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| Progress Report Development of a Multi-party Collusion (Circular Trading) detection algorithm |
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# Introduction

Market manipulation is a deliberate attempt to interfere with fair trading in stock markets around the globe. There are many different types of market manipulation and it is an illegal act that may result in unfair results for traders. A trader being any investor or group of investors trading in a market. The market can be manipulated in many ways; one such method would be for a group of large stock holders working together to increase or decrease the price of a certain security, causing unfair prices to other individuals. For example if a cartel decided to buy a large amount of a certain security they could drive the price upwards. Another example would include releasing false information causing uninformed individuals to buy stocks out of being misinformed. Traders will naturally gravitate to the market with the highest integrity in hopes that the effect of market manipulation has been eliminated. As a result all stock markets would strive to have an environment where the likelihood of market manipulation is minimal.

Clearly all kinds of market manipulation are a large problem and activities must be monitored in all stock markets to prevent any kind of unfair trading. This leads us to my topic which is to develop a collusion detection algorithm. Circular trading collusion is one method of market manipulation which involves two or more traders to trade large volumes between themselves with a small net change of stock ownership. This is done to generate what looks like high activity for the security, which may then increase the price of the said security. Moreover there would be minimal loss for the participants involved as they are simply trading within themselves with no net change in volume. This would generate activity and falsely create the look of a liquid security, attracting other traders. This problem may also occur for large groups of participants which would make it far more difficult to detect than the example above. The general idea for my topic is to create an n-party collusion detection algorithm which can detect collusion between any of the parties in the market.

This will be created as an ‘alert’ which is the name of the detection algorithms that have been built by Nasdaq. The code will be done in a language called ALICE which is an internal language based off of C++ that the alerts are coded in. The alerts look over the market data and compile information based on the events in the market. This compiled information is then examined by the algorithms and suspicious activity will trigger the alert. Note that although alerts trigger on suspicious activity, the traders may not be doing anything illegal; it may just seem like suspicious activity. The alerts run on software native to Nasdaq and this software can also be used to visualize the results of the findings in a graphical format.

# Literature Review

In this section I will examine different sources to firstly give a background of the market and how it can be manipulated. I then discuss why the market should be monitored and look at strategies of market manipulation detection.

## Background on the stock market

The stock market is a market in which the shares (also referred to as stocks) of companies are traded through exchanges or over-the-counter (OTC) markets. Previously stock markets were mainly in physical locations however due to the advancement of technology most trading is now done online as well as in a physical location. The stock market allows companies to register their stocks onto the market and then allow participants to gain equity of these companies through the exchange of money. These participants include both individual investors and institutional investors, and also publicly traded corporations trading in their own shares.

Participants on the market may buy and sell shares of companies to other traders and this trading is mostly done to gain equity in a company to gain profit. If a company is profitable the price of the shares will increase and investors who own these shares will also profit. Hence it is clear that investors are trading on the market with the intention to make profit by buying low and selling high.

Buyers on the market *bid*their desired price for a stock while sellers *ask* for a specific price for a stock. Trades occur when the bid and ask prices match where the stocks are traded on a first-come-first-serve basis if there are multiple traders bidding/asking at the same price. There are mainly two types of orders:

* Market Order – The trader automatically is executed immediately and the stocks are traded at the best available bid/ask price.
* Limit Order – The trader specifies their own price and amount to be traded. These orders may take longer to trade if there are no ask/sell orders at the desired price.

This paper will be referring to limit orders as the algorithm used must analyze price and market orders do not have a set price.

## Types of stock market

### Exchanges

Stock exchanges are places or organizations in which people may trade stocks, derivatives, and other types of securities through a centralized source. Two examples of popular stock exchanges are the NYE and Nasdaq, these two organizations act as the middle-men when two traders want to exchange stocks. All traders that wish to trade through the exchange must follow the exchange rules and usually results in less risk for the traders compared to Over The Counter markets. Moreover market data can be more easily monitored on exchanges which allows for the detection of market manipulation. I will mainly be focusing on the use of my algorithm in an exchange rather than OTC markets as market data is required to find cases of circular trading

### OTC market

An OTC market is a decentralized market without a central physical location and the majority of trading is done by internalization. This means that securities are traded directly between the traders without any mediators like in an exchange. Participants on the market trade through various communication systems such as phone, email, and other electronic trading systems. A simple example of an OTC market is the foreign exchange market. In OTC markets there is “minimal availability of trade executions market data to conduct a proper comparison and identify true outliers” [4] This results in difficulty when monitoring the market for market manipulation techniques compared to looking for market manipulation signs over an exchange. This also concerns my research topic as I will be mainly conducting my data analysis over exchange market data, specifically Nasdaq’s market data.

## Background on Market Manipulation

Market manipulation is an illegal action done by individual or groups of traders in markets to gain an unfair advantage in trading compared to other traders in the market. Market manipulation strategies usually come with a large gain with little or no risk to the trader/cartel (A cartel is a group of traders). All stock markets may be manipulated in different ways and while the issue has decreased on main exchanges, it is still a large issue in over-the-counter (OTC) market in the US, and also in new emerging markets. [1] This is largely due to rules in the exchanges which prevent some types of market manipulation and also new technology which allows the exchanges to detect suspicious activity. There are multiple methods to manipulate the market and some famous market manipulations include comers, and short squeezes. [2] More market manipulation methods exist and may be mixtures of different types of methods which make these strategies far more difficult to detect. These market manipulation tactics often involve “large traders” which are traders whose trades will vastly change the price of a security due to the size of the trade. For example (refer to Figure 1) if a trader puts in a market order for 350 LTC this will match all of the sell orders until the price goes up to $25, causing the price to be manipulated from $22.50 to $25.

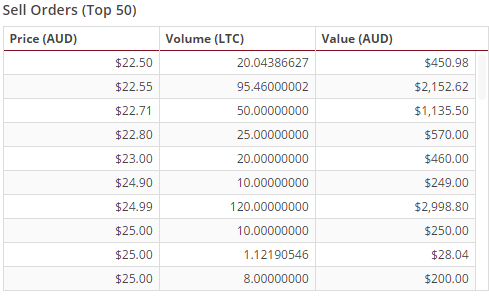


Figure 1. Example of sell side of the order book

Furthermore market manipulation methods are common among parties which have access to insider information as they may use this information unfairly. Although using non-public information to gain an unfair advantage in trading is illegal it is difficult to detect if the traders act with caution. Hence it is clear that these “corporate officers and board members who know of new products or inventions” are suspicious and their actions must be monitored to avoid market manipulation tactics. These particular individuals must “adhere to special regulations when purchasing stock in their companies to avoid penalties. “ [3] These rules are put in place to prevent insiders (individuals with private information) from manipulating the market. This is further emphasized by Jarrow as he states that “potentially informed parties such as corporate insiders, brokers, underwriters, large shareholders, and market makers are likely to be manipulators. “ [2]

## Types of Market Manipulation

There are many different types of market manipulation which can be classified into “classification of stock manipulations into three basic categories: information-based, action-based and trade-based”. [5] The main focus of this paper will be the trade based manipulation which is defined by Allen and Gale to be a “trader attempting to manipulate a stock price simply by buying and then selling (or vice versa), without releasing any false information or taking any other publicly observable action designed to alter the security’s value”. [6] As such popular trade based manipulation techniques often involve large traders [2] as they can move the market and stock prices more easily by executing large trades. This is important to the topic of this paper as one of the criteria for finding a suspect is the volume traded.

To get an idea of why market manipulation is a large issue we will go over a few of the techniques and the results from successfully using these techniques. Below is a discussion of two popular techniques. Further in the document we will be discussing collusion which is the topic of the research.

**Short Squeeze -** First we must define a “short” which is when an individual borrows stocks from a broker to sell. In a short sell the borrowed stock is sold and the individual must later buy the same amount of borrowed stocks to pay the broker back (usually with a small interest). Hence it is clear that investors who are short selling would want the stock price to go down so they can expend less to pay back the broker. A **short squeeze** is a situation where the price of the stock is manipulated to move sharply higher, causing short sellers to panic and buy the stocks while the prices are low to pay back the brokers. This pressure causes the price to be pushed even higher, causing the price of the stock to rise artificially.

**Cornering the market –** Cornering the market is a technique which is more prevalent in smaller exchanges as it requires a trader to gain “sufficient control of a particular stock, commodity, or other asset to allow the price to be manipulated”. [3] By having the greatest market share for a product traders may highly influence the price of the product and may do so without much risk. For example a trader continuously buys a product and pushes up the value of the product (short sellers are driven out of the market via a short squeeze) until it reaches a satisfactory level. After inflating the price to a desired level the manipulator may then begin to sell the shares at the inflated price.

## Motivation for market surveillance

It is evident that due to possible manipulators and the abundance of different market manipulation techniques that surveillance is needed in the markets. Without surveillance many market manipulators will be free to do as they please and likely gain unfair profits. While some argue that it is difficult to distinguish manipulative intent from legitimate intent, Pirrong [7] argues that market power manipulation definitely has an effect on prices and quantities. It is argued that “manipulated prices and quantities can be reliably distinguished… even if fundamental market conditions are unusual”. Pirrong argues that manipulation can be detected and is clearly distinguishable from natural market activity by examining the soybean market [8]. Hence we will assume for this paper that market manipulation can be detected.

If we assume this is true we may look at examples of market manipulation such as the Chinese stock exchange in 2013 which included the Shanghai Stock Exchange and Shenzhen Stock Exchange. It was found that “regulators had litigated 21 manipulation cases by 2003.” Moreover it was also speculated that was” merely a tip of the iceberg, since hundreds (even thousands) of abnormalities of price movements, for no proper reasons regarding fundamentals, could be observed during that period.” [5] Evidently market manipulators may gain the upper hand in the markets at the expense of the fair traders.

Moreover the amount of strange movements created by market manipulators may negatively also influence natural trading behaviors and market liquidity. This further reduces market trading integrity which may be a concern for the organizations that are running the markets and result in fewer customers. This is further emphasized by Cumming, Johan, and Li who state that “trading activity decreases if exchanges fail to adopt surveillance procedures and regulations that assure market integrity” [10].

There are clearly solutions other than looking through the market for manipulators, such as limiting the power of large traders and extra regulations against these large traders. However this is simply deterrence and does not actually solve the problem of market manipulation. The best solution would be to detect market manipulation with a high accuracy as this could detect and remove these traders completely from the market, deterring future manipulators.

## Difficulty of manipulation detection and detection strategies

The detection manipulation on the market is difficult and may not always produce correct results. In some cases, what seems to be market manipulation may instead be a trader acting strangely or outlying behavior from an investor. There does not exist much literature on detection techniques that are applicable in real markets, however Palshikar and Apte use graph clustering algorithms to detect collusion set. [5,8]. Abrantes-Metz and Addanki also developed a model “ to detect manipulation in commodities market and apply the model to the case of Hunt Brother’s manipulation of silver”. [5] Sun et al. also proposes the “analysis of trading networks of stocks to identify fraudulent traders, since they find the trading networks of manipulated stocks exhibit significantly higher degree–strength correlation than that of non-manipulated ones.”[5]

A few other authors also attempt to detect market manipulation however it is reviewed in paper [5] that these algorithms take too many “assumptions to facilitate model formulation” and the assumed behaviors are “far from reality”. It is argued that manipulators will not be as simple as to “pump-dump”. I.e. the manipulators do not just conduct their illegal activities at one time. A smart manipulator will weave their illegal activity with normal market behavior, making the manipulation more difficult to detect. It is clear that the detection of market manipulation is quite difficult and potential manipulators must be examined further before reaching any conclusions. However this is ok in terms of this topic as we are mainly looking for suspects that are colluding, they can be further examined over past trade history and also their future activity in the market.

The detection of market manipulation may also be more complicated due to the various types of methods that may be employed by the manipulators, some of which may still be unknown. Each method may also require different methods of detection, for example for detecting short squeezes we must look at large volumes of sell orders while the detection of insider trading may be based off of what information is released to the public and the trades before the information is released.

## Collusion

Collusion in the market is secret or illegal actions taken by individuals or cartels in cooperation to unfairly influence the market. Collusion may take many forms in different markets and the purpose of the colluding parties is usually to gain an upper hand in the market or to disadvantage another party in the market. Collusion is popular when there an oligopoly exists in the market; this is where a small number of companies own a large majority of the market share and thus have high level of influence over the prices.

An example of collusion is price fixing. This is where there are a small number of companies in the market who are offering the same product. Hence it is possible that these companies may work together to all set their prices to a relatively high price, forcing traders on the market to buy at the new higher price (vice versa for setting a low price). The unfairness of this behavior can be emphasized more when the colluding parties attempt to eliminate all other non-colluding companies in the market so that all individuals must buy at their fixed prices. This may be done through strategies such as advertising to limit knowledge of the product. Despite this there is also the possibility of tacit collusion, where no formal agreement is made which will be more difficult to convict.

Although collusion seems like a simple method to gain the upper hand in the market it is usually prevented by strict exchange rules and it is an illegal action with considerable punishment. Additionally the difficulty of successfully colluding is high, especially with many parties involved. It is difficult to get many parties who are committed and willing to cooperate as there is the risk of one party simply defecting and alerting the authorities of the collusion. Despite the difficulty of collusion there are still preventative measures in place such as forcing firms to “maintain a substantial amount of forward sales, the procompetitive effect can dominate the pro-collusion effect making it harder for firms to sustain collusion.”[11]

For this paper when we are attempting to detect collusion we will firstly be looking for smaller groups of collusion within the large traders of a security as the likely hood of large colluding groups is not high.

# Design

In this section we will be analyzing the problem of this paper, why it is important, and going through different possible ways to solve the problem.

## The problem - Circular Trading

The main aspect that my topic will be focusing on is a circular trading collusion detection system. Circular trading in a market can be defined as a form of collusion where buy/sell orders are traded within a group of participants with a low net change in stock ownership. The colluding participants will know the exact number of shares to trade and the exact time to trade them to each other. Participants within a group may utilize prior knowledge from within the group, allowing participants to enter orders which will be instantly covered by orders of the same size on the opposite side of the order book. An example is shown in **Figure 2** where 5 participants simply trade within the group.

The consequence of this type of collusion will be that trading volumes will be increased for the security. Hence other investors are more likely to become interested in the security, which could possibly drive the price upwards or downwards. This is especially true as traders often look for upward/downward trends in the market based off of the trading volume and they could easily for fall this artificial volume increase. To understand this we must first look inside the mind of a trader.

Clearly, a rising market should see rising volume. If the trade volume is increasing there is evidently an interest in the security which will continue to push the price higher as other traders will most likely notice the higher trade volume and seek to buy in the security. Even if there is a spike in the price of a security, if it is accompanied by a low trade volume it is unlikely that traders will buy into the security as there is a lack of interest. Moreover a price spike with low volume is usually not worth investing in as low volume means low liquidity, which means that the security may be difficult to sell later even if it reaches a higher price.

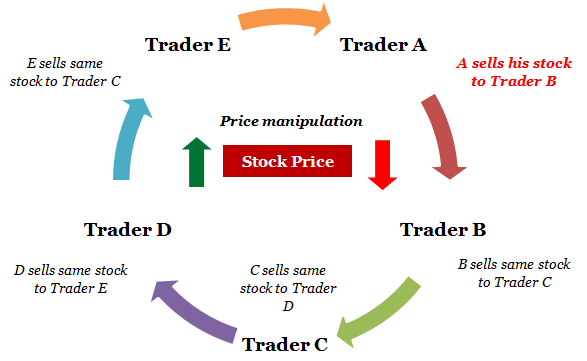
On the other hand, a price spike followed by a large increase in trade volume is a clear indicator that the price will continue to rise. Hence it is clear that by manipulating the volume of a security it could be vastly detrimental to normal traders and could easily benefit manipulators who want to increase the price of securities.  


Figure 2. Example of circular trading

This type of strategy has been utilized by many in the past. One of which is Ketan Parek who used circular trading to scam the Indian stock market by inflating the prices of securities such as Zee Telefilms , Global Telesystems, Himachal Futuristic Communication (HFCL) and Silverline. He would “buy into smaller companies through private placement and then rig share prices” using circular trading. [12]

Another scheme involving circular trading was recently discovered in 2016 where Russians were able to funnel money offshore, using circular trading as a form of money laundering. A Russian broker named Igor Volkov consistently placed two orders simultaneously almost every day between 2011 and 2015. In one trade he would use the Russian Rubles to buy a blue chip stock for a Russian company he was representing. Meanwhile in the second trade Volkov would sell the same quantity of the same Russian stock in London. “In the second trade, Volkov—acting on behalf of a different company, which typically was registered in an offshore territory, such as the British Virgin Islands—would sell the same Russian stock, in the same quantity, in London, in exchange for dollars, pounds, or euros.” [13] Since both companies had the same owner the owner was effectively buying and selling to himself.

At first this appears pointless other than the Deutsche Bank earning commission for executing the buy/sell orders. In regards to the finances the clients all finished with roughly the same amount of money they had in the beginning. However, it was later found that these trades were not done with the intention of making a profit, instead these trades were done to take money out of Russia and put it into an offshore company (since both the Russian company and the offshore company belonged to the same owner). As a result the Rubles in Russia were successfully converted into dollars outside of Russia. This tactic allowed a person or cartel to move a large amount of money outside of Russia, successfully laundering the money.

This tactic was done with only one trader and was effective in terms of laundering large amounts of money (each order done by Volkov was usually for around $10 million worth of the stock) Hence it can be deduced that by using a larger group of people it would be possible to more easily employ this tactic without arousing any suspicions as each individual would be trading less money with each order entry.

Clearly collusion can be limited

## Possible solutions

Use graphical approach.

Search for cycles.

Search for traders with high trading activity with eachother

Analyze all high volume trades.

## Algorithm

Impossible to tell if they’re trading normally or if they’re attempting to manipulate. So just find the worst cases and let the exchange analyze. More accurate if run over a few days.

What to look at.

High volume and low net volume.

Must analyze whole graph.

## Methods to cut down the run time

Only check important trade pairs and important trade participants.

Ignore previously triggered alerts.

# Implementation

## Code

## Analyzing the algorithm

## Unit Tests

# Analysis and Results

## Results

## Test against real market data

## Runtime against real market data

# Work carried out so far

Research has been done for the topic of collusion however there are not many resources as multi-party collusion is a fairly new problem whose solution has not been publically released. I have done research on what types of collusion are possible however the main type of collusion is when there is a group of participants who have traded a large trade volume while there is a low change in net ownership for the participant. Hence this is what my supervisor and I have decided to look for in the market.

The first sub-task was to create a 3-party collusion detection algorithm which I have completed the prototype for. It checks all groups of 3 participants which trade with each other for signs of collusion. To build up these 3 participants I must loop through almost all of the participants which trade with each other, and then find a 3rd participant that they trade with, hence it has a running time of for n participants. This can be considered ok as the amount of participants which trade has been analyzed to be very small for most markets. However another approach must be used for the n-party collusion detection algorithm as would be an unacceptable running time.

The current prototype has been approved and I am now planning on moving on to figuring out how to do an efficient n-party collusion detection algorithm.

# Proposal plan

Next semesters work will include:

1. Get approval for the 3-party collusion prototype and make adjustments as necessary.
   1. This will include fixing all bugs and creating unit tests on the completed prototype.
2. Research algorithms for the n-party collusion alert and write pseudo code for it.
   1. Look up appropriate algorithms; I may attempt a graphical approach for the n-party collusion algorithm as my current approach is inefficient. If no appropriate algorithms then I may have to design a new one with the help of my supervisor.
   2. After pseudo code is written I must confirm with supervisor and get approval that it will be ok to use. I can also use current market analyzing software and scripts to get more knowledge of the markets. Eg. Average number of participants in a market. This is important as it may effect running time of my algorithm.
3. Development of the n-party collusion alert.
   1. Write the code for the alert and conduct developer testing throughout the development phase. Also email supervisor weekly on the progress of the alert to make sure I am on the right track.
4. Submission of the alert and adjustments from feedback.
   1. Create unit tests and make adjustments based on feedback from my supervisor.
   2. Submit final alert code.

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