**SYSTEMATIC TRADING**  
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CHAPTER 1- CONCEPTS OF FINANCE: FROM AN ALGORITHMIC STANDPOINT

* The fundamental law of active management says that the key to generating alpha is having accurate return forecasts combined with the ability to act on those forecasts. It was given by Grinold and Kahn in 2000.
* This law defines the **information ratio** (**IR**) to express the value of active management as the ratio of the return difference between the portfolio and a benchmark to the volatility of those returns. It further approximates the IR as the product of the following:

1. The **information coefficient** (**IC**), which measures the quality of forecasts as their rank correlation with outcomes.
2. The square root of the **breadth of a strategy** expressed as the number of independent bets on these forecasts.

* The trends that have propelled algorithmic trading and ML to their current prominence include:

1. Changes in the **market microstructure**, such as the spread of electronic trading and the integration of markets across asset classes and geographies
2. The development of investment strategies framed in terms of **risk-factor exposure**, as opposed to asset classes
3. The revolutions in **computing power**, **data generation and management**, and **statistical methods**, including breakthroughs in deep learning
4. The **outperformance of the pioneers** in algorithmic trading relative to human, discretionary investors.

* In addition, the financial crises of 2001 and 2008 have affected how investors approach diversification and risk management. One outcome is the rise on low-cost passive investments such as exchange-traded funds (ETFs). Amid low yields and low volatility following the 2008 crisis, which triggered large-scale asset purchases by leading central banks, cost-conscious investors shifted over $3.5 trillion from actively managed mutual funds into passively managed ETFs.
* The 1997 order-handling rules by the SEC (Securities and Exchange Commission) introduced competition to exchanges through **electronic communication networks** (**ECNs**). ECNs are **alternative trading systems (ATS)** that match buy and sell orders at specified prices for currencies and equities and are registered as broker dealers**.**
* **Dark pools** are another type of private ATS that allows institutional investors to trade large orders without publicly revealing their information, contrary to how exchanges managed their order books prior to competition from ECNs. Dark pools do not publish pre-trade bids and offers, and trade prices only become public sometime after execution.
* **Direct market access** (**DMA**) gives a trader greater control over execution by allowing them to send orders directly to the exchange using the infrastructure and market participant identification of a broker who is a member of an exchange. Sponsored access removes pre-trade risk controls by the brokers and forms the basis for **high-frequency trading** (**HFT**).   
  HFT refers to automated trades in financial instruments that are executed with extremely low latency in the microsecond range and where participants hold positions for very short periods. The goal is to detect and exploit **inefficiencies in the market microstructure**, the institutional infrastructure of trading venues.  
  HFT has grown substantially over the past 10 years and is estimated to make up roughly 55 percent of trading volume in US equity markets and about 40 percent in European equity markets. HFT has also grown in futures markets to roughly 80 percent of foreign-exchange futures volumes and two-thirds of both interest rate and Treasury 10-year futures volumes (Miller 2016).  
  HFT strategies aim to earn small profits per trade using **passive or aggressive strategies**. Passive strategies include arbitrage trading to profit from very small price differentials for the same asset, or its derivatives, traded on different venues.  
  Aggressive strategies include order anticipation or momentum ignition. Order anticipation, also known as liquidity detection, involves algorithms that submit small exploratory orders to detect hidden liquidity from large institutional investors and trade ahead of a large order to benefit from subsequent price movements. Momentum ignition implies an algorithm executing and cancelling a series of orders to spoof other HFT algorithms into buying (or selling) more aggressively and benefit from the resulting price changes.
* **Modern Portfolio Theory (MPT)** suggests a diversified portfolio of shares and other asset classes (such as debt in corporate bonds, treasury bonds, or money market funds) will realise more predictable returns if there is prudent market regulation. It introduced the distinction between idiosyncratic and systematic sources of risk for a given asset. Idiosyncratic risk can be eliminated through diversification, but systematic risk cannot. In the 1960s, the Capital Asset Pricing Model (CAPM), identified a single factor that was governing all asset returns: The market portfolio consisted of all tradable securities, weighted by their market value. The systematic exposure of an asset to the market is measured by **beta**, which is the correlation between the returns of the asset and the market portfolio. However, it has since been proved wrong and numerous additional risk factors have been discovered.   
  These risk factors were labelled anomalies since they contradicted the **efficient market hypothesis** (**EMH**). The EMH maintains that market equilibrium would always price securities according to the CAPM so that no other factors should have predictive power (Malkiel 2003).
* The **momentum effect**, discovered in the late 1980s by, among others, Clifford Asness, the founding partner of AQR, states that stocks with good momentum, in terms of recent 6-12 month returns, have higher returns going forward than poor momentum stocks with similar market risk. Researchers also found that value and momentum factors explain returns for stocks outside the US, as well as for other asset classes, such as bonds, currencies, and commodities, and additional risk factors (Jegadeesh and Titman 1993; Asness, Moskowitz, and Pedersen 2013).
* In 1976, Stephen Ross proposed the **arbitrage pricing theory**, which asserted that investors are compensated for multiple systematic sources of risk that cannot be diversified away. The three most important macro factors are growth, inflation, and volatility, in addition to productivity, demographic, and political risk. In 1993, Eugene Fama and Kenneth French combined the equity risk factors' size and value with a market factor into a single three-factor model that better explained cross-sectional stock returns.  
  Over the past several decades, quantitative factor investing has evolved from a simple approach based on two or three styles to **multifactor smart or exotic beta products**. Smart beta funds have crossed $1 trillion AUM in 2017, testifying to the popularity of the hybrid investment strategy that combines active and passive management. **Smart beta funds** take a passive strategy but modify it according to one or more factors, such as cheaper stocks or screening them according to dividend payouts, to generate better returns.
* **Systematic funds differ from HFT** in that trades may be held significantly longer while seeking to exploit arbitrage opportunities as opposed to advantages from sheer speed.  
  Systematic strategies that mostly or exclusively rely on algorithmic decision-making were most famously introduced by mathematician James Simons, who founded **Renaissance Technologies** in 1982 and built it into the premier quant firm. Its secretive Medallion Fund, which is closed to outsiders, has earned an estimated annualized return of 35 percent since 1982.  
  **D. E. Shaw, Citadel, and Two Sigma**, three of the most prominent quantitative hedge funds that use systematic strategies based on algorithms, rose to the all-time top-20 performers for the first time in 2017, in terms of total dollars earned for investors, after fees, and since inception.  
  D. E. Shaw, founded in 1988 and with $50 billion in AUM in 2019, joined the list at number 3. Citadel, started in 1990 by Kenneth Griffin, manages $32 billion, and ranked 5. Two Sigma, started only in 2001 by D. E. Shaw alumni John Overdeck and David Siegel, has grown from $8 billion in AUM in 2011 to $60 billion in 2019. **Bridgewater**, started by Ray Dalio in 1975, had over $160 billion in AUM in 2019 and continues to lead due to its Pure Alpha fund, which also incorporates systematic strategies.
* The familiar three revolutions in computing power, data availability, and statistical methods have made the adoption of systematic, data-driven strategies not only more compelling and cost-effective but a key source of competitive advantage.   
  Predictive **analytics** using ML and algorithmic automation play an increasingly prominent role in all steps of the investment process across asset classes, from idea generation and research to strategy formulation and portfolio construction, trade execution, and risk management.  
  According to the *Economist*, in 2016, systematic funds became the largest driver of institutional trading in the US stock market (ignoring HFT, which mainly acts as a middleman). In 2019, they accounted for over 35 percent of institutional volume, up from just 18 percent in 2010; just 10% of trading is still due to traditional equity funds. Measured by the Russell 3000 index, the **value of US stocks** is around $31 trillion. The three types of **computer-managed funds**—index funds, ETFs, and quant funds—**run around 35 percent**, whereas human managers at traditional hedge funds and other mutual funds manage just 24 percent.
* Two distinct approaches have evolved in active investment management: **systematic** (**or quant**) and **discretionary investing**. Systematic approaches rely on algorithms for a repeatable and data-driven approach to identify investment opportunities across many securities. In contrast, a discretionary approach involves an in-depth analysis of the fundamentals of a smaller number of securities. These two approaches are becoming more similar as fundamental managers take more data science-driven approaches.  
  Even **fundamental traders** now arm themselves with quantitative techniques, accounting for $55 billion of systematic assets, according to Barclays. Agnostic to specific companies, quantitative funds trade based on patterns and dynamics across a wide swath of securities. Such quants accounted for about 17 percent of total hedge fund assets, as data compiled by Barclays in 2018 showed.  
  **Point72**, with $14 billion in assets, has been shifting about half of its portfolio managers to a human-plus-machine approach. Point72 is also investing tens of millions of dollars into a group that analyses large amounts of alternative data and passes the results on to traders.
* Morgan Stanley noted that only 23 percent of its quant clients say they are not considering using or not already using ML, down from 44 percent in 2016. **Guggenheim Partners** built what it calls a supercomputing cluster for $1 million at the Lawrence Berkeley National Laboratory in California to help crunch numbers for Guggenheim's quant investment funds. Electricity for computers costs another $1 million per year.  
  The leading firm **BlackRock**, with over $5 trillion in AUM, also bets on algorithms to beat discretionary fund managers by heavily investing in SAE, a systematic trading firm it acquired during the financial crisis. Franklin Templeton bought Random Forest Capital, a debt-focused, data-led investment company, for an undisclosed amount, hoping that its technology can support the wider asset manager.  
  **WorldQuant** was spun out of Millennium Management (AUM: $41 billion) in 2007, for whom it manages around $5 billion. It employs hundreds of scientists and many more part-time workers around the world in its alpha factory, which organizes the investment process as a quantitative assembly line. This factory claims to have produced 4 million successfully tested alpha factors for inclusion in more complex trading strategies and is aiming for 100 million. Each alpha factor is an algorithm that seeks to predict a future

asset price change. Other teams then combine alpha factors into strategies and strategies into portfolios, allocate funds between portfolios, and manage risk while avoiding strategies that cannibalize each other.

* The evolution of trading strategies: quantitative strategies have evolved in three waves
  + In the 1980s and 1990s, signals often emerged from **academic research** and used a single or very few inputs derived from market and fundamental data. AQR, one of the largest quantitative hedge funds today, was founded in 1998 to implement such strategies at scale. These signals are now largely commoditized and available as ETF, such as basic mean-reversion strategies.
  + In the 2000s, **factor-based investing** proliferated based on the pioneering work by Eugene Fama and Kenneth French and others. Funds used algorithms to identify assets exposed to risk factors like value or momentum to seek arbitrage opportunities. Redemptions during the early days of the financial crisis triggered the quant quake of August 2007, which cascaded through the factor-based fund industry. These strategies are now also available as long-only smart beta funds that tilt portfolios according to a given set of risk factors.
  + The third era is driven by investments in **ML capabilities and alternative** data to generate profitable signals for repeatable trading strategies. Factor decay is a major challenge: the excess returns from new anomalies have been shown to drop by a quarter from discovery to publication, and by over 50 percent after publication due to competition and crowding.
* Data has always been an essential driver of trading, and traders have long made efforts to gain an advantage from access to superior information. These efforts date back at least to the rumours that the House of Rothschild benefited handsomely from bond purchases upon advance news about the British victory at Waterloo, which was carried by pigeons across the channel.  
  Today, investments in faster data access take the shape of the Go West consortium of leading **high frequency trading** (**HFT**) firms that connects the **Chicago Mercantile Exchange** (**CME**) with Tokyo. The round-trip latency between the CME and the **BATS** (**Better Alternative Trading System**) exchanges in New York has dropped to close to the theoretical limit of eight milliseconds as traders compete to exploit arbitrage opportunities. At the same time, regulators and exchanges have started to introduce speed bumps that slow down trading to limit the adverse effects on competition of uneven access to information.
* Market microstructure studies how the **institutional environment** affects the trading process and shapes outcomes like price discovery, bid-ask spreads and quotes, intraday trading behaviour, and transaction costs (Madhavan 2000; 2002). It is one of the fastest-growing fields of financial research, propelled by the rapid development of algorithmic and electronic trading.  
  Today, hedge funds sponsor in-house analysts to track the rapidly evolving, complex details and ensure execution at the best possible market prices and design strategies that exploit market frictions.
* A **market order** is intended for immediate execution of the order upon arrival at the trading venue, at the price that prevails at that moment.   
  In contrast, a **limit order** only executes if the market price is higher than the limit for a sell limit order, or lower than the limit for a buy limit order.   
  A **stop order**, in turn, only becomes active when the market price rises above a specified price for a buy stop order, or falls below a specified price for a sell order.   
  A **buy stop order** can be used to limit the losses of short sales. Stop orders may also have limits.
* An exchange is a central marketplace where buyers and sellers compete for the lowest ask and highest bid, respectively. Exchange regulations typically impose listing and reporting requirements to create transparency and attract more traders and liquidity. OTC markets, such as the Best Market (OTCQX) or the Venture Market (OTCQB), often have lower regulatory barriers. As a result, they are suitable for a far broader range of securities, including bonds or **American Depositary Receipts** (**ADRs**; equity listed on a foreign exchange, for example, for Nestlé, S.A.).
* Exchanges may rely on bilateral trading or centralized order-driven systems that match all buy and sell orders according to certain rules. Many exchanges use intermediaries that provide liquidity by making markets in certain securities. These **intermediaries** include dealers that act as principals on their own behalf and brokers that trade as agents on behalf of others. **Price formation** may occur through auctions, such as in the **New York Stock Exchange** (**NYSE**), where the highest bid and lowest offer are matched, or through dealers who buy from sellers and sell to buyers.
* Today, **trading has fragmented**; instead of two principal venues in the US, there are more than thirteen displayed trading venues, including exchanges and (unregulated) **alternative trading systems** (**ATSs**) such as **electronic communication networks** (**ECNs**). Each reports trades to the consolidated tape, but at different latencies. To make matters more difficult, the rules of engagement for each venue differ with several different pricing and queuing models.
* The rise of high-frequency electronic trading and the 2007 SEC Order Protection rule that intended to spur competition and cut transaction costs through transparency as part of **Regulation National Market System** (**Reg NMS**) drove the growth of dark pools, as traders aimed to avoid the visibility of large trades (Mamudi 2017). Reg NMS also established the **National Best Bid and Offer** (**NBBO**) mandate for brokers to route orders to venues that offer the best price.  
  Some ATSs are called dark pools because they do not broadcast pre-trade data, including the presence, price, and amount of buy and sell orders as traditional exchanges are required to do. However, dark pools report information about trades to the **Financial Industry Regulatory Authority** (**FINRA**) after they occur. As a result, dark pools do not contribute to the process of price discovery until after trade execution but provide protection against various HFT strategies.
* The **primary source of market data** is the order book, which updates in real time throughout the day to reflect all trading activity. Exchanges typically offer this data as a real-time service for a fee. However, they may provide some historical data for free.
* In the United States, stock markets provide quotes in three tiers, namely Level L1, L2, and L3, that offer increasingly granular information and capabilities:
  + **Level 1 (L1)**: Real-time bid- and ask-price information, as available from numerous online sources.
  + **Level 2 (L2)**: Adds information about bid and ask prices by specific market makers as well as the size and time of recent transactions for better insights into the liquidity of a given equity.
  + **Level 3 (L3)**: Adds the ability to enter or change quotes, execute orders, and confirm trades and is available only to market makers and exchange member firms. Access to Level 3 quotes permits registered brokers to meet best execution requirements.