MIS4321
Computational Finance and Algorithmic Trading

Fall 2025

Lecture #3

Algorithmic Trading Strategies

We will assume that the trader has arrived at the decision and consider the problem of how **to implement** the trade.

Consider the situation where **a trader wishes to buy or sell a large amount of a particular stock** within a specific time frame.

A large volume of trade usually moves the price in an adverse direction. Consequently, for a buy order, the trader ends up paying more, while for a sell order, the trader ends up getting less (market impact).

The above discussion suggests that the trader will be better off by **splitting the single order into several child orders.**

Various algorithmic trading strategies have been devised **to address the above problem.**

Time Weighted Average Price (TWAP)

Suppose a trader decides to buy (or sell) S shares within a specified period of time, and S is large.

The simplest strategy: Divide the specified time period into **n sub-intervals** and place a child order for S/n shares in each sub-interval.

A simple measure of performance is the time-weighted average price (TWAP).

For each interval, the average price is determined as the average of the opening, closing, high and low prices in that interval. **The average of these averages** over the n sub-intervals **is the TWAP for the trading duration.**

In fact, a goal of placing equal size child orders at equal intervals is **to achieve the TWAP.**

The Simple Strategy

The simple strategy of placing equal size orders at equal intervals of time is completely **predictable by other traders and algorithms**.

Suppose that a child limit order is placed to buy 1,000 shares at $10 per share.

Another trader who has been tracking these smaller orders places a buy limit order for 500 shares at $10.01 per share.

If the market price reaches $10.01 and then rises, then this trader makes a profit.

If the market **price drops** below $10.01, then **trader sells off the shares** at $10.00, making a loss of 1 cent per share.

So, there is a possibility of **making a profit at a very low risk.**

Volume Weighted Average Price (VWAP)

Volume-weighted average price (VWAP) is another **measure of performance.**

Here **the volume** refers to **the size of an order.**

Suppose n child orders of sizes $S_1,...,S_n$ were placed, where $S = S_1 + \cdots + S_n$ is the total size of all the child orders.

Suppose order S_k traded at price p_k. Then the VWAP for the order is

$$\text{VWAP} = \frac{\sum_{k=1}^{n} S_k p_k}{S}$$

For a VWAP, it is **not required** that the child orders **be placed at regular intervals.**

Note that like **the TWAP, the VWAP** is a performance benchmark which can be **computed after the entire trade is completed**.

High-frequency Trading (HFT)

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).

High-frequency Trading (HFT)

The time to reach the trading decision and the time to place an order on a stock exchange (**the speed** of trading) is of utmost importance in HFT strategies.

The communication times (speed) are determined by the network delays. This time can be **reduced by**

- Using superior computer systems
- High bandwith networks
- Place the trading computers in the same data centers that house the exchange's computer servers **(co-location)**

HFT firms usually do **not hold long-term positions**, move in and out of short-term positions at **high volumes and high speeds**.

The amount of **profit per trade is usually very small**.

Market Making with HFT

The goal is to make a profit from the bid-ask spread. Exchanges have designated **firms who receive discounts for regularly playing market making roles in various stocks.**

HFT firms can simultaneously **place buy and sell quotes to profit from the bid-ask spread.**

Such quotes could be **thin quotes** which are close to the best bid-ask spread and get **filled up** more often or **thick quotes** which are far from the best bid-ask spread and **get filled up less frequently**.

Building **profitable market making strategies** requires **precise modelling** of the target market microstructure and the **use of stochastic control techniques.**

An HFT firm generally does **not act** as a market maker **in the long term.**

Exploiting Limit Order Book by HFT

Detecting the rising demand for an asset is a basic information that can be obtained **from a limit order book.**

If more orders are placed for an asset, then there is an increasing demand for the asset, and **the price** of the asset can be **expected to rise**.

So, a **profit can be made** by buying the asset while the price is rising and then sell it when the price has sufficiently risen.

The limit order book of an exchange will hold a **huge amount of information**.

Searching among such information to **find a number of assets is very difficult for a human to do**. Computer algorithms can be designed to process the information to discover such scenarios and exploit them with high speed .

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.

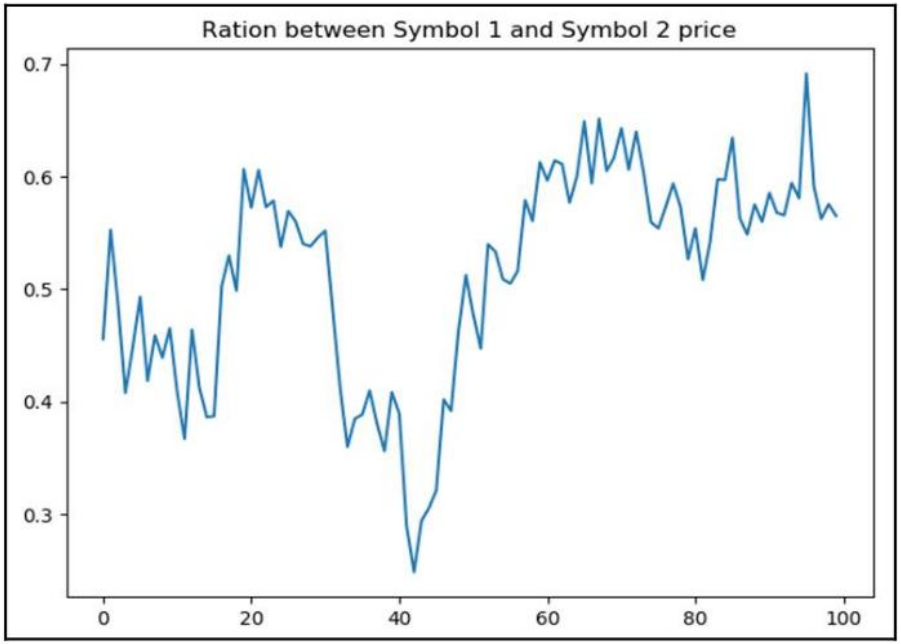
Cointegrated: when the distance between the pair doesn't change drastically over time.

Mean Reversion and Pairs Trading

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.



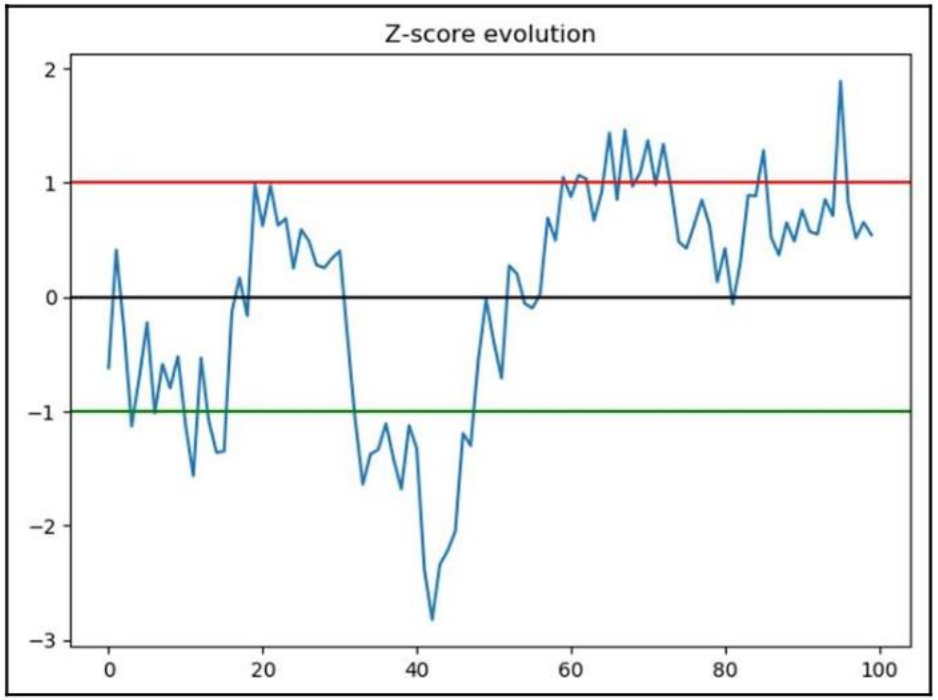
The mean reversion assumption implies that **after a certain amount of time, the prices of symbol-1 and symbol-2 will converge**, i.e. the price of symbol-1 will come down and the price of symbol-2 will go up.

Mean Reversion and Pairs Trading

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

Z Score (Value) = (Value — Mean) / Standard Deviation

A pair trade is set up when the ratio (and the density curve) has deviated convincingly enough from the mean value.

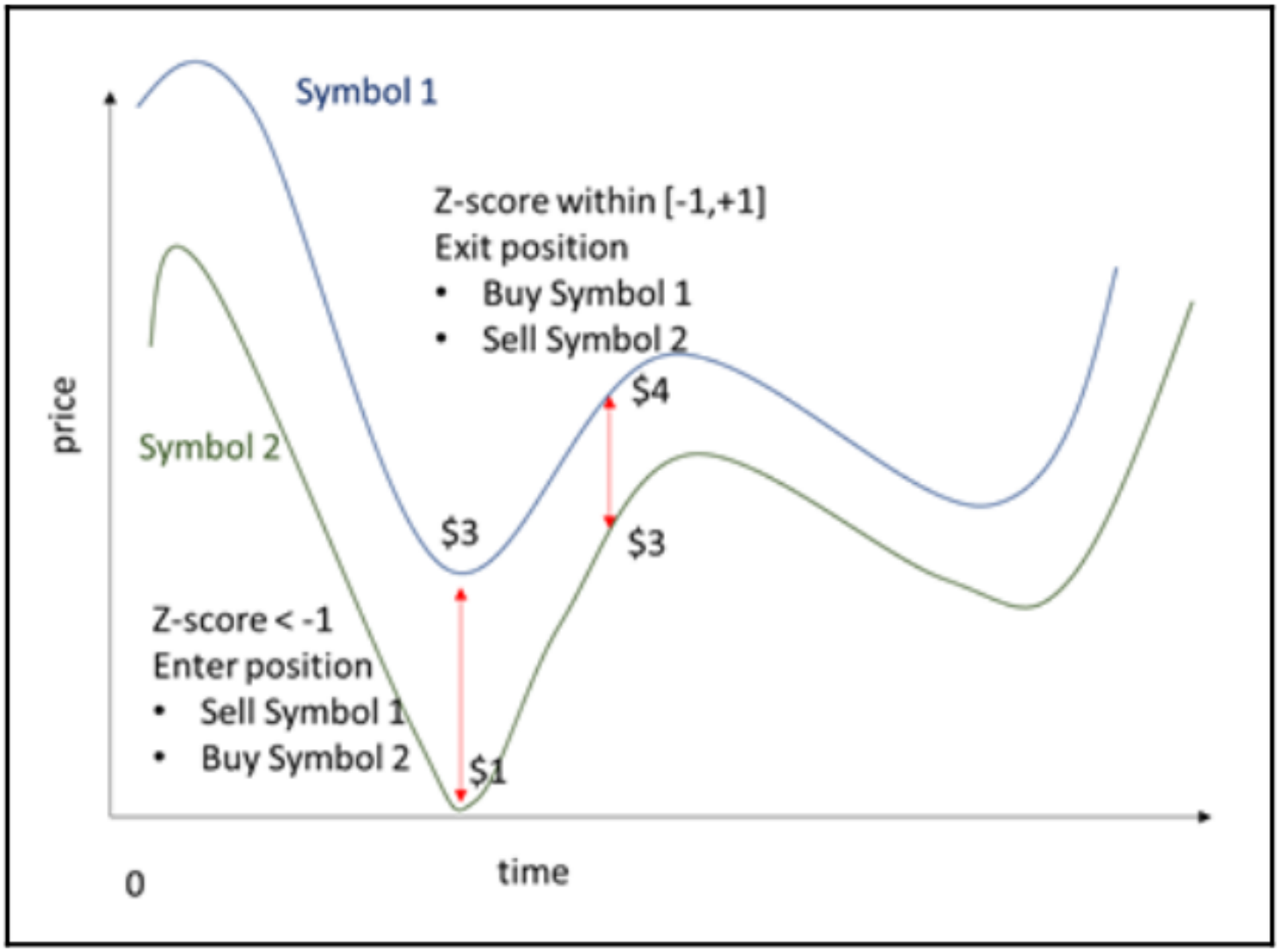


When the Z-score reaches -1 or +1, we will use this event as a trading signal.

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.

Mean Reversion and Pairs Trading



Mean Reversion and Pairs Trading

Hurst Exponent: helps us **determine** whether a **time series is mean reverting or not.** The outputted value *H* from the Hurst formula is some value between 0 and 1.

- H < 0.5 — The time series is mean reverting (Sideways)
- H = 0.5 — The time series is a Geometric Brownian Motion (Random Walk)
- H > 0.5 — The time series is trending (Trending)

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**.

In essence, arbitrage is a situation where a trader can profit from the **imbalance of asset prices** in different markets.

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**.

Arbitrageurs have to be able to **detect such opportunities** and act upon them with **utmost speed**. So, exploiting arbitrage opportunities **calls for HFT**.

Arbitrage Trading Strategy

A More Complicated Arbitrage Example: Triangular arbitrage

Suppose you have $1 million and you are provided with the following exchange rates:
USD/EUR = 1.1586, EUR/GBP = 1.4600, and USD/GBP = 1.6939.

With these exchange rates, there is an arbitrage opportunity:

1. Sell dollars to buy euros: $1 million ÷ 1.1586 = €863,110

2. Sell euros for pounds: €863,100 ÷ 1.4600 = £591,171

3. Sell pounds for dollars: £591,171 × 1.6939 = $1,001,384

4. Subtract the initial investment from the final amount:
   $1,001,384 – $1,000,000 = $1,384

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.

Market Manipulation Strategy

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**.

Similarly, a **large number of sell limit orders** which are placed (but **cancelled** before being filled) may lead to the impression that the price of the asset is falling, **creating a sell pressure on the security**. This allows the trader to buy the security at a lower price than its actual worth.

Market Manipulation Strategy

Layering is placing orders **different price levels** on one side of the market.

This causes the **midpoint of the bid-ask spread to move away** from its otherwise normal value.

The same **trader** then **executes a trade on the opposite side** of the market.

This allows the trader to **obtain a more favourable price** than what he may otherwise have obtained.

Market Manipulation Strategy

Quote stuffing is the practice of **rapidly sending and cancelling orders** with the intention of slowing down.

These so-called **phantom orders accumulate in the buffers of the exchange.**

As a result, the **delay of the usual information feed** released by the exchange **increases.**

High-frequency traders have high capacity feeds, thus they can use quote stuffing to delay the release of the feeds to the general public.

This may **create an opportunity for the trader to act on the obtained information before the general public.**

Market Manipulation Strategy

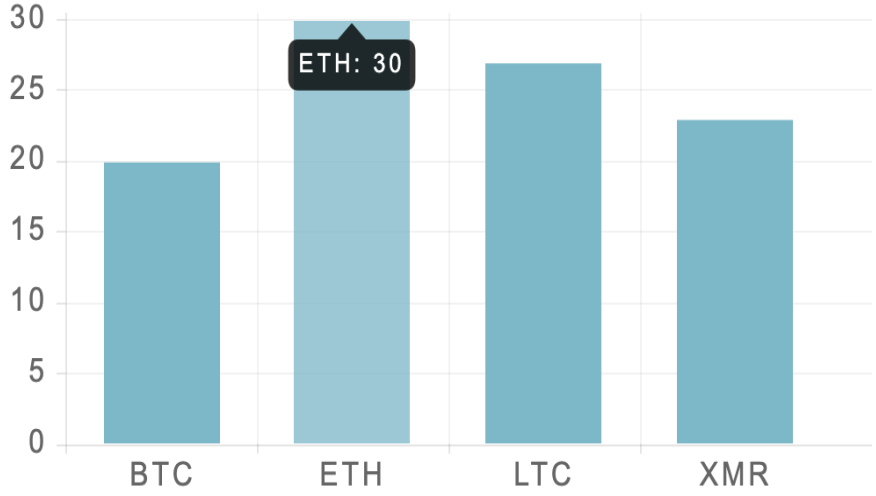
It is to be noted that **market manipulation methods are illegal**.

Various firms have been **penalised** for indulging in such practices.

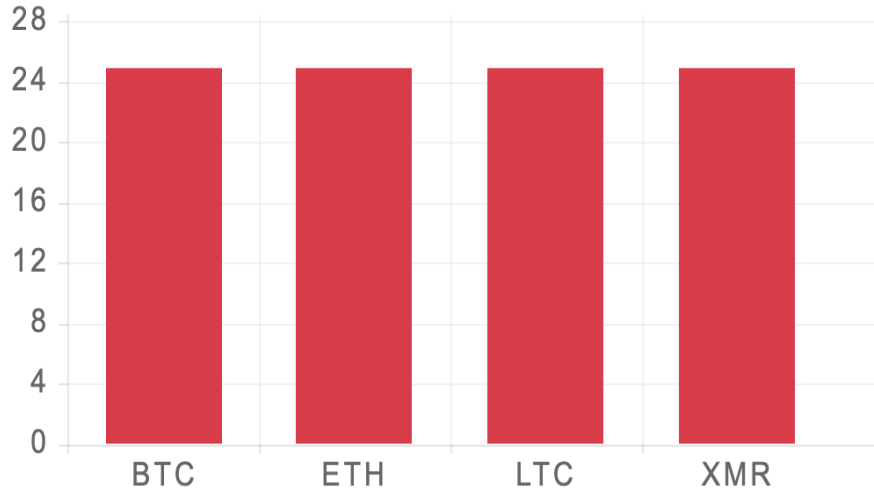
Rebalancing Strategies

Portfolio rebalancing is the act of trading each individual asset in your portfolio **to match a target (desired) set of allocations**.

Current portfolio



Desired (target) allocation



Rebalancing Strategies

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.

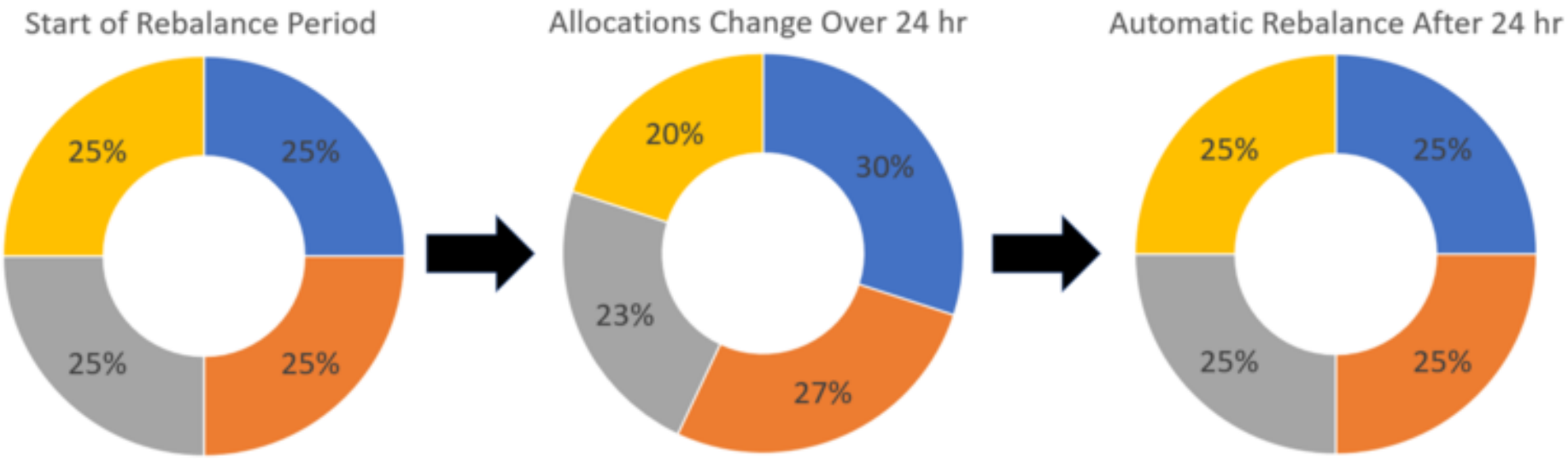
Some examples of common rebalancing periods include **1 hour, 1 day, 1 week, and 1 month** rebalance periods.

Periodic rebalancing has been a **trusted strategy by new investors** due to the **simplicity of understanding** when and how the portfolio will be maintained.

For example, if a **1 day rebalance period** is set for a portfolio, the portfolio will **be realigned with the target allocations** at the same time **every day**.

Rebalancing Strategies

Periodic Rebalancing

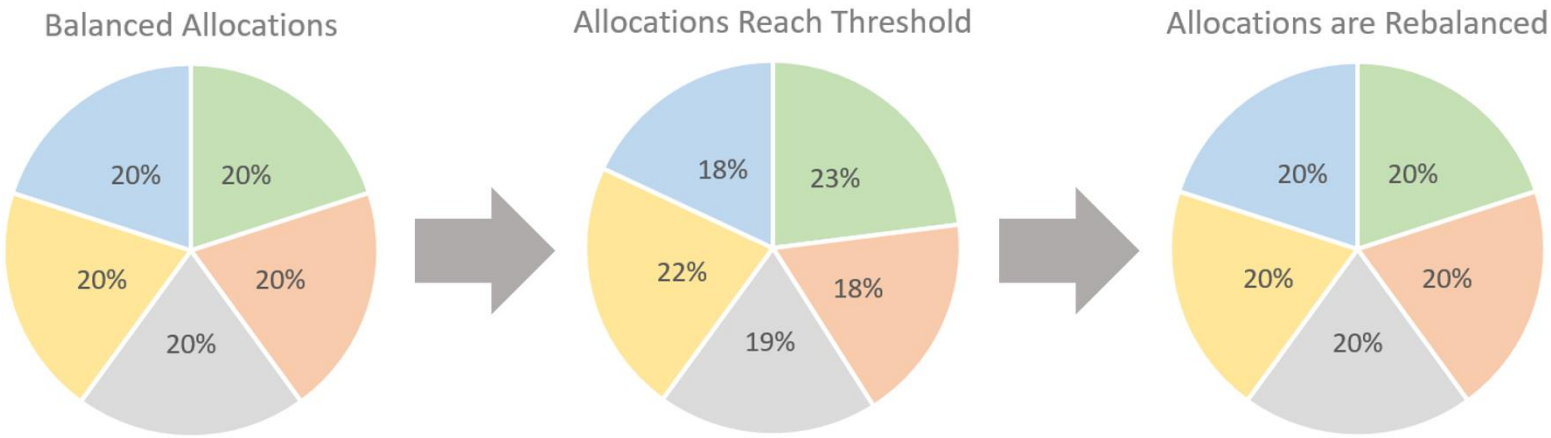


Rebalancing Strategies

Threshold 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**

Where, C is the **current** allocation and D is the **desired** allocation.



This example demonstrates **a 15% deviation threshold**.
D=0.20, C=0.23 → ((0.23-0.20)/0.20)x100=0.15 = 15%

Rebalancing Strategies

Threshold Rebalancing

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.**

It can be **managed by high frequency algorithmic trading strategies.**

The smaller the threshold, the lower the tracking error and the **higher the transaction cost**.

Next week

- **Evaluating Trading Strategies and Backtesting**

Thank you for your participation ☺