Algorithmic trading

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In electronic financial markets, **algorithmic trading** or **automated trading**, also known as **algo trading**, **black-box trading** or **robo trading**, is the use of computer programs for entering trading orders with the computer algorithm deciding on aspects of the order such as the timing, price, or quantity of the order, or in many cases initiating the order without human intervention. Algorithmic Trading is widely used by pension funds, mutual funds, and other buy side (investor driven) institutional traders, to divide large trades into several smaller trades in order to manage market impact, and risk.[1][2] Sell side traders, such as market makers and some hedge funds, provide liquidity to the market, generating and executing orders automatically. A special class of algorithmic trading is "high-frequency trading" (HFT), in which computers make elaborate decisions to initiate orders based on information that is received electronically, before human traders are capable of processing the information they observe.

Algorithmic trading may be used in any investment strategy, including market making, inter-market spreading, arbitrage, or pure speculation (including trend following). The investment decision and implementation may be augmented at any stage with algorithmic support or may operate completely automatically ("on auto-pilot").

A third of all EU and US stock trades in 2006 were driven by automatic programs, or algorithms, according to Boston-based financial services industry research and consulting firm Aite Group.[3] As of 2009, high frequency trading firms account for 73% of all US equity trading volume.[4]

In 2006 at the London Stock Exchange, over 40% of all orders were entered by algo traders, with 60% predicted for 2007. American markets and European markets generally have a higher proportion of algo trades than other markets, and estimates for 2008 range as high as an 80% proportion in some markets. Foreign exchange markets also have active algo trading (about 25% of orders in 2006).[5] Futures and options markets are considered to be fairly easily integrated into algorithmic trading,[6] with about 20% of options volume expected to be computer generated by 2010.[7] Bond markets are moving toward more access to algorithmic traders.[8]

One of the main issues regarding high frequency trading is the difficulty in determining just how profitable it is. A report released in August 2009 by the TABB Group, a financial services industry research firm, estimated that the 300 securities firms and hedge funds that specialize in this type of trading took in roughly $21 billion in profits in 2008.[9]

Algorithmic and high frequency trading have been the subject of much public debate since the U.S. Securities and Exchange Commission and the Commodity Futures Trading Commission implicated them in the May 6, 2010 Flash Crash,[10][11][12][13][14][15][16][17] when the Dow Jones Industrial Average suffered its largest intraday point loss ever to that date, though prices quickly recovered.

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[edit] History

Computerization of the order flow in financial markets began in the early 1970s with some landmarks being the introduction of the New York Stock Exchange's "designated order turnaround" system (DOT, and later SuperDOT) which routed orders electronically to the proper trading post to be executed manually, and the "opening automated reporting system" (OARS) which aided the specialist in determining the market clearing opening price (SOR; Smart Order Routing).

Program trading is defined by the New York Stock Exchange as an order to buy or sell 15 or more stocks valued at over $1 million total. In practice this means that all program trades are entered with the aid of a computer. In the 1980s program trading became widely used in trading between the S&P500 equity and futures markets.

In stock index arbitrage a trader buys (or sells) a stock index futures contract such as the S&P 500 futures and sells (or buys) a portfolio of up to 500 stocks (can be a much smaller representative subset) at the NYSE matched against the futures trade. The program trade at

the NYSE would be pre-programmed into a computer to enter the order automatically into the NYSE's electronic order routing system at a time when the futures price and the stock index were far enough apart to make a profit.

At about the same time portfolio insurance was designed to create a synthetic put option on a stock portfolio by dynamically trading stock index futures according to a computer model based on the Black-Scholes option pricing model.

Both strategies, often simply lumped together as "program trading," were blamed by many people (for example by the Brady report) for exacerbating or even starting the 1987 stock market crash. Yet the impact of computer driven trading on stock market crashes is unclear and widely discussed in the academic community.[18]

Financial markets with fully electronic execution and similar electronic communication networks developed in the late 1980s and 1990s. In the U.S., decimalization, which changed the minimum tick size from 1/16th of a dollar ($0.0625) to $0.01 per share, may have encouraged algorithmic trading as it changed the market microstructure by permitting smaller differences between the bid and offer prices, decreasing the market-makers' trading advantage, thus increasing market liquidity.

This increased market liquidity led to institutional traders splitting up orders according to computer algorithms in order to execute their orders at a better average price. These average price benchmarks are measured and calculated by computers by applying the time weighted (i.e unweighted) average price TWAP or more usually by the volume weighted average price VWAP.

As more electronic markets opened, other algorithmic trading strategies were introduced. These strategies are more easily implemented by computers because machines can react more rapidly to temporary mispricing and examine prices from several markets simultaneously. For example Stealth (developed by Deutsche Bank), Sniper and Guerilla (developed by Credit Suisse[19]), arbitrage, statistical arbitrage, trend following, and mean reversion.

This type of trading is what is driving the new demand for Low Latency Proximity Hosting and Global Exchange Connectivity. It is imperative to understand what is latency when putting together a strategy for electronic trading. Latency refers to the delay between the transmission of information from a source and the reception of the information at a destination. Latency has as a lower bound the speed of light; this corresponds to a few microseconds per 1,000 kilometers of optical fibre. Any signal regenerating or routing equipment will introduce greater latency than this speed-of-light baseline.

[edit] Strategies

[edit] Trend Following

Trend following is an investment strategy that tries to take advantage of long-term moves that seem to play out in various markets. The system aims to work on the market trend mechanism and take benefit from both sides of the market enjoying the profits from the *ups* and *downs* of the stock or futures markets. Traders who use this approach can use current market price calculation, moving averages and channel breakouts to determine the general direction of the market and to generate trade signals. Traders who subscribe to a trend following strategy do not aim to forecast or predict specific price levels; they simply jump on the trend and ride it.

[edit] Pair Trading

The pairs trade or **pair trading** is a market neutral trading strategy enabling traders to profit from virtually any market conditions: uptrend, downtrend, or sidewise movement. This trading strategy is categorized as a statistical arbitrage and convergence trading strategy.[20]

[edit] Delta Neutral Strategies

In finance, delta neutral describes a portfolio of related financial securities, in which the portfolio value remains unchanged due to small changes in the value of the underlying security. Such a portfolio typically contains options and their corresponding underlying securities such that positive and negative delta components offset, resulting in the portfolio's value being relatively insensitive to changes in the value of the underlying security.

[edit] Arbitrage

In economics and finance, arbitrage (IPA: /ˈɑrbɨtrɑːʒ/) is the practice of taking advantage of a price difference between two or more markets: striking a combination of matching deals that capitalize upon the imbalance, the profit being the difference between the market prices. When used by academics, an arbitrage is a transaction that involves no negative cash flow at any probabilistic or temporal state and a positive cash flow in at least one state; in simple terms, it is the possibility of a risk-free profit at zero cost.

[edit] Conditions for arbitrage

Arbitrage is possible when one of three conditions is met:

1. The same asset does not trade at the same price on all markets ("the law of one price").
2. Two assets with identical cash flows do not trade at the same price.
3. An asset with a known price in the future does not today trade at its future price discounted at the risk-free interest rate (or, the asset does not have negligible costs of storage; as such, for example, this condition holds for grain but not for securities).

Arbitrage is not simply the act of buying a product in one market and selling it in another for a higher price at some later time. The transactions must occur *simultaneously* to avoid exposure to market risk, or the risk that prices may change on one market before both transactions are complete. In practical terms, this is generally only possible with securities and financial products which can be traded electronically, and even then, when each leg of the trade is executed the prices in the market may have moved. Missing one of the legs of the trade (and subsequently having to trade it soon after at a worse price) is called 'execution risk' or more specifically 'leg risk'.[note 1]

In the simplest example, any good sold in one market should sell for the same price in another. Traders may, for example, find that the price of wheat is lower in agricultural regions than in cities, purchase the good, and transport it to another region to sell at a higher price. This type of price arbitrage is the most common, but this simple example ignores the cost of transport, storage, risk, and other factors. "True" arbitrage requires that there be no market risk involved. Where securities are traded on more than one exchange, arbitrage occurs by simultaneously buying in one and selling on the other.

See rational pricing, particularly arbitrage mechanics, for further discussion.

[edit] Mean Reversion

Mean reversion is a mathematical methodology sometimes used for stock investing, but it can be applied to other processes. In general terms the idea is that both a stock's high and low prices are temporary, and that a stock's price will tend to have an average price over time.

Mean reversion involves first identifying the trading range for a stock, and then computing the average price using analytical techniques as it relates to assets, earnings, etc.

When the current market price is less than the average price, the stock is considered attractive for purchase, with the expectation that the price will rise. When the current market price is above the average price, the market price is expected to fall. In other words, deviations from the average price are expected to revert to the average.

The Standard deviation of the most recent prices (e.g., the last 20) is often used as a buy or sell indicator.

Stock reporting services (such as Yahoo! Finance, MS Investor, Morningstar, etc.), commonly offer moving averages for periods such as 50 and 100 days. While reporting services provide the averages, identifying the high and low prices for the study period is still necessary.

Mean reversion has the appearance of a more scientific method of choosing stock buy and sell points than charting, because precise numerical values are derived from historical data to identify the buy/sell values, rather than trying to interpret price movements using charts (charting, also known as technical analysis).

[edit] Scalping

Scalping (trading) is a method of arbitrage of small price gaps created by the bid-ask spread. Scalpers attempt to act like traditional market makers or specialists. To *make the spread* means to buy at the Bid price and sell at the Ask price, to gain the bid/ask difference. This procedure allows for profit even when the bid and ask don't move at all, as long as there are traders who are willing to take market prices. It normally involves establishing and liquidating a position quickly, usually within minutes or even seconds.

The role of a scalper is actually the role of market makers or specialists who are to maintain the liquidity and order flow of a product of a market. A market maker is basically a specialized scalper. The volume a market maker trades are many times more than the average individual scalpers. A market maker has a sophisticated trading system to monitor trading activity. However, a market maker is bound by strict exchange rules while the individual trader is not. For instance, NASDAQ requires each market maker to post at least one bid and one ask at some price level, so as to maintain a two-sided market for each stock represented.

[edit] Transaction cost reduction

Most strategies referred to as Algorithmic Trading (as well as algorithmic liquidity seeking) fall into the cost-reduction category. Large orders are broken down into several smaller orders and entered into the market over time. This basic strategy is called "iceberging". The success of this strategy may be measured by the average purchase price against the VWAP for the

market over that time period. One algorithm designed to find hidden orders or icebergs is called "Stealth". Most of these strategies were first documented in 'Optimal Trading Strategies' by Robert Kissell.[21]

[edit] Strategies that only pertain to dark pools

Recently, high-frequency trading, which comprises a broad set of buy-side as well as market making sell side traders, has become more prominent and controversial.[22] These algorithms or techniques are commonly given names such as "Stealth", "Iceberg", "Dagger", "Guerrilla", "Sniper" and "Sniffer".[23] Yet are at their core quite simple mathematical constructs.[24] Dark pools are alternative electronic stock exchanges where trading takes place anonymously, with most orders hidden or "iceberged."[25] Gamers or "sharks" sniff out large orders by "pinging" small market orders to buy and sell. When several small orders are filled the sharks may have discovered the presence of a large iceberged order.

"Now it's an arms race," said Andrew Lo, director of the Massachusetts Institute of Technology's Laboratory for Financial Engineering. "Everyone is building more sophisticated algorithms, and the more competition exists, the smaller the profits."[26]

One of the unintended adverse effects of algorithmic trading, has been the dramatic increase in the volume of trade allocations and settlements, as well as the transaction settlement costs associated with them. Since 2004, there have been a number of technological advances and service providers [27] by individuals like Scott Kurland, who have built solutions for aggregating trades executed across algorithms, in order to counter these rising settlement costs.

[edit] High-frequency trading

Main article: High-frequency trading

In the U.S., high-frequency trading firms represent 2% of the approximately 20,000 firms operating today, but account for 73% of all equity trading volume.[28] As of the first quarter in 2009, total assets under management for hedge funds with high frequency trading strategies were $141 billion, down about 21% from their high.[29] The high frequency strategy was first made successful by Renaissance Technologies.[30] High frequency funds started to become especially popular in 2007 and 2008.[29] Many high frequency firms are market makers and provide liquidity to the market which has lowered volatility and helped narrow Bid-offer spreads making trading and investing cheaper for other market participants.[29][31][32] High-frequency trading has been a subject of intense public focus since the U.S. Securities and Exchange Commission and the Commodity Futures Trading Commission implicated both algorithmic and high-frequency trading in the May 6, 2010 Flash Crash.[10][11][12][13]

High-frequency trading is quantitative trading that is characterized by short portfolio holding periods (see Wilmott (2008), Aldridge (2009)). There are four key categories of high-frequency trading strategies: market-making based on order flow, market-making based on tick data information, event arbitrage and statistical arbitrage. All portfolio-allocation decisions are made by computerized quantitative models. The success of high-frequency trading strategies is largely driven by their ability to simultaneously process volumes of information, something ordinary human traders cannot do.

[edit] Market making

Market making is a set of high-frequency trading strategies that involve placing a limit order to sell (or offer) above the current market price or a buy limit order (or bid) below the current price in order to benefit from the bid-ask spread. Automated Trading Desk, which was bought by Citigroup in July 2007, has been an active market maker, accounting for about 6% of total volume on both NASDAQ and the New York Stock Exchange.[33]

[edit] Statistical Arbitrage

Another set of high-frequency trading strategies are classical arbitrage strategy might involve several securities such as covered interest rate parity in the foreign exchange market which gives a relation between the prices of a domestic bond, a bond denominated in a foreign currency, the spot price of the currency, and the price of a forward contract on the currency. If the market prices are sufficiently different from those implied in the model to cover transactions cost then four transactions can be made to guarantee a risk-free profit. High-frequency trading allows similar arbitrages using models of greater complexity involving many more than 4 securities. The TABB Group estimates that annual aggregate profits of low latency arbitrage strategies currently exceed US$21 billion.[4]

A wide range of statistical arbitrage strategies have been developed whereby trading decisions are made on the basis of deviations from statistically significant relationships. Like market-making strategies, statistical arbitrage can be applied in all asset classes.[24]

[edit] Event Arbitrage

A subset of risk, merger, convertible, or distressed securities arbitrage that counts on a specific event, such as a contract signing, regulatory approval, judicial decision, etc., to change the price or rate relationship of two or more financial instruments and permit the arbitrageur to earn a profit.[34]

Merger arbitrage also called risk arbitrage would be an example of this. Merger arbitrage generally consists of buying the stock of a company that is the target of a takeover while shorting the stock of the acquiring company.

Usually the market price of the target company is less than the price offered by the acquiring company. The spread between these two prices depends mainly on the probability and the timing of the takeover being completed as well as the prevailing level of interest rates.

The bet in a merger arbitrage is that such a spread will eventually be zero, if and when the takeover is completed. The risk is that the deal "breaks" and the spread massively widens.

[edit] Low-latency trading

High-frequency trading is often confused with low-latency trading that uses computers that execute trades within milliseconds, or "with extremely low latency" in the jargon of the trade. Low-latency trading is highly dependent on ultra-low latency networks. They profit by providing information, such as competing bids and offers, to their algorithms microseconds faster than their competitors.[4] The revolutionary advance in speed has led to the need for firms to have a real-time, colocated trading platform in order to benefit from implementing

high frequency strategies.[4] Strategies are constantly altered to reflect the subtle changes in the market as well as to combat the threat of the strategy being reverse engineered by competitors. There is also a very strong pressure to continuously add features or improvements to a particular algorithm, such as client specific modifications and various performance enhancing changes (regarding benchmark trading performance, cost reduction for the trading firm or a range of other implementations). This is due to the evolutionary nature of algorithmic trading strategies - they must be able to adapt and trade intelligently, regardless of market conditions, which involves being flexible enough to withstand a vast array of market scenarios. As a result, a significant proportion of net revenue from firms is spent on the R&D of these autonomous trading systems.[4]

[edit] Strategy Implementation

Most of the algorithmic strategies are implemented using modern programming languages, although some still implement strategies designed in spreadsheets. Basic models can rely on as little as a linear regression, while more complex game-theoretic and pattern recognition or predictive models can also be used to initiate trading. Neural networks and genetic programming have been used to create these models.

[edit] Issues and developments

Algorithmic trading has been shown to substantially improve market liquidity[35] among other benefits. However, improvements in productivity brought by algorithmic trading have been opposed by human brokers and traders facing stiff competition from computers.

[edit] Concerns

“The downside with these systems is their black box-ness,” Mr. Williams said. “Traders have intuitive senses of how the world works. But with these systems you pour in a bunch of numbers, and something comes out the other end, and it’s not always intuitive or clear why the black box latched onto certain data or relationships.”[26]

“The Financial Services Authority has been keeping a watchful eye on the development of black box trading. In its annual report the regulator remarked on the great benefits of efficiency that new technology is bringing to the market. But it also pointed out that ‘greater reliance on sophisticated technology and modelling brings with it a greater risk that systems failure can result in business interruption’.”[36]

UK Treasury minister Lord Myners has warned that companies could become the "playthings" of speculators because of automatic high-frequency trading (HFT). Lord Myners said the process risked destroying the relationship between an investor and a company.[37]

Other issues include the technical problem of latency or the delay in getting quotes to traders,[38] security and the possibility of a complete system breakdown leading to a market crash.[39]

"Goldman spends tens of millions of dollars on this stuff. They have more people working in their technology area than people on the trading desk...The nature of the markets has changed dramatically."[40]

Algorithmic and high-frequency trading were implicated in the May 6, 2010 Flash Crash,[10][12] when the Dow Jones Industrial Average plunged about 600 points only to recover those losses within minutes. At the time, it was the second largest point swing, 1,010.14 points, and the biggest one-day point decline, 998.5 points, on an intraday basis in Dow Jones Industrial Average history.[41]

The daily chart of the Dow during the Flash Crash

[edit] Recent Developments

Financial market news is now being formatted by firms such as Need To Know News, Thomson Reuters, Dow Jones, and Bloomberg, to be read and traded on via algorithms.

“Computers are now being used to generate news stories about company earnings results or economic statistics as they are released. And this almost instantaneous information forms a direct feed into other computers which trade on the news.”[42]

The algorithms do not simply trade on simple news stories but also interpret more difficult to understand news. Some firms are also attempting to automatically assign *sentiment* (deciding if the news is good or bad) to news stories so that automated trading can work directly on the news story.[43]

"Increasingly, people are looking at all forms of news and building their own indicators around it in a semi-structured way," as they constantly seek out new trading advantages said Rob Passarella, global director of strategy at Dow Jones Enterprise Media Group. His firm provides both a low latency news feed and news analytics for traders. Passarella also pointed to new academic research being conducted on the degree to which frequent Google searches on various stocks can serve as trading indicators, the potential impact of various phrases and words that may appear in Securities and Exchange Commission statements and the latest wave of online communities devoted to stock trading topics.[43]

"Markets are by their very nature conversations, having grown out of coffee houses and taverns," he said. So the way conversations get created in a digital society will be used to convert news into trades, as well, Passarella said.[43]

“There is a real interest in moving the process of interpreting news from the humans to the machines” says Kirsti Suutari, global business manager of algorithmic trading at Reuters. “More of our customers are finding ways to use news content to make money.”[42]

An example of the importance of news reporting speed to algorithmic traders was an advertising campaign by Dow Jones (appearances included page W15 of the Wall Street Journal, on March 1, 2008) claiming that their service had beaten other news services by 2 seconds in reporting an interest rate cut by the Bank of England.

In July 2007, Citigroup, which had already developed its own trading algorithms, paid $680 million for Automated Trading Desk, a 19-year-old firm that trades about 200 million shares a day.[44] Citigroup had previously bought Lava Trading and OnTrade Inc.

[edit] Technical design

The technical designs of such systems are not standardized. Conceptually, the design can be divided into logical units:

1. The data stream unit (the part of the systems that receives data (e.g. quotes, news) from external sources).
2. The decision or strategy unit
3. The execution unit.

With the wide use of social networks, some systems implement scanning or screening technologies to read posts of users extracting human sentiment and influence the trading strategies. [45]

[edit] Effects

Though its development may have been prompted by decreasing trade sizes caused by decimalization, algorithmic trading has reduced trade sizes further. Jobs once done by human traders are being switched to computers. The speeds of computer connections, measured in milliseconds and even microseconds, have become very important.[46][47]

More fully automated markets such as NASDAQ, Direct Edge and BATS, in the US, have gained market share from less automated markets such as the NYSE. Economies of scale in electronic trading have contributed to lowering commissions and trade processing fees, and contributed to international mergers and consolidation of financial exchanges.

Competition is developing among exchanges for the fastest processing times for completing trades. For example, in June 2007, the London Stock Exchange launched a new system called TradElect that promises an average 10 millisecond turnaround time from placing an order to final confirmation and can process 3,000 orders per second.[48] Since then, competitive exchanges have continued to reduce latency with turnaround times of 3 milliseconds available. This is of great importance to high frequency traders because they have to attempt to pinpoint the consistent and probable performance ranges of given financial instruments. These professionals are often dealing in versions of stock index funds like the E-mini S&Ps because they seek consistency and risk-mitigation along with top performance. They must filter market data to work into their software programming so that there is the lowest latency and highest liquidity at the time for placing stop-losses and/or taking profits. With high volatility in these markets, this becomes a complex and potentially nerve-wracking endeavor, where a small mistake can lead to a large loss. Absolute frequency data play into the development of the trader's pre-programmed instructions.[49]

Spending on computers and software in the financial industry increased to $26.4 billion in 2005.[1]

[edit] Communication standards

Algorithmic trades require communicating considerably more parameters than traditional market and limit orders. A trader on one end (the "buy side") must enable their trading system (often called an "Order Management System" or "Execution Management System") to understand a constantly proliferating flow of new algorithmic order types. The R&D and other costs to construct complex new algorithmic orders types, along with the execution infrastructure, and marketing costs to distribute them, are fairly substantial. What was needed was a way that marketers (the "sell side") could express algo orders electronically such that buy-side traders could just drop the new order types into their system and be ready to trade them without constant coding custom new order entry screens each time.

FIX Protocol LTD http://www.fixprotocol.org is a trade association that publishes free, open standards in the securities trading area. The FIX language was originally created by Fidelity Investments, and the association Members include virtually all large and many midsized and smaller broker dealers, money center banks, institutional investors, mutual funds, etc. This institution dominates standard setting in the pretrade and trade areas of security transactions. In 2006-2007 several members got together and published a draft XML standard for expressing algorithmic order types. The standard is called FIX Algorithmic Trading Definition Language (FIXatdl).[50] The first version of this standard, 1.0 was not widely adopted due to limitations in the specification, but the second version, 1.1 (released in March 2010) is expected to achieve broad adoption and in the process dramatically reduce time-to-market and costs associated with distributing new algorithms.

[edit] See also

- Outline of finance
- Alternative Trading Systems
- Artificial Intelligence
- Complex Event Processing
- Dark pools of liquidity
- Electronic Communication Network
- Electronic trading
- Electronic trading platform
- Implementation shortfall
- Investment strategy
- Quantitative trading
- Execution Management System
- Flash Crash
- High-frequency trading

[edit] Notes

1. ^ As an arbitrage consists of at least two trades, the metaphor is of putting on a pair of pants, one leg (trade) at a time. The risk that one trade (leg) fails to execute is thus 'leg risk'.

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- [4] The G-Bot Algorithmic Trading Project
- Findings Regarding the Market Events of May 6, 2010, Report of the staffs of the CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues, September 30, 2010