BC 3402
Financial Service
Processes and Analytics

Algorithm Trading (I)

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Book Chapters

- For two sessions
- Kendall Kim (Chapters 3, 5, 6, 11, 13)
- Other chapters in the book covers algorithm related topics, such as alternative execution venues e.g. ECN, order flow (STP)

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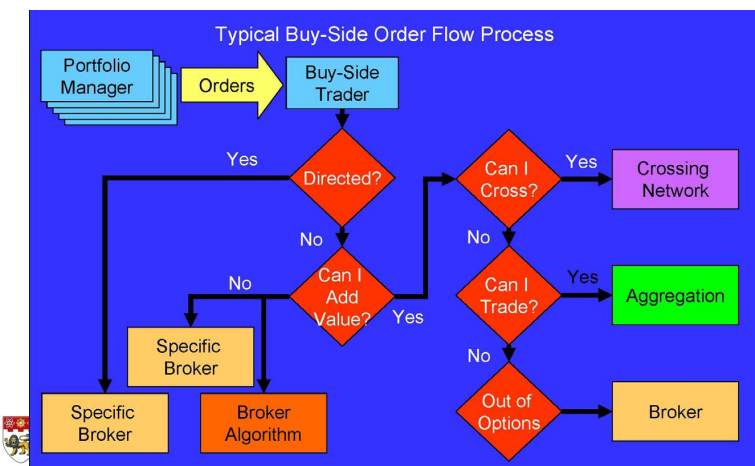Nanyang Business School

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Topics to be covered

- What is algorithm trading?
- Some algorithm strategies
- Industry Trends
- Limitations of the algorithms
- Algorithm Trading for different asset classes
- Providers of the algorithms

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Buy-Side Order Flow

Source: TABB Group

Algorithm Trading

- What is algorithm trading and program trading?
- Definition of algorithm trading: Placing a buy or sell order of a defined quantity into a quantitative model that automatically generates the timing of orders and the size of orders based on goals specified by the parameters and constraints of the algorithm
- All algorithm strategies have an objective, and the algorithm aims to achieve the objective.

Program Trading

- Definition of program trading: Equity securities that encompass a wide range of portfolio-trading strategy involving the purchase or sale of a basket of at least 15 stocks valued at $1 million or more. (Definition from NYSE)
  - 11.6% of total trades in NYSE are program trades in 1995. 22% of all trades in 2000 and 50.6% of all trades in 2004.
  - E.g. Trade all equities that constitute the STI
- Relationship between algorithm and program trading – highly correlated. Most algorithm trading are executing program trades.

The Market Impact

US Equity Share volume and trades

Legend: Total Shares (m) | Total Trades (k) | Shares / Trade
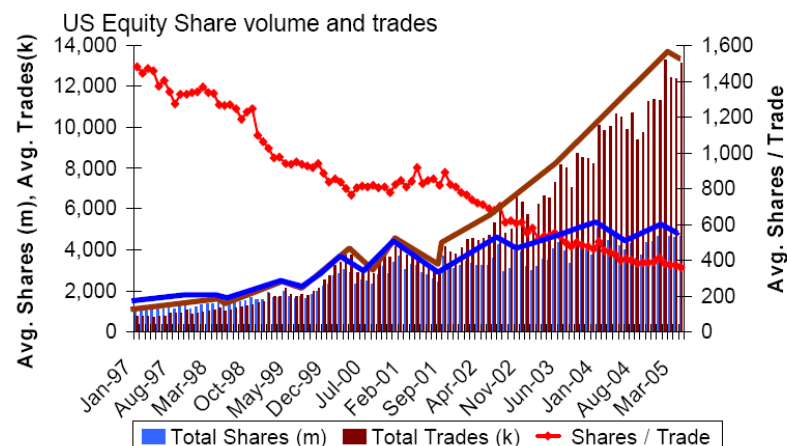
Development of Algorithm Trading

- How trading has changed with the decriminalization of (2001) instead of $0.0625 for price increments
  - Reduced trading margins by 84%
  - Lower margins => traders are less willing to use their capital to provide market liquidity => fragmentation of market liquidity
  - Increased focus on efficiency

Development of Algorithm Trading

- Securities traded now:
  - Mainly highly liquid large cap stocks
  - Future: small cap stocks, commodities, derivatives, forex
  - Remote future: Fixed income instruments (due to lower liquidity)

Development of Algorithm Trading

- FIX Protocol by Salomon Brothers (1992)
  - The original standard for electronic communication networks (ECN)
- Who are involved?
  - Sell-side brokerage firms
  - Mutual funds, pension funds
  - Hedge funds and private investment firms
- Built into DMA tools and OMS
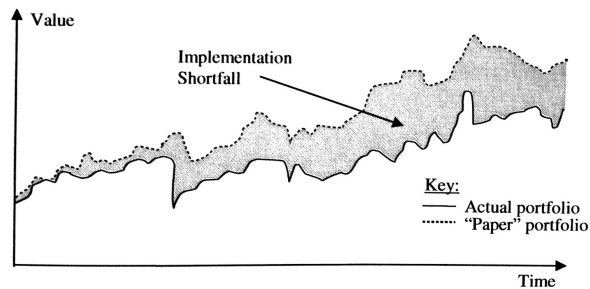
Built-in Algo-Trading (OMS/ DMA tools)

Morgan Stanley Benchmark Execution Strategies

Algorithm strategies

Transaction Costs

- Definition: "Costs paid by buyers, but not received by the sellers"
- In 2000, total transaction costs amount to $120 billion for $12 trillion worth of US equity trade (1% of total trade costs)
- What is a reasonable range of transaction costs?

Breaking down the components

Cost type		Classification				Focus for:	
		Explicit	Implicit	Fixed	Variable	Algorithms	Execution Tactics
Investment	Taxes	✓			✓		
	Delay Cost	✓ 5			✓		
Trading	Commission	✓		✓			
	Fees	✓		✓		○	○
	Spreads		✓ 6		✓		●
	Market Impact		✓		✓	●	○
	Price Trend		✓		✓	●	
	Timing Risk		✓		✓	●	○
	Opportunity Cost		✓		✓	○	

● often ○ sometimes

Note other ways of classifying are possible.

Trading Costs & Opportunity Costs
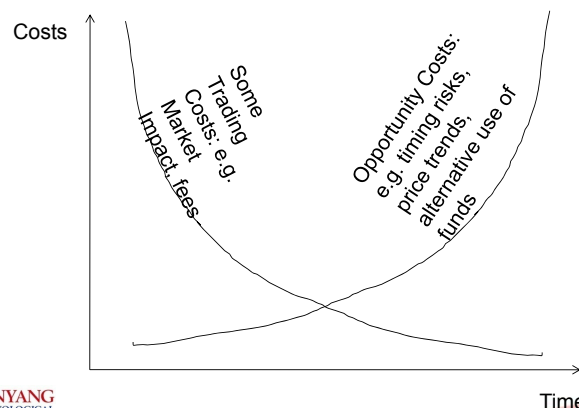
•Trade off between trading costs and opportunity costs
•Implementation shortfall is the sum of both costs

Implementation Shortfall

- The difference in return between a theoretical portfolio and the implemented portfolio
  - Paper portfolio: The ideal situation, all securities at benchmark prices. No transaction costs, no slippage, no opportunity costs etc.
  - Actual portfolio: The portfolio that reflects reality; transacted in real market prices with inefficiencies factored into it.
  - Implementation shortfall = Paper portfolio – Actual portfolio

Formula for Implementation Shortfall (IS)

IS = Profit (or losses) from Ideal – Profit (or losses) from Actual

= Benchmark Volume (Difference between benchmark and current price) –
Actual Volume (Difference between actual and current price +/- Txn. costs)

•The difference between benchmark (BMP) and current prices (CP) could be either (CP – BMP) or (BMP – CP) depending on whether it is a buy or sell order

•The difference between actual (AP) and current prices (CP) could be either (CP – AP) or (AP – CP) depending on whether it is a buy or sell order

•Add txn. costs to AP if it is a buy order, subtract txn. cost from AP if it is a sell order

•There is no specific sign convention for implementation shortfall, for this class, we assume that a positive shortfall is detrimental i.e. the actual profits is less than the ideal profits or the actual losses is greater than the ideal losses.

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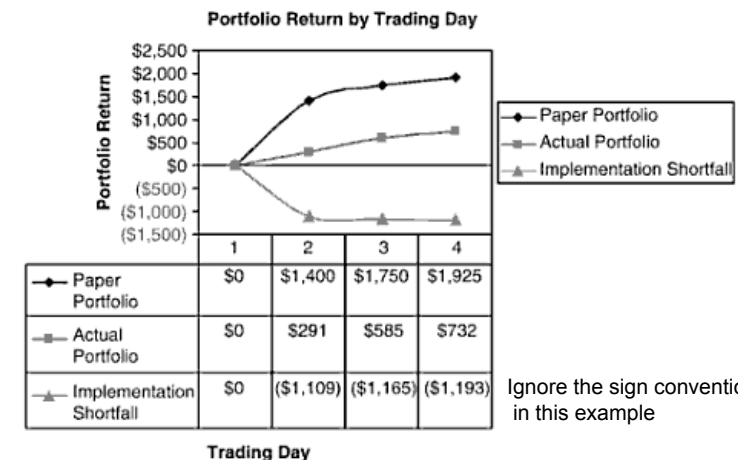
Steps for computing Implementation Shortfall

- Determine the benchmark price(s) and benchmark volume(s) – this is usually the most difficult step: the BM based on the algorithm used
- Determine the executed price(s), transaction costs (e.g. commission) and executed volume
- Compute the paper portfolio profits/losses based on the benchmark price(s)
- Compute the actual portfolio profits/losses based on the actual price(s) considering transaction costs
- Difference between paper portfolio and actual portfolio will be the implementation shortfall

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Example: Implementation Shortfall

- You intend to place a buy order of 700 XYZ shares. Order was placed on Day 0 after the market close at $100.
- Your sell-side broker bought the shares over 3 days in this fashion. Day 1: 300 @ $101; Day 2: 200 @ $101.75; Day 3: 100 @ $102.50. Your broker charge a commission of $0.03 per share purchased.
- Compute the implementation shortfall

Day	Price of Close	Trade Price	Number of Shares
0	$100.00	$100.00	0
1	$102.00	$101.00	300
2	$102.50	$101.75	200
3	$102.75	$102.50	100

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Computing Implementation Shortfall

Portfolio Return by Trading Day

	1	2	3	4
Paper Portfolio	$0	$1,400	$1,750	$1,925
Actual Portfolio	$0	$291	$585	$732
Implementation Shortfall	$0	($1,109)	($1,165)	($1,193)

Ignore the sign convention in this example

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Types of Algorithm Trading Strategies

- Volume-weighted average price (VWAP)
- Time-weighted average price (TWAP) or timing slicing
- Volume participation/ Percentage of Vol. (POV)/ Volume inline
- Adaptive shortfall
- Liquidity driven

Other possible:

- Pegging
- Ratio
- Sniper/ Sniffer

VWAP Strategy

- A trading strategy in general that can be achieved with or without algorithm trading
- Historically, traders are used to "manually" achieve this
- The primary benchmark for algorithm trading (most common)
- Attempt to achieve execution price at or better than VWAP
  – For buy orders at or lower than VWAP; sell orders at or higher than VWAP
- Objective: to lower market impact of the trades

Formulation for VWAP

$$VWAP = \frac{\sum\limits_{i=1}^{n} V_i * P_i}{V_{cum}}$$

for i = 1 to n

VWAP	=	volume weighted average price
V	=	traded volume
i	=	transaction number
P	=	traded price
V_{cum}	=	cumulative traded volume

Types of VWAP

Measure	Definition	Remarks
Full VWAP	Ratio of the dollar volume traded to the corresponding share volume over the trading horizon, including all transactions	Standard definition, usually computed the day of the trade. Some traders use multiday VWAP (in the case of orders broken up for execution over several days) or intraday VWAP for orders executed strictly within the trading day. Unambiguously defined.
VWAP excluding own transactions	Ratio of dollar volume traded (excluding own volume) to share volume (excluding own volume) over the trading horizon	When the trader's order is a large fraction of volume, excluding the trader's *own* transaction volume corrects for bias. Excluding own trades, however, may produce a misrepresentative benchmark since VWAP is an average of prices before and after the bulk of the trading has occurred.
Non-block VWAP	VWAP computed excluding upstairs or block trades	Excluding large-block trades is reasonable for small traders who cannot access upstairs liquidity (Keim and Madhavan [1996]; Madhavan and Cheng [1997]). While some markets flag upstairs trades, others including those in the U.S. do not. It is common to exclude trades of 10,000 or more shares as a proxy for upstairs trades.
VWAP proxies	Proxies for VWAP, including simple average of open, low, high, and close	In emerging markets where tick-level data are unavailable, proxies are readily computed.
Value-weighted average price	Prices weighted by dollar value of trade, not share volume.	Value-weighting is reasonable for volatile securities because the weights are determined by the economic value of the transaction. Other weighting schemes also exist.

Drawbacks of VWAP

- Introduces uncertainty for time dimension into the trade as one cannot control the trading volume
- Large institutional trades may not be able to complete within a single day if the trade quantity exceeds usual volume – multiple days may be required
- Increase trading time has opportunity costs involved
- Not appropriate for traders motivated by short-term momentum
- Not suited for trades that are a significant fraction of daily volume

How to Achieve VWAP: Not Necessarily Algorithm Trading

- Guaranteed principal VWAP bid: The sale/ purchase price is guaranteed by the sell-side. Sell-side assumes the risk to achieve it.
- Forward VWAP cross: buyers and sellers matched electronically and agree to execute at the end of the day at a price equal to full-day VWAP
- VWAP trading:
  - Buy-side using built-in algorithms in DMA tools
  - Sell-side act as agent to trade (without assuming risk) – May use algorithms
 - Algorithm trading usually used in this option

Steps in VWAP Algorithm

- Step 1: Analysis of incoming orders:
  - Pre-trade analysis filters out any orders that would be more appropriately traded using other means. Illiquid block trades or very large relative to average daily volume are diverted for manual attention
  - Why?

Steps in VWAP Algorithm

- Step 2: Intelligent volume distribution
  - Predict the daily volume for the order
  - A trading distribution is then created to match this projected volume pattern, participating more heavily during the periods of the day when volume is expected to be heaviest
  - Why?

Microsoft Corporation Share Volume by Time of Day: April to July 2001
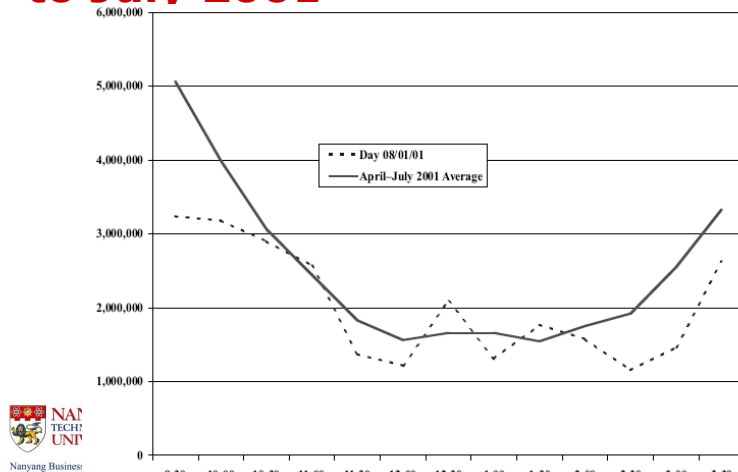
Steps in VWAP Algorithm

- Step 3: Work orders intelligently
  - Ability to obtain best execution on individual trades around the expected volume distribution is the last critical element
  - Actively pursues liquidity, tapping into all available sources and trading most heavily when markets are most liquid
  - E.g. Predicted daily volume, 100 (morning), 200 (afternoon). If one can get the best price for the volume traded proportional to the predicted volume, one will be able to achieve VWAP

Exercise

- Compute the implementation shortfall for the following VWAP algorithm:

Time	Cumulated Volume for day	VWAP (for the hour)	Qty. Sold	Price Sold
1	10,000	$ 7.00	1,000	$ 6.90
2	20,000	$ 7.10	1,000	$ 7.00
3	30,000	$ 7.20	1,000	$ 7.20
4	40,000	$ 7.20	1,000	$ 7.10
5	50,000	$ 7.40	1,000	$ 7.30

TWAP (Time-Weighted Average Price)

- Allows trades to be "time-sliced" over a certain period of time.
- Same amount of trade regardless of market volume at any point in time →trade quantity spread equally throughout the time period.
- One of the easiest algorithm to implement
- Simple objective function
- Used when some form of urgency in executing a trade
- For illiquid stocks where volume analysis is less useful

TWAP Example

- At 2:00pm in the afternoon, you wish to buy 100,000 XYZ, TWAP from 2:30pm to 3:20pm.
  - The algorithm will slice the order into 10 lots of 10,000 shares and put in the bids every 5 minute.
  - Algorithm ignores any changes in volume
  - What are some potential disadvantages?

Advantages and Disadvantages of TWAP

- (ADV) Not dependent on market volume → reduce uncertainty in terms of execution time
- (ADV) Potentially faster in execution. Limit price may be put in place as price protection
- (DISADV) May experience higher execution costs due to greater impact on prices (esp. for block trades)
- (DISADV) May not be good for hiding block trades.

Question

- Assuming you are to sell up to 1 million XYZ shares over the next 10 days. You have decided to use TWAP as the key strategy. XYZ is rather illiquid which makes VWAP less effective.
- Historically, the daily volume of XYZ shares ranges from 100,000 to 500,000. You will not be able to predict the volume prior to trading
- How will you modify the TWAP strategy to ensure that you are able to achieve the sale of 1 million with the less price impact?

Potential Modification

- Modification: 1,000,000 XYZ, TWAP from Day 1 to 10, Max % of daily volume – 50%.
  - Slices the trades into multiple lots
  - Subject to cap of 50% of the total volume for the day – mitigate price impact for illiquid stocks
  - Common to see limits on participation volume together with TWAP, sometimes VWAP too.

Percentage of Volume (POV)

- Sometimes known as %ADV (average daily volume) or Participation
- Places either a upper limit or strict criteria (target) for the trade size to achieve a particular target volume
- To achieve the percentage of volume, the algorithm will rely on both historical data as well as current volume to dynamically adjust the order sizes throughout the trading horizon

Examples of POV

- Target POV
  - Buy 100,000 XYZ start 9:00am and represent 1/3 of trading volume
- Upper limit POV
  - Usually put in place in conjunction with VWAP, TWAP, Arrival Price or other algorithms. Serve as a buffer for price impact
    - E.g. Sell 100,000 XYZ, VWAP from 9:00am to 4:00pm, up to 1/3 of trading volume.

Other algorithms: Arrival Price

- Another common algorithm
- Arrival Price = the price when order was made
- This algorithm is generated with the objective function to best meet (or even beat) the arrival price
- The mechanism behind this algorithm varies from provider to provider and is more complex.

Other Algorithms: Closing Price

- Another common algorithm
- Similar to Arrival Price
- Closing Price = The ending price of the counter that the end of day. Sometimes algorithm is also known as EOD
- This algorithm is generated with the objective function to best meet (or even beat) the closing price of a particular day
- Similar to arrival price, mechanism behind this algorithm varies from provider to provider and is more complex.

Some Misconceptions

- Execution vs Trading Strategies
- What is an "Ideal Profit" while calculating Implementation Shortfall? Maximum or best the Algorithm can achieve?
- Ideal IS = IS choice of algorithm + IS execution of algorithm