

Effect of rumor propagation on the stock market dynamics using cellular automata

Thesis Report

*submitted in partial fulfillment of the requirements
for the award of degree of*

Master of Engineering
in
Computer Science and Engineering

Submitted By

Priksha Vij
(801432022)

Under the supervision of:

Dr. Ajay Kumar
Assistant Professor

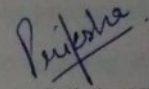


COMPUTER SCIENCE AND ENGINEERING DEPARTMENT
THAPAR UNIVERSITY
PATIALA – 147004
June 2016

Certificate

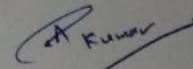
I hereby certify that the work which is being presented in the thesis entitled, "Effect of rumor propagation on the stock market dynamics using cellular automata", in partial fulfillment of the requirements for the award of degree of Master of Engineering in **Computer Science and Engineering** submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Dr. Ajay Kumar** and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.



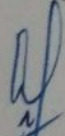
Priksha Vij
801432022
ME(CSE)

This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

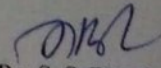


Dr. Ajay Kumar
Assistant Professor
Computer Science and Engineering Department
Thapar University

Countersigned by



(Dr. Maninder Singh)
Head
Computer Science and Engineering Department
Thapar University
Patiala



(Dr. S. S. Bhatia)
Dean (Academic Affairs)
Thapar University
Patiala

Acknowledgement

I would like to express my thanks to my guide Dr. Ajay Kumar for being an excellent mentor for me during my whole course of thesis. His encouragement and valuable advice during the entire period has made it possible for me to complete my work.

He gave me complete freedom, right from choosing the topic for thesis until its completion. Timely checks and guidance about how to improve the work done played an integral role. Also his support and patience in times of difficult situations helped me recover when my steps went astray.

Next most importantly all this would not have been possible without the patience and support of my family. Their constant sense of care encouraged me to complete my work.

I would like to acknowledge Dr. Maninder Singh for setting high standards for his students and encouraging them time and again to achieve them as well.

Priksha Vij

Stock markets are complex systems, so its market participants exhibit relative independence amongst themselves while analyzing the market information that they have, to make their respective decisions. Besides physical parameters, various other factors are responsible to create chaos in the market dynamics like macroscopic parameters and psychological factors. One such psychological factor affecting the normal behavior of the market participants is rumor spread in the market. Since the market participants in our economy interact with their local neighbors and thus rumor is spread by word-of-mouth communication process. As the rumor influences the beliefs of the individual, thus their decision is dependent upon the behavior of their immediate neighbors. Rumor spread in the market may be a positive rumor or it may be a negative rumor. It has been observed that in case of positive rumor, market participants tend to buy the stock whereas in case of the negative rumor, number of sellers increases in the market. Rumors are part of our everyday life. Despite being well known in our daily life, it is surprising that rumors are almost absent from economic theory. The reason seems intuitive. The economic theory is believed to be theory of rationality whereas rumors are considered to be rather illogical.

We build a cellular automaton model for the stock market to illustrate the complexity in the stock market by introducing variables for reflecting stability of the market. We introduced the concepts of rumor propagation to represent the market dynamics. Using this model, behavior of the market participants and their effect on the market dynamics are analyzed. Various constraints are introduced to counter-dynamics of rumor propagation for reflecting the close behavior with stock market and results show the relationship between the rumor propagation and the behavior of stock market.

Table of Contents

Certificate	i
Acknowledgement	ii
Abstract	iii
Table of Contents	iv
List of Figures	vii
List of Tables	viii
List of Keywords	ix
Chapter 1: Introduction	1-14
1.1 Cellular Automata	1
1.1.1 Learning Automata	2
1.1.2 Cellular Learning Automata (CLA)	3
1.2 Rumor Definition	3
1.2.1 Rumor Propagation	4
1.2.2 Structure of the group	5
1.2.3 Interest level in the subject	6
1.3 Rumors in stock market	6
1.4 Rumor classification	7
1.5 Rumor management	8
1.6 Nestle, Maggi	9
1.6.1 Rumor management failure case	10
1.6.2 Nestlé's rumor management	10
1.6.3 Nestlé's expected rumor management	11
1.7 Stock market	12

1.7.1 Definition of stock market	12
1.7.2 History of stock market in India	12
1.7.3 Importance of stock markets	13
Chapter 2: Literature Survey	15-22
2.1 Related Work	15
2.2 Santa Fe Artificial Stock Market (SF-ASM)	16
2.3 Classic cellular automata based financial market	18
Chapter 3: Problem Statement And Proposed Solution	23-28
3.1 Gap Analysis	23
3.2 Objectives	23
3.3 Proposed Solution	24
3.3.1 Methodology	24
Chapter 4: Implementation	29-34
4.1 Overview of MATLAB	29
4.2 System Model	30
4.2.1 Structure of the stock market	30
4.2.2 Working of the model	31
Chapter 5: Simulation Results	35-44
5.1 Experiments	35
5.1.1 Rumor propagation through WOM communication, without constraints	35
5.1.2 Rumor propagation through WOM communication, with constraints	38
5.2 Social Network Market Model	41
5.3 Model Rules	42

Chapter 6: Conclusion And Future Scope	45
6.1 Conclusion	45
6.2 Future Scope	45
References	46-48
Research Publications	49
Video Presentation Link	50
Plagiarism Report	

List of Figures

Figure No.	Description	Page No.
1.1	Von Neumann's neighborhood approach	1
1.2	Moore's neighborhood approach	2
1.3	Process of interaction between environment and the automata	3
1.4	Classification of information	4
1.5	Diffusion of Rumors	8
1.6	Maggi crisis management	11
2.1	The classification of EMH	16
3.1	Social interaction willingness matrix	24
3.2	Neighborhood selection with $\lambda = 8$	25
3.3	Neighborhood selection with $\lambda = 4$	25
3.4	Neighborhood selection with $\lambda = 0$	25
3.5	Social interaction willingness with $\lambda = 8$ for forgetfulness constraint	26
3.6	Social interaction willingness with $\lambda = 8$ before forgetfulness constraint	26
3.7	Social interaction willingness with $\lambda = 8$ after forgetfulness constraint	26
3.8	The leaning function decision to sell the stock	27
3.9	The leaning function decision to buy the stock	28
3.10	The leaning function decision to hold the stock	28
4.1	The Moore neighborhood of market participant	31
4.2	Initial market set up	31
4.3	Initial market configuration with grid size 3×3	32
4.4	Virtual market around the grid	32
4.5	2D convolution matrix configuration	33
4.6	Selection of market for 2D convolution	33
4.7	Convolving the market to find number of buyers	33

4.8	Count of buyers around the target market participant	34
4.9	Count of sellers around the target market participant	34
4.10	Count of holders around the target market participant	34
5.1	The initial configuration of stock market at time $t = 0$	36
5.2	The stock market behavior at $t = 10$	36
5.3	The stock market behavior at $t = 60$	37
5.4	Graph depicting behavior of different MPs	37
5.5	The stock market behavior at $t = 10$ after applying constraint 1	38
5.6	Graph depicting behavior of different MPs after applying constraint 1	39
5.7	The stock market behavior at $t = 10$ after applying constraint 2	40
5.8	Graph depicting behavior of different MPs after applying constraint 2	40
5.9	Graph depicting behavior of different MPs with leaning function	44

List of Tables

Table No.	Description	Page No.
1.1	Two-level variable relations in rumor propagation	6
2.1	Literature Summary	21-22
5.1	Simulation Parameters	35

List of Keywords

CLA	Cellular Learning Automata			
EMH	Efficient Market Hypothesis			
ASM	Artificial Stock Market			
CA	Cellular Automata			
MACA	Multiple Attractor Cellular Automata			
WOM	Word Of Mouth			
MP	Market Participant			
EMA		Exchange	Market	Algorithm

1.1 Cellular Automata

Cellular Automata is a grid of cells in which time and space are discrete. It derives its name “cellular” from the cells that it is build up of and “automata” because each cell follows simple transition rules to update itself. At initial time step, $t = 0$, each cell can have one state from the set of states defined. Local rules also called transition rules are used by the cells to update its states synchronously on discrete time steps. The new state of a cell depends on its previous state, state of its neighbors and local transition rules.

Cellular Automata is the most popular technique because it has made modeling the dynamics of various processes unproblematic. It is mesmerizing that using the simple transition rules complex dynamic patterns are evolved. The standard cellular automata are regular grid of cells i.e. rectangular grid. In a regular grid automaton, the structure of the grid cells and the number of neighbors to a cell are homogenous in cellular space. In a regular cellular automaton, each cell can have a finite set of possible states and a local transition rule defined for the cells to update its state. The local transition rule is a function of the present state of the cell, previous state of the cell and previous state of neighbors of the cell in consideration. In regular cellular automata, cells in the cellular space have identical shape and size. Other types of regular grids are triangular or hexagonal regular cellular automata structures.

The reason that cellular automata can be thought of as a multi-agent system is based on its overlapping interaction structure. The neighborhood in the regular 2-dimensional cellular automata can be either Von Neumann neighborhood (Figure 1.1) or Moore neighborhood (Figure 1.2).

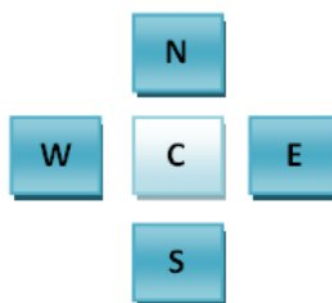


Figure 1.1: Von Neumann’s neighborhood approach [1]

Neumann neighborhood is the smallest 2 dimensional symmetric model defined by the directions on the compass i.e. $N = \{N, W, C, E, S\}$ which is also called as “Five-neighbor squares”. Moore neighborhood is a square lattice usually of the size 3×3 with the output cell in the center C. The neighborhood is defined as the eight directions on the compass i.e. $N = \{NW, N, NE, W, C, E, SW, S, SE\}$. Sometimes the center cell C is omitted. It is also referred to as “Nine-neighbor squares”.

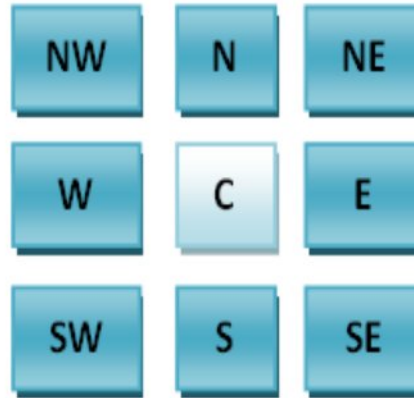


Figure 1.2: Moore’s neighborhood approach [2]

Due to various physical world properties, the cellular automata can be viewed as the first natural computing model. Following are the properties of the cellular automata:

- It consists of huge number of simple objects.
- Each cell is homogenous in space and time.
- It evolves through local interactions among the neighbors.
- It exhibits parallelism.

One more type of automata called as Learning automata [3] are self-reproducing machines capable of performing a set of actions with different probabilities is defined below.

1.1.1 Learning Automata

These machines can learn from their past actions and react on future events based on its learning. Each action performed by these machines, results into a certain response by the environment in which they perform as shown in Figure 1.3 below where $\alpha(n)$ is action selected by the automata. It shows the interaction between the environment and the automata.

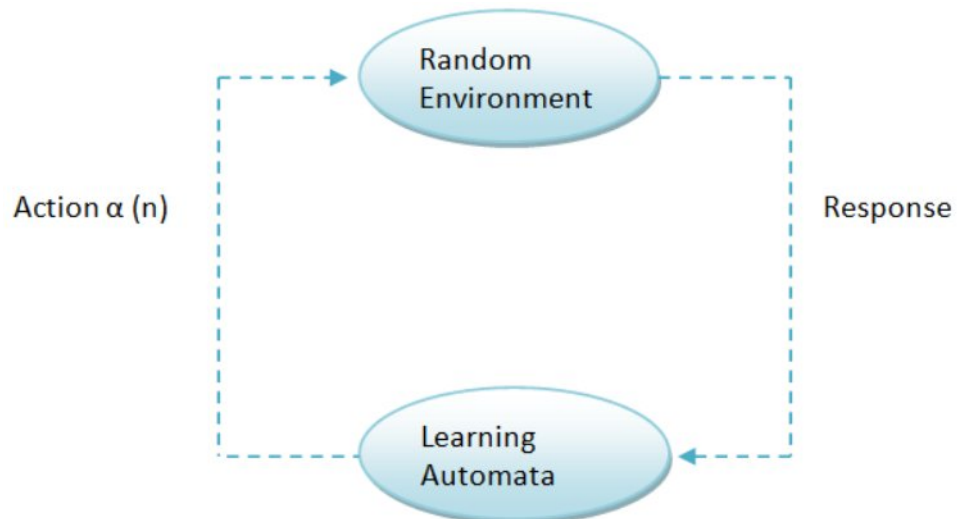


Figure 1.3: Process of interaction between environment and the automata[4]

1.1.2 Cellular Learning Automata (CLA)

The combination of cellular automata and learning automata is known as Cellular learning automata. In this type of automata, each cell acts as an automaton which learns from its past actions. The learning is based on the local interactions with the neighbors of a cell using local transition rules. The cellular learning automata has locality of the cellular automata and learning capability of the learning automata. The learning cellular automata can be of following two types:

- a. Synchronous CLA
- b. Asynchronous CLA

All the cells are activated synchronously in the synchronous CLA. The CLA tool finds its applications in various complex and discrete systems like Job scheduling, Numerical Optimization, Skin detection, Stock market analysis and Mobile wireless networks.

1.2 Rumor Definition

Rumor has been defined as information that is: (a) unproven (b) of some self interest to the source and (c) intended to be believed. From the definition, the first element i.e. it is unproven explains about the information's inferior quality confirmation [5]. Rumors often exist in the shade of uncertainty because they lack any evidence that confirms either the rumor is a genuine or disconfirm it as a deceit. Rumors are believed to be like teasing ghosts, without any well thought-of structure of

verification; verification helps in either solidifying the belief or to banish the existence of these ghosts. The difference between rumor and news is that news is always verified, but rumor is always unverified.

1.2.1 Rumor Propagation

The transfer dynamics of the rumor and its propagation depends on the number of infected people. Not only that the infected people alter their own beliefs but also do they influence and challenge the beliefs held by others in our society. Ignoring the fact that whether or not the rumor is true, its transmission solely depends on the number of neighbors infected by the rumor. The probability with which the person would be infected by the rumor increases with the increase in number of its infected neighbors. Intuitively, if one hears a particular story once, he may or may not believe it, but if one again hears the same story from another person, one is bound to believe that at least something may be true about the story. Thus, it is assumed that every infected neighbor who communicates the rumor with the other person increases their probability to get infected and as a consequence it also starts spreading the same rumor itself. The dynamics followed by rumor are similar to the infection process [6].

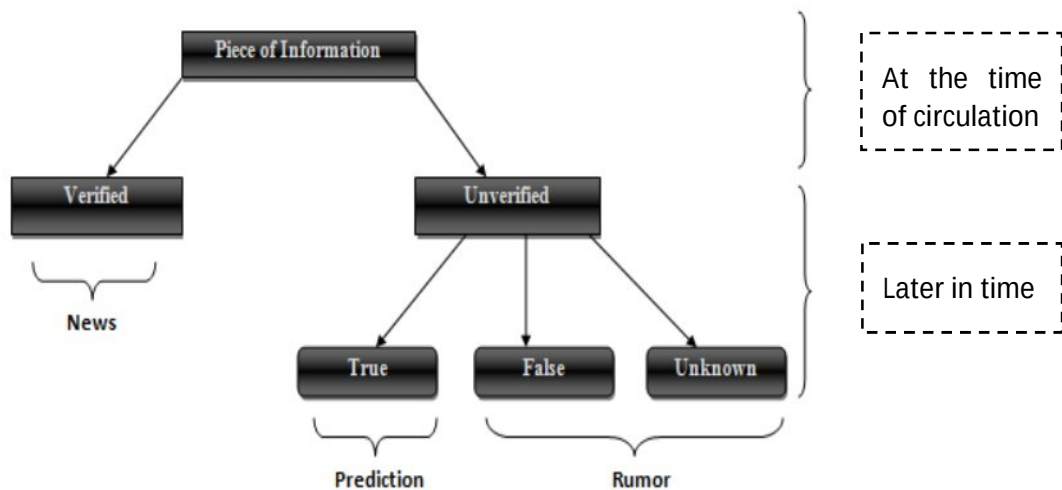


Figure 1.4: Classification of information

While rumor passes through the group or a community, it encounters individuals who have heard it earlier once; some individuals might have heard it more than that whereas some individuals may not have heard it ever. The situation in which the rumor propagates leads to the amount of repetition rumor gets. Some rumors might

need to be repeated more than once, whereas some of them even if they are valid and interesting, might sound embarrassing to repeat. Two group-levels variables operate to retard or promote the spread or repetition of rumors as discussed below [7]:

- a. The structure of public or crowd it propagates through, and
- b. Interest level of the crowd in that particular subject

1.2.2 Structure of the group

There are two kinds of groups present namely, diffuse groups and close groups. This basically follows a socio metric phenomenon. If the group of people are in continuous contact and can see each other without much difficulty then the group is known as “close group”. This type of group may not always be a stable one. It can be brought together in temporary situations as in case of natural disaster.

The socio metric structure does not evolve to any degree in the above instance. In the close groups that exist for some time, reasonably well defined socio metric structure is evolved. Examples of this would be the college fraternity, the mental hospital, the army unit, a small town or village. In the instances mentioned above, there are chances of high degree of interaction among each other and thus the rumor spreads from one person to another back and forth sometimes. In such a scenario, rumor propagates through the same crowd several times and people often hear it more than once. Thus multiple networks are developed in case of close groups.

On the other hand, the diffuse groups or public are chain networks rather than cliques. The size of the diffuse group is much bigger than that of the close groups. Diffuse groups are spread out largely geographically where the face-to-face interaction is not always feasible. One such example of the diffuse group is the nuclear family residing in the city because members of the family hardly interact with the large number of mutual acquaintances frequently as the members of the close group. Since many rumors are role—related, the individual members of the diffuse group hears a role-related rumor. Hence, each individual in the diffuse group, hear a particular rumor only once. However, it is possible that the rumor is of general interest and affects the group at large like rumor of assassination of someone at high official rank, war’s beginning and ending, or a natural disaster. It is possible that the diffuse group changes its structure to close group in case of a powerful rumor. The rumor about the

number of deaths in the Chicago race riots brought many people out on to streets to interact and influence others already there to “even up the score”.

1.2.3 Interest level in the subject

The second parameter in the rumor propagation is the interest of the group in that particular subject. If the rumor affects some of the sub groups in the large group, the interest in the rumor is likely low as compared to the one affecting the whole group as one. The spreading of rumor is directly proportional to the average interest level of the group. Higher the interest level of the group, higher is the motivation of spread and vice-versa.

A diffuse group with higher level of involvement experiences both intense rumor activity and chains of rumors, when people come out together to talk about the rumor. In a close group, if the involvement is high, the rumor repetition is higher. The people of the group hear same rumors more than once and the rumors keep on spreading back and forth.

Caplow found that rumors not related to "major group interests simply failed to move along the rumor channels, though much of it was available at all points". A diffuse group with low interest level does not have much rumor activity. The relation between the two group variables and the rumor activity are listed in Table 1.1 below. This ranking can be viewed as ranking of opportunity as well as motivation.

Table 1.1: Two-level variable relations in Rumor propagation [7]

Involvements	Group Structure	Telling	Repetitions	Pattern
High	Close	Many	Many	Intense network
High	Diffuse	Many	Sporadic	Largely chains, a few small nets
Low	Close	A few	Almost None	A few small chains and nets
Low	Diffuse	Almost None	None	Very short chains

1.3 Rumors in stock market

The basis of our study is to observe the effect of non public information like rumors on the financial market. The different kinds of rumors have different kind of impact

on the price of the stock. Various decisions made by the market participants for investment are studied as behavioral finance. Behavioral finance consists of three different fields: psychology, sociology and finance. The psychology aspect is based on the biases that occur while market participants holding a certain belief, define their preferences and make a decision. The sociology part focuses on the social interactions among the market participants in the stock market. It has been observed that the irrational behavior influenced by the social interactions among the market participants often leads to price run-ups [8]. The rumor can spread in the stock market through the word-of-mouth communication. Rumors are observed to be highly influenced by the psychology and the sociology. Under irrational behaviors, such as stress and fear, a market participant might invoke emotions through rumor propagation. Rumor is included in the study of sociology because the evolution and transfer mechanism of rumor is often through communication among the various investors.

To fill gaps of information during lack of news in the stock market, often rumors are viewed as the substitute for news. Rumors born and evolve when these projections are communicated in the stock market. For example, the rumors may evolve if a CEO of a company is interested in merging with another company, without disclosing the name of the company it wishes to merge with. If this information is of major importance and is stimulating, this may act as a substitute for news and spread in the market. According to Schindler (2007)[9] rumors can be analyzed by behavioral finance in following two ways.

- i. Individual level – At this level, the procedure taken by the market participant to invest in stocks is analyzed.
- ii. Aggregate/Market level – At this level, irrational behavior of the market participants is analyzed which leads to disprove the Efficient Market Hypothesis (EMH).

1.4 Rumor Classification

Koenig (1985)[10] categorizes rumors in following ways:

- i. Based on domain – The rumors may be public or market.
- ii. Based on emergence – The rumors may be general or specific depending upon the crowd it is intended to target at.

For example, if the government decides to increase the production of oil, then by domain, it affects the public and by emergence also it would be considered public since the increase in the price of the oil will affect the public. Additionally, if one bank is interested in merging with another bank, then these rumors will directly affect the market by domain, by emergence these rumors are specific as it focus on the business of two financial entities.

Kapferer (1996)[10] further categorized the rumors based on their origin.

- i. Based on emergence – Spontaneous (unprompted hypothesis, having high chances of being true is generated by the society) or deliberately provoked (statements generated to urge a specific future action).
- ii. Based on source – Derived from an event or fantasy (generated from an unclear origination).

1.5 Rumor Management

Once the rumor starts, it grows rapidly and it takes the shape of the Diffusion Curve proposed by Rogers[11]. The major challenge faced in managing the rumor is that if is not quelled effectively at the ‘innovators’ stage, it will start to grow rapidly and take an upward turn. Therefore, it is essential to control the curve from growing, in its formative stages itself. The blue dotted lines in Figure 1.5 show the points at which the graph can be prevented from growing. The possible preventive measures if taken at these points could cease the graph from growing and helps in its decline. Once the graph passes the ‘early adopters’ stage it gains so much of momentum that it becomes difficult to quell it. Rumor management emphasizes on how to stop the graph from growing and bringing it back to zero.

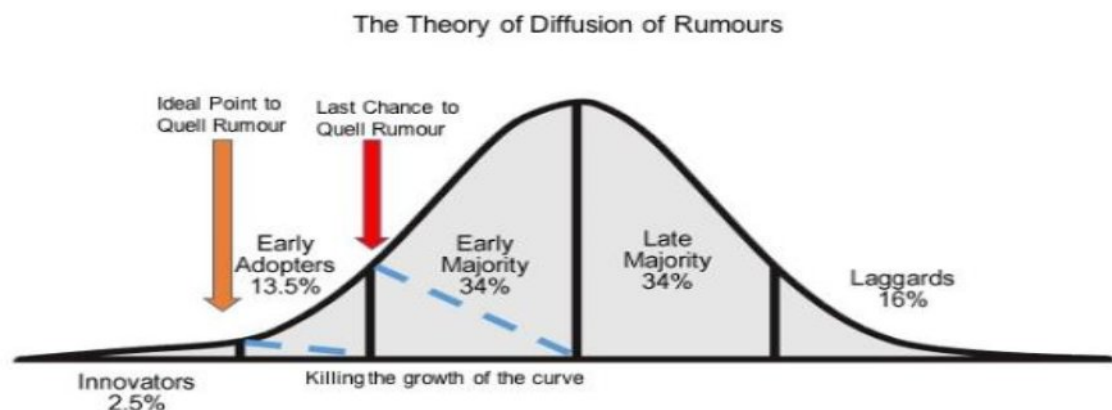


Figure 1.5: Diffusion of rumors [12]

Following are the five types of consumers [13]:

- i. **Innovators:** Although innovators constitute small part of the total market i.e. only 2.5%, the role of innovators is crucial in building up the market. Innovators welcome the new strategies and products in the market easily.
- ii. **Early Adopters:** Constituting 13.5% of the market, these are young and restless opinion leaders. Corresponding to what innovators have discovered, early adopters pay high attention to strategies and products to put them into practical usage. The usefulness of the new product is then communicated by the early adopters to their followers. For the later adopters, early adopters' practices are highly influential as they can change their attitude and behavior.
- iii. **Early Majority:** These are also called as value observers as they observe the early adopters but adopt only those innovative products which are sure to bring value. Early majority adopts the new product only if they see its usefulness in their lives else they do not invest in the products which threaten their money and time. These are the safe players of the markets unlike early adopters who are risk takers.
- iv. **Late Majority:** Well known as Skeptics; these adopt the new product only when majority of the market has accepted it and the price of the product has dropped down. Late majority reflects the behavior of herd affection because they imitate the behavior of majority. If everyone else in the market has adopted the product, late majority adopts it too.
- v. **Laggards:** These are also known as Tradionalists; these are the last ones to adopt the new product. Laggards miss the zeal to adopt the new product, and if they do its out of necessity only.

1.6 NESTLÉ, Maggi

Nestlé, a subsidiary of Nestlé S.A. (Switzerland) formed its company in India and set up its first factory in 1961 at Moga, Punjab. Presently, it is the world's largest and most diversified food company. Maggi holds a commanding position in the noodles segment with over 60% market share. Maggi has a large fan following in the country and a personality such as Amitabh Bachchan has endorsed it in the past. Maggi one of Nestlé's most popular products has come under the scanner lately.

1.6.1 Rumor Management Failure Case

The UP Food Safety and Drug Administration recently carried out systematic raids on retail outlets of Nestlé selling Maggi noodles. Testing in government laboratories in UP and Kolkata revealed that one of the India's favorite snacks had following [14]:

- i. 7 times the permissible amount of MSG (monosodium glutamate) otherwise popularly known as Ajinomoto, a taste enhancer.
- ii. Elemental lead has also been detected of up to 17.2 parts per million.

FDA officials seized more than 2 lakh packets of various quantities of Maggi noodles. FDA officials from other states also began conducting similar raids and samples of the product were sent for testing. FDA, Uttar Pradesh banned the product and there have been rumors that it might be banned across the country too.

The peculiar thing about the rumor is that it is one of the two kinds: true or false. When the rumor spreads in the market virally, the people anxiously wait for its confirmation of being true or false. But in case of Nestlé *Maggi*, India kept wondering if nestle was charged wrongly?

A quote from Nestlé Global Website says,” In light of growing consumer confusion due to an Indian government laboratory detecting lead levels above permissible limits, Nestlé India announced that it would temporarily stop selling *Maggi* noodles until the situation was resolved. The Food Safety and Standards Authority of India (FSSAI) issued an order to recall *Maggi* noodles from the Indian market and banned its sale and production.”

1.6.2 Nestlé's Rumor Management

It was in April, 2015 that presence of MSG (Monosodium Glutamate) was confirmed in Nestlé's Maggi Noodles. However, the news of this in media was announced on May 20, 2015. Nestlé had a complete month to recall the product if it had any doubts on the eventual consequences. But, Nestlé maintained its silence on this issue and let the rumor grow.

Nestlé didn't use any media to communicate with its consumers to prove its innocence. Instead, it cut off all ways of communication. Nestlé didn't give any statement to the press but issued an impersonal computer generated statement to the journalists. It portrayed its passive behavior on social media too. Consumers were unable to believe by now that it is being wronged. The behavior portrayed by the Nestlé was more of passive submission rather than defense.

1.6.3 Nestlé's Expected Rumor Management

Nestlé kept in denial but didn't stop the rumor from growing. It even stopped acknowledging the problem. This was the time when the brand loyal consumers were also forced to think on the rumor being true. It was only because of the bad rumor management that the brand had to suffer. Nestlé could have adopted one of the approaches discussed below to manage the rumor well and to prevent it from propagating endlessly. The approaches of rumor management which Nestlé could have considered as listed below [15]:

- i. Nestlé India could look at roping in a brand ambassador to advocate their products.
- ii. Made necessary changes to the product and that adhere to the norms.
- iii. Cooperated with the FDA and had redressed the issue



Figure 1.6: Maggi crisis management tweets [16]

- iv. Maggi has been in the market for years. They could have revealed statistics of deaths due to Maggi over the past decade which would be none. Hence, using numbers as a positive reinforcement.
- v. Build a campaign around Maggi being a health conscious brand through its latest wheat, oat and ragi noodles.

1.7 Stock Market

Stocks are fabulous category of financial instruments and are looked at as greatest tool for building wealth.

1.7.1 Definition of stock market

The stock market is a place where stocks, shares and other long-term investments or commitments are bought and sold. In stock market, shares of publicly held companies are traded over-the-counter markets or through exchanges. Stock market one of the essential components of a free-market economy as it gives its investors a slice of ownership in the company in exchange of access to their capital.

1.7.2 History of stock market in India

The oldest stock exchange in Asia is at Bombay called Bombay Stock Exchange (BSE), established in 1875 is the first stock exchange in India. Then in 1894, to facilitate shares of textile mills, the Ahmedabad Stock Exchange was started. In 1908, Calcutta stock exchange was started to provide market for shares of jute mills and plantations. In 1920, the Madras Stock Exchange was started. At present, India has a total of 24 stock exchanges, out of which 21 are regional ones [17]. National Stock Exchange (NSE) and Over the Counter Exchange (OICEI), have mandate to have nation- wise trading. They are located at following locations: Ahmedabad, Vadodara, Bangalore, Bhubaneswar, Mumbai, Kolkata, Kochi, Coimbatore, Delhi, Guwahati, Hyderabad, Indore, Kanpur (Jaipur), Ludhiana, Chennai, Mangalore, Meerut, Patna, Pune, and Rajkot.

The stock markets are administered by the executive chiefs and their respective governing boards. Ministry of Finance lays down the policies and its regulation for the stock markets. In April 1988, Securities and Exchange Board of India (SEBI) was constituted by the government, for regulating and developing the securities industry and stock market.

1.7.3 Importance of stock markets

For the capital to be channelized and used effectively in development of most profitable projects, stock markets play vital role. Stock markets perform following functions [18]:

- i. **To raise capital for business**
By selling the shares to the public investors, stock markets help the companies to raise their capital for business.
- ii. **To facilitate the growth of the company**
To merge with another company or takeover bid is the simplest form adopted by the company to expand through fusion.
- iii. **Wealth redistribution**
Large number of investors in public can be profited by buying the shares of the promising enterprises. In this way, stock market helps in reducing the large income inequalities. Through rise in stock prices and dividends, most stock investors get a chance to make money.
- iv. **Mobilizing savings**
Investing in shares helps in better resource allocation of the money which would have been either consumed or kept idle in deposits with banks. By investing the money in stock market productive levels can be higher and economic growth can be stronger.
- v. **Corporate Governance**
In order to satisfy the demands of the public investors, companies tend to have better efficiency and management standards. It is observed that public companies have better management than the privately held companies.
- vi. **Creates investment opportunities**
A person is free to buy the number of shares that it can afford to. So, stock markets encourage the small investors also to be a part of stock market.
- vii. **Helps to aid government development projects**
Government and local municipalities may borrow from the investment firms for the development of huge infrastructure projects by selling the securities to them called as Bonds. These bonds can be bought by the public investors through the stock market.

viii. **Acts as barometer of economy**

Movement of share prices indicates the economy of the country. Stock prices fall or rise depending upon the economy. The prices of the shares increase or remain stable when the economy shows sign of stability.

2.1 Related Work

In this chapter, we will discuss work done by researchers on stock market analysis. Many researchers proposed different models to analyze the dynamics of the stock market. Some of them are discussed in this chapter. The three basic concepts of the stock market analysis are rational investor hypothesis, efficient market hypothesis (EMH), and random walk of yield rate. However, it has not been proved yet that the market is composed of only rational investors. Random walk theory suggests that without assuming additional risks, it is impossible to outperform the market. It believes that stocks take an unpredictable random path. However, critics to random walk theory believe that stocks maintain the price patterns and by carefully examining these patterns and selecting entry and exit equity investments, one can outperform the market. The EMH states that the share prices incorporate and reflect all the relevant information about the stocks hence it is impossible to outperform the market. EMH nullifies the concept of buying the stocks that are undervalued and selling the same at inflated price. It suggests that the only way an investor can obtain higher returns is by investing in the riskier investments.

The three levels at which market might actually be efficient are described below [19]:

- i. **Strong-form EMH:** According to strong-form EMH, if all the relevant information about the stock value is quickly and precisely reflected, the market can become efficient. For example, if X perceives the value of the stock from some private source Y and perceived value is more than that of the current stock price, then X exploits the pricing anomaly by buying the shares. X continues to buy until the excess demand drives the price of the share up to the level supported by Y. This is the point when X withdraws himself from the market and price stabilizes at new equilibrium level.
- ii. **Semi-strong-form EMH:** According to semi-strong-form EMH, if all the relevant publicly available information is reflected in the value of the stock, the market can become efficient. It says that market easily accepts the new information and reaction of the market is reflected in the change in supply and demand caused due to this information.

- iii. **Weak-form EMH:** In weak-form EMH, the concept is confined to just one subset of the public information, namely historic information about the price of the stocks being traded. It simply concludes that the stock's price cannot be predicted from its historic prices. It makes sense because of the argument presented that the new information is “new” only if it is unrelated to the previous available information. It states that with the availability of new information, every movement in stock's price cannot be predicted from its last price because the stock price follows the characteristic of random walk.

A stock market is a complex system, composed of number of investors. The decision of investors is based on the information, public or private, perceived by them from within or outside the market. With the increasing growth of computational capabilities to model the dynamics of complex systems, multi-agent system (MAS), artificial life, and cellular automata are used.

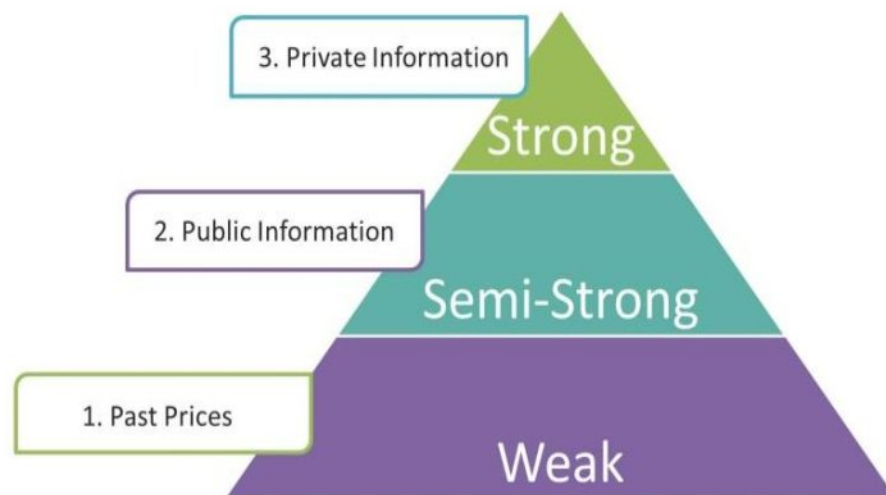


Figure 2.1: The classification of EMH [20]

2.2 Santa Fe Artificial Stock Market (SF-ASM)

The original version of artificial stock market was presented by Santa Fe institution in 1970. It was a kind of multi-agent system, which simulates the behavior of heterogeneous market participants [21].

The investment process of the market can be divided into following:

- i. **Predicting**

In this step, the market participant considers the information that it perceives from different sources, public or private from within or outside the market.

ii. **Decision**

In this step, the market participant reacts to the information available in the predicting step.

We know that apart from public information in capital markets like an announcement, interest rates, annual reports etc., there is also private information which depends upon personal relationships; attitude of an individual, and even emotions, which influence the investment behavior of market participants. For describing non-public information in an artificial stock market model, cellular automaton is used.

A classic SF-ASM consists of N interactive market participants and a financial market, or an exchange, which performs stock exchange if required. Agents in SF-ASM are heterogeneous i.e. they could belong to any category. The agents in SF-ASM cannot interact directly with one another. The interaction among the agents is through trading in the exchange. SF-ASM assumes time to be in discrete steps. One time step lasts for a single unit of time i.e. from t to $t+1$. Bonus is allocated to each share at the end of one time step, following the time series $d(t+1)$. The bonus time series follows stochastic process and is independent of capital market or its participants. The most commonly adopted bonus time series method is Ornstein-Uhlenbeck. In stock market, the interest rates ' r ' and the income assets are fixed, as in a bank. The decision of how much to invest in the financial market and leaving rest in the bank depends solely on the market participant. The total assets of market participant P is:

$$\omega_p(t) = R_p(t) + h_p(t) \times \text{price}(t) \quad (1)$$

Where, $R_p(t)$ is the remaining amount with the bank, $h_p(t)$ is the number of shares hold by the market participant in the stock market and $\text{price}(t)$ is the price of the stock at time t . After time step t , the value of the assets is:

$$\omega'(t+1) = (1+r)R_p(t) + h_p(t) \times \text{price}(t+1) + h_p(t)d(t+1) \quad (2)$$

All market participants in SF-ASM have the same risk preference and utility function. But each market participant has its condition-predict rule i.e.

If (condition is fulfilled), then (predict).

Market participants can use different condition—predict rules, to predict the future trends. And then market participants can make decision based on their predictions.

To provide market participants with self-learning capabilities, various artificial intelligence methods are applied to condition-predict rules. In SF-ASM, trading process is controlled by a 'specialist'. Specialist is responsible for deciding the price of stock for next time step i.e. $p(t+1)$, based on supply-demand conditions. Price drops in case of oversupply and rises in case of undersupply. Thus, investment decision of market participants is influenced by the specialist by the fluctuations in prices.

2.3 Classic cellular automata based financial market

To model the non-public influence in the stock market analysis, cellular automata came into light. Especially under certain circumstances when reliable public information is not available or the market is not mature or developed enough, personal information through non-public sources could be decisive. The two most frequently appearing behavior in the developing financial markets is Herd affection and group psychology.

For modeling the spread of non public information, it is essential to illustrate the interactions among the market participants. The classic cellular automaton is used in this case since it is a discrete dynamic system which consists of number of market participants. The market participants interact with its neighbors i.e. von Neumann neighborhood or Moore neighborhood to spread this non public information in the stock market.

The influence of herd affection is modeled using the cellular automata, in which each cell is a market participant and cellular automata is the stock market. Each cell can have one of the three states i.e. buy, sell or hold with the values -1, 1, and 0 respectively. At step t , the state of the cell is decided by considering the state of the cell at time $t-1$, state of its neighbors at previous time step. The cell decides its state by imitating the behavior which is followed by the majority of its neighbors [22].

A model is formulated for the investment behavior of the market participants whose investment decisions are influenced by the behavior of their trusted peers'. The concept of 'customized' neighborhood was introduced to show the real world neighborhood characteristics. The results obtained demonstrate that customizing the neighborhood reduces the stability of the market. A model was developed to simulate the behavior of market which driven by both the price and social influence. Without including the social influence, it was observed that the model converged to expected equilibrium. By randomly generating the neighbors, the stability of the market would

decrease slightly, but in case of real world trust network, the results obtained were markedly different. This proved that stability of the market does not depend only on the social influence, but on the Epinions networks [23].

To describe the complexity in the stock market, variables reflecting fractal and stability properties were introduced [24]. Following observations were made:

- i. When the market was mature, imitation degree for each market participant was different. The market might not be resourceful but bias random walk behavior was followed by the market participants.
- ii. When the herd affection in the financial market was evident, market participants imitate the behavior of the neighbors. The market participants might imitate or anti-imitate the behavior of its neighbors depending upon the imitation probability of itself. The experiments demonstrated that imitation degree of the market participant was inversely proportional to the stability of the financial market. Lesser the degree of imitation, more stable the market was and vice-versa. When the degree of imitation is approximately 0 i.e. the market participant's behavior was anti-imitating. In anti-imitation, the market participant does exact opposite of what its neighbors did. In such a case, a 'random walk' behavior pattern was observed in the market. When the degree of imitation was closer to 1, the market participant's investment behavior adopted greater imitation. In such a case, a market participant was highly affected by the behavior of its neighbors and this created chaos in market due to great fluctuations.
- iii. The psychology of the market participant was related to the trend and stability of the market. The increase in stability of market corresponded to decrease of imitation probability and decrease in the concentration of trend corresponded to decreasing degree of imitation.

The cellular automata model was used to observe the main characteristics in empirical financial time series. Due to large fluctuation in the price of the stock through the high imitation among the market participants, heavy – tailed return distributions could be generated. Unlike other microscopic simulations (MS) models, it suggested that grouping of the market participants in a specific network topology was not always necessary. Simple rules and local interactions could lead the market to demonstrate complex behaviours. Volatility clustering seemed to relate to the combined effect of

two processes, one of which was a fast process of evolution of news and the other was a slow process of the evolution of market participants, lead to heavy tails. Volatility and price were observed to be mean reverting. The price variations caused due to long range market participants' interactions could also be caused due to local interaction among them. Even though the news arrival followed the Gaussian random process, the behaviour of market participants in response was observed to follow non-Gaussian distribution [25].

For continuous non-linear optimization problems, a new algorithm called Exchange market algorithm (EMA), was proposed [26]. The name exchange market algorithm was inspired by the method how the shares in the market were traded. EMA worked in two different modes as below:

- i. Without oscillation in the market
- ii. With oscillation in the market.

At the end of each mode, the fitness of each individual was evaluated. The algorithm recruited the people towards the successful market participants, in its first mode. While in the mode, with oscillation in the market, algorithm would seek optimal points. Due to presence of two searching operators and two absorbent operators, the generation and optimization of random numbers was performed in best possible manner, which lead to high capability in optimum point extraction. EMA was inspired by human intelligence and experience of the successful market participants in the stock market.

To prevent crashes and bubbles [27] in a complex stock market, financial regulations and monetary policies might be ineffective. Robot traders were introduced in such a scenario as an anti-bubble decoy. A new stochastic cellular automata model of the financial market was devised and its key parameters were calibrated, to fit in the empirical data properties of an actual financial market, the Bovespa [28]. Robot traders were ascribed with an anti-imitation rule to counteract the imitation rule of the market participants.

A special class of Cellular Automata called Multiple Attractor Cellular Automata (MACA) [29], was evolved through Genetic algorithms to perform the pattern classification. This pattern classifier which was evolved was a low cost and high speed pattern classifier. The three major fields in which classification was used were – data mining, fault diagnosis and image compression. The classifier developed was

also known as two-stage classifier, which was built around Cellular Automata. The proposed classifier reduced the complexity. The low memory overhead and classification accuracy proved the superiority of the Cellular Automata based classifier over that of classification algorithm. The simple structure of CA made it ideally suitable for VLSI implementation.

Table 2.1 Literature Summary

Name of the Author	Main Features and Key Findings
1. Wei et al. [22]	i. The influence of Herd Affection is modeled using the cellular automata. ii. The investment preference was the key factor affecting the stability of the market. The bigger the value of coefficient of investment process, the more unstable the market, and vice-versa. iii. They concluded that the complexity of the stock market depends upon the initial state and different initial states of market would cause different evolutions. iv. They concluded that bigger the value of macro coefficient the more unstable was the stock market, and vice-versa.
2. Bakker et al. [23]	i. They introduced the concept of generating neighbors randomly. ii. They observed that by random generation of neighbors, stability of the market would decrease slightly. iii. Proved that stability of the market does not depend on the social influence but on Epinions networks.
3. Fan et al. [24]	i. Variables reflecting fractal and stability properties were introduced to describe complexity in the market. ii. When the mature was mature, imitation degree for each MP is different and thus market follows random walk behavior. iii. They concluded that imitation degree of the MP is inversely proportional to the stability of the market. iv. Higher the degree of imitation for a MP, the more unstable is the

	market, and vice-versa.
4. Qiu et al. [25]	i. They used the cellular automata model to observe main characteristics in empirical financial time series. ii. They observed that due to higher imitation degree of the MPs, heavy- tailed return distributions were generated. iii. They concluded that even though the news arrival in the market followed a Gaussian random process, the behavior of the MPs followed non – Gaussian behavior.
5. Ghorbani et al. [26]	i. Proposed Exchange Market Algorithm (EMA), for continuous non-linear optimization problems. ii. EMA worked in two different modes: Without oscillations in the market and with oscillations in the market. iii. EMA was inspired by the human intelligence and experience of the successful MPs.
6. Suhadolnik et al. [28]	i. Prevented the crashes and bubbles in a complex stock market, robot traders were introduced. ii. Robot traders were ascribed with an anti-imitation rule to counteract the imitation rule of the MPs.
7. Maji et al. [29]	i. Performed the pattern classification, a special class of cellular automata called Multiple Attractor Cellular Automata (MACA) is introduced. ii. MACA reduced the complexity of the stock market. iii. The simple structure of MACA made it ideally suitable for VLSI implementation.

Chapter 3

Problem Statement and Proposed Solution

In this chapter, the gaps which exist in the present work are discussed. The problem proclamation, objectives to be accomplished and methodology followed is discussed in this chapter.

3.1 Gap Analysis

Rumors are part of our everyday life. Despite being well known in our daily life, it is surprising that rumors are almost absent from economic theory. The reason seems intuitive. The economic theory is believed to be theory of rationality whereas rumors are considered to be rather illogical. And hence, were not considered to be fit for model.

Stock markets are complex systems, so its market participants exhibit relative independence amongst themselves while analyzing the market information that they have, to make their respective decisions. In all of this analysis, various events about stock and behavior of other market participants are analyzed. Besides physical parameters; various other factors are responsible to create chaos in the market dynamics like psychological factors. One such psychological factor affecting the normal behavior of the market participants is rumor spread in the market. Since the market participants in our economy interact with their local neighbors and thus rumor is spread by word-of-mouth communication process. As the rumor influences the beliefs of the individual, thus their decision is dependent upon the behavior of their immediate neighbors.

3.2 Objectives

The aim of our model is to show the effects of rumor propagation in the stock market to study the market dynamics. Based on literature survey, following objectives are outlined:

- i. To analyze various techniques of cellular automata applicable in stock market.
- ii. To analyze the impact of rumor spread through word-of-mouth communication on the stock market with and without any constraint on the propagation transfer and;

- iii. To apply the rumor parameter (R_s) in the leaning function [3] to observe its effect in the stock market.

3.3 Proposed Solution

For the rumor not to infect its market participants endlessly, it is essential to add various constraints to act as a counter-dynamic and for the market to behave in close relation to the real market behavior.

3.3.1 Methodology

The following constraints are applied on the existing system:

- i. **Constraint on the interaction of the market participant:** By adding this constraint, we are giving the freedom to the market participant to interact with its neighbors based on its willingness. We therefore introduce social interaction willingness factor λ , where value $\lambda = 0, 1, \dots, 8$ represents the number of neighbors the market participant wants to interact with. By adding this constraint, we are not restricting the market participant to consider the opinion of all eight neighbors that surrounds it. The social interaction willingness matrix is generated randomly.

Consider the stock market of size 3×3 . The λ is defined for each market participant as shown in figure 3.1 below. The value at cell (1, 1) is 7, which represents that the market participant at this site wants to interact with 7 out of its eight immediate neighbors.

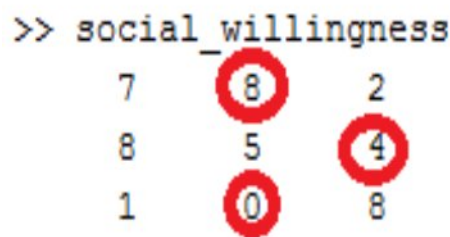


Figure 3.1: Social interaction willingness matrix

At cell (1, 2) the value of $\lambda = 8$, this represents that the market participant at this site wants to interact with all of its eight immediate neighbors. Therefore, all the neighbors of this market participant at site (1, 2) are set to one i.e. these are the active neighbors and influence the investing decision of the target market participant as shown in figure 3.2.

Interaction matrix with 8 neighbors

1	1	1
1	0	1
1	1	1

Figure 3.2: Neighborhood selection with $\lambda = 8$

The neighborhood selection for $\lambda = 4$ is shown below in figure 3.3 where 4 out of eight neighbors of the target market participant are active and set to 1. These 4 are selected randomly using rand () function. These 4 neighbors only participate in the decision making for the target participant.

Interaction matrix with 4 neighbors

0	0	1
1	0	1
1	0	0

Figure 3.3: Neighborhood selection with $\lambda = 4$

The neighborhood selection for $\lambda = 0$ is shown below in figure 3.4 where none of the eight neighbors of the target market participant are active. In this case, the investment decision of the target market participant is not influenced by any rumor as it interacts with no one in its neighborhood. In such a case, rumor is prevented from spreading endlessly.

Interaction matrix with 0 neighbors

0	0	0
0	0	0
0	0	0

Figure 3.4: Neighborhood selection with $\lambda = 0$

- ii. **Constraint on the memory of the infected market participant:** For preventing the market participant from spreading the rumor endlessly, we have suggested the constraint on the memory of the market participant, i.e. there are chances that the market participant may forget the rumor and thus it does not infect other market participants in its neighborhood.

>> Forgetfulness

0	3	6
3	6	8
4	5	8

Figure 3.5: Social interaction willingness with $\lambda = 8$ for forgetfulness constraint

The social interaction willingness matrix for $\lambda = 8$ is same as discussed above. The figure 3.6 below shows all the 8 active neighbors without applying forgetfulness constraint.

Interaction matrix with 8 neighbors

1	1	1
1	0	1
1	1	1

Figure 3.6: Social interaction willingness with $\lambda = 8$ before forgetfulness

After applying the forgetfulness constraint, 2 out of the active 8 neighbors are disabled and set to 0 again representing that these become non-influential to the target market participant's investment decision. The social interaction willingness matrix after applying the forgetfulness constraint is shown below in figure 3.7.

Interaction matrix after forgetfulness

0	1	1
0	0	1
1	1	1

Figure 3.7: Social interaction willingness with $\lambda = 8$ after forgetfulness

iii. **Constraint on the number of stocks:** For the market to behave unbiased towards the behavior of selling or buying, it is suggested that the number of stocks be finite. This constraint is applied using the leaning function [3]. In this method, every buyer is mapped to seller and vice-versa. It has been observed that the market becomes unstable if either the majority of buyers or sellers prevail in the market. To avoid the market biasing towards buying or selling behavior, we consider that the number of stocks in the market are finite and for every buyer there exists a seller and vice-versa. To apply the constraint on the number of stocks, we use the leaning function which helps the market participant to make better investment decision based on the market conditions. For e.g. if the number of buyers are more than the number of sellers, the price of the stock is likely to increase depending on the increased demand. In such a case, leaning function suggests the market participant to sell the stock as it will be more profitable due to increased price.

Consider a stock market of size 3×3 consisting of 9 market participants. At any point of time t , in the stock market, a market participant can be in one of the three states i.e. Buy, Sell or Hold. We represent the state Buy with value -1, the state Sell with value 1 and the state Hold with value 0. The working of leaning function is as shown below in Figure 3.8

1	1	0
-1	-1	0
-1	-1	0

BUYERS = 4
 SELLERS = 2
 HOLDERS = 3
 Decision :SELL, Buyer available

Figure 3.8: The leaning function decision to sell the stock

Similarly, if the number of sellers is more in the market than the buyers, then the price of the stock decreases as supply is more than the demand. In such a case, leaning function suggests the market participant to buy the stock as it is available at low cost. The leaning function suggests the market participant to buy the stock as shown below in Figure 3.9

-1	-1	-1
1	1	1
1	1	-1

```

BUYERS = 4
SELLERS = 5
HOLDERS = 0
Decision :BUY the product

```

Figure 3.9: The leaning function decision to buy the stock

If both the number of sellers or buyers is equal in the stock market, the leaning function suggests holding the stock. If the market participant initially wants to buy the product, it sets itself to hold its decision as price is high to buy. If the market participant initially wants to sell the stock, it sets to hold the decision of selling as selling the stock in this scenario is not very profitable. The leaning function suggests the market participant to hold the stock as shown below in Figure 3.10

1	1	-1
-1	-1	1
0	-1	1

```

BUYERS = 4
SELLERS = 4
HOLDERS = 1
Decision : HOLD,No Buyers/Sellers Available

```

Figure 3.10: The leaning function decision to hold the stock

Chapter 4 Implementation

In this chapter the cellular automata model is used to evaluate the effect of rumor propagation on the stock market dynamics. We use MATLAB R2012a for implementation. MATLAB is used on the grounds that it gives a platform where processing is simple; furthermore programming should be possible in an effective way. In our proposed cellular automata model we have demonstrated the effect of rumor propagation, through word-of-mouth communication among the local neighbors, on the stability of the stock market. In the final output graph we have observed that by putting constraint on the number of stocks, and by using the leaning function for optimizing the stock's price, stability of the stock market can be restored. It prevents the market being biased towards one particular behavior.

4.1 Overview of MATLAB

MATLAB is a platform named as matrix laboratory which provide the numerical computing in multi-paradigm. It is also called as the 4th generation language of programming. The researcher of Math Works Inc. Moler had composed the first form of MATLAB in 1970's. It is developed for the students so that they can access the LINPACK and EISPACK projects without any need of learning the FORTRAN language. By utilizing MATLAB, manipulation of matrix become easy, the information and functions can be plotted easily, calculations can be executed, an algorithm can be implemented, different client interfaces can be made furthermore interfacing should be possible with the projects which are actualized in diverse programming languages like JAVA, C++, C and Python. It is used for matrix theory, linear algebra and numerical analysis. The MATLAB application is fabricated around the MATLAB scripting languages. It also supported, the object oriented programming which includes classes, inheritance, packages, pass-by-reference semantics. It supports to develop the applications with GUI (graphical user interface). It likewise has firmly incorporated diagram plotting components. Many technical and computing problems can be solved by using MATLAB. Many researchers used MATLAB for their simulation. MATLAB is also very useful to simulate the behavior of the artificial

stock market, where the matrix is the stock market and each cell is the market participant.

4.2 System Model

The cellular automata framework that we are using in this paper is based on the model developed by Wei et al. (2003) [1]. It is defined as follows:

- i. A cellular automaton is a grid of cells representing the stock market and every cell in it represents a market participant.
- ii. The state space of the grid consists of its market participants. $S_{ij}(t)$ denotes the behavior of the market participant residing in the cell (i, j) at time t . Time is considered to be in discrete steps i.e. $t = 0, 1, 2, \dots$
- iii. The state of any market participant at time t i.e. $S_{ij}(t)$ can be one of the three, Buy, Sell or Hold.
- iv. The state of Buy is represented with value -1, Hold with 0 and Sell with 1 in the cellular automata.
- v. The state of any cell (i, j) at time $t+1$ is evolved through the model rules and the state is denoted as $S_{ij}(t+1)$.
- vi. Evolution Rules: The state of the cell (i, j) at time $t+1$ is determined by the state of itself at previous time step t , the state of its local neighbors (Moore Neighborhood), and the rumor strength R_s .

4.2.1 Structure of the stock market

Consider the following stock market scenario. The market consists of market participants, each of which resides in the site (i, j) of the cellular automaton. Each market participant can communicate with its indirect eight neighbors (Moore Neighborhood). In our model neighborhoods specifies the social interaction circle of market participants, where interacting with the neighbors is assumed to be the medium for the rumor propagation. A market participant P directly communicates with its adjacent neighbors i.e. $P_1, P_2, \dots, P_7$ as in Figure 4.1. However, since neighborhoods are overlapping, each market participant also communicates indirectly with all other participants in the market. The rumor propagation is assumed to be the word-of-mouth communication, where rumor evolves as it infects the people in its way.

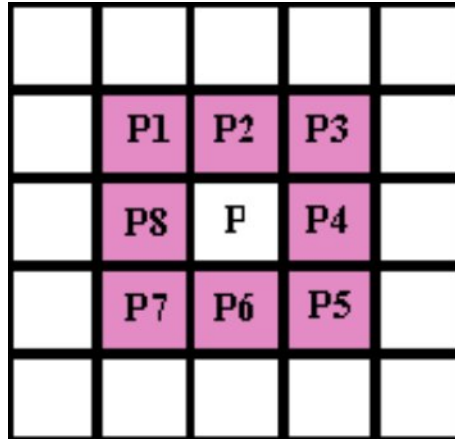


Figure 4.1: The Moore Neighborhood of market participant P.

4.2.2 Working of the model

The implementation of cellular automata model is explained below:

- i. Grid size of 50×50 representing the stock market is developed with three different kinds of investors.
- ii. Buyers are represented using the value -1, sellers are represented with value 1 and holders with value 0.
- iii. In initial stock market set up, No. of buyers are fixed to 289, no. of sellers are 1411 and no. of holders equal to 800.
- iv. The initial stock market set up looks like as shown in the figure below

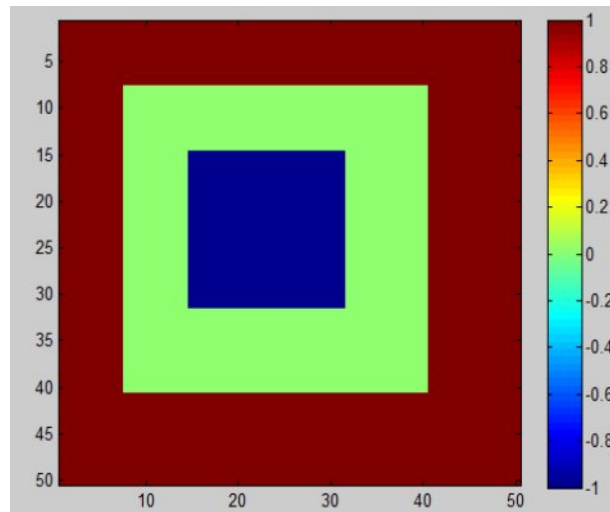


Figure 4.2: Initial market set up

- v. The centre of the stock market is constituted with buyers i.e. in blue color, surrounded with the holders in green color and finally at the ends of the stock market, we have sellers shown in red color.
- vi. We run the simulator for 70 time steps to observe the patterns.

- vii. For each iteration, we build a `virtual_boundary` around our stock market to calculate the number of neighbors as:

```
virtual_boundary = market ([end 1: end 1], [end 1: end 1]);
```

- viii. The resultant market called `virtual_boundary` is developed. For example, we develop a `virtual_boundary` for a market of size 3×3 . The market configuration and resultant `virtual_boundary` is shown below:

-1	1	1	Initial Buyers = 4
-1	0	-1	Initial Sellers = 3
-1	0	1	Initial Holders = 2

Figure 4.3: Initial market configuration with grid size 3×3

1	-1	0	1	-1
1	-1	1	1	-1
-1	-1	0	-1	-1
1	-1	0	1	-1
1	-1	1	1	-1

Figure 4.4: Virtual market around the initial grid

- ix. 2 Dimensional convolution is used to find the number of buyers, sellers and holders around a market participant as:

```
nconv = conv2(double(virtual_boundary==Buy),a,'same');
nconv2 = conv2(double(virtual_boundary == Sell),a,'same');
nconv3 = conv2(double(virtual_boundary == Hold),a,'same');
neighbor_buyers = nconv(2:end-1,2:end-1);
neighbor_sellers = nconv2(2:end-1,2:end-1);
neighbor_holders = nconv3(2:end-1,2:end-1);
```

To count the number of neighboring market participants those are buyers, sellers and holders respectively, we use 2-D convolution method. In this the configuration used to convolve is the following 3×3 matrix.

1	1	1
1	0	1
1	1	1

Figure 4.5: 2-D convolution matrix configurations

Just like the sliding window, this matrix is multiplied by virtual boundary market selecting 3×3 market participants every time. Selecting the 3×3 market it convolves and finds the buyers, sellers and holders respectively. The figure below shows.

1	-1	0	1	-1
1	-1	1	1	-1
-1	-1	0	-1	-1
1	-1	0	1	-1
1	-1	1	1	-1

Figure 4.6: Selection of market for 2D convolution

To find the number of buyers, we select the market and convolve it with the number of -1 around the central element as shown below:

1 × 1	-1 × 1	0 × 1
1 × 1	-1 × 0	1 × 1
-1 × 1	-1 × 1	0 × 1

Figure 4.7: Convolving the market to find number of buyers

As we can see that total number of “-1” around the central element are equal to 3, it returns the count 3 as shown below.

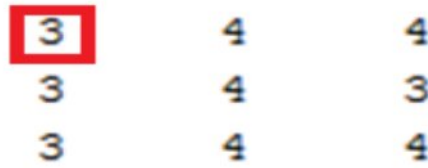


Figure 4.8: Count of buyers around the target market participant

Same procedure is used to calculate the number of sellers and holders around the target market participant. Since the sellers are represented using “1” hence convolution returns the count 3 as shown below.

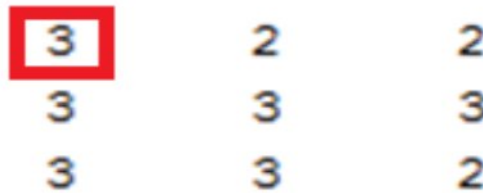


Figure 4.9: Count of sellers around the target market participant

We represent the holders with value “0”. The count of holders is shown below after convolution.

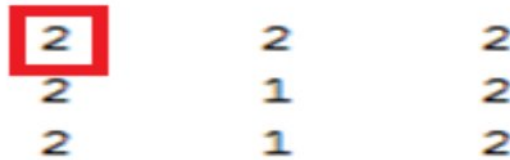


Figure 4.10: Count of holders around the target market participant

Chapter 5

Simulation Results

In this section we perform simulation for checking the performance of proposed model to carry out the effect of rumor propagation in the stock market. The results show that there exists a co-relation between the rumor effect and stability of the financial market. In this section, we have concluded the optimized results using the leaning function where price of the stock being traded acts as the basic element.

The input parameters for the simulation experiments include the initial state of each market participant individual, the evolution rules for updating the state of each market participant, the size of the grid used which denotes the size of the market, the number of neighbors coming in contact with the rumor, the pattern and medium used for rumor propagation to infect the decision of participants coming in its contact.

If the size of the grid is too large, the simulation speed of the experiments becomes too slow, but if the size of the grid is too small, the identification of the simulation experiments is not evident. We have considered the size of the market as 50×50 .

Table 5.1 Simulation Parameters

Simulation tool	MATLAB R2012a
Dimension of grid	50×50
Number of iterations	70 time steps
Number of Buyers	289
Number of Sellers	1411
Number of Holders	800
Total market number of participants	2500

5.1 Experiments

The figure 5.1 depicts the initial dimension (50×50) of the stock market where each cell is a market participant and the market consists of a total of 2500 market participants. Therefore at time $t = 0$, the market looks like as shown in Figure 5.1.

5.1.1 Rumor propagation through WOM communication in stock market, without constraints

In order to explore the influence of word-of-mouth communication in rumor propagation, we do our simulations based on the behavior inclination adopted by the

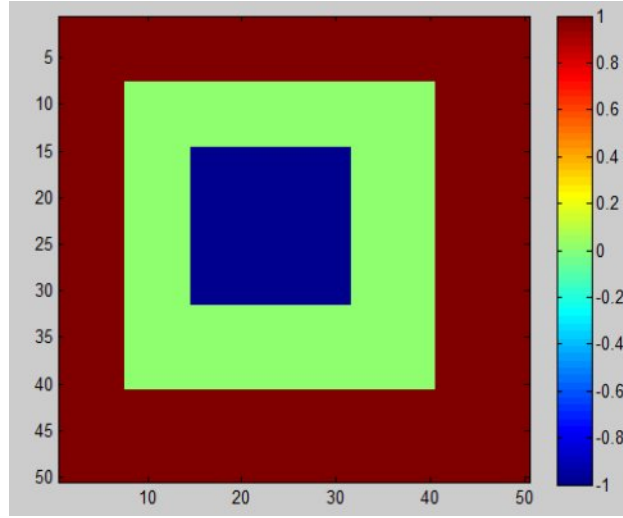


Figure 5.1 The initial configuration of the stock market at time $t=0$

majority of the Moore neighbors. We run the simulator with the initial configuration as $(N_{\text{Buyers}}(0), N_{\text{Holders}}(0), N_{\text{Sellers}}(0)) = (289, 800, 1411)$ as shown in Figure 5.1. Considering the trend of the neighbors, in a few steps all the investors turn into the selling state since the “sellers” are dominating over the stock market $N_{\text{Sellers}}(0) = 1411$.

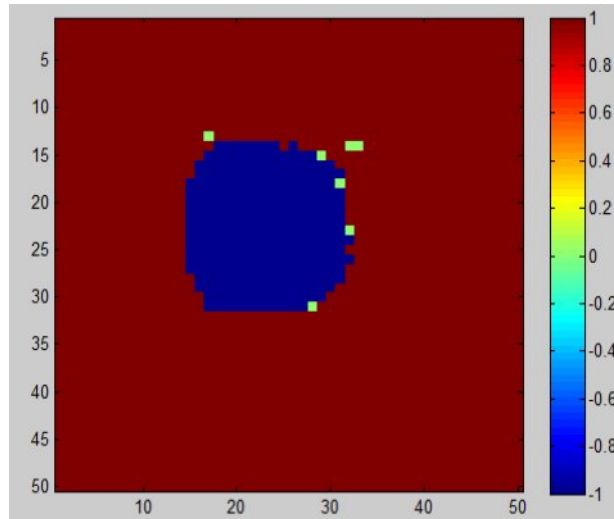


Figure 5.2 The stock market behavior at time step $t = 10$

It is observed that the market tends to lean towards the behavior followed by the majority of its neighboring market participants. The market participant considers the behavior of its eight neighbors and changes its state strictly to the one followed by the maximum market participants. However, if the clear majority does not exist, in doubt,

market participant can either choose to remain unchanged or it may randomly change to one of the other two states.

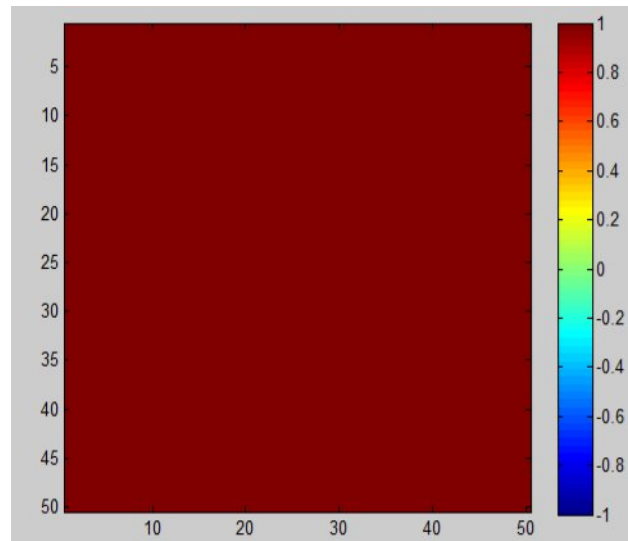


Figure 5.3 The stock market behavior at time step $t=60$

It is observed that without constraints or control variables market becomes unstable and thus the trading stops due to biasing in the market i.e. whole market tends to sell and no buyers are available as in Figure 5.3.

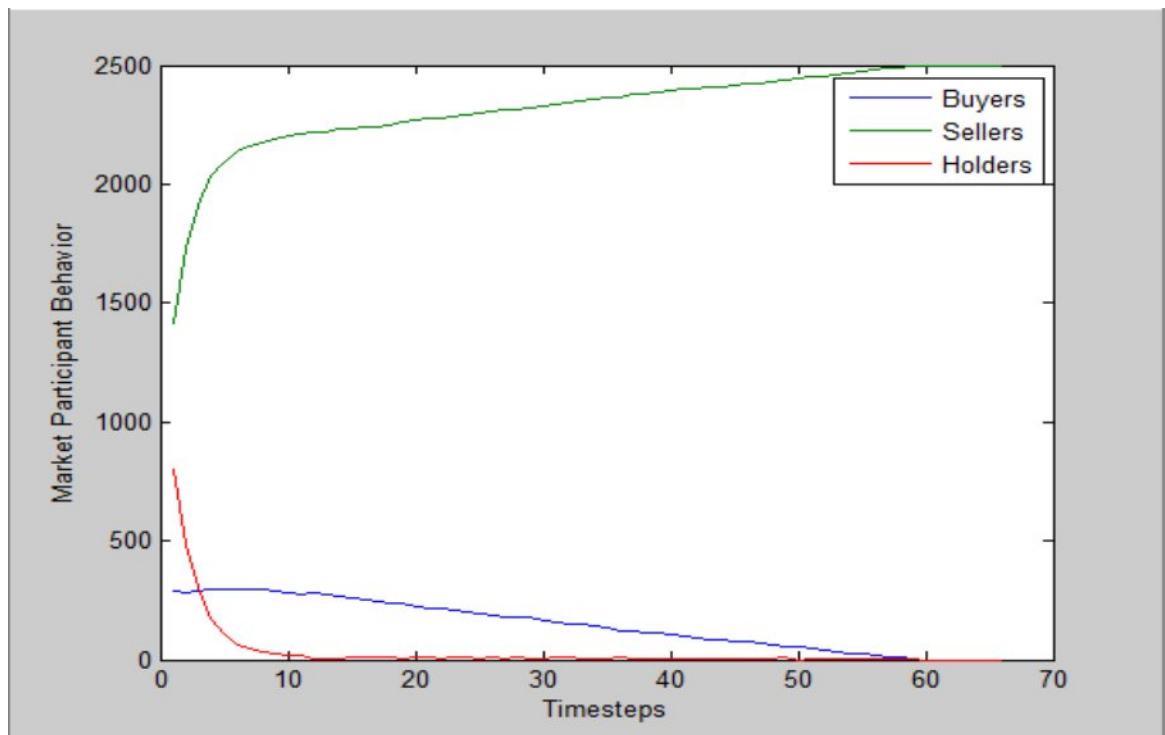


Figure 5.4 Graph depicting behavior of different Market Participants

5.1.2 Rumor propagation through WOM in stock market, with constraints

For the rumor not to infect its market participants endlessly, it is essential to add various constraints to act as a counter-dynamic and for the market to behave in close relation to the real market behavior.

Constraint 1: Social interaction willingness factor λ :

For the market to become more reliable and stable, it is mandatory to introduce some of the control variables. It is suggested that the market participants must not be forced to take into account the behavior of all of its eight neighbors but to be given freedom to choose its reliable neighbors. As in reality, one does not rely on all the people in his locality but a few of them. Thus, social interaction willingness factor $\lambda = 0, 1, \dots, 8$ is introduced to measure the willingness of the market participants to consider the behavior of its neighbors. Where $\lambda = 0$, defines that the market participant is anti-social and does not entertain any communication with its neighbors. Such a market participant acts as a counter dynamic to the rumor propagation through the word-of-mouth communication, since it does not gets infected itself and thus prevents to influence other participants in stock market. For $\lambda = 8$, the market participant is assumed to be highly social and it interacts with all of its neighbors to decide its behavior for the next time step. Such a market participant is believed to be the mean of rumor propagation as it further influences other market participants coming in its contact. Hence, the value of λ , defines the dependency of the participants on their respective neighbors.

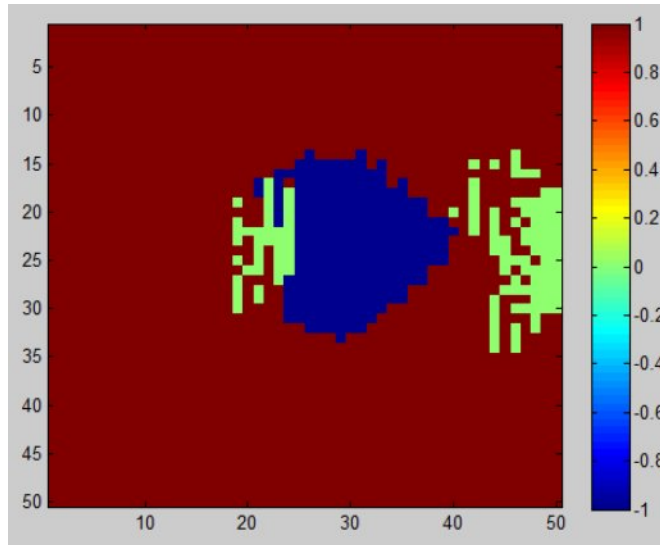


Figure 5.5 The stock market behavior at time step $t = 10$ after applying constraint 1

However, it is observed in Figure 5.6 that the market becomes unstable early than before. This shows the direct correlation between the numbers of market participants being considered by an individual while making an investing decision and the stability of the market. Lesser the number of market participants involved in the decision of an investor, more likely it is for market to behave biased.

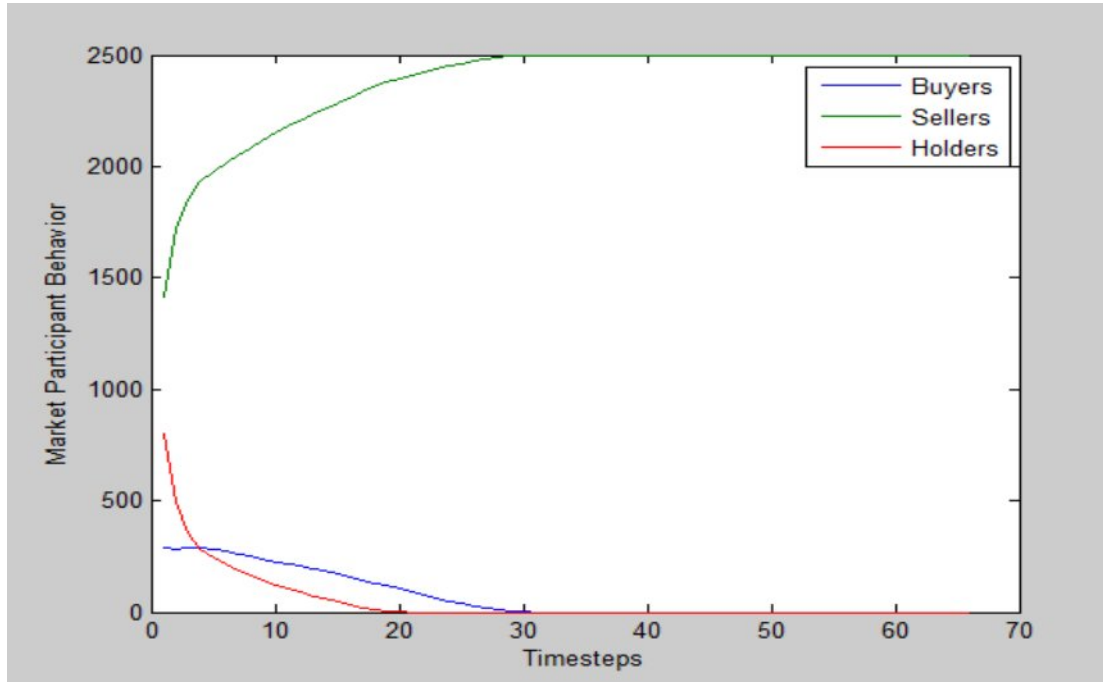


Figure 5.6 Graph depicting behavior of different market participants after applying constraint 1

Constraint 2: Forgetfulness of market participant:

The relevance of the rumor may decline or its importance may fade due to other factors in the everyday communication. The rumor propagation may be hindered if the infected market participant stops thinking about it or if he forgets about the rumor. This constraint is introduced to serve as counter-dynamic to the spread of communication.

Without such constraint, the infected participant would keep on spreading the rumor forever. The probability to forget the rumor FR_{prob} by the market participant is normally distributed with the mean = 0 and standard deviation = 1. The negative probability implies that the market participant would not forget the rumor and thus spreads the rumor to as many other agents as it can, while in contact. The probability $FR_{prob} = 0$ implies that the market participant may or may not forget the rumor depending on the value of the social interaction willingness factor λ . If the probability

FR_{prob} is strictly positive the chances of the market participant to forget the rumor are high.

The observation of this simulation is shown below in Figure 5.8 which shows that market is stable for a longer period of time when just a few market participants forget about the rumor but later on, the market participants adopt the behavior of the majority. Hence it is concluded that by applying above constraint 1 and 2 alone

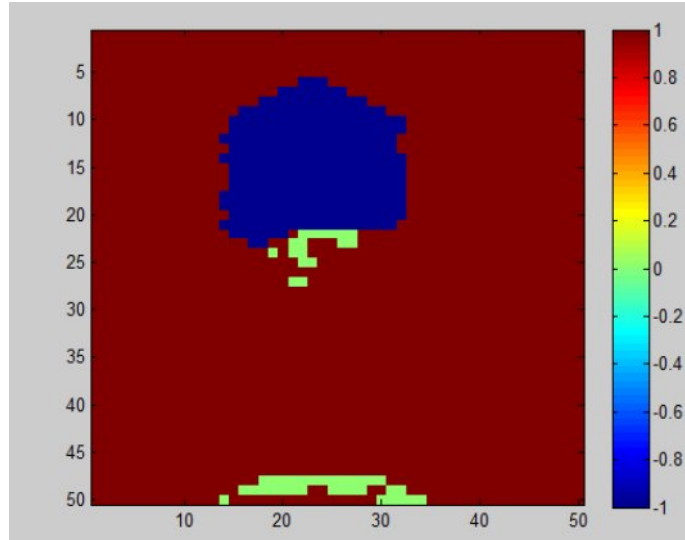


Figure 5.7 The stock market behavior at time step $t = 10$ after applying constraint 2

cannot act as a full proof solution to counter dynamic the instability of the stock market. This encourages us to apply further constraint as described below:

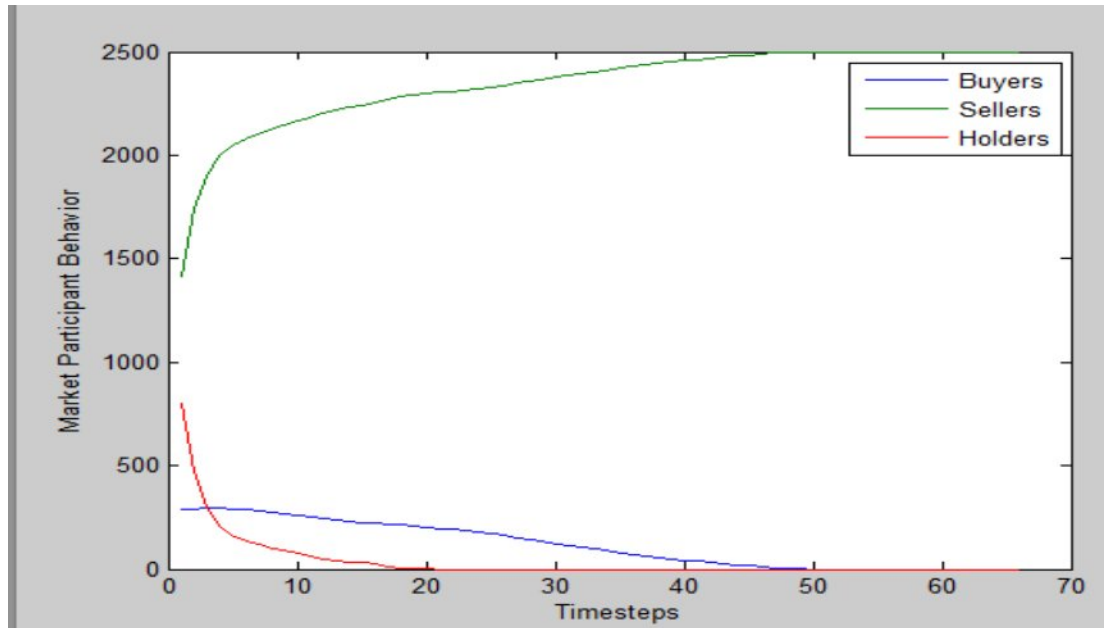


Figure 5.8 Graph depicting behavior of different Market Participants after applying constraint 2

Constraint 3: The amount of stocks available is finite:

We have observed that the market becomes unstable even after applying above constraints. So, we further modify are model based on the concept of leaning function [3] and develop a social market network model.

This model is modification to the already build model with three states i.e. Buy, Sell and Hold. In this model, the evolution rules applied on the state of the market participant depends on: price of the stock perceived ,the influence of the change in price perception, the influence of the neighbors and the Rumor strength. This model incorporates the price of the stock along with the rumor propagation through neighbor market participants. The major assumption of this constraint is that the amount of stock available is finite. This prevents market from being unstable as for every buyer to buy the stock; there must be a corresponding seller to sell that stock and vice-versa. This provides increased stability in the stock price and thus market never becomes unstable. The controlling factor in this model is the stock's price, if the market participants wish to buy the stock, the price of the stock will increase. Conversely, the increase in the stock's price will encourage the sellers to sell the stock; this drives the price of the stock down. To implement this, following social network market model [3] is used.

5.2 Social Network Market Model

The price of the stock being traded acts as the fundamental element of the model. The stock's normalized price is assumed to be equal to the actual worth of the stock, for the purpose of our model. The model constitutes of various market participants where each market participant at a particular time step exists in one of the three states: Buy, Sell or Hold. Hence, each market participant's decision depends upon the current normalized stock price, the difference in the normalized stock price from the previous time step to the current time step, the behavior of the neighbors in the previous time step and the strength of the rumor.

Taking into an account the possible vagueness, the correct normalized price is replaced by the price which is perceived. The perceived price is sum of the correct normalized price and stochastic error based on normal distribution with mean= 0.

$$\text{Perceived price(per}(t)) = \text{Correct normalized price} + \text{stochastic error}$$

For each market participant P we have

- A_p , defines how much the market participant is influenced by the normalized asset price. Market participants with high value of A_p are the ones to look for higher profits by buying the stock which are undervalued and selling the stocks when they are overvalued. Since, the outcome of all the parameters is interdependent to the degree of the other parameter, the value of A_p is normalized to $A_p = 1$ for the market participants.
- B_p , defines the effect of perceived change in normalized price from the previous time step to the current time step. Market participants with positive B_p are considered as rational market participants whereas the negative B_p denotes the emotional market participants who keep the bubble going i.e. they believe in what rises, continues to rise.
- N_p , defines the impact of the neighbors on the behavior of the market participants. The positive N_p denotes how strongly the individual imitates the behavior of its neighbor while communicating the rumor. Negative N_p denotes that the market participants distrust their neighbors and hence act in opposition to their behavior. This also denotes that such market participants prevent the rumor from propagating forever. Hence, negative N_p acts as a counter-dynamic in the rumor propagation.
- R_s , defines the strength of the rumor. Positive rumor denotes that the buy probability will increase whereas the negative rumor denotes that the selling probability will increase.

5.3 Model Rules

At time step $t-1$, each market participant will have an action state $S_p(t) \in \{-1, 0, 1\}$. The state of -1 represents the buyer, 0 represents holder and 1 represents seller. Vagueness in price for each individual market participant is created at the beginning. For each individual, personal skew factor ϵ_p for every market participant P is generated as a random normal distribution around 0 and standard deviation σ_ϵ .

The action state at time step t is determined by an individual leaning function $L_p(t)$, which is a modification to the social network model [3] to study the effect of rumor propagation while the amount of stock is kept to be finite. The leaning function is defined using the four parameters $A_p > 0$, $B_p \in \mathbb{R}$, $N_p \in \mathbb{R}$ and $R_s \in \mathbb{R}$, and the

social interaction influence factor α_p . The leaning function for individual P at time t is defined as

$$L_p(t) = A_p(per(t) + \varepsilon_p(t)) + B_p((per(t) + \varepsilon_p(t)) - (per(t-1) + \varepsilon_p(t-1))) + N_p(\alpha_p, S_p(t-1)) - R_s \quad (1)$$

In order to determine the state of an individual market participant, the Leaning function F is defined as follows

$$F(L) = \begin{cases} -1 & \text{if } L_p < b \\ 0 & \text{if } b \leq L_p \leq s \\ 1 & \text{if } s < L_p \end{cases}$$

Where $b \leq 0 \leq s$ are the buy-sell spread parameters. Using F, state of each market participant P at time t is computed as $S_p(t) = F(L_p(t))$.

Therefore, action states of individuals at time t are based on information at time step t-1 and price at time step t. For this at time t price of the stock must be defined. To conserve the stocks within the market, it is mandatory for each buyer to be matched with a seller. Thus the value of the stock fluctuates during each time step until the stock market has equal number of buyers and sellers. Hence, the price of the stock at the end of each time state t will summate to zero as below:

$$\sum_{i=1}^n F(L_p(t)) = 0 \quad (2)$$

The result of the simulation shown below considers the following scenario:

- i. The value of B_p is randomly distributed using normal distribution with mean = 0 and standard deviation = 1;
- ii. The value of C_p is randomly distributed using normal distribution with mean = 5 and standard deviation = 2;
- iii. The value of R_s is randomly distributed using normal distribution with mean = 0 and standard deviation = 1;

In the Figure 5.9 shown below, it is observed that using the leaning function by the market participants to decide their action state helps the market to stay stable. The market does not become unstable because the number of stocks is finite and each buyer is mapped to a seller. The factor that controls the market from being biased is

the price of the stock, if number of buyers increase in the market, the price of the stock will increase which will in return encourage the sellers to sell the stocks at a higher price, which again brings the price of the stock down.

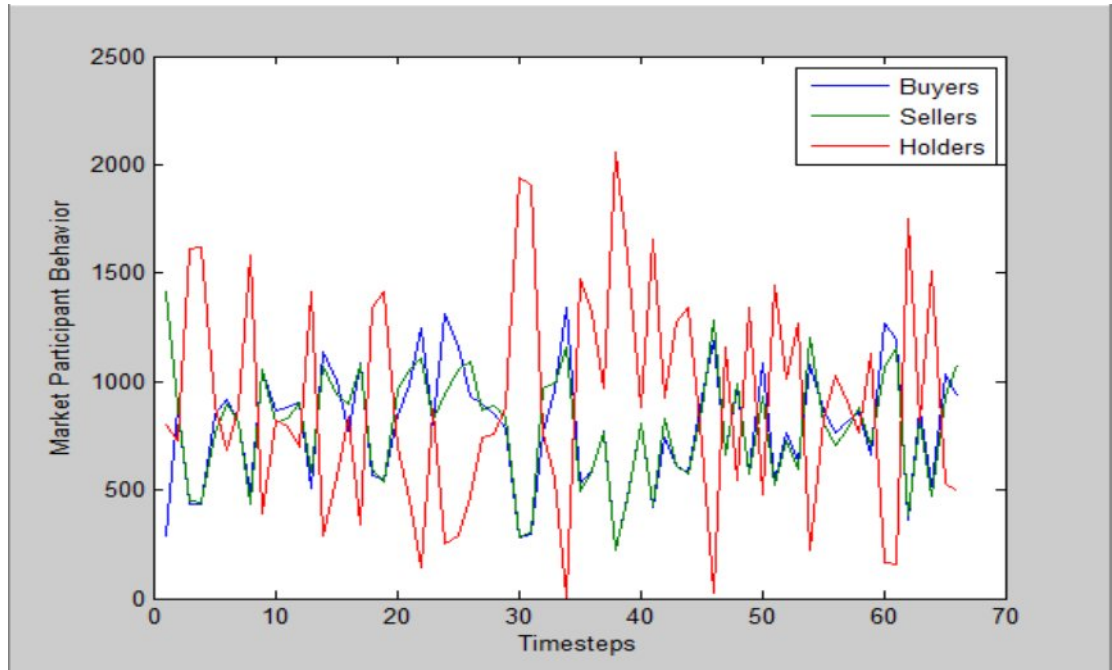


Figure 5.9 Graph depicting behavior of different market participants with leaning function

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

In this study, we have modified an already existing cellular automata model of the stock market behaviour which is not restricted to interact with exactly eight of its immediate neighbours to exhibit the neighbourhood characteristics of the social networks close to real world. It is observed that ‘customized’ neighbourhood defined using the social interaction willing factor reduces the stability of the market. Hence, we further modified our model to simulate the market which considers not only the social influence but also the price of the stock. We have observed that behaviour of market by applying various constraints on the model. Firstly, we tried to eliminate the restriction of communicating with exactly eight neighbours. Secondly, we applied a further constraint on the memory of the market participant. The conclusion of our study is discussed below:

- i. Lesser the number of neighbors a market participant interacts with, lesser is the stability of stock market.
- ii. Lesser the number of infected participants, higher is the stability of the market.
- iii. Stability of the market can sustain by keeping the number of stocks finite i.e. for each buyer there is a seller and vice-versa.

6.2 Future Scope

We believe there is a lot that is yet to be explored in this area. Following are the points that can be considered for further research on this topic:

- i. We have ignored the stochastic error while calculating the perceived value of the stock for the market participants.
- ii. We have introduced the social willingness factor to customize the interactions of the market participants with its neighbours giving each of it equal weight. Whereas in real life, one might interact with four or five of its neighbours but while making any decision, he might consider one of them with the highest trust weight. Therefore, idea of weighted social interaction influence is yet to be explored.

References

- [1].“Von Neumann neighborhood with cardinal directions” [Online] Available: https://commons.wikimedia.org/wiki/File:Von_neumann_neighborhood_with_cardinal_directions.svg [Accessed on 11 June 2016]
- [2].“Moore neighborhood” [Online] Available: https://en.wikipedia.org/wiki/Moore_neighborhood [Accessed on 11 June 2016]
- [3].M. Mozafari and R. Alizadeh, “Neurocomputing A cellular learning automata model of investment behavior in the stock market,” *Neurocomputing*, 122, 470–479, 2013.
- [4].“A Collaborative Approach for LA- DHBMO: Learning Automata” [Online] Available: http://file.scirp.org/Html/27-7400960_24139.htm [Accessed on 1 July 2016]
- [5].N. Difonzo, “Rumor and Prediction : Making Sense (but Losing Dollars) in the Stock Market,” 71(3), 329–353, 1997.
- [6].M. Kosfeld, “Rumours and markets,” 41, 646–664, 2005.
- [7].“A Theory of Rumor Transmission: Group involvement and group structure and their expected effects on rumor transmission” [Online] Available: <http://www.tbuckner.com/Rumor.htm> [Accessed on 18 June 2016]
- [8].H. Chou and G. Y. Tian, “Takeover Rumors : Returns and Pricing of the Rumored Targets Takeover Rumors : Returns and Pricing of the Rumored Targets Abstract : Rumors can be classified into two types according to whether they can credibly,” 1–54, 2012.
- [9].M. Schindler ,” Rumors in financial markets: Insights into behavioral finance,” 413, John Wiley & Sons, 2007
- [10].“Rumor Psychology” [Online] Available: <http://rumorpsychology.com/excerpts/> [Accessed on 3 July 2016]
- [11].“Diffusion of innovations” [Online] Available: https://en.wikipedia.org/wiki/Everett_Rogers [Accessed on 2 July 2016]

- [12].“Nestle: Case of bad rumor management” [Online] Available: <http://www.adageindia.in/marketing/cmo-strategy/nestle-case-of-bad-rumor-management/articleshow/51231980.cms> [Accessed on 2 July 2016]
- [13].“The Five Classes of Consumers” [Online] Available: <http://study.com/academy/lesson/classes-of-adopters-innovators-early-late-and-laggards.html> [Accessed on 24 June 2016]
- [14].“Nestle: Case of Bad Rumor Management” [Online] Available: <https://www.linkedin.com/pulse/nestle-case-bad-rumour-management-prabhakar-mundkur> [Accessed on 19 June 2016]
- [15].“Nestle handled communication badly” [Online] Available : <http://www.adageindia.in/marketing/cmo-strategy/nestle-case-of-bad-rumor-management/articleshow/51231980.cms> [Accessed on 19 June 2016]
- [16].“The Story of Maggi crisis” [Online] Available: <http://www.slideshare.net/priya98760/the-story-of-maggi-crisis-48745978> [Accessed on 1 July 2016]
- [17].“History of stock exchange in India” [Online] Available: <http://www.yourarticlelibrary.com/stock-exchange/history-of-stock-exchange-in-india/23488/> [Accessed on 15 June 2016]
- [18].“Indian Stock Market: Functions and importance” [Online] Available: http://www.academia.edu/17744500/INDIAN_STOCK_MARKET_FUNCTIONS_AND_IMPORTANCE [Accessed on 23 June 2016]
- [19]. “Open Learn: 3 the efficient market hypothesis” [Online] Available: <http://www.open.edu/openlearn/money-management/money/accounting-and-finance/the-financial-markets-context/content-section-3> [Accessed on 18 June 2016]
- [20].“Efficient Market Hypothesis (EMH)” [Online] Available: <http://knowledgegrab.com/learners-zone/study-support/decision-making-financial-management/investment-decision/business-valuation-17/efficiency-market hypothesis-18/> [Accessed on 26 June 2016]
- [21].J. Ding, “Cellular Automata based Artificial Financial Market”, INTECH Open Access Publisher, 2011
- [22].Y. Wei, S. Ying, Y. Fan, and B. Wang, “The cellular automaton model of investment behavior in the stock market,” 325, 507–516, 2003.

- [23].L. Bakker, W. Hare, H. Khosravi, and B. Ramadanovic, “A social network model of investment behaviour in the stock market,” *Physica A*, 389(6) ,1223–1229, 2010.
- [24].Y. Fan, S. Ying, B. Wang, and Y. Wei, “The effect of investor psychology on the complexity of stock market : An analysis based on cellular automaton model,” *Comput. Ind. Eng.*, 56(1), 63–69, 2009.
- [25].G. Qiu, D. Kandhai, and P. M. A. Sloot, “Understanding the complex dynamics of stock markets through cellular automata,” 75(4), 1–11, 2007.
- [26].N. Ghorbani and E. Babaei, “Exchange market algorithm,” 19, 177–187, 2014.
- [27].D. Abreu and M . K. Brunnermeier, “Bubbles and Crashes,” *Econometrica*, 71(1), 173–204, 2003.
- [28].N. Suhadolnik, J. Galimberti, and S. Da Silva, “Robot traders can prevent extreme events in complex stock markets,” *Physica A*, 389(22), 5182–5192, 2010.
- [29].P. Maji and C. Shaw, “Theory and Application of Cellular Automata For Pattern Classification,” 58, 321–354, 2003.

P. Vij and A. Kumar, “Effect of Rumor propagation on the stock market dynamics using cellular automata”, *International Conference on Inventive Computation Technologies*. IEEE – 2016.

[Communicated]

Video Presentation Link

The video on thesis can be seen on the following link:

Video Link: <https://www.youtube.com/channel/UCVP-ZPAGYkdIfkiMtlV2qwxw>