

CS213/293 Data Structure and Algorithms 2023

Lecture 15: Application: Algorithmic trading

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Trading

What is trading?

A wants to sell X and B wants to buy X.

What price should they pay for the transaction?

There is no price set by any other entity.

Market decides

A and B come to a market.

A sells to the highest buyer.

B buys from the cheapest seller.

Example: market game

Example 15.1

We need 10 volunteers for the demonstration.

There are 5 buyers and 5 sellers. All of them are trading the same product.

Each buyer has a price **above which they will not pay** and will **minimize** the purchase price.

Each seller has a price **below which they will not sell** and will **maximize** the sale price.

You cannot walk away. You have to make a deal.

Example: market game(2)

Buyer prices

- ▶ 20
- ▶ 40
- ▶ 60
- ▶ 80
- ▶ 100

Seller prices

- ▶ 10
- ▶ 30
- ▶ 50
- ▶ 70
- ▶ 90

Topic 15.1

Market

Components of market

1. Market maker: a place to meet. NSE, NASDAQ
2. Broker: guarantor of transaction.
 - ▶ Brokers place orders on the trader's behalf
 - ▶ Brokers ensure that deals are honored.
3. Trader : orders are initiated by buyers and sellers

Order types

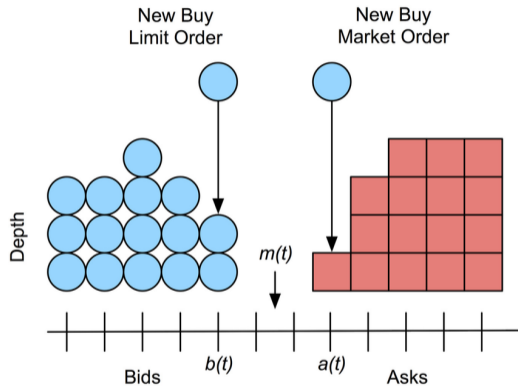
There are three (basic) kinds of orders

- ▶ `MARKETORDER(q)`: Buy/Sell q stocks at current price
- ▶ `LIMITORDER(p,q)`: Buy/Sell q stocks whenever the price falls **below/above** p
- ▶ `STOPLOSSORDER(p,q)`: Buy/Sell q stocks whenever the price rises **above/below** p

The transactions happen at which price?

Limit Order Book

The following is the **limit order book** at time t , which contains the list of orders that are waiting.



For a buy market order, the price is $a(t)$ (smallest sell limit order that is waiting).

Exercise 15.1

Can a market order match with another market order?

Liquidity

The **liquidity** of a stock is the sum of the quantity of limit orders in the book.

The market maker broadcasts the order book at regular intervals.

What does an algorithmic trader do?

- ▶ Long-term: Execute large orders in a systematic manner
 - ▶ Large orders may cause liquidity problems, therefore, price rise.
- ▶ Short term: Buy low and sell high in a short time interval (Or the other way around).
- ▶ Arbitrage

Topic 15.2

Managing large orders

Large orders

Supply and demand: If one posts a large buy order on the limit order book, sell order prices will sharply rise.

They are broken into smaller parts.

The goal is to buy whenever prices are low: buy at each price dip. As soon as they buy the price moves up again.

If the price is repeatedly bumped up from a point, we say that the price has **support**.

Topic 15.3

Short term trading

Short term trading

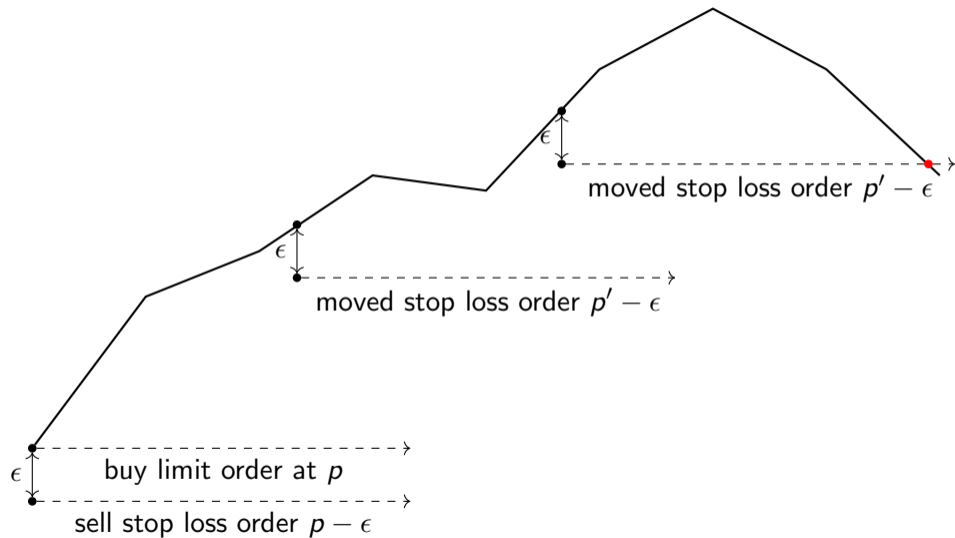
1. Guess a stock that is about to **go up from** price p .
2. Buy the stock at the price: `LIMITORDER(Buy, p , q)`.
3. Whenever step 2 is successful, `STOPLOSSORDER(Sell, $p - \epsilon$, q)`. Let $p := p - \epsilon$.
4. After every period, if the current price p' is $> p + \delta$ and the order is still not filled, then replace the order by `STOPLOSSORDER(Sell, $p' - \epsilon$, q)`. Let $p := p' - \epsilon$.

In the above strategy, we sell as soon as the price starts falling.

Exercise 15.2

Define the strategy if we expect the price to fall (called shorting).

Example: Short-term trading



Understanding the strategy

Our strategy is defined by the following parameters.

- ▶ Choice of stock
- ▶ Direction (Buy or sell)
- ▶ ϵ is the risk factor
- ▶ δ is the expected gain
- ▶ t is time horizon

If ϵ is small, a small drop in prices will stop the strategy. Otherwise, we may have a greater loss.

If t or δ are large, we may miss an opportunity. Otherwise, we pay large modifications cost.

When, what, and which direction to trade?

Watch the data stream from the stock exchange, including the limit order book.

When?

There are many prediction schemes. Here is a very simple prediction.

If prices are going up in the last three rounds, the price will go up in the next round.

The user decides the size of a round (it can be from 1 minute to 1 day).

User must test their strategies on historical data.

When, what, and which direction to trade? (2)

What?

We want to trade on the most promising stock.

NSE has more than 20k+ instruments. We need to process megabytes of data every time tick.

We may store them on a **priority queue** for quick access.

Topic 15.4

Arbitrage

Arbitrage

Let us suppose we have three currencies A , B , and C , with the following exchange rates.

- ▶ $1 A = 2 B$
- ▶ $1 B = 3 C$
- ▶ $1 C = 1/5 A$

How can we make money from the above market condition?

$A \rightarrow 2B \rightarrow 6C \rightarrow 1.2A$ and make money.

Since prices are decided by pairwise supply and demand, there is a possibility of the existence of arbitrage.

Finding cycles

We see the currencies as nodes of a **graph** and the edges are the exchange rates.

We may look for cycles in the graph, where the multiplication of edges is not 1.

We expect the cycles to exist because finding the cycle is computationally expensive.

A trader can exploit the cycles!

Topic 15.5

High-frequency trading

Colocation

Exchanges allow brokers to place their servers right next to the matching engine.

They have fast access to the trading systems.

There are dedicated network cards for trading, where one can install their trading strategy within the circuits of the card.

Topic 15.6

Market maker checks

Exchange checks

The exchange needs to monitor the participants if there are any undesirable behaviors.

For example,

- ▶ Sudden price changes
- ▶ Pump-and-dump
- ▶ etc

They also need algorithms to monitor the markets.

Pump-and-dump

Artificially, inflate the prices of a stock by doing repeated transactions among related parties.

This may attract other market participant to buy the stock.

This artificial demand may push the price up significantly.

Original parties may dump their stocks at a high point?

How do we detect pump-and-dump?

Find cycles in transaction volume graphs!

End of Lecture 15