On the Feasibility of Automating Stock Market Manipulation (LASER Workshop)

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Unknowns of Automated Market Manipulation

- What can bots automate?
- How can they automate, communicate?
- Who will they compromise?
- How will they evade detection?
Market Basics (Simplified)

Seller → Exchange

Order Book

Exchange → Buyer

ask → bid
### Layering

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<th>Bids</th>
<th>Asks</th>
<th>Spoofs</th>
<th>Real Bid</th>
<th>Cancels</th>
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Real Bid

Spoofs

Bids

Asks

Cancels
Evaluation Options

• Real-world attack?
  - Obviously illegal

• Stock-trading game?
  - Uncontrolled variables
  - Still not ethical if other players are human
  - What kind of game?

• “Paper trading” simulation?
  - No slippage
Simulation Plan

• Agent-based simulation
  - Modeling slippage
  - Stock value beliefs
  - Factoring computation, communication
Simulator

- **ABIDES: Agent-Based Interactive Discrete Event Simulation environment** [Github] [PDF]
  - Developed by Tucker Balch’s lab at Georgia Tech
  - Research collaborations with major USA investment banking firm

- **Agent-based**: traders, brokerages, exchanges, dark pools, news websites, belief oracles, etc.

- **Discrete Event Driven**: a kernel delivers messages at discrete time steps, “awakens” agents at predetermined events
Modeling Beliefs

Agent (Trader)

Agent (Trader)

Agent (Trader)

Order Book

subscriptions

P + n

Agent (Exchange)

Agent ("Belief Oracle")

True Fundamental Value
Agent Types

- **Oracle**
  - Knows the fundamental value of a stock, when asked, returns a noisy reading

- **Exchange**
  - Maintains order book for 1 stock, receives orders, executes trades, sends subscribers layer info and trade notifications

- **Botmaster**
  - Buys max shares as attack begins, signals botnet, dumps after fixed time

- **Spoofing Agent (Botnet)**
  - Maintains an open bid at a price just below the best bid, canceling as needed
Background Traders

- “Spoofing the Limit Order Book: An Agent-Based Model” by Xintong Wang and Michael P. Wellman

- Zero Intelligence Agent (ZI)
  - Randomly buys or sells shares based on current price and fundamental belief

- Heuristic Belief Learning (HBL)
  - Also factors order book: open asks/bids, previously completed transactions
Additional Modeling

- Delay factor: $a + b_{(i,j)} + P(i, j)$
  - $i$: sender, $j$: receiver, $a$: computational delay constant, $b$: min network latency, $P$: Poisson distribution (added network latency)
Simulation Timeline

1) Simulation begins
2) Market opens
3) Background traders arrive with Poisson distribution delay
4) Botmaster buys shares
5) Botmaster triggers spoofing agents to begin layering
6) Botmaster sells shares, signals spoofing agents to stop
7) Simulation ends
Experimental Variables

• Ratio bots to background traders
• Network latency of bots vs. background traders
Experimental Design

• Control: background traders, botmaster, no spoofing agents

• Treatment: with spoofing agents

• Trials: 100 control, 100 treatment per configuration

• Configs: 1 to 21 bots, 49 ZI, 16 HBL, 0% to 200% added latency to botnet

• Measurements: Botmaster/spoofing agent cash $\Delta$
Findings

- Attack Duration: < 1 minute
- Network Latency Tolerance: > 200% added (3x)
- Required Trade Volume: 1.5%
- Per-Session ROI: 2.8% ROI
- Annual ROI: 1022%
Findings (Cont’d)

- IBM, March 2020: 9,120 shares traded per minute
- $9,120 \times 1.5\% \times \text{Market Price} = \sim$5,000/session
- 2.8\% \text{ROI} \times 1 \text{ session per day} \times 252 \text{ trading days} \times $100k \text{ initial investment}
- \text{Profit: } > $1 \text{ million}
- \text{Botnet Loss: Commission Fees}
- \text{Self-Sustaining}
Discussion

• Factors not modeled
  – Intermediary parties (brokerages, brokers, dark pools)
  – Anomaly detection
  – Background volatility, changing beliefs (e.g., using historical data)
  – Liquidity & designated market makers

• Measuring cash $\Delta$
  – Compare control & treatment for the same seed
Resources

- Code: https://github.com/carter-yagemann/bot2stock
- Talk: Thursday, 12 PM EST
- Contact: yagemann@gatech.edu (carteryagemann.com)