MARKET-BASED SYSTEMS

University of St Andrews
Department of Computer Science
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Lecture 3

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The Contents

NB This is a 3-hour partial tutorial overview of Market-Based Systems ... in three 60min chunks

- partial as in incomplete: we can’t cover everything in three hours
- partial as in biased: this is my version of the story...

• Lecture 1: Rationale and Background
  ----------------------------------------------
  Here we’ll find out why computer scientists should care about market-based systems, review some notable applications, and also cover some of the background economics. They call economics "the dismal science" for a reason, so that background economics stuff won't delay us too long...

• Lecture 2: Artificial Trading Agents for Fun and Profit
  --------------------------------------------------
  This lecture tells the story of some of the best-known algorithms used for autonomous "trader-robots", and how they were found to consistently beat human traders.

• Lecture 3: What's hot, what's not, and where next: Tales from the City
  ---------------------------------------------------------------------
  Looks at work on automatic optimization and design of trader-agents, and online market mechanisms, with particular reference to the current hot topics in the automated trading technology in the financial markets.
Recap of Lectures 1 & 2...

- Transition to utility-scale/"cloud" computing & service-oriented business models gives need for automated trading strategies/software
- Human traders do a lot, quickly
- More than zero intelligence is necessary
- Non-economists at HP and at IBM motivated to develop trader “robots”
- The Autonomous Agents academic research community start playing games

- 1997: ZIP open-sourced
- 2001: IBM do ZIP a very nice favour
- The financial markets start to take an interest

- But there was something that IBM didn’t know…
GA-optimization of ZIP traders

• Meanwhile at MIT & HP Labs…
  - Genetic Algorithms (GAs) to optimize ZIP-trader parameters to particular markets
    • First presented at CIFEr’98, New York, Mar’98; & ASCMA98, Minneapolis, May ‘98
  - if GA-tuned ZIP traders had been used by IBM, maybe ZIP would have dominated

• ZIP-trader marketplaces have 8 control parameters
  - initially set by educated guesswork

• Trivial to use a genetic algorithm (GA) to optimize the 8 parameters
  - genome: a single point in the eight-dimensional real hyperspace \( \mathbb{R}^8 \)
    • actually, points constrained to lie within the unit hypercube in 8-space
  - vanilla GA: with annealing mutation; population size 30; 500 generations
ZIP: quantitative margin adjustments

- ZIP algorithm is adaptive: adjusts margins up or down using simple machine learning rules

- Quote-price \( p_i(t) \) set by limit price \( \lambda_i \) and margin \( \mu_i(t) \): 
  \( p_i(t) = \lambda_i \cdot (1+\mu_i(t)) \)
  - Seller \( \mu_i(t) \) in \([0,\infty]\) for all \( t \); \( \mu_i(t) += \) raises margin; \( \mu_i(t) -= \) lowers margin
  - Buyer \( \mu_i(t) \) in \([-1,0]\) for all \( t \); \( \mu_i(t) -= \) raises margin; \( \mu_i(t) += \) lowers margin

- ZIP uses Widrow-Hoff learning rule to adjust actual output \( A \) wrt desired \( D \) using rate \( \beta \):
  \( A(t+1) = A(t) + \Delta(t) \); where \( \Delta(t) = \beta \cdot (D(t) - A(t)) \)
  - With momentum (damping) factor \( \gamma \) in \([0,1]\): 
    \( A(t+1) = \gamma \cdot A(t) + ( (1-\gamma) \cdot \Delta_i(t) ) \); \( 0 \leq \gamma \leq 1 \)

- So for ZIP we have:
  - \( \mu_i(t+1) = (p_i(t) + \Delta_i(t)) / \lambda_i - 1 \)
  - \( \Delta_i(t) = \beta_i \cdot (\tau_i(t) - p_i(t)) \); where target price \( \tau_i(t) = (A_i(t) + R_i(t) \cdot q(t)) \); \( A() \) & \( R() \) stochastic

- Giving:
  - \( \mu_i(t+1) = (p_i(t) + \Gamma_i(t)) / \lambda_i - 1 \); where \( \Gamma_i(0)=0 \) and \( \Gamma_i(t+1) = \gamma_i \cdot \Gamma_i(t) + ( (1-\gamma_i) \cdot \Delta_i(t) ) \)
The Genetic Algorithm: not a lot of code

See e.g.:

D. Goldberg
*Genetic Algorithms*
Addison-Wesley, 1986

M. Mitchell
*An Introduction to Genetic Algorithms*
MIT Press, 1998

```c
/*population size*/
POP_SIZE=30;
/*number of generations to evolve for*/
MAX_GENS=200;
/*create initial population at random*/
generate_random_population(Pop1[]);
/*evolve...*/
for(g=0;g<MAX_GENS;g++)
{
  /*evaluate fitness of each member of population*/
  for(i=0;i<POP_SIZE;i++)
  {
    evaluate_fitness(Pop1[i]);

    /*identify the best member*/
    elite=find_fittest(Pop1[]);

    /*breed new population using tournament selection*/
    for(i=0;i<POP_SIZE;i++)
    {
      /*randomly pick 3 distinct possible parents*/
      parents[1]=irandpick1st(POP_SIZE);
      parents[2]=irandpick2nd(POP_SIZE,parents[1]);
      parents[3]=irandpick3rd(POP_SIZE,parents[1],parents[2]);
      /*sort them into order of fitness*/
      sort_fitness(parents[]);

      /*the two fittest parents "breed" to make a kid*/
      Pop2[i]=breed_new_kid(parents[1],parents[2]);
    
    /*preserve the elite*/
    Pop2[0]=Pop1[elite];

    /*new population replaces old population*/
    Pop1[] = Pop2[];
  }
}
```
GA optimizing from “easy” genomes

- Initial population genomes seeded with original parameter values as used in the initial ZIP trader studies. 200 generations; population size = 30.

Slight improvement: shows that the GA can improve on the parameter values used by the inventor of the ZIP algorithm.
GA optimizing from “zero” genomes

- Initial population genomes all seeded with positively unhelpful \((0,0,0,0,0,0,0,0)\) values
- 200 generations; populationsize=30

Definite improvement: shows that the GA can improve even when commenced inconveniently with traders that (initially) have no adaptation or memory.
GA optimizing from “hard” genomes

- Initial population genomes all seeded with absolutely ridiculous parameter values: each value deliberately way too high or way too low. 200 gens; population size = 30.

Definite improvement: shows that the GA can improve even when initiated from trader genomes with maliciously/idiotsically poorly-chosen parameter values.
If the computer twiddles the knobs...

...why limit the number of knobs?

- ZIP60, and ZIP100, both have too many parameters for a human to set by hand without dying of boredom.

- But a small cluster of PCs can happily spend a couple of days/weeks finding the right settings for the 60 or 100 knobs.

- And, on a decent-sized HPC facility, you get the twiddling done in a few minutes.

- “Real-world” trading algorithms are now routinely being developed and deployed that assume the availability of adaptation, learning, and/or optimization.

- But if all the traders (or just the majority of traders) in the marketplace are robots, why use a human-compatible marketplace?
Now evolve the auction mechanism too

• If you’re going to use trading agents instead of humans, then why use market mechanisms designed by humans for humans?

• Use GA to search a space of possible auction types

• GA simultaneously co-adapts ZIP trader parameters, as before

• Fitness measure: minimize root mean square deviation of transaction prices from equilibrium price
  - (front-weighted average of Smith’s $\alpha$, as before)

• Problem: how to encode for a range of auction styles?

A continuum of auction mechanisms

• Let $Q_s$ denote the probability that the next quote comes from a seller,
  - i.e. $Q_s$ denotes the probability that the next quote is an offer/ask
  - NB probability of a quote coming from a buyer $Q_b = 1.0 - Q_s$

• In the English Auction, $Q_s = 0.0$

• In the Dutch Auction, $Q_s = 1.0$

• In a CDA a quote is equi-probable from either the seller-side or the buyer-side, so $Q_s = 0.5$

• What if we interpret these 3 human-designed mechanisms (0.0, 0.5, & 1.0) as points on a $Q_s$ continuum?
  - e.g. how about auction based on $Q_s = 0.1$?

Nonstandard values of $Q_s$ are easily implementable in online e-marketplaces
Doing it for real: really not a lot of code.

Real $q_s = 0.1$;

$r = \text{uniform\_random\_real}(0.0, 1.0)$;

if ($r < q_s$)
  { get\_next\_quote(sellers); }  
else
  { get\_next\_quote(buyers); }
Doing it for real: manually, with humans

• Spin-the-wheel…
Effects of shock-changes to schedules

• Maybe the fact that a single unchanging schedule is used for the duration of each experiment is too simplistic?
  
  - The ZIP traders don’t have to deal with any changes in supply/demand
  - Over-fitting?

• Using same experiment set-up, see what $Q_s$ evolves when, partway through each evaluation, there is a sudden “shock” change in the supply and demand schedules

Lots of results…

• data in orange is significantly different from CDA $Q_s=0.5$
  (Wilcoxon-Mann-Whitney@1%)

• The non-CDA auctions are all better than CDA


• Hypothesis: there are exploitable regularities in most markets, most of the time.
That was just the start

- Replications and extensions by postgraduate students…
  - Zengchang Qin (Bristol, 2002) replicated & extended to pure English/Dutch auctions
  - Vibhu Walia (Birmingham, 2002) demonstrated evolution of hybrid auctions in ZI-C traders
  - Neil Robinson (Sussex, 2002) evolved hybrid auction mechanisms for MBC of UDC
  - David Shipp (Leeds, 2004) explored longer sequences of supply/demand shocks
  - Dan Wichett (Birmingham, 2004) explored co-adaptive dynamics of heterogeneous gene-pools

- Andrew Byde (HP) demonstrated GA-evolution of optimally hybrid n\textsuperscript{th}-price sealed-bid auctions, \textit{regardless} of intelligence of traders

- Dave Cliff (HP) developed new 60-parameter super-variant of ZIP traders
  - 60-dimensional hyperspace better than the original 8-parameter version
  - evolutionary control of dimensionality demonstrated to be beneficial

Quantum foot in the door

ALL around us are tiny doors that lead to the rest of the Universe. Predicted by Einstein’s equations, these quantum wormholes offer a faster-than-light short cut to the rest of the cosmos—at least in principle. New physicists believe they could open these doors wide enough to allow someone to travel through. Quantum wormholes are thought to be much smaller than even protons and electrons, and until now no one has modelled what happens when something passes through one. So Sean Hayward at Ewha Womans University in Korea and Il-woo Shin at the Kias Institute of Physical and Chemical Research in Japan decided to do the sums.

They have found that any matter travelling through adds positive energy to the wormhole. That unexpectedly collapses it into a black hole, a supermassive region with a gravitational pull so strong not even light can escape. But there’s a way to stop any would-be traveller being crushed into oblivion. And it lies with a strange energy field nicknamed “ghost radiation”, predicted by quantum theory. Ghost radiation is a negative energy field that damps normal positive energy. Similar effects have been shown experimentally to exist. Ghost radiation could therefore be used to offset the positive energy of the travelling matter, the researchers have found. Add just the right amount and it should be possible to prevent the wormhole collapsing—lots more and the wormhole could be widened just enough for someone to pass through. It would be a delicate operation, however. Add too much negative energy, the scientists discover, and the wormhole will briefly expand into a new universe that expands at the speed of light, much as astrophysicists say ours did immediately after the big bang.

For now, such space travel remains in the realm of thought experiments. The CERN Large Hadron Collider in Switzerland is expected to generate one mini-black hole per second, a potential source of wormholes through which physicists could try to send quantumised particles. But sending a person would be another thing. To keep the wormhole open wide enough would take a negative field equivalent to the energy of a mass of Jupiter.

Charles Gla
note: www.uns.sic/t/c/0351at

Duncan Grant-White

Market maker

Earn megabucks from natural selection

A STOCK market that’s not only run by computers but designed by them too would generate hundreds of billions of dollars’ worth of extra profit for their human controllers. So says artificial intelligence expert David Cliff, who applied the principles of evolution to allow his software to develop the ideal marketplace.

Cliff’s software created a super-auctioneer that understands buying and selling in a new type of stock market, where the traders are all software-based agents. The idea could even introduce an ethical dimension to trading. Cliff found that in his marketplace, even people paid inflated prices and everyone was able to maximise profits.

Last year, New Scientist reported on research from IBM which showed that software agents trading commodities such as precious metals or coffee beans outperformed their human counterparts, earning on average 7 per cent more (11 August 2001, p 21). One of the software agents used in that experiment was developed by Cliff, who works at Hewlett-Packard’s research lab in Bristol.

But Cliff found it odd that these software agents were being shoehorned into computer models of marketplaces designed by people for people. So he set about designing a marketplace that is better suited to artificial buying and selling agents.

To do this, he designed a range of possible market models using software incorporating a genetic algorithm, a type of program inspired by evolution. The GA uses a process similar to natural selection to “evolve” continually until it reaches the best solution to a problem.
The Economist  Nov 30\textsuperscript{th}, 2002

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The future’s still not clear

French national champion, by pushing Credit Lyonnais into the arms of Credit Agricole. But when Credit Agricole refused to pay €44 per share (that, the lowest price he was prepared to accept, he lost patience; now Paribas, the auction’s winner, sold €2.1 billion, or €354 a share, for the stake, a 40% premium over the market value and a quarter more than the next highest bid. Advisers to Mr Mera joked that now Paribas’s bid document must have contained a typing error.

The losers from the sudden sale are Credit Agricole and Credit Lyonnais’s chief executive, Jean Peyrelevade. Having refused to pay €44 a share in a private deal, Credit Agricole reportedly offered that amount in the public auction, only to lose. Part of the problem is that Credit Agricole’s decentralized, mutual structure makes it difficult for it “to advise” the countrywide to agree on anything quickly.

Mr Peyrelevade, who wants to keep his bank independent, has so far maintained what one French banker calls a Soviet balance of power between the bank’s biggest shareholders. As soon as one loses the majority, he courts another: This time though, he miscalculated, saying out his negotiations with Credit Agricole to a point where Mr Mera stopped believing that the two banks had any real desire to merge.

Mr Peyrelevade now faces the likelihood that now Paribas or, more likely, Societe Generale, will buy for the whole of Credit Lyonnais once a shareholder pact designed to protect the bank from takeover ends at the end of June 2003. Either bank would hold Credit Lyonnais’s wholesale banking business into its own operations. To avoid that, Mr Peyrelevade may have to run back to Credit Agricole, which has already owned 10.5%, with more conciliatory words than those of recent months.

For now, now Paribas denies that it intends to buy the whole Credit Lyonnais. But Michel Pehnaim, its chairman, is unlikely to have paid such a high price for a stake unless he has designs on the whole.

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Robo-traders

Computerised trading agents may help humans build better markets

Thanks to shunting machines, investment banks are shedding many of their highly-paid traders. When markets recover, the banks might be tempted to replace them with cheaper talent. One alternative has been around for a while but has yet to catch on: autonomous trading agents—computers programmed to act like the human version without such trade breaks as holidays, sick leave or bonuses. Program trading has, of course, been going on for some time now on the stockmarket and online, as the market makers use computer simulations for price-making and not for trading. But what to call such multi-ethnic hybrids? Here’s introducing the “Cheetahs”.

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St Andrews: Market-Based Systems — Copyright © 2007, Dave Cliff
“Algorithmic Trading has the potential to replace human traders completely, according to one of the scientists who pioneered the use of advanced trading systems in the financial markets. Speaking at last week’s Financial News Trading for Investors conference in London, David Cliff, head of complex adaptive systems research at Hewlett-Packard, said: “I don’t see why everything a trader does can’t be done by a machine. I don’t want to say when it will happen as the technology is not there yet.”

http://www.efinancialnews.com/
“Traders under threat from rise of machines’, screamed a recent headline in the Financial News. It seems a professor of complex adaptive systems who dresses like the bad guy in a Bond movie has been talking about traders being an unnecessary cost who can be replaced by algorithms.”

Richard Balarkas,
Global Head of AES Sales,
Credit Suisse

http://www.thetrade.ltd.uk/cissue_realitycheck.htm
HP Labs & London Stock Exchange

- Alas, NDAs mean I can say very little about this project
- I can tell you that I led the HP side of it from the outset

Five years ago it was abundantly clear that:
- The current wave of M&A activity in the exchange-operator space was coming soon
- Algorithmic Trading & Automated Execution increasing very rapidly
- New technology (e.g. Net/Web/DMA/STP) lowering barriers to entry for disruptive technologies, and for disruptive new companies

- Technology innovations could give LSE an edge

- HP Labs team worked with LSE’s nascent R&D unit
- HP: global revenues of $80bn p.a.; $4bn R&D spend; $200m of that on HPLabs; HP established in 1939 – centralised innovation established at HP Labs in 1966
- LSE: a UK-based SME; significant revenue slice from data provisioning; enjoys accidental privilege of national monopoly status; R&D unit a recent addition in its 200yr history.
And then I became a banker…

• Joined Deutsche Bank London FX Complex Risk Group
  - Wondered when I would be shown the secret technology

• Started out on a tour around the trading floor on “rotation”, learning what everyone did and how it fitted together: Spot & Derivs; Prop & Client; Trading & Sales

• Coming in as a techie, with expertise in Computer Science & AI, thought I would be able to help out a lot of folk by coming up with whizzy innovative solutions to their problems, but…
  • Dissatisfaction/distrust of technology was much higher than I expected
  • A lot of the solutions needed did not need a PhD to solve
  • A lot of the solutions needed did not actually need any technology innovation

- My impression is that the above three points are true:
  • At many investment banks, not just Deutsche
  • And in many asset classes, not just FX
Algorithmic Trading in Foreign Exchange

• FX is interestingly different from equities
  - No single central exchange pumping out price/vol data; still a lot of OTC
  - Massively liquid: $1,900bn/day, 24*7
  - Regulatory structure is pleasantly relaxed (verging on the non-existent)
  - Approx 2-3 years or more behind equities wrt uptake of algorithmics
  - Oh, and there’s not much in the way of historical data. Really there isn’t.

• Deutsche Bank London FX Trading Floor
  - biggest & best in Europe
  - 70% of DB London FX spot trades go through a single robot (>>£1bn/day)
  - aggressively developing more advanced technologies

  - My main job was to help improve the robot for high-frequency trading
What I did at DB (1): Price Discovery

- EBS screen (pre-ICAP)
- The whole curve

- “Laddered” prices

![EBS screen](image)

![Price curve](image)
Really Reality: Reuters FX dealing

- Reuters D2000-2 spot USD/DEM supply and demand curves, derived from the raw internal order-book data (hidden by the GUI) – usually known only to Reuters.
- EBS must have this sort of data too, but their GUI hides it.
- At DB, I worked on ways to recover the hidden curves from what EBS does show.

4pm: ~$80m on each side
6pm: ~$20m ask; ~$65m bid

cf Price “Ladders” showing a list of ~180 prices

What I did at DB (2): Execution Logic

• Pre-existing hand-coded “points” in strategy space

• Smooth interpolation between the points
  - generated stochastic “hybrid” strategies

• Not a million miles from what I had previously done on ZIP etc

• No pretty pictures, and no details here either 😊
What I did at DB (3): Visualisation

FIG. 4: (Color) The Min the correlations between the years 1993 and 1994.
FIG. 11: (Color) Currency tree (MST) for a 2 week period in June 2004.
FIG. 12: (Color) Currency tree (MST) for a 2 week period in July 2004.
Where next?

• All three of these areas still hold some interesting challenges

• Will come to some future research challenges in a bit

• But first: some observations on technology innovation…
Innovation at HP & DB: spot the differences

• Research & Development Process
  - HP: Well established processes & checkpoints; woven into the company’s DNA
    • Recruit skilled scientists and engineers; separate paths for managers & techies
    • Innovation workshops & training in creative/innovative thinking
    • Mapping of Intellectual Property “landscape” and of business sector “ecosystems”
    • Patent Strategy Review Panels staffed by senior technologists
    • Execution is an issue: mañana, mañana...
  - DB: Often ad-hoc, accidental, introspection-based, suck-it-and-see
    • Recruit immensely bright and quick-witted talent, from diverse educational backgrounds
    • Lack of formal innovation process(es) gives great speed and agility
    • Execution is almost immediate: Is it done yet? Is it working? How much has it made?

• Performance/Effectiveness Timescales & Measures
  - HP: 20-year patent lifetime; delay on feedback means intangibility is an issue
    • “10% success bankrolls the 90% of failures”; plus a specific success, squeezing ink onto paper
  - DB: 3-month P&L driven; conservatism is favoured: better out than down
Innovation at HP & DB: why the differences?

• HP has, from its outset, been a technology company
  - Makes its money from excelling in particular technologies
  - The specific technology HP excels in has changed from decade to decade over 60yrs
  - Hewlett invented HP’s first patent; the patent made the money; that set the trend
  - HP employment contract lays claim to all IP of its employees, now and forevermore

• Corporate/Investment Banks have traditionally not been technology companies
  - Successful CIBs excel in customer relationship management
  - Successful CIBs excel in innovation too, but not necessarily innovating technology
    • An innovation might be a new financial product; a new business model
  - My DB contract non-compete clauses, stated that on departure:
    • No stealing DB’s customers
    • No poaching DB’s staff
    • Er, that’s it

• But technology is now inter-woven and on the critical path for all CIBs
  - CIBs are fast becoming technology companies, partially at least
  - even if they don’t realise it yet
Banks lay traps for copycats

The starting pistol has been fired on the race to register financial patents, write Saskia Scholtes and Gillian Tett

W anes features are emerging in the market for intellectual property rights. The race is on to secure patents for financial services, says Piers Mitchell.

People haven't traditionally associated these types of products with intellectual property. What they pay the lawyers for is to ensure they are protected.

But now they're looking at the market for intellectual property rights. The race is on to secure patents for financial services.

Now they're looking at the market for intellectual property rights. The race is on to secure patents for financial services.

Banks have historically been highly secretive about their intellectual property, but are now more open about their methods.

The Economist

January 9th, 2007

Beware the ‘patent trolls’ of finance

The growth of proprietary trading in the financial services industry is creating a new breed of investors who are more interested in getting rich from the patents of others.

Competition: They're coming for the business models that are sometimes seen as the business of the future.

And, yes, the few financial services patents that are defended in the US are likely to be worth their weight in gold.

The Economist

January 9th, 2007
Don’t all rush at once

- Data from USPTO database of granted patents, June 2007, results of keyword searches:
  - “algorithmic trading”: 0
  - “trading algorithm”: 2
    - 6892186(HP), 5101353(Lattice); + 2 irrelevant
  - “implementation shortfall”: 1
    - 7110974(Lehman).
  - “volume weighted average price”: 6
    - 7228289(Trading Tech.), 7110974(Lehman), 6462758 (Reuters);
      6098051+6012046+5845266(Optimark).
  - “automated execution”+“financial”: 6
    - 7209896+7181424(Nasdaq), 7085739(Accenture),
      6112189+6098051+6012046(Optimark) + 19 irrelevant + 8 designs.
So why don’t CIBs have Laboratories?

• Just because big companies like HP (and IBM, and MSFT, and Xerox, etc) have centralised research & development labs, doesn’t mean that CIBs should too

• In fact, the idea of a central internal R&D Lab/function is starting to look distinctly last-century

• The new buzzwords on the Tech Innovation street:
  - Open Innovation
  - R&D replaced by A&D

• Attractively Darwinian

• R&D risk is borne by the investors in the start-ups
  - Not by the customers of the products

• Start-up exit strategy is acquisition by a gorilla
  - Not bubble-style IPO

A few examples from my time at Deutsche…
Overview

- FlexFX helps to minimize market impact, transaction costs, and risk exposure, with an array of tools for implementing intelligent trading strategies, including user-defined analytics for real-time, quantitative trading and order management. The system also operates as a real-time, risk management tool.

FX algorithmic trading

- FlexFX allows traders to create individual trading strategies with fully customizable analytics and visual alarms, coupled with integrated quantitative capabilities, smart routing, connectivity, and real-time data. FlexFX offers the most robust and flexible FX trading system in the marketplace today.
Codefarm Automated Credit/CDO Structuring
Complexity Science for real: www.eurobios.com
Oh, and Syritta Algorithmics too, one day…
The truth lies in the middle

• RoI for an industrial R&D Lab has time horizons way longer than are commonly acceptable in CIBs – that culture will not change in a hurry

• But the basic practice of an R&D Lab can be incorporated into a CIB community, whether cash or dreivs, trading or sales, or any cross-product too

• What I call the “P-I-P-E-R” loop: Predict – Invent – Protect – Exploit - Repeat
  - Anticipate/guess at likely future scenarios
  - Imagine the opportunities and problems in those scenarios
  - Plan to exploit the opportunities, and to avoid/ameliorate the problems
  - Protect the intellectual property/capital thereby generated
  - Exploit – get your RoI

• This takes practice/training, but it is way cheaper than setting up Central Labs
  - If you are practiced/trained, you can better evaluate the offerings of A&D innovators

• It’s this practice of technology innovation that students should get educated in
Some predictions for the next few years

• “Semantic web” machine-readable semantic tags on ticker news-feeds and real-time Natural Language Processing on time-based media (voice channels, video feeds) combine to allow algo trades to be triggered/modified by text/voice/video data.

• Algorithms structuring & executing cross-asset trades on basis of searching vast databases for high-order nonlinear correlations will become the de facto norm.

• “Arms-race” co-adaptive dynamics in algorithm sophistication continues to drive up complexity of algorithms; so hand-design gives way to machine-design & optimization.

• Barriers to entry continue to lower: plug-and-play piping & interfaces & algos & services.

• Speed & Latency:
  - Co-location “proximity servers” give way to direct hosting on exchange servers.
  - Algorithms move into silicon (FPGA, ASIC, etc) for nanosecond execution.
  - Exchange API via a motherboard/backplane (…leading to stochastic polling?)

• Trader Interfaces: “ungameability” (impact-reducing obfuscation) is a hot topic.
  - More sophistication needed to for X-asset “battlefield command” “head-up display”
When you have HPC/Grid/Utility capacity…

You can do this…

…and then wrap a GA around it?
Trader HUD/UUI

- Human traders will be around for several more years
- But the job could get **much** more complex
- The trader’s human-computer interface is an area **ripe** for productive innovation
  - numeric tickers & spreadsheets not enough
- Lots of numeric data can instead be combined into dynamic graphic displays
  - with audio warnings
  - maybe with haptic input/feedback
- It’s easy to get this sort of stuff very wrong
- Combat aircraft could hold some clues…
Trader HUD/UUI

![HUD/UUI Interface](image1)

![C/D Improvement Candidate Example](image2)
Good interfaces support good people…

…they don’t replace them

(video from www.zawodny.com/blog/archives/006426.html)
Where have all the traders gone?

Time is running out for Wall Street's high rollers. A new breed of traders is muscling in, says Robert Matthews

BRAD BAILEY was visiting the trading floor of an investment bank in New York City when he first noticed it. As a former Wall Street trader, he should have felt at home amid all the screens, phones and bundles of billions of dollars in trades. But that was just it: there wasn’t any battle. In fact, there were hardly any traders. "You could hear a pin drop," he recalls. Then he saw: machines had taken over the role of people and computer servers don’t make any noise.

There’s a quiet revolution happening all over the financial world. Gone are the days of Gordon Gekko look-alikes screaming obscenities and dumping a lose-making stock onto an unsuspecting market. Investors have realised that the processing speed and sheer volume of trades a computer can make can help them to outbid the sharpest of dealers. As a result, they are investing heavily in what has fast become an arms race between investors. Their goal is to develop the best "algorithmic trading" systems - software that helps decide which trades are the most profitable, and then does the deals. Ten years ago, algo trading was almost non-existent, but according to a recent report by Bailey, now at the Boston-based consultancy from Aon Group, one-third of all trading decisions in US markets are now made by machines. He predicts that by 2010 more than half will be done this way. At Deutsche Bank in London, over 70 per cent of a category of foreign currency trades, called "spot trades", are now carried out without human intervention every day. All this will have an impact on more than just high-rolling investors. Even if you don’t own any shares you can bet that millions of those owned by your pension fund are already being bought and sold using "algo" trading techniques.

It’s not hard to see why algorithmic trading is so attractive. Machines can make multiple trades, monitor thousands of stocks and do it all at breakneck speed. Crucially, they can do it without anyone noticing. There are big profits to be made in buying and selling shares that other traders haven’t yet realised are being lucratively traded. The more discreetly you can do this - by spreading the deal over lots of small trades, for example - the less likely other traders are to wake up to the opportunity and dilute your profit potential. Such discretion is near impossible for a human, as it requires constant monitoring of the market to make sure your trades don’t alter stock prices in an undesirable direction.

As a result, investment houses are becoming increasingly tech-savvy. Every drop on traders today and you are more likely to hear talk of "low latency access" (which will get you to later than what they'd like to do at their own expense). "Anyone who's been on Wall Street since the early days will have had to reinvent themselves," says Bailey. Back then, success as a trader hinged on an instinct for what the market was "thinking", plus reactions fast enough to make the most of the opportunities the market presented. In the early years of computerised trading, when machines were simply communication tools, hitting a key a few tenths of a second faster than a competitor could make a real difference to your profit margins. Nowadays human traders struggle to keep up. "It’s taking over from carbon on Wall Street," says Bailey, as beige boxes proliferate across trading floors. Computers have the edge over humans in many ways. Take something as simple as reaction time. When a human trader sees a stock change price, he might react in a few hundred milliseconds. A computerised trader is at least ten times faster, depending on how much you are willing to fork out to speed things up. A few hundred milliseconds might seem insignificant, but if the price changes by a fraction of a per cent in the split-second before a trade worth many millions, it could mean a swing of tens of thousands of dollars.

The key for any trader is "low latency" market access - that is, minimal delay between placing an order and seeing it fulfilled.
Artificial intelligence, once the stuff of sci-fi fantasies, is closing in on Wall Street. A corps of scientists is trying to teach computers to think like traders—and outsmart human stock pickers.

By Jason Kelly

Way up in a New York skyscraper, inside the headquarters of Lehman Brothers Holdings Inc., Michael Kearns is trying to teach a computer to do something other machines can’t: think like a Wall Street trader.

In his cubicle overlooking the trading floor, Kearns, 44, consults with Lehman Brothers traders as Ph.D.s tap away at secret software. The programs they’re writing are designed to sift through billions of trades and spot subtle patterns in world markets.

Kearns, a computer scientist who has a doctorate from Harvard University, says the code is part of a dream he’s been chasing for more
My family and other algorithms

by Professor Dave Cliff, University of Bristol

In the summer of 1996, I invented a trading algorithm that outperforms human traders. The algorithm, known by the acronym "ZIP" (for zero-intelligence plus) is embarrassingly simple. Being very simple makes ZIP very fast, which, nowadays, with major players running their algorithmic trading operations on proximity-servers huddled as close as physically possible to the main servers on major exchanges, is a notable point in ZIP's favour. Another thing that makes ZIP attractive to many people is that you can use it for free (and I've been told that some major algo houses do exactly that!) Full details of the algorithm, including the "C" source-code, were published on the web in 1997 and have been available there ever since.

In the 10 years since it was invented, other algorithms have come along to challenge ZIP, but over the same period I've been involved in the development of various extended versions of the original ZIP - there is now a whole family of ZIP algorithms, and the original has been re-christened "ZIP2" (for reasons that will become clear later). This family of extended ZIPS demonstrates significant improvements in performance, with little or no increase in latency. The most recent of the ZIPS to be given away for free goes by the name of "ZIP3". I will come back to ZIP3 later.

ZIP – the basics

In 1996 I was working as a lecturer in computer science and artificial intelligence at the University of Sussex, and supplementing my meagre academic salary by day trading equity options on LIFFE, the main London futures exchange. The good folk at Hewlett-Packard labs in Bristol offered me a seven month stint working with them as a visiting academic, and told me that I could come up with my own research project for my stay there. In those days, trading at LIFFE was still based heavily on face-to-face open-outcry trading.

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Balarkas says human traders will still have plenty to keep them occupied, for the time being at least. “People who think computers are going to put them out of business really don’t understand traders,” he says.
End of the road for human traders?

- Human traders are just humans; humans are just animals
- Animals are the result of 4 billion years of trial-and-error evolution;
- For 99.9999% of those 4bn yrs
  - humans and their ancestors were **not** evolving to become traders
  - Rather, they were evolving to satisfy the **Four Fs**
- For last 2000/200/20 years humans have tried to adapt to trading in markets
- But we humans are **not** purpose-built to trade…
  …we’re limited in **speed** and in **bandwidth**; and trading just keeps getting harder/faster/higher-bandwidth
- ZIPs (and other “robot” traders) are **purpose-built to trade**; this gives them a distinct advantage
- No convincing argument **in principle** for why human traders could **never** be replaced by machine traders, **but** the technology isn’t quite there yet
If you won’t believe me, will you believe IBM?

“The trader is dead, long live the trader!”


• “Power will shift from the traders who have benefited from merely facilitating transactions, to the buyers & sellers who take positions on either end of the trade…”

• “Transparency and speed are driving firms to develop a true client orientation and optimize risk/return efficiency, and are pushing them to become specialist enterprises – a task that will require a conscientious approach to innovation and significant modification of their operating models.”
Balarkas says human traders will still have plenty to keep them occupied, for the time being at least. “People who think computers are going to put them out of business really don’t understand traders,” he says.

“Traders who think computers AREN’T going to hugely change their business really don’t understand technology”

People who are going to put them out of business really don’t understand technology
My day-job: www.lscits.org
Summary

• Market-based systems are worth knowing about.
• Know you know everything that I know.
Thanks

• Collaborators, Colleagues, Competitors
  • At HP: Andrew Byde, Janet Bruten, Steve Gjerstad, Chris Preist, John Cartlidge
  • At MIT: Rod Brooks, Jake Beale, Won-Suk Chun, and the FABLab UROPs
  • At London Stock Exch: David Birch, Howard Miller, Laura Pandit, Tom Stenhouse
  • At Deutsche Bank: Tony Hall, Gio Pilliteri, Rhomaios Ram, Phil Wood.
  • At Southampton: Nick Jennings, Krishnen Vytelingum
  • The IBM guys

• At St Andrews:
  • Ian Sommerville for the invite & hosting
  • You lot, for listening. 😊