Autonomous Agents in Financial Markets: Implications and Risks

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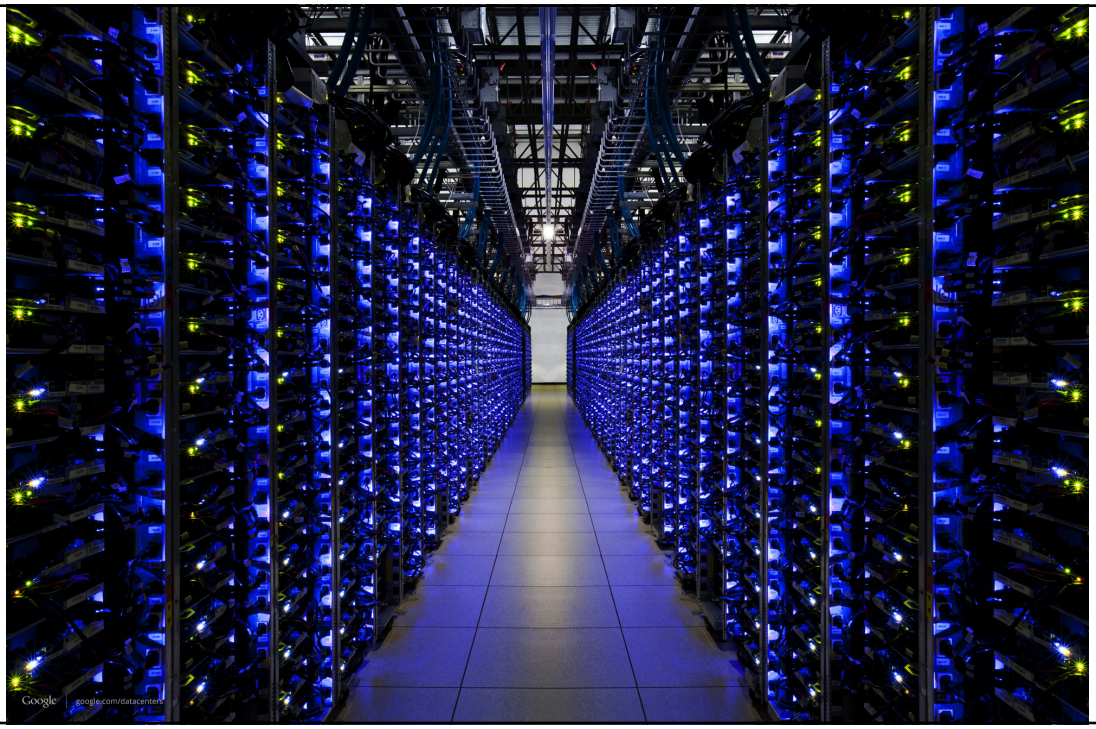
Colloquium on Robust and Beneficial AI
15 June 2016

Why Finance?

- Critical sector of economy
- Potentially fragile, driven by information (beliefs, expectations), complex interdependencies
- Already highly infiltrated by AI
  - Trading in financial markets
  - Credit decision making

Trader



Algorithmic Trading

- By any measure, accounts for major fraction of activity on financial markets
- How does it work?
  - Specific methods and practices highly secretive
  - General ingredients readily apparent
    - Fast computing and communication
    - Real-time data analysis, risk management
    - Clever strategies, detailed understanding of microstructure
    - AI & machine learning

What is Special about Algorithms?

1. Speed and Precision
   - Response far faster than human reaction times
   - Can implement complex strategies involving coordinated actions across many markets
   - Enables latency arbitrage, "anticipatory" strategies, novel manipulations
2. Autonomy
   - Applies programmed and learned models to potentially unanticipated circumstances
3. Scalability
   - Replicate methods across securities, exchanges… worldwide

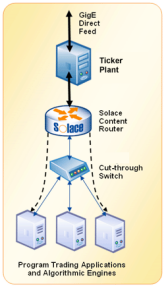
Latency Arms Race: Source of Instability?

Direct exchange feeds

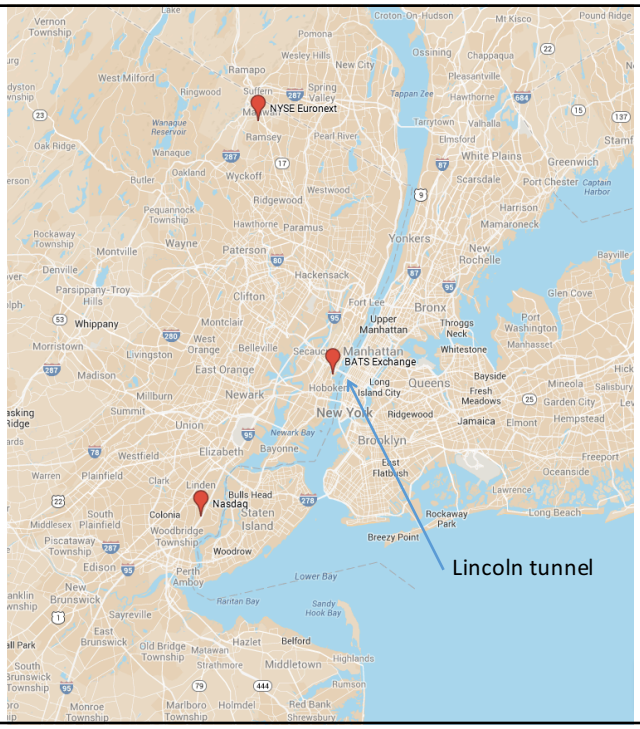
Dedicated communication lines

Co-location

Specialized hardware/software



- NYC trader splits order for multiple exchanges
- First order arrives at BATS exchange in Weehawken
- HFTs see order and race to Mahwah (NYSE) and Carteret (Nasdaq)
- ~200 µs



One-Second Call Markets

- Latency arms race an artifact of *continuous-time* market operation
  - no lower bound on a difference in speed that could matter
- Call market
  - Trade periodically rather than continuously
  - Orders received within interval hidden
  - Potential efficiency and stability advantages

Wellman blog entry July 2009

Countering High-Frequency Trading

Posted on | July 30, 2009 | 3 Comments

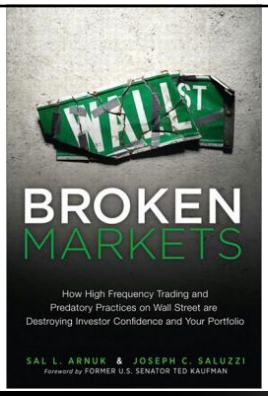
The recent NYT article by Charles Duhigg on high-frequency trading (HFT) has set off a flurry of argument about the benefits and threats of this activity to financial trading systems. The revelation that some systems provide advance information (exposing incoming orders 30-500 milliseconds before they are submitted to the general market) to select HFT systems has drawn particular fire. Some have suggested that rapidity of response capability per se could open up manipulation possibilities or is otherwise destabilizing. We have also seen questions about whether diverting trade surplus toward whomever builds the biggest fastest network is an efficient use of resources, and the implications for perceptions of fairness across the trading public.

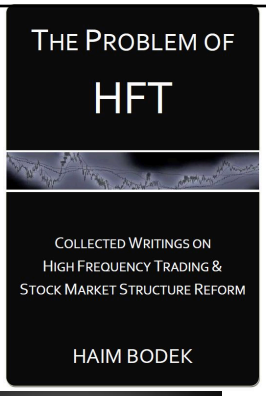
Let us start from the premise that asymmetry of information about incoming orders is inherently undesirable. Leveling the playing field in information promotes efficiency and lowers the cost of entry for the broader investing public.

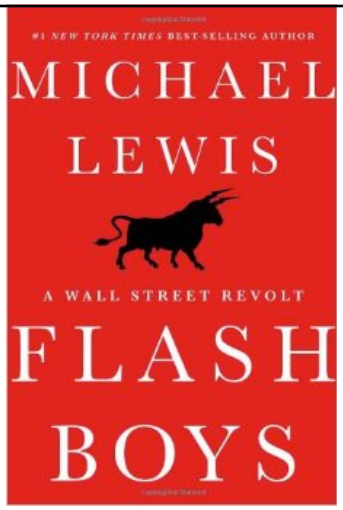
The root of the problem, in my view, is the system's support for *continuous-time trading*. In a continuous market, trades are executed instantaneously whenever there are matching orders, and introduction of an unmatched order likewise causes an instantaneous update to the information available to traders.

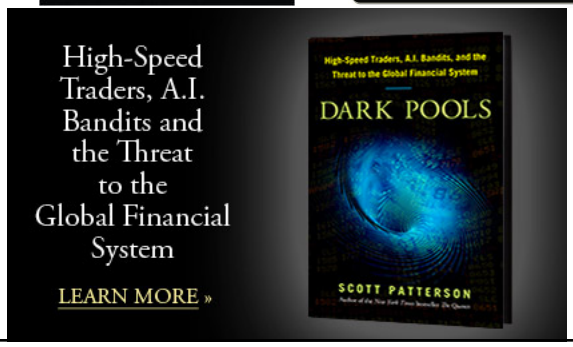
An alternative would be a *discrete-time market mechanism* (technically, a *call market*), where orders are received continuously but clear only at periodic intervals. The interval could be quite short–say, one second–or

Flash Crash: 6 May 2010



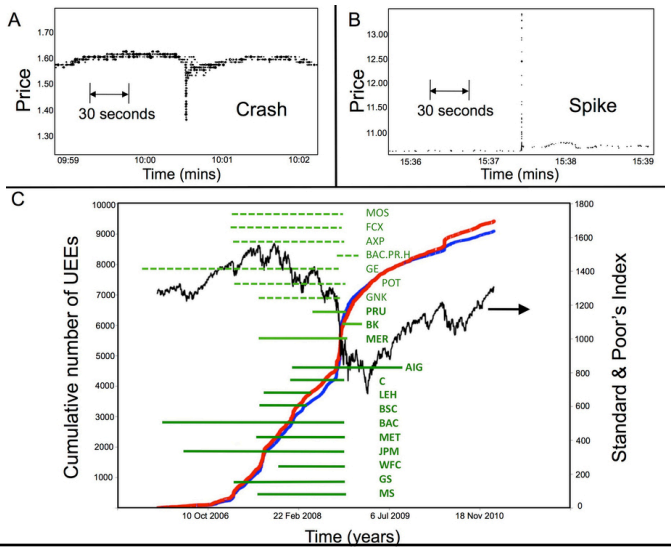






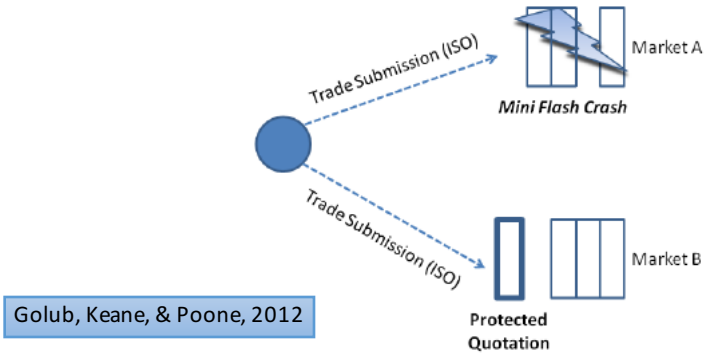
Ultrafast Extreme Events

- Johnson et al., "Abrupt rise of new machine ecology beyond human response time", *Scientific Reports* 2013
- Documented 18,520 UEEs in 5yr period
- Authors argue: *Must* be artifact of dynamic interacting agents



Alternate Explanation: ISOs

- Intermarket Sweep Order (ISO)
  - Special order type, allows override of NBBO-based routing



Golub, Keane, & Poone, 2012

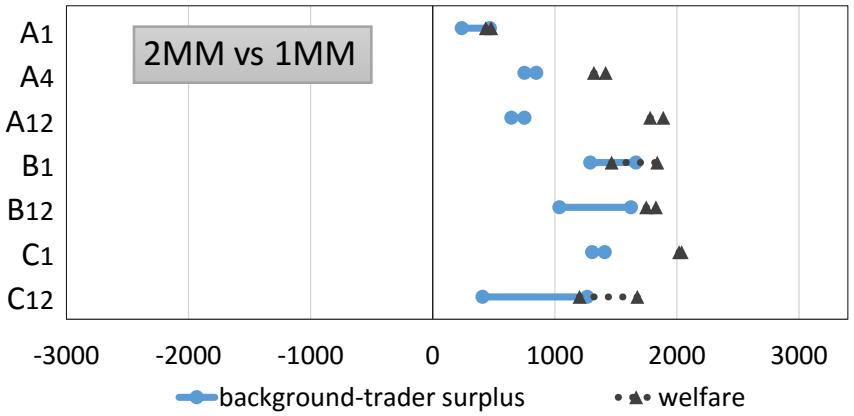
Strategic Agent-Based Analysis

- Model-based studies of effects of algorithmic trading
- Challenge: sensitive to specification of agent behavior
- Empirical game-theoretic analysis
  - Combines agent-based simulation with game-theoretic reasoning
  - Explore a space of heuristic strategies, using strategic stability for selection

<u>Studies</u>

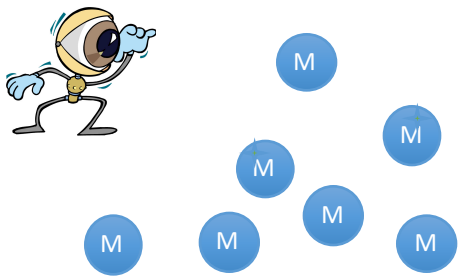
- Latency arbitrage (EC-13)
- Market making (AAMAS-15)
- Market choice by fast and slow traders (AMMA-15)
- Strategic shading (AGTw-16)
- Market manipulation (in progress)

Illustrative EGTA Results: Effects of MM Competition (N = 25)



ARB-BOT: A General Framework for AI Traders

- Arbitrage:
  - taking advantage of price differences across markets for the same asset
- Simple arbitrage agent:
  - monitor multiple markets for price discrepancies, then execute
  - Issues
    - Transaction costs
    - Transport/storage costs
    - Execution risk
    - What is meant by "same" asset?



ARB-BOT Early Warning System

- Develop public (non-trading) Arb-Bots as an alert to what the AIs might be finding
- Search approaches
  - Reasoning from security descriptions
  - Automated discovery by machine learning

Levels of ARB-BOT Behavior

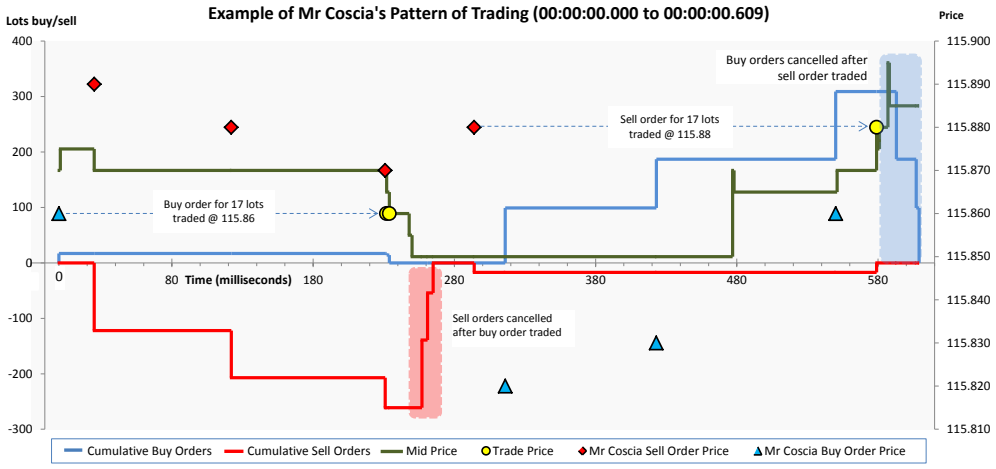
1. Passive search for arbitrage opportunities
2. Attempts to amplify arb opps through purposeful instigation of market movements (e.g., spoofing)
3. Attempts to create new arb opps
   - new financial instruments
   - deliberate fragmenting
4. Malicious subversion of markets

most aggressive

Level 2: Market Manipulation

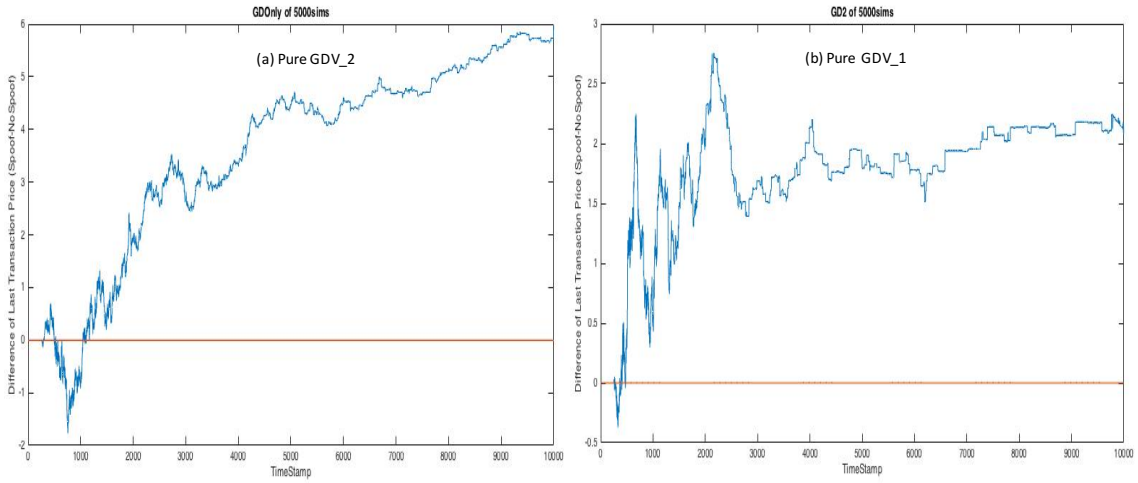
- SEC Definition: Intentional conduct designed to deceive investors by controlling or artificially affecting the market for a security
- Spoofing
  - Dodd-Frank defn: bidding or offering with the intent to cancel the bid or offer before execution
  - Widely known strategies, several recent prosecutions

Example: Dynamic Layering



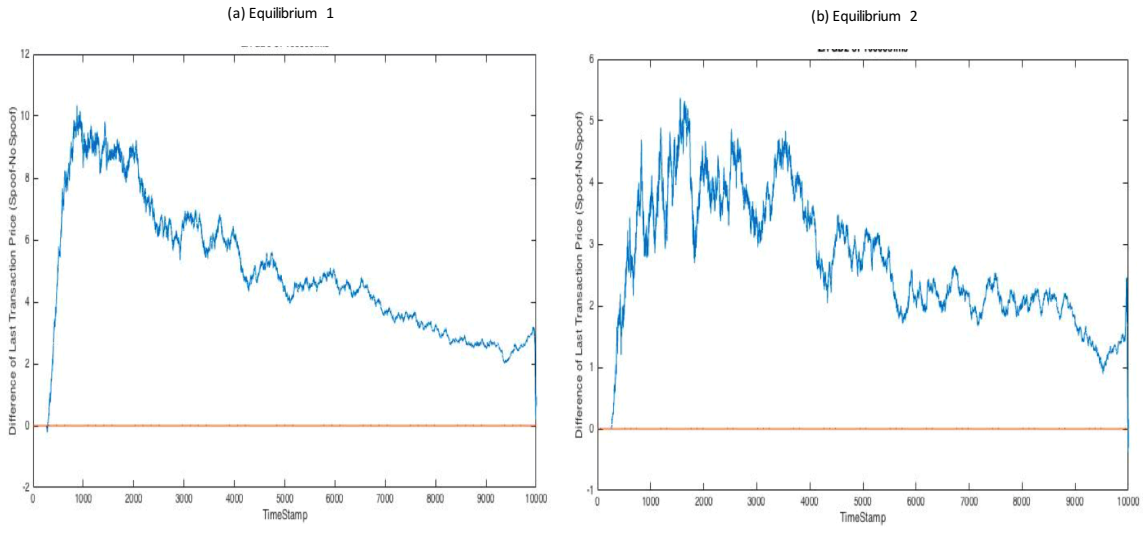
Source: UK Financial Conduct Authority

Spoofable Agents



A spoofing agent can exploit the heuristic-based learning strategy and manipulate the market price.

Spoofing Equilibrium Strategies



Manipulation: Current Questions

- Can we automatically learn manipulation strategies?
- Can we reliably detect manipulation in market data?
- Can we build spoof-proof trading agents?

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Level 4

Finance and Design for Beneficial AI

- A consequential domain at the leading edge of AI automation
- Qualitatively new phenomena, interaction at superhuman time scales
- Rich technical (AI+Econ) and Social (Law+Policy) challenges