Cryptocurrency Orderbook Analysis Tool

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Contents

1 Introduction

This project is an extension of my thesis, A Study of CUSUM Statistics on Bitcoin Transactions, where I was tasked with implementing CUSUM statistic processes to identify price actions periods in bitcoin markets. After developing a tool for market orders, the natural extension was to find relationships from activities in the limit order book. I started developing this tool to record instances of the limit order book in order to record Limit Order insertions (LO), cancellations (CO), and Market Orders (MO).

As the project grew I wanted to make a tool that could be used by academics looking to apply and develop market microstructure models in live markets. As a result, the styles in which the limit order book and order book events are recorded are being developed in accordance to the conventions presented in recent market microstructure papers correspond to the following papers:

1. Huang W., Lehalle C.A. and Rosenbaum M. - Simulating and analyzing order book data:The queue-reactive model[1]

2. Cont R., Stoikov S. and Talreja R. - A stochastic model for order book dynamics[5]

3. Cont R., Kukanov A. and Stoikov S. - The price impact of order book events[4]

4. Cartea. A, Jaimungal S. and Wang Y. - Spoofing and Price Manipulation in Order Driven Markets[2]

5. Silyantev, E. - Order flow analysis of cryptocurrency markets[6][1]

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[1]This paper shows a working model implementing Order Flow Imbalance (OFI) and Trade Flow Imbalance(TFI) to BTC-USD trades was done by Ed Silyantev. He developed a tool to assess OFI and TFI of XBT-USD pair.

2   crobat Features

2.1   Orderbook updating

- Order book recording module that maintains a time-series of:

    1. Limit order insertions, cancellations and market orders,
    2. volumes at n^{th} best limits, and
    3. prices at n^{th} best limits.

- Outputs these time-series objects as .xlsx files.

3   Getting Started and Installation

3.1   CoPrA

3.2   Installation

This project is a work in progress. I suggest you fork the project, and clone to your local environment. The file `csv_out.py` located in crobat/crobat/test/ will contain a basic testing environment for a set length.

Note: crobat is not an optimized order book implementation and may not be I/O bound. This suboptimality is due to frequent scanning of all prices for insertion forces the complexity to be greater than $\sim O(n)$ for n being the length of the snapshot being iterated over. You may find that depending on the popularity of the asset and the computational power of your PC, you may run into errors arising from the computer not being able to keep up with the market (especially BTC-USD). I would suggest experimenting with an unpopular pair, (e.g., XRP-USD), or a crypto-crypto pair (e.g., XRP-BTC), and timing your queries outside of NYSE, and London Stock Exchange trading hours as they tend to have less activity.

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however if you want an easy installation:

"'pip3 install crobat"'

4   Time-series Data Structure Layout

4.1   Introduction

Since this is an order book *recorder* my use until now has been to record the order book. However there are accessors in the `LOB_funcs.py` file, under in the `history` class. In the /test folder there is a small use case called `csv_out_test.py` wiith the associated jupyter notebook pending.

1. For now we only have the full order book and we call that `recorder_full.py`.
2. We change the `settings` variable in the `CSV_out_test.py` file that has arguments for:

Parameter	Function Arg	Type/Format	Description
Recording Duration	`duration`	`int`	recording time in seconds
Position Range	`position_range`	`int`	ordinal distance from the best bid(ask)
Currency Pair	`currency_pair`	`str`	The currency pair from list of supported pairs

2

3. When you are ready, you can start the build. When it finishes you should get a message `Connection Closed` from CoPrA. And the files for the limit order book for each side should be created with a timestamp in the form YYYY-MM-DDTHH:MM:SS.ffffff. Currently it will output everything given in the table below, but I will update the function to only output select things for people.

Filename	side	Time Series Description
L2_orderbook_events_ask+timestamp	ask	Order book events on the ask side
L2_orderbook_events_bid+timestamp	bid	Order book events on the bid side
L2_orderbook_events_signed+timestamp	both	Order book events on both sides, - sign for bid, +sign for ask
L2_orderbook_ask_volm+timestamp	ask	Volume snapshots of order book on the ask side
L2_orderbook_bid_volm+timestamp	bid	Volume snapshots of order book on the bid side
L2_orderbook_signed_volm+timestamp	both	Volume snapshots of the signed order book, - sign for bid, + sign for ask
L2_orderbook_ask_volm+timestamp	ask	Price snapshots of order book on the ask side
L2_orderbook_bid_volm+timestamp	bid	Price snapshots of order book on the bid side
L2_orderbook_signed_volm+timestamp	both	Price snapshots of the signed order book, - sign for bid, +sign for ask

4.2   Understanding The Raw Order Book Data

The Coinbase exchange operates using the double auction model, the Coinbase Pro API, and by extension the CoPrA API makes it relatively easy to get still images of an instance of the orderbook as `snapshots` and it sends updates in real time of the volume at a particular price level as `l2_update` messages. If you would like to know more O'Hara's book[3] does a great job introducing the double auction model for the purposes of defining the types of orders, and how they record events and make sense of them.

4.2.1   Order Book Snapshots

Private data providers (e.g., NASDAQ - BookViewer,LOBSTER provide reconstructions of order books. Coinbase updates the levels on the instance of a update message from the exchange of the order book. The format of the order book snapshot at time t is a $2 \times n$ array for n price levels, where the first element is the price-level, and the second element is the volume at that price-level. The time series of order book snapshots is also an array with dimensions $2 \times m$, for m recorded timestamps, where the first element is the timestamp,t_m, and the second element contains the entire $2 \times n$ snapshot at t_m.

Event recording are a time series of MO, LO, CO's as afforded from the `l2_update` messages which are used to update the price, volume pair size at each price level. The format of the Event recorder is as follows:

Item	Description	format
Timestamp	Timestamp of when the event occurred	YYYY-MM-DDTHH:MM:SS.ffffff
order type	MO, LO, CO	str $\in$ {'market','limit', 'cancellation'}
price level	price of event occurrence in quote currency	float64
event size	size of event in base currency	float64
position	signed position ($-$ for bids, $+$ for asks)	int
mid price	(best-ask + best-bid)/2	float64
spread	best-ask + best-bid	float64

4.2.2 Signed Order Book

4.2.2.1 Signed Order Book Snapshot Prices The signed orderbook takes a different approach to position labelling so please keep that in mind. (note: I should shift the position index to start at 1, for singe side order book snapshot time series). The signed orderbook snapshot is generated in a similar fashion with a volume, and price at each position. However, it uses the convention established in [3] for the signed order book. where positions on the bid are negative, with negative volume (XTC). I'll show the default setting that displays the 5 best bids and asks on each side.

Item	Description/Format
Timestamp	YYYY-MM-DDTHH:MM:SS.ffffff
$-n$	price quote at the nth best bid (i.e., worst bid)
$-n+1$	aggregate XTC limit buys at the second to worst bid
$\ldots$	$\ldots$
-2	aggregate XTC being bid for at the 2nd best bid
-1	aggregate XTC limit being bid for at the best bed bid
1	aggregate XTC offered at the best ask
2	aggregate XTC offered at the 2nd best ask
$\ldots$	$\ldots$
$n-1$	aggregate XTC offered at the second worst ask
n	aggregate XTC offered at the worst ask

Similar to the single side implementation, there is an associated price quote (e.g., USD per XTC) snapshot generated at each timepoint. The default format is given below:

Item	Description/Format
Timestamp	YYYY-MM-DDTHH:MM:SS.ffffff
$-n$	price quote at the nth best bid (i.e., worst bid)
$-n+1$	price quote at the second to worst bid
$\ldots$	$\ldots$
-2	price quote at the 2nd best bid
-1	price quote at the best bed bid
1	price quote at the best ask
2	price quote at the 2nd best ask
$\ldots$	$\ldots$
$n-1$	price quote at the second worst ask
n	price quote at the worst ask

4.2.2.2 Signed Events

Signed event recordings follow the convention from The Price impact of Orderbook events, where positive order flow is due to MO's on the buy side, CO on the sell side, and LO on the buy side. Conversely, negative order flow is due to MO's on the sell side, CO on the buy side, and LO on the buy side. The format is similar to the single side order book events time-series, but the order volume is signed based on the aforementioned construction.

Item	Description	format
Timestamp	Timestamp of when the event occurred	YYYY-MM-DDTHH:MM:SS.ffffff
order type	MO, LO, CO	str $\in$ {'market','limit', 'cancellation'}
price level	price of event occurrence in quote currency	float64
event size	size of event in base currency	float64
position	signed position (– for bids, + for asks)	int
side	bid/ask side where the event occurs	str $\in$ {'buy','sell'}
mid price	(best-ask + best-bid)/2	float64
spread	best-ask + best-bid	float64

4.3   Final notes on Orderbook interpretation

write about how the program object sees the orderbook with an example of code.

Start

5   Usage

Preface: crobat is used with an open websocket connection to the Coinbase exchange. It uses CoPrA to parse JSON objects, and it records time series arrays of order book snapshots and events.

We demonstrate where crobat is used by beginning with CoPrA's `heartbeat.py` example:

```python
import asyncio

from copra.websocket import Channel, Client

loop = asyncio.get_event_loop()

ws = Client(loop, Channel('heartbeat', 'BTC-USD'))

try:
    loop.run_forever()
except KeyboardInterrupt:
    loop.run_until_complete(ws.close())
loop.close()
```

If we were to execute the code, we would run methods in the instance of the class `Client` based on the arrival of messages on the heartbeat channel for the pair BTC-USD. crobat primarily inherits methods from this class and adds logic for managing incoming messages. Below we introduce our own version of this loop found in `CSV_out.py`.

```python
import recorder_full as rec
import asyncio, time
from datetime import datetime
import copra.rest
from copra.websocket import Channel, Client

class input_args(object):
    def __init__(self, currency_pair='ETH-USD', position_range=5, recording_duration=5):
        self.currency_pair = currency_pair
        self.position_range = position_range
        self.recording_duration = recording_duration

def main():
    settings_1 = input_args()

    loop = asyncio.get_event_loop()

    channel1 = Channel('level2', settings_1.currency_pair)
    channel2 = Channel('ticker', settings_1.currency_pair)

    ws_1 = rec.L2_Update(loop, channel1, settings_1)
    ws_1.subscribe(channel2)

    timestart=datetime.utcnow()

try:
    loop.run_forever()
except KeyboardInterrupt:
    loop.run_until_complete(ws_1.close())
    loop.close()

if __name__ == '__main__':
    main()
```

In this modified event loop we have the context where the bulk of crobat sits, the class l2_update. we can the `loop` object that is passed to `ws_1`, the instance of the class `L2_Update`, receives `msg` objects through the async methods inherited from Client. Here we give an example of what `l2_Update` looks like:

```python
import asyncio, time
from datetime import datetime
import copra.rest
from copra.websocket import Channel, Client

class L2_Update(Client):
  def __init__(self, loop, channel, input_args):
    self.time_now = datetime.utcnow() #initial start time
    self.position_range = input_args.position_range
    self.recording_duration = input_args.recording_duration
    self.snap_received = False
    super().__init__(loop, channel)

  def on_open(self):
    print("Let's count the L2 messages!", self.time_now)
    super().on_open() # inheriting things from the parent class who really knows

  def on_message(self, msg):
    if msg['type'] in ['snapshot']:
      print("received the snapshot")
      time = self.time_now
      self.snap_received = True
    if msg['type'] in ['ticker']:
      print("received ticker message")
      if self.snap_received:
        # Do Something Here
      else:
        print("market order arrived but no snapshot received yet")

    if msg['type'] in ['l2update']:
      print("received an l2update message")
    else:
      print("unknown message")

    if (datetime.utcnow() - self.time_now).total_seconds() >    self.recording_duration:
      self.loop.create_task(self.close())

  def on_close(self, was_clean, code, reason):
    print("Connection to server is closed")
    print(was_clean)
    print(code)
    print(reason)

def main():
  pass

if __name__ == '__main__':
  main()
```

Here we can see that we can create an instance of this class, and on its initialization we create arrays that can hold our changes and order book states. The logic tree for when each type of message arrives can dictate what kinds of records, and changes to the snapshot are made the arrival of a message. In this current version, the history module contains methods to both update the order book and record changes, but in future versions the processes should be separated as other may have better ideas as to what to do with order book changes. In the following section we will introduce the modules and their associated functions and classes.

6   Modules

Introduction: corbat has one main module, `recorder_full` typically imported as `rec`. Its dependencies are:

1. asyncio, time for asynchronous methods,
2. datetime, to work with datetime objects,
3. copra.websocket, to connect to coinbase,
4. pandas, to store out time series arrays,
5. LOB_funcs.py, to manage messages and create time series arrays,
6. history_funcs.py, for some helper functions, and
7. gc and numpy.

The modules, and their dependencies are listed in the tree diagram below.

```
CSV_out_test.py
 └─ recorder_full.py
     ├─ asyncio, time
     ├─ dateime
     ├─ copra.websocket
     ├─ pandas(note can move this later)
     ├─ LOB_funcs.py
     │   ├─ pandas
     │   ├─ copy
     │   ├─ bisect
     │   ├─ numpy
     │   └─ history_funcs.py
     ├─ history_funcs.py
     │   ├─ pandas
     │   └─ bisect
     ├─ gc
     └─ numpy
 ├─ datetime
 ├─ copra.rest
 └─ copra.websocket
```
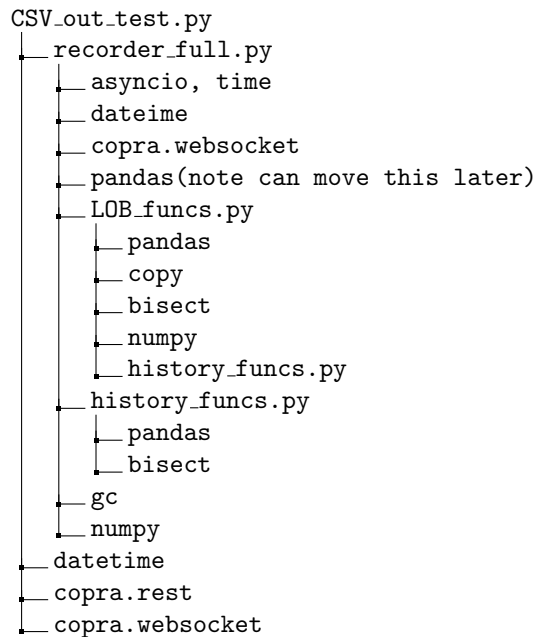
6.1   recorder_full

6.1.1   Description

The `recorder_full` module contains the class `L2_Update`. `L2_Update` is responsible for:

- initializing instances of the order book history class, `history`.
- interpreting the snapshot, ticker and l2update messages that come from the websocket.
- calling the appropriate functions and classes to carry out the orderly update to the limit order book, and order book history arrays.

6.1.2   *class* `L2_Update`

Description: The class that handles messages incoming from the websocket connection. Its methods are:

- `__init__(self, loop, channel, input_args)`
- `on_open(self)`
- `on_message(self, msg)`
- `on_close(self, was_clean, code, reason)`

`__init__(self, loop, channel, input_args)` begins by inheriting attributes `loop`, and `channel`, from `Client`, and it

1. initializes the class `history` imported from `LOB_funcs` and
2. passes on the settings from the class `input_args` and
3. uses functions `on_message(self, msg)`,
4. `on_close(self, was_clean, code, reason)` to manage incoming messages.

6.1.2.1   *function* `__init__`(self, loop, channel, input_args)

Description: Initializes the class, using the attributes `loop, channel` from `Client` and attributes `position_range`, `recording_duration` from the class `input_args`. It also creates an instance of the class `history`.

parameters:	loop:	object	
		Comes from CoPrA	
	channel:	object	
		comes from CoPrA	
	input_args:	class	
		passes on arguments for recording duration, and position range	

returns: None

Example: None

6.1.2.2   *function* on_open(self)

Description: From class `Client` uses method `on_open()` to set things up. See ACoPrA `on_open()` for more information.

restated from `CoPrA`:

> `on_open` is called as soon as the initial WebSocket opening handshake is complete. The connection is open, but the client is not yet subscribed.
>
> If you override this method it is important that you still call it from your subclass' `on_open` method, since the parent method sends the initial subscription request to the WebSocket server. Somewhere in your `on_open` method you should have `super().on_open()`.
>
> In addition to sending the subscription request, this method also logs that the connection was opened.

    parameters: None: None
    returns: None: None
  Example: None

6.1.2.3 *function* on_message(self, msg),

Description: After matching msg['type'] to 'snapshot','ticker', 'l2update' do one of three actions,

msg['type'] ==	action
'snapshot'	initialize the limit order book using the initialize_snap_events
'ticker'	parse a market order,
'l2update'	parse a limit order insertion or cancellation to the limit order book.

restated from CoPrA:

> **on_message**on is called every time a message is received. message is a dict representing the message. Its content will depend on the type of message, the channels subscribed to, etc. Please read Coinbase Pro's WebSocket API documentation to learn about these message formats.
>
> Note that with the exception of errors, every other message triggers this method including things like subscription confirmations. Your code should be prepared to handle unexpected messages.
>
> This default method just prints the message received. If you override this method, there is no need to call the parent method from your subclass' method.

> **parameters:** msg: dict
> **returns:** None: None
> **Example:**

```python
# Let our module be imported and our channels be assigned as follows:
import recorder_full as rec
channel1= Channel('level2', 'BTC-USD')
channel2= Channel('ticker', 'BTC-USD')


#Let the instance of the class L2_Update be ws_1
ws_1 = rec.L2_Update(loop, channel1, settings_1)
ws_1.subscribe(channel2)

#Let the message received from the websocket be:
msg = {
  "type": "l2update",
  "product_id": "BTC-USD",
  "time": "2019-08-14T20:42:27.265Z",
  "changes": [
  [
  "buy",
  "10101.80000000",
  "0.162567"
  ]
  ]
}

# let the current state of the orderbook be defined as follows:
ws_1.orderbook_instance.snapshot_bid = [
  [10101.00, 5.23], [10101.50, 1.11], [10101.80, 0.5]
  ]

ws_1.orderbook_instance.snapshot_signed = [
  [10101.00, -5.23], [10101.50, -1.11], [10101.80, -0.5],
  [10101.90, 0.4], [10102.00, 1.3], [10102.10, 5.00]
  ]

ws_1.orderbook_instance.bid_events = []
ws_1.orderbook_instance.signed_events = []
#Suppose on loop you this message was passed to on_message(msg)
on_message)(msg)

# the new values for the the snapshots, and events would be:
>>print(ws_1.orderbook_instance.snapshot_bid)
>>[[10101.00, 5.23], [10101.50, 1.11], [10101.80, 0.162567]]

>>print(ws_1.orderbook_instance.snapshot_signed)
>>[[10101.00, -5.23], [10101.50, -1.11], [10101.80, -0.162567], [10101.90, 0.4],
    [10102.00, 1.3], [10102.10, 5.00]]

>>print(ws_1.orderbook_instance.bid_events)
>>[[2019-08-14T20:42:27.265Z, 10101.80, cancellation, 0.337433, 1, 10101.85, 0.10]]

>>print(ws_1.orderbook_instance.signed_events)
>>[[2019-08-14T20:42:27.265Z, 10101.80, cancellation, 0.337433, -1, 10101.85, 0.10]]
```

6.1.2.4 *function* on_close(self, was_clean, code, reason)

description: The function called when the close() task is executed. Begins the post processing of accumulated time-series using the functions:

- hf.convert_array_to_list_dict

- hf.convert_array_to_list_dict_sob

- hf.pd_excel_save

and gc.collect() to clear memory after storing .xlsx files of the processed data.

restated from CoPrA:

> on_close is called whenever the connection between the client and server is closed. was_clean is a boolean indicating whether or not the connection was cleanly closed. code, an integer, and reason, a string, are sent by the end that initiated closing the connection.
>
> If the client did not initiate this closure and client.auto_reconnect is set to True, the client will attempt to reconnect to the server and resubscribe to the channels it was subscribed to when the connection was closed. This method also logs the closure.
>
> If your subclass overrides this method, it is important that the subclass method calls the parent method if you want to preserve the auto reconnect functionality. This can be done by including super().on_close(was_clean, code, reason) in your subclass method.

parameters:	was_clean:	bool
	code:	int or None
	reason:	str or None
returns:	None:	None

```
52    # Needs an Example
```

Listing 1: Python example

6.2   LOB_funcs

6.2.1   Description:

Contains the class `history` and the methods, `UpdateSnapshot_Bid_Seq` and `UpdateSnapshot_Ask_Seq` that outline how to update snapshots.

6.2.2   *class* `history()`

Description: Contains attributes for the time series array of the limit order book, the current snapshot of the limit order book and the time-series of the events in the limit order book. We detail the role of each attribute in the table below. The class contains methods that operate on these attributes, in order to update the order book and record changes. The functions `UpdateSnapshot_bid_Seq` and `UpdateSnapshot_ask_Seq`found outside of these methods, dictate the sequence in which the methods contained in `history` are executed.

6.2.2.1   *function* `__init__(self)`
Description: Initializes the lists and variables that will be operated on by other class methods. Each side, bid, ask and the combined signed has a list demarked by `_history`, that will be populated by timestamped states of the limit order book. The lists prefixed by `snapshot` are populated by the state of limit order book demarked by the suffix `bid`, `ask`, and `signed`. The variables `order_type`, `position` and `event_size` denote the type, position and size of the event based on the change in the order book as a result of an `l2_update` message. The `token` variable determines whether the change in the order book is recorded in the events list.

   parameters: None: None
   returns: None: None
   Example: None

6.2.2.2 *function* `initialize_snap_events(self, msg, time)`

Description: Method that parses the `msg` payload if `msg['type'] == snapshot` . Adds the first entry to the collection of `_history` variables. Uses np.round and hf.min_dec to calculate the smallest amount of the quote currency is needed to make the ticks 0.01 units of the base currency.[3]

function dependency:

- np.round

- hf.min_dec

  parameters: msg: dict
  time   datetime object
  returns: None: None
  Example:

```
53  # let the instance of our L2_Update class be defined as follows:
54  channel1= Channel('level2', 'BTC-USD')
55  ws_1 = L2_Update(loop, channel1, settings_1)
56
57  # from our __init__ method, we initialized the arrays in history:
58  >>print(vars(ws_1.hist))
59  >>{bid_history:[],ask_history:[], signed_history:[], snpashot_bid:[],snapshot_ask:[],
        snapshot_signed:[], bid_events:[], ask_events:[], signed_events:[], order_type:None,
         token:False, position:0, event_size:0}
60
61  #after receiving the snapshot from our event loop we will run initialize_snap_events
62  #to populate the variables created in __init__.
63
64  #Let our message be
65  ws_1.time_now = "2019-08-14T20:42:27.265Z"
66  msg = {
67    "type": "snapshot",
68    "product_id": "BTC-USD",
69    "bids": [["10101.10", "0.450541"],["10101.20", "0.44100"], ["10101.55", "0.013400"]],
70    "asks": [["10102.55", "0.577535"],["10102.58", "0.63219"], ["10102.60", "0.803200"]]
71  }
72
73  #note there is not a timestamp for the snapshot that we receive from coinbase so it is
        passed from the datetime.utcnow() from the init method of the L2_Update class.
74
75  ws_1.hist.initialize_snapevents(msg, ws_1.time_now)
76
77  >>print(vars(ws_1.hist))
78  >>{bid_history:[[2019-08-14T20:42:27.265Z,  [[10101.10, 0.450541], [10101.20, 0.44100],
        [10101.55, 0.013400]]]],
79    ask_history:[[2019-08-14T20:42:27.265Z, [[10102.55, 0.577535], [10102.58, 0.63219],
        [10102.60, 0.803200]]]],
80    signed_history:[2019-08-14T20:42:27.265Z, [[[10101.10, -0.450541], [10101.20,
        -0.44100], [10101.55, -0.013400], [10102.55, 0.577535], [10102.58, 0.63219],
        [10102.60, 0.803200]]]],
81    snapshot_bid:[[10101.10, 0.450541],[10101.20, 0.44100], [10101.55, 0.013400]],
82    snapshot_ask:[[10102.55, 0.577535],[10102.58, 0.63219], [10102.60, 0.803200]],
83    snapshot_signed:[[10101.10, -0.450541],[10101.20, -0.44100], [10101.55, -0.013400],
        [10102.55, 0.577535],[10102.58, 0.63219], [10102.60, 0.803200]],
84    bid_events:[], ask_events:[], signed_events:[], order_type:None, token:False, position
        :0, event_size:0}
```

---

[3]For example if BTC-USD = 10101 USD/BTC, then min_dec would return the number of BTC needed for 0.01 USD in BTC and np.round truncates the volume returns to the decimal places returned by hf.min_dec. Doing so resolves the issue with artifacts from floating point arithmetic.

6.2.2.3 add_market_order_message

Description: Parses a message object, aggregates for duplicate timestamps, and appends them to the events lists.

      parameters: message: array
                         events   array

      returns: events: array

      Example:

```python
# let our events be take the form
# some_event = [time, order_type, float(msg['price']), size, position, mid_price, spread
    ].
# for 4 events we have

bid_events = [
  [2019-08-14T20:42:27.265Z, "market", 10101.80, 0.123030, 0, 10101.85, 0.10],
  [2019-08-14T20:42:27.560Z, "insertion", 10100.00, 0.123030, 2, 10101.85, 0.10],
  [2019-08-14T20:42:28.123Z, "insertion", 10100.00, 0.256000, 2, 10101.85, 0.10],
  [2019-08-14T20:42:27.560Z, "cancellation", 10100.00, 0.256000, 2, 10101.85, 0.10]
]

# we receive a 'ticker' message from our event loop

msg = {
  "type": "ticker",
  "trade_id": 20153558,
  "sequence": 3262786978,
  "time": "2019-08-14T20:42:27.966Z",
  "product_id": "BTC-USD",
  "price": "10101.8000000",
  "side": "sell", // Taker side
  "last_size": "0.03000000",
  "best_bid": "10101.8000000",
  "best_ask": "10101.9000000",
}

# on message conventiently converts the message into an array that can be used by
    add_market_order_message

message = [2019-08-14T20:42:27.966Z, "market", 10101.80, 0.030000, 0, 10101.85, 0.10]

bid_events = add_market_order_message(message, bid_events)

# we would see that the event would be appended to the list of bid events
>>print(bid_events)
>>[[2019-08-14T20:42:27.265Z, "market", 10101.80, 0.123030, 0, 10101.85, 0.10],
[2019-08-14T20:42:27.560Z, "insertion", 10100.00, 0.123030, 2, 10101.85, 0.10],
[2019-08-14T20:42:28.123Z, "insertion", 10100.00, 0.256000, 2, 10101.85, 0.10],
[2019-08-14T20:42:27.560Z, "cancellation", 10100.00, 0.256000, 2, 10101.85, 0.10],
[2019-08-14T20:42:27.966Z, "market", 10101.80, 0.030000, 0, 10101.85, 0.10]] #new msg!
```

Example 2: When two ticker messages arrive at the same time

```python
# starting from our last entry, lets examine what would happen if another ticker message
    containing a market order with an identical timestamp were to be received from the
    event loop.
bid_events = [
  [2019-08-14T20:42:27.265Z, "market", 10101.80, 0.123030, 0, 10101.85, 0.10],
  [2019-08-14T20:42:27.560Z, "insertion", 10100.00, 0.123030, 2, 10101.85, 0.10],
  [2019-08-14T20:42:28.123Z, "insertion", 10100.00, 0.256000, 2, 10101.85, 0.10],
  [2019-08-14T20:42:27.560Z, "cancellation", 10100.00, 0.256000, 2, 10101.85, 0.10],
  [2019-08-14T20:42:27.966Z, "market", 10101.80, 0.030000, 0, 10101.85, 0.10]
]

# we receive a new message
msg = {
  "type": "ticker",
  "trade_id": 20153559,
  "sequence": 3262786979,
  "time": "2019-08-14T20:42:27.966Z",
  "product_id": "BTC-USD",
  "price": "10101.8000000",
  "side": "sell", // Taker side
  "last_size": "0.15000000",
  "best_bid": "10101.8000000",
  "best_ask": "10101.9000000",
}

```

```
24  # converting with on_message
25  message = [2019-08-14T20:42:27.966Z, "market", 10101.80, 0.150000, 0, 10101.85, 0.10]
26
27  #running bid events again
28  bid_events = add_market_order_message(message, bid_events)
29
30  # we would observe a concatenated form
31  >>print(bid_events)
32  >>[[2019-08-14T20:42:27.265Z, "market", 10101.80, 0.123030, 0, 10101.85,  0.10],
33  [2019-08-14T20:42:27.560Z, "insertion", 10100.00, 0.123030, 2, 10101.85, 0.10],
34  [2019-08-14T20:42:28.123Z, "insertion", 10100.00, 0.256000, 2, 10101.85, 0.10],
35  [2019-08-14T20:42:27.560Z, "cancellation", 10100.00, 0.256000, 2, 10101.85, 0.10],
36  [2019-08-14T20:42:27.966Z, "market", 10101.80, 0.180000, 0, 10101.85, 0.10]]
```

6.2.2.4 *function* `remove_price_level`(`snap_array`, `level_depth`, `match_index`)

Description: Checks the level depth of an `l2_update` message, removes the existing price level from the snapshot array if the level depth is 0. Counts as a change to the limit order book therefore self.token is set to True.

parameters:	snap_array	array
	level_depth	float64
	match_index	int

returns: snap_array: array

Example:

```
1   # let our snapshot_bid be:
2   snapshot_bid =  [[10101.80, 0.013400],[10101.20, 0.44100], [10101.10, 0.450541]]
3
4   # we receive a 'l2update' message from our event loop
5
6   msg = {
7   "type": "l2update",
8   "product_id": "BTC-USD",
9   "time": "2019-08-14T20:42:27.265Z",
10  "changes": [
11  [
12  "buy",
13  "10101.80000000",
14  "0.0"
15  ]
16  ]
17  }
18
19  # on_message() conventiently parses the message to create relevant local variables
20  # time, changes, side, price_level, level_depth, pre_level_depth, hist.token
21  >>print(time, side,price_level, level_depth, prelevel_depth, hist.token)
22  >>2019-08-14T20:42:27.265Z "buy" 10101.80000000 0.0 0 False
23
24  # in on_message(), the variable price_match_index is assigned by finding the index
25  # with the matching price, in the snapshot. In this case:
26  price_match_index = [0]
27
28  snapshot_bid = remove_price_level(snapshot_bid, level_depth, price_match_index)
29
30  >>print(snapshot_bid, hist.token)
31  >>[[10101.20, 0.44100], [10101.10, 0.450541]] True
```

6.2.2.5 *function* update_level_depth(snap_array, level_depth, match_index, pre_level_depth)

Descirption: updates the existing price level to a new size. Sets `self.order_type` to insertion if the new size is larger than the old size, or cancellation if the new size is smaller than the old size. sets the position to the `self.position` variable to the index where the event occurred.

parameters:	snap_array:	list
		The snapshot array that will be modified.
	level_depth:	float64
		The new level depth that will be checked against the old level depth in the snapshot array.
	match_index:	list
		single item list that contains the index where the price in the snapshot array matches that of the `l2update` message.
returns:	snap_array :	list
		The modified snapshot array.
	pre_level_depth:	float64
		An updated pre_level_depth[4]

Example:

```
1   # let our snapshot_bid be:
2   snapshot_bid = [[10101.80, 0.013400],[10101.20, 0.44100], [10101.10, 0.450541]]
3
4   # we receive a 'l2update' message from our event loop
5
6   msg = {
7       "type": "l2update",
8       "product_id": "BTC-USD",
9       "time": "2019-08-14T20:42:27.265Z",
10      "changes": [
11      [
12      "buy",
13      "10101.80000000",
14      "0.500000"
15      ]
16      ]
17  }
18
19  # on_message() conventiently parses the message to create relevant local variables
20  # time, changes, side, price_level, level_depth, pre_level_depth, hist.token
21  >>print(time, side,price_level, level_depth, prelevel_depth, hist.token)
22  >>2019-08-14T20:42:27.265Z "buy" 10101.80000000 0.500000 0 False
23
24  # in on_message(), the variable price_match_index is assigned by finding the index
25  # with the matching price, in the snapshot. In this case:
26  price_match_index = [0]
27
28  snapshot_bid, pre_level_depth = updatedate_price_level(snapshot_bid, level_depth,
        price_match_index, pre_level_depth)
29
30  >>print(price)
31
32  >>print(snapshot_bid, hist.token)
33  >>[[10101.20, 0.44100], [10101.10, 0.450541]] True
```

6.2.2.6 *function* `update_price_index_buy(self, level_depth, price_level, pre_level_depth)`

Description: If there is a new price level introduced, this function determines its location and appropriately inserts it into the snapshot bid array. It will also set the position, and token depending on where the change occurs.

	parameters:	level_depth:	float64
			level depth received from the `l2update` message
		price_level:	float64
			The price level being introduced
		pre_level_depth:	float64
			some pre_level_depth that is reset to 0, idk this feature
	returns:	snapshot_bid	list
			The modified snapshot_bid.
		bid_range:	list
			The modified range of bids available in the snapshot.
		pre_level_depth	float64
			again the pre level depth that idk why i still have this.
	latent changes:	token	boolean
			bool that informs whether a significant change has occurred in the order book.
		order_type	

Example: None

```
1    # let our snapshot_bid be:
2    snapshot_bid =  [[10101.80, 0.013400],[10101.20, 0.44100], [10101.10, 0.450541]]
3
4    # we receive a 'l2update' message from our event loop
5
6    msg = {
7      "type": "l2update",
8      "product_id": "BTC-USD",
9      "time": "2019-08-14T20:42:27.265Z",
10     "changes": [
11     [
12     "buy",
13     "10101.90000000",
14     "0.500000"
15     ]
16     ]
17   }
18
19   # on_message() conventiently parses the message to create relevant local variables
20   # time, changes, side, price_level, level_depth, pre_level_depth, hist.token
21   >>print(time, side,price_level, level_depth, prelevel_depth, hist.token)
22   >>2019-08-14T20:42:27.265Z "buy" 10101.90000000 0.500000 0 False
23
24   # in on_message(), the variable price_match_index is assigned by finding the index
25   # with the matching price, in the snapshot. In this case:
26   price_match_index = []
27
28   snapshot_bid, pre_level_depth = update_price_index_buy(level_depth, price_level,
29     pre_level_depth)
30
31   >>print(snapshot_bid, hist.token)
32   >[[10101.90, 0.500000], [10101.80, 0.013400],[10101.20, 0.44100], [10101.10,
33     0.450541]] True
```

6.2.2.7 *function* `update_price_index_sell(self, level_depth, price_level, pre_level_depth)`

Description: If there is a new price level introduced, this function determines its location and appropriately inserts it into the snapshot ask array. It will also set the position, and token depending on where the change occurs.

parameters:	level_depth:	float64
		level depth received from the `l2update` message
	price_level:	float64
		The price level being introduced
	pre_level_depth:	float64
		some pre_level_depth that is reset to 0, idk this feature
returns:	snapshot_ask:	list
		The modified snapshot_ask.
	bid_range:	list
		The modified range of bids available in the snapshot.
	pre_level_depth	float64
		again the pre level depth that idk why i still have this.
latent changes:	token:	boolean
		bool that informs whether a significant change has occurred in the order book.
	order_type:	string
		type of order in ['market', 'insertion', 'cancelation']

Example:

```
1   # let our snapshot_bid be:
2   snapshot_ask =  [[10101.90, 0.013400],[10102.00, 0.52100], [10102.11, 0.89041]]
3
4   # we receive a 'l2update' message from our event loop
5
6   msg = {
7     "type": "l2update",
8     "product_id": "BTC-USD",
9     "time": "2019-08-14T20:42:27.265Z",
10    "changes": [
11    [
12    "sell",
13    "10101.95000000",
14    "0.500000"
15    ]
16    ]
17  }
18
19  # on_message() conventiently parses the message to create relevant local variables
20  # time, changes, side, price_level, level_depth, pre_level_depth, hist.token
21  >>print(time, side,price_level, level_depth, prelevel_depth, hist.token)
22  >>2019-08-14T20:42:27.265Z "buy" 10101.90000000 0.500000 0 False
23
24  # in on_message(), the variable price_match_index is assigned by finding the index
25  # with the matching price, in the snapshot. In this case:
26  price_match_index = []
27
28  snapshot_ask, pre_level_depth = update_price_index_sell(level_depth, price_level,
      pre_level_depth)
29
30  >>print(snapshot_bid, hist.token)
31  > [[10101.90, 0.013400],[10101.95, 0.500000],[10102.00, 0.52100], [10102.11, 0.89041]]
      True
```

6.2.2.8 *function* update_snapshot_bid(self)

Description: Updates the variable bid_range. I'm not sure why I need to do this but it does keep update snapshot bid/ask from making mistakes when doing bisect/insert.

parameters:	None:	None
		None
returns:	snapshot_bid:	list
		The snapshot on the bid side.
	bid_range:	list
		ordered range of prices for the bid side
latent changes:	None	None
		None

Example: None

```
1   x = __my_function__(1.234, True, 3)
2   >>print(x)
3   >>-1.23
4
5   x = __my_function__(1.234, False, 3)
6   >>print(x)
7   >>1.23
```

6.2.2.9 *function* `update_snapshot_ask`(self)

Description: Updates the variable `ask_range`. I'm not sure why I need to do this but it does keep update snapshot bid/ask from making mistakes when doing bisect/insert.

parameters:	None:	None
		None
returns:	snapshot_ask:	list
		The snapshot on the ask side.
	ask_range:	list
		ordered range of prices for the ask side
latent changes:	None	None
		None

Example: None

```
1    ?????????
```

6.2.2.10   *function* `trim_coordinator(self, position, bound)`
Description: Sets the tokenvariable to False if the change to the orderbook was outside of thte position
bound.

parameters:	position:	int	
		position where the order book was updated.	
	bound:	int	
		the largest position where the function can trigger	
returns:	token	boolean	
		The boolean argument that determines whether the change in the order book is recorded.	
latent changes:	None	None.	

Example: None

```
??????
```

6.2.2.11 *function* append_snapshot_bid(self, time, price_level)
Description: Appends the current form of the snapshot to bid_history and computes the event and appends the event record to bid_events.

parameters:	:	float64
		some input that will be passed to the function
param_2:	boolean
	a conditional that will be checked by the function
param_3:	int
	some int that is needed for the function
returns:	trans_number	float64
	The number with the correct significant digits and sign.
latent changes:	trans_number	float64
	The number with the correct significant digits and sign.

Example: None

```
1   x = __my_function__(1.234, True, 3)
2   >>print(x)
3   >>-1.23
4
5   x = __my_function__(1.234, False, 3)
6   >>print(x)
7   >>1.23
```

6.2.2.12   *function* append_snapshot_ask(self, time, price_level)

Description: Appends the current form of the snapshot to ask_history and computes the event and appends the event record to ask_events.

parameters:		time:	datetime object
			timestamp that when the message was received
		price_level:	float64
			price level where the change occurred
returns:	snapshot_ask	list	
			The snapshot on the ask side.
	ask_range	list	
			the range of prices in snapshot_ask.
latent changes:	None:	None	

Example: None

```
1   x = __my_function__(1.234, True, 3)
2   >>print(x)
3   >>-1.23
4
5   x = __my_function__(1.234, False, 3)
6   >>print(x)
7   >>1.23
```

6.2.2.13   *function* append_signed_book(self, time, price_level)

Description: Appends the current form of the snapshot to ask_history and computes the event and appends the event record to ask_events.

parameters:	time:	datetime object
		timestamp that when the message was received
	price_level:	float64
		price level where the change occurred
returns:	snapshot_ask	list
		The snapshot on the ask side.
	ask_range	list
		the range of prices in snapshot_ask.
latent changes:	None:	None

Example: None

```
1   x = __my_function__(1.234, True, 3)
2   >>print(x)
3   >>-1.23
4
5   x = __my_function__(1.234, False, 3)
6   >>print(x)
7   >>1.23
```

6.2.2.14 *function* chk_mkt_can_overlap(self, events, order_type)

Description: passes the order_type either market order or canceled order. If it was a market order checks for a recent canceled order of the same size and delectes the canceled order. likewise, if the ordertype passedwas a canceled order it looks for a recent market order and deletes the canceled order.

The reason this is done this way is because the l2update channel only updates queue sizes while the ticker channel only announces market order arrivals.

parameters:	events:	list
		current event list to be modified
	order_type:	string
		type of order observed ['market','cancellation']
returns:	events	list
		modified event list
latent changes:	None:	None

Example: None

```
1    x = __my_function__(1.234, True, 3)
2    >>print(x)
3    >>-1.23
4
5    x = __my_function__(1.234, False, 3)
6    >>print(x)
7    >>1.23
```

Accessors: The following functions, prefaced with `last_` are the currently named accessors. They cover the last order of a named type, the last state of the order book, and the market depth for a the last given state of the order book. If I come up with other relevant accessors or refine how each function works their changes will likely be noted in the versions, or at least a git entry.

6.2.2.15 *function* `last_inserted_order`(self, side=''signed'')
Description: Returns the latest limit order insertion from the bid, ask, or signed events. Defaults to signed.

  parameters: side: string
          market side to query

  returns: out(please rename) list
           The last inserted event.

  latent changes: None: None
  Example: None

```
1    x = __my_function__(1.234, True, 3)
2    >>print(x)
3    >>-1.23
4
5    x = __my_function__(1.234, False, 3)
6    >>print(x)
7    >>1.23
```

6.3   history_funcs.py

Description: Helper functions that operate in recorder_full.py and LOBfuncs.py. It contains simple methods that are agnostic to side (e.g., bid/ask/signed) for the most part.

6.3.0.1   *function* check_order(snapshot, side)
Description: Checks that the snapshot is sorted correctly. Used in debugging when snapshots do not look well ordered. Only checks bid and ask side, because signed snapshot is a concatenated form of a bid and ask snapshot. **pass** placeholder can be changed to a print statement.

parameters:	snapshot:	list
		snpshot to check
	side:	string
		side bid, ask
returns:	snapshot	list

latent changes: None: None

Example: None

```
1  # let our snapshot_bid be:
2  snapshot_bid =  [[10101.80, 0.013400],[10101.20, 0.44100], [10101.10, 0.450541]]
3
4  #I will say that if the snapshot is not ordered I can ask the function to return a
     boolean, True if ordered, else False
5  >>x = check order(snapshot_bid, "bid")
6  >>print(x)
```

6.3.0.2 *function* `conver_array_to_list_dict`(history, pos_limt=5)

Description: converts the time-series of order book states into a list of dictionaries for a single side.

	parameters:	history:	list
			time series of order book states
		pos_limit:	int, default := 5
			ordinal distance from the best bid/ask that is worth saving.
	returns:	volm_list:	list
			list of dictionaries for volume sizes and their respective position.
		price_list:	list
			list of dictionaries for prices and their respective position.
	latent changes:	None:	None

Example: None

```
1   # let our snapshot_bid be:
2   bid_history = [
3   [2019-08-14T20:42:27.265Z,[[10101.80, 0.013400],[10101.20, 0.44100], [10101.10,
       0.450541], [10100.55, 5.24501], [10099.00, 10.24511], [10090.11, 24.21395]]],
4   [2019-08-14T20:42:27.500Z,[[10101.20, 0.44100], [10101.10, 0.450541], [10100.55,
       5.24501], [10099.00, 10.24511], [10090.11, 24.21395],[10090.05]] ],
5   [2019-08-14T20:42:27.963Z,[[10101.20, 0.55200], [10101.10, 0.450541], [10100.55,
       5.24501], [10099.00, 10.24511], [10090.11, 24.21395]]]
6   ]
7
8   ordinal_volumes, ordinal_prices = convert_array_list_to_dict(snapshot)
9
10  >>print(ordinal_volumes)
11  >>[{"time":2019-08-14T20:42:27.265Z, "1":0.013400, "2":0.44100, "3":0.450541, "4"
       :5.24501, "5":10.24511},
12  {"time":2019-08-14T20:42:27.500Z, "1":0.44100, "2":0.450541, "3":5.24501, "4"
       :10.24511, "5":24.21395},
13  {"time":2019-08-14T20:42:27.963Z, "1":0.52200, "2":0.450541, "3":5.24501, "4"
       :10.24511, "5":2421395}]
14
15  >>print(ordinal_prices)
16  >>[{"time":2019-08-14T20:42:27.265Z, "1":10101.80, "2":10101.20, "3":10101.10, "4"
       :10100.55, "5":10099.00},
17  {"time":2019-08-14T20:42:27.500Z, "1":10101.20, "2":10101.10, "3":10100.55, "4"
       :10099.00, "5":10090.11},
18  {"time":2019-08-14T20:42:27.963Z, "1":10101.20, "2":10101.10, "3":10100.55, "4"
       :10099.00, "5":10090.11}]
```

6.3.0.3 *function* `conver_array_to_list_dict_sob`(history, events, pos_limt=5)

Description: converts the time-series of order book states into a list of dictionaries for the signed order book. This has some nuance because the signed book format has negative volumes, and the ordinal scale is prefaced by a negative sign. Works similarly to `conver_array_to_list_dict` but uses the mid-price from `events` to find where to separate the bid and ask sides.

parameters:	history:	list	
		time series of order book states	
	events:	list	
		The events list where the function will extract the mid price from.	
	pos_limit:	int, default := 5	
		Ordinal distance from the best bid/ask that is worth saving.	
returns:	volm_list:	list	
		list of dictionaries for volume sizes and their respective position.	
	price_list:	list	
		list of dictionaries for prices and their respective position.	
latent changes:	None:	None	

Example: None

```
1   # let our snapshot_bid be:
2   bid_history = [
3   [2019-08-14T20:42:27.265Z,[[10101.80, 0.013400],[10101.20, 0.44100], [10101.10,
        0.450541], [10100.55, 5.24501], [10099.00, 10.24511], [10090.11, 24.21395]]],
4   [2019-08-14T20:42:27.500Z,[[10101.20, 0.44100], [10101.10, 0.450541], [10100.55,
        5.24501], [10099.00, 10.24511], [10090.11, 24.21395],[10090.05]] ],
5   [2019-08-14T20:42:27.963Z,[[10101.20, 0.55200], [10101.10, 0.450541], [10100.55,
        5.24501], [10099.00, 10.24511], [10090.11, 24.21395]]]
6   ]
7
8   ordinal_volumes, ordinal_prices = convert_array_list_to_dict(snapshot)
9
10  >>print(ordinal_volumes)
11  >>[{"time":2019-08-14T20:42:27.265Z, "1":0.013400, "2":0.44100, "3":0.450541, "4"
        :5.24501, "5":10.24511},
12  {"time":2019-08-14T20:42:27.500Z, "1":0.44100, "2":0.450541, "3":5.24501, "4"
        :10.24511, "5":24.21395},
13  {"time":2019-08-14T20:42:27.963Z, "1":0.52200, "2":0.450541, "3":5.24501, "4"
        :10.24511, "5":2421395}]
14
15  >>print(ordinal_prices)
16  >>[{"time":2019-08-14T20:42:27.265Z, "1":10101.80, "2":10101.20, "3":10101.10, "4"
        :10100.55, "5":10099.00},
17  {"time":2019-08-14T20:42:27.500Z, "1":10101.20, "2":10101.10, "3":10100.55, "4"
        :10099.00, "5":10090.11},
18  {"time":2019-08-14T20:42:27.963Z, "1":10101.20, "2":10101.10, "3":10100.55, "4"
        :10099.00, "5":10090.11}]
```

6.3.0.4 *function* pd_excel_save(title, hist_obj_dict)

Description: Convert the list of dictionary objects into a pandas dataframe object. Excises the first entry, because it is usually empty, saves the dataframe object as a .xlsx file with the title given as an argument.

parameters:	title:	string
		Title of the output .xlsx file
	hist_obj_dict:	list
		The list of dictionaries to be converted to a pandas dataframe object.

returns: None: None
latent changes: None: None
Example: None

```
1  ordinal_volumes = [{"time":2019-08-14T20:42:27.265Z, "1":0.013400, "2":0.44100, "3"
       :0.450541, "4":5.24501, "5":10.24511},
2  {"time":2019-08-14T20:42:27.500Z, "1":0.44100, "2":0.450541, "3":5.24501, "4":10.24511,
       "5":24.21395},
3  {"time":2019-08-14T20:42:27.963Z, "1":0.52200, "2":0.450541, "3":5.24501, "4":10.24511,
       "5":2421395}]
4
5  volm_title =  "L2_orderbook_volm_bid"+str(bid_events[-1]['time'])+".xlsx"
6
7  >>pd_excel_save(volm_title, ordinal_volumes)
```

Below a simple table generated from L2_orderbook_volm_bid2019-08-14T20:42:27.963Z.xlsx is shown.

time	1	2	3	4	5
2019-08-14T20:42:27.265	0.013400	0.44100	0.450541	5.24501	10.24511
2019-08-14T20:42:27.500	0.44100	0.450541	5.24501	10.24511	24.21395
2019-08-14T20:42:27.963	0.52200	0.450541	5.24501	10.24511	24.21395

6.3.0.5 *function* set_sign(event_size, side, order_type)

Description: Sets the multiplicative sign,either 1 or -1 depending on the order type and event side.

parameters:	event_size:	float64
		Size of the event, artifact from when I returned the signed event
	side:	string
		Event side either "bid" or "ask"
	order_type:	str
		the type of order either ``insertion'', ``cancellation'' or ``market''.
returns:	sign	int
		The correct sign given the event's order type and side.
latent changes:	None:	None

Example: None

```
1   x = __my_function__(1.234, True, 3)
2   >>print(x)
3   >>-1.23
4
5   x = __my_function__(1.234, False, 3)
6   >>print(x)
7   >>1.23
```

6.3.0.6 *function* set_signed_positiion(position, side)

Description: Simple conditional that sets the position for the bid side.... I'm tired...

parameters:	param_1:	float64
		some input that will be passed to the function
	param_2:	boolean
		a conditional that will be checked by the function
	param_3:	int
		some int that is needed for the function
returns:	trans_number	float64
		The number with the correct significant digits and sign.
latent changes:	trans_number	float64
		The number with the correct significant digits and sign.

Example: None

```
1   x = __my_function__(1.234, True, 3)
2   >>print(x)
3   >>-1.23
4
5   x = __my_function__(1.234, False, 3)
6   >>print(x)
7   >>1.23
```

6.3.0.7 *function* `get_min_dec`(min_currency_denom, min_asset_value)

Description: determines the decimal place for the smallest amount of base currency needed for the minimal denomination of the float currency.

Example: Suppose you have an exchange rate of $10010.99USD/BTC$, (i.e., you need $10010.99USD$ to buy $1BTC$) then the amount of BTC in 1 cent or 0.01 USD which is the smallest denomination of the USD is $0.000000999BTC$. We see that this is 10^{-7}, `get_min_dec` would return 7, to pass onto `numpy.around`.

> **parameters:**   min_currency_denom :   float64
>   the minimum currency denomination (e.g., 0.01 USD)
>   min_asset_value: float646
>   the smallest current valuation of the asset.

> **returns:**   min_dec_out   int
>   The number of decimal places out for the smallest movement of the asset for a minimal

> **latent changes:**   None: None

> **Example: None**

1 `??????`

7   Credits

7.1   Development Lead

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8   License

GNU GPLv3 License

9 Appendix

10 To do list

1. daily goals

    (a) write 2 whole function definitions with description, examples, i/o,

    (b) help format or rewrite one unique section.

10.0.0.1 *function* __my_function__(self, param_1, param_2=False, param_3)

Description: Put your description here. In the next table we will state the parameters, on the left, with the object type on the right. just below it on the next line, we will give a brief description of the input parameter. After that we will use the returns portion in the exact same way. The final section is an example that uses lstlisting package to write snippets of python code for us. The filled out template is then included in the class .tex file and the class .tex file is included in the master manual .tex file.

For example this function will convert param_1 as a float to the nearest significant digits as defined by param_3 and will multiply by -1 if param_2:=True.

parameters:	param_1:	float64
		some input that will be passed to the function
	param_2:	boolean
		a conditional that will be checked by the function
	param_3:	int
		some int that is needed for the function
returns:	trans_number	float64
		The number with the correct significant digits and sign.
latent changes:	trans_number	float64
		The number with the correct significant digits and sign.

Example: None

```
1   x = __my_function__(1.234, True, 3)
2   >>print(x)
3   >>-1.23
4
5   x = __my_function__(1.234, False, 3)
6   >>print(x)
7   >>1.23
8
```

variable name	type
	definition/description
snapshot_bid:	list
	The modified snapshot_bid.
bid_range:	list
	The modified range of bids available in the snapshot.
pre_level_depth:	float64
	again the pre level depth that idk why i still have this.

10.0.0.2 *function* __my_function__(self, param_1, param_2=False, param_3)

Description: Put your description here. In the next table we will state the parameters, on the left, with the object type on the right. just below it on the next line, we will give a brief description of the input parameter. After that we will use the returns portion in the exact same way. The final section is an example that uses `lstlisting` package to write snippets of python code for us. The filled out template is then included in the class .tex file and the class .tex file is included in the master manual .tex file.

For example this function will convert **param_1** as a float to the nearest significant digits as defined by **param_3** and will multiply by -1 if **param_2:=True**.

parameters:	param_1:	float64
		some input that will be passed to the function
	param_2:	boolean
		a conditional that will be checked by the function
	param_3:	int
		some int that is needed for the function
returns:	trans_number	float64
		The number with the correct significant digits and sign.
latent changes:	trans_number	float64
		The number with the correct significant digits and sign.

Example: None

```
1    x = __my_function__(1.234, True, 3)
2    >>print(x)
3    >>-1.23
4
5    x = __my_function__(1.234, False, 3)
6    >>print(x)
7    >>1.23
8
```

References

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