Introduction to Algorithmic Trading Systems

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09/02/2021

Overview

Instructor: Dr. Steve Yang, Babbio 536,
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- **Class Time:** Lectures on Thursday 06:30PM-09:00PM
  $01 - 19 - 2017 - 05 - 18 - 2017$
- **Office Hours:** Wednesday 2:00AM-3:00PM at Babbio 536
- **Prerequisites:** FE570 Required

- **Topics:**
  This course investigates methods implemented in multiple quantitative trading strategies with emphasis on automated trading and quantitative finance based approaches to enhance the trade decision making mechanism. The course provides a comprehensive view of the algorithmic trading paradigm and some of the key quantitative finance foundations of these trading strategies. Topics explore markets, financial modeling and its pitfalls, factor model based strategies, portfolio optimization strategies, and order execution strategies. The data mining and machine learning based trading strategies are also introduced, and these strategies include, but not limited to, Bayesian method, weak classifier method, boosting and general meta-Algorithmic emerging methods.

- **Textbooks:**
  - **Raja Velu, Maxence Hardy, Daniel Nehren, Algorithmic Trading and Quantitative Strategies, Chapman and Hall/CRC Financial Mathematics Series, 1st Edition (2020)**
  - Frank J. Fabozzi, Sergio M. Focardi, and Petter N. Kolm, "Quantitative Equity Investing: Techniques and Strategies" (Wiley, 2010). ISBN 978-0-470-26247-4
  - Stefan Jansen, Machine Learning for Algorithmic Trading: Predictive models to extract signals, Packt Publishing, Ltd. 2nd Edition (2021)
  - Barry Johnson, "Algorithmic Trading & DMA", 4Myeloma Press London, 2010.

Policies

Homework Honor Policy:

▶ You are allowed to discuss the problems between yourselves, but once you begin writing up your solution, you must do so independently, and cannot show one another any parts of your written solutions. The homework is to be pledged (for undergraduate students).

▶ Your solutions to the homework and exam problems have to be typed (written legibly) and uploaded to the Moodle course website in one single PDF file (no other file format will be accepted). Any changes to the course schedule or due date of assignments will be announced through the course website.

▶ Each homework assignment will contain 3-5 problems, and will be posted on the class website. No late homework will be accepted under any circumstances.

Exams & Grades

Grades: Homework Assignments - 40%; Mid-term - 30%; Final Project- 30%.

Exams: Two Exams. (Mid-term) EXAM I: September 30 - (Thursday). (Final) EXAM II: December 9 - (Thursday). These exams will consist of short questions, and mathematical problems.

Exam must be taken at these times No Exceptions!

Mathematical Finance - Financial Engineering

STATEMENT: "Although most would agree that finance, micro investment theory and much of the economics of uncertainty are within the sphere of modern financial economics, the boundaries of this sphere, like those of other specialties, are both permeable and flexible." (Robert Merton - A tribute to Paul Samuelson, 2006).

Financial economics theorists have been divided into two camps:

1. those who believe that economics is a science and can thus be described by mathematics
2. those who believe that economic phenomena are intrinsically different from physical phenomena which can not be described by mathematics

Finance Economic Theory - A Mathematical Science?

- ▶ Financial markets are driven by unpredictable unique events and, consequently, attempts to use mathematics to describe and predict financial phenomena are futile.

- ▶ Financial phenomena are driven by forces and events that cannot be quantified, though we can use intuition and judgment to form a meaningful financial discourse.

- ▶ Although we can indeed quantify financial phenomena, we cannot predict or even describe financial phenomena with realistic mathematical expressions and/or computational procedures because the laws themselves change continuously.

Algorithmic Trading

Algorithmic trading: is commonly defined as the use of computer algorithms to automatically make trading decisions, submit orders, and mange those orders after submission.

Goal: *The main objective of Algo trading is not necessarily to maximize profits but rather to control execution costs and market risk.*

- Different strategies may target at different frequencies, and the profitability of a trading strategy is often measured by certain return metric.

The Market in Numbers

- Algorithms started as tools for institutional investors in the beginning of the 1990s. Decimalization, direct market access (DMA), 100% electronic exchanges, reduction of commissions and exchange fees, rebates, the creation of new markets aside from NYSE and NASDAQ and Reg NMS led to an explosion of algorithmic trading and the beginning of the decade.

- Today, brokers compete actively for the commission pool associated with algorithmic trading around the globe a business estimated at USD 400 to 600 million per year.

- Orders come from institutional investors, hedge funds and Wall Street trading desks

Why Algorithms?

- Institutional clients need to trade large amounts of stocks. These amounts are often larger than what the market can absorb without impacting the price.
- The demand for a large amount of liquidity will typically affect the cost of the trade in a negative fashion ("slippage")
- Large orders need to be split into smaller orders which will be executed electronically over the course of minutes, hours, day.
- The procedure for executing this order will affect the average cost per share, according to which algorithm is used.
- In order to evaluate an algorithm, we should compare the average price obtained by trading with a market benchmark.

Main issues in Algorithmic Trading

▶ **Efficiency** - has been one of the key drivers for the sell-side; a skilled trader is valuable commodity, anything that helps make them more productive is clearly beneficial. Once an algo is chosen the smaller orders need to be executed electronically.

   Capacity, Speed

▶ **Usability** - is obviously a major issue for most users. A convoluted trading method is unlikely to be popular, even if it gets good results.

   Control, Transparency, Anonymity, Market Conditions, Asset Knowledge

▶ **Performance** - may be measured by comparing the average execution price to a specific benchmark. Note that it is also important to consider the variability, or volatility, of these averages.

   Performance, Commission, Risk/Cost Control

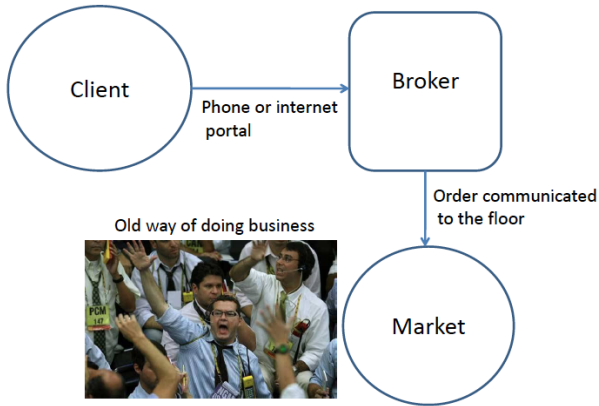# 1. ``Ancient'' brokerage model

Figure: Ref: Marco Avellaneda, NYU

2. Electronic market

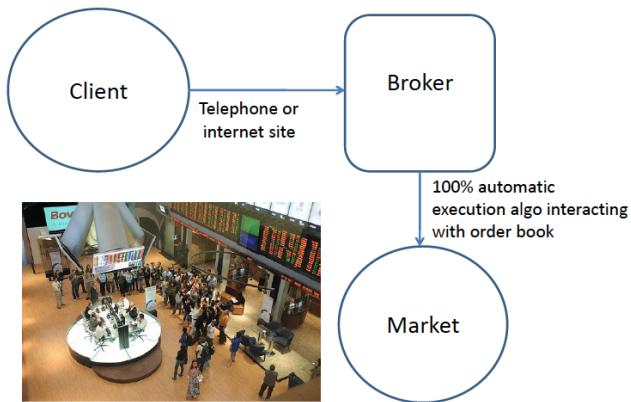Figure: Ref: Marco Avellaneda, NYU
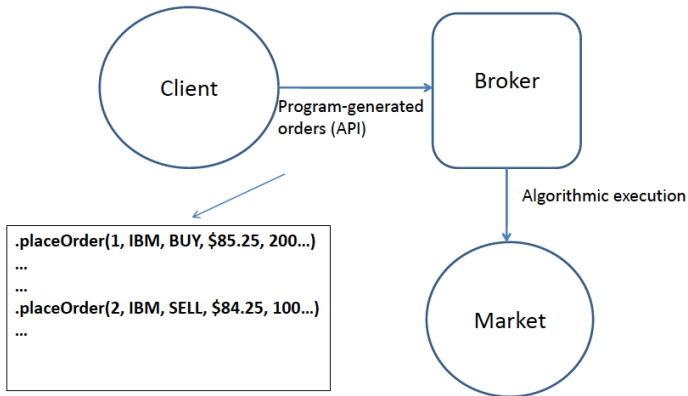
3. Electronic execution model with API

Figure: Ref: Marco Avellaneda, NYU

4. Direct Market Access (DMA)

Client sends orders
directly to the market

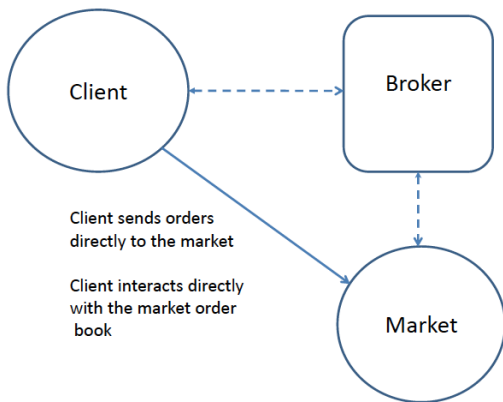Client interacts directly
with the market order
 book

Figure: Ref: Marco Avellaneda, NYU

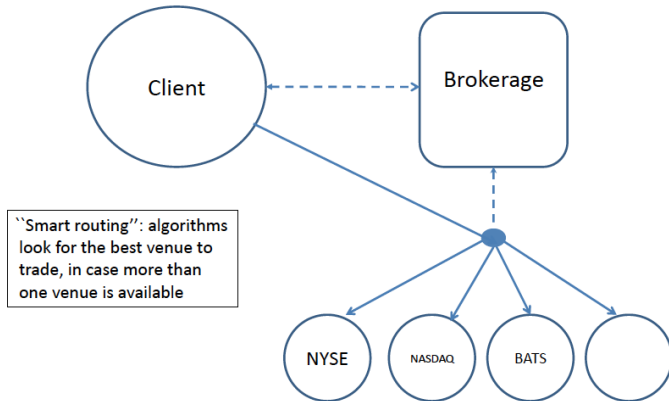# ECNs, Dark Pools, Multiple Execution Venues


Figure: Ref: Marco Avellaneda, NYU

- ▶ **Direct Market Access** - extends the principle of remote access to a broker's clients. The client can take advantage of the broker's infrastructure to send their orders to the exchange, much like the broker's own orders.

- ▶ **Sponsored Access** - caters for buy-side clients with high-frequency trading strategies. This allows the client to connect to the market using their broker's unique market identifier (MPID), but without having to go through their entire infrastructure.

- ▶ **Crossing** - Crossing systems provide an electronic mechanism allowing investors to carry out their own block trading anonymously. The focus is on achieving a better price and minimizing information leakage.

- ▶ **Direct Liquidity Access** - incorporates DMA and Crossing, as well as features such as liquidity aggregation.

- ▶ **Direct Strategy Access** - clients can have direct access to algorithms, much as orders via DMA.

Market Risk Measurement

Market Risk Measurement: there are several possible causes of financial losses (see Jorion 2000).

- ▶ *Market risk* is resulted from unexpected changes in the market prices, interest rates, or foreign exchange rates.

- - *Liquidity risk* is determined by a finite number of assets available at a given price, and another form of liquidity risk refers to the inability to pay off debt on time.

- - *Credit risk* arises when one of the counterparts involved in a financial transaction does not fulfill its obligation.

- - *Operational risk* is a generic notion for unforeseen human and technical problems, such as fraud, accidents, and so on.

Trading Process
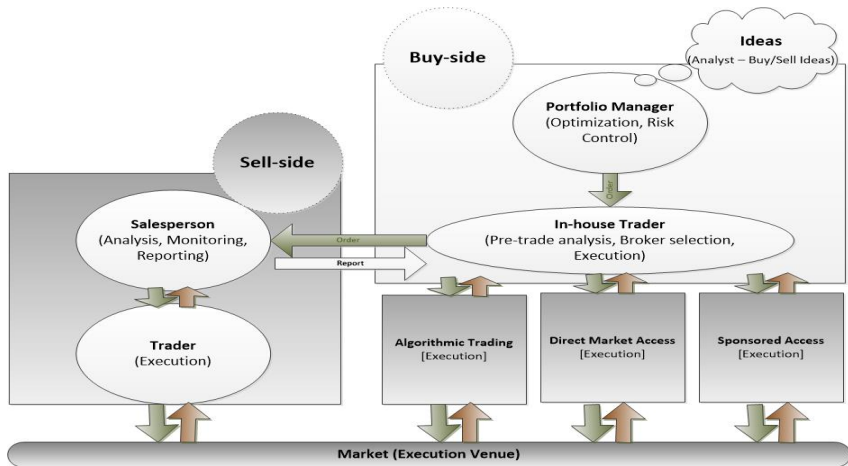
Trading Types
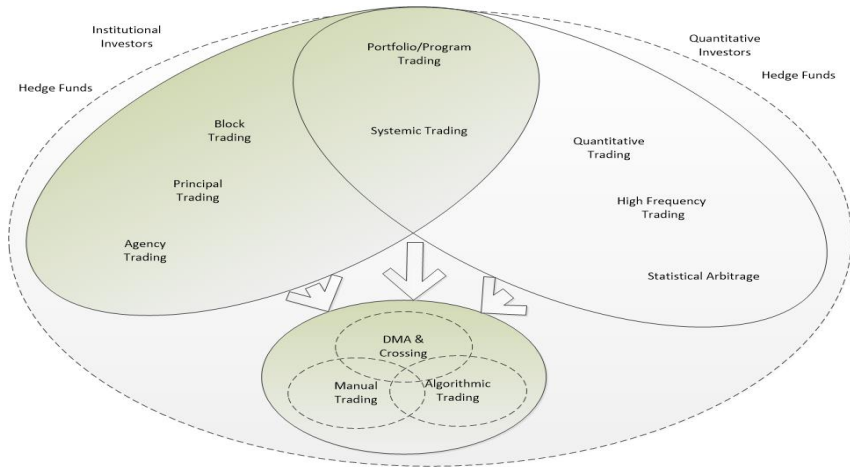
Trading Types

- *Block trading* is trading in which an order or trade submitted for sale or purchase of a large quantity of securities. A block trade involves a significantly large number of shares or bonds being traded at an arranged price between parties, outside of the open markets, in order to lessen the impact of such a large trade hitting the tape.

- *Principal trading* occurs when a brokerage buys securities in the secondary market, holds these securities for a period of time and then sells them. The purpose behind principal trading is for firms (also referred to as dealers) to create profits for their own portfolios through price appreciations.

Trading Types

- *Agency trading* is a practice that an agency transaction is the other popular method for executing a client's orders. More complicated than regular principal transactions, these deals involve the search for and transfer of securities between clients of different brokerages. The increasing number of participants in the securities market and the need for extremely accurate bookkeeping, clearing, settlement and reconciliation make ensuring the smooth flow of the markets quite a task.

Trading Types

- *Portfolio trading* is sometimes referred to as basket or program trading. It provides investors with a cost-effective means of trading multiple assets, rather than having to trade them individually. It is used when they need to adjust or rebalance their portfolios.

- *Systemic trading* is about consistently adopting the same approach for trading. This may be used to dictate points for trade entry and exit, for instance by comparing market prices with boundary conditions, e.g. Bollinger bands.

- *Quantitative trading* (sometimes referred to as "Black-box" trading) is often confused with algorithmic trading. Here the trading rules are enforced by adopting proprietary quantitative models.

Trading Types (cont.)

- *High frequency trading* aims to take advantage of opportunities intraday. The time scales involved range from hours down to seconds or even fractions of a second. Effectively, it is a specialized form of black-box/quantitative trading focused on exploiting short-term gains.

- *Statistical arbitrage* represents a systematic investment/trading approach, which is based on a fusion of real-time and historical data analysis. Strategies try to find trends or indicators from previous data (intraday and/or historical) and then use these to gain an edge. Time series analysis, data mining and even machine learning are employed to try to isolate useful information from the mass of data that is available.