Out of Sync: Slowing down the rate of High Frequency Trading

by

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Master of Fine Arts 2013

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Abstract

Out of Sync is an interdisciplinary art project that examines how High Frequency Trading (HFT) has accelerated trading on financial markets. This thesis makes visible how the speed increases inherent within HFT are out of sync with the pace of human perception. The body of work consists of three projects that each discuss a specific topic within HFT including the data mining techniques used by HFT algorithms, the history of HFT, and the loss of space brought about by electronic trading. I use the method of deceleration to illustrate these differences in speed and represent HFT algorithms using text, video game design and sound synthesis. Finally, I analyze HFT through the theories of Paul Virilio and I demonstrate how the speed at which HFT occurs contributes to the loss of physical space as well as the potential for global accidents.

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Preface

My art practice centers on creating interactive systems by programming software and building hardware for projects that in the past have included kinetic sculpture, interactive audiovisual installations and experiential software for mobile devices. My work usually incorporates interactive elements, as I use participant interaction as a method of exploration. Participants can experience the underlying subject matter by performing some sort of task through touch or bodily actions.

While my past work has examined various subjects, in general I am interested in how computing developments in both software and hardware affect culture. As this thesis demonstrates, the Financial Industry increased the speed of electronic trading systems by investing in computing technologies. Trading now occurs at speeds unimaginable 20 years ago when traditional stock trading took place. Over the course of two decades the speed of trading has certainly changed the landscape of the major stock exchanges. But the speed of computation can move beyond stock trading. Advances in data mining analysis have also benefited from increased processing speeds. I view HFT as the beginning of how computational speeds will facilitate the ability to analyze huge amounts of data in extremely short periods of time. As most human activities are now converted and stored as digital data, computer algorithms can potentially analyze this data and form opinions about people's habits, their opinions conveyed through social media and equally used to monitor people's behavior to single out potential threats. Corporations and government agencies seeking to capitalize on these vast amounts of data can equally reproduce the infrastructure built by HFT firms.

While I recognize the importance HFT plays in providing liquidity to financial markets, I question whether in the long run, HFT will just further cause instability to markets. I am not opposed to the existence of HFT but rather to the effects brought about through increased speeds. Quote stuffing, market crashes and increased volatility are not productive qualities and if anything should be regulated as a way of minimizing instability. The fears Paul Virilio warns about are apparent within HFT and so collectively we should act with caution when technological developments begin to accelerate our existing systems even faster. Technological systems continuously build on improvements and so any sort of regulation or criticism to changes will be seen as slowing down the rate of progress. If progress means making things more efficient, less expensive, and faster, then ultimately advances within capitalism such as HFT will move forward as these changes are regarded as providing growth for economies. If growth is the overall goal, then technologies that facilitate this growth will not be eliminated even if they are socially detrimental.

As I produced each of the works for this thesis, my intention was to represent High Frequency Trading in various forms so that it can be publically discussed in order to fully understand what is at stake. My opinions towards HFT are more visible in the *High Frequency Trader* arcade game than in *News Aggregate* or *Mobile Trader*. I made this game accessible to a general public while trying to maintain that in contained a critical analysis on the effects of speed. I see this work as a form of serious play. Because of the complex nature of HFT, it would be unfair to simply represent HFT as being immoral and thus should be eliminated at all costs. My strong feelings towards the effects that speed has on our ability to act within our cultural systems are evident within this game. The difference in speeds between a user's avatar and the HFT avatars demonstrates that these discrepancies are a problem. I have highlighted this issue by making the game extremely difficult to play during these moments of increased speeds. My intention is ultimately to upset players to a point that they get frustrated and stop playing the game. However, their anger might also cause them to try to devise strategies to counteract these speed differences and result in them playing the game even longer. By provoking players I hope to achieve some sort of reaction. By intentionally disrupting traditional game design I am able to state how the infrastructure of electronic trading favors the speed of HFT algorithms.

With *News Aggregate* I have intentionally stopped my algorithm from making final trading decisions because I felt that it was important for viewers to analyze this work themselves and form their own opinions on HFT. I want people to question why certain words that they personally regard as important fade away while other words are highlighted and become larger. The timing in which this installation develops exists at a pace that I personally relate to. My personality is such that I will not act unless I have carefully thought about the effects that my actions might bring about. I have a hard time relating to media that caters to reactionary responses and so I tend to prefer slower practices that are better suited to the way in which I think. As a result, this body of work is in fact highly personal as I have equally slowed down computational practices to a speed in which I cam comfortable working with. While my art practice utilizes computing technologies I am drawn to the logic of these systems but not to the speed at which they function. The speed of computing technologies frightens me because I have a personality that prefers to deal with slower paced situations.

To conclude, the complex nature of HFT cannot be represented by any one work and so collectively my goal was to have each piece reveal the different qualities about HFT. As a result, each of these works is quite different in scale and approach and reflects the many opinions I have with regards to HFT. Overall however, I believe that these works demonstrate how HFT must be slowed down so that we can understand what is happening beyond our comprehension.

I. Introduction

Out of Sync is an interdisciplinary art project that explores how High Frequency Trading (HFT) has accelerated electronic trading on financial markets. I was first exposed to HFT when I learned about the Flash Crash of May 6, 2010 in which the Dow Jones Industrial Average (DJIA) on the New York Stock Exchange (NYSE) fell almost 10 percent within 20 minutes. Market selloffs have occurred in the past but never have they taken place in such a short period of time. After looking into this particular event, I learned about a technique known as HFT that is thought to have facilitated the rate at which this market crash took place.

HFT is the use of computer algorithms for placing trades on Stock Exchanges allowing for large numbers of transactions to occur within microseconds. This enables financial institutions using HFT algorithms to buy and sell stocks and securities faster than any human trader could ever envision. HFT creates the ability for automated buying and selling to occur based on the criteria outlined within the code of an algorithm. HFT firms running different types of algorithms compete with one another, trying to acquire the competitive advantage to generate as much capital as they can on a daily basis. As I will outline in detail in the coming section, HFT algorithms both serve as the infrastructure of the major Stock Exchanges, and at the same time these algorithms are used by financial firms to generate wealth. HFT has not only altered the way stock trading takes place but this change also signifies a trend where computing technologies push our cultural systems to speeds that are harder for people working within these systems to comprehend. HFT may improve the ease with which assets can be bought and sold; however, this type of trading has also made financial markets more volatile. As the Flash Crash of 2010 demonstrated, huge amounts of capital can be pulled out of the market at such a fast rate that it makes it difficult for human traders to respond in time. Thus HFT has the potential to accelerate market selloffs to a point that endangers not only the stability of the markets but also everyone's livelihood. As the Credit Crisis in 2008 demonstrated, the complex nature of certain mortgage-backed securities threatens so many people if any sort of crash does in fact occur.[1]

The goal of this thesis is to illustrate how the speed increases inherent within HFT are out of sync with the capacity for human comprehension. The thesis project will consist of three projects that each discuss a specific topic within HFT; namely, the data mining techniques used by HFT algorithms, the history of HFT, and the displacement of physical space brought about by this acceleration. As HFT is highly abstract in nature, the works I am producing are equally abstract. While I cannot simply visualize HFT from the algorithms themselves,[2] as it would be impossible to grasp the rate at which these calculations occur, I have designed three projects that explore certain areas within HFT that I believe need to be examined and brought into the public sphere. These three works are representations of HFT algorithms and I have intentionally slowed down the rate of change in order for the general public to begin to understand how HFT functions and what types of decisions these algorithms make at a microsecond level. My intention is for each work to draw spectators into the logic of HFT algorithms, and for people to live out

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[1] While HFT was not directly responsible for the Credit Crisis, the markets during this time period were extremely volatile due to HFT practices.

[2] HFT algorithms are not publicly available, as trading firms that design these algorithms are not willing to give up their trade secrets.

the actions of these algorithms from within their own rate of understanding.

As this thesis project focuses on a specific area within finance, I will provide a concise historical background to how HFT came about and discuss how HFT firms go about trading. Further, I will demonstrate how HFT has now become the underlying framework of financial trading on the major Stock Exchanges. HFT came about over the course of two decades culminating in the displacement of traditional human floor traders who would buy and sell on behalf of institutional and individual investors. The transition from human-centric trading to electronic trading also changed the speed at which transactions can take place. Electronic trading means that stock orders can be routed between buyers and sellers more easily and efficiently. Transactions can thus occur within seconds rather than minutes. With time however, trading firms invested in computing technologies to speed up these transaction times. High Frequency Trading was born out of computational improvements in the pursuit of generating more capital in less time. The pursuit of capital has not changed with the introduction of High Frequency Trading but what has changed is how fast capital can be generated. Trades take place within milliseconds and microseconds and are slowly approaching the duration of nanoseconds.[3]

I will describe this narrative through the writing of Scott Patterson, who describes the transition by focussing on one particular individual, Joshua Levine, who contributed significantly to these changes. I will also discuss the general strategies of HFT firms as

[3] 1 millisecond = 1/1,000 of a second, 1 microsecond = 1/1,000,000 of a second, 1 nanosecond = 1/1,000,000,000 of a second.

described by insiders, in order to provide a theoretical background in which to situate the body of work that I create.

The first project, *News Aggregate (slowed down by 500,000 %)* simulates HFT algorithms that scan machine readable news feeds. The work consists of algorithmically collected news articles projected onto sheets of newsprint. The second project, *High Frequency Trader,* illustrates the history of HFT. This project is a two-dimensional arcade game where users are immersed within a simulated trading environment. The third project, *Mobile Trader*, consists of a mobile application for creating audio soundscapes. Participants in the gallery space act as HFT algorithms and use their phone as a tool for matching trades resulting in audio tones being generated on their phones. As Media theorist MacKenzie states, “Speed is always relative to delay. Only a *change* in speed is ever felt as such. We have no experience of speed except as a *difference* of speeds” (MacKenzie 122). The tempo of each of these projects has been slowed down, pushed to the opposite extreme, to illustrate the offsetting divide between the rate of HFT algorithms and the rate of a viewer’s mode of perception.

The focus of this thesis is to demonstrate how HFT has accelerated trading to speeds that are faster than our modes of perception. To situate this project within our broader cultural landscape, I draw connections between my research and the theories of Paul Virilio. Virilio believes that our “Global society is currently in a gestation period and cannot be understood without the speed of light or the automatic quotations of the stock market in Wall Street, Tokyo or London” (Redhead 43). He states that real-time practices have now taken precedence over “real space and the geosphere” (Virilio 1995). In accordance with Virilio's understanding of real-time, HFT algorithms placing trades on markets are in fact happening faster than real-time, if real-time is understood as taking place within human sense perception. As it is impossible to visualize HFT algorithms at the rate at which they function, and in order to draw attention to this time gap, I will examine how to dismantle our understanding of real-time in relation to computing technologies. Rather than having our perception bend to fit into the real-time of these trading algorithms, I will slow the algorithm execution times down. While this goes against the objectives of the financial industry, where time is money, the goal of this project is to examine HFT by slowing it down in order to form clear informed opinions about what is in fact occurring beyond our comprehension. Within the installation spaces of this thesis project, money-time is reduced to a pace suitable for humans, and in essence, the tempo of HFT is reduced to an anthropocentric rate of operation.

II. Historical Background

Introducing High Frequency Trading

In the last two decades, the financial markets have seen a great deal of change brought about by electronic trading. What originated on Wall Street has now also spread to other global financial markets. Computerized trading on Wall Street was only introduced in 1971 when the NASDAQ emerged as the first electronic exchange to compete with the New York Stock Exchange (NYSE), which at the time was a monopoly (Patterson, *Dark Pools)*. Over the course of two decades, smaller exchanges began to enter the market, competing with the NASDAQ and the NYSE. As computers became smaller and faster over time, these smaller exchanges were able to trade stocks for investors without having to rely on the larger exchanges. Small financial firms in the business of trading stocks for profit were now able to trade on these new exchanges. This was the beginning of High Frequency Trading.

High Frequency Trading (HFT) is the buying and selling of large volumes of shares using computer algorithms. These algorithms are able to place buy and sell orders every microsecond, which can amount to millions of shares being executed every minute. HFT firms are small companies that buy and sell millions of shares electronically every day. For example, one HFT algorithm might place buy orders for 500 shares of General Electric at $20 every millisecond for the duration of 10 seconds. This would amount to buying 5,000,000 shares over 10 seconds. The same algorithm would then sell these shares at $20.01 each.[4] The price difference of 1 cent is not much, however when you sell 5 million shares with a penny gain, you are left with a $50,000 dollar gain. High Frequency, or the buying and selling of huge amounts of shares, is what makes these transactions profitable. While these types of transactions might not seem to be problematic, I will later illustrate how certain techniques take advantage of these fast speeds and exploit the trading systems in order to generate large amounts of capital. To

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[4] Until the year 2000, stocks listed on the NYSE and the NASDAQ were listed with fractions rather than decimals. Stock prices were sectioned into sixteenths of a dollar, which amounts to 6.25 cents (*Dark Pools* 174). For each stock traded, the fraction pricing meant that the lowest Bid-Ask Spread possible was 6.25 cents. In the year 2000, when the exchanges on Wall Street joined the rest of the global financial markets to trade according to decimalization, the lowest possible Bid-Ask Spread was reduced to one cent. Decimalization thus provides increased liquidity to the Stock Market as the spreads are reduced.

put these numbers into perspective, we can look at the number of trades that an Exchange undergoes each day. The NASDAQ collects 50 gigabytes worth of information each day as it records trades every nanosecond, or one billionth of a second (Spicer and Lash). Before discussing High Frequency Trading in detail, I will first provide a brief history of how this form of electronic trading came about on Wall Street. Scott Patterson, a finance journalist on Wall Street, has written extensively on HFT. His in-depth coverage of the history of HFT is outlined in his book, *Dark Pools,* which I am using as the main source for my historical analysis of HFT.

Origins of High Frequency Trading

The origins of how High Frequency Trading came about are not without controversy. Before the electronic trading infrastructure existed on Wall Street, trading was done through stock traders known as market makers. The NYSE, having existed for 200 years, and the NASDAQ introduced in 1971, both had a monopoly on how trades were placed. Both exchanges charged high trading fees to investors and provided inside information to the market makers working on the trading floors. These practices were not appreciated by many, including Joshua Levine, who was a young programmer living in New York. Being of the hacker activist mentality, Levine viewed Wall Street as an old system that needed to be knocked down. From the late 1980’s until the late 1990’s, he would be instrumental in designing computer systems that would eventually give birth to High Frequency Trading.

Previous to the Flash Crash of 2010, Black Monday, occurring on October 19, 1987, was the largest one-day stock crash in the history of Wall Street.[5] At the end of the trading day on Black Monday, the Dow Jones Industrial Average (DJIA) fell 23 percent (Patterson, *Dark Pools* 78). During the hysteria of the market crashing, market makers did not answer phone calls from frantic investors. Thus, the market makers did not fulfill their roles as liquidity providers and this resulted in the average investor being locked out of the markets as the DJIA plummeted.

In existence at the time, yet not widely used, was the Small Order Execution System (SOES). The SOES was designed so that average investors could place orders directly to market makers on the NASDAQ, and was the first instance of electronic trading. Market makers received orders from the SOES and then placed the trades themselves, still charging investors high fees. After Black Monday revealed that market makers had not fulfilled their duties, the NASDAQ made the SOES mandatory. However, the SOES was only to be used by individual investors, as the large institutional investors such as Investment banks and large trading firms did not have access to the SOES (Patterson, *Dark Pools* 79).

Small trading firms were hit hard on Black Monday. Rushmore Securities, run by Harvey Houtkin and Datek run by Sheldon Maschler were two such firms. After Black Monday, Houtkin discovered a loophole whereby the SOES essentially provided a "back door" into the NASDAQ (Patterson, *Dark Pools* 79). Houtkin shared this knowledge with Maschler who began using the SOES to place trades on the NASDAQ. Maschler and the traders at Datek quickly learned the workings of the SOES and began to exploit the

[5] The 1929 market crash was the largest to date, however it occurred over the course of 3 days.

system. They realized that when share prices began to rise some Bid prices were slow to react to the upward trends. Datek traders would buy shares at one price and then shortly turn around and sell them back to slower market makers through the SEOS for a fraction of a difference. They picked off fractional differences that would add up as they were purchasing 1000 shares at a time. Market makers on the NASDAQ soon learned of this technique, and called the Datek traders “SOES Bandits” (Patterson, *Dark Pools* 81).

Joshua Levine at the time was running his software consulting company, Joshua Group, which provided software services for financial firms on Wall Street. Shortly after Maschler and Houtkin began trading through SOES, Levine was hired at Datek to fine-tune their system. During his time at Datek in the late 1980’s and early 1990’s, he created two tools, known as “The Watcher’ and ‘The Monster Key’, that exploited the SOES, giving competitive advantage to the Datek traders.

All the trades placed through the SOES were manually entered into a computer at Datek and then printed out revealing each trader’s transactions. At the end of each day, Datek traders had to manually record their gains and losses for each trade into a computer and so Levine wrote a software program that would automate this task. Levine simply routed the outgoing signal from the printer cable into another computer that would interpret the signal and display all the data on a computer screen. Now the traders could access the stock prices through the SOES and see their gains and losses for each trade electronically, as these occurred throughout the day. This was ‘The Watcher’ (Patterson, *Dark Pools* 89). Levine also created keyboard shortcuts in order for traders to quickly place trades in the system, refining the capabilities of ‘The Watcher’. The ‘SOES

Bandits' now had a speed advantage and raked in thousands of dollars a day by beating the slower market makers on Wall Street.

'The Monster Key' built upon the infrastructure of 'The Watcher' program. A trader at Datek named Joe Cammarata discovered that the SOES gave preference to prices over the time that each trade order was placed. Cammarata realized that he could place an order for a particular stock way above the current Ask price, which would push his order to the beginning of the queue. The best price entered into SOES would bypass all other orders that had Ask prices lower than the current stock price. For example, if Cammarata saw that a particular stock had an Ask price of $50 ¼, he could enter in a price that was 20 percent higher than the current bid, at $60 a share. Since the SOES gave preference to orders with the best price, his order would be executed; however, the SOES would still fill his order with the current Ask price of 50 ¼. (Patterson, *Dark Pools* 94). Cammarata revealed this loophole to Levine, who wrote 'The Monster Key' software program that would automate this process by using the keyboard. 'The Monster Key' was the first trading algorithm to be used by traders on Wall Street, and this loophole further allowed the Datek traders to scrape thousands of dollars from slower market makers (Patterson, *Dark Pools* 95).

The Datek traders used Levine's software algorithms all the way into the early 1990's. Then in 1994, two Finance professors published a paper[6] showing that market makers on the NASDAQ rarely posted prices with odd eighths (⅛, ⅜, ⅝, ⅞). What this

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[6] Christie, William G., and Paul H. Schultz, "Why Do NASDAQ Market Makers Avoid Odd-Eighth Quotes?" *Journal of Finance*, 49(5), December 1994.

meant was the lowest Bid-Ask spreads were not in fact 1/16, or 6.25 cents, but more like 25 or 50 cents. The market makers were deliberately inflating the spreads to pocket the difference. Soon after this paper was published, the Securities and Exchange Commission (SEC) and the Justice Department investigated. What emerged from the investigation facilitated the beginning of electronic trading coming to replace the traditional market makers (Patterson, *Dark Pools* 102).

Datek never officially employed Levine, who was used merely as a consultant paid to build software programs. As a result, other trading firms soon began using 'The Watcher'. Levine soon realized that the market could allow traders to interact with each other through computer systems so they did not have to rely on the market maker middlemen at the NASDAQ. He began to program a new software program called "Jump Trades" that would route trades between traders using 'The Watcher' program. He had officially designed a system that no longer relied on the NASDAQ. This was the beginning of the company known as Island. At this time, Island had a few firms using the trading system but this was about to change very fast. In 1996, after several years of investigation, twenty-four NASDAQ trading firms (including Lehman Brothers, Goldman Sachs and Morgan Stanley) were charged with inflating Bid-Ask spreads. Soon after, the SEC issued a new set of regulations (Patterson, *Dark Pools* 125-126).

The SEC introduced the Order-Handling Rules, which forced the NASDAQ to post quotes from competing firms, such as Island. They also introduced a new type of trading system called an Electronic Communications Network (ECN). An ECN could be any firm who had the technology to match trades by sending their competing quotes to the NASDAQ. Island qualified, and at the time had a superior trading system (Patterson, *Dark Pools* 127). Several years later the SEC also introduced another rule known as the Regulation National Market System, or Reg NMS, which stated that any order placed had to be routed to the ECN who offered the best price (Patterson, *Dark Pools* 239). Now holding the official status as an ECN, Island began attracting small High Frequency Trading firms such as Renaissance Technologies, Getco and Timber Hill. Island's extremely fast system paved the way for HFT to eventually displace the traditional market makers. Electronic trading was becoming the way in which market makers matched orders, and High Frequency traders became the new market makers. They provided liquidity to the market, buying and selling stocks for a penny difference. Levine had succeeded in tearing down the monopolies of the NYSE and the NASDAQ and also brought an end to the old market makers who were charging extremely high commission fees. Island kept attracting new firms and High Frequency Trading was thriving. Eventually however, Levine would face the reality of the old monopolies flexing their muscles.

The NASDAQ had to improve its own technologies in response to the competition from the other ECN's. Another ECN known as Instinet would eventually merge with Island. In reality, however, the Instinet-Island merger still used the Island system. The NASDAQ, the NYSE, Instinet-Island and all the other ECN's all competed with one another to route as many trades through their own electronic networks. In 2005, however, the last blow came to Levine. Although the true founder of Island, Levine neither had an official title, nor did he take part in management decisions. The NASDAQ formed a deal with the management of Instinet-Island to purchase their trading system, namely the system Levine had built at Island (Patterson, *Dark Pools* 238).

Levine had disrupted the old monopolies, but ironically his innovative computer systems opened the door to a new type of technocracy. HFT emerged from the electronic infrastructure Levine had built. In a twist of irony, Levine's intention to free the financial markets from the privy of information shared by the NYSE and the NASDAQ backfired.[7] He was successful, however, in forcing electronic trading systems to become the standard way of trading which lowered trading fees for the average investor. But due to the fact that Joshua Levine was only interested in programming computer systems and did not want to get involved with management decisions, his name rarely is mentioned in literature relating to the emergence of HFT.

Insider's Perspective

HFT firms are now the new market makers providing liquidity to the financial markets, but they must also generate profits based on the trades they make in order to remain viable as market makers. As HFT firms compete with one another, they are extremely adamant about not revealing their strategies. As a result, this industry is quite secretive and there is little literature discussing how these firms design the algorithms that they use on the exchanges. Few firms agree to interviews, and those that do only disclose a general overview of how HFT operates (Perez 45).

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[7] Another ECN competing with Island at the time was Archipelago. Around the same time that the NASDAQ purchased the trading platform of Instinet-Island, Archipelago merged with the NYSE. For a detailed account of the histories of Island and Archipelago and how the NYSE and the NASDAQ came to acquire these ECNs, see Scott Patterson's *Dark Pools. High-Speed Traders, AI Bandits, and the Threat to the Global Financial System.*

In order for HFT to be profitable, firms must buy and sell thousands of shares each day. What allows HFT firms to generate profits is the law of large numbers. Manoj Narang, who is the founder and CEO of Tradeworx, discusses the overall strategy of how High Frequency Trading remains profitable.

> "To get this high level of consistency, you must exploit the 'law of large numbers,' which is the most fundamental principle of statistics, to the maximum possible degree. This means making as many independent bets as possible within a single trading day. In order to do this with a finite set of tradable securities, you must turn your positions over very quickly. So the most *consistently* profitable high-frequency trading strategies therefore are the ones that have the shortest holding periods" (Perez 196).

According to Narang, the fundamental HFT strategy is the rate of portfolio turnover. If a company bought $1 million in stock in one day, they would also sell $1 million before the end of the day. This is known as turning over their portfolio once per day. They could also buy and sell $100,000 worth of stock, which would turn over their portfolio ten times each day (Perez 196). HFT firms never keep any stock holdings past the end of a trading day, as any news that occurs after the Stock Exchanges have closed can affect stock prices the following day. Since they are dealing with price fluctuations every microsecond, any new information must be analyzed to make adjustments to their strategies and then adjusted in the code of their trading algorithms that will then be used the following trading day.

Being the new market makers, High Frequency Traders provide liquidity by remaining in the market throughout the trading day, ready to buy and sell at any time. Regardless of how the markets are functioning within a given day, High Frequency Traders can achieve profits by taking advantage of opportunities that their competitors might not see, or by beating them to it. They also do not run strategies that are known to their competitors (Perez 106). Mass sell-offs during times of panic such as the Credit Crisis of 2008, are equally seen as opportunities. Being market makers, if investors are frantic to sell off their shares during a time of panic, High Frequency traders are there to ensure that they can. During 2008, several HFT firms earned 10 times their usual profits (Spicer and Lash). One firm which was extremely successful during this time was Global Electronic Trading Co., or Getco, founded by two former floor traders, Dan Tierney and Stephen Tierney. In 2009, they were the biggest market makers on Wall Street, accounting for between 10 and 20 percent of daily trading volume. On one trading day in 2009, they traded close to 2 billion shares, which amounted to more than 10% of the trading volume that day. It is estimated that Getco earned close to $400 million during the 2008 period of highly volatile markets. (Patterson, "Meet Getco, High-Frequency Trade King"). High Frequency Traders refer to the mass sell-offs of 2008 as proof that their existence in the markets allows for increased liquidity and prevents markets from seizing up (Spicer and Lash).

In the last couple of years HFT has been blamed for the increased volatility to the markets. Manoj Narang of Tradeworx is extremely defensive about these accusations and points the blame at long-term investors rather than HFT for these systemic risks. According to Narang, long-term investors tend to follow herd-like behaviours and they are the investors who create large bubbles such as the Tech stock bubble in the late 1990s. These bubbles form when investors decide to enter into a certain area of the market, and then burst when they all decide to get out at the same time, creating mass sell-offs.

However, Narang does not discuss how HFT can accelerate the sell-offs when these bubbles do in fact burst. For example, the extent to which these sell-offs are catalyzed by HFT was not the case during Black Friday in 1987 or the market crash in 1929.

HFT firms are undoubtedly defensive as to their roles in financial markets and they are correct to say that they do provide liquidity to the markets and reduced trading fees to investors. However, few insiders are willing to admit the negative consequences of these practices and they fail to address how the speed of HFT can in fact accelerate market crashes.

Unintended Consequences

One of the major criticisms of HFT is that at times certain practices do not provide actual liquidity to the market. One such practice is known as quote stuffing or high frequency quoting. Quote stuffing is the tactic of "sending large numbers of orders and cancellations in rapid succession" to slow down competitors trying to place orders on similar stocks (Tse, Lin and Drew 3). Due to the extremely fast speeds of HFT, it is possible to place thousands of quotes every second. One possible use of quote stuffing is to take advantage of the fragmented structure of the market due to the many ECN's competing for the best possible prices. As many ECNs exist for placing trades, High Frequency traders are able to "stuff" one venue with thousands of quotes, slowing down other trading algorithms, and then place the same quotes through another ECN where they will execute the trades (Malmgren and Stys 24). HFT algorithms thus exploit the response times of competing algorithms and the response times of the ECN's electronic infrastructure.

Nanex is a company that provides real-time market data to financial firms and they have also discovered many irregularities in HFT which they publicize on their website. They have revealed several cases of quote stuffing in an effort to have the SEC investigate these practices. One important case of extreme quote stuffing occurred on August 25, 2011, where Nanex discovered that within one second, 10,000 quotes were placed for shares of Dell stock (See Figure 1). None of the quotes placed, however, resulted in an actual trade, as each quote was quickly cancelled soon after it was placed. The Bid prices, shown as green circles, and the Ask prices, shown as red circles, remained at the same prices, apart from a slight change after the first 7,000 quotes. The Bid price remained at the same price while the Ask price repeatedly oscillated back and forth between two prices, resembling a sinusoidal wave. Nanex's analysis of this event is that these quotes must have originated from one source, pointing the origin to a HFT algorithm (Nanex).

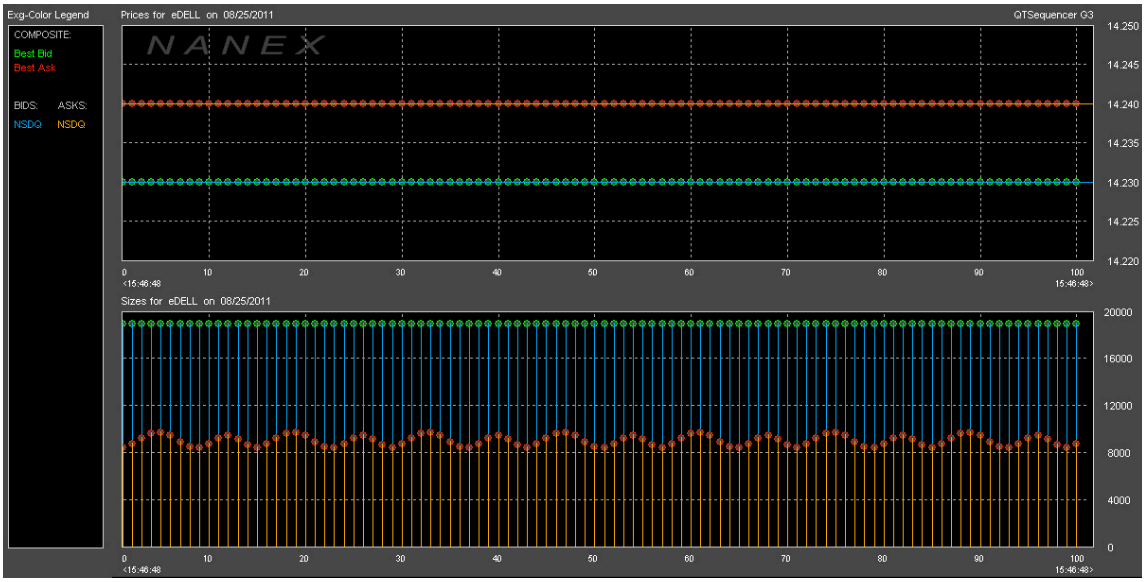

Figure 1: Quote stuffing of Dell Stock on August 25, 2011 (Nanex.net)

While quote stuffing is technically not illegal and the SEC regulators know of its existence, critics such as Nanex question how these tactics provide liquidity to the market. It is also unsure of how often this practice takes place. The NASDAQ, however, recently announced that on June 1, 2012, they would begin penalizing firms that use excessive quote stuffing on their exchange (Avramovic). Quote stuffing also reveals there is in fact market fragmentation due to the many trading venues in existence.

Mini market crashes are a second negative consequence of HFT and are described as “abrupt and severe price changes that occur in an extremely short period” (Golub, Keane and Poon 2). In a paper titled “High Frequency Trading and Mini Flash Crashes”, the authors blame the SEC regulations, specifically the Reg NMS, for the fragmented nature of the markets.[8] While the intention of Reg NMS was to provide competitive pricing for investors, the authors describe the repercussions of these rules as having created a market where irregularities can occur. They write, "While the regulation has served its purpose initially, the current market environment might not be suitable for an ecosystem dominated by speed traders. Mini flash crashes have become the consequence of the fragmented liquidity that is indicative of the current market structure with its myriad of trading venues" (Golub, Keane and Poon 19).

While the Flash Crash of 2010 was a major market crash that affected many stocks, mini flash crashes can affect the price of just one stock. For example on October 7, 2008 the Goldman Sachs Group, Inc. stock fell 1.6% in 400 milliseconds. This mini crash included 58 trades totalling 86,000 shares (Golub, Keane and Poon 3). Figure 2 below illustrates the Goldman Sachs mini crash.

[8] 13 public exchanges, 30 dark pools and over 200 internalizing broker dealers (Golub, Keane and Poon 19).

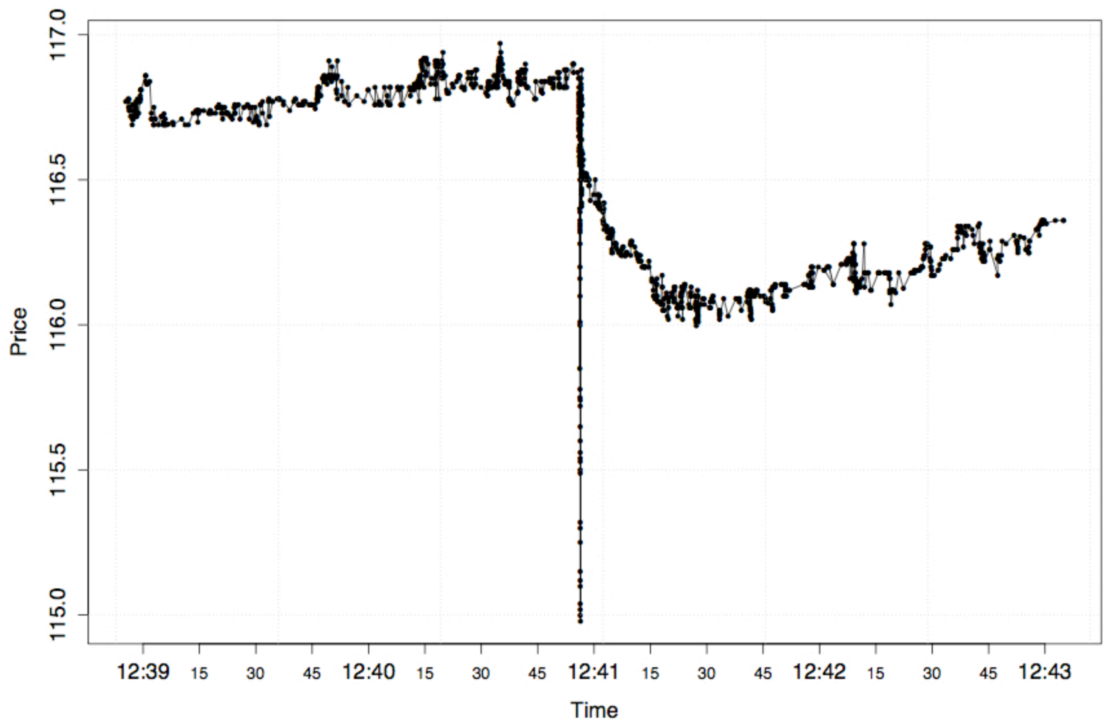

Figure 2: Goldman Sachs Group, Inc. Mini Flash Crash (Golub, Keane and Poon 3).

Mini flash crashes reveal that the speeds of HFT allow for irregular behaviours such as this to occur. Fifty-eight trades occurring within 400 milliseconds are impossible for a human trader to respond to. This almost instantaneous crash, which decreased the share price of Goldman Sachs by $1.89, was not based on any real news data. It was a type of glitch or possible price manipulation. Thus mini crashes, like quote stuffing, describe an environment within electronic trading that do not add value to the markets through actual liquidity. Both types of occurrences illustrate how the speed of HFT does in fact have negative effects on the overall fairness of financial markets. If the stock market is to provide liquidity and thus capital for companies and investors, the role of HFT is questionable if practices such as quote stuffing and mini flash crashes continue to occur.

The Complex Nature of HFT

While HFT does add value to financial markets through increased liquidity, I am interested in the repercussions brought about by these increases in speed such as mini market crashes and quote stuffing. Similarly, as HFT now serves as the infrastructure of the major Stock Exchanges, simply eradicating this type of trading would be impossible and slowing down the rate at which transactions occur would affect the ease with which stocks are traded. Furthermore, the major Stock Exchanges record every quote placed on their exchange; however, there is no universal system in place that analyzes each of these quotes for irregularities. The individual Exchanges such as the NYSE and the NASDAQ might penalize firms that use excessive quote stuffing but the sheer volume of trading that occurs on a daily basis, now that HFT has taken over the landscape of these Exchanges, makes this task extremely difficult to enforce. It is also in the interest of the Exchanges that these high volumes of trading exist as they generate fees from every transaction that occurs.

These varying roles are why HFT is such a complex topic and why there is so much controversy surrounding the future of this type of trading. The speed at which HFT algorithms occur describes a system that favors institutions with large amounts of wealth they can invest in building the infrastructure that can support these types of practices. The initial support of integrating electronic trading into the major Stock Exchanges on Wall Street was to make trading more fair and accessible to the average investor. Government regulation paved the way for electronic trading and finally HFT was set in place to reduce the competitive advantage that insiders on Wall Street had over everyone else. Over time however, this equalization disappeared, and insiders using HFT once again have an advantage. Understanding the history of HFT and thinking about how it may evolve as computing speeds are further increased has made me consider how I might begin to uncover the logic that is inherent within these algorithms.

The Abstract Nature of HFT

While Patterson illustrates how HFT came into existence and I have described why insiders believe HFT is of benefit to markets, I will now address David Graeber's research into the history of debt in order to demonstrate how HFT is further alienating our understanding of virtual capital. While stock trading is an abstract concept where stock value is far from the actual value of the objects that are represented, Graeber demonstrates that money also originated as a virtual entity as it was derived from the concept of debt. Only later did money acquire a physical medium in the form of coins and currency (Graeber 7). For example, Graeber describes an early form of recording debt in the form of tally-sticks between two parties, whereby sticks would be broken in half and each party would take one half as proof of the debt agreement. These sticks were not actual currency for trading but a signifier for debt. The early days of stock trading were similar to the representations of tally-sticks: as stocks traded hands, a paper receipt indicated that a transaction had taken place. Although brokers trade stocks, which represent a price that the market believes something is worth, stocks are intended to represent things that exist as products in our economies. This, however, is becoming less common as new types of abstract financial products are being introduced into trading systems. According to Graber, our current era is a "'financialisation' of capital, whereby speculation in currencies and financial instruments becomes a domain unto itself, detached from any immediate relation with production or even commerce" (Graeber 14).[9]

This detachment Graeber speaks of is further abstracted through the instruments of HFT, which likewise have little direct connection to the commerce of everyday life. When the majority of trading shifts to automated trading thorough HFT, all trading thus becomes a highly abstracted form. The virtual understanding of currency, credit and debt have existed for centuries, but with the progression from one form to the next, we see an increasing degree of virtualization until we finally arrive at where we are today. We are able to comprehend the virtual nature of debt, currency and stocks, but we begin to lose comprehension when these virtual products are traded at the microsecond level. When prices fluctuate faster than our ability to act and make sense of these changes, then we are in fact living in a purely abstracted world that is better suited for the logic of code. Building on Graeber's account of the history of debt and its relationship to virtual currency, HFT further facilitates the progression towards a domain that is becoming comprehensible solely to the instruments that make up this highly abstracted landscape.

[9] Graeber speculates that 97% to 98% of money in Western economies is in fact debt (Graeber 5).

III. Theoretical Influences

Paul Virilio on Speed

The emergence of HFT and the significance of these changes can be discussed from various perspectives. I have chosen to examine HFT through the theories of Paul Virilio in order to focus specifically on what the speed of HFT means within a broader cultural context. I will discuss HFT comparing this area of finance to Virilio's thoughts on the accelerated society, the loss of space, and the global accident.

Virilio is interested in both negative and positive speeds, and the acceleration and deceleration of our cultural phenomena (Redhead 53). When technologies become hyper-accelerated and operate at speeds that approach the speed of light, it becomes difficult for analytical decisions to be made. Virilio understood this, stating "What lies ahead is a disturbance in the perception of what reality is; it is a shock, a mental concussion" (Virilio 1995). The speed of communication technologies alters the way in which we see and perceive.

> "Speed enables you to see. It does not simply allow you to arrive at your destination more quickly, rather it enables you to see and foresee. To see, yesterday with photography and cinema, and to foresee today with electronics, the calculator and the computer. Speed changes the world vision" (Redhead 45).

Speed, according to Virilio, has altered our understanding of reality. For Virilio, the ultra fast speed of electronic systems in our contemporary milieu is tyrannical. When information systems become fully integrated into our cultural practices, we are constrained by the speed at which these events take place. Virilio believes that ultimately the world is undergoing a transformation where all localized events are being eliminated as we enter into an era where one globalized time takes precedence.

Economies and Stock Exchanges once were localized systems. With the rise of electronic trading and HFT, these markets are now interconnected, forming one large global network where stocks can trade on multiple exchanges at all hours of the day such that "speed and wealth go hand in hand" (Redhead 44). From the perspective of the integrated financial markets of the global economy, Virilio is correct when stating that we are living according to a one-time system or global time (Redhead 53). Local events on the global financial system no longer occur in isolation but rather all local events become intertwined and feed off one another. When one financial exchange is sick, another one catches a cold. A one-time system allows for capital to freely move between markets; however, the potential for systemic collapses becomes ever more serious.

Reduction of Space

Acceleration has also brought about a disruption to our perception and understanding of geographical space. Local events that occurred within physical space and held significance are no longer relevant. Electronic networks that allow for events to occur in a non-space or in several spaces at once shifts the importance of the actual event to the importance of the speed of the event. Virilio, discussing this loss, writes,

> "The reduction of distances has become a strategic reality bearing incalculable economic and political consequences, since it corresponds to the negation of space. The manoeuvre that once consisted in giving up ground to gain Time loses its meaning: at present, gaining Time is exclusively a matter of vectors. Territory has lost its significance in favor of the projectile. In fact, the strategic value of the non-place of speed has definitely supplanted that of place" (Virilio, 1986 133).

Comparing this to the rise of HFT, we see that localized trading loses its importance. The speed of electronic trading becomes the new pursuit. Computer servers replace the trading floors of the Stock Exchanges and computer algorithms replace the human floor traders. Technological innovation focuses on increasing the speed at which HFT algorithms can function more efficiently and thus maximizing the speed of transactions becomes the one overarching goal of the financial industry.

Colocation, which is the latest trend in HFT, reveals that the loss of space in favour of speed is in fact very real. With colocation, HFT algorithms are installed onto servers that physically exist in close proximity to the Stock Exchanges on which they are placing trades. By placing these algorithms as close as they can to the exchanges, the amount of time a trade takes to be executed is reduced. Colocation is a clear example of how the significance of space has been replaced with "the strategic value of the non-place of speed" (Virilio, 1986 133).

The reduction of space is also evident in a second area of technological innovation aimed at increasing HFT speeds. Known as Seasteading, the goal is to place servers strategically around the world, situated between the major Stock Exchanges, to reduce the latency of electronic trading (Price). This includes placing servers in regions completely outside of the centres of finance such as oceans and in rural uninhabited areas (See Figure 3). While these servers occupy space, the transactions only pass through these electronic hubs and are thus in strategic non-places. The significance is not the location of the server, but the speed at which a trade can be executed through these electronic hubs.

Value is therefore placed on the speed of trading and is "attributed to the delocalization of the vector, of a vector in permanent movement. All that counts is the speed of the moving body and the undetectability of its path" (Virilio, 1986 135). Colocation demonstrates a trend that is in fact eradicating the importance of geography. Geography is being altered solely for the purpose of creating low latency information highways.

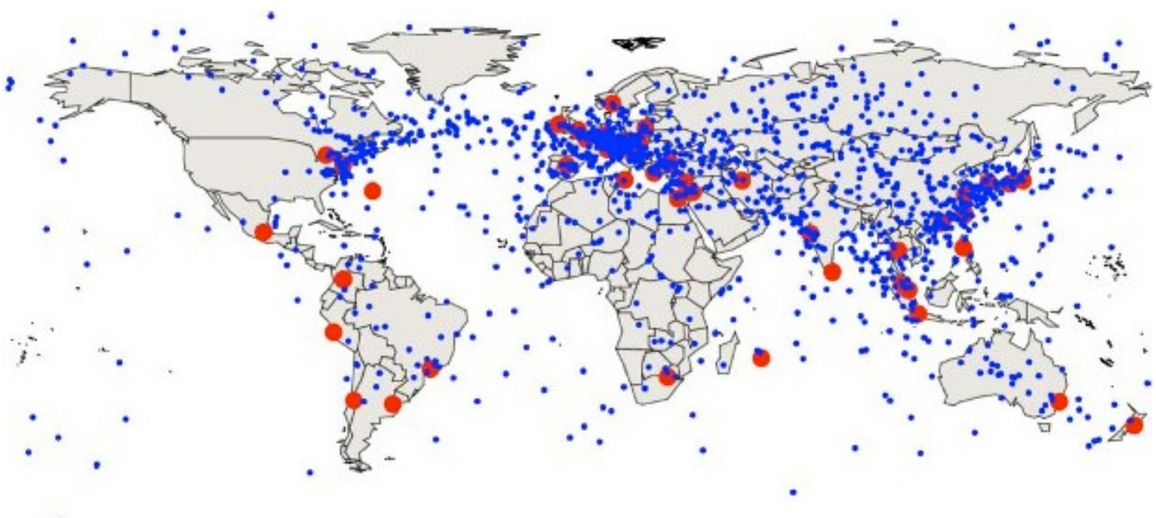

Figure 3: Seasteading Map: red circles represent Stock Exchanges and blue circles represent locations for trading servers. (ThemisTrading.com)

Global Accident

Virilio insists we understand the dual essence of technology. For every new technology introduced, "an accident is invented together with it" (Armitage 32). For example, when the railway was invented, the possibility of derailment was also introduced and with the invention of airplanes, the potential for plane crashes is created. Each of the accidents associated with these particular technologies are localized events.

They happen at a particular time in one particular place. They are localized because they function at relative velocities (Armitage 32). With the introduction of telecommunication technologies, whose speed of execution approaches the speed of light, the accidents these technologies create are no longer local. These accidents are general accidents, occurring in multiple locations at the same time. This gives rise to the possibility that this type of accident can "destroy everything" everywhere at the same exact time (Armitage 32).

Electronic trading, thereby linking all the global financial markets together into one large network, has created the potential for a large-scale systemic accident. The Flash Crash of 2010 is a perfect example of what Virilio meant by the global accident. The speed of electronic trading, accelerated by HFT algorithms, created a chain reaction throwing every Stock Exchange around the world into disarray. Before electronic trading, market crashes on a given Stock Exchange might have affected other exchanges in a given day; however, market crashes did not happen simultaneously. The global accident Virilio warns about is inherent in the new system of HFT that occurs on the global financial trading system. With the speeds of HFT, we see that "a very small occurrence changes everything, as the speed of quotations and programmed trading spreads and enhances any trend instantaneously" (Armitage 32).

Was the Flash Crash of 2010 and the credit crisis of 2008 in fact the global accident Virilio spoke of? The global credit crisis clearly was felt all over the world from the United States to Europe and Asia, as was the Flash Crash, which spread to all of the major Stock Exchanges instantaneously. However, Virilio does not believe that a stock market crash is the real global accident. "The stock-market collapse is merely a slight prefiguration of it. Nobody has seen this generalized accident yet" (Virilio 1995). Whether or not a stock market crash is in fact the global accident Virilio spoke of, HFT algorithms have the potential for acting as catalysts, accelerating these global accidents when they do in fact occur. The potential for catastrophe always remains present as the accident is embedded within the infrastructure of HFT. Speaking about the dangers of acceleration in relation to nuclear weapons Virilio writes,

> "Today, the reduction of warning time that results from the supersonic speeds of assault leaves so little time for detection, identification and response that in the case of a surprise attack the supreme authority would have to risk abandoning his supremacy of decision by authorizing the lowest echelon of the defense system to immediately launch anti-missile missiles" (Virilio, 1986 137).

The same danger is true for the global stock markets if we understand HFT as having the potential for similar destructive responses. Limited response times for both these electronic systems simply trigger reactionary responses. What was evident with the Flash Crash was that HFT algorithms began firing in response to mass selloffs, thus triggering additional declines. HFT accelerated the panic and left little room for investors and traders to pause and think rationally about what was in fact occurring.

Global Capitalism

Now that HFT constitutes the majority of daily stock trading across all of the major Stock Exchanges, it is becoming clearer how global capitalism has become one intertwined network. The potential global accident is clearly becoming a looming reality. Arthur Kroker, in the wake of the global credit crisis that occurred in 2008, writes about Virilio's precise understanding of the impact of speed on telecommunication technologies and how they have affected financial markets.

He writes,

> "hyper-technologies of global financial manipulation that can move so quickly because, just as Jean Baudrillard long ago warned, the hyperreal, simulational world of derivatives, credit swaps, and mortgage backed securities long ago blasted off from material reality, reaching escape velocity, and then orbiting the world as star-like high finance satellites—purely virtual satellites which have no real meaning for the rest of us as long as they stay in space as part of the alienated, recursive loops of advanced capitalism. But when the meltdown suddenly happens, when that immense weight of over-indebtedness and toxic mortgages and credit derivatives plunge back into the gravitational weight of real politics and real economy, we finally know what it is to live within trajectories of the catastrophic" (Kroker 160).

Kroker clearly states that the speed of technologies that Virilio spoke of has enabled the financial industry to achieve a level of moving virtual capital around very well, but yet so out of sync with the realities of what this capital is supposed to represent. Only when there is a meltdown or catastrophe, does the significance of these high-speed actions appear. The problem remains that these realities, or "trajectories of the catastrophic", occur after the crisis has occurred, and at a delayed response. The credit crisis did not occur overnight, but the speed at which financial transactions occurred during this period accelerated the impact of this crisis. Writing about the impact of the credit crisis, again Kroker states,

> "Here, the brilliant software innovations and computerized trading programs that run so much of the world's economy move so quickly but respond so slowly to the complex information feedbacks of recursive loops of bank failures and toxic debt and storms of warring political opinions that they do the only logical thing possible. They quickly, globally, and simultaneously abandon their own hyperreal world of virtuality, and go to ground in a panic search for authentic value" (Kroker 161).

The HFT algorithms Kroker references are responsible for moving around so much of the global capital but they are not able to respond to the complexities within these markets.

As seen during the Flash Crash of 2010, the selling off of assets, causing a 20 percent drop in the DJIA within 20 minutes, revealed that these algorithms were not robust enough to deal with this type of event. Kroker is correct when he states that these algorithms facilitate the quick dumping of assets in search of “authentic value”. Broadening the implications of the speed of HFT algorithms, he reveals the true nature of what these accelerated processes bring about. If the speed of transactions occurred in sync with our understanding of what these financial products represented, we might be able to foresee their impact on a larger scale. The speed at which the financial markets shift capital around on a microsecond level, however, hinders this type of analysis.

By analyzing HFT from the perspective of Paul Virilio's theories, my intention is to demonstrate that the speed of HFT is what is of significance. HFT is clearly reducing space to a non-space and likewise creating the possibility for global accidents to take place. Each of the dangers Virilio describes, however, would not exist without the acceleration brought about through HFT.

IV. Methodology/Body of Work

Similar artworks focusing on Stock Trading

In order to situate the work I have produced within a larger artistic context, I will discuss three similar projects that concentrate on the nature of stock trading. These artworks highlight the controversial qualities of stock trading through the mediums of video art, software design and art installation. They draw attention to the decision-making processes made by stock traders and financial analysts by rendering these processes visible.

Crisis in the Credit System is a series of videos written and directed by Melanie Gilligan. Gilligan has performers act out hypothetical scenarios playing out the roles of various professions within the financial industry. Each scene in her videos takes the form of brainstorming sessions, whereby performers try to devise strategies for dealing with the credit crisis. In one scenario, two fund managers speculate on how rising food costs will put a strain on the spending habits of the population and so good eating habits will become less important. As a result they determine that "fat will be the new thin" and so they will "go long on fat", meaning they will invest long term on the hope that fat will become the new norm.[10] And so they will sell their shares in companies such as Weight Watchers that provide healthy food options and buy companies that sell fast food. Gilligan's scenarios are clever descriptions that reveal the logic of how certain financial practices go to these types of extremes in order to maximize profits. The rationale revealed in these videos is the same as that found within HFT algorithms. Gilligan uncovers the internal reasoning made by financial analysts representing these scenarios as fictional stories. These scenarios might seem absurd and extreme, however they are not far off from what actually occurs within the financial industry.

The Superstitious Fund is a project by Shing Tat Chung where the artist has designed a trading algorithm that bases its decisions on lunar cycles and numerology. Chung outlined the rules of an algorithm based on superstitious data and then had a

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[10] Melanie Gilligan, *Crisis in the Credit System.* http://www.crisisinthecreditsystem.org.uk

computer programmer implement these rules into computer code. Chung would then use his algorithm to place trades on various stock exchanges. The total value of Chung's fund rises and falls on a daily basis based on how well the trading algorithm performs on a given day. Chung has tried to reveal that superstition is part of our cultural logic and thus should also be embedded in the logic of trading algorithms. He cites the example that in the United States, an estimated $2.4 billion is lost annually due to the fear of Friday the 13th.[11] Chung reveals how superstitious beliefs contribute to economic decisions and concludes that this same logic should thus be used within stock trading. *The Superstitious Fund* similarly pokes fun at the internal reasoning found in trading algorithms.

The final project I will discuss is Nancy Patterson's *Stock Market Skirt*. This project takes the form of an art installation that consists of computer monitors displaying stock prices situated around a blue party dress. The hemline of the dress is raised and lowered based on the current price of a particular stock. Patterson reveals the erratic fluctuations in the market but she also has to some degree slowed down the rate of change. By converting the signal from the stock price into motion that is activated through a motor and pulleys that move the hemline, Patterson has in fact slowed down the rate in which the stock prices actually change and has given this impersonal data significance on a cultural level. Her project is also ultimately a statement on how women's fashion follows economic activity.[12]

Each of these projects investigates particular areas within financial trading. Gilligan examines the social consequences that emerge when insiders make changes to

[11] Shing Tat Chung, *The Superstitious Fund.* http://shingtatchung.com/the-superstitious-fund-project
[12] Nancy Patterson, *Stock Market Skirt*. http://www.vacuumwoman.com/MediaWorks/Stock/stock.html

their strategies to survive during a time of panic, Chung reveals the strange logic or illogic that is part of financial trading and Patterson looks at financial trading from a feminist perspective, calling into question how women's fashion is dictated by economic and trading decisions. The work I have created discusses stock trading by focusing specifically on the speed of HFT as my goal is to reveal the strange decisions that these algorithms make by slowing them down to a rate that we can begin to understand. I also use deceleration as a way to comes to terms with how fast HFT algorithms function by experiencing these algorithms within our normal rate of interacting with phenomena.

Representation of HFT Algorithms

I am using new media technologies as a method of investigating how HFT can be made accessible in order to understand the controversial characteristics of HFT practices that are occurring faster than we can comprehend. HFT algorithms used in actual trading are designed by writing code that outlines the precise logic that an algorithm will follow when placing trades. I am writing my own code to describe how the artworks will function in order to simulate this process. While the executed code running within my projects occurs almost as fast as HFT algorithms, the visual representations that are observed occur at reduced rates. Slowing down the speed at which these algorithms are made visible, my intention is to ask: What does this deceleration reveal about the HFT algorithms these projects are symbolizing? Each of these projects acts as a circuit breaker highlighting the need for deceleration. The audio and visual representations of HFT algorithms in these projects suspend the movement of these algorithms for long enough that we are able to see and hear within our localized time.

Deceleration as a Mode of Inquiry

Each of the works I have created are renditions of HFT algorithms. I am using deceleration as a mode of investigating how we can begin to understand the inner working of HFT algorithms. As the speeds of our systems are accelerated to such a degree that "fundamentally interrupts human capacity for understanding and judgment", I am intentionally overturning this progression to highlight the qualities that are being lost through acceleration (McQuire 93).

With the aid of HFT algorithms, traders are able to see and foresee market trends. On the microsecond level, HFT algorithms are capable of perceiving and reacting to market events before they have come to fruition. HFT algorithms are exceptionally good at doing this; however, these algorithms cannot contemplate what these market events mean on a larger cultural scale. When a HFT algorithm has reacted to an event, and once financial analysts and traders respond to these price movements, we finally see the results.

Contemplation, analysis and informed judgements are a form of deceleration. Our human perception can never exist within the microsecond world of HFT. Our normal well-informed mode of being is in fact deceleration. Slowing down our decision-making processes allows us to make informed decisions and think about the consequences of these decisions. The importance of deceleration exists within our shared mode of being. Deceleration thus allows us to see and act. However, the tyrannical speeds of HFT threaten our ability to maintain this mode of action. How can we preserve our slower cultural practices when the systems in which we operate obstruct these modes of action from occurring?

Within the Stock Exchanges, circuit breakers exist to slow down generalized market flash crashes and prevent individual stocks from experiencing mini crashes. The three works I have created all aim to act as metaphorical circuit breakers. The pace at which events occur within my work happen slowly in order for people to see the intricate operations and logic that is embedded within HFT algorithms.

The approach I am utilizing for these projects is similar to the technique used in *Skulls* by Robert Lazzarini as described by Mark Hansen. Hansen discusses how Lazzarini's technique of distorting the scale and perspective through digital techniques reveals the "disjunction between human perception and digital techniques" (Cecchetto 13). In his work, Lazzarini has digitized an actual skull into a two dimensional image, then applied digital transformations to the image and finally outputted the form to a rapid prototyping machine to create a three dimensional skull once more. The result is a series of skull sculptures whose geometries do not make sense. What these digital transformations reveal is that although we can perceive the objects as skulls, we recognize that they do not fit in to the physical logic we are accustomed to. Hansen believes that the content that is perceived by viewing the skulls is not in fact visual as it "displays a logic that is fundamentally at odds with that of vision" (Cecchetto 12).

The three works I have created each aim to highlight the disconnected logic inherent within HFT algorithms. While I am simulating HFT algorithms at reduced rates, the odd qualities brought about by the logic embedded within these algorithms are rendered visible. Because HFT algorithms are not seen as they truly exist, but rather through the abstractions I have created in the form of these projects, we come to understand how foreign HFT really is. In the following sections, I will discuss each project and talk about what is revealed through the process of deceleration.

News Aggregate (slowed down by 500,000 %)

News Aggregate (slowed down by 500,000 %) simulates existing HFT algorithms, which scan online news feeds. These algorithms collect relevant data from these feeds in order to determine whether a particular stock should be bought or sold. The work I have created is a dual projection where custom software projects extracted news articles collected (See Figure 4). Over time, the text from each article slowly fades away leaving behind only the relevant keywords collected by the HFT algorithm. The size and speed of this installation are inversely proportional. The size of this installation is expanded across a large wall space creating an installation setting that is impossible to view in its entirety. Similarly, the speed at which the newsprint fades away and steps through each article is slowed down to a pace that is comprehensible and thus allows for contemplation to occur. This HFT algorithm is out of sync with the actual environment in which it exists. As the title suggests, the speed of human perception has taken precedence.

Deceleration reveals how an HFT algorithm makes decisions about what type of information is relevant and what words should be discarded. The keywords used by HFT algorithms to determine what information within a news article should determine trading, are all that remains once the irrelevant words in the article fall away. Words and contexts having significance within our cultural environment may not be of significance to an HFT algorithm. This is evident when observing this installation over time. Overall, this process reveals bizarre summaries that emerge from each news article. In one example, only the words ***reduce***, ***improve***, ***percent*** and ***hold*** remain as the HFT algorithm has decided that all other contexts are insignificant. The resulting decision made by the algorithm is to hold on to this particular stock and not place a buy or sell order. As the HFT algorithm is in pursuit of generating a profit, the summary of the remaining words reveals an impersonal outcome that has no interest in the world in which these decisions are made.

Deceleration thus allows us to make informed judgements of what is in fact taking place at the microsecond level. Virilio understood that speed allows us to see. Deceleration, similarly, also allows us to see, where seeing consists of contemplating, questioning and understanding.

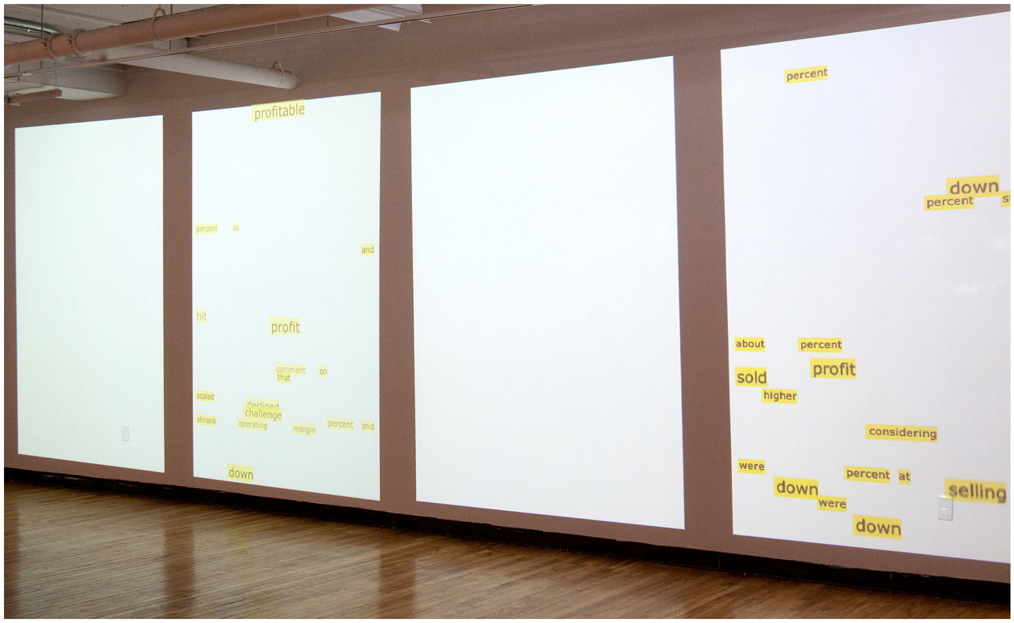

Figure 4: News Aggregate (slowed down by 500,000 %)

High Frequency Trader

High Frequency Trader is a game that represents both the historical changes and speed of HFT. This artwork pays homage to the tabletop arcade games that existed in the late 1980s, a time when HFT began to emerge. The intention of the game is to create a playful environment that is equally critical of HFT techniques.

The game exists within the historical candlestick price charts[13] of the Dow Jones Industrial Average from 1990 to the present day. Each candlestick represents the daily price changes of the DJIA and is a level in the game. Within each level the player is represented by an avatar of a businessman, who acts as an independent trader on the stock exchange. Within the game environment there are two types of traders, one being High

[13] A candlestick chart represents the price movements of a stock over time. See Figure 5.

Frequency traders and the second being all other investors. All of these traders are also represented as businessmen avatars. A player's avatar can trade with other avatars in order to generate capital. Similarly, a player's avatar must try to avoid HFT avatars, who, in the process of making trades, will steal capital from the player's portfolio. The goal of the game is not to complete every level (which is challenging as there are over 8000 levels) but to generate as much capital during the course of the trading day.

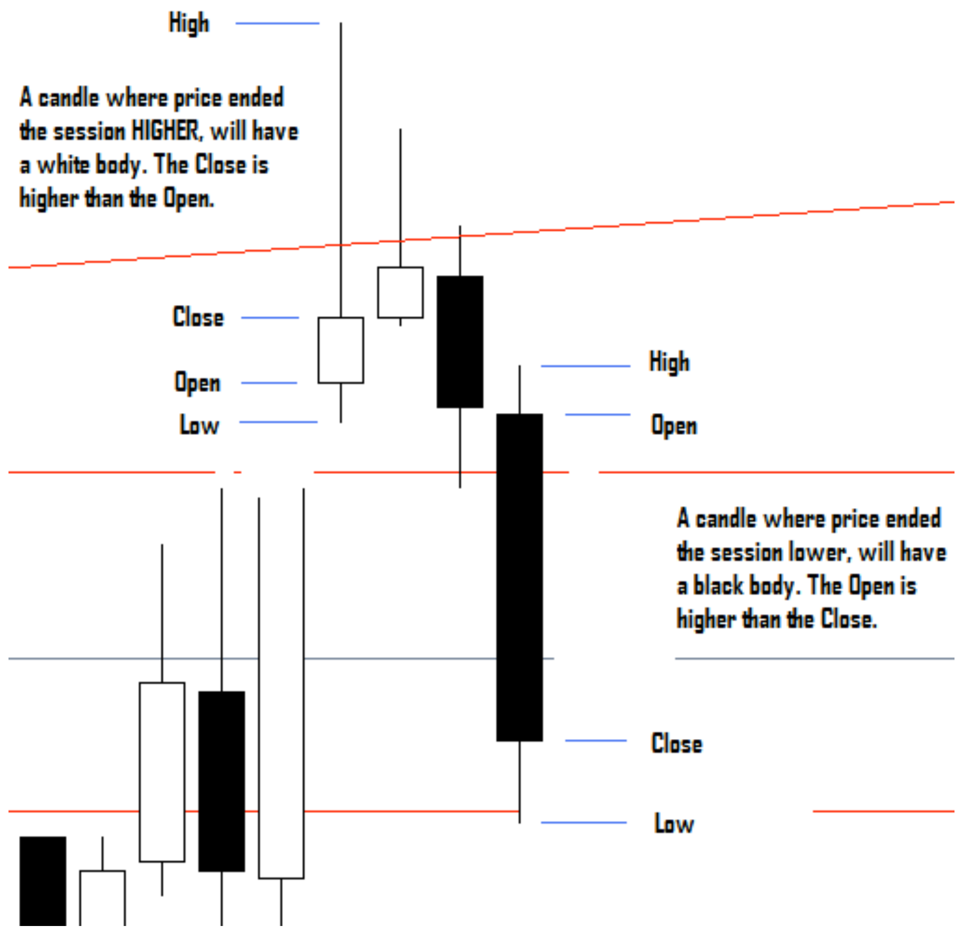

Figure 5: Candle Stick Price Chart (ferrowolf.wordpress.com)

The background scene of each level is used to mimic the candlestick of that particular trading day (See Figure 6). A daytime background scene is used to represent the white candlesticks signifying that the DJIA closed higher than it opened. A night scene is used to represent the black candlesticks, in which the DJIA closed lower than it opened. These slight changes to the game landscape are used to further show the scale of each level in relation to the entire period a player of the game traverses over time.

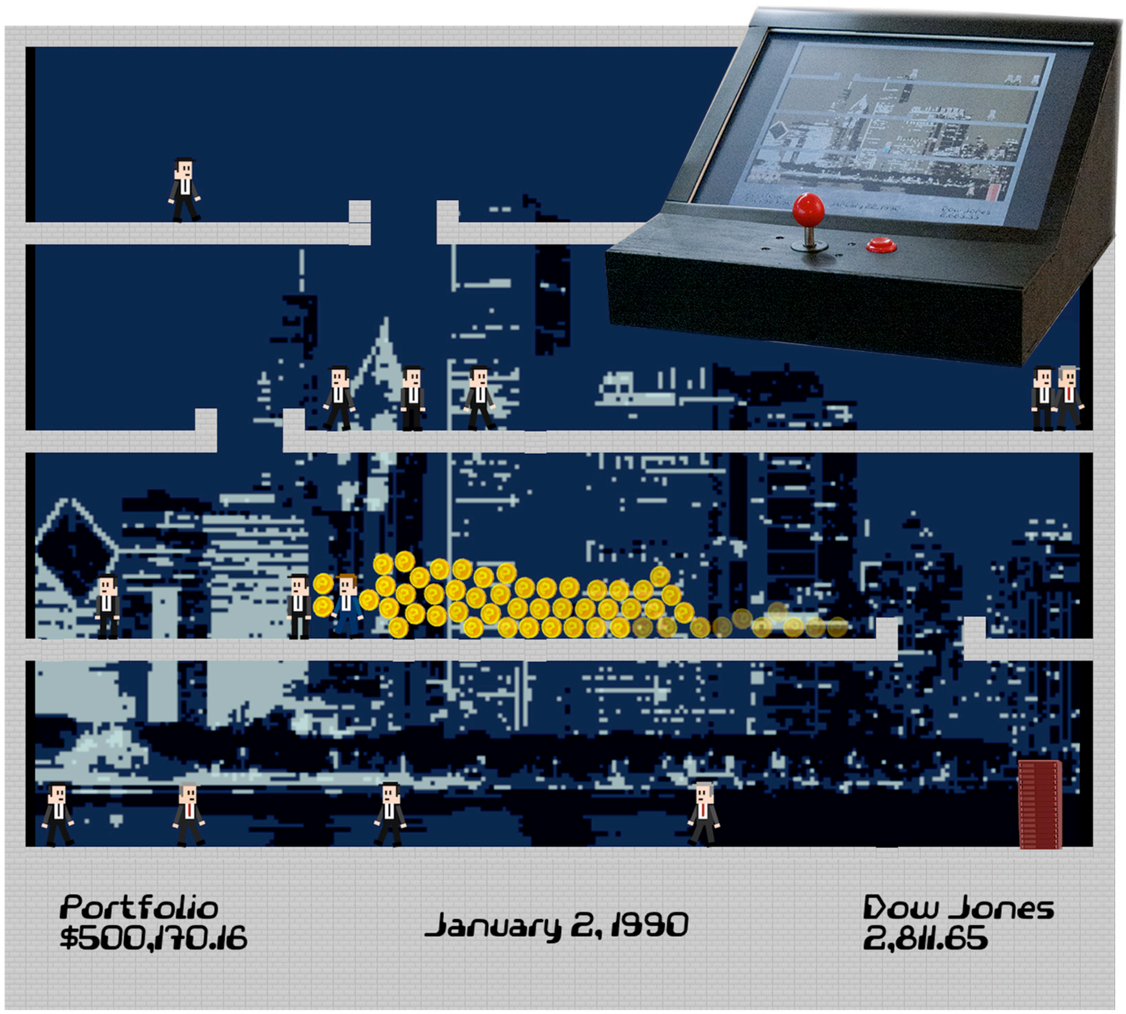

Figure 6: High Frequency Trader

The game play and graphics are minimal, emulating early arcade aesthetics. The speed of the avatar's movement in relation to the HFT avatars is where I am addressing the nature of HFT. During times of increased HFT on the Stock Exchange, I am altering the physics and speed of the avatars. The speed of the High Frequency traders become extremely fast during these moments, while the speed of the player's avatar slows down significantly. By decelerating the rate at which a player can move, the HFT avatars are able to attack the player and steal pennies from them. This is addressing the concern that HFT does not in fact create added liquidity to the market, but rather the high speed trading environment allows for HFT algorithms to accumulate penny differences each time, stealing fractional differences from individual investors.

The game play is extremely frustrating when a player's avatar is slowed down while the HFT avatar's movement remains quite fast. The unfair advantage that HFT avatars have during these times of deceleration is clearly evident. This design decision was made to reveal the idea discussed by MacKenzie that we cannot perceive speed but only the difference of speeds.

The unending nature of the game also illustrates the nature of HFT algorithms. During the game, a player's avatar continuously adds capital to his/her overall portfolio. There is no real way of reaching a Game Over state, unless the portfolio drops below zero, resulting in bankruptcy. However, I have designed the game so that the portfolio begins with a high value making the possibility of bankruptcy unlikely. Similarly, since the game consists of over 8000 levels, there is little chance of completing the game entirely. My intention is to create an environment for a person to play for a short period of time and then leave the game as is. The idea is that over time the portfolio will rise and fall. HFT firms trade daily and over time build up their investment portfolios. As they are the market makers on financial exchanges, they are in the business of ensuring that transactions continue to occur. The HFT algorithms continuously run behind the scenes even when it seems that they are not present.

The extremely slow pace of the game during times of increased HFT volume demonstrates the absurdity that exists between the differences in speeds. Players cannot escape these imposed circumstances within the game and so they must fully address why these changes in speed are occurring. The speed of HFT algorithms that are usually invisible running behind the scenes have been made visible, and through this manifestation the difference in speed cannot be ignored. The change completely limits the player's ability to act and hinders his/her control of the game. During these decelerated times, the HFT algorithms become ruthless and it becomes difficult to not get upset and feel cheated as the HFT avatars steal hundreds of pennies from the player's avatar. In these moments it is clear that the game is biased and weighted in favour of the HFT players. Overall, the player thus is able to experience the space in which HFT algorithms exist, and realize that this non-space is quite unjust.

High Frequency Trader creates an environment for players to understand what is occurring on a microsecond level. The black humour, arcade aesthetic, cartoon characters and playful sound effects all contribute to providing a player with a fun experience while allowing for them to form their own critical perspective on HFT.

Mobile Trader

Similar to *News Aggregate*, the speed at which *Mobile Trader* takes place has been slowed down significantly. This project exists as an audio-visual mobile application that runs on smartphone devices. People entering the gallery space can download the app and have it run during the duration of their stay. The mobile app is a simulation, placing users in the role of HFT algorithms.

This work focuses on the changes that HFT brought about on financial markets. HFT displaced the traditional floor traders for matching trades between buyers and sellers. The work is a sound installation that exists both on a mobile device and in the way that participants interact with one another through the software. Participants interact with one another on a simulated trading floor within the gallery space. The virtual out of sync nature of HFT is brought back to a localized environment. By having people place trades using audio tones, the speed of transactions are slower and thus perceivable.

Trades are represented by audio tones that reference the opening bell of a trading day that still exists and is rung on the trading floor of the NYSE. The ringing of the bell is symbolic, as it is not required for informing electronic trading systems that the trading day has begun. I have incorporated the opening bell into this work as a playful gesture to reference the absurdity of this tradition.

The playful approach of the software allows participants to trade amongst themselves at a reduced rate. When two participants agree to place a trade, the audio tones from their phones are switched and the resulting tones are played back on their devices (See Figure 7). I am using Frequency Modulation (FM) synthesis as a technique for matching trades so that participants receive audio feedback when a transaction has occurred. This synthesis technique is simple enough for participants to understand the interaction that has occurred. By creating a space where multiple people trade with one another, an overall soundscape constantly evolves.

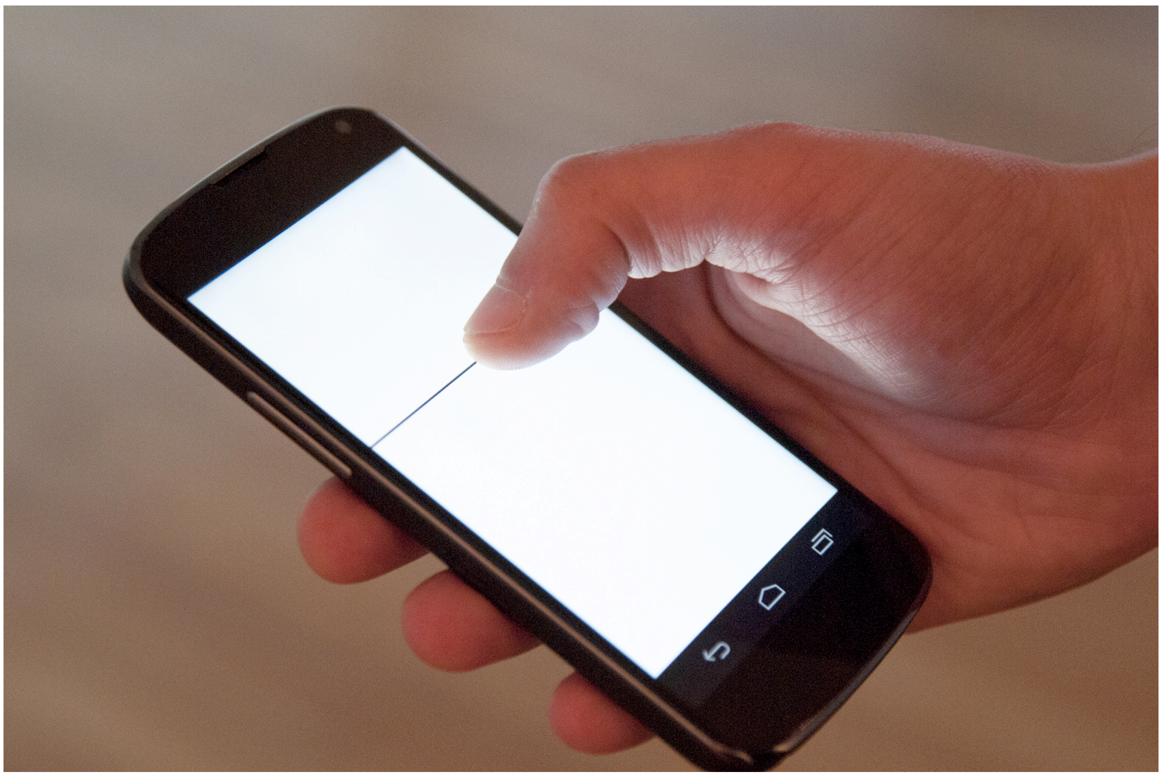

Figure 7: Mobile Trader

By converting HFT trades into sound waves, I am slowing down the speed of these algorithms into a medium that is audible. Although FM synthesis can create frequencies beyond our hearing range, the tones I am using as source material consists of frequencies that are quite low. The lower tones signify slower sound waves as opposed to higher frequencies that occur in the thousand hertz range, which are closer to the actual speed of HFT algorithms.

As participants must place trades through a touch interface on their mobile device and move within the gallery space to form interactions with a variety of participants, the trades that occur happen much slower than they should. The physical limitations of our bodily actions naturally hinder the rate in which synthesized bell tones can be generated. HFT algorithms that are represented through sound in this abstracted form of trading, have brought the rate of trading into an arena that the public can begin to contemplate. Deceleration through interaction and the use of audible sound tones has made HFT comprehensible. Only when we realize that our actions within the gallery space are simulations of what is in fact occurring every microsecond, do we realize that HFT is quite incompatible with our daily, lived experiences.

V. Conclusion

The *Out of Sync* exhibition and this thesis document have described the accelerated nature of HFT. The historical background provides a description of how HFT functions and how this form of trading came to exist within financial trading systems. The theoretical explanations situated HFT in a larger cultural context by discussing Virilio's theories on speed and how HFT contributes to the loss of space and creates the potential for a global accident. I have demonstrated how the use of deceleration allows for a place where we can unpack and begin to understand the implications of the ultra fast pace of HFT. In addition, the technique of deceleration reveals the decision-making processes built into the code of HFT algorithms and how the events I have made visible through these works exposes the temporal divide between the place in which these algorithms occur and that of our localized experiences. Each of these projects has put into practice the method of decelerating HFT algorithms into forms that are more easily discerned.

As these projects aim to represent HFT algorithms through computation, I am demonstrating that in order to begin to understand what is lost and gained with HFT, we must slow down the process of execution. Through deceleration, I am able to reveal the hidden realities of HFT algorithms. Within software design, large design problems are broken down into smaller parts and executed in subroutines. The logic is that when these subroutines are once again combined, the larger design problem can be solved, as the whole becomes the sum of its parts. Within this thesis project, I have utilized this technique in order to break down the complexities of HFT algorithms. As demonstrated with *News Aggregate*, we can begin to understand how HFT algorithms function if we are given enough time to analyze the qualities that emerge by running these subroutines at a reduced rate. Similarly, these projects have allowed me to situate these virtual forms into a space where participants can begin to understand this abstract form of finance that no longer exists within a local environment.

HFT is isolated from most of our daily activities; however, it does represent the beginning of a trend to accelerate other types of information systems. Since financial institutions had the capital to invest in the infrastructure that made HFT possible, the question remains what will happen when these ultrafast execution times begin to enter into other cultural systems. Virilio's warning of a global accident could in fact begin to take place on a larger scale if these changes do occur. As I have previously stated, it would be difficult to simply eliminate HFT, as it now performs the majority of daily trading on the global Stock Exchanges. An outright ban would also come across as blocking the progress within financial trading systems. So what will happen when HFT and other systems reach nanosecond speeds? This thesis acts as a gesture by questioning what is at stake if we fail to slow down and take the time to make informed decisions about our future accelerated society.

Bibliography

Armitage, John. *Virilio Live: Selected Interviews*. London: Sage Publications, 2001.

Avramovic, Ana. "Who Let the Bots Out? Market Quality in a High Frequency World." *Credit Suisse,* March 19, 2012.

Brekke, Dan. "Daytrading Places. Forget Nasdaq. Island ECN is tearing down Wall Street." *Wired Issue 7.07*, July 1999. http://www.wired.com/wired/archive/7.07/island.html.

Cecchetto, David. "Deconstructing Affect: Posthumanism and Mark Hansen's Media Theory." *Theory, Culture & Society*. September 2011.

Christie, William, and Schultz, Paul. "Why Do NASDAQ Market Makers Avoid Odd-Eighth Quotes?" *Journal of Finance*, 49(5), December 1994.

Chung, Shing Tat. *The Superstitious Fund.* July 12, 2013. http://shingtatchung.com/the-superstitious-fund-project.

Crosswaite, Paul. 'The Accident of Finance.' *Virilio Now: Current Perspectives in Virilio Studies*. Ed. John Armitage. Cambridge: Polity, 2011.

Featherstone, Mark. "Virilio's Apocalypticism." September 16, 2010. CTheory.net http://www.ctheory.net/articles.aspx?id=662.

Gilligan, Melanie. *Crisis in the Credit System.* July 12, 2013. http://www.crisisinthecreditsystem.org.uk.

Golub, Anton, John Keane, and Ser-Huang Poon. "High Frequency Trading and Mini Flash Crashes". *Social Science Research Network.* http://www.ssrn.com.

Graeber, David. "Debt: The First Five Thousand Years." The Anarchist Library, 2010.

Johnson, Neil, Zhao Guannan, Hunsader, Eric, Ravindar, Amith, Carran, Spencer and Tivnan, Brian. "Financial black swans driven by ultrafast machine ecology". arXiv, February 7, 2012.

Kroker, Arthur. 'Three Theses on Virilio Now.' *Virilio Now: Current Perspectives in Virilio Studies*. Ed. John Armitage. Cambridge: Polity, 2011.

McQuire, Scott. 'Virilio's Media as Philosophy.' *Virilio Now: Current Perspectives in Virilio Studies*. Ed. John Armitage. Cambridge: Polity, 2011.

MacKenzie, Adrian. *Transductions: bodies and machines at speed.* New York, NY: Continuum, 2002.

Malmgren, Harald and Stys, Mark. "The Marginalizing of the Individual Investor". *The Magazine of International Economic Policy*. Summer 2010.

Nanex, "Dear HFT, Please Explain This". Nanex, August 25, 2011, October 12, 2012 http://www.nanex.net/StrangeDays/08252011.html.

Patterson, Nancy. *Stock Market Skirt*. July 12, 2013. http://www.vacuumwoman.com/MediaWorks/Stock/stock.html

Patterson, Scott. *Dark Pools. High-Speed Traders, AI Bandits, and the Threat to the Global Financial System*. New York: Crown Business, 2012.

Patterson, Scott. "Meet Getco, High-Frequency Trade King" *The Wall Street Journal*, August 27, 2009. <http://online.wsj.com/article/SB125133123046162191.html>

Perez, Edgar. *The Speed Traders: An Insider's Look at the New High-Frequency Trading Phenomenon That is Transforming the Investing World*. New York: McGraw-Hill, 2011.

Price, Michelle. "Is the sea the next frontier for high-frequency trading?" September 17, 2012. http://www.efinancialnews.com/story/2012-09-17/is-the-sea-the-next-frontier-for-high-frequency-trading?mod=rss-tradingandtechnology.

Redhead, Steve. *Paul Virilio: Theorist for an Accelerated Culture*. Toronto: University of Toronto Press, 2004.

Spicer, Jonathan and Lash, Herbert. "Who's Afraid of High-Frequency Trading?" *Reuters*, Dec 2, 2009. http://www.reuters.com/article/2009/12/02/us-highfrequency-idUSN173583920091202.

Tse, Jonathan, Lin, Xiang and Vincent, Drew. "High Frequency Trading - The Good, The Bad, and The Regulation". *Credit Suisse,* December 5, 2012.

Virilio, Paul. "Speed and Information: Cyberspace Alarm!" August 27, 1995. http://www.ctheory.net/articles.aspx?id=72.

Virilio, Paul. *Speed and Politics.* New York: Semiotext(e), 1986.

Zubulake, Paul and Lee, Sang. *The High Frequency Game Changer*: *How Automated Trading Strategies Have Revolutionized the Markets*. Hoboken, NJ: John Wiley & Sons Inc., 2011.

Glossary of Terms

Algorithm: A process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer.

Ask Price: The price that a dealer is willing to sell for stocks or other assets.

Bid Price: The price a prospective buyer is prepared to pay for stocks or other assets.

Bid-Ask Spread: The difference between the Bid and Ask prices.

Dow Jones Industrial Average (DJIA): The average of the 30 largest publicly traded companies that describe the performance of several industrial sectors within the United States.

Electronic Communications Network (ECN): Trading firms that electronically match buy and sell orders routing these transactions to the major Stock Exchanges.

High Frequency Trading (HFT): The use of computer algorithms for placing trades on Stock Exchanges allowing for large numbers of transactions to occur within milliseconds.

Liquidity: The ease where an asset such as a stock can be bought and sold without affecting the price of the stock.

Mini Flash Crash: Abrupt and severe price changes on a stock that occurs in an extremely short period.

Quote Stuffing: The tactic of sending large numbers of orders and cancellations in rapid succession to slow down competitors trying to place orders on similar stocks.

Stock: Capital raised by a business or corporation through the issue of shares.

Stock Exchange: A place that provides services for stock traders to trades stocks and other securities and for the price of these assets to be publicly listed.

Appendix A: News Aggregate Algorithm

The following lines of code are written using the Processing programming language.[14] They outline the set of rules I have decided upon that will determine how my HFT algorithm will place trades based on the types of keywords found in business news articles.

```
// Load the lines of text of an article from the Database into one long String
void loadArticle() {

  if (mysql.connect() ) {
    loading = true;
    longText = "";

    try {
   // SQL: SELECT id FROM article WHERE title = title
  PreparedStatement ps = mysql.connection.prepareStatement("SELECT * FROM article
WHERE ID = ?");
      ps.setInt(1, currentArticleID);
      ResultSet rs = ps.executeQuery();
      while (rs.next () ) {
        int articleID = rs.getInt("id");
        String articleTitle = rs.getString("title");
        String articleURL = rs.getString("url");

        // Get Lines using articleIDPreparedStatement psLine =
mysql.connection.prepareStatement("SELECT * FROM article_line WHERE newsID =
?");
        psLine.setInt(1, articleID);
        ResultSet rsLine = psLine.executeQuery();
        while (rsLine.next () ) {
          String line = rsLine.getString("line");

          // Add line to longText
         longText += line + " ";
```

[14] Processing programming language. http://www.processing.org

```
      }
}
     loading = false;
     println(longText);
   }
   catch (SQLException e) {
     System.out.println(e.getMessage());
   }
  }
  else {
   println("MYSQL Error: Cannot connect to database " + database + ".");
  }
}

// Format the long String into individual lines (wrap text around white News Print)
// 1. Adjust font size based on area of News Print
// 2. Natural Language Processing. Check keywords and surrounding words for context
// 3.  Call subroutine WrapText to create justified text
void reformatText() {

  fadeTextIn = true;
  wordsFaded = false;
  fadeTimer = millis();
  lines.clear();
  words.clear();
  fadeHash.clear();

  // Create 100 lines initially
  for (int i = 0; i < 100; i++) {
   Line line = new Line(i);
   lines.add(line);
  }

  String[] wordArray = split(longText, " ");

 // Determine fontSize based on area of current NewsPrint and number characters in
longText
  float area = (dim.x * dim.y);
  int totalChars = longText.length();

  println("Number of chars " + totalChars);
  println("Area/totalWords " + area/totalChars);

  // fontSize based on area of current NewsPrint (between 10 and 20 sizes)
```

```
fontSize = (int)map(area/totalChars, 0, 350, 10, 20);
println("fontSize " + fontSize);

for (int i = 0; i < wordArray.length; i++) {
  String word = wordArray[i];
  textSize(fontSize);
  float wordWidth = textWidth(word);
  Word w = new Word(word, wordWidth);
  words.add(w);
}

// CHECK NEIGHBOURS IF THEY ARE CONTEXTUAL
// CHECK i-1 AND i+1 for keyword status isVerb OR isAdjective
// Make i-1, i+1 a keyword (only highlight and fadeOut, doesn't have gravity)

// Rita Lexicon (Natural Language Processing library)
RiLexicon lexicon = new RiLexicon();

for (int i = 1; i < words.size()-1; i++) {
  Word w = (Word) words.get(i);
  Word pMinus = (Word) words.get(i-1);
  Word pPlus = (Word) words.get(i+1);
  // is Word w a keyword ?
  if (w.isInDictionary == true) {
    // pMinus VERB OR ADJECTIVE ?
    if (lexicon.isVerb(pMinus.getWord() ) || lexicon.isAdjective(pMinus.getWord() ) ) {
      pMinus.isInDictionary = true;
    }
    // pPlus VERB OR ADJECTIVE ?
    if (lexicon.isVerb(pPlus.getWord() ) || lexicon.isAdjective(pPlus.getWord() ) ) {
      pPlus.isInDictionary = true;
    }
  }
}

// Wrap Text (Full Justify)
wrapText();

// delete unused lines
for (int i = lines.size()-1; i >= 0 ; i--) {
  if (i > lineIndex) {
    lines.remove(i);
  }
}
```

```
  for (int i = 0; i < lines.size(); i++) {
    Line line = (Line) lines.get(i);
    line.justify(dim.x);
  }

  // Total Number of Words
  totalWords = numberTotalWords();
  totalKeywords = numberKeyWords();
  println("Total: " + totalWords + ", Key: " + totalKeywords);
}

// WrapText Subroutine: Split longText String into individual lines (Full Justify)
void wrapText() {
  lineIndex = 0;
  int numChars = 0;
  float charWidth = textWidth(" ");
  int charsPerLine = (int)(dim.x/charWidth);
  int lineNumber = 1;
  float lineWidth = 0.0;

  for (int i = 1; i < words.size(); i++) {
    Word w = (Word) words.get(i);
    Word pw = (Word) words.get(i-1);
    if (lineWidth + w.dimension + textWidth("contractinging") > dim.x) {
      lineWidth = 0;
      lineNumber++;
      lineIndex++;
    }
    else {
      lineWidth += pw.dimension + textWidth("  ");
    }

    w.setLocation(loc.x + lineWidth, loc.y + (lineNumber*fontSize) );
    Line currentLine = (Line) lines.get(lineIndex);

    // First word is missing since starting from i=1, so set pw (i-1) manually
    if (i == 1) {
      pw.setLocation(loc.x + lineWidth, loc.y + (lineNumber*fontSize) );
      currentLine.addWord(pw);
    }
    currentLine.addWord(w);
  }
  //println("LineIndex: " + lineIndex);
}
```