Algorithmic trading
Automated trading in financial markets

Tutorial

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Summary

• Background
• Algorithmic trading methods
  – Technical (Trend, Mean reversion, Seasonality)
  – Arbitrage
  – Statistical arbitrage (Statarb)
  – Fundamental
  – High frequency trading (HFT)
• Optimizations
Algorithmic/automated trading

• Classic way
  – Analyst analyses the market and makes a decision to buy or sell some specific asset
  – Trader executes the trade

• Automated trading way
  – Analyst finds some reoccurring trading opportunities and codes the logic into the algorithm
  – Computer performs analysis and executes the trade
Algorithmic/automated trading

• Computer program makes a decision: buys and sells without human intervention
• Decision depends on
  – Human entered order (big order execution)
  – Single instrument market data (trend, TA, HFT)
  – Multiple instrument market data (statarb, trend)
  – Fundamental data (global macro, ratios)
  – News feed (event arbitrage)
  – Weather patterns ? Moon phases ?
Algorithmic trading

Trading frequency

Long term trend following

High frequency trading
Also known as

- Algorithmic trading
- Automated trading
- Robot trading / trading robots
- Program trading
- Mechanical trading
- Systematic trading
- High frequency trading
- Low latency trading
- Ultra low latency trading
- Black-box trading
- Trading models
- Quant trading
Individual

- Trading strategy
- Trading system
- Trading robot
- Trading algorithm (algo)
- A model
Individual

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- Trading system
- Trading robot
- Trading algorithm (algo)
- A model

?
Pros / Cons of Algorithmic Trading

• Pros
  – Speed – can react quicker than human
  – Can be infinitely replicated
  – Emotionless
  – Will not quit or get sick
  – Can be tested using >20 years of historical data

• Cons
  – Cannot react to unknown changes
  – Is not able to see the big picture
People - Quants

• Mathematics
• Statistics
• Signal processing
• Game theory
• Machine learning
• Computer science
• Finance and Economics
Quant?
Quants and Models
Quants do it with models
Strategy: One Moving Average
Period = 9
Equity Curve Line - AAPL 1440 min. (05/17/04 16:00 - 05/03/11 16:00)
Algorithmic trading examples

• Execution of big orders
• Technical analysis
  – Trend Following
  – Mean reversion or contra-trend
  – Chanel breakout
• HFT, Market making, scalping
• Arbitrage

• Statistical arbitrage (pairs trading)
• Seasonality
• Fundamental analysis
• Event arbitrage / news trading
• Many unknown
• Moon phases / weather
Arbitrage

• Buy low in one place, sell high in other place
• Speed is the main factor
• Arbitrage opportunities exist for a very short time
• Arbitrage opportunities usually makes small profit
  – Hence big quantities
• I.E. Forex brokers, if one sells lower then other buys
• I.E. same stock traded in US and EU (LSE: BP, NYSE: BP)
• I.E. wheat traded in EU ir US
  – Keep in mind transportation, tax and other fees
• Moves liquidity from one market to another
Arbitrage: illustration

Broker #1

Broker #2

Profit

Price

Time

Price

Time

Price

Time

buy

sell

Arbitrage: 2 way example

• Suppose Walmart is selling the DVD of Shaft in Africa for $10. However, I know that on eBay the last 20 copies of Shaft in Africa on DVD have sold for between $25 and $30. Then I could go to Walmart, buy copies of the movie and turn around and sell them on eBay for a profit of $15 to $20 a DVD. It is unlikely that I will be able to make a profit in this manner for too long, as one of three things should happen:

• 1. Walmart runs out of copies of Shaft in Africa on DVD
• 2. Walmart raises the price on remaining copies as they've seen an increased demand for the movie
• 3. The supply of Shaft in Africa DVDs skyrockets on eBay, which causes the price to fall.
Arbitrage: 3 way example

- The basic formula for the relationship of three related currency pairs, having 3 different currencies, is as follows.

- \[\text{AAA/BBB \times CCC/AAA = CCC/BBB}\]

- Chance of triangular arbitrage occurs whenever this equation goes wrong. A triangle arbitrator buys BBB spending AAA, then buys CCC spending BBB and lastly returns to AAA selling CCC, capturing a small profit. The chance of profit is maximized by utilizing margin from brokers and trading with higher amounts.

- For example take exchange rates EUR/USD = 0.6522, EUR/GBP = 1.3127 and USD/GBP = 2.0129. With $500,000 one can buy 326100 Euros, using that he can buy 248419.29 Pounds. He can now sell the pounds for $500043.19. Thus he can earn a profit of $43.19.
Long/Short equity (StatArb)

• AKA “pairs trading”
• Buy one and sell short the other
• Can trade more than 2 instruments
• Mostly known for equities
  – Similar companies prices move together
  – Difference moves mean reverting
• Suitable to correlated instruments:
  (crude/heating oil      corn/wheat)
• Moves liquidity from one asset to another
Statistical Arbitrage

Stock 1
Stock 2
Time
Price

sell
buy

or or
Mean reversion

• Price moves around the mean
• One instrument or spread between the two
• If the price deviates from the mean too much take the reverse direction position
• Similar to contra-trend type trading
Cullen/frost Bankers vs. Commerce Bancshares Inc

- price diff
- 252d average
Index arbitrage

• Stock index is composed of weighted stocks
• Some stocks lead, some lag the index
• If you can identify the lagger you can buy the stock and short the index
• Or you can short the leader and buy the index
Index arbitrage: illustration

Price

Time

Leader

INDEX

Lagger

sell

buy

buy

sell
Volatility arbitrage

• All comes to the fact that one can predict future volatility more accurately than others
• Usually one trades an option and its underlier
• Profit comes from the difference of implied volatility and realised volatility
• Usually one has immunity to market movements
Market makers

• A.k.a. specialists
• Always quotes bid and offer
• Supplying liquidity to the market
• Gets some advantages for their work
• Generates profit from small market moves
• Moves liquidity from one time to another
Market makers

- Investor 1 wants to sell - MM buys from investor
- Investor 2 wants to buy - MM sells to investor

Ask

Bid

Price

Time

buy

sell

liquidity

bid/ask

spread
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Market maker
High frequency trading / scalping

- Similar to market makers but no obligation always stay in the market
- Position last sometimes only several sec/ms
- Profit per trade very small & volume is huge
- Sometimes profit is just liquidity rebate
- Very valuable as has low risk
- Problem - limited capacity
- Very crowded now - profits are shrinking
"Boston Shuffle". 1250 quotes in 2 seconds, cycling the ask price up 1 penny a quote for a 1.0 rise, then back down again in a single quote (and drop the bid size at that time for a few cycles).
BATS BZX Exchange Fee Schedule
Effective February 11, 2013

The following is the Schedule of Fees (pursuant to Rule 15.1(a) and (c)) for BATS Exchange, Inc. (“BZX Exchange” or “BZX”). The Schedule of Fees is divided into Equities Pricing, Options Pricing and Physical Connection Charges.

**Equities Pricing:**

All references to “per share” mean “per share executed.”

**Fees for Accessing Liquidity for All Securities Priced $1.00 or Above**

$0.0029 charge per share that removes liquidity from the BZX Exchange order book

**Liquidity Rebates for All Securities Priced $1.00 or Above**

$0.0029 rebate per share for adding displayed liquidity for Members who have an ADV\(^1\) equal to or greater than 1.0% of average TCV\(^2\)

$0.0027 rebate per share for adding displayed liquidity for Members who have an ADV equal to or greater than 0.5% but less than 1.0% of average TCV

$0.0025 rebate per share for adding displayed liquidity to the BZX Exchange order book for all other Members

$0.0002 additional rebate per share for adding displayed liquidity to the BZX Exchange order book on an order that sets the NBBO for Members who have an ADV equal to or greater than 0.5% of TCV

$0.0017 rebate per share that adds non-displayed\(^3\) (hidden) liquidity to the BZX Exchange order book

No liquidity rebate for non-displayed\(^3\) (hidden) orders or orders subject to price slippage that add liquidity to the BZX Exchange order book and receive price improvement when executed
Simple HFT logic in easylanguage

- input: e(0), x(0);
- var: tick(minmove/pricescale);
- if marketposition = 0 then buy next bar close - e*tick limit;
- if marketposition = 1 then sell next bar close + x*tick limit;
Trend following /momentum

• Classic technical analysis example
• Buy if prices are rising
• Sell short if prices are falling
• The idea is the anticipation that trend will continue for a while
• The art is to detect the beginning of a trend as early as possible
Trend following

![Trend Following Graph](image)

- **Buy** at peaks
- **Sell** at troughs

- **Price** axis
- **Time** axis
Two clear Buy Signals are shown on this chart of The Gap (GPS-NYSE) with RED ARROWS
Counter-trend / Contra-trend

• Classic technical analysis example
• The idea behind is that market moves in waves or in a channel
• A trading system must identify top of the wave/channel and take opposite position
• Close after market goes back to trend
Counter-trend

Time

Price

sell

buy

sell

sell

buy

buy

buy
Trend following and counter-trend can work at the same time

- Both can work but on different time frames
- For example:
  - Counter-trend on the daily basis
  - Trend following on 3 month basis
Channel breakout

• A type of mean reversion
• Most famous example is Bollinger bands
• Around the price one draws a channel where prise sits most of the time
• If price brakes out of the channel:
  – Take the trade in the same direction
  – Or take the trade in opposite direction
Bollinger
Bollinger

Support and Resistance at the Upper and Lower Bollinger bands
News trading

• Thomson Reuters, Dow Jones, and Bloomberg provide news feed (some claim low latency)
• Algorithm can analyse text, content, keywords stocks tickers and then buy or sell
• Sources: Facebook, Twitter, Google, ...
• Voice recognition from TV announcements
• Speed matters a lot here ...
Sesonality

• End of Year effect
• Harvesting effect
• Heating oil and heating season effect
• Political seasonality: 4 year US presidential election
• Other seasonality
  – During the day
  – During the month
• End of tax year effect
Corn – yearly average
volume by business day in the year (in 9604 stocks)

\[ \times 10^5 \]

- **actual**
- **21d average**

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</table>

```
x 10^5

volume by business day in the year (in 9604 stocks)

- **actual**
- **21d average**

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Fundamental analysis

• Company accounts report analysis
• Country economy analysis
• Typical/classic investment type

• If fundamental data is available then process can be automated
• Reuters and Bloomberg and others provide fundamental numbers
• **1. Discounted Cash Flow (DCF):** While the concept behind discounted cash flow analysis is simple, its practical application can be a different matter. The premise of the discounted cash flow method is that the current value of a company is simply the present value of its future cash flows that are attributable to shareholders. Its calculation is as follows:

   If we know that a company will generate $50 per share in cash flow for shareholders every year into the future; we can calculate what this type of cash flow is worth today. This value is then compared to the current value of the company to determine whether the company is a good investment, based on it being undervalued or overvalued.

• **2. Ratio Analysis:** Financial ratios are mathematical calculations using figures mainly from the financial statements, and they are used to gain an idea of a company’s valuation and financial performance. Each valuation ratio uses different measures in its calculations. For example, price-to-book compares the price per share to the company’s book value.

   The calculations produced by the valuation ratios are used to gain some understanding of the company’s value. Valuation ratios are also compared to the historical values of the ratio for the company, along with comparisons to competitors and the overall market itself.

• **3. Price-Earning Ratio (P/E Ratio):** A valuation ratio of a company’s current share price compared to its per-share earnings. Calculated as:

   In general, a high P/E suggests that investors are expecting higher earnings growth in the future compared to companies with a lower P/E. It’s usually more useful to compare the P/E ratios of one company to other companies in the same industry, to the market in general or against the company’s own historical P/E.

   The P/E is sometimes referred to as the “multiple”, because it shows how much investors are willing to pay per dollar of earnings. If a company were currently trading at a multiple (P/E) of 20, the interpretation is that an investor is willing to pay $20 for $1 of current earnings.
Other Quant Application Areas

• Another **Big** area is **Pricing**
• Used mostly by major investment banks
• Quant construct models to price options and other derivative instruments
• Must do it right: credit default swaps, collateralized debt obligations and synthetic CDOs played major role in 2007-2008 crisis
Trading strategy optimization

• Optimization is very important process in automated trading
• a.k.a. calibration, tuning
• For example: what periods of 2MA to use to maximize the profit?
• One needs to check different combinations to find the best ones
• Brute force and Genetic are most popular
• Simulated annealing and other heuristics
2 Moving average heatmap
In sample / Out of Sample

• The same as in pattern recognition
• Optimise your model on one set (older)
• Test performance on new/unseen data
• Results in out of sample are worse
• Optimization process is important
• The best result in sample is not the best in out of sample (aka past performance is not necessarily indicative of future results)
Typical Trap

![Graph showing in-sample and out-of-sample profit over time from 2004 to 2012. The graph indicates a significant increase in profit, particularly after 2008.](image-url)
Diversification

- r1, sharpe=1.6, dd=11
- r2, sharpe=1.6, dd=10
- r3, sharpe=1.6, dd=9.2
- r4, sharpe=1.6, dd=9.1

- r1 + r2 + r3 + r4, sharpe=3.2537, dd=3.1
Algorithmic trading funds

- Altegris 40 Index
  - [http://www.managedfutures.com](http://www.managedfutures.com)
Algorithmic trading funds

• Barclay Systematic Traders Index
  – [http://www.barclayhedge.com](http://www.barclayhedge.com)
Literature

- Trading and Exchanges: Market Microstructure for Practitioners by Larry Harris
- Inside the Black Box: The Simple Truth About Quantitative Trading by Rishi K Narang
- Options, Futures & Other Derivatives by JOHN C HULL
- Algorithmic Trading: Winning Strategies and Their Rationale by Ernie Chan, 2013
Thank You
Additional Slides
Metatrader
```c
#include <Expert\Signal\SignalMA.mqh>
#include <Expert\Trailing\TrailingParabolicSAR.mqh>
#include <Expert\Money\MoneyNone.mqh>

//--- inputs for expert
input string Inp_Expert_Title ="ExpertMAPS";
int Expert_MagicNumber =14598;
bool Expert_EveryTick =false;

//--- inputs for signal
input int Inp_Signal_MA_Period =12;
input int Inp_Signal_MA_Shift =6;
input ENUM_MA_METHOD Inp_Signal_MA_Method =MODE_SMA;
input ENUM_APPLIED_PRICE Inp_Signal_MA_Applied =PRICE_CLOSE;

//--- inputs for trailing
input double Inp_Trailing_ParabolicSAR_Step =0.02;
input double Inp_Trailing_ParabolicSAR_Maximum=0.2;

// Global expert object
CExpert ExtExpert;

// Initialization function of the expert
int OnInit()
{
    //--- Initializing expert
    if(!ExtExpert.Init(Symbol(),Period(),Expert_EveryTick,Expert_MagicN
```
inputs:
DayOrGTF( 1 ), { pass in 1 for day order, 2 for good-till-filled }
RangeHi( 105 ),
RangeLo( 95 ),
Quantity( 1000 ),
EffectiveBarDate_YYMDD( 030102 ), { pass in date of bar at which orders should become effective }
EffectiveBarTime_HHMM( 1300 ); { for intraday chart, pass in time of bar at which orders should become effective, 24 hr format; for daily chart, time is ignored, can pass in 0 }

variables:
EffectiveBarDate( iff( EffectiveBarDate_YYMDD < 500000, EffectiveBarDate_YYMDD + 1000000, EffectiveBarDate_YYMDD ) ),
ValidDay1Bar( false ),
ValidLaterBar( false ),
ValidBar( false ),
OneEntryDone( false );

ValidDay1Bar = Date next bar = EffectiveBarDate and ( BarType = 2 or ( BarType = 1 and Time next bar >= EffectiveBarTime_HHMM ) );
ValidLaterBar = Date next bar > EffectiveBarDate ;

if DayOrGTF = 1 then
  ValidBar = ValidDay1Bar
else
  ValidBar = ValidDay1Bar or ValidLaterBar ;

if ValidBar then
  begin
    if OneEntryDone = false
    and ValidBar[1]
    and ( High >= RangeHi or Low <= RangeLo )
    then
      OneEntryDone = true ;

    if OneEntryDone = false then
Deltix
Other vendos

- QuantHouse
- OpenQuant
- Ninja Trader
- Multicharts
- ...

75
Ultra Fast Databases

• Fast data need to be processed fast
• In memory databases are wildly used

• CSQL - [http://www.csqldb.com/](http://www.csqldb.com/)
• SQLite – can work in memory `rc = sqlite3_open(":memory:", &db);`

• Some commercial
  – TimesTen – ORACLE
  – kdb+ KX systems
    • Non SQL
    • Uses its own Q query language
  – TimeScape - Xenomorph

• Many more
Aistis Raudys

- Msc in Computer Science
- PhD in Neural Networks
- Work experience in finance
- Now practitioner
- Now academic at Vilnius University, Lithuania
  - Lectures
  - Research
S&P MidCap 400
What can be automated

• Can one program it?
• Possible if
  – Structural data is available
  – Decision is clear

• Qualitative vs. Quantitative
May 6, 2010
Flash Crash

• Sell of e-mini SP500 75000 contracts—4.1 billion USD
• Drives prices down
• Arbitrages moved stock prices down
• Market makers scared switched off systems
• Liquidity dried
• Avalanche effect
• Some stocks traded at 1 cent 😊 (PG)
• Prices returned to previous level
• All took several minutes
Flash Crash

VW&R highest selling rate occurs after the bottom and at a point when market is supposed to have zero liquidity.

VW&R sells fewest contracts during actual flash crash, which contradicts SEC report.