Computational Finance and Algorithmic Trading

Week 1

What is Algorithmic Trading?

Algorithmic Trading is a method of executing trades using automated pre-programmed trading instructions.

It has revolutionized the way financial markets operate, allowing for faster and more precise trading decisions.

What are Algorithms?

An algorithm is a set of rules to be followed in calculations or other problem-solving operations.

In trading, algorithms are used to analyze large amounts of data and make trading decisions based on that analysis

Types of Algorithmic Trading

There are several types of algorithmic trading strategies, such as:

- **trend-following** : aim to identify and follow trends in the market
- **mean reversion**: look for opportunities to buy low and sell high

- **statistical arbitrage**: use statistical models to identify mispricings in the market

Advantages and Challenges of Algorithmic Trading

It is **fast, accurate** and **consistent**. Also it helps to make precise decisions in real-time. As they are not subject to human emotions or biases, it ensures **unbiased** trading decisions.

But on the other hand, they rely on high quality data to make accurate predictions. Overfitting can occur when algorithm is too closely tailored to the historical data. Market volatility can lead to unexpected results too.

Week 2

Fundamentals of Algorithmic Trading

A **trade** means: Either a purchase or sale of some kind
of **financial instrument**.

The financial instruments include:

- stocks
- bonds (fixed-income instrument that pays a fixed interest rate or coupon to its holders)
- commodities (a raw material or primary agricultural product that can be bought and sold, such as copper or coffee.)
- currencies
- derivatives

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 (interchangeability with each other) which essentially means that two different units are exchangeable and possess the same financial value.

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.

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 are negotiateing among themselves on behalf of their clients to conduct trades. Brokers earn commissions, and both buyers and sellers become clients of brokers.

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: Market makers generally try to **buy at the current best bid** or **sell at the current best offer**, i.e., they are making a market that is reflected in the current last price. Market makers are almost always willing to buy or sell, but may be inclined to step away in times of extreme volatility.

Market Taker: Market takers are less concerned with executing at the best bid or offer. Instead, they seek **liquidity and immediacy**, which is enhanced by the **constant availability** of a tight bid/ask spread created by the market makers. The relationship between market makers and market takers is **symbiotic**. Each needs the other in order to thrive.

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.

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 byclients. 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).

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.

Limit Orders: They are one step up in complexity from market orders. A limitorder specifies the quantity and the price indicating that the trade forthe quantity is to be made at the specified or better price.A buy limit order can be fulfilled by purchasing at the specified orlower price, while a sell limit order can be fulfilled by selling at the specified or higher price.

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.

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

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?

Week 3

High Frequency Trading

HFT uses algorithms and extremely fast connections to make rapid trades, often in fractions of a second. It uses proprietary (special) tools and computer programs that analyze markets, identify trends, and execute trades for very short-term gains. The order-to-trade ratio is the number of orders placed by the trader in the market divided by the number of orders that are actually filled. A high order-to-trade ratio typically indicates that the trader has placed many orders, but has modified or cancelled them before they could be executed. Usually, HFT leads to high order- to-trade ratios. HFT usually has a high turnover rate (the total value of stock traded in a unit of time).

Mean Reversion and Pairs Trading

Mean reversion is the general principle that an asset has a stable (or mean) price to which it will return after possible periods of volatility arising from external shocks.

Suppose two assets (symbol-1 and symbol-2) are of similar types and historical data show the prices of the two assets to be correlated.

Correlated: when two securities move together in the same direction or opposite direction.

Cointegrated: when the distance between the pair doesn't change drastically over time.

For some reason, this correlation may temporarily weaken.

As a result, the prices of the two assets diverge more than what is predicted from historical data. Suppose the price of symbol-1 goes up and the price of symbol-2 goes down. This suggests the following trading strategy. Short sell symbol- 1 and go long on symbol-2.

Z-Scores is used to define the entry and exit points of pair trading

When the **Z-score** reaches **-1 or +1**, we will use this event as **a trading signal**.

Usually, **Entry** should be taken when Z-Score is **less than -1 or greater than 1.**

Exit should be around **between -0.5 to 0.5.**

Half-Life

How long the spread typically takes to **revert back to the mean**. A half-life of 10 days for example indicates that this pair typically takes 10 days to revert.

Arbitrage Trading Strategy

Arbitrage is the strategy of taking advantage of **price differences** in different markets for the **same asset**.

For it to take place, there must be a situation of at least two equivalent assets with differing prices.

The simplest form of arbitrage is purchasing an asset in a market where the price is lower and simultaneously selling the asset in a market where the asset's price is higher.

Market Manipulation Strategy

Pump and Dump Scheme:

In this scheme, the fraudster initially acquires a significant holding in a security.

Then, trader spreads misleading information about the security using various means with the goal of creating a false impression that the price of the security is going to rise. This is the pump phase. When the price actually rises, the fraudster sells off his holdings giving rise to the dump phase.

Spoofing:

A high-frequency trader can place many limit buy orders and then cancel them before they are executed. This can create an impression on the other traders that the price of the security is rising.

Rebalancing Strategy

Periodic Rebalancing:

It is the act of rebalancing a portfolio at a regular interval or **“period”**. At the end of each interval, the portfolio will be rebalanced to once again match the target allocations.

Treshold Rebalancing:

is triggered when the portfolio breaches a specific percentage of deviation from the target allocation.

The threshold that is evaluated for triggering a threshold-based rebalance is based on the following formula: ((C - D) / D) x 100

One major drawback of threshold-based rebalancing: It requires that the portfolio be monitored frequently and is thus not practical for investors who manage their own portfolios.

Week 4

Evaluating Trading Strategies and Backtesting

Backtesting a trading strategy involves testing a strategy on historical market data to evaluate its effectiveness.

To backtest a trading strategy, the common steps:

1. **Define the trading strategy**: You need to have a clear understanding of the strategy you want to test. This includes the entry and exit rules, the position sizing, and risk management.

2. **Gather historical data**: You need historical market data to test your trading strategy. This data can be obtained from various sources such as online brokers, data vendors, or financial websites.
3. **Develop a trading algorithm**: You need to code the trading strategy into an algorithm that can automatically execute trades based on the historical data.
4. **Run the backtest**: Run the backtesting algorithm on the historical data to simulate the trades and generate performance metrics such as profit and loss, win rate, and drawdown.
5. **Analyze the results**: Analyze the performance metrics to evaluate the effectiveness of the trading strategy. You can also use the results to optimize the strategy by adjusting the parameters or rules.

It's important to note that backtesting has limitations and may not accurately reflect the future performance of a trading strategy. Therefore, it's important to use backtesting as a tool for evaluating a strategy, but not as the only factor in making trading decisions.

Some important statistics:

Profit and loss (P and L): The money made by the strategy without transaction fees.

Net profit and loss (net P and L): The money made by the strategy with transaction fees.

Investment: The capital invested.

Number of trades: The number of trades placed during a trading session.

Building a Backtester

Backtesting helps us to generate results **showing risk and profitability** before risking any capital loss.

If the backtesting **returns good results** (high profits with reasonable risk), it will encourage getting this strategy to **go alive**. If the results are not satisfactory, backtesters can help to find issues.

Trading strategies define rules for entry and exit into a portfolio of assets.

We will make assumptions based on the experience. **But if the model is not close enough to reality**, the trading strategies will end up not performing as well, which will result in **financial losses**.

Assumptions in Backtesting

Survivorship-bias free data: Such datasets only include historical data for stocks that are still actively trading. For a long-term

position strategy, it is important to use the survivorship-bias free data (that include also delisted stocks). This will prevent you from focusing on winners alone without considering the losers.

Look-ahead data: When you build a strategy, you should not look ahead to make a trading decision. This type of bias occurs when a simulation relies on data or information that was not yet available or known during the time period being studied. It generally leads to inaccurate results from a study or simulation.

Market change regime: Modeling stock distribution parameters are not constant in time because the market changes regime.

Transaction costs: It is important to consider the transaction costs of your trading. It is very easy to forget this cost and results in loss of money in the real market.

Data quality/source: Since there are many financial data sources, data composition differs a lot. For instance, when you use OHLC (Open-high-low-close) data from Google Finance, it is an aggregation of many exchange feeds. It will be difficult to obtain the same highs and lows with your trading system. Indeed, in order to have a match between your model and reality, the data you use must be as close as possible to the one you will use.

Money constraint: Always consider that the amount of money you trade is not infinite. Additionally, if you use a credit/margin account, you will be limited by the position you take.

Average daily volume (ADV): The average number of shares traded over a day for a given ticker. The quantity of shares you choose to trade will be based on this number so as to avoid any impact on the market.

Benchmark testing: To test the performance of your trading strategy, you will compare against another type of strategy or just against the return of some indexes. If you trade futures, do not test against the S&P 500. If you trade in airlines, you should check whether the airline industry as a whole performs better than your model.

Initial condition assumption: You should not depend on the day you start your backtesting or the month (the initial condition is not always the same.)

Fill ratio of orders: One of the first assumption you need to consider is the fill ratio. If you trade with a high-frequency trading strategy, you may have 95% of the orders rejected. If you trade when there are important news on the market (such as FED announcements), you may have most of your orders rejected. Therefore, you will need to give a lot of thoughts on the fill ratio of your backtester.

Order execution time: It is important to create an assumption regarding when your order will be executed (or maybe it will not be executed). This assumption will add a condition to the backtester. We may get additional data.

Latency assumptions: Each commponent of a trading system causes some latency such as generation, execution and acknowledge time for an order.

Types of Backtesting

For-loop backtesting

The for-loop backtester is a very simple infrastructure.

It reads price updates line by line and calculates more metrics out of those prices (such as the moving average at the close).

It then makes a decision on the trading direction. The profit and loss is calculated and displayed at the end of backtester.

The design is very simple and can quickly discern (recognize) whether a trading idea is feasible (or not). An algorithm to picture how this kind of backtester works is:

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for each tick coming to the system (price update):
create_metric_out_of_prices()
buy_sell_or_hold_something()
next_price()
```

Event-Driven Backtest Systems

An event-driven backtester uses almost all the components of the trading system (such as the order manager system, the position manager, and the risk manager). The components will read the input one after the other and will then generate events if needed (or triggered).

Important events we encountered when we coded the trading system were the following:

Tick events – When we read a new line of market data
Book events – When the top of the book is modified
Signal events – When it is possible to go long or short
Order events – When orders are sent to the market
Market response events – When the market response comes to the trading system

Week 5

Financial Data Storage

Financial data refers to **quantitative information** that is used by organizations **to make financial decisions**. It is essentially data concerning a company's financial health and performance.

This data includes information about an **organization's income**, expenses, assets, liabilities, and cash flow. This vital information is gathered from traditional sources, such as public documents and external data sources. It can be historical or current and collected on an ongoing, periodic (e.g., quarterly, annually), or as-needed basis (e.g., related to a transaction).

Financial Data Types

Financial data is categorized into two main types: traditional financial data and alternative data.

Traditional financial data: Traditional financial data refers to information from long-established sources, such as financial statements, press releases, and SEC (Securities and Exchange Commission) filings. Financial information about assets consists of the organization’s real, personal, tangible, and intangible property. Alternative financial data: It is external data that an organization does not directly report. It is usually gathered in three ways:

1. Acquiring it from raw data sources (e.g., sensors, Satellite images)
2. Licensing third-party data
3. Web scraping (the use of a program or algorithm to extract and process large amounts of data from the web.)

Fidelity of Financial Data

While the information included in financial data sets can be interpreted differently by various audiences, the raw information must be protected to ensure the integrity of downstream decisions.