Mathematical Models and AI in Finance

An Introduction to Financial Engineering

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AM 100: GUIDANCE TO APPLIED MATHEMATICS

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Lecturer Biography

Pasin Marupanthorn, Ph.D.

Quantitative Researcher, ResilientML

- Ph.D. Actuarial Mathematics
- M.Sc. Financial Engineering
- M.Sc. Mathematical Modelling (with Engineering, Biology and Finance)
- M.Sc. Mathematics
- B.Sc. Applied Mathematics (with Physics)
- Member QuantConner Community

Nuthdanai Wangpratham

Quantitative Analyst Manager, KAsset

- Quantitative Analyst Manager
- Sustainability Risk Manager
- Insurance-Linked Productions Pricing
- Co-Founder QuantConner Community

Career

Career

1. Risk Manager
2. Fund Manager
3. Financial Advisor
4. Financial Engineer
5. Quantitative Analysis
6. Quantitative Developer
7. Quantitative Researcher
8. etc.

Salary

Statistic of the Global Salary:

https://www.payscale.com/research/US/Country=United_States/Salary

Salary by Quant Type:

https://www.reddit.com/r/quant/comments/vr9ufe/compensation_for_the_types_of_quants/

Salary in Thailand:

https://rb.gy/krlcy3

Introduction

Introduction to Financial Engineering

Mathematics

- Calculus and Differential Equations
- Statistics, Probability Theory, Stochastic Process, and Time Series Analysis
- Linear Algebra and Optimization
- Numerical Methods and Simulation

Finance

- Financial Market, Financial Instrument and Economics
- Portfolio Theory
- Equity and Interest Rate Derivatives, Including Exotics
- Credit-Risk Products

Programming

- Python, R, C, C++, SQL, etc.
- Database (BB/LSEG)

Portfolio Management

What is Portfolio Optimization?

Determining the appropriate proposition of capital allocation each asset in the portfolio.

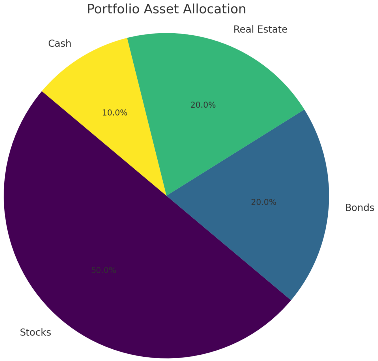

Figura: Multi-Asset Portfolio Allocation

Portfolio vs. Single Asset: The Power of Diversification

Investing in a portfolio rather than a single asset offers several key advantages, central to which is the concept of diversification. Here's why diversification through a portfolio is crucial:

- **Risk Reduction:**
- **Improved Risk-Return Trade-off:**
- **Access to More Opportunities:**
- **Mitigation of Unsystematic Risk:**

The mantra "Don't put all your eggs in one basket"aptly summarizes the essence of diversification, highlighting its role in creating a more resilient and efficient investment strategy.

Portfolio Variance

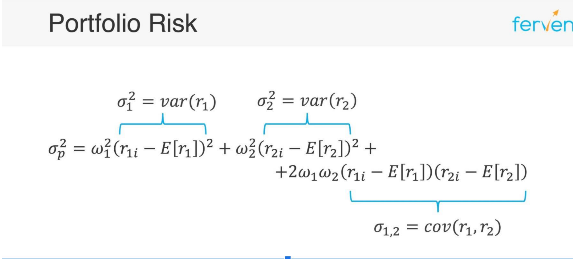

Figura: Portfolio Variance

Portfolio Expected Return VS. Variance

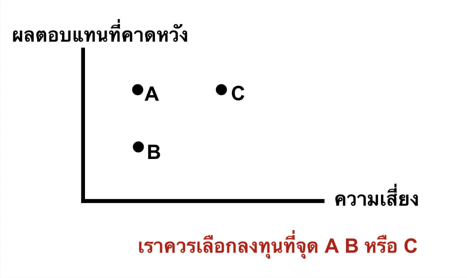

Figura: Portfolio Expected Return VS. Variance

Mean-Variance Portfolio Optimization I

Objective

Minimize portfolio risk for a given level of expected return, or equivalently, maximize expected return for a given level of risk.

Optimization Problem

$$\min_{\mathrm{w}} \mathrm{w}^\top \Sigma \mathrm{w}$$

subject to

$$\mathrm{w}^\top \mu = \mu_p,$$
$$\mathrm{w}^\top 1 = 1,$$

where:

- w is the vector of portfolio weights,
- Σ is the covariance matrix of asset returns,
- μ is the vector of expected asset returns,
- μ_p is the desired portfolio return,

Mean-Variance Portfolio Optimization II

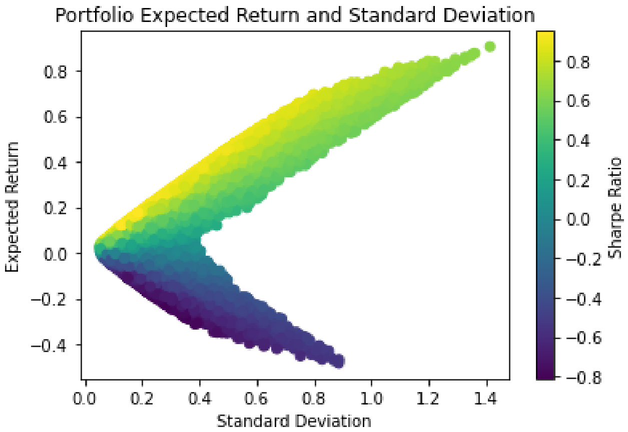

Figura: Trade-off Between Risk and Return: Efficiency Frontier

Goal-Based Portfolio Optimization I

Goal-Based Portfolio Optimization tailors investment strategies to achieve specific, personal financial goals. Unlike traditional portfolio management, which focuses on maximizing returns for a given level of risk, goal-based investing emphasizes meeting clearly defined objectives.

- **Personalized Objectives:** Investment strategies are designed around the investor's unique goals, such as retirement, purchasing a home, or funding education.
- **Multiple Portfolios:** Investors create separate portfolios for each goal, considering the distinct time horizons and risk levels.
- **Risk Management:** Focuses on the likelihood of achieving specific goals rather than solely on portfolio returns or market volatility.
- **Dynamic Adjustment:** Portfolios are regularly reviewed and adjusted to align with changing financial situations, goals, and market conditions.

Goal-Based Portfolio Optimization II

Consider an investor aiming to save for retirement (Goal 1) and fund a child's education (Goal 2) with two distinct time horizons and risk tolerances.

Objective:

- Maximize the probability of achieving each goal within their respective time horizons.

Constraints:

- Budget constraint: Initial investment must not exceed available capital.
- Risk constraints: Adjust for different risk tolerances for each goal.
- Investment limits: Some investments have minimum or maximum investment amounts.

Goal-Based Portfolio Optimization III

Maximize:

$$P_{retirement}(w_1, T_1) \geq \tau_1$$

$$P_{education}(w_2, T_2) \geq \tau_2$$

Subject to:

$$w_1 + w_2 \leq W$$

$$0 \leq w_1, w_2 \leq W$$

$$\sigma(w_1) \leq \sigma_{max1}, \sigma(w_2) \leq \sigma_{max2}$$

where:

- P_{goal} is the probability of achieving the goal,
- w_i are the portfolio weights for goal i,
- T_i are the time horizons,
- τ_i are the target probabilities,
- W is the total available capital,
- $\sigma(w_i)$ is the portfolio risk, and
- σ_{maxi} are the maximum tolerable risks.

Factor Investing I

Factor investing is a strategy that seeks to enhance portfolio return and manage risk by targeting specific factors identified as the main drivers of returns across asset classes. Key points include:

- **Factors:** Quantifiable characteristics that influence asset prices and returns. Common equity factors include size (small vs. large caps), value (cheap vs. expensive), momentum (trending up vs. down), and volatility (stable vs. risky).
- **Approach:** Investors can access factor exposures through smart beta funds, which systematically select, weight, and rebalance portfolios based on factor criteria, or through active strategies that seek to exploit factor premiums.
- **Benefits:** Factor investing aims to offer a more systematic approach to portfolio construction, improving diversification, enhancing return potential, and reducing risk relative to traditional market cap-weighted indices.

Factor Investing II

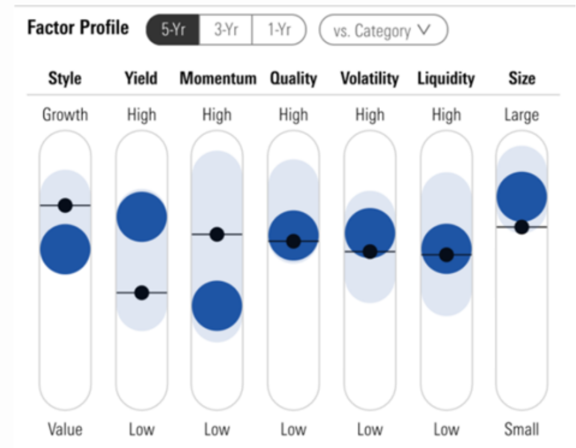

Figura: Morningstar Factor Profile of Portfolio

Factor Investing III

Factor models play a crucial role in the analysis of financial markets and portfolio management. They aim to decompose the returns on securities into contributions from various underlying factors.

The general expression of a factor model is given by:

$$R_i = \alpha_i + \beta_{i1} F_1 + \beta_{i2} F_2 + \cdots + \beta_{in} F_n + \epsilon_i$$

where:

- R_i is the return on asset i,
- α_i represents the asset's expected return not explained by the factors,
- β_{ij} measures the sensitivity of the return on asset i to factor j,
- F_j is the value of factor j,
- ϵ_i is the idiosyncratic return component for asset i.

Factor Investing IV

Factor models help in identifying the primary sources of risk and return in a portfolio, guiding investors towards more informed investment decisions.

Commonly used factors include:

- **Market return** (CAPM): The excess return of the market over the risk-free rate.
- **Size, value, and momentum factors** (Fama-French Three-Factor Model): Small minus Big (SMB), High minus Low (HML), and Winners minus Losers (WML).
- **Additional factors** in extended models can include profitability, investment, etc.

These factors account for a significant portion of the variability in asset returns and offer insights into the fundamental risk factors affecting portfolio performance.

Factor Investing V

Index tracking portfolio optimization aims to construct a portfolio that closely follows the performance of a benchmark index. The goal is to minimize the tracking error, which is the standard deviation of the difference between the portfolio's returns and the index's returns.

Optimization Objective:

$$\min_{\mathrm{w}} \sqrt{\sum_{t=1}^{T} (R_{p,t} - R_{i,t})^2}$$

where:

- w is the vector of portfolio weights,
- $R_{p,t}$ is the return of the portfolio at time t,
- $R_{i,t}$ is the return of the index at time t.

Factor Investing VI

Key Considerations:

- Budget constraint: The sum of the portfolio weights equals one.
- Risk management: Incorporating risk constraints to align with the investor's risk tolerance.
- Transaction costs: Minimizing the costs associated with adjusting the portfolio.

Successful index tracking involves balancing these considerations to closely replicate the index's performance with minimal cost and risk.

Financial Derivatives Pricing

What Are Financial Derivatives?

Financial derivatives are instruments whose value is derived from the value of one or more underlying assets or indices. Common forms include:

- **Futures:** Contracts to buy/sell an asset at a future date at a predetermined price.
- **Options:** Contracts offering the right, but not the obligation, to buy/sell an asset at a set price before a certain date.
- **Swaps:** Contracts to exchange cash flows or other financial instruments between parties.
- **Forwards:** Customized contracts to buy/sell an asset at a future date at a price agreed upon today.

Derivatives are used for hedging risks, speculation, arbitrage, or accessing assets or markets otherwise hard to reach.

Why Use Financial Derivatives?

- **Risk Management:** Derivatives allow businesses and investors to hedge against price movements in underlying assets, protecting against losses from adverse market conditions.
- **Speculation:** Traders can speculate on the future direction of asset prices to generate profits, leveraging the use of derivatives to expose themselves to higher gains (or losses).

Their strategic use can significantly enhance portfolio performance while mitigating risk, making derivatives an indispensable tool in financial markets.

How We Model Stock Price: Geometric Brownian Motion I

Geometric Brownian Motion (GBM) is a continuous-time stochastic process used to model the dynamics of stock prices. It is defined by the differential equation:

$$dS_t = \mu S_t dt + \sigma S_t dW_t$$

where:

- S_t is the stock price at time t,
- μ is the drift coefficient (average return rate of the stock),
- σ is the volatility of the stock returns,
- dW_t is the Wiener process (or Brownian motion) component, representing random shocks.

GBM captures two essential characteristics of stock prices:

1. The relative change in price is normally distributed,
2. The price is always positive, reflecting the nature of stock prices in real markets.

How We Model Stock Price: Geometric Brownian Motion II

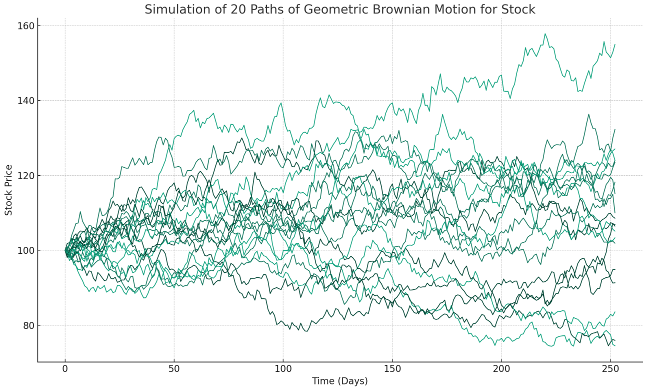

Figura: Simulation of GBMs

Examples of Option Pay-off I

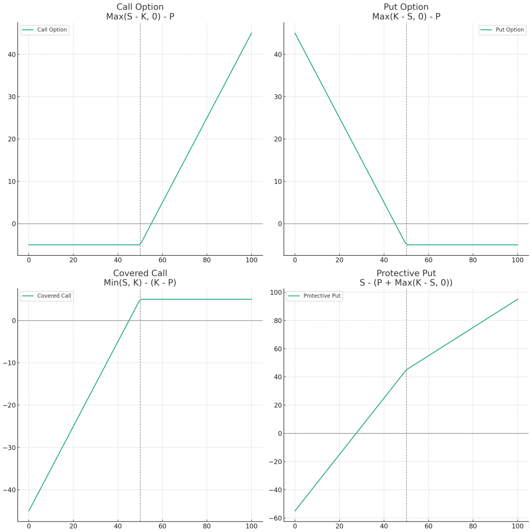

Figura: Option Pay-off Functions

Examples of Option Pay-off II

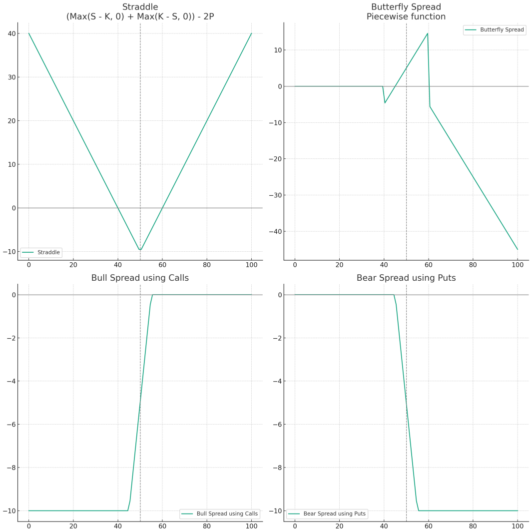

Figura: Option Pay-off Functions

Option Pricing: Black-Scholes Equation

The Black-Scholes equation is a cornerstone of modern financial theory, providing a theoretical estimate for the price of European-style options. The equation is:

$$\frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS\frac{\partial V}{\partial S} - rV = 0$$

where:

- V is the price of the option as a function of S (underlying asset price) and t (time),
- σ is the volatility of the underlying asset's returns,
- S is the current price of the underlying asset,
- r is the risk-free interest rate,
- $\frac{\partial V}{\partial t}$, $\frac{\partial V}{\partial S}$, and $\frac{\partial^2 V}{\partial S^2}$ represent the partial derivatives of the option price with respect to time and the underlying asset price.

Solution to the Black-Scholes Equation

Call Option Price:

$$C(S,t) = S_0 N(d_1) - Xe^{-r(T-t)} N(d_2)$$

Put Option Price:

$$P(S,t) = Xe^{-r(T-t)} N(-d_2) - S_0 N(-d_1)$$

where:

- $C(S,t)$ and $P(S,t)$ are the call and put option prices,
- S_0 is the current price of the underlying asset,
- X is the strike price of the option,
- T is the time to maturity,
- r is the risk-free interest rate,
- $N(\cdot)$ is the cumulative distribution function of the standard normal distribution,
- $d_1 = \frac{\ln(\frac{S_0}{X}) + (r + \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}}$,
- $d_2 = d_1 - \sigma\sqrt{T-t}$,
- σ is the volatility of the underlying asset's returns.

Call Option Pricing

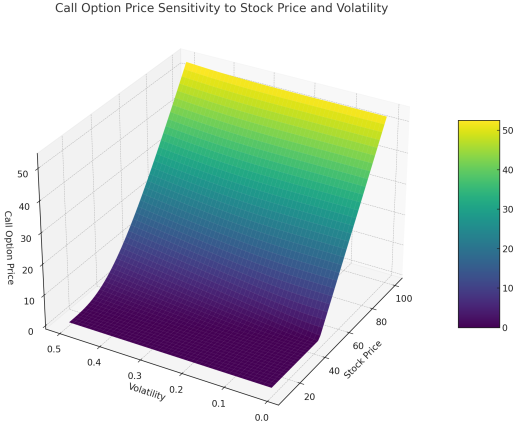

Figura: Call Option Pricing

The Greeks in the Black-Scholes Model

The "Greeks"are crucial risk management tools, providing insights into how option prices are affected by changes in market conditions. Derived from the Black-Scholes model, the main Greeks include:

- **Delta (Δ):** Measures the rate of change of the option price with respect to changes in the underlying asset's price.

$$\Delta_{call} = N(d_1),\ \Delta_{put} = N(d_1) - 1$$

- **Gamma (Γ):** Measures the rate of change in Δ with respect to changes in the underlying price.

$$\Gamma = \frac{N'(d_1)}{S\sigma\sqrt{T}}$$

- **Theta (Θ):** Measures the rate of change of the option price with respect to time.

$$\Theta_{call} = -\frac{SN'(d_1)\sigma}{2\sqrt{T}} - rKe^{-rT}N(d_2)$$

$$\Theta_{put} = -\frac{SN'(d_1)\sigma}{2\sqrt{T}} + rKe^{-rT}N(-d_2)$$

- **Vega (not a Greek letter):** Measures sensitivity to volatility.

$$Vega = S\sqrt{T}N'(d_1)$$

Option Trading Strategy: Covered Call

The Covered Call is a popular option trading strategy that involves holding a long position in an underlying asset and selling a call option on the same asset. This strategy is used to generate additional income from the option premium, especially in flat to slightly bullish market conditions.

Implementation Steps:

1. Own or purchase shares of a stock.
2. Sell call options on the same stock, typically above the current price (out of the money).

Key Benefits:

- Generates income through the receipt of the option premium.
- Provides limited protection against a decline in the underlying asset's price.

Risks:

- Limited upside potential: Profit is capped at the strike price of the sold call. Potential loss if the underlying asset's price falls significantly, although this is mitigated by the option premium received.

Thai Market Option

https://www.tfex.co.th/th/products/equity/set50-index-options/market-data

Call							Strike Price	Put					
ชื่อย่อสัญญา	สถานะคงค้าง (สัญญา)	ปริมาณ (สัญญา)	IV	เสนอซื้อ	เสนอขาย	ล่าสุด		ล่าสุด	เสนอซื้อ	เสนอขาย	IV	ปริมาณ (สัญญา)	สถานะคงค้าง (สัญญา)
S50H24C725	24	-	-	123.2	125.7	-	725	-	-	0.2	53.5548	-	4,917
S50H24C750	7	-	-	98.3	100.5	-	750	-	-	0.2	43.0733	-	9,485
S50H24C775	124	-	-	73.6	75.1	-	775	0.1	-	0.1	32.7021	4	8,733
S50H24C800	385	3	33.5537	49.0	49.9	48.7	800	0.1	-	0.1	22.3219	133	14,380
S50H24C825	3,168	105	21.4554	24.1	25.0	24.2	825	0.3	0.3	0.4	14.2217	274	8,070

Figura: SET50 Index Options

QC Option Web App

https://bs-model-qc.streamlit.app/

Credit Risk

What is Credit Risk Modeling?

Credit Risk Modeling refers to the use of statistical models to assess the likelihood of a borrower defaulting on loan obligations. It is a critical component in the management of credit risk, helping financial institutions determine the risk associated with lending and to set appropriate interest rates that reflect that risk.

- **Assessment of Credit Risk:** Estimating the probability of default (PD) for individual borrowers or groups.
- **Loan Pricing:** Setting interest rates commensurate with the assessed risk.
- **Regulatory Compliance:** Meeting requirements set by financial regulators to hold capital against potential losses.

Credit Default Swaps (CDS)

A Credit Default Swap (CDS) is a financial derivative that allows an investor to "swap"or offset their credit risk with that of another investor. It's akin to insurance against the default of a borrower.

How it Works:

- The **buyer** of the CDS pays a periodic fee to the seller, akin to an insurance premium.
- The **seller** of the CDS commits to compensating the buyer in the event of a default by the reference entity (the issuer of the underlying debt).

Uses:

- **Risk Management:** Investors use CDS to hedge against the risk of default by the debt issuer.
- **Speculation:** Traders may speculate on changes in a debtor's creditworthiness without owning the underlying bond.

Key Component: The *spread* of a CDS is the annual fee the buyer pays, usually quoted in basis points of the notional amount. It reflects the market's assessment of the risk of default.
CDS contracts have played a significant role in financial markets, offering flexibility in managing credit exposure but also involving complex risk factors.

Merton's Model for CDS Pricing - Mathematical Approach

The Merton model calculates the default probability and expected loss, essential for determining the CDS spread. The model uses the Black-Scholes option pricing formula as its base.

Mathematical Formulation:

- The value of equity (E) as a call option: $E = VN(d_1) - De^{-rT}N(d_2)$,
- Where V is the firm's asset value, D is the debt's face value, r is the risk-free rate, T is time to maturity,
- $d_1 = \frac{\ln(V/D)+(r+0.5\sigma^2)T}{\sigma\sqrt{T}}$, $d_2 = d_1 - \sigma\sqrt{T}$,
- σ is the asset volatility, $N(\cdot)$ is the cumulative distribution function for a standard normal distribution.

CDS Spread Calculation: The CDS spread can be inferred by equating the cost of protecting a bond (the CDS premium) with the expected loss from default, which is a function of the default probability derived from Merton's model.

This approach provides a direct link between a firm's structural characteristics and the pricing of credit risk in the market.

Algorithmic Trading

Algorithmic Trading: Overview

Algorithmic Trading involves the use of computer algorithms to execute trading orders at high speed and volume based on predefined criteria. It's a significant component of modern financial markets, facilitating a large portion of transactions.

Key Features:

- **Speed:** Trades acn be executed in milliseconds or microseconds, far beyond human capability.
- **Volume:** Algorithms can process and trade on vast amounts of data, enabling high-frequency trading (HFT).
- **Efficiency:** Reduces the cost of trading and can exploit arbitrage opportunities quickly.
- **Strategy:** Used in various strategies including market making, trend following, and statistical arbitrage.

Implications:

- **Market Impact:** Can significantly affect market dynamics, liquidity, and volatility.
- **Regulatory Focus:** Due to its impact, algorithmic trading is a focus of financial regulation to prevent abuse and ensure market stability.

Pair Trading: A Market Neutral Strategy I

Pair Trading is a market-neutral trading strategy that aims to capitalize on the price relationship between two historically correlated securities. It involves simultaneously buying one security and selling short the other when their price ratio diverges from the historical norm, betting on the convergence of their prices.

Steps in Pair Trading:

1. **Selection of Pairs:** Identify two securities (often stocks) that exhibit a strong historical correlation.
2. **Identification of Spread:** Monitor the spread between the prices of these securities for divergence from their historical average.
3. **Execution of Trades:** Buy the underperforming security while short-selling the outperforming one when the spread widens.
4. **Reversion to Mean:** Close the positions when the prices of the securities revert to their historical price relationship, securing a profit.

Advantages:

- **Market Neutrality:** Strategy profits from relative price movements, independent of market direction.
- **Risk Mitigation:** Hedging one position with another reduces the portfolio's overall risk.

Pair Trading: A Market Neutral Strategy II

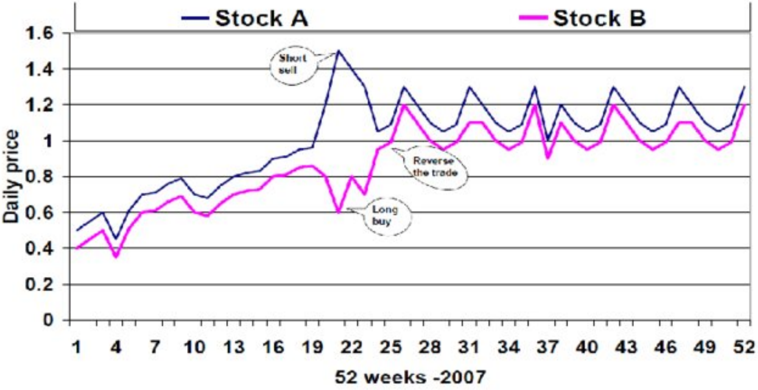

Figura: Pair Trading from "Mining Pairs-Trading Patterns: A Framework"

Pair Trading: A Market Neutral Strategy III

Pair Trading is grounded in the statistical concept of cointegration, implying that even if the prices of two securities drift apart, they will eventually revert to an equilibrium.

Cointegration Model:

$$P_t^A - \beta P_t^B = \epsilon_t$$

where:

- P_t^A and P_t^B are the prices of securities A and B at time t,
- β is a coefficient measuring the relative price movement,
- ϵ_t is the spread or error term, ideally stationary.

Spread Analysis: The spread ϵ_t is monitored for deviations from its historical mean. A significant deviation indicates an opportunity for pair trading.

Trade Execution:

- **Long the Underperformer:** If ϵ_t exceeds the mean, buy A and short B.
- **Short the Outperformer:** If ϵ_t falls below the mean, short A and buy B.

This approach relies on statistical tests (e.g., Augmented Dickey-Fuller) to confirm cointegration and thus the feasibility of pair trading strategy.

Delta Hedging: Strategy for Managing Option Risk

Delta Hedging aims to offset the price risk inherent in an options position by adjusting a hedge in the underlying asset. The mathematical foundation revolves around the concept of delta (Δ), which measures the sensitivity of an option's price to changes in the price of the underlying asset.

Delta (Δ) Calculation:

- For a call option: $\Delta = N(d_1)$,
- For a put option: $\Delta = N(d_1) - 1$,
- Where $N(d_1)$ is the cumulative distribution function of d_1 in the Black-Scholes model.

Achieving Delta Neutrality: The portfolio's delta is adjusted to zero by setting:

$$\begin{aligned}\Delta_{portfolio} =& \Delta_{option} \times \text{Number of options} \\ &+ \Delta_{underlying} \times \text{Number of underlying units} = 0\end{aligned}$$

Dynamic Rebalancing: Given that Δ varies with the asset's price and time, continuous rebalancing is required:

- Adjust the number of underlying units or options to maintain delta neutrality.
- This process is influenced by gamma (Γ).

AI in Finance

Artificial Intelligence in Finance

Artificial Intelligence (AI) is transforming the financial industry by automating complex processes, enhancing decision-making, and creating personalized customer experiences. AI's capabilities extend to various domains within finance, including trading, risk management, customer service, and fraud detection.

- **Algorithmic Trading:** AI algorithms analyze vast datasets to execute trades at optimal prices, manage portfolios, and identify market trends.
- **Credit Scoring and Underwriting:** Machine learning models predict the likelihood of default more accurately than traditional models, enabling better lending decisions.
- **Fraud Detection:** AI systems identify unusual patterns that indicate fraudulent activity, significantly improving the accuracy and speed of fraud detection.
- **Personalized Banking:** AI-powered chatbots and virtual assistants offer personalized financial advice and customer service, enhancing the customer experience.

Example I: FX Market Pattern Recognition I

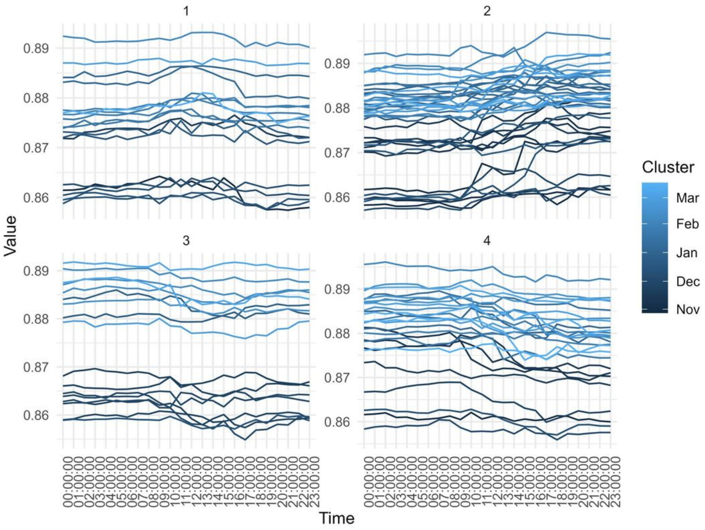

Figura: Pattern in FX Market

Example I: FX Market Pattern Recognition II

Principal Component Analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components.

Objective: The goal of PCA is to select the smallest number of components that captures the maximum variance in the data.

Optimization Problem:

- Maximize the variance of the projected data:

$$\max \; Var(\mathrm{Xw}) = \max \; \mathrm{w}^T \mathrm{X}^T \mathrm{Xw}$$

- Subject to:

$$\mathrm{w}^T \mathrm{w} = 1$$

where X is the data matrix and w is the weight vector of the principal component.

Solution: The solution involves eigenvalue decomposition of the covariance matrix $\mathrm{X}^T\mathrm{X}$ or singular value decomposition (SVD) of the data matrix X. The principal components are the eigenvectors associated with the largest eigenvalues.

Example II: GPT for Summarizing ESG Report I

In our paper "Leveraging Generative Pre-trained Transformers (GPT) for the Integration of Environmental, Social, and Governance (ESG) Considerations into Investment Management for Thai Stock"

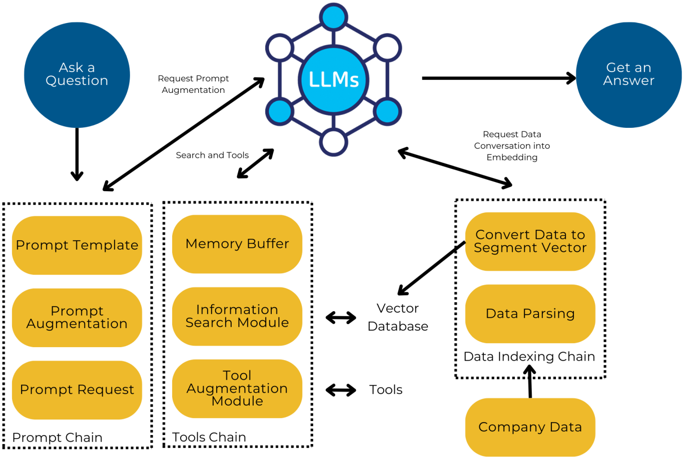

Figura: Training Process on LangChain

Example II: GPT for Summarizing ESG Report II

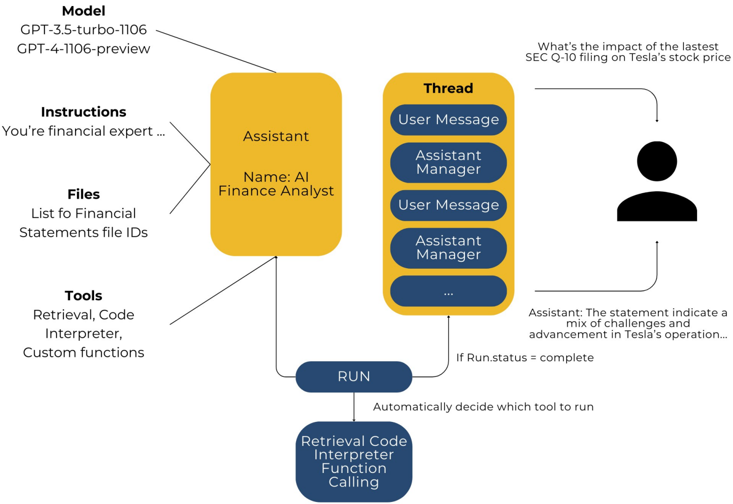

Figura: Retrieval-Augmented Generation Flow

Example II: GPT for Summarizing ESG Report III

E Score: 7/10

Reason: The company demonstrates a strong commitment to environmental issues, particularly in areas such as energy consumption (GRI 302-1), GHG emissions (GRI 305-1, 305-2, 305-3), and waste management (GRI 306-1, 306-2, 306-3). However, there are opportunities for improvement in areas like water management and more aggressive targets for reducing environmental impact.

S Score: 8/10

Reason: The company shows a high level of engagement in social dimensions, evidenced by its policies on labor practices (GRI 401, 403), health and safety (GRI 403-2), and diversity (GRI 405-1). They also actively work on community engagement and stakeholder management. Room for improvement lies in more detailed reporting and impact assessment in community development.

G Score: 7/10

Reason: Governance is well-structured with clear policies and management oversight (GRI 102-18, 102-19). The company adheres to anti-corruption policies (GRI 205) and shows a commitment to ethical business practices. Enhancements can be made in more transparent and detailed reporting on governance mechanisms and board diversity.

Key Priorities:

1. Strengthening water management strategies to enhance environmental sustainability.
2. Enhancing transparency and impact assessment in community engagement and development.
3. Improving diversity and inclusion policies, especially at the leadership levels.

Challenges and Future Actions:

1. Implementing more aggressive targets for reducing environmental impacts, particularly in areas like water usage and GHG emissions.
2. Developing more comprehensive and transparent reporting mechanisms to better communicate the company's sustainability initiatives and impacts.
3. Increasing focus on diversity and inclusion within the governance structures and decision-making bodies.

Engagement Point:

Engaging with stakeholders on developing more holistic and inclusive diversity policies, and exploring opportunities for partnerships in environmental sustainability projects, especially in water management and carbon footprint reduction.

Figura: Output Display from 'ESG Materiality Assessment Analysis GPT' Upon Processing PTT's One Report

Learning Resource

QuantConner

- Facebook: `https://www.facebook.com/quantcornerthailand`
- Discord: `https://discord.gg/fkazqYXtUs`
- Website: `https://www.quant-corner.com/`
- Youtube: `https://www.youtube.com/@QuantCorner`

Q&A