QUANT INSTI™
GO ALGO

MCX
METAL & ENERGY
Trade with Trust

Getting Started with ALGORITHMIC TRADING

A HANDBOOK

Getting Started with
ALGORITHMIC TRADING

A HANDBOOK

QUANTITATIVE LEARNING
PVT. LTD.

TRAINING, CERTIFICATION, and
EDUCATION DEPARTMENT

Quantinsti Quantitative Learning Pvt. Ltd.
A-309, Boomrang, Chandivali Far Road, Powai,
Mumbai - 400 072

Multi Commodity Exchange of India Ltd.
Exchange Square, 255, Suren Road, Chakala,
Andheri (East), Mumbai – 400093

Set in 11 pt Myriad Pro

Website: www.mcxindia.com | www.quantinsti.com
For mobiles: http://m.mcxindia.com

CIN: L51909MH2002PLC135594

TABLE OF CONTENTS

Getting Started with Algorithmic Trading

1. Introduction

This course will help you to understand the basics and terminology related to algorithmic trading. It will detail out the requirements for setting up an algorithmic trading platform in terms of capital, technology, infrastructure, skillset and regulatory environment. You'll be given a comprehensive overview of the different Algorithmic Trading strategy paradigms which are popular among the traders. A comparative study on different programming languages, available tools and software is also included in this module. The course will help you appreciate the advantages of algorithmic trading over traditional training techniques.

The course is designed for capital market professionals who are already Algorithmic traders and want to expand their reach; for electronic and manual traders and businesses that want to adapt technology into their trading systems; for stock market enthusiasts who are curious about Algorithmic Trading; for technocrats who want to use their quantitative and programming skills in financial markets domain and finally for anyone who would like to expand their knowledge and prepare themselves for the expected change in markets.

At the end of this course, you'll have a good idea of the steps involved and available options for all requirements related to algorithmic trading. This is a one stop shop for all the information that you'll need to get started in Algorithmic Trading. This course is most also suitable for students and entrepreneurs who want to set up their own algorithmic trading desk or join an existing desk in a trading firm or hedge fund. There are no pre-requisites required for this course, however it will give you a good idea of pre-requisites required to get started in Algorithmic Trading.

2. What is Algorithmic Trading?

Algorithm trading is a system of trading which facilitates trading decision making in the financial markets using advanced mathematical tools. In simple words, using defined set of instructions in the form of an algorithm to generate trading signals and placing orders is called Algorithmic Trading. A simplistic understanding of algorithmic trading is to imagine computer programs or algorithms that break down large order sizes into tiny orders which are executed at different times to achieve better prices and profits. The real time data is automatically fed into the automated systems with minimal lag in time, analyzed to generate trading signals and orders are executed automatically to achieve best possible price and fills.

In India, Securities & Exchange Board of India (SEBI), started allowing Direct Market Access (DMA) facility which allows buying or selling of orders by institutional clients without manual intervention by brokers in April 2008. As per the market participants, the DMA results in greater transparency, increased liquidity, lower impact costs for large orders, better audit trails and more efficient markets.

Very soon leading brokerages along with stock exchanges were preparing the ground for operationalizing Direct Market Access (DMA). Algorithmic Trading now account for 40 percent of the overall volume on the leading exchanges in India, one of the highest proportion in the developing world and up from the low single digits few years ago, according to SEBI circular dated August 2016.

The exchanges provide co-location services which allow traders to get closer to the exchanges and reduce latency by putting their computers in the exchange data centers. To get a perspective on latency, imagine the fastest reaction time you have displayed recently, say blinking of your eyes. The fastest human reaction has been noted around 300 milliseconds, which is less than one-third of a second. Compare that to the maximum number of orders which are permitted by the different exchanges in India, varying from a little more than a dozen to hundreds or orders in one second. So in the time you blink your eyes, a system can place dozens of orders. The existing technology in trading allows hundreds of execution in a millisecond, with some developed markets seeing orders around thousands of orders in a second from one system.

3. History Lesson: Technology evolution in stock market exchanges

Technological innovations have played a principal role in shaping the history of stock market exchanges over the last three centuries. Let us take a step back and see how technology has been influencing stock markets and how trades happen in the exchanges.

- **Open Outcry:** When communication 'as a technology' was non-existent!
  A system of financial trading in which dealers shout their bids and contracts aloud in the trading pit. The verbal communications method was started with first exchange in Amsterdam in 1700s, which was taken over by telephone and then by electronic trading in the 1980s. The open outcry dominated for almost 250 years and until recently it was still being used for commodity trading at some leading global exchanges.
  Telegraphs were used to deliver information regarding last traded prices across exchanges and countries. Some news delivering agents even used indigenous communication systems involving pigeons!

- **Calling Broker:** After telephones were invented!
  Calling Brokers on telephone to place orders at the best prices started along with open outcry that resulted in an unprecedented increase in the number of participants, trades and volumes in the exchanges.

- **Electronic Trading:** The computer era!
  Sending orders over an electronic network instead of calling a broker. Electronic trading was the first technological intervention that enabled trading to move out of the physical space of exchanges. It also enabled individual investors and traders to actively participate in stock markets with minimal involvement of broker intermediaries.

- **Algorithmic Trading:** After computers started beating humans in mathematical computations and in reaction-time!
  A natural progression from electronic trading with the rise in programming and information technology is to allow computers and automation to take over mundane manual tasks such as data management, high speed analysis, calculations and order execution. Algorithms are used to generate trading signals, send orders and manage portfolios and humans are required to write and manage those algorithms.

- **Quant Trading:** Statistics & Physics as the primary drivers!
  Quant or Quantitative trading makes use of market data and quantitative analysis to create trading strategies which can be fed into automated trading systems for computerized execution or for manual execution. These strategies rely on mathematical models and historical data to identify trading opportunities in future. The real-time data monitoring, analysis and signal generation process is automated by quantitative traders. The execution of these signals could be semi or fully automated, depending on the strategy.

- **High Frequency Trading (HFT):** Fast to Faster to touch the speed of light!
  Traders recognize that the speed in getting real time market data and placing orders plays a differentiating role in today's trading world. HFT is a special category of algorithmic trading characterized by unusually brief position-holding periods, low-latency response times, and high trading volumes. High Frequency traders place a lot of orders in a short period of time to make profits from very small price differences or arbitrage opportunities. HFT traders also help the market participants by bringing in ready liquidity through their market making strategies. Studies have suggested that an average retail trader in some developed markets save hundreds of dollars because of better bid ask spread, which has become narrower, thanks to the technology driven market makers.

How Speed of Information Has Always Mattered: Historical Anecdotes

A HFT trader, nowadays, uses cutting edge technological innovations to get information faster than anyone else and then be able to execute his trading order faster than anyone else. Interestingly, the phenomenon of 'fast information' delivery goes long back to 17th century. An interesting anecdote is about Nathan Mayer Rothschild knowing about the victory of the Duke of Wellington over Napoleon at Waterloo before the government of London did and made a vast fortune in the stock markets.

Julius Reuter, the founder of Thomson Reuters, in 19th century used a combination of technology including telegraph cables and a fleet of carrier pigeons to run a news delivery system. His agent in Brussels would copy the latest stock prices once the Brussels Bourse had closed and deliver them through a network of three pigeons in Aachen in France to be delivered to his small circle of subscribers!

4. Why Algorithmic Trading?

The high growth and acceptance of algorithmic trading is because of the benefits it holds over traditional trading methods. The main advantages of Algorithmic trading include speed, fast-processing, accuracy and scalability. As we have seen in the previous section, technology has always been used to speed up the information flow, between the exchanges and brokers. In the age of computers, manual computations are not only slow and cumbersome, but also erroneous. The advancement of newer computational methods and complex instruments on exchange have come along with the technological tools that are required to process computations otherwise impossible by manual methods.

1) **Speed:** Automated systems can perform computations and place orders much faster. Trading algorithms are designed to react to changing situations in microseconds. A faster trader can sell at a higher price and buy at a lower one because he gets there first. Being able to trade fast not only depends on how fast your algorithm calculates and places orders but also how fast your orders reach the exchange. A connection that's just one millisecond faster than the others could boost a high-speed firm's earnings by millions per year, according to an estimate. Everyday trading firms are pushing limits to establish fastest connections between trading hubs. Every extra foot of fiber-optic cable adds about 1.5 nanoseconds of delay; each additional mile adds 8 microseconds, so the focus is to connect financial centres using shortest routes possible. The final lap to boost high speed for single destination oriented strategies is colocation- which is placing your servers within the exchange premises and on the exchange's local network itself. Most of the global exchanges charge thousands of dollars per month to firms that want to place their servers in exchange's colocation facility. We will discuss more about this facility in the Infrastructure requirements section.

2) **Real-time Quantitative Analysis**: Algorithms can run on past data to help traders in analysing strategy's performance in terms of profit and loss and some popular performance statistics like Sharpe Ratio. This was not possible by manual means in which traders were only able to analyse trades in the live markets, which is a highly risky proposition. The ability to backtest and quantify the strategy's return over risk has allowed many individual traders to learn by their own mistakes in simulated environment before taking the strategy in live markets. A backtest is a historical simulation of an algorithmic trading strategy to see how it would've performed on the historical data. Careful backtesting allows traders to evaluate and fine-tune a trading idea. However, some traders get caught up in over-optimization at the time of backtesting which gives excellent result in paper trading environment, while failing terribly in live markets. In later sections, we discuss on how to avoid excessive curve fitting.

3) **No constant market monitoring:** Trading systems can help remove constant market monitoring from trading. Algorithms can monitor and take trading decisions based on market movements within microseconds, so no more continuous monitoring the market for hours manually is required. However, automated trading systems require some monitoring to check for mechanical failures, such as connectivity issues, power losses or computer crashes, and to system quirks. It is possible for an automated trading system to experience anomalies that could result in errant orders, missing orders, or duplicate orders. If the system is monitored, these events can be identified and resolved quickly. Nevertheless, the amount of time saved per trader without the need of constant supervision has considerably reduced the transaction costs in trading.

4) **Segregates Emotions from Trading:** Trading psychology is an extremely important aspect related to trading which is taken care of when trading algorithmically. An algorithm generates trading signals based on predefined set of instructions and not based on fear, greed or any other emotion which might affect a human trader's judgement. Even in volatile markets discipline is preserved.

5) **Scalable:** Algorithmic trading strategies are easily scalable, both in terms of size that can be executed as well as the number of instruments that can be traded. Usually a large sized order is broken down into hundreds of smaller orders which are executed within a fraction of second and thereby reducing the impact cost that the market would have incurred had it been a single large order execution.

   An algorithm can implement your trading strategy on hundreds of instruments simultaneously while monitoring them, which you would not have been possible to achieve manually. Since trades can be analysed and executed faster, more opportunities

are available at better prices. The computer is able to scan for trading opportunities across a range of markets, generate orders and monitor trades.

6) **Better Risk management & Accuracy:** Using algorithms and automatic monitoring allow traders to spread risk over various instruments while creating a hedge against losing positions. The system is emotion free and will automatically cut the positions when algorithm orders it to do, as per the trading strategy. The fat finger error or manual errors are avoided. It would not erroneously read 100 shares as 1000 shares.

7) **Cost Effective:** Algorithmic trading or computer-directed trading cuts down transaction costs and allows fund managers to take control of their own trading processes. With the hours saved from human monitoring, algorithmic trading has proved to be very cost effective. Employing rules-based strategies has enabled buy-side firms to increase productivity, lower commission costs and reduce implementation shortfall.

There are plenty of benefits of Algorithmic Trading which has resulted in instant popularity and growth of the same in all developed and developing economies. However, it is a complex field of study which requires multi-disciplinary knowledge and skill sets for traders and institutions to reap the benefits. Quantitative skill sets, programming knowledge, market acumen and deep understanding of instruments and market behaviour are few of the areas which Algorithmic traders need to build their expertise on. Poorly designed and tested automated systems can lead to heavy losses and market crashes. Initial investment involved in High Frequency trading that requires cutting edge technology, co-location facilities and complex network of lines is not affordable by all market participants, while it gives added advantage to those who invest in the same.

5. Strategy Paradigms

In the most simplistic sense, a strategy is a trading idea or hypothesis which takes real-market data feed as input and based on pre-defined set of rules or logic, generates trading order with all specifications such as order type, side, quantity as output. Once a strategy is clearly defined and written down as an algorithm, there is no scope for different interpretations. This enables computer to execute it exactly as it is coded, without any surprises or errors. A strategy can be as simple as a moving crossover indicator and as complex as a VWAP (volume weighted average price) based execution strategy to get prices.

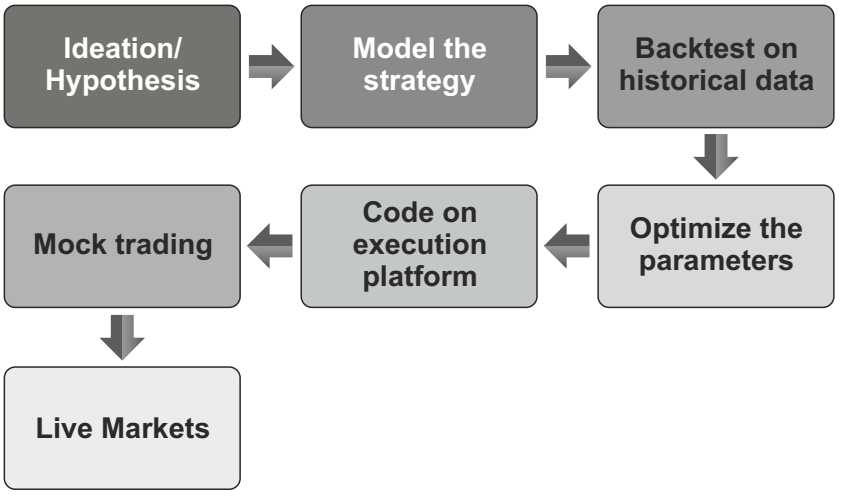
What are the popular Algorithmic strategy paradigms?

There are certain strategy paradigms or theoretical and standard concepts which are usually employed by Algorithmic traders in designing algorithms. The final strategies, read algorithms, that follow from a paradigm, say Statistical Arbitrage, may be vastly different at the time of implementation. The initial capital allocation to a strategy, entry-exit logics and different risk appetites are few of the parameters which creates all the difference in implementation of a strategy.

In this section, we will discuss popular strategy paradigms, theories behind them and modelling ideas around them. The strategy ideas we discuss here include:

- **Market Making Strategies**
- **Arbitrage Strategies**
- **Statistical Arbitrage**
- **Momentum or Trend Following Strategies**
- **News based Trading Strategies**
- **Machine Learning Trading Strategies**

These paradigms define the core areas around which the strategy idea or hypothesis will lie. At the time of modeling these strategies, quantitative methods and tools are employed to test the idea on historical data and optimize the parameters. Once the strategy has proved profitable in the back testing environment, it is coded on execution platforms and tested in simulated environment before taking it to the live markets. A rough sketch of the steps which are taken by Algo traders to design and test their strategies is shown below.



Detailed Explanations of popular Algorithmic Strategy Paradigms

1) **Market Making:** Market-making is aimed at infusing liquidity in both liquid as well as illiquid securities on the Stock Exchanges. Two main measures of liquidity are bid-ask spread and trading volumes. These algorithms try to profit from the bid ask spread. Market makers are liquidity providers who quote on both buy and sell side in a financial instrument hoping to make profit from the bid-offer spread. They accept the risk of holding the securities they quote prices for and once the order is received, they often immediately sell from their own inventory or seek an offsetting offer in seconds and vice versa. For illiquid securities, the spreads are usually higher to compensate for the higher risk that market maker has to undertake. Several segments in the market lack investor interest due to lack of liquidity as they are unable to get exit from several small- and mid-cap stocks at any given point in time. Market Makers are helpful as they are always ready to buy and sell at the price quoted by them. In fact, much of high frequency trading is passive market making. The strategies are present on both sides of the market (often simultaneously) competing with each other to provide liquidity to those who need. The profitability of their strategy is not just a function of speed but also the ability of the quantitative models to predict short term movements rightly more often than not.

Modeling ideas- The bid-ask spread and trade volume can be modeled together to get the liquidity cost curve which is the fee paid by the liquidity taker. If the liquidity taker only executes orders at the best bid and ask, the fee will be equal to the bid ask spread times the volume. When the traders go beyond best bid and ask taking more volume, the fee becomes a function of the volume as well. Trade volume is difficult to model as it depends on the liquidity takers execution strategy. The objective should be to find a model for trade volumes that is consistent with price dynamics. Market making models are usually based on one of the two- the first focuses on inventory risk. The model is based on preferred inventory position and prices based on the risk appetite. The second is based on adverse selection which distinguishes between informed and noise trades. Noise trades do not possess any view on the market whereas informed trades do. When the view of the liquidity taker is short term, its aim is to make short term profit by utilizing the statistical edge. In case of long term view, the objective is to minimize the transaction cost. The long-term strategies and liquidity constraints can be modeled as noise around the short-term execution strategies. Optimal executions based on short term views along with trading volumes form the basis of the second model.

2) **Arbitrage:** These algorithms take advantage of temporary mispricing of identical or similar financial instruments. These include cross asset, cross market arbitrage strategies. Cross asset arbitrage involves simultaneously taking a position in a security and an offsetting position in another security. It can be between two different markets (cross market) or between different kind of instruments like stock versus futures or futures versus options, etc. in order to profit from a difference in price without exposing yourself to the market risk. The 'classical' arbitrage strategies do not include taking any market risk. Furthermore, one might also classify statistical arbitrage into this category, where mathematical modelling techniques are used to find price inefficiencies between products and often involves taking some amount of market risk.

3) **Statistical Arbitrage:** These strategies seek to profit from statistical mispricing of one or more assets based on the expected value of these assets. A more academic way is to explain statistical arbitrage is to spread the risk among thousand to million trades in a very short holding time to, expecting to gain profit from law of large numbers. Statistical Arbitrage Algorithms are based on mean reversion hypothesis, mostly as a pair.

Modelling ideas- Pairs trading is one of the several strategies collectively referred to as Statistical Arbitrage Strategies. In pairs trade strategy, stocks that exhibit historical co-movement in prices are paired using fundamental or market-based similarities. The strategy builds upon the notion that the relative prices in a market are in equilibrium, and that deviations from this equilibrium eventually will be corrected. When one stock

outperforms the other, the outperformer is sold short and the other stock is bought long with the expectation that the short term diversion will end in convergence. This often hedges market risk to a certain extent from adverse market movements i.e. make the strategy beta or value neutral. However, the total market risk of a position depends on the proportion of capital invested in each stock and the sensitivity of stocks to such risk.

4) **Momentum:** Momentum Strategies seek to profit from the continuance of existing trend by taking advantage of market swings. In simple words, buy high and sell higher and vice versa. This can be achieved by taking short-term positions in stocks that are going up or down until they show signs of reversal. It can be seen by some as counter-intuitive to other well-known strategies. Value investing is generally based on long-term reversion to mean whereas momentum investing is based on the gap in time before mean reversion occurs. Momentum is chasing performance, but in a systematic way taking advantage of other performance chasers who are making emotional decisions. There are usually two explanations given for any strategy that has been proven to work historically, either the strategy is compensated for the extra risk that it takes or there are behavioural factors due to which premium exists. There is a long list of behavioural biases and emotional mistakes that investors exhibit due to which momentum works. However, this is easier said than done as trends don't last forever and can exhibit swift reversals when they peak and come to an end. Momentum trading carries a higher degree of volatility than most other strategies and tries to capitalize on the market volatility. It is important to time the buys and sells correctly to avoid losses by using proper risk management techniques and stop losses. Momentum investing requires proper monitoring and appropriate diversification to safeguard against adverse price movement.

Modelling ideas- Price momentum can be detected by following stocks or commodities that have been continuously going up for days, weeks or even several months in a row. For instance, identify the stocks trading within 10% of their 52 week high or look at the percentage price change over the last 12 or 24 weeks. Similarly, to spot a shorter trend, include a shorter term price change. An example of momentum is oil and energy sector in mid-2008; based on its 12 week or 24-week performance, it was continuously ranked as one of the top sectors even while it was collapsing. We can also look at earnings to understand the movements in stock prices. Strategies based on either past returns ("price momentum strategies") or on earnings surprise (known as "earnings momentum strategies") exploit market under-reaction to different pieces of information. An earnings momentum strategy may profit from the under-reaction to information related to short-term earnings. Similarly, a price momentum strategy may profit from market's slow response to a broader set of information including longer-term profitability.

5) **Machine Readable News:** Algorithms are used to read & interpret the news/economic data for making trading decisions in an automated fashion. There are many competent feed providers for machine readable news and goes without saying that speed of delivery is paramount as the window of profitable trading opportunity after a major economic announcement is small. Many data providers deliver the feeds to the major colocation facilities as well. Also the feed should not contain random "filler" news but price sensitive events that have genuine actionable information. Expectation of content range has expanded as participants have developed greater insights into the quantitative relationship between news events and price action. Feed includes news related to both scheduled and unscheduled economic events. Prime examples of scheduled economic releases covered in news feeds include employment figures, central bank interest rate decisions, housing statistics, business climate indices, inflation figures, GDP, treasury auctions result, etc. Unscheduled news takes algorithmic trading to the next level, as the timing and content is unknown which makes processing it immensely complex but at the same time significantly rewarding if done correctly.

6) **Machine Learning based trading strategies:** Machine Learning is learning from and making predictions on data. It originated from the study of "pattern recognition" and the theory that computers can learn without being programmed to perform specific tasks. The advantage of using Artificial Intelligence (AI) is that humans develop the initial software and the AI itself develops the model and improves it over time. In Machine Learning based trading, algorithms are used to predict the range for very short term price movements at a certain confidence interval. A large number of funds rely on computer models built by data scientists and 'quants' but they're usually static, i.e. they don't change with market. ML based models on the other hand can analyse large amounts of data at high speed and improve themselves through such analysis. A form of machine leaning called "Bayesian networks" can be used to predict market trends while utilizing a couple of machines. An AI, which includes techniques such as evolutionary computation (which is inspired by genetics) and deep learning might run across hundreds or even thousands of machines. It can create a large and random collection of digital stock traders and test their performance on historical data. It then picks the best performers and uses their style/patterns to create a new set of evolved traders. This process repeats multiple times and a digital trader that can fully operate on its own is created.

6. Backtesting and Optimization

A backtest is a historical simulation of an algorithmic trading strategy to see how it would've performed on the data in the past. Instead of applying a strategy for the time period forward (to judge performance), which could take years, a trader can simulate his or her trading strategy on relevant past data.

For example, say, a trader wants to test a strategy based on the notion that Internet IPOs outperform the overall market. If you were to test this strategy during the dotcom boom years in the late 90s, the strategy would outperform the market significantly. However, trying the same strategy after the bubble burst would result in dismal returns. The maxim 'past performance does not necessarily guarantee future returns' has to be kept into consideration while backtesting.

When backtesting, we need to understand the difference between in-sample (IS) and out-of-sample (OOS) performance. IS performance is the one recorded over the data set used in designing the strategy while OOS performance is simulated over data set not used in designing the strategy. Using backtesting we can develop strategies that would've performed well in the past by optimizing our strategy parameters. Be careful to avoid overfitting causing strategy perform well IS but not in OOS data. A backtest is realistic when the IS performance is consistent with OOS performance. Backtesting can be divided into two categories listed below:

1) **Research Backtesting:** The tools used for this do not fully simulate all aspects of market interaction but make approximations to provide rapid determination of potential strategy

performance. While these tools are frequently used for backtesting and execution, they are not suitable for strategies that approach intraday trading at higher frequencies. They are widely used within the professional quantitative trading industry to get the "first draft" for all strategy ideas before going for a rigorous backtest in a more realistic environment.

2) **Event-Driven Backtesting:** In event driven backtesting, the automated trading strategy is connected to a real-time market feed and a test broker/simulator such that the system receives new market information that will be sent to a system, which triggers an event to generate a new trading signal. These systems run in a continuous loop and can have sub-components such as historic data handler and broker simulator, making backtesting estimates very close to the results one can expect in live execution. Only drawback is that these systems have a complicated design and are more prone to bugs owing to the complexity.

Below is the list of a few backtesting/live trading platforms among many others that are available in the market.

For backtesting:

1. **TradeStation**
2. **MetaTrader**

Web Based Platforms:

1. **QuantConnect**
2. **Quantopian**

Institutional Backtesting and Live Trading Software:

1. **Deltix**
2. **Quanthouse**
3. **AlgoTrader**
4. **FlexTRADER**
5. **Progress Apama**
6. **RTS**

7. Algorithmic Trading Platform

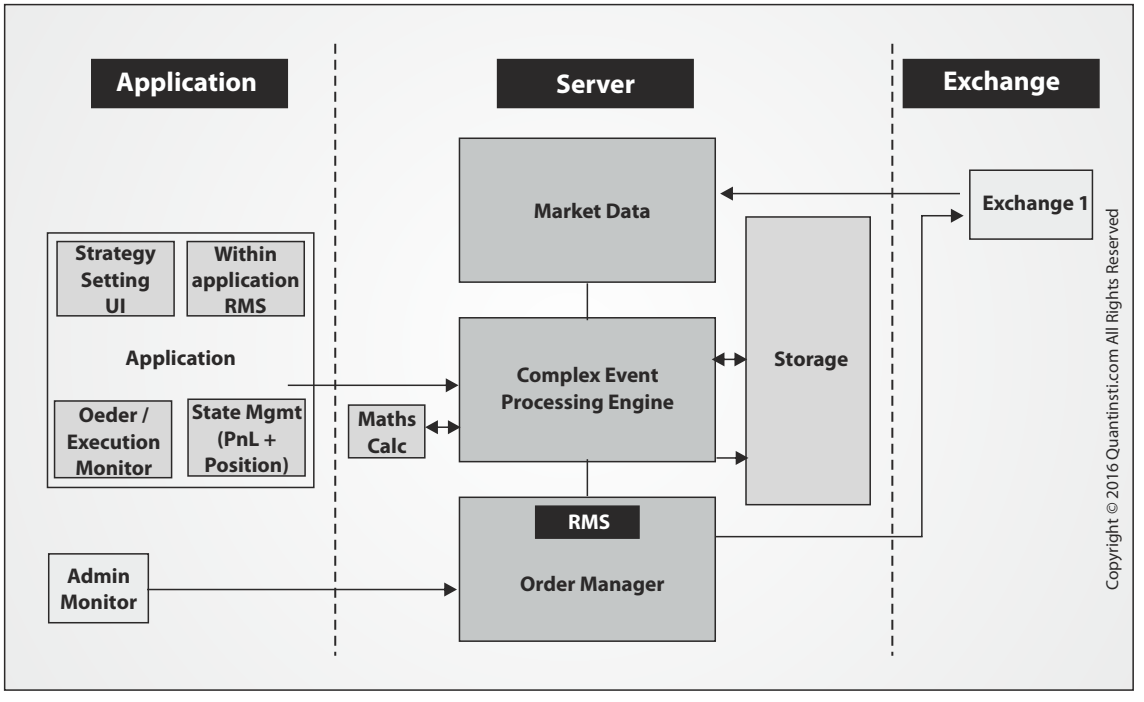
Any trading system has two basic components within it: receiving data from the exchange and placing orders in the exchange. In manual trading, we see market data flickering on our screens and electronically or telephonically, we place orders for execution. The analysis of data or decision making happens separately, either by tools and software or trader's discretion. This decision making is the third part which is also built within an algorithmic trading system.

An algorithmic trading platform has three main parts-

1) **Market Data Adapter (MDA):** MDA is used to receive data from exchange and convert it to the format that the trading system can understand. Data received from exchange is raw, unprocessed consisting of chunks of data packages which when processed by the adapter gets updated and stored in the order book.

2) **Complex Events Processing (CEP) Engine:** CEP is the brain of the system, the main strategy lies here. This is where incoming market data is analyzed, trading algorithm runs here to generate trading order.

3) **Order Routing/Management System (OMS):** CEP sends instructions to OMS which converts the order to a format that exchange understands. FIX is the most widely used format in most exchanges, some exchanges also have their own native formats as well. When an exchange uses both, the native and FIX format, sometimes native might be preferred due to faster processing as the FIX converter might be applied as an additional layer but using the exchange's native format might also involve more efforts in terms of



maintenance, which can become more complex when you are maintaining adaptors for multiple exchanges.

Main blocks in the system architecture of an algorithmic trading platform

Choice of programming language is very important while deciding which platform to use for automating your trading strategy. Different languages have different pros and cons. Most commonly used programming languages used for algorithmic trading are discussed below:

C++: for ultimate execution speed, offers most flexibility for managing memory and optimising execution speed but can lead to subtle bugs and is difficult to learn.

C# and Java: perform automatic Garbage Collection which leads to performance overhead but more rapid development. Both are good choices for developing a backtester as they have native GUI capabilities, numerical analysis libraries and fast execution speed.

MATLAB, R and Python: MATLAB is commercial IDE with multiple numerical libraries for scientific computation. It boasts high execution speed and is getting popular in individual professional traders these days. R is a dedicated statistics scripting environment which is free, open-source, cross-platform and contains a wealth of freely-available statistical packages for carrying out advanced analysis but lacks execution speed unless operations are vectorised.

Python is another free open-source and cross-platform language which has a rich library for almost every task imaginable and specialized research environment. Execution speed is more than sufficient for intraday traders trading on the time scale of minutes and above.

8. Regulations & Compliance

Securities and Exchange Board of India (SEBI) is the regulatory body for securities market in India. Forwards Market Commission (FMC) used to be the commodities market regulator which merged with SEBI in December 2015. SEBI has laid down certain compliance requirements for algorithmic trading in Indian markets.

1) **Audit Requirements:** In India, all HFT firms have to undergo half yearly audit. Auditing can only be done by Exchange empaneled system auditors (CISA certified) listed on the exchange's website. As an audit requirement you need to maintain logs for order, trade, control parameters etc. for past few years. Control parameters are specifically required by Indian exchanges as they help to identify if an order has been generated by a verified strategy or not. Other global exchanges like the ones in US, require similar data (except control parameters) to be saved of the past few years for audit purposes.

2) **Execution Related:** All orders placed must be tagged with a unique identifier as specified by the exchange. New orders can only be executed after accounting for the executed, unexecuted orders placed earlier. The system should have sufficient checks to stop execution in the events of a loop or a runaway situation. Any modifications to the algorithm must be approved by the Exchange.

3) **Specific to Commodity Markets:** Order level risk controls like Daily Price Range (DPR), Maximum Order Size, Position Limit, etc. should be taken care of. Market orders and IOC (Immediate or Cancel) orders shall not be placed, only Limit orders can be placed. Algorithmic trading is not allowed on mini and micro contracts. Sending out more than 20

orders per second and high Order-to-Trade Ratio invites penalties. All orders should be routed through member servers located in India and from approved IDs. These systems cannot have any links with any system or ID located/linked outside India. Members must ensure that their strategy induces liquidity into the market and should submit a document explaining the same. Members shall also maintain all logs as specified above and ensure regular audits and get approvals for any changes to existing strategies.

9. Requirements for setting up an Algorithmic Trading desk

Setting up an Algorithmic Trading desk is similar to starting proprietary trading business that requires inputs of various kinds: legal, financial, regulatory, human resources, technological and infrastructural. In this section, we will explain all major requirements and steps that you need to go through to start your own Algorithmic Trading business. Below are the steps to set up your own Algorithmic Trading desk:

- **Register your own company**
- **Capital Requirements for Trading and Operations**
- **Choose your trading philosophy**
- **How to get Market Access**
- **Infrastructure requirements: Hardware, Software and networking**
- **Backtesting on Algorithmic Trading Platform**
- **Risk Management**
- **Conformance and Empanelment**
- **Audit & Compliance**
- **Team & Skills Required**

1) **Registering your own company:** You can register your trading firm (for proprietary trading) as a Company, Partnership, LLP or even as an Individual. LLP is an alternative corporate business form that gives the benefits of limited liability of a company and the flexibility of a partnership. Compliance requirements and regulations are relatively easier as compared to a company. The approximate market cost for registering a company as a LLP or a company is as below:

Country	Cost (USD)
Developing Economies	Few Hundred
Developed economies	Few Thousand

If, however you want to raise money from outside investors, other approvals from regulators (SEBI in India, MAS in Singapore, etc.) are also required and the compliance rules and regulations are much stricter and the yearly expenses can go up much higher.

2) **Capital for Operations and Trading:** Broadly speaking, capital required for High Frequency Trading is usually relatively less than that required for Low Frequency Trading. LFT is scalable and can be much more capital intensive. Some of the big market players in LFT have USD 100-200 billion worth assets under management, whereas in case of HFT even the biggest of desks would have approximately USD 2-3 billion worth. To start an HFT desk few hundred thousand dollars is a decent amount to be posted as margin unless you are doing arbitrage across exchanges which might require more capital deployment.

Capital and Cash Efficiency: Giving cash margins is often avoided as it is riskier in case of default by the broker. Usually there are regulations and exchange rules which will define the distribution of margin between cash and non-cash assets that can help you in managing and efficiently allocating your assets for maximum profitability. There are several ways of managing your capital efficiently which you should be aware of, for e.g., if you are investing in stocks and taking delivery then that can be used as collateral for your derivative positions. Also, if you've offsetting positions on certain instruments, the exchange might provide you with margin benefits.

3) **Trading Philosophy:** You need to decide on the trading philosophy you'll adopt. The most common trading philosophies include:

a) **Execution Based:** Aim of these strategies is to get the best price for execution rather than focusing on alpha. E.g. VWAP (Volume weighted average price), TWAP (Time weighted average price), Implementation Shortfall, etc. Mostly institutional brokers would generally go for these strategies.

b) **Ultra HFT:** Ultra high frequency strategies are extremely latency sensitive and mainly include Market Makers and Arbitrageurs.

- **Market makers** provide quotes on both buy and sell side and hence are generally required to be the first ones to react on any news/information.

- **Arbitrageurs** may go for inter-exchange or intra-exchange strategies. In case of Intra-exchange, the latency depends on the hardware and the trading system. Many firms focusing on this go for FPGA to reduce latency further as the strategy is coded directly on the FPGA chip but it still remains a very expensive technology for most firms. In case of Inter-Exchange, it would primarily depend on the network lines as that would be the primary source of latency. In case of network lines, point to point lines with high bandwidths are required and the cost goes up with the distance and bandwidth of the line. After fiber leased lines, now we also have microwave lines, which are far better in terms of latency but often have higher downtimes.

c) Medium Frequency & Less latency sensitive strategies: If you are a quant, machine Learning based and other 'relatively' less latency sensitive strategies can be preferred. You'll still need a pretty good infrastructure but not that cutting edge infrastructure/technology which comes for a good cost as would have been required in case of Ultra HFT strategies.

4) Market Access: There are different kinds of memberships which exchanges offer. For instance, MCX (India's leading Commodity exchange) offers the below mentioned categories of memberships:

a) TCM (Trading-cum-Clearing Member / Stock Broker and Self Clearing Member- Non-Deposit Based and Deposit Based): These members can trade and clear trades for themselves and their clients only. TCMs are divided into two sub-categories: non-deposit based members and deposit-based members. The minimum net worth for the purpose of eligibility is Rs. 10 million

b) ITCM (Institutional Trading-cum-Clearing Member/Stock Broker and Clearing Member): They are entitled to trade on their own as well on their clients' accounts and can clear and settle their own trades as well as of TMs and TCMs. The minimum net worth for the purpose of eligibility is Rs. 30 million

c) PCM (Professional Clearing Member/Clearing Member): They are entitled only to velar and settle trades executed by TCMs or TMs. The minimum net worth for the purpose of eligibility is Rs. 50 million

d) TM (Trading Member/Stock Broker): TMs can trade on their own and on their clients' accounts, they have no right to clear or settle trades. All TMs must be affiliated by any one of the ITCMs or PCMs having clearing rights on MCX. The minimum net worth for

the purpose of eligibility is Rs. 1 million for Non-Corporates and Rs. 2.5 million for Corporates.

CME (Chicago Mercantile Exchange) which has 4 different exchanges CME, COMEX, NYMEX, CBOT offers membership in the form of full package with access to all four exchanges for approximately USD 700K-800K and in the form of individual membership for USD 100K-200K, the exact price varies as the membership is traded. In CME, you can also take membership in select categories on lease for approximately USD 1K-3K per month.

5) **Infrastructure:** Main focus areas are Colocation, Algorithmic Trading platform, Hardware and Network.

a) **Colocation:** Colocation means that your server is in the same premises and on the same LAN as the exchange. Most stock exchanges in India provide colocation facility now. In some cases, when exchanges do not provide colocation facility, there are vendors who provides colocation or proximity hosting facility. Such advances in technology have fundamentally changed the way orders are generated and executed in market. A significant percentage of orders received by exchanges are now generated by algorithms. Further, most of such orders are generated in the co-located space. Current regulations do not permit colocation at Commodity exchanges in India. Hence most of the Indian Commodity Exchanges or vendors offer proximity hosting only.

b) **Algorithmic Trading Platform:** Latency of various platforms vary from system to system and so does the price. Below is a very approximate cost estimate varied over the typical latency expectation provided by various vendors and shall not be taken as a benchmark.

Latency (in micro sec)	Cost (approx. in USD)
200 to 300	10K per annum
50 to 100	3K-5K per month
20 to 50	10K per month
5 to 20	You might need to get it built by your own team or by dedicated vendors
<5	FPGA solutions (250K to 2MM p.a.)

c) **Hardware:** Most of the leading hardware manufacturing companies provide servers conducive for Algorithmic Trading setup. Customizable hardware for HFT is also

available which is modified to improve performance as per requirement, like increasing cache memory etc. The production servers in case of HFT deployment is often required to be changed or updated with the latest one almost every year.

d) Network Equipment: Includes Routers/Modems, Switches and NICs etc.

- **Routers / Modems:** You need to check compatibility with exchanges to make sure the version you are using is compatible as that is often the primary criterion on which model you can use, even if more advanced versions are available in the market.

- **Switches:** Most popular switches with HFT firms are 10 Gigabit switches, which have a much better performance than 1 GB switch, but also costs almost 10 times than the latter.

- **NICs:** Network Interface Controller is basically an Ethernet card or network/LAN adapter which connects a computer or server to the network. NICs are one of the primary locations where you can pick latency and using better NIC cards can improve latency reasonably and are generally a good value for money. Most of the advance NICs only works with 10GB switches.

- **FPGA:** FPGA stands for Field Programmable Gate Array, which helps in removing all the latency associated with your operating system as you code your strategies as well as exchange adaptors in the hardware chip itself.

e) Network Lines: Network lines can be broadly categorized into Trading Lease Line and Market Data Lease Line. MCX provides Point-to-Point leased line connectivity which is a low latency data connection between two nodes or end-points.

i) Trading Lease Line- Used for sending out orders to the exchange. The exchange allows Point-to-Point leased line connectivity for 2 / 10 / 20 / 30 / 40 / 45 Mbps.

ii) Market Data Leased Line- There are two main formats ways in which exchanges send market data-

a. Tick By Tick (TBT)- Tick data is a collection of sequential "ticks" which is the latest quote, trade, price and volume along with other market data information. MCX offers Tick by Tick Market Data to the members through MarketXStream API over

multi-cast and TCP / IP. MarketXStream also provides Snapshot information which is useful in case of intraday outages.

b. Snapshot/Broadcast Data- Snapshot Data feed contains data pertaining to Stock Exchange trade quotations and other related information pertaining to the trading on different instruments generated at regular intervals of time. MCX provides streaming data through a Data feed server which is connect to the Exchange server. Real-time data feed is provided in two levels (1 and 2). Level 1 consists of only touchline information and Level 2 consist of Level 1 data and market depth data that is up to 5 best bid and ask prices. Real-time Data feed is provided over the Internet or through a dedicated 2 mbps leased circuit.

Apart from Point-to-Point Leased lines there are several other forms of connections facilities that MCX provides- MPLS (Multi-Protocol Label Switching) connectivity, VSAT connectivity and also Internet connectivity. More details (including cost, providers and bandwidth) for each type of connectivity are provided on MCX website.

6) **Backtesting on Algorithmic Trading platform:** As explained in previous section, backtest is a historical simulation of an algorithmic trading strategy to see how it would've performed on the data in the past. Before going live you'll want to see your strategy's performance. Most Algorithmic Trading Platforms (ATP) come with backtesting modules which can be used to obtain simulated results in terms of profit and loss and performance statistics over the duration of the backtested data which help in quantifying the strategy's risk adjusted return. The next step generally is to test the strategy in the "Test markets" which we briefly discussed in the previous section. You'd observe that for HFT strategies, most of the tests in the test market are only to make sure that there are no technical glitches while connecting to the market through the strategy and most of the strategy related performance testing is done on the simulators only. The primary reason is that for HFT strategies you need a lot of orders/liquidity, which is often not available in the test market.

7) **Risk Management:** Conventional risk management involves more focus on managing the risks related to the price movements (market risk), whereas in case of High Frequency trading, managing operational risk is given more importance. Failures related to technology, network, data streams can be disastrous. It is important to have multiple level checks for data starting from socket level to capture any anomalies and stop the strategy if something is wrong instantly. Matter of seconds can lead to huge losses hence it is important to disconnect within a few milliseconds or lesser time duration. Wherever exchange permits, most of the HFT firms have COD (Cancel on disconnect) functionality

activated, which allows them to automatically cancel all their outstanding orders on the exchange if a lost connection is detected on the exchange side.

8) **Conformance and Empanelment:** In India exchange's approval is required before you decide to take a strategy live. The process involves participating in a mock / giving a demo to the exchange and if all required conditions are satisfied then the strategy can be taken live. Most global exchanges don't require each strategy to be tested separately; they just test Trading Systems and grant access.

9) **Audit & Compliance:** In India, all HFT firms have to undergo half yearly audit. Auditing can only be done by certified auditors listed on the exchange's website. As an audit requirement you need to maintain order logs, trade logs, control parameters etc. for past few years. Control parameters are specifically required by Indian exchanges as they help to identify if an order has been generated by a verified strategy or not. Other global exchanges like CME require similar data (except control parameters) to be saved for the past few years for audit purposes.

10) **Team & Skills Required:** Algorithmic trading is a multi-disciplinary field which requires knowledge in three domains, namely,
    - Quantitative Analysis/Modelling
    - Trading Knowledge
    - Software Programming Skills

    Broadly speaking you'll need Traders / Strategists, IT professionals, Network managers, Risk Managers, HR and Legal teams. But to start with IT professionals and Traders / Strategists should be sufficient. A small team of 3-5 Traders and IT professionals, along with Support Staff, i.e. a total of about 7-10 people can be a good start for an algorithmic trading start up.

Reference

1. Carnegie Mellon University, study content from Department of Statistics
   http://www.stat.cmu.edu/~abrock/algotrading/
2. Quantinsti blog on trading strategies
   https://www.quantinsti.com/blog/algorithmic-trading-strategies/
3. Quantinsti blog on backtesting
   https://www.quantinsti.com/blog/top-backtesting-platforms-for-quants/
4. MCX membership details https://www.mcxindia.com/membership
5. MCX circular no: MCX/CTCL/116/2013

Further Reading

1. Mark Berenson, David Levine, Kathryn A Szabat, Timothy C Krehbiel, Basic Business Statistics: Concepts and Applications – Pearson
   https://books.google.co.in/books?hl=en&lr=&id=2TDiBAAAQBAJ&oi=fnd&pg=PP1&dq=basic+statistics+quantitative&ots=CADCqEOib1&sig=JvL3zmxBLBhoLk0oAr57Xm3Y7Kk#v=onepage&q=basic%20statistics%20quantitative&f=false
2. E.P. Chan, Quantitative Trading: How to Build Your Own Algorithmic Trading Business (Wiley Trading)
3. *http://epchan.blogspot.in/*
4. Book - Understanding Arbitrage An Intuitive Approach to Financial Analysis- Randall S. Billingsley
   http://ptgmedia.pearsoncmg.com/images/9780137010028/samplepages/0137010028.pdf