

An Agent-Based Simulation Of Trader Behaviour In Modelling Emergent Phenomena In Stock Market

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Abstract

This project report presents the development of an agent-based simulation of stock market emergent phenomena from traders' behaviour perspective. By following Object Oriented Design process with the aid of MASON programming toolkit, the report explores the emergent phenomena in stock market prices changes affected by the interaction of different traders.

For the aim to observe the stock market emergent phenomena showed on the order book prices movements, the multi-agent model is designed to simulate different types of traders to interact and generate visualized results. By analyzing the emergent prices changes from market participants' aspect, as well as comparing the experimental results to the real market data from Nanex (an external software in catching up and filing daily market data into diagrams), we can prove the traders' behaviour in causing the stock market emergent phenomena. Thus providing the observed research resources for the further research in controlling the financial market emergent behaviour or complicated simulation model development etc.

In order to easily understand and investigate in emergent behaviour in financial markets, we chose the one particular stock market (FTSE 100) to represent the market structure. Also focusing on the trader behaviour in specific type of the traders- the fundamental traders through interaction with the market makers with orders execution operation.

Our project starts with the research of the related literature regarding emergent phenomena, financial markets dynamics, agent-based modeling and markets' participants' behaviour. Followed by the problem analysis derived from the background research related to the project objectives. Then the technical part of the object oriented software design with experimental implementation & testing. And finally the conclusion with further works discussion.

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1. INTRODUCTION

1.1 Motivation

An emergent behaviour is defined as a complex behaviour formed by the interactions of individual entities operated collectively. Thus emergent phenomena happened in various forms. Natural emerging examples are like traffic jam, earthquakes, species evolution; Humanity emergent phenomena are like the emerging of cities, Internet, financial system etc. Considering the financial system, the stock market is an example of emergent behaviour on a grand scale. As a whole the stock market has no leader but forms the security prices of companies all over the world. There is also no one single regulate entity manipulates the overall market operations. All the participants including agents, brokerage institutions and investors each build their own knowledge of investing portfolios and strategies according to the collective approved rules and regulations. Either through individual transactions or large group orders, the overall interactions of the trading performance emerge as the trends and patterns showed in the stock market analysis diagrams. Especially the recent forbidding in short selling of four European countries, the financial market is intensively related behavioral economics. Therefore, the focus on the emergent behaviour in financial markets provides a new approach in exploring the impact of market participants and their behavioral causes and effects.

This project is carried out by analyzing stock market based on the financial markets hypotheses and theories, then the trader types and trading strategies and finally exploring the mechanisms in modeling the emergent phenomena in the experimental stock market.

1.2 Introduction To The Simulation Model

An agent-based model is a collective group of autonomous agents simulating and interacting model, which provides a way of observing and analyzing the relationships for the whole system, and sometimes also combines with multi-agent system or multi agent simulation.

ABM dates back to 1940s of the concept setting computation-intensive procedures, with introducing the reproduction and the first of the devices of cellular automata by von Neumann, came along later with John Conway's well known Game of Life, improved the simple rules to

be virtually 2-dimension. Till the late 1980s, Craig Reynolds' work on biological agent-based models tried to contain the social characteristics as well as the first 'agent' definition been used by the John Holland and John H. Miller's 1991 paper "Artificial Adaptive Agents in Economic Theory". Afterwards, the ABM methods basing on agent-based simulation been largely used through different areas and cross-fields of social science subjects.

The project is built up based on the agent based modeling approach for the agents' interaction and simulation. The simulation is aimed to show trading participants behaviour in the experimental stock market. As mentioned above, this project is inspired by the recent financial markets price volatility and the impact of the traders trading strategies towards short straddling. Especially from the Nanex- 'crop of the day' - an observed phenomena termed "Quote Stuffing", in which bursts of quotes (at very high rates) with extremely unusual characteristics were observed. Therefore, by analysing the stock markets unexpected emergent phenomena, we are trying to explore the traders' reaction behind them. This project will implement ABM in simulating three types of traders with their investing strategies thus generate the overall interactions outcome to identify the emergent behaviour in the financial market. By identifying fundamental traders and market makers with their strategies in buying and selling in the experimental stock market, the ABM model is aiming to prove the observed emergent quotes crash diagrams as showing in NANEX.

1.3 Topic Outline And Objectives

Through the previous research, the related topics on the modeling economics all concerned about the statistical mechanism solutions in explaining the emergent behaviour in financial markets. However, by introducing ABM, we could provide new insights from the behavioral finance area to explore the agents' relationships and interactions throughout the trading decision making process. Therefore, the research area could be narrowed to the direction of observing perspective trading strategies and the collective group interactions through the order book bid-ask quotes analysis, with the aid of ABM tool to visualize the results from the simplest state to the aggregate level. The research questions are generating as follows:

A. How can we model the behaviour of stock market order book and provide an interaction environment regarding the market rules and trading rules for users as well as integrating it with MASON.

B. Using the dataset of trades' activity carried out on 10 selected FTSE100 companies over a limited time-based period, how can we develop an experimental model of stock market order book movement with different characteristics and trading rules respectively, showing traders movement (highly informed fundamentalists, noisily informed fundamentalists), and market price movement?

C. How to design the model from the simple agent interaction to the complex levels to carry out the accordingly possible emergent phenomena?

I will present an artificial stock market in which simple trading agents enter to trade in a single order book. Beginning with a population of basic fundamental trading agents, drawing their bid prices based on the underlying company values, from a normal distribution around the current price, we compare the statistical properties of the emergent stock price distribution to that observed on real prices. After that, adding more traders with two different trading strategies i.e. highly informed fundamental traders with correct valuation of the underlying assets and noisily informed fundamentalists with partially valuation strategy.

Then I will introduce simple technical trading agents to this market for order execution, using mason simulation with each trader's characteristics as the design rules as the fitness function. We will then show that the agent populations that produce the different or maybe new results from the rule based order book prices changes, which presented by the emergent behaviors in the complex financial markets.

Objectives

1. Research on the present trading order book and prices changes.
2. Analyzing the causes and effects of the order book price clashes and unpredicted results from the traders perspective.
3. Including three types of traders within their trading strategies: highly informed fundamentalists, noisily informed fundamentalists, and market maker.

4. Combining each type of trading strategies with the problems emerging: the order book price unpredicted results from the collective agents multi reactions which could never caused by the single type of traders.
5. Analyzing the problem from the emergent behavior perspective.
6. Come up with mason as the simulation agents for the testing tool thus designing the model with the order book trading rules and each agents' characteristics then set up the model with multiple agents interactions.
7. Analyze the simulated scenarios from the relationship and interaction between the agents and explain the emergent behavior based on the simulated results.

1.4 Report Structure

Chapter 1 introduce the project topic including the motivation of the topic and research area related to the key elements of the emergent behaviour of financial markets. Gives the reader a simple and overall description.

Chapter 2 focus on the background research of the related literature attributed to the key elements of the topic. By separating the topic into technical review of the agent based modelling and mason toolkit and financial review of the emergent phenomena in financial markets as well as the detailed traders behaviour regarding the related research papers.

Chapter 3 gives a brief outline of the object-oriented analysis including the user requirements gathering and user analysis according to the project goals and objectives.

Chapter 4 identifies the design structure and specific objectives of different phases in system design as well as the full processes of the implementation and testing of the simulation design followed the object oriented design guides.

Chapter 5 analyses the simulated results and explains the experimental processes in details. Compare the scenarios to the actual results based on daily market data.

Chapter 6 summarise and conclude the report and discuss for the stretched and further research approach regarding to the further developments suggestions.

2. BACKGROUNDS AND RESEARCH INFORMATION

2.1 Agent-Based Modelling

2.1.1 Agent-Based Simulation Models

Agent based modelling is a computational modelling paradigm, which defined as the modelling of agents' interaction phenomena in dynamics. Agent-Based Models (ABM) can be seen as the natural extension of the Ising model (Ising 1925) or Cellular Automata-like models (Wolfram 1994), which have been very successful in the past decades in shedding light on various physical phenomena.

However, by comparing to cellular automata (Wolfram 1994), the most distinct ABM characteristic is the interaction synchrony of the agents as well as the simulated environments. As the cellular automata are focused on the same time performance, the ABM actions are implemented by the discrete step simulated with different environments separately. Moreover, as the actual social or biological environment containing a large variety of interacting components, ABM's detailed methodology could provide a simulation for ensuring heterogeneity (Levy and Solomon 2000) as a whole.

Traditionally, ABM was implemented mostly in the computational and numerical simulation. Aiming at predicting the dynamics of the simulated agents behaviour in computational methods, the ABM were more likely combining with the equations for the specific analysis. By describing each agent's particular reaction data under certain rules, the ABM acts as a theoretical tool to help explain the mathematical terms. More recently, ABM tends to be more in visualised interaction model. By redefining the agents as the conscious entities with adaptation or learning abilities, there is more emphasis on the macroscopic system behaviours related to emergent phenomena.

Agents, as the actors in the ABM system, is therefore, identified as an entity with some degree of autonomy (de Oliveira and Stauffer 1999). For each agent type which is identifiable, there are several distinguishable characteristics. Either through the interaction with the environments

or other agents, every entity contains its own attribute including spatial, temporal and functional aspects. Without the external manipulation, the agent needs to deal with the environment randomly with the autonomy action, thus keeps the agent as a complete entity in completing tasks. For the lower level of simple interaction of agents, the basic rules and specified reaction to the environment simulation build up the relationships between the agents. For the higher-level interaction, examples are like insect colonies, financial markets and the artificial life (Langton 1989), ABM system looks at more on revealing the collective efforts in achieving the goals throughout the process.

Environments, as the simulated society for the agents, are identified as the operational support for the interaction to take place. By defining the space, the agents need to inhabit the space in the state in following the simulation rules. Therefore, the environments' properties can be roughly summarised as accessible, deterministic and static (Russell and Norving 1997).

Generally, ABM was largely used to simulate a certain phenomena with identifiable agents. Before setting up the interaction rules or overall criteria for the agent actors, the following needs to be considered for simulation process designing:

Firstly, the agents are carrying their own characteristics and data attributes. The internal attributes are presented as either discrete or continuous states. Secondly, the internal states of each agent type determines the agent's behaviour i.e. the finite state automata (Rocha, Luis 2000). The finite state machine thus enables the transition and interaction between the agents. Thirdly, the particular interaction types of agents need to be specified as global interaction, local interaction or local interaction with some degree of global reach. Fourthly, the agent behaviour occurrence needs to be serialized and randomized. Therefore, the agents' interaction should take place in parallel order but not sequential. Finally, constrained by time and space, each of them could be either discrete or continuous, thus the certain constraints are classified as four possible parameters as: continuous space and continuous time, continuous space and discrete time, discrete space and continuous time, discrete space and discrete time. Additionally, for the more complicated ABM applications, we need to consider further based on the state-determined automata and introducing random-access memory capabilities. The agents thus are enabled to store the updated information in memory as well as sharing knowledge among the whole environment. This concept also relates to the traditional artificial

life (Langton 1989), intelligence and game theory, which the self-organised memory access could choose between the previous state memory or the dynamics change in the interaction society (Wolfram 1994).

ABM is aimed open to all the possible programming languages. However, the object oriented programming is most commonly adopted as the emphasis on the agents concept. Yet since the introduction of the frames (Minsky, M. 1987) containing the original elements of the super agents, the early stage of OOP are stemmed on the frames classes. As focus on the object-the agent, many software toolkits are developed to facilitate the ABM systems, such as MASON, SWARM, REPAST.

2.1.2 MASON

MASON is defined as Multi-Agent Simulator Of Neighbourhoods (or Networks) is an multi-agent simulation environment. George Mason University's Evolutionary Computation Laboratory in conjunction with the GMU Centre for Social Complexity introduces Mason while using pure Java programming for development. Since the creation and initiation in 2003, Mason maintains and adjusts to the current requirements as well as applying in more agent-based implementation researches.

Generally, MASON is recognised as a fast, easily extendable, discrete-event multi-agent simulation toolkit in Java (Sean, Claudio, Liviu & Keith, 2003). The objectives of MASON design aims to simulate multi agents' interaction with separate modelling and visualization platforms. In order to model the social complexity to explore agents' relationships based on the experimental interaction simulation, the MASON toolkit designed to platform-independent simulation model. Thus the specified design goals are summarised as follows:

- Easily operated platforms
- Enabling 2D and 3D visualisation
- Platform independent visualisation and model builder structure
- Provide large amount of agents' interactions environments
- Enabling visualise the relationship between agents
- Support large memory and instantiation libraries for system model building

Therefore, the basic architecture of MASON design is showed as the following diagram. The two-layered structure represents the independent processing bundles. The bottom layer includes utilities and simulation model. The utilities store the various purposed utilities data. The simulation model is a classes container of discrete-event schedule, intensive random number generator, fields classes packages with locations. And the top layer is the display system for visualising the model activities. By adding GUI tools to visualise the model simulation, the whole system is distinctively separate the visualizer and model constructor in order to satisfy the above goals in designing. Moreover, the introduction of checkpoint function enables the agent-based system to restart and pause the simulation at any moment. Without interrupting or modifying in other layers thus provide an easy operation platform for model users and developers in both.

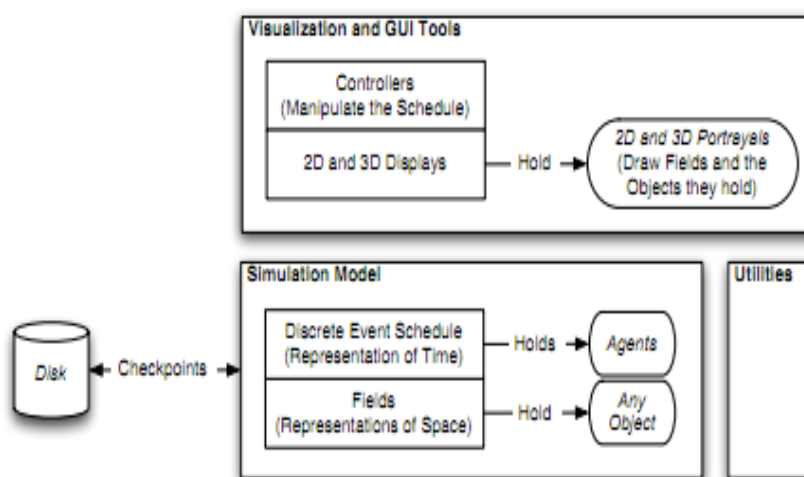


Figure 1.1 Basic elements of the MASON model and visualization layers.

Moreover, as MASON was designed in coping with the Java.net environment, the more active innovation is now shifted to Google Code. Also, Mason applications range from social sciences to economics as well as mathematical engineering, examples are like Craig Reynolds' Boids algorithm, Balls and Bands, a simulation of Hooke's Law, an L-system generator, Conway's Game of Life and Sugars cape etc.

2.2 Introducing Emergent Phenomena

Before understanding the emergent behaviour, we need to know what are emergent phenomena, why the emergent phenomena are important and what's the relationship between the emergent behaviour and ABM. By reviewing the real examples of implementing the ABM, we will then focus on the ABM in identifying the emergent behaviour in financial market.

Firstly, an emergent behaviour is defined as a complex behaviour formed by the interactions of individual entities operated collectively. From the empirical view, emergent phenomena caused by nature are the systems self-organize into a complex state, poised between predictable cyclic behaviour and unpredictable chaos (Akira 2006). For example, a traffic jam, which results from the behaviour of and interactions between individual vehicle drivers, may be moving in the direction opposite that of the cars that cause it. From the operational view, emergent behaviour could be defined as the system-wide behaviour reemerges from interactions among individual elements (K. Mills, 2004). For instance, the slime molds, insect colonies and stock markets in which all the internal entities' interactions gradually build up the whole functional society. Furthermore, the most direct way in understanding the concept of emergent behaviour is thinking about a traffic jam. The most common traffic happening almost everyday actually is a complex emergent phenomena example. By looking at the individual, every driver is aiming to go to the destination with obeying driving rules and regulations such as speed limit, traffic light or slow down to change directions before letting others to pass. In contrast, by looking at the traffic jam as a whole, the situation is a distinctly separate state emerges from those individual reactions. A single driver but an aggregate collection of different intentioned drivers, however, could never cause the traffic jam. Therefore, simple example reveals the three important elements of the emerging occurrence (Eric Bonabeau 2002):

- Emergent phenomena can be unpredictable and often counterintuitive. For example the driver chooses ways to get out of the traffic but could never imagine how the others react as a whole. The reaction differs from each individual as the result of unpredicted and sometimes counterintuitive depends on the complicated entities.

- A small change of each individual could lead a radical alteration of the collective behaviour. The driver chooses to change decisions any moment depending on the situation.
- There is no formalized logic in constructing the emergent phenomena but the random selection of reactions. As the driver's intention varies from judging the situation leads their way of following different rules. And collectively, the traffic jam phenomenon is randomly generated.

Therefore, we could not conclude the emergent behaviour by dividing them into individual part behaviour but need treat the result as a whole entity emerging from enormous sub entities.

Secondly, the importance in understanding emergent behaviour help explain the bizarre phenomena thus for further control or prediction. As the traffic example (Dietrich 1968) first investigated, emergent phenomena actually exhibit almost everywhere in real life. Examples are like hiring more experienced professionals result in company suffering from total knowledge level decline; higher employer bonus incentives leads corporate performance dropped for some organizations; slight increase number of shoppers make certain items in dramatic sales drop; a single trader's false trading leads to the whole bankruptcy of a financial institution etc (Eric Bonabeau 2002). All these situations are hard to be identified by the normal logic or intuition but often representing in an unpredictable way as emergent phenomena. Additionally, with much more complicated developed society, every improvement aggregate together made the emergent phenomena occur much often recently. Partially because of the variety of population, growing intensity of the technology development as well as the business detailing, all areas are more inter connected and much more complicated. The stock market is an example of increasingly complex emergent behaviour as large amount of new participants and derivatives invented. Thus under the presence of more and more counterintuitive mysteries, the importance in analyzing the emergent behaviour is for the further controlling, shaping or predicting the possible solutions. Therefore, by considering the emergent phenomena with the computer-based simulation, the organization could avoid unnecessary loss before actual implementing some uncertain new strategies.

Thirdly, as emergent phenomena occurred from the interactions of individual entities, especially they cannot be reduced into the separate constituent entities. Moreover, the emergent phenomena should be treated as a whole sum of its individuals as the effects of each other's interactions. Also, from the traffic jam example, the driver's reaction could be the opposite directions from the jam or keeping staying in the same directions, different interactions between individual could lead the jam being unexpected. Thus the unpredicted results of the emergent phenomenon could be varied from degrees of the participants' perceptions of the environments. Therefore, ABM by its nature could be a appropriate approach to model the emergent phenomena. The agents of the model could facilitate with the characteristics of the actual entities. As well as the certain rules could implement as the simulation environment parameters, thus implementing ABM system to capture the interactions between the particular types of agents within the specific environment, thus providing possible results to prove the observed phenomena in the reality world.

More generally, emergent phenomena could be implemented by ABM when satisfies following (Eric Bonabeau 2002):

1. Nonlinear characteristics. The individual behaviour is nonlinear, discontinuous and different in strategies. There is no global equations to demonstrate the individual intentions and cannot be characterized in a whole.
2. Random behaviour. The individual reactions towards the contingency situations tend to memory update, non-market behaviour or adaptation learning.
3. Heterogeneous networks effect. Various agents' types and their corresponding strategies interact with each other usually happen as the heterogeneous mix. The collective aggregation of the interaction mix lead to the significant change differs from any individual behaviour.
4. Averages will not work. Aggregate differential equations tend to smooth out fluctuations, not ABM, which is important because under certain conditions, fluctuations can be amplified: the system is linearly stable but unstable to larger perturbations.

Additionally, as agent-based models normally tended to use into two categories (Duncan 2005) - demonstrate particular phenomenon or model the nature reality, the distinct purpose in model design should be specified before building up the models. It is important to distinguish to build

the theory simulation or the reality world interaction. Thus considering emergent behaviour processes, we need make sure the theory building of ABM to prove the emergent phenomena in the financial market activities from the micro level to the macro level.

2.3 Financial Markets Dynamics

In the recent decades, more researches all focused on discovering the financial markets with the aid of ABM simulation. Before designing our own stock market simulation model, we need to understand the market structure, specifying on the stock market formation. Then we will introduce the past work on agent-based financial market models. And finally explain the inspiration in designing our own agent-based financial market environment based on these research.

2.3.1 Introducing Financial Markets

In this section we will focus the operational structure of the financial markets. From the market microstructure, we will get the conceptual framework of the price formation of the financial markets. Then we will identify the stock markets organization in details including the trading instruments, orders execution, market participants and market rules respectively.

The financial market microstructure is about analyzing the trading and market structure. As the market structure is defined as the rules and regulation system, the trading process thus enables to be executed (Harris, 2003). The market organization is fully equipped with all the market functions and provides an operation framework. Therefore, financial markets research majorly concern the following: price formation, market structure design and information disclosure. And inevitably the market dynamics should be considered through different levels as the presumption.

Generally, the market dynamics is majorly related to price dynamics. As prices are results of the order execution, the price formation structure decides the market prices. Also, the market information and participants' reaction influence the trader's decision making on orders varies in different degrees.

Also, the participants and their reaction decide the order placing, execution and structure parameters. However, these behavioral aspects are difficultly in observing, such as the price

structuring mechanism, trader decision-making mechanisms, etc. And the market microstructure researches are more focused on these issues called “black box” (Madhavan, 2000) which includes following objectives:

- Investigating rules and structure effects on “black box”.
- Identifying prices and volumes realization based on the “black box” demands condition.
- Analyzing “black box” influence on the trader behaviour and trading strategies.

Therefore, we need understand the stock market organization in detail and then deepens the market structure in order to tackle the “black box” inside. Thus we will look at the stock market from the static view in showing the structural elements. Then we will consider the real market elements to design the experimental markets. And the next section we will analyze the stock markets organization determinants (trading instruments, market participants, order making system and market rules) separately.

Firstly, the trading instruments are the exchange objects which are majorly defined as assets and contracts. Assets include physical assets and financial assets: physical assets are the physical commodities and financial assets could be the ownership of real assets or derivatives from them. And stocks belong to financial assets that defined as the ownership of the corporate assets (Harris, 2003). Accordingly, the market regulated the qualified stock to be traded will be listed on the stock exchanges when the corporation satisfies the certain financial requirements and market rules.

However, when looking closer at the stock price of a particular stock market, the price is not accordingly reveals the real price of the company with considering other market issues. The valuation of the company not solely depends on the corporate assets but also the total liabilities, net income, dividends payments as well as the long-term performance (Harris, 2003). Therefore, the contingency environments of the stock market provides the trader with different expectation towards the company real value and strategically make most of them.

Secondly, the market participants play an important role in the financial markets in connecting the assets and the furthermore the operation of the whole system. Based on the involving areas and roles the participants are identified as investors and traders. The market investors can be individuals, money managers, corporate pension funds and mutual funds etc. (Harris, 2003).

And traders or agents are trading intermediaries act as a third party in trading (Schwartz & Francioni, 2004). There are two main groups of trader agents: brokers collectively deal with large amount of the customer orders and market makers provides market liquidity of certain stock types. As acting on behalf of certain financial service institutions or clients, the agents are given opportunities to activate the orders according to different requirements and financial goals. The following diagram generally explains the relationship between different market involvers.

As the investors could either choose to enter the market to trade with market makers through electronic trading systems or ask the brokers to place orders. By consulting the brokers in the marketplace, the broker agents help to make decisions in investing on buying or selling orders. The brokers thus work both inside and outside the marketplace either as independent dealer with market makers or the representatives of individual investors. Normally, the trading process begins with investors request the broker to make an order, the broker decides on trade with other brokers or market makers, then the market makers are responsible to take orders and make execution accordingly. Additionally, the order execution depends on the market conditions within order arrival times as well as the traders' own strategic goals, which are operated through the order book platform either automatically traded or manually executed.

Thirdly, the order book platform is built based on the orders and quotes and systematically enables the order execution operated in a formalized way. Orders quantify the traded instruments in sizes with intention to buy and sell. The market orders thus show the order size and side (buying or selling size). Also there are normally certain market conditions to specify the order book types. The limit orders refer to the additional requirements to limit the market orders in limiting the accepted order price ranges or time period. For instance, if the current price is not in the range of the limited price levels, the order will be activated at market price at the moment of arrival. Order books thus execute the orders in sequence of their arrival. Therefore, the buy and sell orders are put in a sequence queue after entering the order book system and wait to be executed till satisfies certain requirements. Order books with the limit orders constraints are called the limit order books.

Normally, the market participants based on individual tasks and roles operated through order book system in executing orders and collectively constructing the stable trading platform. For showing their intention to trade with each other, they act as quote (Harris, 2003) prices and

volumes. A bid quote means the willingness to buy and a ask quote means the willingness to sell. Basically, the quotes contain the instruction of the instruments name, trading side and agreed price with trading volumes. The bid-ask spread thus represents the difference between the highest bid price and lowest offer price. As a result, the traders make bids (offers) to offer liquidity (Reilly & Brown 2003) and accept bids (offers) to take liquidity.

Additionally, only through obeying certain market rules could enable the traders to buy and sell orders in transparency. As a series of regulations referred as protocol (Madhavan, 2000) differed from markets and stock types. The market information dissemination (Demarchi & Foucault, 2000), for example, is regulated with certain rules with market participants involved in the trading processes. By defining the information availability level of both pre and post trade information, the related data related quotes, transactions, price publication and limit order levels are required to be published in a certain degree. Considering the order execution, for instance, the conditions (Demarchi & Foucault, 2000) on the order placing sequence, bid-ask spread levels and quotes decimals etc. are all ruled in a formalized way.

Thus the trader behaviour all happened under the market rules and regulation frameworks. According to separate roles and objectives, the market participants choose to react to the market price dynamics based on the market constraints strategically interact with each other to fulfill the tasks.

2.3.2 Agent-Based Financial Markets

The literature on the agent-based financial markets is classified as market microstructure, experimental market and simulated markets. The recent emphasis on modeling the dynamic interactions of agent types to optimize the expected utility and markets are not equilibrium (Farmer 1999, LeBaron 1995). In this respect based on the behavioral economics, the heuristics in and out of equilibrium with bounded rationality (Simon 1982) are developed through external inspirations in computer science, psychology and agent-based model constructing literatures.

Market microstructure defined from Adam Smith's (1776) as the supply and demand level from the theoretical and empirical approaches. Till the earliest model (German 1976) of dealership and auction markets with the order processing activities, more complex models of market-making activities arise. Many papers also develop optimal market-making (Campbell 1996, O'

Hara 1995, Schwartz 1993) behaviour according to theoretical contexts. Based on the market structure theories, our project is constructing the simulation model on a double auction market while the traders making orders via order book system. The general double auction market contains the agents with trading a single dividend paying security every trading period and the activities of submitting orders. During the trading period, there are several trading internals and the last internal within the dividends payment. In each interval, update information and trading execution are occurred through the prices and order flows (Nicholas, Blake, Andrew, Tomaso 1999).

Furthermore, the recent literature also covers the exploration of the experimental markets (Davis & Holt 1993, Kagel & Roth 1995). The emphasis on the rational expectations model combined with other studies on informational efficiency classifies the research into two types: the relationship between fully informed agents and uninformed agents, the interaction among the partially informed agents. The first type experiments the assumptions on the market prices represent the insider information, thus the uninformed agents could recognize the market true price reflecting the information. The second type investigates on the aggregation of the market information through the gradual revelation of the trading processes by the partially informed traders. According to Plott & Sunder (1982) and Forsythe, Palfrey (1982)'s research on the informed and uninformed traders, they observe the emerging of the equilibrium prices through reveling the inside information. However, through the analysis on the partially informed traders, the aggregated information efficiency are bounded with the certain market conditions, such as the identical preferences, common knowledge of the dividend structure, complete contingency (Forsythe & Lundholm 1990), and complexity of the market parameters (O'Brien & Srivastava 1991).

Therefore, by implementing and testing the experimental markets, the simulated markets researched later on extended the theoretical experiments by software simulation agents. Without the human involvement, the human behaviour dynamics could be explicitly tested. The agent-based models tested various assumptions ranges from learning behaviour of market constraints (Cole, Sunder 1993), to zero-intelligence in quotes restriction (Cliff & Bruten 1997) as well as algorithmic double auction trading strategy (Rust, Miller & Palmer 1992). Additionally, the more and more complex computer simulated markets also developed the simulation on capturing long term phenomena (LeBaton 1999) based on the individual trading strategies.

2.4 ABM Application On Financial Markets Emergent Phenomena

As the financial markets is apparently the most dynamic market and inter related subject of other research areas. The highly developed financial systems provide high quality data and frequently updated products, which enable all the activities in organize. Also, as more participants and efficient centralized system crated, which provides a variety of the financial instruments and related services as well as more complicated and volatile movements. By exploring the solution to predict the unpredicted market changes, the issues on behavioral economics (Arthur, Holland, Palmer & Tayler 1997) extend the traditional economic theories. The general question of market stability and price formation looms all through economics (Blake 2001). As the market information and supply demand balance all present on the price movements, the price changes triggers various buying and selling strategies. Compared to other systems, the financial markets identified as the complex social and economic environment. Where individual optimizing behaviour does not necessary lead to a socially efficient outcome (Schelling 1978) and the possible behaviour of a large macro system, which can act as efficient social coordinating mechanism (Hayek 1945).

Therefore the ABM develops more precisely from investigating the experimental markets to implementation in reality, more and more organizations are benefit from the agent-based modeling (Eric 2002). Examples range from Macy's usage of the models technology in designing its departments stores, to Hewlett-Packard in investigating the hiring strategy in affection on the corporate culture, also with Socite Generale's ABM in identifying the management risk etc. Yet the pioneer benefit organization from the ABM is the NASDAQ in the last few years. In 1999, as NASDAQ wanted to reduce the tick size of the order book from 1/8 dollar to 1/16 dollar in order in narrowing the bid and ask prices, the organization tried to test the effects of the creation. Worked with the consultants in Sante Fe BiosGroup, the experimental agent-based model simulated with a computer based software. By including virtual trading individuals as market makers, institutional investors, pension fund managers, day traders, casual investors, and other market participants, the agents each operated as buying and selling within strategies. However, as the random simulated results showed, the smaller tick size actually leads to wider bid-ask spreads as reduced the market's ability in discovering the price movements (Eric 2002). Thus allows the organization predicts the possible unexpected results before actually launching the new application.

Additionally, as mentioned in the motivation section, the idea of building up the agent-based model came from observing the unexpected market data came from Nanex reports (<http://www.nanex.net/FlashCrash/CCircleDay.html>). By looking at the Crop Circle of the Day - Quote Stuffing and Strange Sequences which provides the evidence of monitoring markets quotes with hundreds of examples to choose from on any given day. Based on observing order book quotes, the charts shown on the page demonstrate bizarre price or size cycling, some demonstrate some large burst of quotes in extremely short time frames and some will demonstrate both. In most cases these sequences are from a single exchange with no other exchange quoting in the same time frame. The observed phenomena termed as "Quote Stuffing", in which bursts of quotes (at very high rates) with extremely unusual characteristics were classified as the emergent phenomena of the stock market. Therefore, by applying the ABM to simulate the agents' interactions related to the order book bid and ask quotes change thus explaining the observation.

2.5 Introducing Behavioral Aspects

After previous identification of the stock markets structure, then we will move on in analyzing the participating dynamics from the behavioral aspects. We will separately introduce investors, brokers and market makers and their behavioral aspects towards orders making based on their roles and strategies in the financial markets.

As orders trigger the market participants to trade for their benefit in order to meet inventory requirements, keep liquidity or higher profit level. Especially the traders are required to rebalance their portfolio (i.e. the appropriate proportion of different trading instruments) composition according to the market movements. By selecting and rearranging the appropriate new portfolio combination, the traders need to consider following elements referred to the portfolio management (Reilly & Brown 2003): policy construction, investment strategy under policy guidelines, portfolio construction, continuous monitoring. Accordingly, the behaviour aspects thus emerge during each phase throughout the whole portfolio management process.

Firstly, for the market investors, the market policy not only constraints the investment strategies but also ensures the risk levels accordingly. Depending on investors' short or long-term goals the policy constraints the investment level in converting cash and liquidity holding

requirements. Also referring to different investors' risk preferences, the willingness to take the risk of market price changes determines the profit level accordingly.

Therefore, the investment strategies vary from different traders on behalf of the investors' objectives. By deepening into the financial and economic environment as well as the social even political events, the analysts try to achieve the goal of forecasting prices during a period in the future. Thus there are different derived measurements called indicators (Haugen 2001) for studying. There is basically two types of indicators exist: the fundamental and technical indicators. Fundamental indicators focus on the intrinsic value of underlying assets (Reilly & Brown 2003) concerning current economic factors and company's performance levels. While technical indicators emphasize the historical statistics and presumption on the future trends. The two types of analysts are referred as fundamentalists (informed traders) and technical analysts (noise traders) respectively. However, in reality there are no specific distinctive traders who fully following only one type as more combination of these two approaches for arbitrage purposes.

In order to balance the investment risk and profits, the portfolio agents are continuously relocating the contents types and weights referring from the analysis. As a result, the changes of portfolio structures thus affect the orders parameters in trading stock types, sizes and sides of the orders. The order execution thus initiated with price limits representing the willingness of buying and selling underlying stocks. Within placing limit orders in the market, traders will quote a specific price range on behalf of their expected level. Also if the market prices are not matched to their price limits, the order executed based on the timing of order placement. Moreover, in monitoring the selected portfolio performance, the trader needs adjust and modify the strategy accordingly, which is the adaptive trader behaviour of study areas.

Secondly, for brokers in the marketplace, their strategies and roles are based on the requirements of investors or financial institutions. And their goal is to select the appropriate orders to execute after receiving. Normally, market orders continuously arrive while the unmatched orders are stored in the order book for later selection. Thus the selection strategy varies from time of arrival, price priority and other priorities parameters according to different brokers. And the selection therefore decides the design of the execution system (Schwartz & Francioni 2004). Briefly, the execution system considers following three types of situations: internal execution orders after receiving; negotiating with other traders to trade each side;

submit orders for the central execution to be automatically chosen to trade. Furthermore, the transaction costs also affects the selection and execution strategy.

Thirdly, for the market makers, their roles are monitors in maintaining the continuous market trading as well as encouraging the trading activities in the market. By helping traders to quote bid and ask prices and adjust bid-ask spread, continuously provide sufficient orders in the market, add liquid stocks etc., the market makers are facilitating the whole trading environment being efficient operated. Especially during the order execution process, the market makers are responsible to decide bid and ask quotes. As the first order arrives they will match it to the quoted ask bid or ask price. Then if it is matched the order is executed with transaction costs charged, if not, the orders go to the limit order book for later match. However, there are other elements (Katalian 2008) to affect the market makers decision making such as market liquidity, information dissemination, competitive behaviour, investors' expectation etc.

2.6 Conclusion

After reviewing the related the background researches, we have the essential understanding of how the financial market works as well as the relation to the natural science. For the past few decades, the mechanisms derived in explaining the economic activities developed into various approaches. Yet the most distinctive approach is agent based modeling. Since the dramatic changes of the economic environments, the models based on the theories also have an impact on the behavioral finance. Therefore, we combine behavioral finance with computer science modeling mechanisms in exploring the stock market trader interaction.

Aiming in constructing the agent based simulated stock market in observing the trader behaviour, we separately investigates the following areas related to the objectives: agent-based modeling, emergent phenomena in finance, financial market structure and market participants' behaviour.

From understanding the financial markets structure, we get the general structure of how the financial market especially the stock market works based on the established rules and regulations. In deepening in analyzing the stock market, we get to know the stock market trading processes with involved trading instruments, participants and orders execution procedure. After understanding the operating systems of the financial markets, we focus on

presenting the observations of market dynamics. Relating to our prospect on emergent phenomena in finance, our research direction is on the recent researches on explaining the emergent behaviour in financial markets. Aided by the agent based modeling technics, the recent research in discovering the financial market emergent behaviour largely implemented the different modeling approaches. Yet the ABM is majorly adopted for different purposes in analyzing the emergent behaviour in finance.

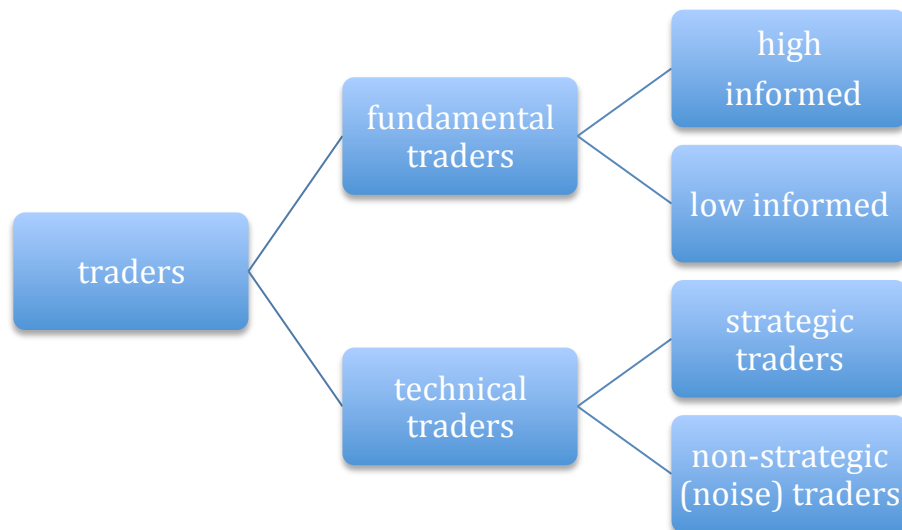
The past researches in applying ABM in explaining financial markets characteristics are majorly based on the computational mechanisms. From the observing area, the dynamics are formed into mathematical equations with determined rules as the assumptions. For the experimental area, the designed systems are more focused in simplifying the parameters in identifying the particular elements in affecting the observed results. Furthermore, most of the mentioned modeling technics are based on the assumption of the perfect market with efficient information dissemination. Also the participants are randomly interacted with the system environments.

Therefore, from the social science view of point, we are aiming to take the simple agent based simulation system in modeling the behaviour aspects to observe the market dynamics. While exploring visualized agents' interaction with derived price movements, we can therefore analyze behavioral aspects impact from the models rather than complicating the mathematical equations.

Moreover, considering the different researches in investigating the behavioural finance, there's still a developing area in identifying the emergent behaviour causes and effects related to agents' interactions. Yet MASON is only sufficient in modelling and visualising the agents' behaviour with the specific parameters, our research only helps in showing the emergent phenomena for the further application from the observations but can't fully explain the causes behind it.

3. PROBLEM ANALYSIS – TRADING STRATEGIES BRIEF

As explained above from the literature review, the market participants are classified into different types according to different motives, the most common classification are involving the fundamental traders, technical traders and noise traders.



The fundamental traders are traders who depend on the fundamental value of the underlying assets. By calculating the real intrinsic value of the underlying assets, the fundamentalists compare the price to market price. As the market price can't represent the real value of the assets, the assets are identified as over-valued or under-valued. Normally the fundamental traders consider the underlying assets within the company's financial issues as well as the dividends and the market interest rate etc. By including more parameters in affecting the real value of the underlying assets, the valuation is more precise and accurate to the actual value. Thus the fundamental traders can be divided into highly informed traders and low informed traders according to their information dissemination.

Comparing to the fundamental traders, there are technical traders considering the historical data for analyzing the price trends. By predicting the future price changes, within analyzing the historical charts, performances of the portfolio and future risk possibilities etc., the technical traders relate the data to judge the investment strategies. Thus there are different types of trading strategies regarding to focus different perspectives of the future trends. Generally, there are strategic technical traders such as momentum and contrarian traders. For the momentum

traders, they believe in the increasing (decreasing) price will lead the further price increase (drop). The contrarian traders see the price change leads to the opposite direction of future trend thus arbitraging the opportunity. On the other hand is the non-strategic traders who randomly trade with making decisions without considering the exact strategies but providing liquidity ensuring the market in operation.

For comparing the trader behaviour of the real stock market, we choose the fundamental traders (highly informed and noisily informed) and market makers to represent agents and their strategies in details. We will focus on different types of fundamentalists with the interactions with the market makers in the experimental stock market thus further exploring the price movements.

4. OBJECT ORIENTED ANALYSIS

4.1 Introduction

Before initiating the software design, the analysis phase is built up for conceptualizing the outline of the project objects and goals in details. As for the agent-based simulation, we will follow the object oriented design steps for the software development. Therefore, from the object oriented analysis phase, we will be focusing on developing object classes and use cases according to the problem analysis; the agents' interaction showed by the sequence diagrams and activity diagram and finalized user requirements and system requirements.

Objectives

Experimental stock market

Aim to build an experimental stock market simulation environment by using order book model, presenting traders behaviour according to order book price changes and collect trader interaction data for further results analysis via FTSE100 market data.

Agent based modeling

The aims of the agent based simulation system is designed to provide the model users to observe the stock market emergent phenomena by simulating the agents' interaction based on the order book quotes change. By selecting 10 companies from the FTSE100 components and developing the experimental order book model for different trading strategies from the fundamental traders, as well as the impact on the market makers in orders execution coping with the fundamental traders, the system is designed to capture the observed price emergent phenomena such as strange quotes clashes, in which large amounts of quotes executed in seconds with unusual characteristics.

4.2 System Design Guidance

As treating the interacted agents as individual makes their own decisions on trading strategies, the involved agents are classified from the automatic algorithmic traders. By adopting the object oriented design system from the software engineering methodology, our project is mainly following the Object Oriented design approach throughout the whole process. From initiating the project from gathering user requirements, to system design within UML diagrams and use case specifications, to prototype functionally and technically, till the experiments and testing for the final system evaluation, our project aims to implement each phase accordingly. However, considering the past research methodologies in exploring agent-based modelling of market dynamics, there are major trend in building up the computational models in quantifying the figures into equations. We focus on the agents' interaction and their relationships between each other with decision-making process as well as the visualised presentation, thus we consider the Object Orient design methodology is the proper guide for our experimental research.

User Analysis and Use Cases

The simulation model is developed for the potentially improvement of the financial information systems, thus the aimed users would be traders, brokers, bank dealers, consultancy services and information research organisations. Different users will require the specific features for different perspectives of the simulation results. Thus the built-in parameters should enable the users to alter the time period or price limits etc. Therefore, the system users are separated into two types: model maintainers and model users. The user requires the model to be running and

selecting the pre load model. The developer will design, develop and edit the model for further amends.

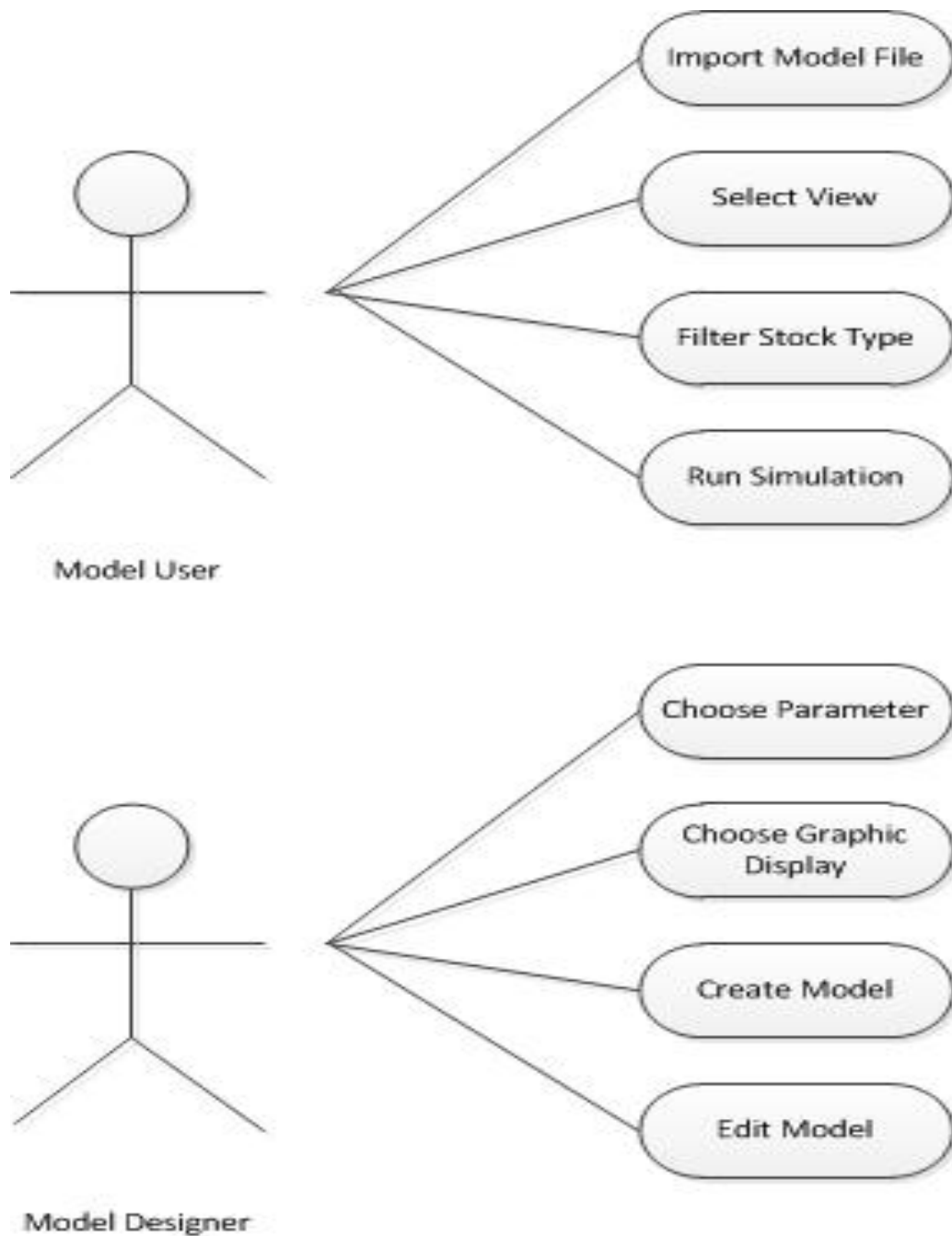


Figure 2.1 Use case diagram

Import model file

Model user uploads the model from the folders for the system to import the model file from the existing location.

Select view

Model user selects the specific type of stocks from the FTSE100 for viewing by the stock code. All the stock market data of FTSE100 companies will be displayed for choose and stored in the view filter menu folder.

Filter stock type

By names or ID the user chooses different types of stocks for the order book simulation. For setting a certain parameter i.e. time period, price limits etc. then filter the stock type for execution.

Run simulation

Model user chooses simulation parameters and enabled to run each simulation accordingly. The visualised the simulation system also enables the user to start and stop the running at any moment. The paused current state is temporarily saved to allow the system to keep the later simulation.

Choose parameters

The parameters default settings do provide the user or developer to do any changes or alteration thus enabling the users to use any parameters accordingly.

Choose graphic display

As the visualised the simulation model, the user needs to select the graphic view in different ways. By showing different movement diagrams or simulation results in graphic display, the users could see the order book price movement, quotes movement graphs and charts as well as the agents' simulation state.

Create model

Model maintainer creates the model from the imported file and set up the parameters as well as monitoring and maintaining the whole system for any further amends and alteration.

Edit model

Model designer changes any parameter according to requirements or further editing.

User requirements

User requirements gathering and analysis is the first essential base for the object-oriented design. The first phase includes the discussion and interaction with the users and aims to specify the users' needs for the design or the improvement of the existing system.

UR-1. The system must have model simulation builder and user interface.

UR-2. The system must enable the model user to import model file from the market data files for the model builder and creation.

UR-3. The system must enable the visualized interface for the simulation interaction and results.

UR-4. The system must provide interface for user to choose parameters and stock types.

UR-5. The system must react to the users' selection for the certain simulation.

UR-6. The system must generate both the visualized trader interaction interface and separate stock quotes movements.

UR-7. The system must enable the user to choose the specific order book and stock for the simulation.

4.3 System Requirements

System requirements are for the development of the model designer with user requirements. By enabling the specified user requirements as well as the whole system running, the system requirements will separate to functional requirements and non-functional requirements. Furthermore, the requirements can be classified as must have, should have and could have levels for implementing the design.

Functional requirements

FR-1. The system must enable traders to move randomly and interact with each other with different parameters.

FR-2. The system must enable the user to alter the simulation parameters by changing text files.

FR-3. The system must update each step and movement based on the trader behaviour parameters change.

FR-4. The system must provide the visualized simulation results for the interaction and quotes change diagrams.

FR-5. The system should include three types of traders which represent the highly informed fundamental traders, noisily informed fundamental traders and market makers.

FR-6. The system must enable trader ball to choose from different pre loaded stocks and specific order book to trade.

FR-7. The system must have output graphs and diagrams for further analyzing trader interaction.

FR-8. The system must enable huge amount of random behaved traders to trade in the particular order book.

FR-9. The system could include the simulated market quotes change with comparison to the external system of quotes change diagrams.

FR-10. The system should enable the update history and saved the alteration files.

Non-functional requirements

NFR-1. The system should enable separate model creation coding package and user interface builder package for least interfere of update coding.

NFR-2. The system should provide the developer the availability to upload and import from the external systems.

5. OBJECT ORIENTED DESIGN

Object oriented design is the implementation guideline to the actual system design based on the previous technical analysis. Furthermore, before the programing and coding development, the developer should be fully informed of the design requirements. Thus by specific analyzing the whole system and technical and objectives, the following part is concentrate on understanding

the previous analysis and their relationships for the further implementation. Therefore, the object-oriented design should include the finalized explanation of simulation environment design, basic system design, interaction diagram, class diagram and activity diagrams.

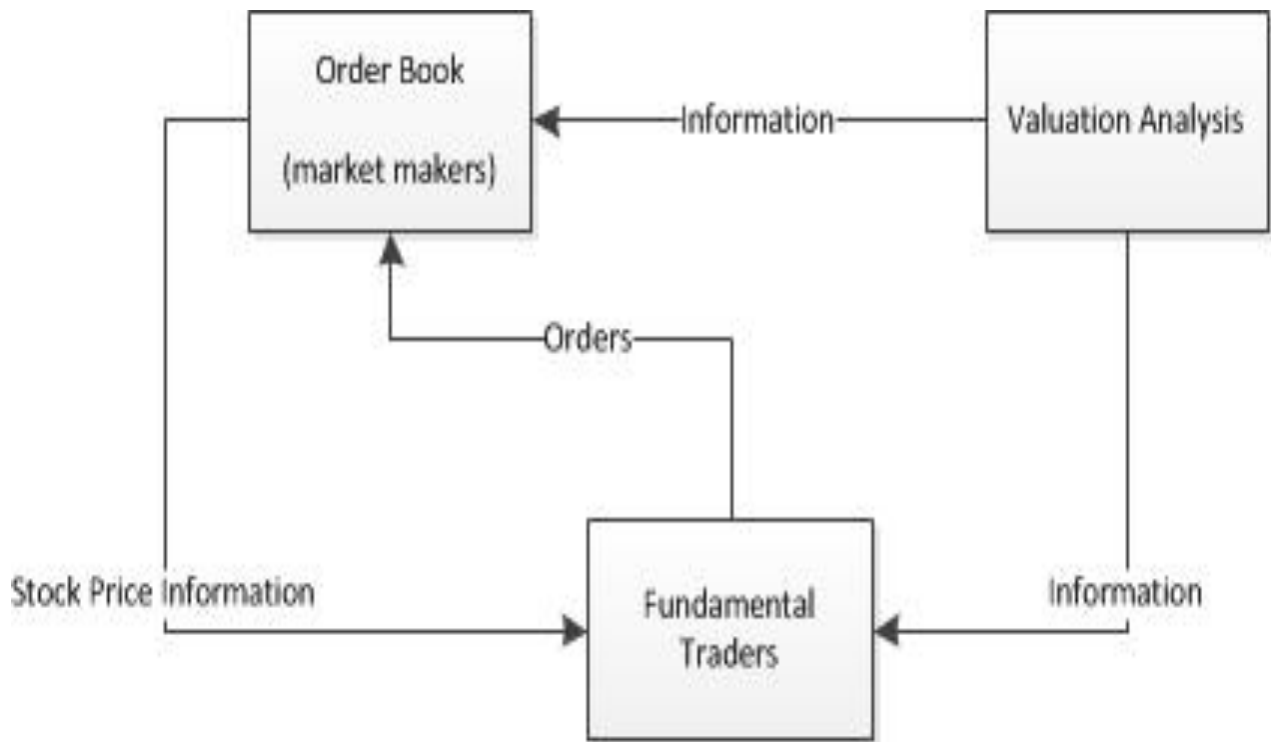
5.1 The Basic Stock Market System Design

From this section, we will introduce the simulated market structure with the general market framework structure, then move to the system design and finally focus on the order submission process regarding to the trader behaviour aspects.

Generally, the agent-based simulated stock market has the following components for constructing the market functionalities.

The trading instruments are the stocks picked up from the FTSE 100 companies. By assessing the risk levels and their portfolios management, the information resources are the judgment basics for the fundamental traders. Both highly informed and noisily informed traders requirement the information affects the fundamental valued of the underlying stocks. And further compared with the real market values. The orders are including limit orders and market orders. Each order contains the stock type, size, time period and listed prices. The market agents are stock market participants including the traders (fundamental traders with different trading strategies) and market makers for the simple experimental interactions. As fundamental traders make decision on arbitraging the profits from over or under valued stock comparing their intrinsic real value to the market value, the market maker for each stock then decides on the execution of the particular order within further updating the bid-ask quotes. Also the trading process we try to model is the continuous series however, we separate break down the steps into small time period then aggregate the steps to be randomly continuous trading sessions. By following the certain market rules and regulations, the experimental market is simply constructed with essential components for observing the fundamental traders types and market maker interactions.

Figure 2.2 the general simulated market structure



The system design is based on experimental stock market and interacted traders buying and selling quotes via order book system. As the experimental market is only derived from the real market data, it contains the basic markets characteristics for the simulation interaction. In our simulation process, as the external markets news will affect the price movements, the traders are triggered to making decisions on choosing particular stocks quotes in reaction. According to different information perception and trading strategies, different types of traders will prioritize the particular quotes targeting in buying and selling. Detailed order book price movements thus representing the traders' behaviors with strategic intentions in making profits or fulfilling the certain trading requirements. As the trader sending the particular orders message, the large amount trader's quotes aggregate together to collectively drive the price movements. For the simulation system, by modeling the trader movements in the stock market with further comparison with the external quotes change diagrams, thus identifying the emergent phenomena happened through real market quotes crash results.

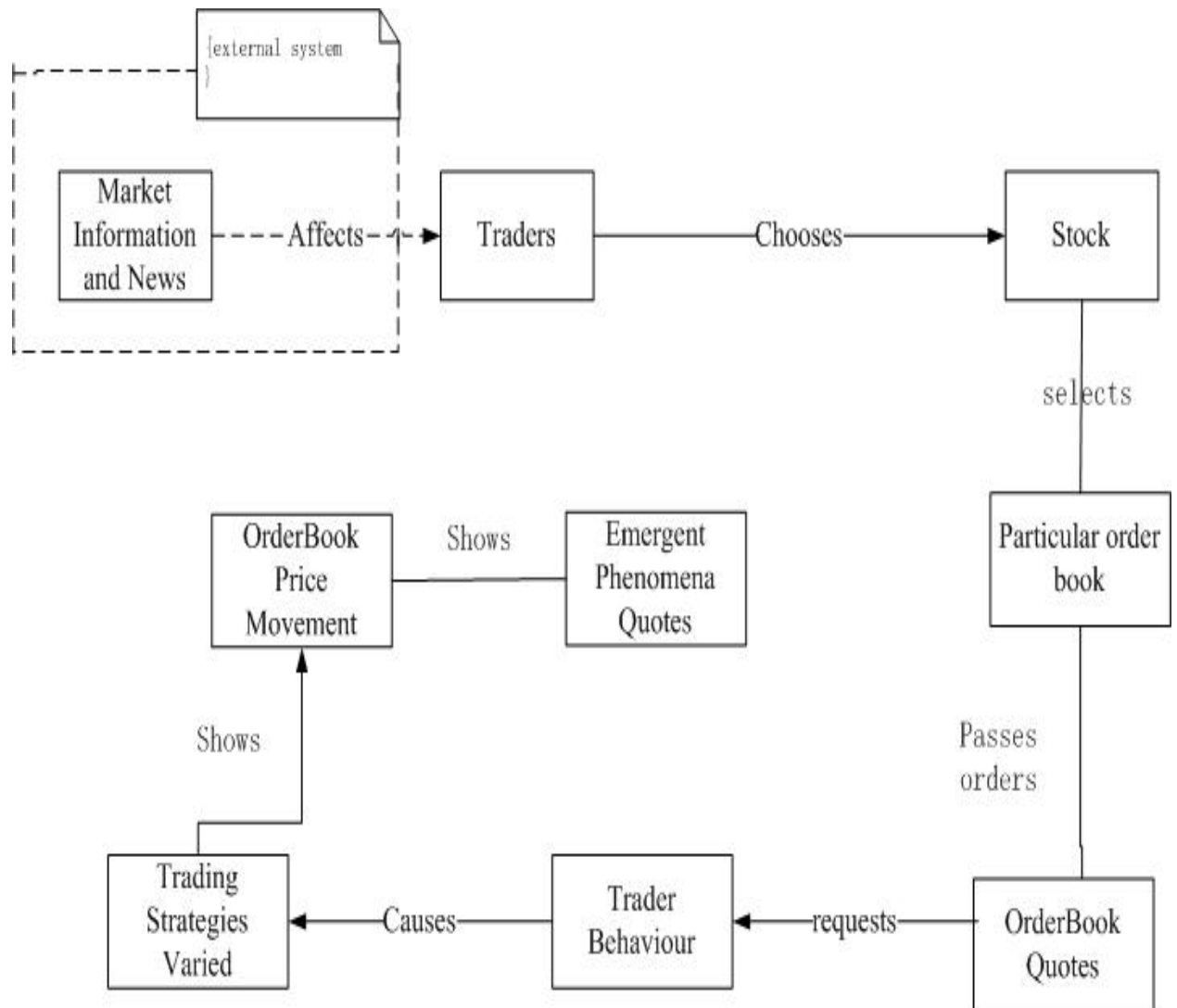


Figure 2.3 the system design diagram

5.2 Class Diagram Analysis

According to the technical requirements, the system design in coding should be least interfere the model builder and interface system. Therefore, the class diagrams below identify the model simulation and interface simulation separately based on the data and responsibility design approaches.

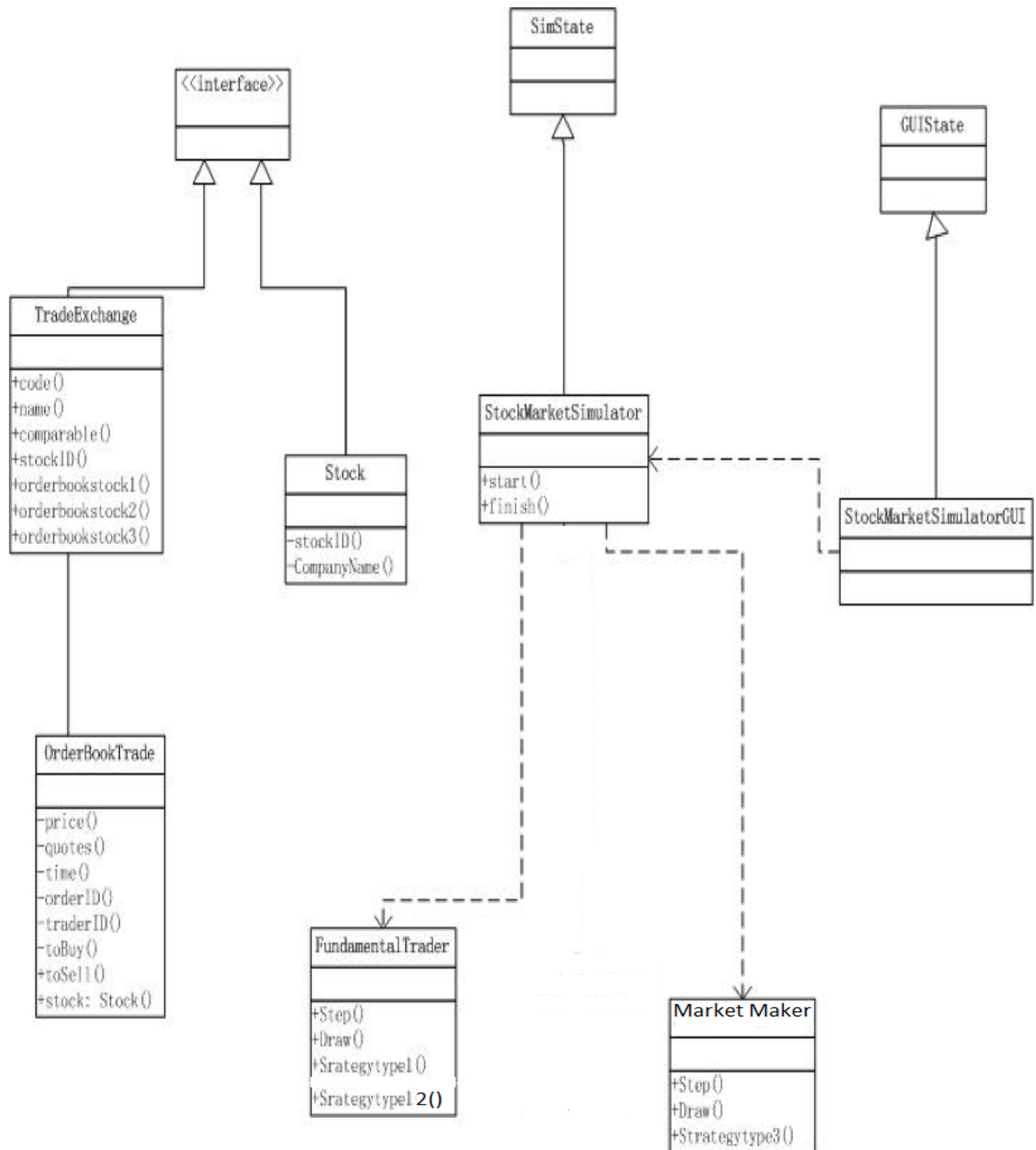


Figure 2.4 agent based simulation stock market class diagram

5.3 Agent-Based Sequence Diagram

The sequence diagram is the direct states by explaining separate operations of the invoker in a sequential approach. For our simulation system, the involved objects are basically the particular chosen stock and three types of traders. Moreover, as the object is to simulate the massive aggregate reaction of the traders' interaction, the each sequence represents separate repeatable process for the whole random based simulation.

In our experiment, we set the rules that if the stock is getting close to a fundamental trader, different trader type will assess the stock ball information with their valuation strategy to judge its over or under valued compared to the market value and later on reacts to the stock ball by choosing changing colors accordingly.

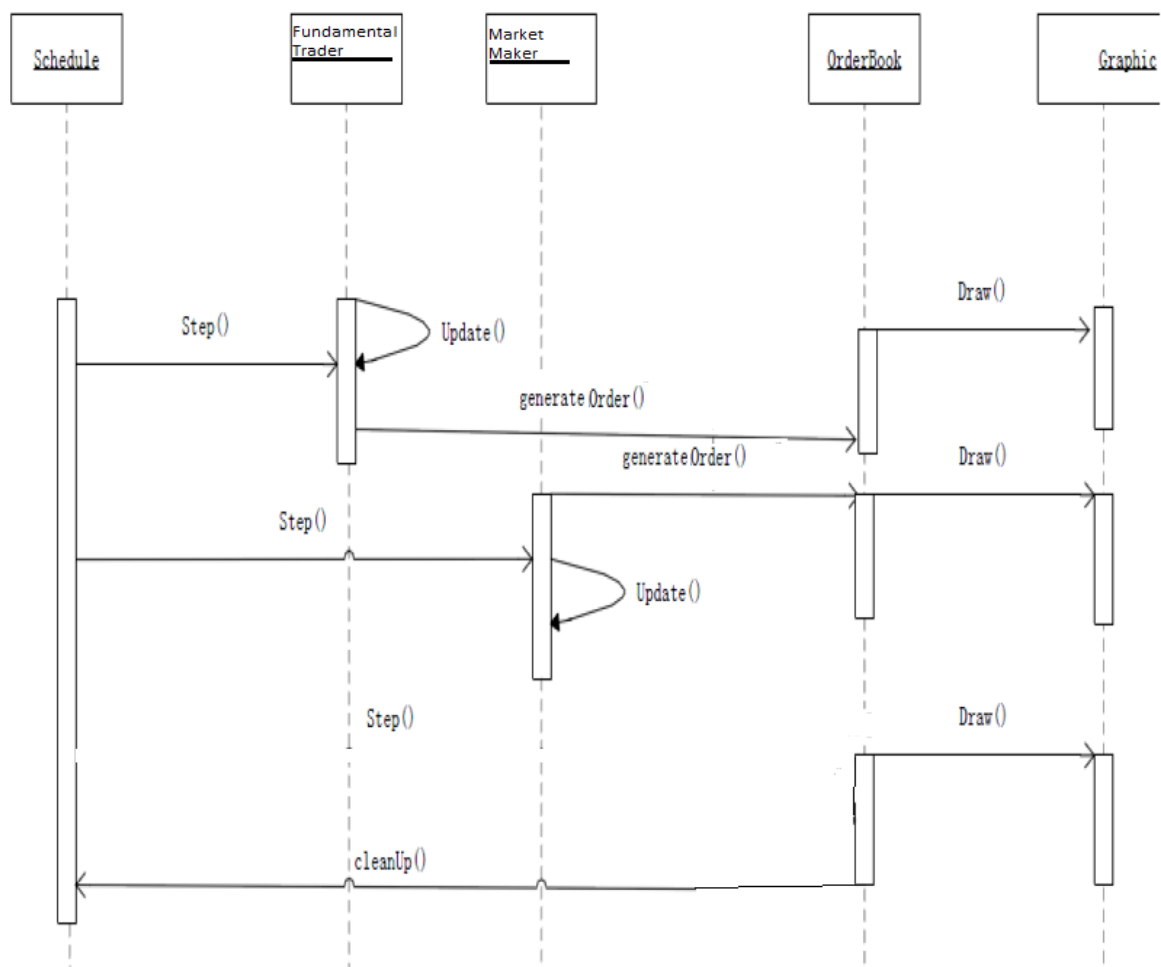


Figure 2.5 agent based simulation sequence diagram

Specifically, before we exploring the agents' behaviour in choosing different strategies according to the environment contingencies, the order submission for execution process determines the trading reaction to take place. For each agent, after receiving the environment triggers, then analyses the responding strategies then make the decision in orders submission for order book execution as following diagram showing:



Figure 2.6 the agent behaviour procedure of order making

5.4 Activity Diagram Analysis

As the activity diagram shows the process of the activity flow in a continuous way, the simulation is simply made up with the interaction between the fundamental trader and the market maker. By specifying a series of activities of these two types of agents, the activity diagram below shows the detailed state of activities of each stoppable simulation repeatedly.

For the fundamental traders, their activity starts from receiving the market information then transforms the messages into valuation of the underlying stock. In deciding to update their portfolio proportions according to the messages or wait till the time expired the fundamental traders could keep the previous orders unchanged. Also if the traders receive the over value or under value of the underlying stock prices compared to the market data, the highly informed and noisily informed fundamental traders will place the orders with different price levels which represent the different trading strategies regarding the valuation parameter.

Considering the market maker agent, they start to receive market orders considering the market information as well. For the orders in the market price levels they operate in executing the market orders according to the matching rules. For the unmatched orders, they will store them in the limit order books. By evaluating the real stock value and study the difference between the market price and the accurate intrinsic value, the market maker derives different strategies in order executions submitted from the fundamental traders. Then confirm the order transactions and update the new bid-ask quotes to end the step.

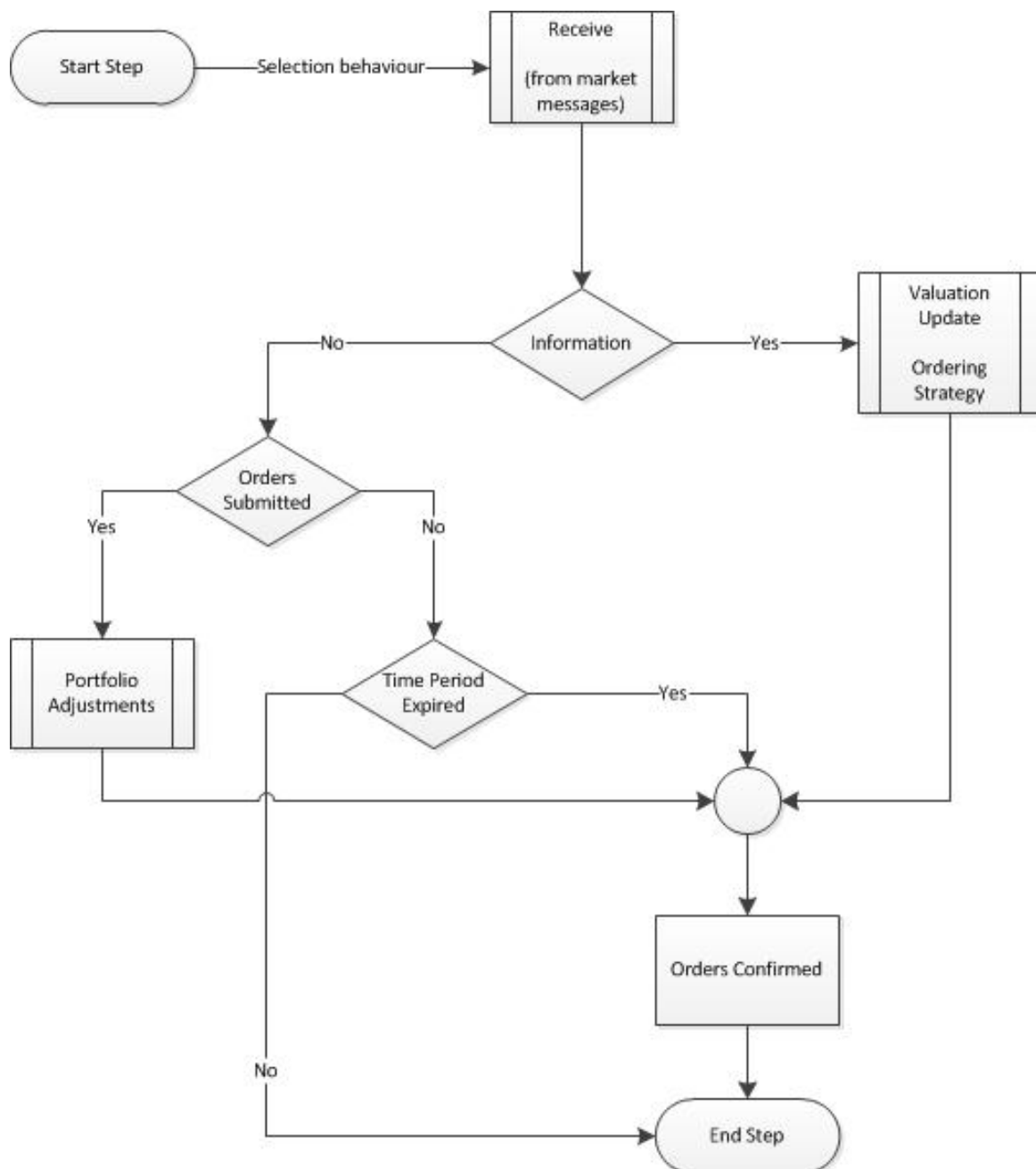


Figure 2.7 fundamental trader agent activity diagram

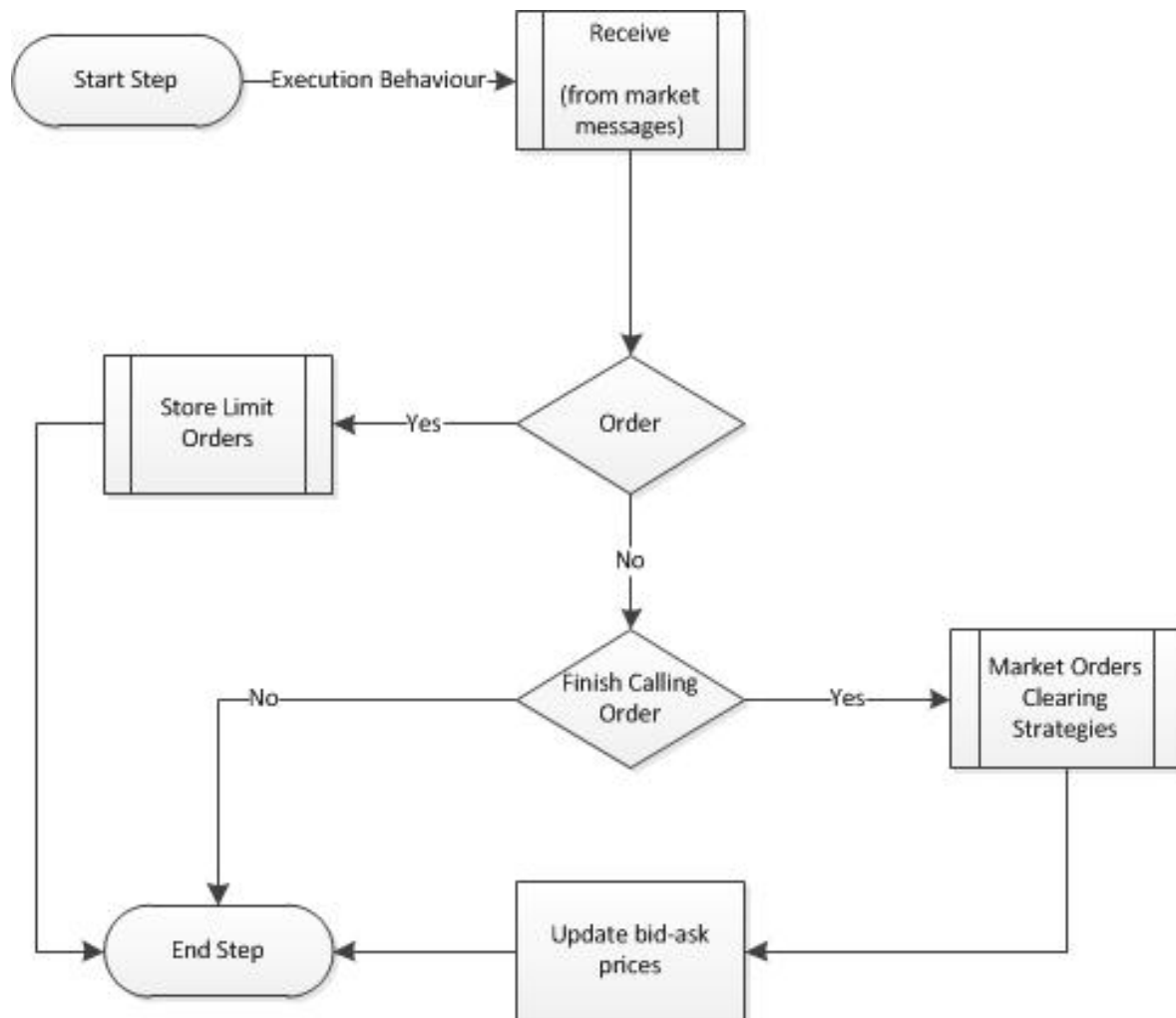


Figure 2.8 market maker agent activity diagram

Followed the previous phases, the final stage of our agent-based simulation market is to visualize the interaction results in the graphic charts. And our aim is to construct the model to generate the trading participants' activities to show the price emergent phenomena. By looking at the market as a whole, the orders aggregate into either market orders or limit orders through the fundamental traders' orders submission, then the market maker strategically executes each order and consequently all the orders collectively drive the market price continuously with updating price changes.

6. IMPLEMENTATION AND TESTING

6.1 Software Used For Development

JDK 6u27 with NetBeans 7.0.1

The JDK 6 including NetBeans IDE is the Java programming platform. It provides the Java programming facilities as well as the applications for constructing the systematic environments. Combining the packages in constructing projects including Java SE7, supported applications bundles and compiler together, the Netbeans platform enables the whole process in coding, compiling, testing and further experiments. Furthermore, the bundle also supports external utilities and systems such as GlassFish 3.1, Oracle WebLogic, Oracle Database, Maven 3, and HTML 5 etc.

MASON

Java platform enabled agent-based models simulation. The simulation builder introduces the concept of separating the visualization and model builder into independent packages. Thus ensuring the easy adjustments of each element without interfering with others at any time. The system includes the model constructor using Java programming languages and the visualizer containing PNG snapshots, Quicktime movies, graph generators and data output streams. Also it provides the console in controlling the panel includes GUI, Graphics and other simulated outputs results. The control panel is displayed as plays, stops, pauses buttons as well as self-checkpoint functions. The user-friendly model console enables the alteration of the parameters as well as inspecting the models for further changes and updates.

By enabling I-text, Jcommon, Jfreechart and Jmf, MASON toolkit enables the applications on importing text files, exporting simulated charts, and media control console within built in Java compatible packages.

Nanex

External comparison system for implementation results analysis. By creating the NxCore- a market data generator from streaming the whole dataset then transforms into graphic outputs using API. Nanex develops the NxCore platform in running the separate applications in

analyzing the market prices, dataset, and trends and also provides related analysis reports of the effects and causes of the special occurrences. We are using the Nanex quotes generator from the real market data and processed quotes prices and sizes graphs for the experimental results.

Microsoft Visio Professional 2007

This is the professional diagramming application. By providing advance diagrams layouts and templates enabling the users to generate different graphic pictures for different purposed system design. It also provides easily display for user with data compatible functions within the diagrams; the professional information diagram drawer programme is used for generating UML diagrams for our project.

JUnit

JUnit is used for the system testing. It is a Java enabling unit testing application derived from the external Java library. It contains methods in examining the functions of the experimental systems and provides the testing results according to the requirements.

6.2 Agent-Based Simulation Of Emergent Behaviour In Stock Market

As described in the problem section of the structure of the market participants, the traders interact with the environment all the time. They continuously decides to take action depend on the internal strategies as well as on the contingency environment conditions. Thus inspired us to implement the agent-based simulation to model the trading environment for emergent phenomena from trader behaviour impact.

During this section, we will firstly introduce the agent-based simulation environment model packages, and we will specify the package classes in details. Then, we will present the interaction model elements as well as a whole organized structure with analysis. Finally, set up the implementation specification of the simulated market for observing the emergent phenomena.

6.2.1 The Simulation Environment

The simulated environment is based on the agent-based simulation built on MASON –Java based agent simulation modeling toolkit. In totally compliance with Java programming

platform for object-oriented design, MASON enables the independent modeling, visualization and utility components, checkpoint and easily implemented prototype presenting.

The MASON simulation structure consists of three main parts, which are running independently on the same simulation environment, thus there are basically three main package bundles:

- The model packages:
 - *Model* class presents the model and all the subclasses of all the components in the package.
 - *Model Market* class simulates the interaction result of market price dynamics according to model parameters.
 - *Model Market Books* packages contain the execution order books in order matching and execution generated.
 - *Model Agents* consists of market participants in separate classes represent different trader types i.e. highly informed fundamental traders, noisily informed fundamental traders and market maker agents.
- The visualization packages:
 - *GUI* visualizes the SimState model without mixing into the simulation by wrapping the visualized tools construction separately.
- The utilities packages:
 - *Support* collects the external programming utilities variables in supporting Java constructing.

6.2.2 Class Specifications

Model

The Model class is the main simulation engine in conducting trader interaction in a number of steps within a time series. The Model subclass acts as the SimState extended class. The *main()* method implements the do loop in calling *start()* and *finish()* method. The *start()* method initiates the simulation and the *finish()* method pulses at the time when the scheduler is called to pause. The Model class is compliance with *modelManager* in supporting inserting, locating

and deleting components in the Maps. Thus it implements hash functions with data location and storage method called *HashMap* with *parameterMap* and *optionMap* enabled.

Model Manager

The Model manager enables the reading files in values from the text files with implementing *buffer reader* in loading values from the data files. Before simulating certain agents stored in the Arraylist in the scheduling order with the *buffer reader* reads the instances from the *agent Configuration* files. Then set up the corresponding running model from reading the selected model form *main.properties* files.

Model. Market

The market class implements Arraylist in storing order books platform with presenting the stock market price dynamics.

Model. Agents

Basically, all the interacting agents represent the traders comes from *GenericTrader* object. There are three types of trader including *FundamentalTrader* (*Hplayer*, *Nplayer*) and *Marketmaker*. All the agents are operated on the MASON simulated stock market order book platform with either *MarketOrders* or *LimitOrders*. As MASON implements the stoppable agents simulation concept in modeling, the agents construction sets up the operation in separate stoppable steps. Therefore each agent is randomized called by *step()* function for individual iteration loop. As implementing the same interface of *sim.engine.steppable*, the agents react to the step calling and follow the scheduler to interact in an order from *schedule()* method. Each agent thus enabled with firing or pulsed actions in simulation. With referring from the *stockmarketModel* and a *setups()* function from *ModelManager*, the participant reacted randomly.

Order Book

The *OrderBook* implements the trading platform interface. As providing different order books according different trading strategies, the interface operates as order initiation and execution platform for executing market orders or limit orders. It implements *DoubleAuctionOrderBook* interface derived from the stock market order book structure. Thus containing *FundamentalTrader* place their limit orders according to the underlying value of the company

in judging the overvalued or undervalued generated internally; *MarketmakerTrader* random proposes their market orders in providing liquidity; Equipped with *HashSet* and *TreeSet* from *Set* interface, the limit orders are stored in the sorted order with easy location search functions.

GUI visualizer

The GUI visualizer interface is divided into two main package parts: the *StockMarketModelWithUI* class and *GUIReporter* class. They are functioning as constructing and managing the visualizer respectively. As *StockMarketModelWithUI* is built as a subclass of *GUIState*, it contains *main()* method in visualizing the operation console, thus enabling the model user to change parameters accordingly. By altering X and Y axis as well as managing running steps of the simulation model, the *start()* and *quit()* methods controls the orders of portraying the fields. As the agents been fired out, the *init()* method is called to visualize the display the framework. Also with each step generated, the corresponding data updating of each agents need to be refreshed into the memory files. Therefore, the *GUIReporter* class stored in the array list is implemented. As the simulation is running, the temporary and updated console data are stored and further written on a *timeseries* files during a step series period.

SetUps Manager

In order to enable selecting different parameters of the simulation to run, the *SetUps manager* consists of all the parameters configuration files. Thus the chosen order books are easily altered according to specific parameters for certain interactions. By providing a number of instances for each trader types, the simulation is running by supporting different traders in separate lines of operation.

Recorder

The recorder class contains *buffered writer* in recording interacted results in a text file as well as keeping updated and historical data in *time series* text files when simulating the interaction.

6.3 Model Structure Analysis

The agent-based simulation model is aimed to identify the emergent phenomena in stock market from the impact of traders' behaviour. Therefore, the model needs to generate

visualized representations of price movements from traders' interactions through order book trading processes.

As aim to implement the agent-based simulation on stock markets, we are setting the continuous time simulated environment for our experiments as the financial markets are actually acting as continuous trading within autonomous traders' interactions. And our objective focuses on the learning market maker (Das 2005), which explores the information impact on the price movements i.e., the bid-ask spread in the stock market. We thus build our implementation framework on the object-oriented design. Within defining each object as each class package to achieve specific goals through the whole simulation based on agent-based modeling approach.

The model focuses on the interactions between the traders, which particularly chose the fundamental traders and market makers throughout the information dissemination. Therefore, the transaction set is based on the market maker in discovering the fundamental value of a stock to set bid-ask quotes in learning behaviour. For a particular transaction, the stock price shown on the market either overvalued or undervalued compared to its intrinsic value. The market maker thus tracks the fundamental value continuously to change the bid-ask spread in order to reflect the real market prices. During this session, different types of fundamental traders take the advantage of the value difference to arbitrage the profit in different strategies, thus the market maker has to react quickly to changes and publish new market quotes. In order to ensure the order book trading to correctly represent the market prices, the market maker needs to react timely to intensive order changes with regarding expectation of the stock's real value, the order movements, and knowledge on fundamental trader ratios (Glosten & Milgrom 1985).

Therefore, the stock market implementation concerns the following aspects in assumption:

- The organizational structure
- The fundamental value
- The market participants behaviour

From the organization structure, we set the trading sessions being continuously executing with quote-driven matching system. For every session, there is only one stock traded. With one market maker with a number of traders involved without dividends payment. The fundamental

value of the underlying stock during time period t is V_t (in pence). As the market maker sets up the bid-ask quotes according to the collective information perception, the bid-ask spread prices are determined as $V_t - d/2$ and $V_t + d/2$ respectively. The trading session happens through double auctions and every trading includes one trader chosen from the traders' pool. The chosen one to operate trading in selling bid or buying offer. While the market maker is providing liquidity for the stock market thus responsible to execute the orders as well as updating the bid-ask prices i.e. P_b and P_a according to the market information. All the execution orders are traded in unit size with time period in steps (seconds). For the fundamental value V_t , we set it discretely changes every trading period through a normal distribution process. Within the probability of change in 0.01 and the value follows the distribution of $V_t' = V_t + w(0, g)$ where $w(0, g)$ identifies the mean value of zero and standard deviation of g .

For the investors' behaviour, the fundamental traders we particularly analyze can be divided into two groups according to their information reception: informed and uninformed traders. Furthermore, the informed traders can be identified as highly informed and noisily informed traders. Therefore, as the highly informed trader derives the real fundamental value V_t , the noisily informed trader does really know the true value behaves in trading randomly and receives the fundamental value of $N_t = V_t + v(0, m)$ where $v(0, m)$ shows the normal distribution of the difference in valuation from the real value. As motivated by price misvaluation, the informed traders decide to buy or sell or not trading. If $V_t > P_a$ for highly informed traders or $N_t > P_a$, which means the observed fundamental value of the underlying stock is higher than the market maker's ask price, they will react in buying and vice versa. Additionally, there is set the equal opportunity for the uninformed traders to trade with probability of 0.5 for each side regarding informed traders.

For the market maker, their responsibility is ensuring the trading session in providing liquidity. Their behaviour includes in executing orders and updating bid-ask quotes according to price movements. Therefore, they are setting P_b and P_a regarding to the reception on fundamental value changes according to the informed and uninformed traders' quotes submission reactions. Therefore, the model console needs to present the simulation results in graphs for further analysis. The graphs thus include price movements' charts of the experimental stock market, trading volume charts as well as the order book operation graphs. Also within representing the whole stock market, the simulation display set also enables in presenting full market simulation

charts group for further research including: Prices Chart, Returns Chart, Sizes Chart, Diagram, Orderbook Chart.

6.4 Testing And Evaluation

6.4.1 Testing

For the purpose of tracking the system design to properly implement according to the functional objectives, the testing process focus on examining correctness and accuracy of the implementation separately through unit test-first steps. In verification in units of the system functions individually to check each elements correctly implemented for the model, the unit testing needs to regard each components from debugging errors or inaccuracies. Through testing each aspect of the model structure, our functional testing phases include data testing and functional cases testing.

Therefore, we take the correctness inspection on following:

- Data testing in correctly set:
 - Generated orders with price changes
 - Autocorrelation of returns
- Functional cases testing in correctly build up:
 - Parameter settings
 - Bid-ask spread settings

6.4.2 Validation

Model validation is about constructing the right models. Therefore, by following the design objectives, the model needs consistently runs with accuracy in application processes. As the project aims to build up the simulated stock market model in observing price emergent phenomena, the basic objective is to compare the results in explaining the real market phenomena. Thus within inspiration from external Nanex application in presenting real market emergent quotes behaviour, our model focuses on running out similar simulated results

observed in the current stock market. By presenting the output graphs compared with Nanex data recorded, the emergent phenomena are graphically visualized as price dynamics and increased volatility as price plot and autocorrelation returns graphs presented.

6.4.3 Evaluation

Regarding the agent-based simulation is the simple version in presenting the agents' behavioral interaction following the bottom up approach. As well as the project goal is in identifying emergent phenomena from the simulated results compared to the observed facts in the reality. Therefore, the running results cannot be guaranteed to present every single result in emerging form, which are the price volatility graphs. However, by adding more random acting agents and ensure the large amounts of randomized traders; the random seeding wrapper enables the simulated parameters to relate to the real situation. Moreover, as the simple generated model can not fully implements the complex continuous trading sessions, the bid-ask spread results are much different from the real spread. With eliminating transaction costs in determining the fundamental value, the estimated bid-ask spread prices are not perfectly accurate. However, the focus on observing the emergent phenomena characteristics showed on market prices movements is in accordance with the previous findings.

6.4.4 Performance Testing

The market model we are experimenting in general 20 transactions have been simulated during per step series. The time series generated in the continuous mode are around over 2000 steps. In case of continuous trading session, the agents number added in proportion in 20 percent for each level and finally accumulates to 60 percent in total for enabling random agents complexity. The total time in running the project package takes about 6 seconds with console for selecting display features. As for calling particular visualization results takes about 2 seconds each. The simulated results stably presented all the time over the performance testing. The market dynamics such as price plots updated with the speed of 4 seconds in response after changing parameters. For each session given the more random agents interacted, the price movements continuously change in a normal speed as before through each step.

Technically, the simulated transaction numbers running based on the computer processing speed, particularly the computational speed. Therefore, for each computer used, the speed slightly differs respectively. However, the construction of the market affects the running speed as the market maker as well. Providing that the market makers has to select orders for execution and further update the bid-ask quotes continuously, the delayed time in decision making is intrinsically related to the computational speed throughout the whole session. In order to minimize the market makers dealing time without stuffing orders, the system is designed to allow the operating delay in 2 seconds. Moreover, the unit testing processed are following software engineering design in object-oriented design, and carried out on Netbeans platform by obeying JUnit testing procedures.

6.5 Experiments

In this section, we are presenting the simulation outputs results with experimental hypothesis. In order to observe and prove the objectives proposed in problem analysis section, we set up the experiments and explore the results based on agents' interaction. We will revise the hypothesis we set up in the beginning with objective goals for the project, and then focus on simulation results with experimental settings.

6.5.1 Hypothesis

The hypotheses we specify is to simulate emergent behaviour arise from the stock market fundamentalists trading for further analyze the financial markets emergent phenomena in reality. Therefore, our hypothesis focuses on examining:

How do the different types of fundamental traders perform for arbitrage profits in driving the order prices?

How does the market maker to react to the fundamental value changes to update the new quotes?

How does the interaction between the fundamental trader and the market maker to cause the emergent phenomena observed in the stock market?

6.5.2 Experimental Settings

The experimental settings consist of two parts, the first part we will identify parameter settings include fundamental value settings, trader behaviour settings and market maker behaviour settings. The second part we will give the experimental operation time line assumption of the repeated interaction. Finally present the simulated results findings through the experiments.

Fundamental value settings

- Set the starting value V_t is 100 pence.
- Set the standard deviation w is 5 pence.
- For the continuous time simulation of the agent-based modeling, our project is simply setting up the continuous transaction steps for the agents' in trading for the underlying fundamental valued stocks. In order to easily simulate in judging the fundamental values of the underlying assets, the value changes in the random direction with normal distribution for a time series with a mean of 0 and standard deviation of 5 pence.

Trader behaviour settings

- The proportion of highly informed traders increment added throughout the experiments. While the low amount of traders cannot represent the enormous individuals for the emergent behaviour occurrence, we will give the values of 20%, 40% and 80% highly informed traders involved to implement the more interacting agents.
- All the traders involved send order messages for one type of stocks on FTSE100 companies. There is no cancellation of orders after submission.
- The proportion of informed and uninformed traders keeps 80% and 20% respectively. Of which the probability in deciding in buying and selling orders from the informed traders is 0.4 for each.

Market maker behaviour settings

- The market makers have the knowledge of proportion of the informed and uninformed traders with their possibility in trading sides.

- The market maker also has the precise reception of the fundamental values of the underlying companies. Based on the FTSE100 with 10 selected companies, the market maker derives the fundamental values compared to the currently published prices. Details of the 10 selected companies with prices valuation presentation are on the appendix.

Experimental operation time line assumption

We are going to take 2000 trading steps with each transaction running for 2 minutes approximately. Depending on the computational performance of the particular computers, the running time of the experiments may slightly vary. However, since the project is focus on simulation results in discovering the emergent phenomena happened after certain interaction steps, therefore, the trading delay is considered within acceptable degree. Thus the operation time line focuses on the repeated loop in finishing the simulation transaction as following:

- The bid-ask prices are initialized from the beginning of the transaction.
- The fundamental traders randomly participated and will compare the current price of the underlying stock value to the values the perceived according to different valuation strategies.
- Informed and uninformed traders make decision on buying or selling or staying on the previous positions accordingly.
- The market maker operates as carrying out the order execution.
- The market maker update new bid-ask spreads.

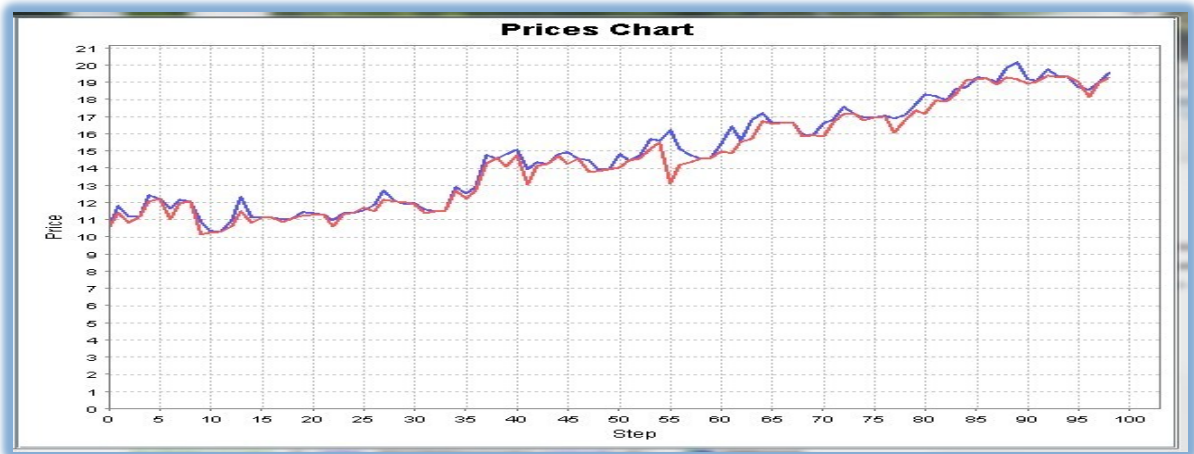
6.5.3 Experimental Results

Figure 3.1 presents the general process repeated of the market maker continuously update the new fundamental values after order executions. As the informed traders percentage increments,

the price fluctuates compared to the previous less agents involved. The uncertainty and wide spread of the bid and ask prices move volatily as the aggregation result from the price plots presented. Therefore, getting a closer look on separate set graphs by changing the market maker numbers increasingly, which as figure 3.2 and 3.3 shown below. We enlarge the individual proportion graphs after replacing new fundamental values and investigate the particular phenomenon during each stage.

From the general figure 3.1 including 2000 transaction steps and 500 market maker, the most distinctive feature of increasing the proportion of informed traders involved from 20% to 40% till 80% indicate the price movements from the visualization results. The aggregated price fluctuations indicate the market makers' reaction to the increase amount of informed traders in dealing with their individual orders. The diverse of the trading strategies according to the judgment on fundamental values perception, the market maker's bid-ask prices start to fluctuate violently.

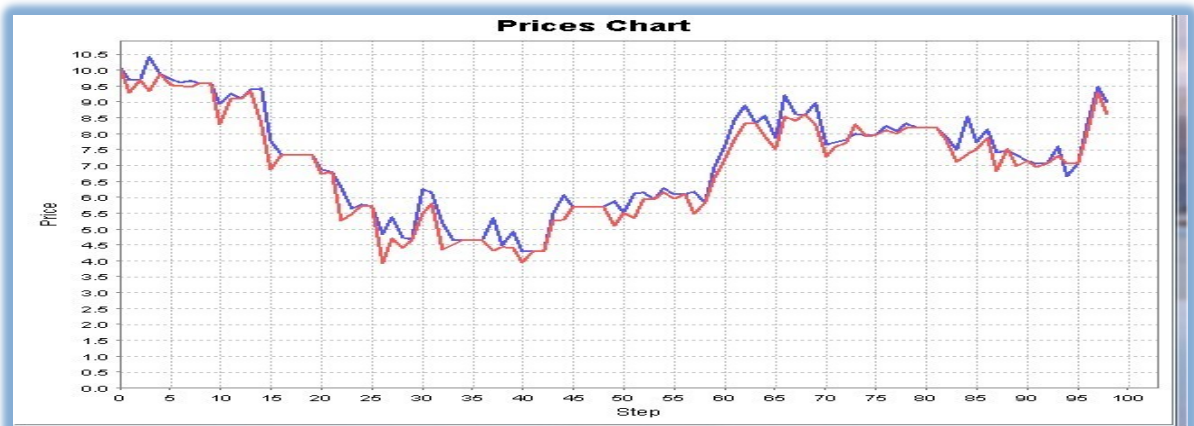
From figure 3.2 and 3.3 when getting the closer view of the price changes, the more intensive reaction by increasing market numbers from 1000 to 1500 are observed after updating the new fundamental values quotes. Especially when look at the 80% of informed traders as the large amount of agents interact in the environments thus the complex response interrelated together to affect the whole price trends to be unstable for the market maker to analyze. Compared to the lower level of agents participation from 20% and 40% informed traders, the relative small number of traders with particular strategies make slightly flat price movements. Particularly, as more highly informed traders added in the simulation, their immediate reaction to the fundamental value changes and large quantities in trader numbers, the market maker needs respond to the aggregate collective phenomena when all of them aimed in arbitraging the profit before the next price jump. Therefore, the emergent phenomena happened, of which all the traders quickly place large amount of orders in a short period thus as visualized on price fluctuations presented as extreme peaks appeared frequently.



(a) Prices plot with 20% highly informed and 80% noisily informed fundamental traders



(b) Prices plot with 40% highly informed and 60% noisily informed fundamental traders

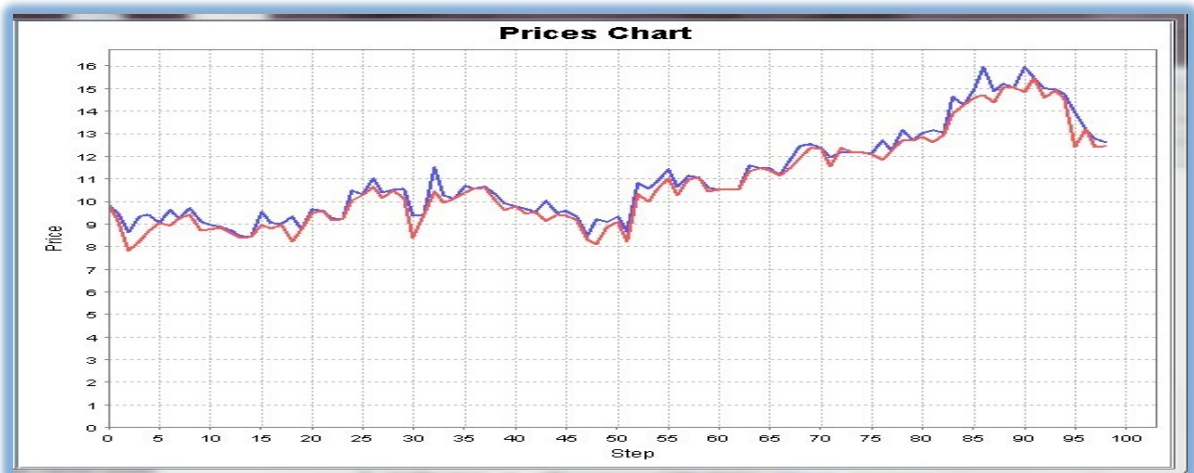


(c) Prices plot with 80% highly informed and 20% noisily informed fundamental traders

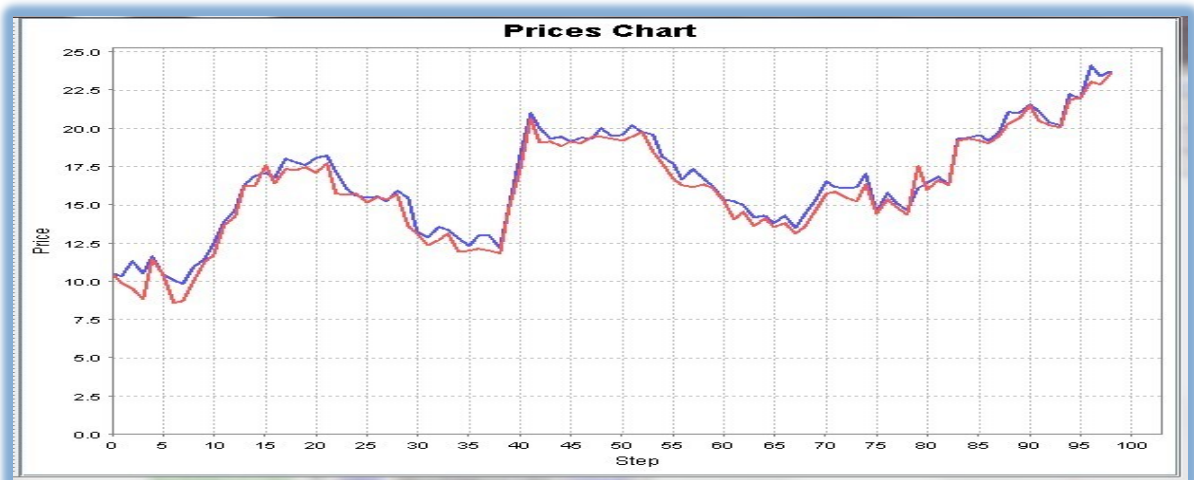
Figure 3.1 prices plot with involvement of different informed fundamental traders proportions and 500 market makers



(a) Prices plot with 20% highly informed and 20% noisily informed fundamental traders



(b) Prices plot with 40% highly informed and 20% noisily informed fundamental traders



(c) Prices plot with 80% highly informed and 20% noisily informed fundamental traders

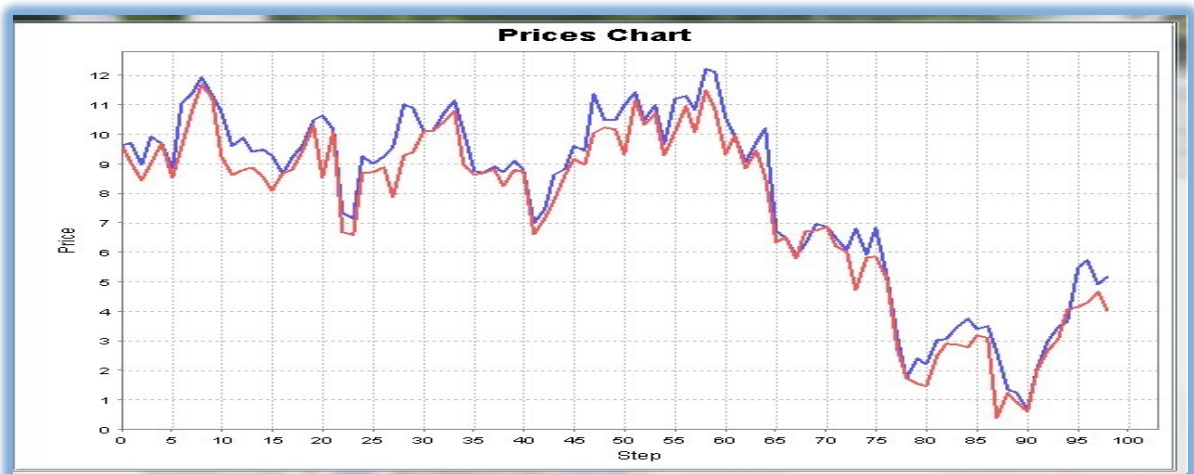
Figure 3.2 prices plot with involvement of different informed fundamental traders proportions and 1000 market makers



(a) Prices plot with 20% highly informed and 20% noisily informed fundamental traders



(b) Prices plot with 40% highly informed and 20% noisily informed fundamental traders

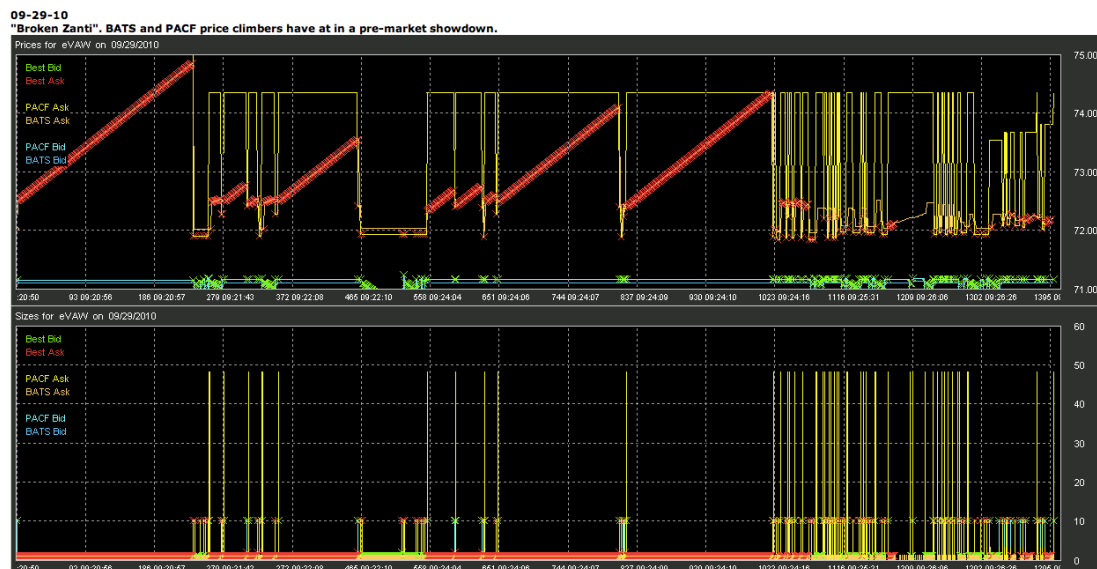


(c) Prices plot with 80% highly informed and 20% noisily informed fundamental traders

Figure 3.3 prices plot with involvement of different informed fundamental traders proportions and 1500 market makers.

Additionally, in comparing with the external quotes recording application Nanex, the crop of the day reports the strange quotes flooding in seconds or aggressive quotes placing movements in a short period, the simulated results show the similar fluctuates in bid-ask prices as follows.

09-29-10 “Broken Zanti”. BATS and PACF price climbers have at in a pre-market showdown.



09-27-10 PACF “Morning Zanti”. Another pre-market Zanti Misfit from PACF running in TZI.



7. CONCLUSION

For this section, we will give the summary of the project with evaluating the whole process with objectives from first chapter. And also discuss on the findings of the experimental results as well as the inspiration for the further research.

7.1 Project overview

As implementing the project goal in designing an agent-based simulation experimental market in explaining the emergent behaviour in the stock market, we follow the objects in constructing the simple interaction model from the traders' behaviour view and visualized in price movements.

Basically, in order to easily understand and investigate in emergent behaviour in financial markets, we chose the one particular stock market to represent all the market structures in financial markets. Also focusing on the trader behaviour in specific type of the traders- the fundamental traders through interaction with the market makers with orders execution operation.

Technically, the system design are built in following object oriented design approach to develop the simulation model and further visualize the interaction results in price movements in the markets. Mainly implemented with MASON agent-based simulation modeling toolkit programmed in Java language, the system is constructed aimed in giving the experimental results compared to the real market data. Moreover, we have entirely fulfilled all user requirements stated in system analysis section, as well as all the 'must' functional requirements through out the application.

7.2 Project evaluation

In order to explore the emergent phenomena in financial markets we used agent-based simulation approach to model the complex traders' interaction in specific stock market. Therefore, we specified our project goal in separate objectives in understanding the emergent behaviour results. The following evaluation is classified as objectives evaluation and work progress evaluation.

Firstly, by revising the objectives from the chapter 1, we carried out the background research on the related literature include financial aspects and modeling aspects as well as emergent phenomena in social science. Therefore, we specifically studied the following areas:

- Agent-based modeling

In investigating the recent developments in agent-based simulation and modeling papers and research topics, as well as studying MASON toolkit for our project particularly, we revised the former areas in analyzing the observation in aim of agent-based models.

- Emergent phenomena in finance

Combined with the social science in explaining the nature interaction among the individuals, the complex emergent occurrence influenced the all other social activity components. By understanding the characteristics and its implication in finance and economics, our project focused on the simulated results and findings in designing the experimental environment in observing the emerged phenomena.

- Financial market structure

By including organizational, functional aspects of the financial markets, our goal is getting well known of how the financial markets work with a series of standard operations, and furthermore to simplify our objectives into certain research aspects.

- Market participants' behaviour

In looking at various financial markets participants with their reaction, we classified three types of market involvers: traders, brokers and market makers with respective behavioral strategies. Thus narrowing our system design focused on the interaction between market makers and traders.

Secondly, in carrying out the system design for our investigation, we adopted the object oriented design approach to guide the development our MASON simulation model. Followed by later chapters with object oriented design analysis, implementation & testing and finally the experimental results. Despite the issues in dealing with specifying the system design parameters as well as installing different programming platforms on both Mac and Windows systems, the overall performance was been fairly successful throughout the whole timeline.

Moreover, as the aim of the project is to observe the simulated results compared to the real market phenomena, the design was kept simple and easy to operate with the respect of basic knowledge of the programming skills contained. And that's also the reason to choose MASON as pure Java language in basic coding.

Finally, the experimental results in some degree did prove the assumptions in emergent phenomena in the financial markets. Visualized price emergent properties as a result of the simulation identified the emergent behaviour occurrence in the financial market. Related to the aspects of the strategic behaviour and emergent characteristics, the view on financial market emerging occurrence is proved by the price movements' model.

However, based on simple agents' interaction simulation model, we eliminated several elements in affecting the financial markets from reality. For the purpose of developing fairly easy visualized model, we could only include a few areas in setting up the parameters for the simulated environments as well as kept the basic functionality of a specific stock market. Therefore, there are also much more possible directions and complicated areas for the future research.

7.3 Further research

As financial market emergent phenomena happened in different aspects as well as arise from various forms of interaction. There are also different areas in investigating emergent properties in financial markets either on explaining the phenomena or developing applications for different purposes. Thus the further research could be stretched in the following possible aspects:

- Complicated simulation environment

Considering different elements in affecting market dynamics, there is still a hard work in defining the simulation environment involving in the experiments to mimic the real complicated market structure. The existing research on constructing experimental agent-based simulation models keeps exploring the possible identifiable properties in quantified ways including in the models. As the emergent behaviour is naturally

happened from the bottom up collective results with the interaction with all the possible environment components, the further research on market environment dynamics is still remain complicated.

- Including more agent types interaction

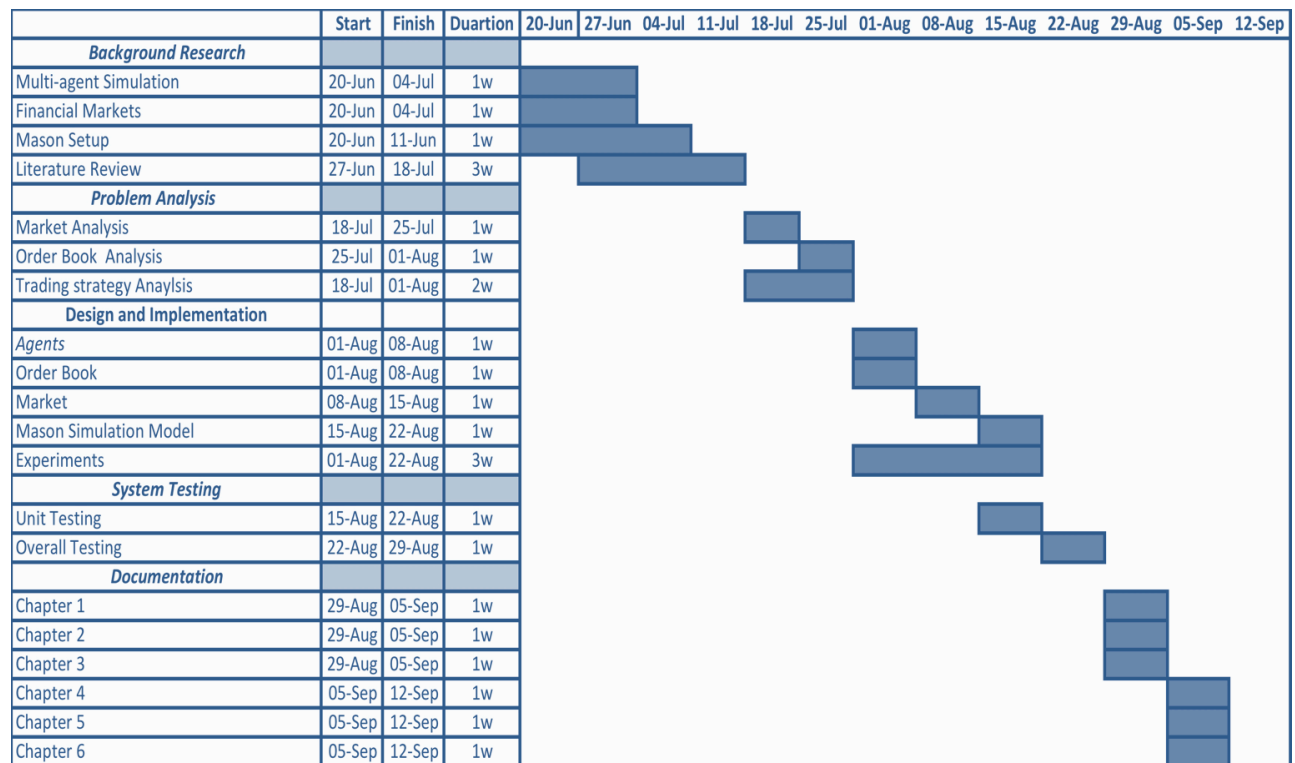
Compared our project only focused on fundamental traders with market maker's relationship, the further work could be diverted in identifying other types of the market participants such as investors, brokers, speculators or purely automatic algorithmic trading systems and their behavioral aspects. Also the timeline in developing the simulation could also have effects in accuracy in modeling the agents' interaction. Either modeling the discrete or continuous time series with different trading strategies, the further research could be varied accordingly.

- Modeling application in controlling financial emergent phenomena

Despite in explaining the emergent properties from the observation, the further development could also be motivated in using the modeling application in controlling the emergent phenomena. By investigating the possible solutions in preventing unexpected results emerged, the simulation methods could be implemented as prediction tools for future analysis.

8. APPENDIX

8.1 Project timeline



8.2 User manual

The user manual shows the process from installing to running and testing the designed experimental system for the users.

Before installing the main project packages, the user needs to download the MASON packages and Netbeans bundle as well as Java 3D application aid.

1. Download the file `jdk-6u26-nb-7_0-windows-ml.exe` form <http://www.oracle.com/technetwork/java/javase/downloads/jdk-netbeans-jsp-142931.html>. That will install/update JDK + NetBeans Bundle.
2. Download Java3D framework by selecting the 'Download Java 3D 1.5.1 Software'

option from <http://www.oracle.com/technetwork/java/javase/tech/index-jsp-138252.html>, and download the file java3d-1_5_1-windows-i586.exe.

3. Download the file 'mason.zip' from <http://cs.gmu.edu/~eclab/projects/mason/>.

4. Download the file libraries.zip called libraries from <http://cs.gmu.edu/~eclab/projects/mason/>.

5. Download the Market Model source packages from <http://svn2.assembla.com/svn/MarketModel/>.

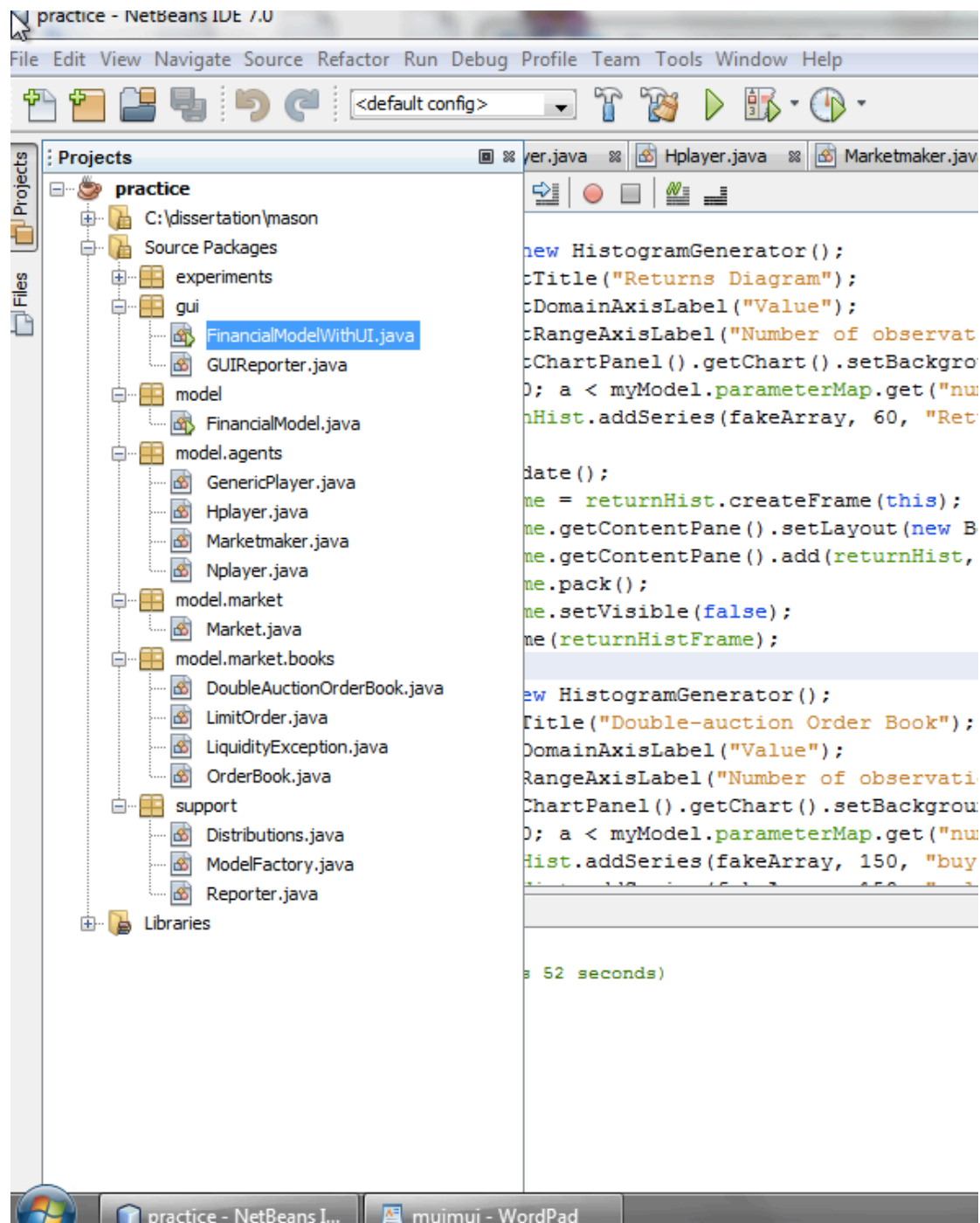
Installing

The installing process includes installing MASON in Netbeans for the system programming and compiling the codes for outputs.

MASON Installation

1. Launch NetBeans 7.0
2. Select 'File -> New Project'. It opens a window to choose the category 'Java' with the type of project 'Java Project with Existing Sources'. Then click 'Next'.
3. In the next window, type the project name 'Project'; And then create a folder for the project 'project' in the Documents folder.
4. While keeping the 'Built Script Name' as the default 'build.xml', and select the option 'Set as Main Project', and not selecting the option 'Use Dedicated Folder for Storing Libraries'. Then Click 'Next'.
5. From the next window, click to add the folders under 'Source Package Folders' as follows: My documents -> Java3D and My documents -> MASON. And leave the 'Test Package Folders' empty. Then click 'Finish' to close this window.

6. Then Netbeans window will show the project window on the left as following:



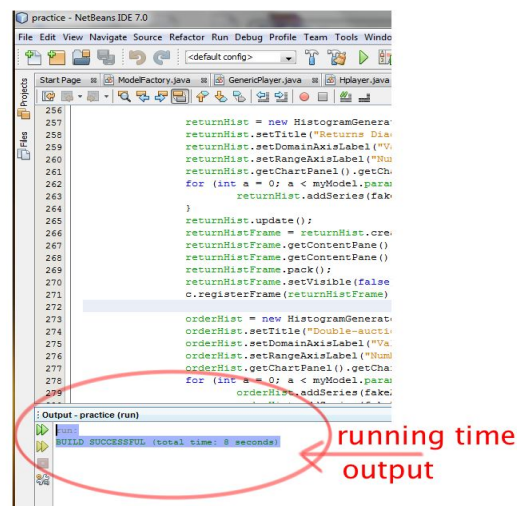
7. From the main project window, under 'Project' tree, right-click 'Libraries', select 'Add JAR/Folder'. It then opens a window to add JAR files from my documents -> MASON folder. Double-click on the all the JAR files accordingly then adds to the project library.

Experimental Model installation

1. Select 'File -> New Project'. It opens a window to choose the category 'Java' with the type of project 'Java Project with Existing Sources'. Then click 'Next'.
2. After creating a name for your model, then in the main project window, right-click on project and select 'Properties'. In the next window, choose the category 'Sources' and add the folder 'Market Model' under 'Source Package Folders', while not adding any folders under 'Test Package Folders'.
3. Then under project source packages directory, then right click then select New-> Java Class then select to import the 'market -> model' and 'market -> agents' sources from the experimental model folder.

Compilation

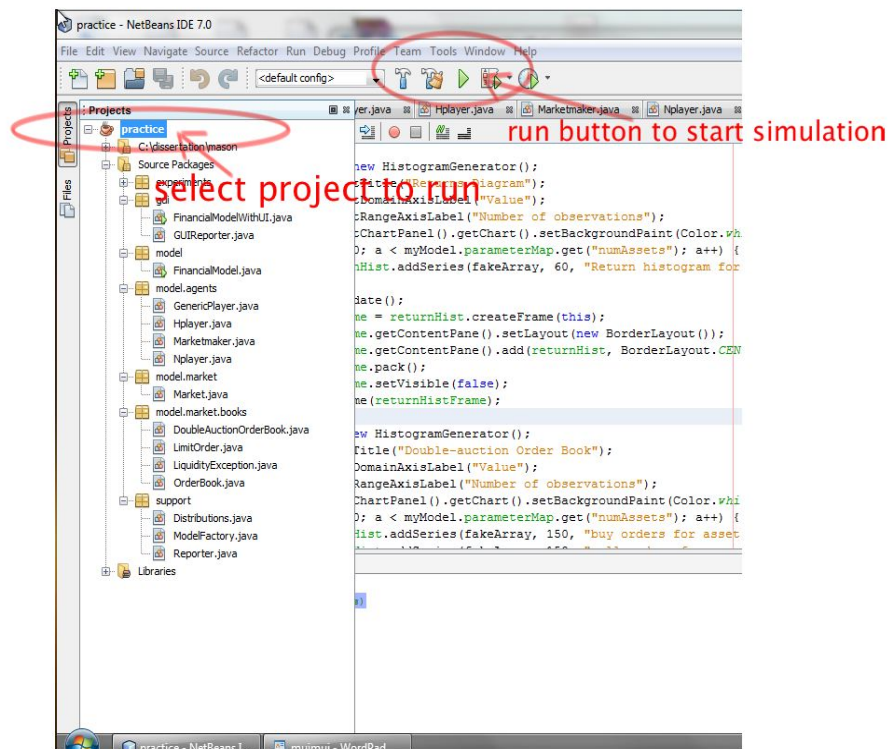
From the main project window, right-click on the name you have given for the project and select 'Properties', which will open a new window. There select the category 'Run' and browse to find and select the 'Main Class' and Leave everything else as default and click 'OK'.



As Netbeans combined the compiler as a part of the programming platform, thus the user can run the codes on Netbeans built-in compiler to get output results at the bottom.

System Model Running

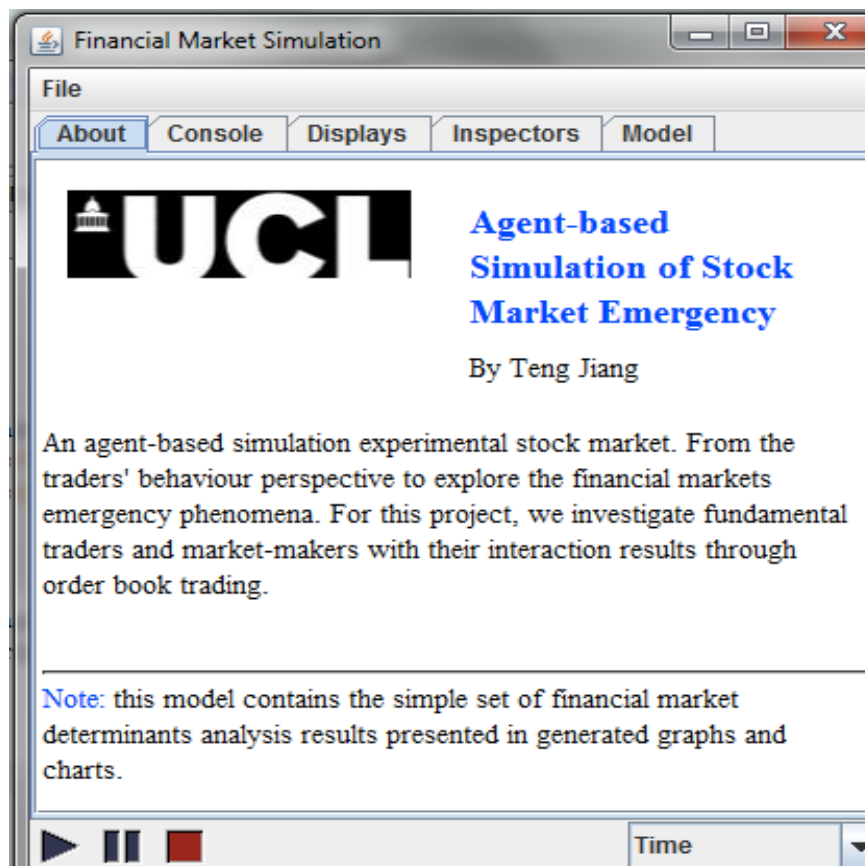
1. In the Netbeans window, select the project by clicking it then choose Run -> Run main project. This then will open a window of the control panel of the model console.



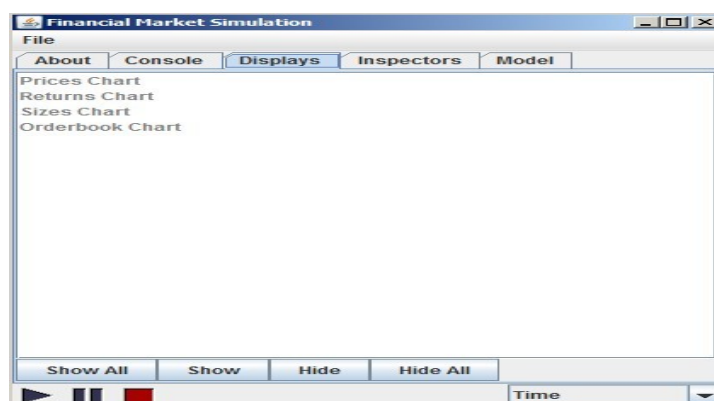
2. The console window is a separate pops out window containing five sub selection windows on the top and start, pause, restart buttons on bottom left and parameters on the right bottom.



3. Once the console window is opened after run the project, the default page is called ‘About’ window, showing the model description.



4. Users can choose windows (About, Console, Displays, Inspectors, Model) accordingly from the control panel window by clicking each item.
5. To choose a particular display to simulate, click ‘Display’ button, the window will present: Prices Chart, Expected Returns Chart, Average Volatility Chart, Trading Sizes Chart, Autocorrelation of Returns Chart, Returns Diagram, Double-auction Order Book. Double click one item; there is another window pops out for example, the prices chart.



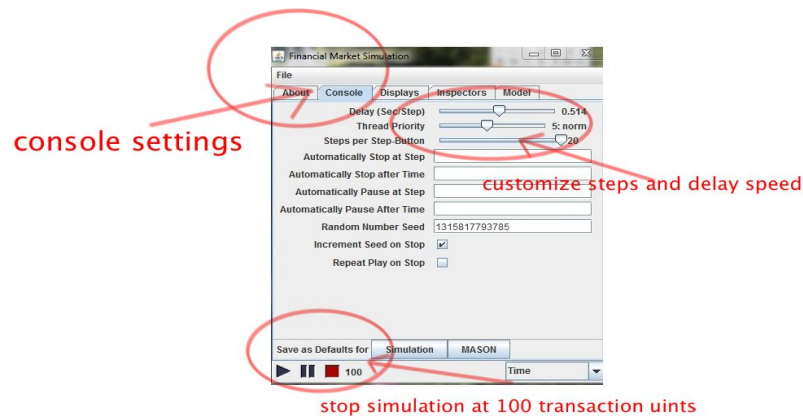
6. The left side of the prices chart is the parameters to customize according to the users' requirements, basically the users can alter the graph's X and Y axis settings and bid-ask graph settings. The right side of the window is the main graphs or charts generated as the user click the start button on the console panel.



7. Users then can choose to pause or fully stop the model running through console panel. Also the users can change the parameters such as time, steps and rate.
8. At the same time, as the users stops the graph lines movements at a specific step, by clicking another display item, a new pop-up window will show the simulated results at the same step time.



9. For the console settings window, the users are enabled to set up the speed as well as random seeds amount etc.



10. Also, by referring the setups files from the project folder, the users can change simulated player numbers and save the result, the Netbeans will automatically update the changes and carry out the running model for the new simulation scenarios.

Testing

11. In the Netbeans window, select the project by clicking it then choose Run -> Test main project. Then the output window at the bottom of Netbeans interface will generate the tested results with details explanations.

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- **10 selected companies from FTSE100**

BP Plc (BP.L)

http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/B/bp_second_quarter_2011_results.pdf
<http://uk.finance.yahoo.com/q?s=BP.L>

Burberry Group PLC (BRBY.L)

<http://www.burberryplc.com/bbry/financial-reports/>
<http://uk.finance.yahoo.com/q?s=BRBY.L>

BT Group PLC (BT-A.L)

http://www.btplc.com/Sharesandperformance/Annualreportandreview/pdf/2011_Financial_Statements.pdf
<http://uk.finance.yahoo.com/q?s=BT-A.L>

Man Group PLC (EMG.L)

<http://www.mangroupplc.com/assets/pdf/press-releases/2011/press-release-26may2011.pdf>

<http://uk.finance.yahoo.com/q?s=EMG.L>

Icap Plc (IAP.L)

<http://reports.icap.com/2011/ar/financialstatements/balancesheet.html>

<http://uk.finance.yahoo.com/q?s=IAP.L>

Imperial Tobacco Group PLC (IMT.L)

<http://www.imperial->

[tobacco.com/files/financial/results/hy2011/halfyear11_report.pdf](http://www.imperial-tobacco.com/files/financial/results/hy2011/halfyear11_report.pdf)

<http://uk.finance.yahoo.com/q?s=IMT.L>

Itv PLC (ITV.L)

<http://www.itvplc.com/investors/reports/?year=2011>

<http://uk.finance.yahoo.com/q?s=ITV.L>

Marks & Spencer Group PLC (MKS.L)

http://corporate.marksandspencer.com/documents/press_releases/2011/full_year_results_2010-11.pdf

<http://uk.finance.yahoo.com/q?s=MKS.L>

Rolls-Royce Group PLC (RR.L)

<http://www.rolls->

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<http://uk.finance.yahoo.com/q?s=RR.L>

Royal Bank of Scotland Group PLC (RBS.L)

http://www.investors.rbs.com/results_presentations

<http://uk.finance.yahoo.com/q?s=RBS.L>

Company	Shareholders' equity	Shares issued	price
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BP Plc (BP.L)	\$ 107,494m	18,940m	\$ 5.67
Burberry Group PLC (BRBY.L)	£ 713.6m	444.0m	£ 1.61
BT Group PLC (BT-A.L)	£ 1925m	8116m	£ 0.24
Man Group PLC (EMG.L)	\$ 4436m	1776.5m	\$ 2.50
Icap Plc (IAP.L)	£ 1231m	664m	£ 1.85
Imperial Tobacco Group PLC (IMT.L)	£ 7453m	1017.3m	£ 7.33
Itv PLC (ITV.L)	£ 747m	3383m	£ 0.22
Marks & Spencer Group PLC (MKS.L)	£ 2673.5m	1592.7m	£ 1.68
Rolls-Royce Group PLC (RR.L)	£ 4750m	1874m	£ 2.53
Royal Bank of Scotland Group PLC (RBS.L)	£ 74076m	107798m	£ 0.69

* Shareholder's equity / No. Of shares issued = the underlying company value per share