Exploring the effect of network topology on the performance of different trading strategies in distributed financial markets

Natalie Lang, supervised by Dr. John Cartlidge and Prof. Dave Cliff
University of Bristol, Department of Computer Science

Overview

To explore the effects of different network topologies on market dynamics and measure the success of different trading strategies using metrics like Smith's α, allocative efficiency and profit dispersion. To use replicator dynamics to find the 'best' trading algorithm.

Motivation

In 1962, Vernon Smith published a paper discussing his Nobel Prize-winning experiments which explored the dynamics of the continuous double auction (CDA) [1]. Since then, research into the performance of algorithmic traders and markets have used the same format as Smith: each trader can interact with every other trader, what happens if they can't?

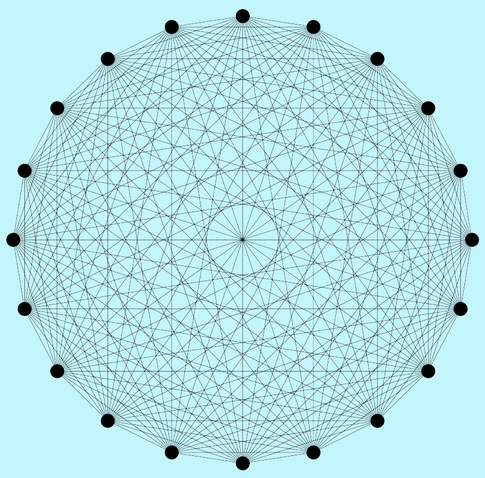
Objectives

- Simulate Smith's experiments using a fully-connected network.
- Vary network topology and analyse the effect on performance metrics.
- Modify the trading strategy for each network topology and evaluate its success.

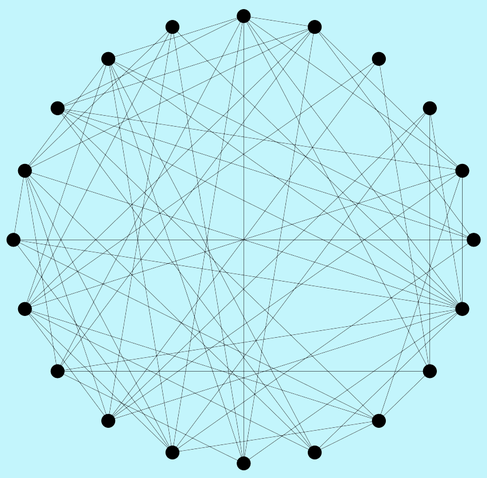
Method

- Extend Bristol Stock Exchange (BSE) to allow trading within different network topologies.

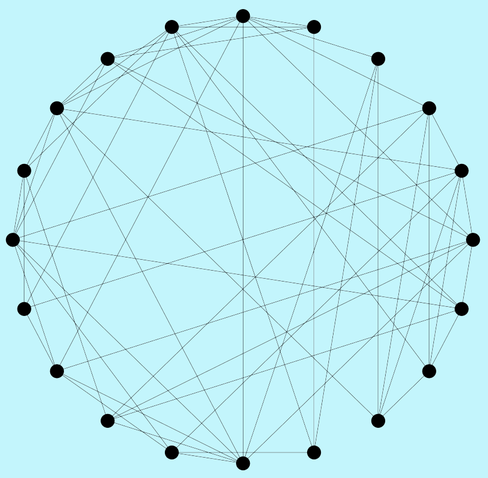
Fully Connected
edge between every pair of nodes



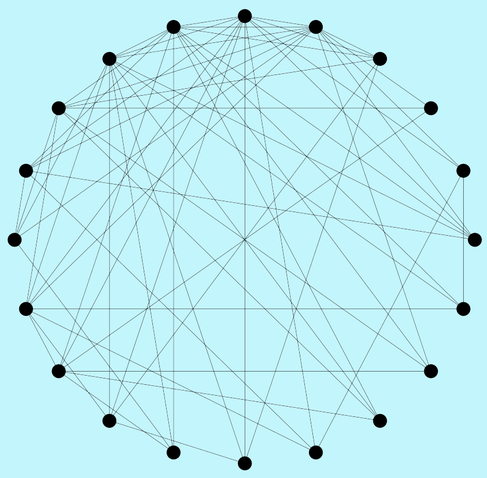
Random [2]
each edge has a fixed probability of being present, independently of the other edges



Small World [3]
short average path length and high clustering



Scale Free [4]
follows a power law degree distribution



- Implement MGD and AA trading algorithms in BSE.

ZIP [5]
(Zero Intelligence Plus)
ZIP agents are profit-driven traders that adapt their profit margins based on the price of other bids and asks in the market.

MGD [6]
(Modified Gjerstad and Dickhaut)
GD agents trade at a price which maximises their expected gain (expected profit × probability of acceptance at that price). IBM modified GD to reduce volatility, creating MGD agents.

AA [7]
(Adaptive Aggressive)
AA agents have an aggression parameter which is updated based on previous market information. Aggressive agents will forgo profit for a quick trade; passive agents will hold out for a greater profit.

- Analyse market performance using the following metrics [8]:

Smith's Alpha

root mean square deviation of transaction prices around the theoretical equilibrium price

$$\alpha = \frac{1}{P_0}\sqrt{\frac{1}{n}\sum_{i=1}^{n}(p_i - P_0)^2}$$

n transactions
p_i prices
P_0 equilibrium price

Allocative Efficiency

total profit earned by all traders, divided by the theoretical maximum possible total profit

$$E = \frac{1}{n}\sum_{i=1}^{n}\frac{\pi_i}{\pi_i^*}$$

n traders
π_i realised profit
π_i^* theoretical profit

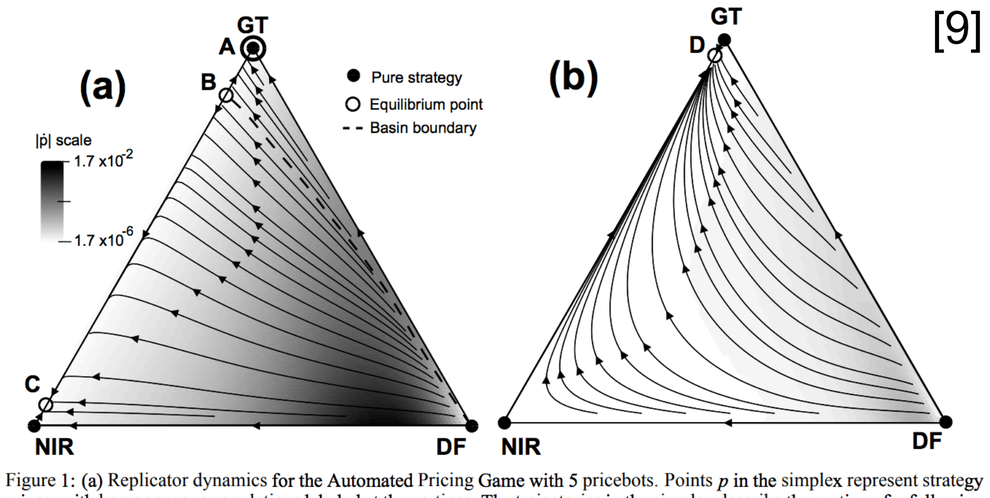
Profit Dispersion

extent to which profit generated by a group of traders differs from the profit generated if all transactions occur at theoretical equilibrium price

$$\pi_{disp} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\pi_i - \pi_i^*)^2}$$

n traders
π_i realised profit
π_i^* theoretical profit

- Use replicator dynamics to find the 'best' trading strategy for each network topology.



[9]

Figure 1: (a) Replicator dynamics for the Automated Pricing Game with 5 pricebots. Points p in the simplex represent strategy mixes, with homogeneous populations labeled at the vertices. The trajectories in the simplex describe the motion of p following Equation 2. Open circles are Nash equilibria, corresponding to fixed points of Equation 2, with labels corresponding to those in Table 1. The dashed line denotes the boundary of the two basins of attraction. The gray shading is proportional to the magnitude of $\dot{p}$. (b) Replicator dynamics for the Automated Pricing Game with 20 pricebots.

References

[1] Smith, V. (1962). An experimental study of comparative market behaviour.
[2] Erdős, P., Rényi, A. (1959). On Random Graphs. I.
[3] Watts, D. J., Strogatz, S. H. (1998). Collective dynamics of 'small-world' networks.
[4] Albert, R., & Barabási, A. (2002). Statistical mechanics of complex networks.
[5] Cliff, D., & Bruten, J. (1997). Zero is Not Enough: On The Lower Limit of Agent Intelligence For Continuous Double Auction Markets.
[6] Das, R., Hanson, J., Kephart, J., & Tesauro, G. (2001). Agent-human interactions in the continuous double auction.
[7] Vytelingum, P. (2006). The Structure and Behaviour of the Continuous Double Auction.
[8] Stotter, S., Cartlidge, J., & Cliff, D. (2013). Exploring Assignment-Adaptive (ASAD) Trading Agents in Financial Market Experiments.
[9] Walsh, W., Das, R., Tesauro, G., & Kephart, J. (2002). Analyzing Complex Strategic Interactions in Multi-Agent Systems.