# Cryptocurrency Orderbook Analysis Tool

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## Contents

# 1 Introduction

This project is an extension of my thesis, ¡a 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 orderbook and orderbook 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
3. Cont R., Kukanov A. and Stoikov S. - The price impact of order book events
4. Cartea. A, Jaimungal S. and Wang Y. - Spoofing and Price Manipulation in Order Driven Markets
5. Silyantev, E. - Order flow analysis of cryptocurrency markets[1]

[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 $n^{\mathrm{th}}$ best limits, and
  3. prices at $n^{\mathrm{th}}$ best limits.

# 3 Getting Started and Installation

## 3.1 CoPrA

## 3.2 Installation

Given that this is still very much a work in progress, it may make more sense to fork the project, or download the project as a compressed folder, and build `CSV_out_test.py` with your preferred settings.

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**Note:** 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 orderbook ¡u¿recorder¡/u¿ my use until now has been to record the orderbook. However there are accessors in the "'LOB_funcs.py"' file, under in the *history* class. In the /test folder there is a small usecase if you would like to see it but documentation is pending.

1. For now we only have the full orderbook, with no regard for ticksize, 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[2] | `currency_pair` | `str` | |

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 orderbook for each side should be created with a timestamp:

## 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, the cited papers do 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

Below there is a graph of the snapshot where bids (green) show open limit orders to buy the 1 unit of the cryptocurrency below $7085.930, and asks (red) show open limit orders to buy 1 unit above $7085.930. The x-axis shows the price points, and the y-axis is the aggregate size at the price level. Note that the signed order book calls volume on the bid side negative.

Early and current works relied on exchanges and private data providers (e.g., NASDAQ - BookViewer,LOBSTER to provide reconstructions of order books. Earlier works were limited to taking snapshots and inferring the possible sequence of order book events between states. Coinbase and by extension crobat update the levels on the instance of a update message from the exchange so there is no guess as to what happened between states of the order book. The current format of the order book snapshot is not aggregated. The format of the order book snapshot for a single side is shown below

| Item | Description/Format |
|---|---|
| Timestamp | YYYY-MM-DDTHH:MM:SS.ffffff |
| 1 | total BTC at position 1 |
| 2 | total BTC at position 1 |
| ... | ... |
| $n$ | total BTC at position n |

**Incl. sample output of an entry**

The associated price quote (price quote (USD per XTC))snapshot is also generated, to make generation of market depth feasible.

| Item | Description/Format |
|---|---|
| Timestamp | YYYY-MM-DDTHH:MM:SS.ffffff |
| 1 | price quote at position 1 |
| 2 | price quote at position 1 |
| ... | ... |
| $n$ | price quote at position n |

Event recording are a timeseries 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[3] | `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 $n^{\text{th}}$ best bid (i.e., worst bid) |
| $-n+1$ | aggregate XTC limit buys at the second to worst bid |
| ... | ... |
| $-2$ | aggregate XTC being bid for at the $2^{nd}$ 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 $2^{\text{nd}}$ best ask |
| ... | ... |
| $n-1$ | 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:

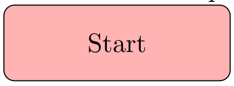
| Item | Description/Format |
|---|---|
| Timestamp | YYYY-MM-DDTHH:MM:SS.ffffff |
| $-n$ | price quote at the $n^{\text{th}}$ best bid (i.e., worst bid) |
| $-n+1$ | price quote at the second to worst bid |
| ... | ... |
| $-2$ | price quote at the $2^{nd}$ best bid |
| $-1$ | price quote at the best bed bid |
| 1 | price quote at the best ask |
| 2 | price quote at the $2^{\text{nd}}$ best ask |
| ... | ... |
| $n-1$ | 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[4] | `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.



# 5 Context: Where does crobat operate?

Following CoPrA's example as to how to set up a web socket connectin we provide context as to where crobat operates. Lets begin with copras 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 run it we would execute 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 overwrites this Client class and inserts its new methods. Below we introduce our own version of this loop.

```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:

```
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 can create light weight 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 furture versions the processes should be separated as other may have better ideas as to what to do with order book changes.

# 6 Modules

The module dependency of the program are organized as follows:

```
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`

**Function list**:

- `__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)`

**Description:** Inheriting attributes `loop`, and `channel`, from `Client`, 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<br>Comes from CoPrA |
| | channel: | object<br>comes from CoPrA |
| | input_args: | class<br>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:**

```
# 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

```
 # Needs an Example
```

Listing 1: Python example

## 6.2 LOBF_funcs

**Description:** module that houses the class `history` and the methods that outline how to update snapshots.

#### 6.2.1 *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 whateever. The class contains methods that operate of these attributes, in order to update the order book and record changes. The functions `UpdateSnapshot_bid_Seq` and `UpdateSnapshot_ask_Seq`found outside ofthese methods, dictate the sequence in which the methods contained in `history` are executed.

##### 6.2.1.1 *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**

##### 6.2.1.2 *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.[5]

**function dependency:**

- np.round
- hf.min_dec

**parameters:** msg: dict
time datetime object

**returns:** None: None

**Example:**

```
# let the instance of our L2_Update class be defined as follows:
channel1= Channel('level2', 'BTC-USD')
ws_1 = L2_Update(loop, channel1, settings_1)

# from our __init__ method, we initialized the arrays in history:
>>print(vars(ws_1.hist))
>>{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}

#after receiving the snapshot from our event loop we will run initialize_snap_events
#to populate the variables created in __init__.

#Let our message be
ws_1.time_now = "2019-08-14T20:42:27.265Z"
msg = {
  "type": "snapshot",
  "product_id": "BTC-USD",
  "bids": [["10101.10", "0.450541"],["10101.20", "0.44100"], ["10101.55", "0.013400"]],
  "asks": [["10102.55", "0.577535"],["10102.58", "0.63219"], ["10102.60", "0.803200"]]
}

#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.

ws_1.hist.initialize_snapevents(msg, ws_1.time_now)

>>print(vars(ws_1.hist))
>>{bid_history:[[2019-08-14T20:42:27.265Z,  [[10101.10, 0.450541], [10101.20, 0.44100],
    [10101.55, 0.013400]]]],
```

[5] 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.

```
  ask_history:[[2019-08-14T20:42:27.265Z, [[10102.55, 0.577535], [10102.58, 0.63219],
    [10102.60, 0.803200]]]],
  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]]]],
  snapshot_bid:[[10101.10, 0.450541],[10101.20, 0.44100], [10101.55, 0.013400]],
  snapshot_ask:[[10102.55, 0.577535],[10102.58, 0.63219], [10102.60, 0.803200]],
  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]],
  bid_events:[], ask_events:[], signed_events:[], order_type:None, token:False, position
    :0, event_size:0}
```

#### 6.2.1.3 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:**

```
# 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**

```
# 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",
}

# converting with on_message
message = [2019-08-14T20:42:27.966Z, "market", 10101.80, 0.150000, 0, 10101.85, 0.10]

#running bid events again
bid_events = add_market_order_message(message, bid_events)

# we would observe a concatenated form
>>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, 0.180000, 0, 10101.85, 0.10]]
```

#### 6.2.1.4 *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:**

```
# let our snapshot_bid be:
snapshot_bid =  [[10101.80, 0.013400],[10101.20, 0.44100], [10101.10, 0.450541]]

# we receive a 'l2update' message from our event loop

msg = {
"type": "l2update",
"product_id": "BTC-USD",
"time": "2019-08-14T20:42:27.265Z",
"changes": [
[
"buy",
"10101.80000000",
"0.0"
]
]
}

# on_message() conventiently parses the message to create relevant local variables
# time, changes, side, price_level, level_depth, pre_level_depth, hist.token
>>print(time, side,price_level, level_depth, prelevel_depth, hist.token)
>>2019-08-14T20:42:27.265Z "buy" 10101.80000000 0.0 0 False

# in on_message(), the variable price_match_index is assigned by finding the index
# with the matching price, in the snapshot. In this case:
price_match_index = [0]

snapshot_bid = remove_price_level(snapshot_bid, level_depth, price_match_index)

>>print(snapshot_bid, hist.token)
>>[[10101.20, 0.44100], [10101.10, 0.450541]] True
```

#### 6.2.1.5 *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[6]

**Example:**

```
# let our snapshot_bid be:
snapshot_bid =  [[10101.80, 0.013400],[10101.20, 0.44100], [10101.10, 0.450541]]

# we receive a 'l2update' message from our event loop

msg = {
  "type": "l2update",
  "product_id": "BTC-USD",
  "time": "2019-08-14T20:42:27.265Z",
  "changes": [
  [
  "buy",
  "10101.80000000",
  "0.500000"
  ]
  ]
}

# on_message() conventiently parses the message to create relevant local variables
# time, changes, side, price_level, level_depth, pre_level_depth, hist.token
>>print(time, side,price_level, level_depth, prelevel_depth, hist.token)
>>2019-08-14T20:42:27.265Z "buy" 10101.80000000 0.500000 0 False

# in on_message(), the variable price_match_index is assigned by finding the index
# with the matching price, in the snapshot. In this case:
price_match_index = [0]

snapshot_bid, pre_level_depth = updatedate_price_level(snapshot_bid, level_depth,
  price_match_index, pre_level_depth)

>>print(price)

>>print(snapshot_bid, hist.token)
>>[[10101.20, 0.44100], [10101.10, 0.450541]] True
```

#### 6.2.1.6 *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**

```
# let our snapshot_bid be:
snapshot_bid =  [[10101.80, 0.013400],[10101.20, 0.44100], [10101.10, 0.450541]]

# we receive a 'l2update' message from our event loop

msg = {
  "type": "l2update",
  "product_id": "BTC-USD",
  "time": "2019-08-14T20:42:27.265Z",
  "changes": [
  [
  "buy",
  "10101.90000000",
  "0.500000"
  ]
  ]
}

# on_message() conventiently parses the message to create relevant local variables
# time, changes, side, price_level, level_depth, pre_level_depth, hist.token
>>print(time, side,price_level, level_depth, prelevel_depth, hist.token)
>>2019-08-14T20:42:27.265Z "buy" 10101.90000000 0.500000 0 False

# in on_message(), the variable price_match_index is assigned by finding the index
# with the matching price, in the snapshot. In this case:
price_match_index = []

snapshot_bid, pre_level_depth = update_price_index_buy(level_depth, price_level,
  pre_level_depth)

>>print(snapshot_bid, hist.token)
>[[10101.90, 0.500000], [10101.80, 0.013400],[10101.20, 0.44100], [10101.10,
  0.450541]] True
```

#### 6.2.1.7 *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:**

```
# let our snapshot_bid be:
```

```
snapshot_ask =  [[10101.90, 0.013400],[10102.00, 0.52100], [10102.11, 0.89041]]

# we receive a 'l2update' message from our event loop

msg = {
  "type": "l2update",
  "product_id": "BTC-USD",
  "time": "2019-08-14T20:42:27.265Z",
  "changes": [
  [
  "sell",
  "10101.95000000",
  "0.500000"
  ]
  ]
}

# on_message() conventiently parses the message to create relevant local variables
# time, changes, side, price_level, level_depth, pre_level_depth, hist.token
>>print(time, side,price_level, level_depth, prelevel_depth, hist.token)
>>2019-08-14T20:42:27.265Z "buy" 10101.90000000 0.500000 0 False

# in on_message(), the variable price_match_index is assigned by finding the index
# with the matching price, in the snapshot. In this case:
price_match_index = []

snapshot_ask, pre_level_depth = update_price_index_sell(level_depth, price_level,
  pre_level_depth)

>>print(snapshot_bid, hist.token)
> [[10101.90, 0.013400],[10101.95, 0.500000],[10102.00, 0.52100], [10102.11, 0.89041]]
   True
```

#### 6.2.1.8 *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**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>1.23
```

#### 6.2.1.9 *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**

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

#### 6.2.1.10 *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**

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

#### 6.2.1.11 *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**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>1.23
```

#### 6.2.1.12 *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**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>1.23
```

#### 6.2.1.13 *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**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>1.23
```

#### 6.2.1.14 *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**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>1.23
```

**Accessors:** The folowing 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.

#### 6.2.1.15 *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**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>1.23
```

**list to create**

1. accessors

   (a) last CO, MO
   (b) last image
   (c) last event
   (d) last market depth

2. price_match

3. update bid seq

4. update ask seq

## 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**

```
# let our snapshot_bid be:
snapshot_bid =  [[10101.80, 0.013400],[10101.20, 0.44100], [10101.10, 0.450541]]

#I will say that if the snapshot is not ordered I can ask the function to return a
  boolean, True if ordered, else False
>>x = check order(snapshot_bid, "bid")
>>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**

```
# let our snapshot_bid be:
bid_history = [
[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]]],
[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]] ],
[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]]]
]

ordinal_volumes, ordinal_prices = convert_array_list_to_dict(snapshot)

>>print(ordinal_volumes)
>>[{"time":2019-08-14T20:42:27.265Z, "1":0.013400, "2":0.44100, "3":0.450541, "4"
  :5.24501, "5":10.24511},
```

```
{"time":2019-08-14T20:42:27.500Z, "1":0.44100, "2":0.450541, "3":5.24501, "4"
  :10.24511, "5":24.21395},
{"time":2019-08-14T20:42:27.963Z, "1":0.52200, "2":0.450541, "3":5.24501, "4"
  :10.24511, "5":2421395}]

>>print(ordinal_prices)
>>[{"time":2019-08-14T20:42:27.265Z, "1":10101.80, "2":10101.20, "3":10101.10, "4"
  :10100.55, "5":10099.00},
{"time":2019-08-14T20:42:27.500Z, "1":10101.20, "2":10101.10, "3":10100.55, "4"
  :10099.00, "5":10090.11},
{"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**

```
# let our snapshot_bid be:
bid_history = [
[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]]],
[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]] ],
[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]]]
]

ordinal_volumes, ordinal_prices = convert_array_list_to_dict(snapshot)

>>print(ordinal_volumes)
>>[{"time":2019-08-14T20:42:27.265Z, "1":0.013400, "2":0.44100, "3":0.450541, "4"
  :5.24501, "5":10.24511},
{"time":2019-08-14T20:42:27.500Z, "1":0.44100, "2":0.450541, "3":5.24501, "4"
  :10.24511, "5":24.21395},
{"time":2019-08-14T20:42:27.963Z, "1":0.52200, "2":0.450541, "3":5.24501, "4"
  :10.24511, "5":2421395}]

>>print(ordinal_prices)
>>[{"time":2019-08-14T20:42:27.265Z, "1":10101.80, "2":10101.20, "3":10101.10, "4"
  :10100.55, "5":10099.00},
{"time":2019-08-14T20:42:27.500Z, "1":10101.20, "2":10101.10, "3":10100.55, "4"
  :10099.00, "5":10090.11},
{"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**

```
ordinal_volumes = [{"time":2019-08-14T20:42:27.265Z, "1":0.013400, "2":0.44100, "3"
    :0.450541, "4":5.24501, "5":10.24511},
{"time":2019-08-14T20:42:27.500Z, "1":0.44100, "2":0.450541, "3":5.24501, "4":10.24511,
    "5":24.21395},
{"time":2019-08-14T20:42:27.963Z, "1":0.52200, "2":0.450541, "3":5.24501, "4":10.24511,
    "5":2421395}]

volm_title =  "L2_orderbook_volm_bid"+str(bid_events[-1]['time'])+".xlsx"

>>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**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>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**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>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 $10010.99 USD/BTC$, (i.e., you need $10010.99 USD$ to buy $1 BTC$) then the amount of BTC in 1 cent or 0.01 USD which is the smallest denomination of the USD is $0.000000999 BTC$. 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 c

**latent changes:** None: None

**Example: None**

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

# 7 Credits

## 7.1 Development Lead


- Ivan E. Perez - perez.ivan.e@gmail.com


## 7.2 Contributors


- BTC-DAVE - jewmansown69@gmail.com

# 8 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**

```python
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>1.23

```

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

**Example: None**

```
x = __my_function__(1.234, True, 3)
>>print(x)
>>-1.23

x = __my_function__(1.234, False, 3)
>>print(x)
>>1.23

```

# References

[1] Weibing Huang, Charles-Albert Lehalle, and Mathieu Rosenbaum. Simulating and analyzing order book data: The queue-reactive model. *Journal of the American Statistical Association*, 110(509):107–122, 2015.