MIS4321
Computational Finance and Algorithmic Trading

Fall 2025

Lecture #2

Fundamentals of Algorithmic Trading

By a **trade** we will understand either a purchase or sale of some kind of **financial instrument**.

The financial instruments include stocks (or shares), bonds, commodities, currencies, derivatives and possibly other instruments.

The term **security** is used to cover **any kind of financial instrument that can be traded**.

A **trade** can be realized by **a seller offering to sell** at a particular price and **a buyer willing to buy** at that price. Such a buyer and seller are matched, and a trade between them becomes possible.

Goods that are traded should possess the property of **fungibility** which essentially means that two different units are **exchangeable and possess the same financial value**. Cash is a fungible asset.

Trading Systems

The **flow of information from an electronic trading exchange to the market participants**:

The trading exchange maintains a book of client **buy orders (bids) and client sell orders (asks),** and publishes market data using market data protocols to provide the state of the book to all market participants.
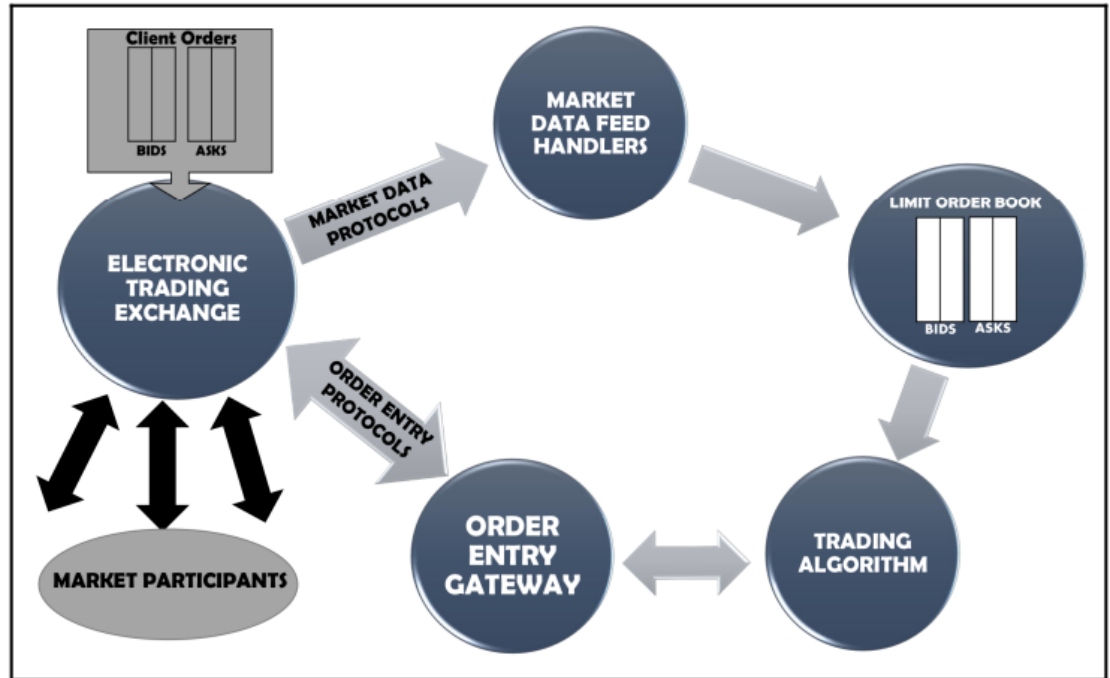
The outgoing order flow is communicated to the exchange via order entry protocols. This, in turn, will generate further market data flow, and so the **trading information cycle** continues.

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Trading Systems

A **stock exchange** (or a simply an exchange) is a place where buyers and sellers can negotiate and **conduct trades**.

Typically, buyers and sellers do **not directly negotiate**.

The brokers who negotiate among themselves on behalf of their clients to conduct trades. Brokers earn commissions, and **both buyers and sellers become clients of brokers.**

An **electronic stock exchange** is essentially a piece of **software**. There are **two basic tasks:**
1. Entering orders in an order book
2. Matching buy and sell orders

Direct market access: Buyers and sellers can also obtain direct access to the order book of a stock exchange (there is no broker).

Concepts in Algorithmic Trading

Liquidity: Market liquidity of a financial asset refers to the property whereby the asset can be quickly sold or purchased **without a significant change in the price of the asset**. **Liquidation** simply means selling the asset for cash.

Market maker: A market maker is an entity which places **limit orders** that **cannot be immediately executed**, i.e. it places buy orders at prices below the current selling price and/or sell orders at prices above the current buying price. Such orders introduce liquidity into the market, thus a market maker is also called **a liquidity provider**.

Market taker: A market taker is an entity which places orders that are **immediately executed**. This means that the entity places a buy order at a price which is at or above the current selling price and/or places a sell order at a price which is at or below the current buying price. Such orders remove liquidity from the market and so, these entities are also called **liquidity takers**.

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Concepts in Algorithmic Trading

Maker, taker fees: **Makers** "create or make a market" for other traders and **bring liquidity** to an exchange. **Takers remove liquidity** by "taking" available orders that are filled immediately. **Taker fees** are usually **slightly higher** than maker fees to encourage market makers.

Bid-ask spread: The difference in the selling and buying prices of the security in an exchange. **One measure of liquidity** of an asset is the size of the bid-ask spread. If this **spread is small**, then **the asset is very liquid.**

Market impact: **The effect on the price** when an entity buys or sells an asset. Market impact is **quantified by the amount** in which the **price moves** in the opposing direction.

Concepts in Algorithmic Trading

Short: A short sale (or going short) of an asset refers to **the act of sale of an asset that the seller does not possess.** So, the sale has to be made good **by borrowing the asset** from another entity. At a later point of time, **the seller repurchases the asset** from the market and **pays back the lender**. This is called covering the short position. The **seller gains if the price decreases** between the time it makes the sale and the time it buys from the market to pay back to the lender.
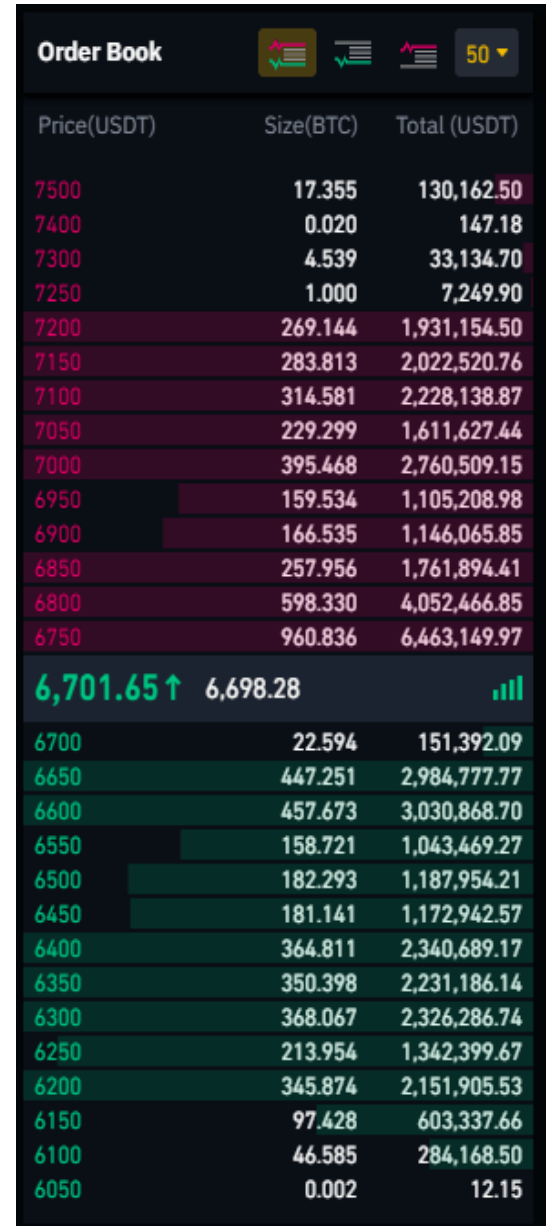
Long: An entity having a long (buy) position in an asset means that **the entity owns a positive amount of the asset**. This is the conventional concept of investing. An entity buys a certain amount of the asset. **If the price of the asset goes up, the entity stands to gain,** while if the price goes down, then the entity potentially loses.

Exchange Order Book

The exchange order book **maintains all incoming buy and sell orders** placed by clients. It tracks all attributes for incoming orders—prices, number of contracts/shares (amount), order types, and participant identification.

Buy orders (or bids) are sorted from the highest price (best price) to the lowest price (worst price). Bids with higher prices have a higher priority as far as matching is concerned.

Sell orders (or asks) are sorted from the lowest price (best price) to the highest price (worst price).

Price(USDT)	Size(BTC)	Total (USDT)
7500	17.355	130,162.50
7400	0.020	147.18
7300	4.539	33,134.70
7250	1.000	7,249.90
7200	269.144	1,931,154.50
7150	283.813	2,022,520.76
7100	314.581	2,228,138.87
7050	229.299	1,611,627.44
7000	395.468	2,760,509.15
6950	159.534	1,105,208.98
6900	166.535	1,146,065.85
6850	257.956	1,761,894.41
6800	598.330	4,052,466.85
6750	960.836	6,463,149.97

6,701.65 ↑ 6,698.28

Price(USDT)	Size(BTC)	Total (USDT)
6700	22.594	151,392.09
6650	447.251	2,984,777.77
6600	457.673	3,030,868.70
6550	158.721	1,043,469.27
6500	182.293	1,187,954.21
6450	181.141	1,172,942.57
6400	364.811	2,340,689.17
6350	350.398	2,231,186.14
6300	368.067	2,326,286.74
6250	213.954	1,342,399.67
6200	345.874	2,151,905.53
6150	97.428	603,337.66
6100	46.585	284,168.50
6050	0.002	12.15

Order Book   50 ▼

Exchange Order Book

The simplest **FIFO (First In First Out)** algorithm uses an outomatic rule of prioritizing **orders at the same price in the order in which they came in.**

Market depth of a security refers to the various price levels for the security.

It is provided as a list of the price levels and **the total quantity that is to be traded at each price level.**

It is the **size of the order that is needed to move the market price** by a specified amount. A deep market maintains a stable price.

⊖ **418.41** ⊕
Mid Market Price

$418.10 $418.15 $418.20 $418.25 $418.30 $418.35 $418.40 $418.45 $418.50 $418.55 $418.60 $418.65 $418.70

ORDER BOOK

Market size	Price (USD)	My size		Market size	Price (USD)	My size
				0.32578000	418.68	-
21.23336000	418.40	-		0.02256000	418.67	-
0.01000000	418.39	-		0.15730000	418.66	-
0.01000000	418.31	-		0.95597000	418.65	-
0.01000000	418.30	-		0.16940000	418.64	-
0.01000000	418.29	-		1.37110400	418.63	-
0.01000000	418.28	-		2.69360000	418.62	-
0.01000000	418.27	-		0.03200000	418.61	-
0.05000000	418.26	-		0.17200000	418.60	-
0.01000000	418.23	-		6.42753821	418.59	-
0.01000000	418.22	-		1.96500000	418.58	-
0.01000000	418.21	-		3.35532000	418.57	-
1.45900000	418.20	-		0.07500000	418.56	-
0.01000000	418.19	-		0.03750000	418.55	-
1.47000000	418.17	-		0.80500000	418.54	-
1.45800000	418.14	-		0.30670000	418.53	-
1.49000000	418.10	-		5.93968000	418.52	-
2.27100000	418.07	-		0.03500000	418.51	-
0.06000000	418.06	-		6.11465568	418.50	-
0.06000000	418.05	-		1.59490000	418.49	-
1.53300000	418.04	-		2.36500000	418.48	-
0.07000000	418.03	-		0.39489096	418.47	-
0.76670000	418.00	-		1.03616569	418.46	-
1.48500000	417.99	-		0.04434039	418.45	-
1.49300000	417.92	-		0.58720572	418.44	-
16.48700000	417.91	-		2.41500000	418.43	-
0.01000000	417.90	-		0.02500000	418.42	-
1.43800000	417.89	-		9.51880170	418.41	-
1.21400000	417.88	-				

Order Types

Market orders:

The simplest order is a market order. Such an order **specifies the quantity, but not the price**. It is to be **immediately fulfilled** at the best available market price.

For example, a **buy market order** is **fulfilled at the lowest ask price** and **a sell market order is fulfilled at the highest bid price**.

Limit orders:

They are one step up in complexity from market orders. A limit order **specifies the quantity and <u>the price</u>** indicating that the trade for the quantity is to be made at the specified or better price.

A buy limit order can be fulfilled by purchasing at the specified or lower price, while a sell limit order can be fulfilled by selling at the specified or higher price.

The limit order is entered into the order book queue and **has to wait for matching orders**.

Order Types

Fill or Kill (FOK): The orders are either to be filled completely or cancelled.

Immediate or Cancel (IOC): The orders are to be executed immediately or cancelled. Unlike FOK, <u>partial fulfillment</u> is allowed.

All or Nothing (AON): Either the order is filled completely or not at all. Partial fulfillment is not allowed. Unfilled AON orders are not cancelled.

Stop Order: This is an order to transact a trade **when the market price reaches a specified price**. Once the specified price is reached, the stop order **becomes a market order**. So, the trade will definitely take place even if the price changes adversely with respect to the stop order price.

Mid-Price Peg: Such an order specifies a limit price which is the average of the best bid and the best offer prices.

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Order Types

Market-if-Touched: Trade is to be conducted at the best available price if the market price reaches a specified 'if touched' level. As soon as the trigger price is reached, the order is treated as a market order.

One Cancels Other: This is a pair of orders for two instruments. If one of the orders is executed, then the other order stands cancelled.

One Sends Other: This specifies a cascade of orders. If the first order is executed, then the next one is triggered. The orders are executed sequentially.

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Exchange market data protocols are outgoing communication streams from the exchange to all market participants that are well-documented for new participants to build their software applications to subscribe, receive, decode, and check for errors and network losses.

Market data feed handlers are software applications that market participants build with a view to interfacing with the specific exchange market data protocol. These are able to subscribe, receive, decode, and check for errors and network losses,

Exchange order entry protocols are how market participant software applications send order requests (new, cancels, modifies) and how the exchange replies to these requests.

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Order entry gateways are the market participant client applications that communicate with the exchange matching engine over the order entry protocols. These have to deal with order flow in a reliable manner, sending orders to the exchange, modifying and canceling those orders, and getting notifications when these orders are accepted, canceled, executed, and so on.

Open Positions: A buy side execution is called having **a long position**, while a sell side execution is called having **a short position**. When we have no position at all, this is referred to as **being flat.**

Volume Weighted Average Price (VWAP): Multiple buy executions, or multiple sell executions for different amounts and prices, cause **the overall position price** to be the volume weighted average of the execution prices and quantities.

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Unrealized profit and loss (PnL): Open positions are marked to market to get a sense of what the unrealized **Profit and Loss** (**PnL**) of the position is.

Realized PnL: Profit or loss is **realized when an open position is closed**, meaning you sell to close a long position and you buy to close a short position.

Market data subscription : These components are responsible for interacting with the feed handler components that publish normalized data. This data can be delivered over a network or locally using a variety of **Inter-Process Communication** (**IPC**) mechanisms from the feed handlers.

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Signals: Once limit order books are built, every time they are updated due to new incoming market data information, we build signals using the new information.

Signals are called by various names—signals, indicators, predictors, calculators, features, alpha, and so on.

A trading signal is a well-defined **piece of intelligence** that is derived from incoming market data information, limit order books or trade information that **allows a trading strategy to get a statistical edge** (advantage).

Signal aggregators: Often, a lot of algorithmic trading systems combine a lot of different kinds of signals in order to gain a bigger edge than individual signals provide. The approach is to essentially **combine different signals** that have different predictive abilities/advantages under different market conditions.

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Execution logic

A key component of algorithmic trading is **quickly and efficiently managing orders based on signals** in order to gain an edge over the competition. It is important to react to changing market data, changing signal values in a fast but intelligent manner. Oftentimes, **speed and sophistication are two competing goals**, and good **execution logic will try to balance the two objectives** in an optimal manner.

Slippage is defined as **the difference in the expected price of a trade and the price at which the trade is actually executed**. This can happen for predominantly **two reasons**:

1. If the order reaches the exchange **later than expected (latency),** then it might end up either not executing at all, or executing at a worse price than you might expect.
2. If the **order is very large** such that it executes at multiple prices, then the VWAP of the entire execution may be significantly different from the market price observed when the order was sent.

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Fees are another issue with executing orders efficiently. Typically, there are exchange fees and broker fees **proportional to the size of the orders** and the total volume traded.

Position and PnL management
All algorithmic trading strategies need **to track and manage their positions and PnLs effectively.** Depending on the actual trading strategy, this can be complex.

For more sophisticated trading strategies, such as **pairs trading**, you have **to track positions and PnLs on multiple instruments.**

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Risk management

Good risk management is one of the cornerstones of algorithmic trading. Bad risk management practices can **turn potential profitable strategies into non-profitable ones.**

There is an even bigger risk of **violating rules and regulations** at trading exchanges that can often lead to legal actions and **huge penalties**.

Finally, one of the biggest risks with high- speed automated algorithmic trading is that **poorly programmed computer software is prone to bugs and errors.**

Concepts in Algorithmic Trading

Backtesting

When researching an automated trading strategy for expected behavior, **a key component** in a good algorithmic trading research system is **a good backtester**.

A backtester is used to **simulate automated trading strategy** behavior and retrieve statistics on expected PnLs, expected risk exposure, and other **metrics based on historically recorded market data.**

The **basic idea** is to answer the question: given historical data, **what kind of performance would a specific trading strategy have?**

Building Trading Strategies

Building a trading strategy takes time and goes through **numerous steps:**

1. You need an **original idea** (a money-making strategy).

2. Once we get the idea, we **need data** to validate the idea. There are many tools that we can use to get trading data.

3. You will then need to use a large amount of historical data to **backtest your trading strategy** assuming this rule: what worked in the past will work in the future.

Next week

- **Trading strategies**

Thank you for your participation ☺