999999999 (9999999999) with volume 0.
#
# ----------------------------------------------------------

#______________________________________________________________________________
#
# Data Preparation - Order Book File
#______________________________________________________________________________

# Take only order books during the continuous trading period
# from 9:30:00 to 16:00:00
# ----------------------------------------------------------
# Trading hours (start & end)  16:00:00.000 in ms after midnight
```

```
timeIndex = theMessageBook.index[(theMessageBook.Time >= startTrad) &
(theMessageBook.Time <= endTrad)]

theOrderBookFiltered = theOrderBook[theOrderBook.index == timeIndex]
# Convert prices into dollars
#    Note: LOBSTER stores prices in dollar price times 10000

for i in list(range(0,len(theOrderBookFiltered.columns),2)):
    theOrderBookFiltered[theOrderBookFiltered.columns[i]]  = theOrderBookFiltered[
theOrderBookFiltered.columns[i]]/10000

#_____________________________________________________________________________
#
# Plot - Snapshot of the Limit Order Book
#_____________________________________________________________________________
# Note: Pick a random row/event from the order book
totalrows = len(theOrderBookFiltered)
random_no = np.random.choice(range(0,totalrows+1), size = None, replace = False, p =
None)

theAsk = theOrderBookFiltered[theOrderBookFiltered.columns[range(0,len(
theOrderBookFiltered.columns),4)]]
theAskVolume = theOrderBookFiltered[theOrderBookFiltered.columns[range(1,len(
theOrderBookFiltered.columns),4)]]

theAskValues = list(it.chain.from_iterable(theAsk[theAsk.index == random_no].values))
theAskVolumeValues = list(it.chain.from_iterable(theAskVolume[theAskVolume.index ==
random_no].values))
theDataAsk = pd.DataFrame({'Price': theAskValues, 'Volume': theAskVolumeValues})
theDataAsk = theDataAsk.sort_values(by=['Price'])

theBid = theOrderBookFiltered[theOrderBookFiltered.columns[range(2,len(
theOrderBookFiltered.columns),4)]]
theBidVolume = theOrderBookFiltered[theOrderBookFiltered.columns[range(3,len(
theOrderBookFiltered.columns),4)]]

theBidValues = list(it.chain.from_iterable(theBid[theBid.index == random_no].values))
theBidVolumeValues = list(it.chain.from_iterable(theBidVolume[theBidVolume.index ==
random_no].values))
theDataBid = pd.DataFrame({'Price': theBidValues, 'Volume': theBidVolumeValues})
theDataBid = theDataBid.sort_values(by=['Price'])

# Chart
fig = plt.figure()
ax = fig.add_subplot(111)

plt.ylim(0,max(theDataBid['Volume'].max(),theDataAsk['Volume'].max()) + 200)
plt.xlim(min(theDataBid['Price'].min(),theDataAsk['Price'].min()),
max(theDataBid['Price'].max(),theDataAsk['Price'].max()))
plt.suptitle('Limit Order Book Volume for ' + ticker + ' at ' + str(random_no))
plt.ylabel('Volume')
plt.xlabel('Price($)')

ax.bar(theDataBid['Price'], theDataBid['Volume'], width = 0.007, color='#13fc04',
label='Bid')
ax.bar(theDataAsk['Price'], theDataAsk['Volume'], width = 0.007, color='#fc1b04',
label='Ask')
```

```
plt.legend()
plt.show()
```

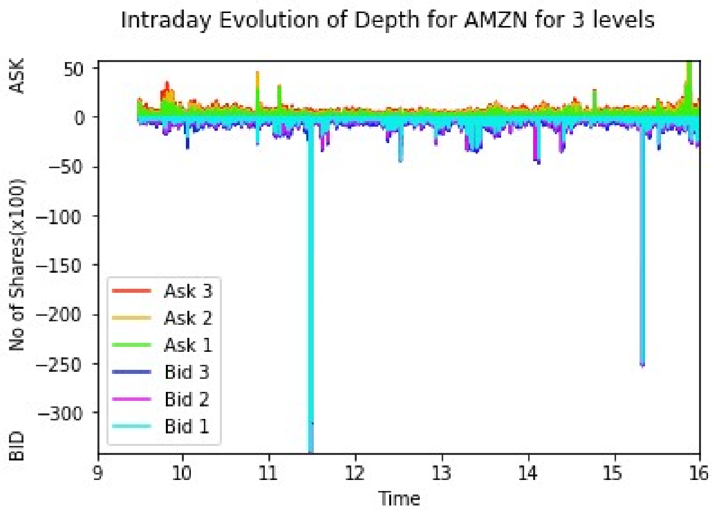



```
#_____________________________________________________________________________
#
# Plot - Relative Depth in the Limit Order Book
#_____________________________________________________________________________
# Plot variables
theAskVolume = theOrderBookFiltered[theOrderBookFiltered.columns[range(1,len(
theOrderBookFiltered.columns),4)]]
totalSizeAsk = list(theAskVolume[theAskVolume.index == random_no].values.cumsum())
percentAsk = totalSizeAsk/totalSizeAsk[len(totalSizeAsk)-1]

theBidVolume = theOrderBookFiltered[theOrderBookFiltered.columns[range(3,len(
theOrderBookFiltered.columns),4)]]
totalSizeBid = list(theBidVolume[theBidVolume.index == random_no].values.cumsum())
percentBid = totalSizeBid/totalSizeBid[len(totalSizeBid)-1]

# Chart
fig = plt.figure()
ax = fig.add_subplot(111)

plt.ylim(-1,1)
plt.xlim(1,10)
plt.suptitle('Relative Depth in the Limit Order Book for ' + ticker + ' at ' +
str(random_no))
plt.ylabel('% Volume')
plt.xlabel('Level')

ax.step(list(range(1,11)), percentBid, color='#13fc04', label='Bid')
ax.step(list(range(1,11)), -percentAsk, color='#fc1b04', label='Ask')

plt.legend()
plt.show()
```




```
#_____________________________________________________________________________
#
# Plot - Intraday Evolution of Depth
#_____________________________________________________________________________
# Calculate the max/ min volume to set limit of y-axis
maxAskVol = max(theOrderBookFiltered['Ask Size 1'].max()/100,theOrderBookFiltered['Ask Size 2'].max()/100,theOrderBookFiltered['Ask Size 3'].max()/100)  # calculate the maximum ask volume

# Calculate the max Bid volume , we use negative here and calculate min as we plot Bid below X-axis
maxBidVol = min(-theOrderBookFiltered['Bid Size 1'].max()/100,-theOrderBookFiltered['B
Size 2'].max()/100,-theOrderBookFiltered['Bid Size 3'].max()/100)  # calculate the maximum ask volume

aa = range(int(theMessageBookFiltered['Time'].min()/(60*60)),
int(theMessageBookFiltered['Time'].max()/(60*60))+2)
theTime = [int(i) for i in aa]

fig = plt.figure()
ax = fig.add_subplot(111)

plt.ylim(maxBidVol,maxAskVol)
plt.xlim(theTime[0],theTime[len(theTime)-1])
plt.suptitle('Intraday Evolution of Depth for ' + ticker + ' for 3 levels')
plt.ylabel('BID              No of Shares(x100)               ASK')
plt.xlabel('Time')
#plt.grid(True)

askSizeDepth3 = (theOrderBookFiltered['Ask Size 1']/100) + (theOrderBookFiltered['Ask Size 2']/100) + (theOrderBookFiltered['Ask Size 3']/100)
ax.plot((theMessageBookFiltered['Time']/(60*60)),
        askSizeDepth3,
        color='#fc1b04',
        label='Ask 3')

askSizeDepth2 = (theOrderBookFiltered['Ask Size 1']/100) + (theOrderBookFiltered['Ask Size 2']/100)
ax.plot((theMessageBookFiltered['Time']/(60*60)),
        askSizeDepth2,
        color='#eeba0c',
        label='Ask 2')
```

```
askSizeDepth1 = (theOrderBookFiltered['Ask Size 1']/100)
ax.plot((theMessageBookFiltered['Time']/(60*60)),
        askSizeDepth1,
        color='#3cee0c',
        label='Ask 1')

bidSizeDepth3 = (theOrderBookFiltered['Bid Size 1']/100) + (theOrderBookFiltered['Bid
Size 2']/100) + (theOrderBookFiltered['Bid Size 3']/100)
ax.plot((theMessageBookFiltered['Time']/(60*60)),
        -bidSizeDepth3,
        color='#0c24ee',
        label='Bid 3')

bidSizeDepth2 = (theOrderBookFiltered['Bid Size 1']/100) + (theOrderBookFiltered['Bid
Size 2']/100)
ax.plot((theMessageBookFiltered['Time']/(60*60)),
        -bidSizeDepth2,
        color='#e40cee',
        label='Bid 2')

bidSizeDepth1 = (theOrderBookFiltered['Bid Size 1']/100)
ax.plot((theMessageBookFiltered['Time']/(60*60)),
        -bidSizeDepth1,
        color='#0ceee7',
        label='Bid 1')

plt.legend()
plt.show()
```



As usual any comments welcome