orderbook

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Introduction

The **orderbook** package provides functions for exploring and visualizing orderbook data. Using the **orderbook** package, analysts can create a object of class `orderbook` that is able to accept limit orders, replace and cancel messages, as well as market orders. From this object summary statistics such as the spread, number of price levels, and depth of the market can be retrieved.

Background

An orderbook keeps track of the outstanding limit orders for a current stock. A limit order is an order to buy (sell) a security for no more (less) than the specified limit price. For example, person A may want to purchase 100 shares of IBM at $11.00, in which case A would submit a limit order of type *bid* with limit price $11.00 and size 100. Suppose person B submits the same order. Then there would be a size of 200 at $11.00. Next, consider a Person C wants to sell 150 shares of IBM at $11.05. The orderbook now has an *ask* order.

```
                   Price            Ask Size

                   $11.05           150
      200          $11.00

Bid Size           Price
```

The best ask (bid) is the lowest (highest) price level that individuals are willing to sell (buy) stocks. In this case the best ask is $11.05, and the best bid is $11.00, so the *spread*, which is the difference between the two, is $0.05. The *depth*, or number of shares being offered at each price level, is 150 at $11.05, and 200 at $11.00. We call this the *inside market*. Another noteworthy statistic is the *midpoint*, which is the simple average of the best bid and best ask.

Although not displayed here, all orders in the orderbook have a timestamp representing the time at which they were submitted, as well as a unique identifier. The identifier allows for the orderbook to accept replace and cancel messages from market participants. For example, if A decided he only wanted to buy 50 shares of IBM he could submit a replace message to reduce the number of shares he is willing to purchase. Note that a replace message can never increase the number of shares to be purchased or sold. The reason for this is that in the event of a market order, the orders submitted earliest are processed (filled) first. Now perhaps B decides that he wants to buy IBM at $10.95 instead of $11.00. A replace message can only alter the size of an order, and not change its price level, so B would cancel his order, then submit a new limit order at the lower price. This would result in two *price levels* on the bid side.

```
                   Price            Ask Size

                   $11.05           150
      25           $11.00
     100           $10.95

Bid Size           Price
```

A person D may come in and submit a market order to sell 125 shares of IBM. A market order is an order to buy (sell) stock immediately at the current best available price. In this case, A will buy 50 shares at $11.00, and B will buy 75 shares at $10.95. Note that D continues to sell stock even after the current best price level is exhausted.

```
                   Price            Ask Size

                   $11.05           150
      25           $10.95

Bid Size           Price
```

Hundreds of thousands of orders are submitted daily for a single stock, and the orderbook package allows users to examine the orderbook at any point during the day.

Examples

Consider the first 10,000 orders for NVIDIA (NVDA) on June 8, 2010. Start by loading and examining the input data.

```
> library(orderbook)

> file <- system.file("data", "sample.txt",
+     package = "orderbook")
> ob <- orderbook(file = file)
> ob <- read.orders(ob, 10000)
> ob

An object of class orderbook
--------------------------
Current orderbook time:    09:35:02
File Index:                10,000
Bid Orders:                630
Ask Orders:                1,856
Total Orders:              2,486
```

We create the orderbook object by giving the object the location of our data file. Then we read in the first 10,000 orders. Only 2,487 orders remain, indicating that many have either been cancelled or removed through trades.

```
> summary(ob)


Current time is 09:35:02

Ask price levels:   540
Bid price levels:   179
Total price levels: 719
-----------------------------
Ask orders:         1,856
Bid orders:         630
Total orders:       2,486
-----------------------------
Spread:             0.02

Mid point:          11.370
-----------------------------
Inside market

Best Bid:           11.36
Size:               200

Best Ask:           11.38
Size:               100
```

In addition to the number of orders, with `summary` we also see the number of price levels, spread, midpoint, and inside market.

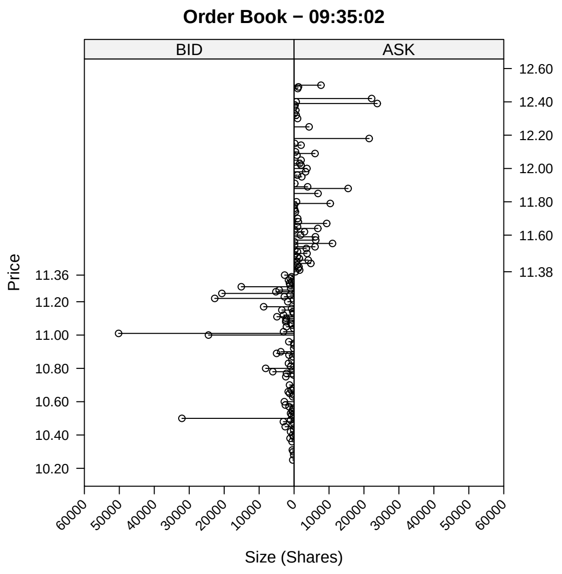
```
> display(ob)


Current time is 09:35:02

                 Price          Ask Size
---------------------------------------------
                 11.42          900
                 11.41          1,400
                 11.40          1,205
                 11.39          1,600
                 11.38          400
---------------------------------------------
  2,700          11.36
    700          11.35
  1,100          11.34
  1,600          11.33
    700          11.32
---------------------------------------------
Bid Size          Price
```

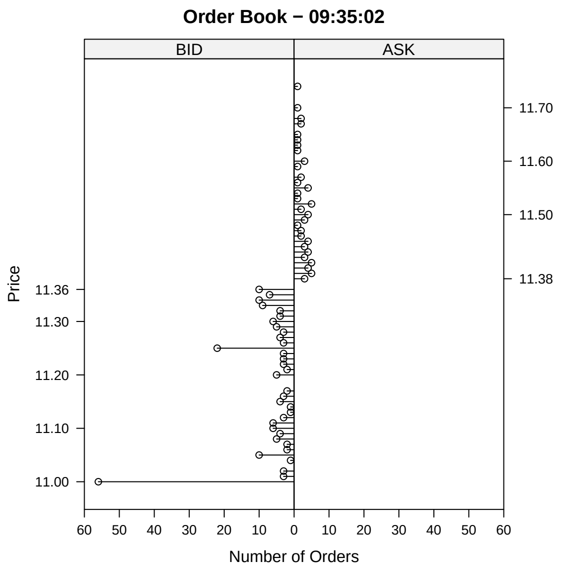
`summary` provides the user with a set of important summary statistics, while `display` shows the top five bid and ask price levels, along with the corresponding depth. Finally, `plot` shows a graphical representation of the orderbook with price levels on the y-axis, and size on the x-axis. By default, the maximum and minimum price levels are 10% above and below the midpoint price, respectively.

```
> plot(ob)
```



Note that there is a particularly large order at $11.01. It is helpful to know whether the depth at that price level is comprised of a single order, or several. Additionally, we lower the bounds since we are only concerned with the $11.01 price level.

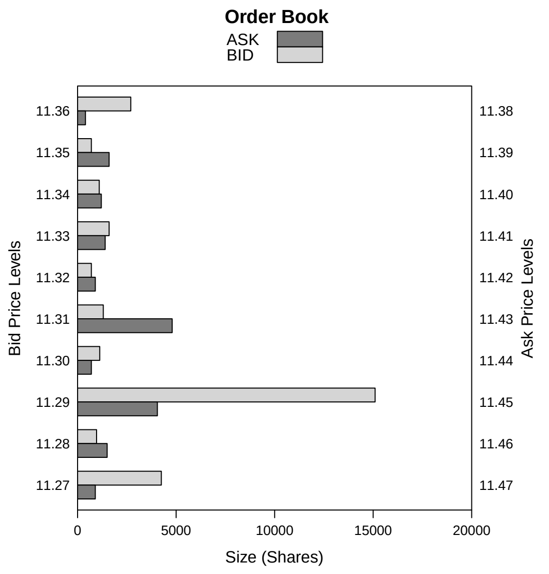
```
> plot(ob, bounds = 0.033, type = "o")
```



At first it appears that there are many orders at $11.01, but upon closer examination we see that there are 56 orders at $11.00, but only 3 at $11.01, indicating that the size at that price level is composed of a few very large orders (in this case one order for 50,000).

Viewing the orderbook with bids on one side and asks on another is useful, but sometimes users may want to view them side by side to more directly compare the supply and demand at each price level.

```
> plot(ob, type = "s")
```

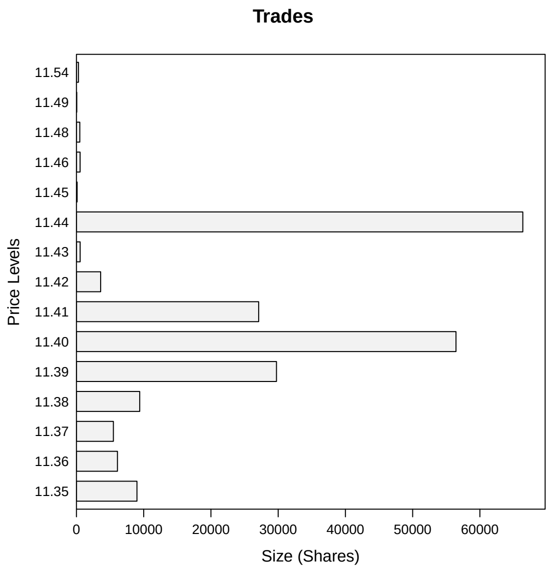


Additionally, The user can view a simple animation of the orderbook between two times. The `preload` method creates a file that contains the Trellis objects of the plots between the two times, and `animate` is a simple loop that prints the objects.

```
> preload(ob, "9:30:00", "9:31:00")
> animate("example.Rdata")
```

Finally, users can plot the trade data by using `plot.trade`. This creates a simple bar graph of the number of shares traded at each price level.

```
> plotTrade(ob)
```



Aside from the ability to retrieve summary statistics and create graphics, **orderbook** can create different `orderbook` objects for viewing the orderbook at different times. For example, the user may want to view the orderbook when the market opens.

```
> ob <- read.time(ob, "9:30:00")
```

Suppose the user wants to view the last pre-market trade. `previous.trade` returns the state of the orderbook at the time of the trade immediately preceding the current time ocurred, and `next.trade` returns the state of the orderbook at the time of the next trade.

```
> next.ob <- next.trade(ob)
> prev.ob <- prev.trade(ob)
```

To look at the 50 orders preceding `next.ob` or following `next.ob`, we use the `read.orders` command.

```
> a <- read.orders(next.ob, n = 50)
> b <- read.orders(next.ob, n = -50)
```

Data

Most brokers and exchanges have their own format of transmitting raw order data to customers, so it would be unfeasible for us to write scripts to automatically process that data. Consequently, raw data for an `orderbook` object should be in the following form:

```
A,31285893,1231884,11.49,200,ASK
R,31295779,1231884,150
T,31295779,1231884,11.49,50
C,31295781,1231884
```

where A, R, T, C mean Add, Replace, Trade, and Cancel order, respectively. The first number is the timestamp of the order in milliseconds after midnight of the users timezone, and the second number (or string) is the ID of the order. For a Replace the next number is the new size, while for Add and Trade price comes before size, followed by the type of order in the case of Add (BID/ASK).

Simulation

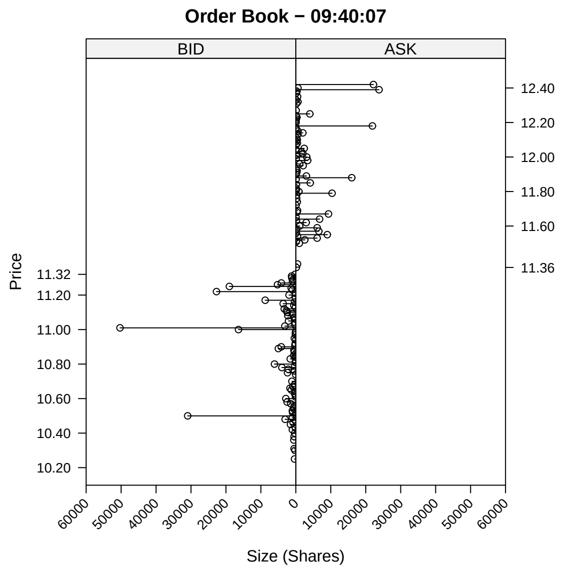
The orderbook object supports adding, replacing, and cancelling orders. To add an order, the user needs to specify the price, size, and type. Time and ID are optional, and will default to the maximum time and the maximum ID + 1, respectively. For replacing an order, only ID and size need to be given, and for cancelling an order, only ID is necessary. Market orders are also possible by specifying the size and side (BUY/SELL).

```
> display(ob)
> ob <- add.order(ob, stuff)
> ob <- remove.order(ob, stuff)
> ob <- replace.order(ob, stuff)
> ob <- market.order(ob, 200, "BUY")
> display(ob)
```

Using these tools, the user can write functions to simulate the movement of an orderbook. In the following example, we consulted Gilles (2006). We simulate 1,000 orders. In each iteration of our simulation there is a 50% chance for a cancel order to be placed, 20% chance for a market order, and 30% chance for a limit order. Orders are cancelled completely randomly, and for a market order there is a 50-50 chance for a buy or sell order to be placed. The size of the market order always corresponds to the size of the best ask or bid at the front of the queue. When a limit order is placed, there is a 50-50 chance for it to be an ask or bid. Then there is a 35% chance for the price to be within the spread, in which case a price is chosen based on a uniform distribution. If the price is determined to be outside of the spread, a price is chosen using a power law distribution. The size follows a log-normal distribution.

```
> ob <- simulate(ob)

> plot(ob)
```



Conclusion

In this article, we have described the orderbook package. orderbook aims to provide user-friendly statistical and visualization tools for analyzing orderbooks. We demonstrated the functionality of the package through a series of examples. Users who deal frequently with orderbook data (i.e high frequency traders) will hopefully find the package useful. While the curent package is not complex enough to be a stand-alone platform for developing trading stategies, it can be useful for generating ideas for strategies.

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Bibliography

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