THE APPLICATION OF CHAOS THEORY TO ECONOMICS AND ORGANIZATION MANAGEMENTS

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JEERANA NOYMANEE. THE APPLICATION OF CHAOS THEORY TO ECONOMICS AND ORGANIZATION MANAGEMENTS. ADVISOR: ASST. PROF. DR. WIMOL SAN-UM, 82 PP.

The typical logistic map has been utilized in a variety of applications such as in biological modeling and secure communications. Nonetheless, such a typical logistic map has only a single control parameter that sets all dynamic behaviors. This paper therefore introduces a new arbitrary power in the quadratic term in order to control stability of the system. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties are described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Ardino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain. The experimental results is to understand behaviors of the impact of Chaos theory to organization management and how basic and practice of management, as well as the role of managers and management guidelines for engaging in the practice of organization management. A current view of management theory stresses the changing nature of the external environment and the need to understand and address these external forces for change. Participation and the role of systems theory and the theory of organization to organization management process focused.

Graduate school Student’s signature……….…………………

Field of Study Engineering Technology Advisor’s signature……...………………...

Academic Year 2014

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Jeerana Noymanee

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Introduction

1.1 Introduction

This chapter gives a background of a research approaches, involving dynamical system and chaos theory. It also includes the motivation, statement of problem, research scope, research objective, expected outcomes and definition of technical terms.

1.2 Background

Isaac Newton has brought the idea of modeling the motion of physical systems with equations. It was necessary to invent calculus along the way, since fundamental equations of motion involve velocities and accelerations, which are derivatives of position. The greatest single success was the discovery that the motion of the planets and moons of the solar system resulted from a single fundamental source: the gravitational attraction of the bodies. The circular, elliptical, and parabolic orbits of astronomy were no longer fundamental determinants of motion, but approximations to laws specified with differential equations. Subsequent generations of scientists extended the method of using differential equations to describe how physical systems evolve. Such sets of equations are called dynamical systems. The theory of dynamical systems describes phenomena that are common to physical and biological systems throughout science. It has benefited greatly from the collision of ideas from mathematics and these sciences. The goal of scientists and applied mathematicians is to find nature's unifying ideas or laws and to fashion a language to describe these ideas.

Recently, an active research field in modern physics is that of nonlinear dynamics and the subfield of chaotic dynamics. Although chaotic dynamics had been known to exist for a long time, its importance for a broad variety of applications began to be widely appreciated only within the last decade or so. Concurrently, there has been enormous interest both within the mathematical community and among engineers and scientists. The field continues to develop rapidly in many directions, and its implications continue to grow.

The chaos theory is a complicated and disputed mathematical theory that seeks to explain the effect of seemingly insignificant factors. The chaos theory name originates from the idea that the theory can give an explanation for chaotic or random occurrences. The first real experiment in the chaos theory was done in 1960 by a meteorologist, Edward Lorenz who was working with a system of equations to predict what the weather would likely be.

In 1961, he wanted to recreate a past weather sequence, but he began the sequence mid-way and printed out only the first three decimal places instead of the full six. This radically changed the sequence, which could reasonably be assumed to closely mirror the original sequence with only the slight change of three decimal places. However, Lorenz proved that seemingly insignificant factors can have a huge effect on the overall outcome. The chaos theory explores the effects of small occurrences dramatically affecting the outcomes of seemingly unrelated events.

The chaos theory has been applied to many scientific areas, including finance. In finance, the chaos theory has been used to argue that price is the last thing to change for a security. Using the chaos theory, a change in price can be determined through mathematical predictions of the following factors: a trader's personal motivations such as doubt desire or hope that are nonlinear and complex, changes in volume, acceleration of changes and momentum behind the changes. The application of the chaos theory to finance remains controversial.

A basic logistic map use to apply into many applications in now a day. Whether it is population biology field, epidemiology field, economics research field and so on. The logistic map has been analyzed in many papers, being one of the topics of interest in dynamical systems with chaotic behavior. The behavior of logistic map at stability can be linearly modeled and the controller can be designed by using the nonlinear control conceptions. To design the controller, the transfer function of converters are needed which is usually a complicated task.

The classic problem in management require solutions to keep organization stable and continue improves. Many researches try to control stability by of organization management using chaos such as logistic map. This work therefore focuses on a framework design to control logistic map and implement in to organization management.

1.3 Motivations

There are many companies and corporations today on the market, which is confirmed by regularity, but also there are many examples of incorrect decisions of their management, exposed to ruthless struggle for survival, almost like that in nature. Fighting for survival, the phases of the lifecycle are characteristics of living organisms. In organisms are very difficult to determine the causes and consequences of their actions. They behave almost chaotic, and chaos can only be established by means of probabilities, the approximate value of the so-called Fuzzy process. The interaction between an organization and its environment is not predictable. Chaos theory explains many natural phenomena and found its application in many areas of human endeavor. The application of this theory has brought many new in explaining the behavior of business organizations in terms of eddy environment, and their transitions from a state of instability in the state of stability.

1.4 Statement of Problem and Hypothesis

Predicting chaos is hard, controlling chaos is easier. Long term predictions of deterministic chaos are hard, since even very small amounts of noise can change the motion significantly. Short term predictions and even medium term predictions of chaos are not that difficult, since the motion is governed by a deterministic equation, plus some small noise Simulation of managing a real world social organization or business entity

1.5 Objectives

15.1 To study a new arbitrary power in the quadratic term in order to control stability of the system.

15.2 To apply a new arbitrary power in the quadratic term in order to control stability of the system into organization management

15.3 Research Scopes

15.3.1 Study a new arbitrary power in the quadratic term in order to control stability of the system.

15.3.2 Apply a new arbitrary power in the quadratic term in order to control stability of the system into organization management

15.3.3 Apply chaos theory to organize management

15.4 Expected Outcomes

15.4.1 Gain knowledge on a new arbitrary power in the quadratic term in order to control stability of the system.

15.4.2 Gain framework on a new arbitrary power in the quadratic term in order to control stability of the system.

15.5 Definitions

15.5.1 **Chaos theory** is a field of study in mathematics, with applications in several disciplines including meteorology, sociology, physics, engineering, economics, biology, and philosophy. Chaos theory studies the behavior of dynamical systems that are highly sensitive to initial conditions—a response popularly referred to as the butterfly effect. Small differences in initial conditions such as those due to rounding errors in numerical computation yield widely diverging outcomes for such dynamical systems, rendering long-term prediction difficult in general. This happens even though these systems are deterministic, meaning that their future behavior is fully determined by their initial conditions, with no random elements involved. In other words, the deterministic nature of these systems does not make them predictable. This behavior is known as deterministic chaos, or simply chaos.

15.5.2 **Exponential growth** occurs when the growth rate of the value of a mathematical function is proportional to the function's current value. Exponential decay occurs in the same way when the growth rate is negative. In the case of a discrete domain of definition with equal intervals it is also called geometric growth or geometric decay

15.5.3 **Polynomial** is an expression consisting of variables and coefficients that involves only the operations of addition, subtraction, multiplication, and non-negative integer exponents. An example of a polynomial of a single indeterminate. Polynomials appear in a wide variety of areas of mathematics and science. For example, they are used to form polynomial equations, which encode a wide range of problems, from elementary word problems to complicated problems in the sciences; they are used to define polynomial functions, which appear in settings ranging from basic chemistry and physics to economics and social science; they are used in calculus and numerical analysis to approximate other functions. In advanced mathematics, polynomials are used to construct polynomial rings and algebraic varieties, central concepts in algebra and algebraic geometry.

15.5.4 **MATLAB** is advanced computer program (High-level Language) for technical computing that includes numerical computation. Complex graphics And replication to visualize the image is simple and clear name MATLAB stands for Matrix Laboratory original MATLAB program is written to use in the calculation of matrix or a matrix software which MATLAB is a program developed unceasingly. The program is easy to understand. And complex programming When put to use, and can see the results quickly. For this reason it makes MATLAB program has been used extensively in various fields.

Chapter 2

Related Theories and Literature Reviews

2.1 Introduction

This chapter 2 presents a synthesis of the related theory, particularly a key concept of chaos theory, nonlinearity, bifurcation, strange attractor, fractal and self-organization, implication to issue managements and implication to crisis managements in with knowledge. Literature reviews on existing chaotic maps and its control techniques will be presented.

2.2 Related Theory

2.2.1 Key Concept of Chaos theory

Chaos Theory is an alternative name for nonlinear dynamical system theory. The latter is term for the study of phenomena such as attractors, bifurcations, chaos, fractals, catastrophes, and self-organization, all of which describe systems as they change over time. This thesis will examine the basic patterns of movement, and their applications to a wide range of psychological theories. Chaos itself is a particular nonlinear dynamic and is perhaps the centerpiece of this field of study. In chaotic phenomena, seemingly random events are actually predictable from simple deterministic equations. Thus, a phenomenon that appears locally unpredictable may indeed be globally stable, exhibit clear boundaries, and display sensitivity to initial conditions. The latter property is also known as the “Butterfly Effect”. Chaos has a close relationship to other dynamics, such as attractors, bifurcations, fractals, and self-organization.

2.2.2 Nonlinearity

Nonlinearity is defined as a relationship which cannot be explained as a linear combination of its variable inputs. Nonlinearity is a common issue when examining cause-effect relations. Such instances require complex modeling and hypothesis to offer explanations to nonlinear events. Nonlinearity without explanation can lead to random, and unforecasted outcomes.

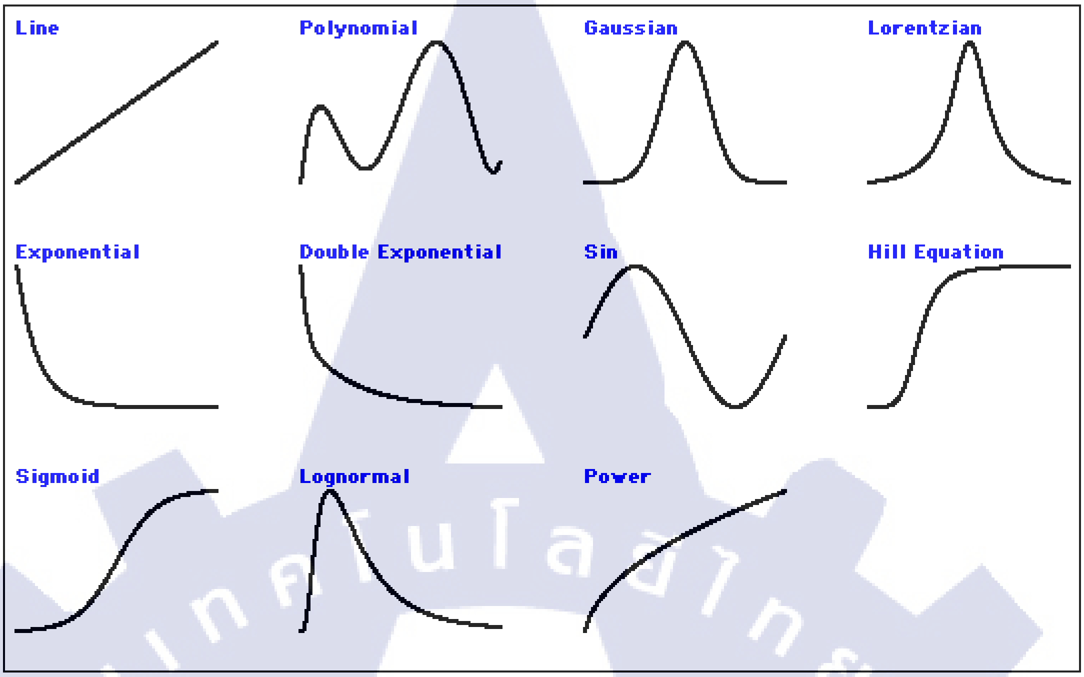

Figure 2.1 Some well-known nonlinearity that can be used for chaos generation.

Some nonlinear systems have no solutions whatever to a given initial value problem. On the other hand, some systems have infinitely many different solutions. Even if a solution of such a system, this solution need not be defined for all time. For example, what happens if the initial condition of system very so slightly? Does the corresponding solution very continuously? This problem is easy clear for linear system but absolutely not clear in nonlinear case. This means that the underlying theory behind nonlinear system of differential equations is quite bit more complicated than that for linear system. Fig.2.1 shows some well-known nonlinearity that can be used for chaos generation.

2.2.3 Bifurcation

Bifurcation in a term of dynamical system, a bifurcation is a period doubling, quadrupling, etc., that accompanies the onset of chaos. It represents the sudden appearance of a qualitatively different solution for a nonlinear system as some parameter is varied. The illustration above shows bifurcations of the logistic map is the parameter *r*, which is varied. Bifurcations come in four basic varieties; flip bifurcation, fold bifurcation, pitchfork bifurcation, and transcritical bifurcation. Fig.2.2 depicts the bifurcation diagram of the simple Logistic map showing effects of the parameter *r* in the equation.

Bifurcations describe changes in the stability or existence of fixed points as a control parameter in the system changes. As a very simple explanation of a bifurcation in a dynamical system, consider an object balanced on top of a vertical graph. The mass of the object can be thought of as the control parameter. As the mass of the object increases, the graph deflection from vertical, which is *x*, the dynamic variable, remains relatively stable. But when the mass reaches a certain point, at the bifurcation point the graph will suddenly buckle. Changes in the control parameter eventually changed the qualitative behavior of the system.

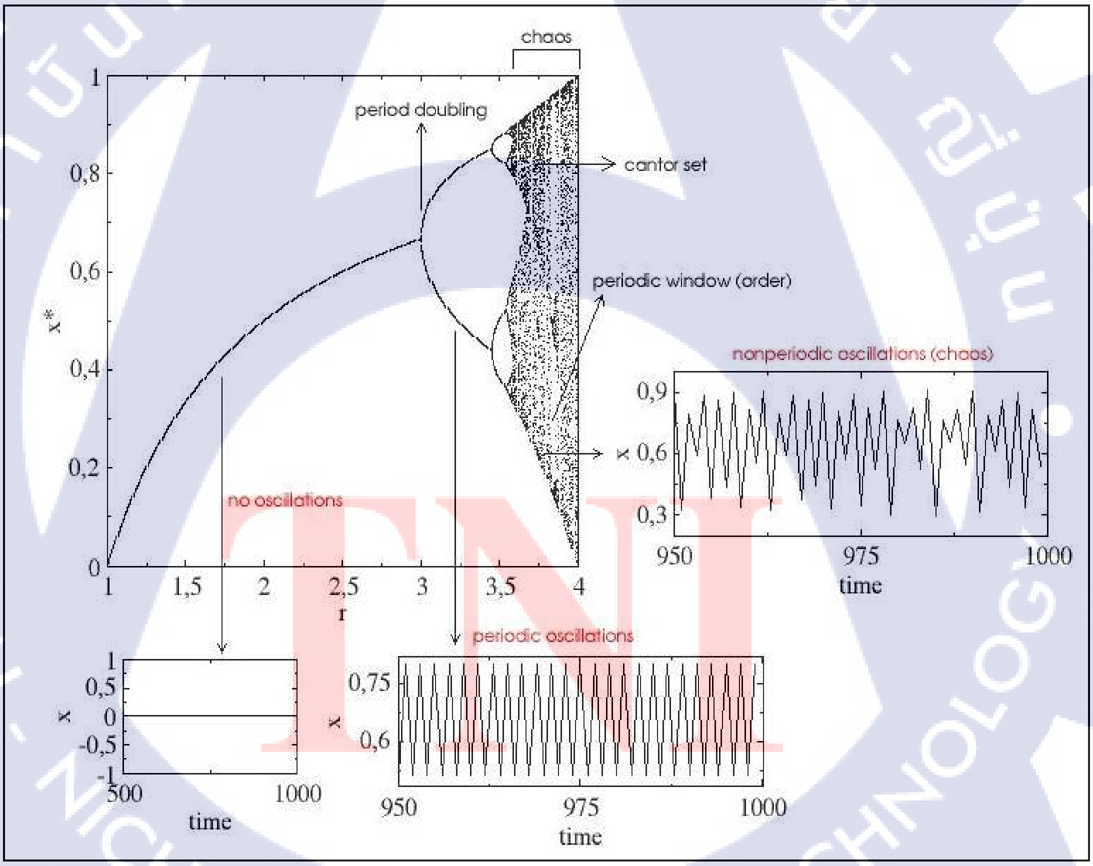

Figure 2.2 Bifurcation diagram of the simple Logistic map showing effects of the parameter *r* in the equation

2.2.4 Strange Attractor

Attractor is a set of states of a dynamic physical system toward which that system tends to evolve, regardless of the starting conditions of the system. Also explains in an organizing principle, shape and nature or state of affairs, which may seem like a phenomenon that often tends to return to its evolution, no matter how random each moment. An attractor is informally described as strange if it has non-integer dimension or if the dynamics on it are chaotic.

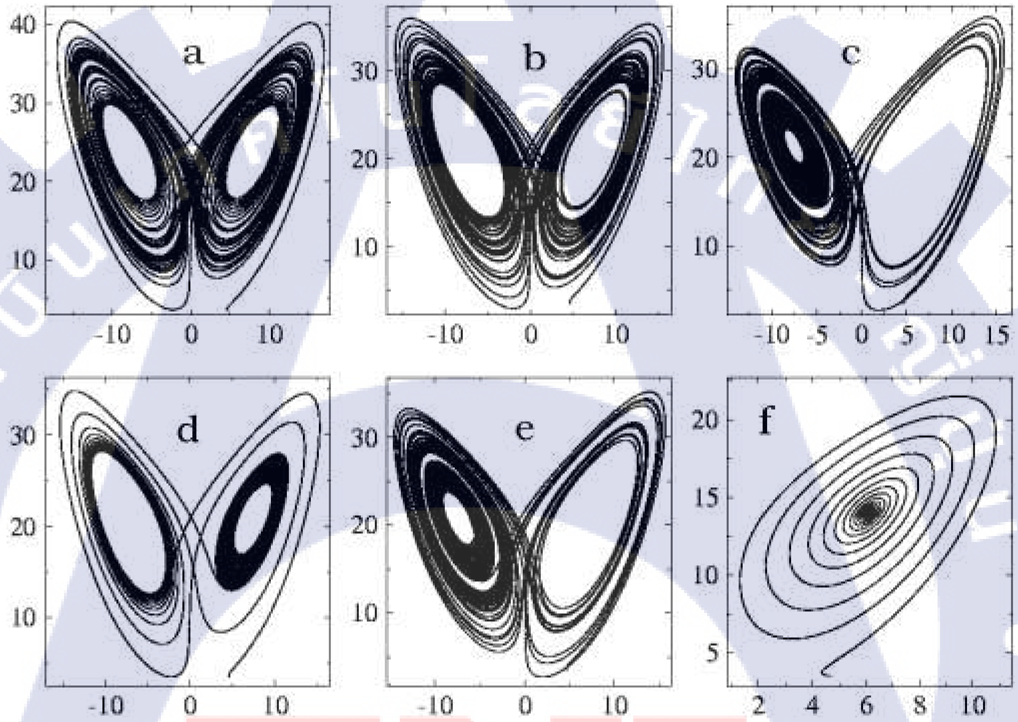

Figure 2.3 Strange attractor and its forming mechanisms of the Lorenz system.

Some attractor patterns can be easily mapped via traditional analysis. For example, the straight line of a static attractor maps an outcome that continues unchanged at a given level; the general waving line of a dynamic attractor maps an outcome that varies periodically and predictably about a mean. However chaotic situations are characterized by strange attractors where outcomes wander constantly and unpredictably within a bounded range. Maps of such situations, in which multiple variables are pulling events in contradictory directions, may resemble scribbled doughnuts or butterfly wings. However, the underlying order represented by the attractor constrains excessively erratic behavior and imposes a structure even though discrete events may be unpredictable within the bounds of that structure. Fig.2.3 illustrates the strange attractors and its forming mechanisms of the Lorenz system.

On a social level, attractors have been seen as indices of human agency and free choice. For example, deterministic societies with little room for human change follow the patterns of static or dynamic attractors; societies that allow some variation within an overall conformity can be mapped; societies patterned after linked offer still more freedom for human choice, and so forth On an individual level, psychological constructs like personality may operate in a manner analogous to an attractor. This idea may explain why personality variables often have low predictability for a single behavioral incident, but a pattern of behavior reflecting a personality style can be established. Some researchers view organizational culture as a strange attractor, a common set of values that informs behavior but is not articulated in words as a corporate mission statement.

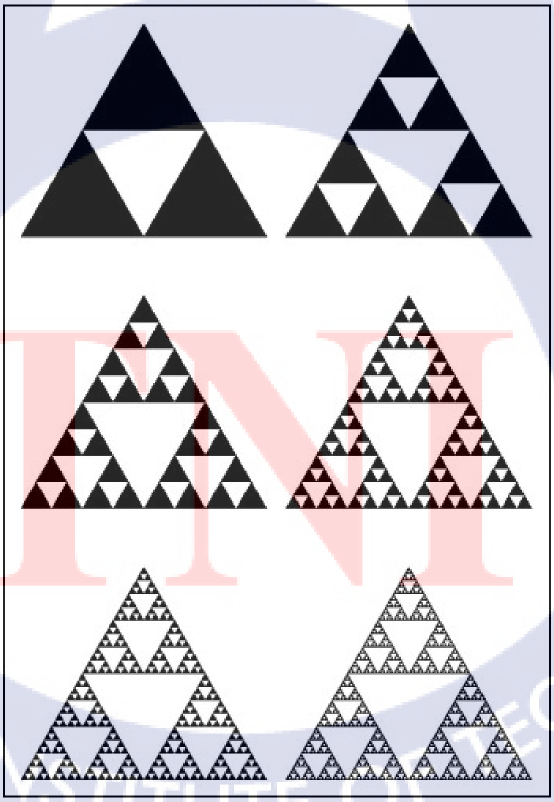

Figure 2.4 Examples of simple frcatal in trinagular geometry.

2.2.5 Fractal and Self Organization

Fractal is an object or quantity that displays self-similarity, in a somewhat technical sense, on all scales. The object need not exhibit exactly the same structure at all scales, but the same type of structures must appear on all scales. A plot of the quantity on a log-log graph versus scale then gives a straight line, whose slope is said to be the fractal dimension. The prototypical example for a fractal is the length of a coastline measured with different length rulers. The shorter the ruler, the longer the length measured, a paradox known as the coastline paradox. Fig.2.4 shows examples of simple fractal in triangular geometry. Additionally, Fig.2.5 shows the well-known Mandelbrot fractal demonstrating an infinite shape of chaos.

Self Organization is the ability of the system to be classified as a natural component or components of the target effects, under appropriate conditions but without the help of an external source. It is as if the system knows how to do its own thing. Many natural systems such as cells, chemical compounds, galaxies, organisms and planets show this property. Animal and human communities too display. In term of chaotic systems, self-organization is the system that has ability to generate their own new forms from inner guidelines rather than the imposition of form from outside.

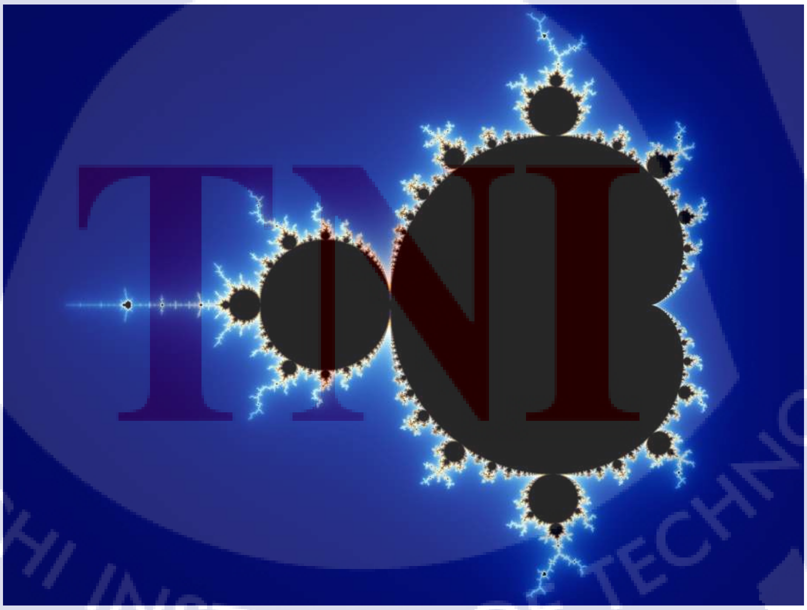

Figure 2.5 The well-known Mandelbrot fractal demonstrating an infinite shape of chaos.

2.2.6 Implication to Issue Managements

Chaos theory has emerged as new currencies in social sciences in general and in systems design and management, and in futuristic studies in individual. Chaos theory is practical for structuring up-and-coming social concerns and interest-group behavior, the province of issues management. Issues management attempts to tell the variance trends in public opinion so that an organization can respond to them before they increase into serious tension which breaches the social structure and eludes control-that is, before chaos sets in.

Successful issues management has the ability to show the interplay between factors as diverse as social concerns, news events, cultural values, and corporate goals, an approach which demands a high level of context sensitivity. In a process similar to analyzing fractal patterns, issues managers look for relationships between emerging social concerns, and then seek correspondences between industry or organizational actions on a micro scale, and the social context on a macro scale.

Such linkages are often invisible linear cross-sectional analysis. It manifests itself through a holistic analysis of the model. The manager explains how complex fractions. They refined their recognition is a key condition, which works like a different point of coupling between different events; By using these key words to search the database computer, they are essentially following the attractor associated random events into the corresponding polymorphous problem.

As well as issues that interest groups might best be understood in terms of chaotic systems. The separation of the individual often is dissatisfactions easy they were meant when they find each other. They gather strength and sophistication when lobbying groups have been involved. Interest groups often resemble a chaotic system in such a break. As a result, it may be difficult to find the right spot. For the use of communication or even to see what the real problem is. Intel faced with such a situation during the 1994 controversy about computer chips Pentium started as a trickle of messages posted on the Internet news Pentium, user complaints cascades over the Internet to leak into the group. Others were picked up by journalists become common knowledge and profoundly redefined Intel's reputation for cutting edge technology.

As with many technological controversies, the combination point for these unequal groups was very likely concern about institutional, not electrical, power. Thus the integrating ideology of interest groups acts as a strange attractor: a set of principal beliefs, assumptions, values, and customs that powerfully govern the behavior of individual constituents. However, the attractor is often clear only after the fact; it would be difficult to tell the difference it in the original complaint, or to identify it along the way by sampling group member's protests. From a practical standpoint, therefore, chaos theory offers little help in predicting the evolution or outcome of interest group activities, but it does suggest that the most efficient way to coexist with interest groups is to look beyond their immediate demands and identify the true attractor. Corporating social responsibility can be understood as an effort to accommodate such attractors by fitting the organization into them rather than by attempting to change them.

In fact, the chaotic nature of interest groups severely limits public relations ability to 'manage' such groups, so that efforts to reshape a group's perceptions, whether through education, negotiation, or coercion, often have little impact. Attractors resist change, regardless of outside pressures, because chaotic systems are inherently reflexive. Such systems follow their own logic; while their inherent instability makes change inevitable, external forces have limited power to affect the timing or nature of the change.

A similar dynamic governs the issue that comes out of nowhere, the emerging social concern that comes to dominate public attention virtually overnight. On the one hand, attractors in the form of dominant ideologies resist change. On the other hand, positive feedback-r accumulated dissonance within the system-constantly works against the status quo. As a result, after a number of symmetrical iterations, a chaotic system becomes vulnerable to destabilization even by very small changes-the classic "straw that broke the camel's back". In a social context, the chaos model shows that issues can develop a critical mass very quickly, so that radical opinion change "does not require that all configurations within a given culture be self-similar, but when enough of them are, initial perturbation will have large-scale effects"

This vulnerability of chaotic systems to small changes explains why organizations can be caught off guard by initially small-scale events that undergo catastrophic social amplification. Such situations are often dominated by large issues of timing and context against which public relations measures have little efficacy.

2.2.7 Implification to Crisis Managements

Chaos theory provides a particularly good model for crisis situations. Typically a crisis forms as a sequence of events that seems, over time, to gather volume and complexity with increasing speed. Its dynamic therefore resembles that of a chaotic system as it iterates through increasingly complex phases toward a disordered state. At the onset of a crisis, an organization may have power to influence events, but after a certain escalation point, it often loses this capacity.

Crises therefore act as bifurcation points that permanently redefine an organization in a new and unexpected light. Indeed, some theorists define a crisis as a point in an organization's history which irreversibly changes its culture and business; it is this criterion that distinguishes a true crisis from a mere bad event. Nonetheless, chaos theory stresses that these cataclysmic moments are not random, but rather the culmination of accumulated 'noise' within the system itself put another way, certain organizations contain flaws within themselves that amplify over time to self-generate crises independent of outside factors. On the one hand, traditional management theory stresses the role of negative feedback, a regulatory mechanism by which organizations preserve their status. However, chaotic organizations fall prey to positive feedback in that their managerial shortcomings amplify over time until they breed a crisis that transforms them permanently.

NASA's evolution toward the Challenger disaster exemplifies the effect of such dysfunctional organizational attractors. Writing from a Freudian standpoint, Schwartz argued that the pre-Challenger NASA had become enthralled with an organizational "fantasy" of perfection and invulnerability: "the business of NASA had become the creation of the image of American society's perfection.“ Indeed, for all NASA employees "the motivational base of organizational life" had become this sense of perfection; in terms of chaos theory, the notion of NASA's infallibility functioned as an organizational strange attractor.

Amplification of this strange attractor through successive shuttle launches led directly to the attractor's sudden reversal. Before the Challenger, NASA managers had repeatedly sent shuttles into space with safety defects, thereby intensifying the sense that the agency could do anything: “it was largely because of its history of success, and the attendant attribution of perfection, that NASA developed the ‘can’t fail’ mentality. “ Each time disaster failed to materialize, managers would take a larger risk with the following launch, thereby amplifying defects in successive iterations of the shuttle launches.

The Challenger explosion marked a bifurcation in this cycle of positive feed-back. It brought to a head what some researchers have termed the “Challenger Chernobyl syndrome” the widespread realization that scientific competence cannot be taken for granted anymore and thus marked a critical shift in attitudes toward technological expertise. Indeed, the tragedy wholly reversed the space agency’s image so that its new attractor became incompetence and bad luck. The power of the new attractor has been confirmed in public notice of NASA’s misfortunes since the Challenger: satellite transmission failures, Hubble telescope repairs, and cutbacks in funding. Multiple shuttle launch postponements, meant to signal caution, now appear to corroborate technical incompetence.

Chaos theory also lends structure to ongoing low-level conflicts between an organization and its publics. Often such chronic friction comes from misperceptions that cannot be extinguished permanently, or misinformation that resists all efforts to correct it. Recurrent rumors exemplify this pattern. Typically, as a rumor is reiterated over time, it acquires variations so that each account differs from the next; although details may change in the telling, it retains elements of its original structure. In chaos theory terms, this characteristic suggests that rumors follow their own strange attractors that impose “a recognizable configuration of meaning or action in ever-changing and unique iterations,...unpredictable yet patterned. “ Such attractors may underlie persistent “urban legends” that express dominant cultural attitudes.

Organizations often try to combat rumors with facts. However, if rumors are indeed chaotic systems, facts will have little permanent effect against the underlying cultural anxieties that govern response to a given product, company, or technology.

2.3 Literature Reviews on Chaotic Maps and its Control Techniques

2.3.1 Logistic Map

The logistic map is a polynomial mapping of degree 2, often cited as an archetypal example of how complex, chaotic behavior can arise from very simple non-linear dynamical equations. The map was popularized in a seminal 1976 paper by the biologist Robert May, in part as a discrete-time demographic model analogous to the logistic equation first created by Pierre François Verhulst. This nonlinear difference equation is intended to capture two effects; First, the reproduction where the population will increase at a rate proportional to the current population when the population size is small. Second, starvation where the growth rate will decrease at a rate proportional to the value obtained by taking the theoretical "carrying capacity" of the environment less the current population. However, as a demographic model the logistic map has the pathological problem that some initial conditions and parameter values lead to negative population sizes. Typically, the logistic map is expressed as

$$x_{n+1} = rx_n(1 - x_n). \tag{2.1}$$

The bifurcation parameter *r* is shown on the horizontal axis of the plot and the vertical axis shows the possible long-term population values of the logistic function. The bifurcation diagram nicely shows the forking of the possible periods of stable orbits from 1 to 2 to 4 to 8 etc. Each of these bifurcation points is a period-doubling bifurcation. The ratio of the lengths of successive intervals between values of r for which bifurcation occurs converges to the first Feigenbaum constant.

2.3.2 Henon Map

The Hénon map is a discrete-time dynamical system. It is one of the most studied examples of dynamical systems that exhibit chaotic behavior. The Hénon map takes a point (x_n, y_n) in the plane and maps it to a new point

$$\begin{aligned} x_{n+1} &= 1 - ax_n^2 + y_n \\ y_{n+1} &= bx_n. \end{aligned} \tag{2.2}$$

The map depends on two parameters, *a* and *b*, which for the classical Hénon map have values of a = 1.4 and b = 0.3. For the classical values the Hénon map is chaotic. For other values of *a* and *b* the map may be chaotic, intermittent, or converge to a periodic orbit. An overview of the type of behavior of the map at different parameter values may be obtained from its orbit diagram.

2.4 Related Publications

Table 2.1 summary of related publications

Authors	Titles
J. T. Ambadan and K B. Joseph [1]	Asymmetrical Mirror Bifurcations in Logistic Map with a Discontinuity at Zero
J. Gao et al. [2]	The Construction of the Cubic Logistic Chaotic Function Family
M. Pariazar et al. [3]	Chaos theory and application in sells management
Z. Hao et al. [4]	Research on characteristics of chaos in enterprise strategic system and chaos management
B.M. Khoshroo and H. Rashidi [5]	Towards a Framework for Agile Management Based on Chaos and Complex System Theories
M. Rania and R. Agarwalb [6]	Generation of fractals from complex logistic map
X. Liu [7]	The impaction of non-linearity dynamics theories in management
E. Campos-Cantóna et al. [8]	A family of multimodal dynamic maps.
X. Ping Zong et al. [9]	Control of arbitrary periodic orbit of Logistic Map
A. G. Radwan [10]	On some generalized discrete logistic maps

Table 2.1 summary of related publications (Cont.)

Authors	Titles
E. A. Levinsohn et al. [11]	Switching induced complex dynamics in an extended logistic map
J. A. de Oliveira et al. [12]	Relaxation to Fixed Points in the Logistic and Cubic Maps: Analytical and Numerical Investigation
M. D. Shrimali [13]	Delayed q-deformed logistic map
S. C. Hunga and M. F. Tub [14]	Is small actually big? The chaos of technological change
S. Mesbaha [15]	One-dimensional map-based neuron model: a logistic modification

As shown in Table 1, J. T. Ambadan and K. B. Joseph [1] have studied the properties of the logistic map with a negative control parameter which is a variant of the standard logistic map with a positive control parameter. In this case it is found that the map gives asymmetrical mirror cascades with a discontinuity at zero (From here onwards, the logistic map with negative control parameter is termed as Discontinuous Logistic Map: DLM). Compared to the standard logistic map the bifurcation in the DLM occurs earlier and this hastens the onset of chaos. The findings are in agreement with the complex features observed in the behaviour of certain experimental systems. Even though asymmetrical in nature the map preserves the universality of the Feigenbaum constant δ .

J. Gao et al [2] presents that chaotic time sequence has huge application value. The author analyses the essence of the chaotic time sequence which is created by the logistic map, points out the limitation of the logistic chaotic sequence in the application and suggests the new scheme which is at the core of constructing cubic self-map chaotic function families. In this article, the author discusses the principle of constructing cubic function family and analyses the constructing process of the cubic logistic chaotic function families. For several functions with a series of special control parameters, computer simulation is implemented, and simulation result is listed.

Simulation experiment data show the validity and correctness of the structured scheme of the chaotic Logistic chaotic function family

M. Pariazar et al [3] propose progresses in calculation tools in recent decades have provided us with the possibility of utilizing theories based on existence of certain or chaotic non-linear patterns. Chaotic theory with more through study of specifications of complicated behavior and data that seem to be random, try to recognize order and pattern governing them and use them for predictability future trend in short term. Nowadays this knowledge with the help of data behavior analysis has provided the base of structural changes in future performance prediction. In this article, probability of chaos in daily sales volume in an industrial unit with regard to test of strange attractor and biggest Lyapunov exponent has been investigated. Result of applying the method discloses existence of some degree of certainty in these data.

Z. Hao et al [4] show that in recent years, the nonlinear science which takes the chaos theory as the representative is developing rapidly. Applying the chaos theory to the enterprise strategy management is useful for the enterprise to adapt to the dynamic and complex external environment. This article analyses the chaotic characteristics of enterprises strategy system, and gives some thoughts and measures of chaos management from the aspects of strategic thought, the strategic coordination, the structure, the culture and the ability. The chaos management which possesses all-pervading applicability resurveys the strategy system by nonlinear and indefinite thought. Applying the thoughts and the methods of chaos management, the enterprise may consider systematically, perfect its strategic management system, overcome the strategic crisis, and possess the ability of defense and protection.

B.M. Khoshroo and H. Rashidi [5] presents the necessity of a paradigm shift in software project management, particularly with advent of agile methods, nowadays is an interesting and challenging issue. The values and principles that have centrality in agile thought need new approaches in relation to project management. The main causes of this needed paradigm shift are unpredictability and dynamicity of software processes, and inefficiency of traditional approaches. With respect to these factors, and increasing growth of applying chaos and complex system theories in organizational study and strategic management, this research attempts to design a framework for managing agile projects based on these two theories. Concepts of these theories will be a lens to investigate software project management and propose new practices. Our analyses indicate that chaos theory can further shape strategic decisions in comparison to complex system concepts that can further help designing an appropriate agile team in the level of people interaction.

M. Rania and R. Agarwalb [6] demonstrated remarkably benign looking logistic transformations $x_{n+1} = r\, x_n(1 - x_n)$ for choosing x0 between 0 and 1 and $0 < r$ 4 have found a celebrated place in chaos, fractals and discrete dynamics. The strong physical meaning of Mandelbrot and Julia sets is broadly accepted and nicely connected by Christian Beck to the complex logistic maps, in the former case, and to the inverse complex logistic map, in the latter case. The purpose of this paper is to study the bounded behavior of the complex logistic map using superior iterates and generate fractals from the same. The analysis in this paper shows that many beautiful properties of the logistic map are extendable for a larger value of r.

X. Liu [7] presents the application of the dissipative structure theory, cooperate theory and chaos theory in management domain is deeply studied and broadly extended in west management. But in China, it is not so. This paper introduces the application in briefly. The effect of the application of the dissipative structure theory, cooperate theory and chaos theory on Chinese enterprises management's reform also is discussed.

E. Campos-Cantóna et al [8] introduce a family of multimodal logistic maps with a single parameter. The maps domain is partitioned in subdomains according to the maximal number of modals to be generated and each subdomain contains one logistic map. The number of members of a family is equal to the maximal number of modals. Bifurcation diagrams and basins of attraction of fixed points are constructed for the family of chaotic logistic maps.

X. Ping Zong et al [9] represent according to discrete system stability criterion, a feedback controller is designed to impose extrinsic incentives to Logistic Map. Any desired stability targets including odd orbits can be obtained from Logistic Map via feedback controller. This control method applies not only to low periodic orbits, but also to the higher periodic orbits. The simulation results verify the effectiveness of this method.

A. G. Radwan [10] presents conventional logistic maps have been used in different vital applications like modeling and security. However, unfortunately the conventional logistic maps can tolerate only one changeable parameter. In this paper, three different generalized logistic maps are introduced with arbitrary powers which can be reduced to the conventional logistic map. The added parameter (arbitrary power) increases the degree of freedom of each map and gives us a versatile response that can fit many applications. Therefore, the conventional logistic map is considered only a special case from each proposed map. This new parameter increases the flexibility of the system, and illustrates the performance of the conventional system within any required neighborhood. Many cases will be illustrated showing the effect of the arbitrary power and the equation parameter on the number of equilibrium points, their locations, stability conditions, and bifurcation diagrams up to the chaotic behavior.

E. A. Levinsohn et al [11] indicate that switching strategies have been related to the so-called Parrondian games, where the alternation of two losing games yields a winning game. They can consider two dynamics that, by themselves, yield different simple dynamical behaviors, but when alternated, yield complex trajectories. In the analysis of the alternate-extended logistic map, they observe a plethora of complex dynamic behaviors, which coexist with a super stable extinction solution.

J. A. de Oliveira et al [12] shows the manifestation which convergence to a period one fixed point is investigated for both logistic and cubic maps. For the logistic map the relaxation to the fixed point is considered near a transcritical bifurcation while for the cubic map it is near a pitchfork bifurcation. They confirmed that the convergence to the fixed point in both logistic and cubic maps for a region close to the fixed point goes exponentially fast to the fixed point and with a relaxation time described by a power law of exponent -1. At the bifurcation point, the exponent is not universal and depends on the type of the bifurcation as well as on the nonlinearity of the map.

M. D. Shrimali [13] presents the delay logistic map with two types of q-deformations: Tsallis and Quantum-group type are studied. The stability of the logistic map and its bifurcation scheme is analyzed as a function of the deformation and delay parameters. Chaos is suppressed in a certain region of deformation and delay parameter space. By introducing delay, the steady state in one type of deformation is maintained while chaotic behavior is recovered in another type.

S. C. Hunga and M. F. Tub [14] develop themes from complexity and chaos theory that help to explain the technological change process. They apply two quantifiers, correlation dimensions and Lyapunov exponents, to examine the signs and degrees of chaotic technological dynamics. To illustrate our ideas, we study the development of electronic displays from 1976 to 2010, using patent data. The results of the chaos model are matched against the profiles of patent citations. Their analysis contributes to the development of a chaotic model of technological change.

S. Mesbaha [15] represent a one-dimensional map is proposed for modeling some of the neuronal activities, including different spiking and bursting behaviors. The model is obtained by applying some modifications on the well-known Logistic map and is named the Modified and Confined Logistic (MCL) model. Map-based neuron models are known as phenomenological models and recently, they are widely applied in modeling tasks due to their computational efficacy. Most of discrete map-based models involve two variables representing the slow-fast prototype. There are also some one-dimensional maps, which can replicate some of the only specific neuronal activities. However, the existence of four bifurcation parameters in the MCL model gives rise to reproduction of spiking behavior with control over the frequency of the spikes, and imitation of chaotic and regular bursting responses concurrently. It is also shown that the proposed model has the potential to reproduce more realistic bursting activity by adding a second variable. Moreover the MCL model is able to replicate considerable number of experimentally observed neuronal responses introduced. Some analytical and numerical analyses of the MCL model dynamics are presented to explain the emersion of complex dynamics from this one-dimensional map.

2.5 Conclusions

This chapter has presented the synthesis of the related theory particularly a key concept of chaos theory, nonlinearity, bifurcation, strange attractor, fractal and self-organization, implication to issue managements and implication to crisis managements in with knowledge. Literature reviews on existing chaotic maps and its control techniques that support the evaluation of the logistic map, Henon map and Gauss iterated map has also been included.

Chapter 3
Research Methodology

3.1 Introduction

This chapter presents research methodology, including research process, data collection and research tools that will be used in this thesis.

3.2 Research Process

3.2.1 Study the operation and function of logistic map

3.2.2 Design the controller of the logistic map

3.2.3 Simulate the properties of chaotic maps, including time domain waveforms, bifurcation diagram, power spectral density, cobweb plot.

3.3.4 Design the empirical models for an implication of managements.

3.3.5 Summarize the results and make comparisons of related works.

3.3 Data Collection

The data will be collected from time domain waveform of the design chaotic map. The data from different value of controller will be collected and investigated. The behavior data of the chaotic map will be used for implification to the management in organization.

3.4 Research Tools

In this thesis, research tool is MATLAB version 2013a. The microcontroller is Arduino board.

3.5 Conclusions

This chapter has presented research methodology, including research process, data collection and research tools that will be used in this thesis.

Chapter 4
Experimental Results

4.1 Introduction

Chaos theory in organization management, human communication, social interaction and team collaboration is an example of the process of engaging in a dynamic system of organization implementation are in Chapter 4 of this thesis, We present the application to. present concepts chaos theory to various aspects of enterprise management. Some of these programs are already used in research and some of them offer only the theoretical concept of chaos theory, which reflect the actual experience of the author.

4.2 Analysis of Logistics Map

Chaotic system is typically a dynamic system that possesses some significant properties, involving the sensitive dependence on initial conditions and system parameters, the density of the set of all periodic points, and topological transitivity. In particular, a chaotic map is the lowest one-dimensional evolution function in a discrete-time domain that can exhibits chaotic behaviors. The simplest chaotic map may be a logistic map which realizes quadratic polynomials as nonlinearity, i.e.

$$x_{n+1} = a - x_n^2 \tag{4.1}$$

where a is a control parameter. The well-known variant of (4.1) that has been employed in a variety of applications is in the form

$$x_{n+1} = ax_n(1 - x_n) \tag{4.2}$$

In other words, it can be considered in (4.2) that the equation comprises two terms, i.e. linear and nonlinear terms as follows

$$x_{n+1} = ax_n - ax_n^2 \tag{4.3}$$

This equation normally utilizes for a classic example of nonlinear dynamic system behaviors. Originally, the Logistic Map is a discrete-time demographic model analogous to the logistic equation first created by Pierre François Verhulst. The variable x_n is a number between zero and one that represents the ratio of existing population to the maximum possible population. The coefficient a is a number means the sum of the rate of reproduction and malnutrition. This equation models the distribution of human populations and estimates the increasing in populations of other species under limited circumstances.

The common feature found in both (4.1) and (4.2) is a single changeable parameter a that sets overall dynamic behaviors of the overall system. Conventionally, the adaptive control of logistic map was therefore proposed using additional controller, i.e.

$$x_{n+1} = ax_n - bx_n^2 + u_k \tag{4.4}$$

where a and b are two system parameters and u_k is a controller. Recently, a generalized Logistic Map has been proposed in the form

$$x_{n+1} = ax_n^{\alpha}(1 - x_n^{\beta}) \tag{4.5}$$

where α and β are arbitrary power of the variable x_n. It can be considered from (4.4) and (4.5) that the equations are complicated in terms of at least three parameters that control both linear and nonlinear terms.

This paper therefore presents a new technique for controlling stability of the logistic map through the use of fractional power in the nonlinear term. The dynamic behaviors can be controlled effectively. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties will be described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Arduino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain.

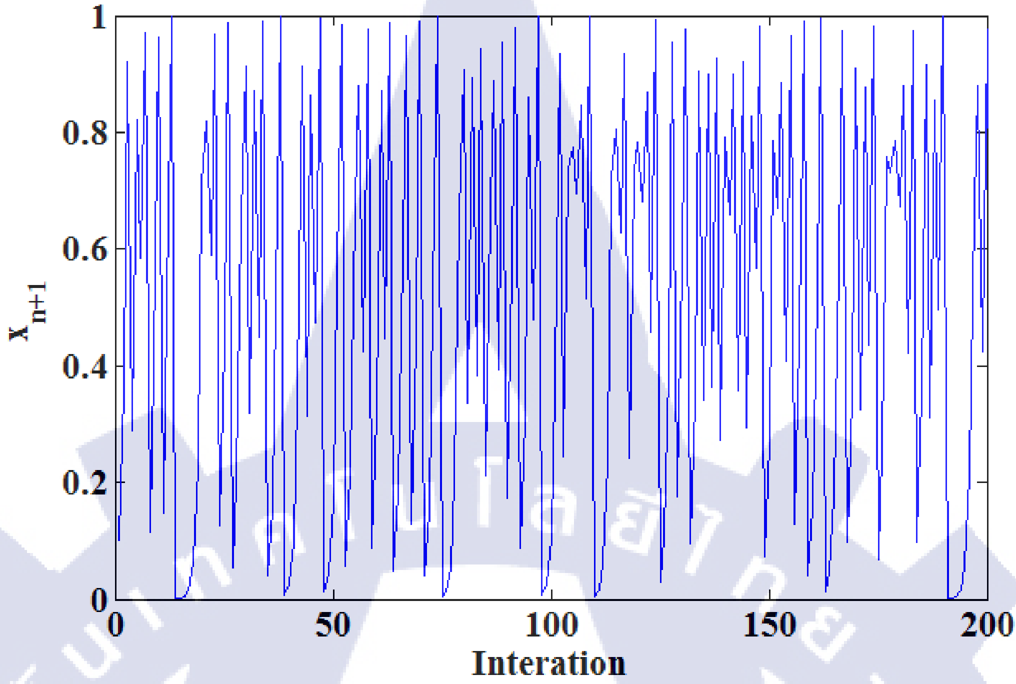

Figure 4.1 The apparently chaotic waveform in time-domain at a = 3.99 and b = 0.

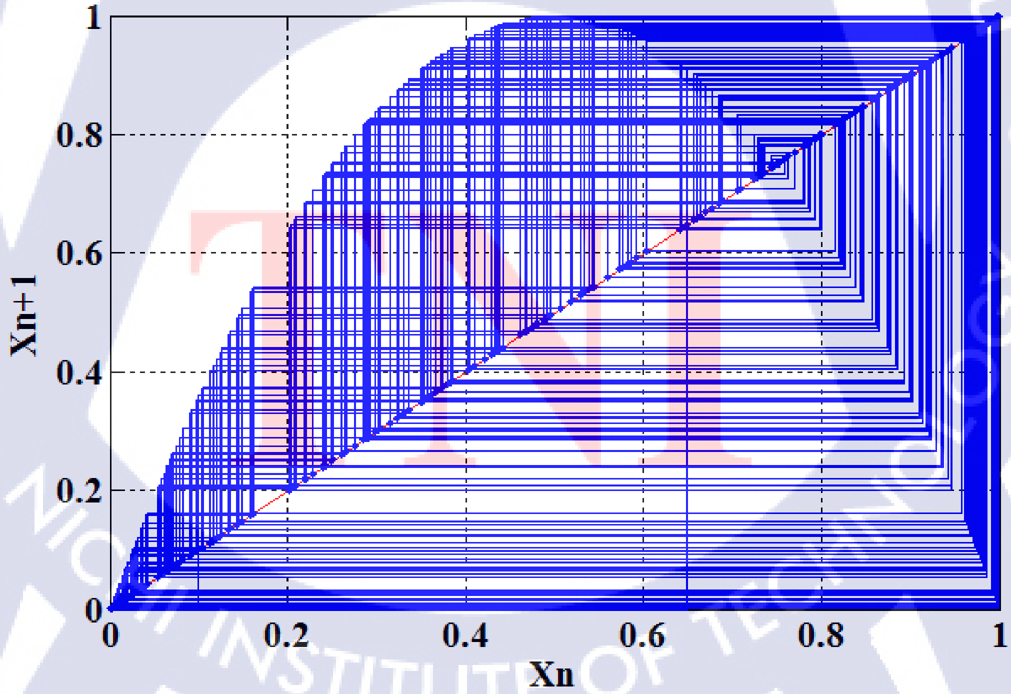

Figure 4.2 The cobweb plot at a = 3.99 and b = 0.

I Proposed Modified Logistic Map with Arbitrary Power in Nonlinear Term

The proposed new technique for controlling stability of the logistic map through the use of fractional power in the nonlinear term is expressed as

$$x_{n+1} = ax_n(1 - x_n^{1-b}) \quad (4.6)$$

where a is a typical control parameter and b is a newly introduced parameter. Eq. (4.6) can be re-written as

$$x_{n+1} = ax_n - ax_n^{2-b} \quad (4.7)$$

It can be considered from (4.7) that the linear term (ax_n) is kept as original logistic map. However, the power of nonlinear term is reduced from 2 to fractional number. According to (4.8) the fixed point (x_p) can be found at

$$x_p = \left(\frac{1}{3-b}\right)^{\frac{1}{2-b}} \quad (4.8)$$

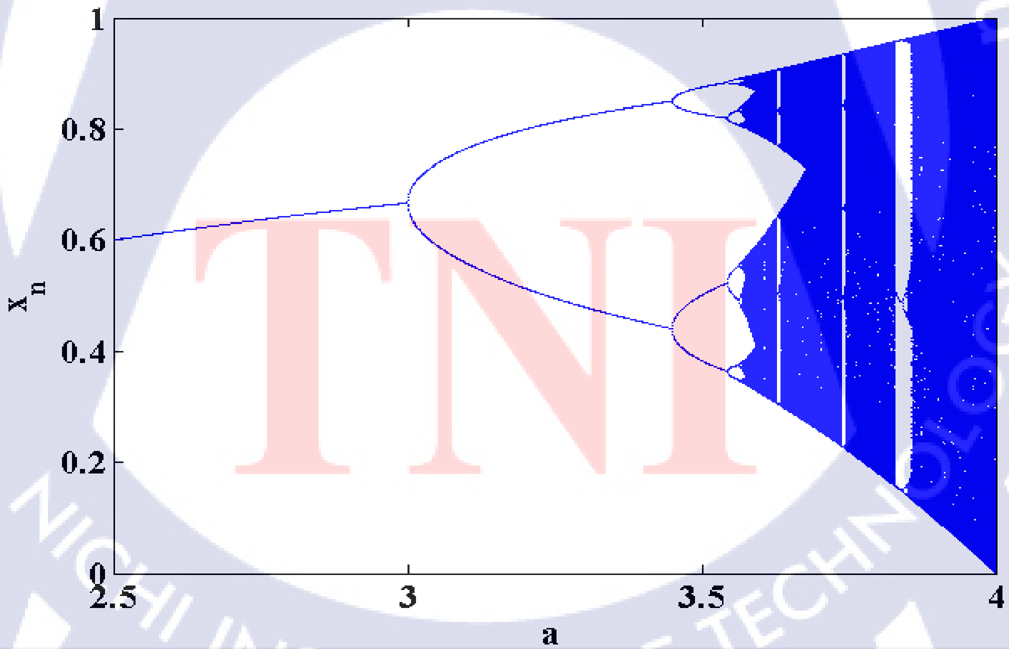

Figure 4.3 The period doubling bifurcation diagram in the region of [0,4].

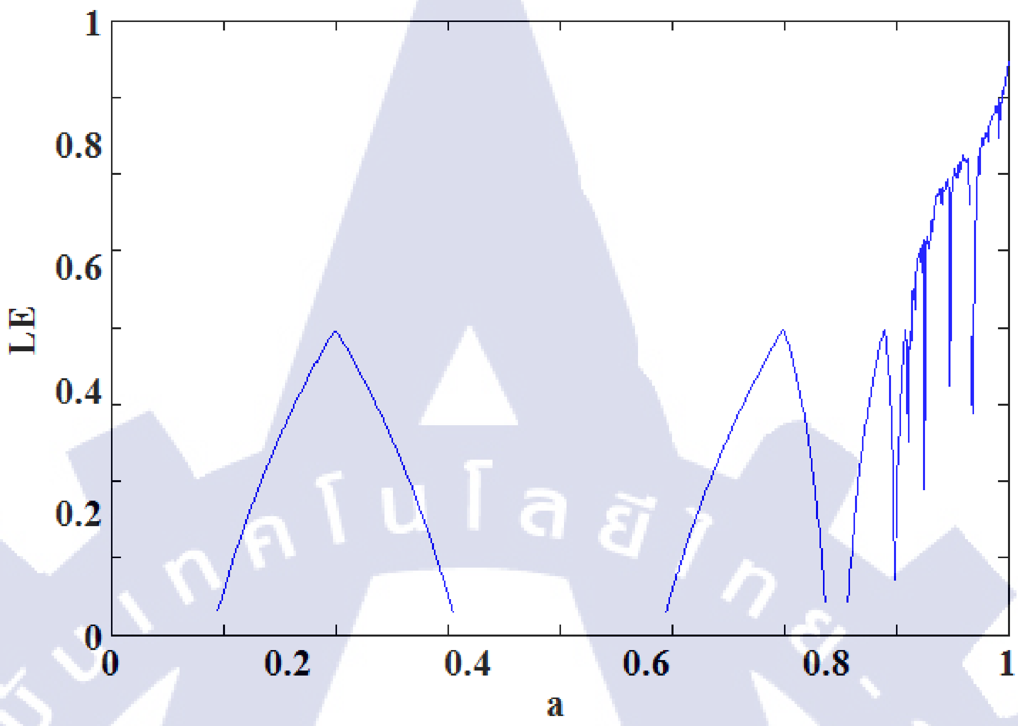

Figure 4.4 The *LE* spectrum where chaos appears when *LE* is greater than zero.

Generally, preliminary investigations of chaotic behaviors in chaotic maps can be achieved qualitatively and quantitatively through a bifurcation diagram and the Lyapunov Exponent (*LE*), respectively. The bifurcation diagram indicates possible long-term values, involving fixed points or periodic orbits, of a system as a function of a bifurcation parameter. The stable solution is represented by a straight line while the unstable solutions are generally represented by dotted lines, showing thick regions. On the other hand, the *LE* is defined as a quantity that characterizes the rate of separation of infinitesimally close trajectories and is expressed as

$$LE = \lim_{n\to\infty} \frac{1}{N} \sum_{n=1}^{N} \log_2 \frac{dX_{n+1}}{dX_n} \tag{4.9}$$

where N is the number of iterations. Typically, the positive LE indicates chaotic behaviors of dynamical systems and the larger value of LE results in higher degree of chaoticity. In this paper,

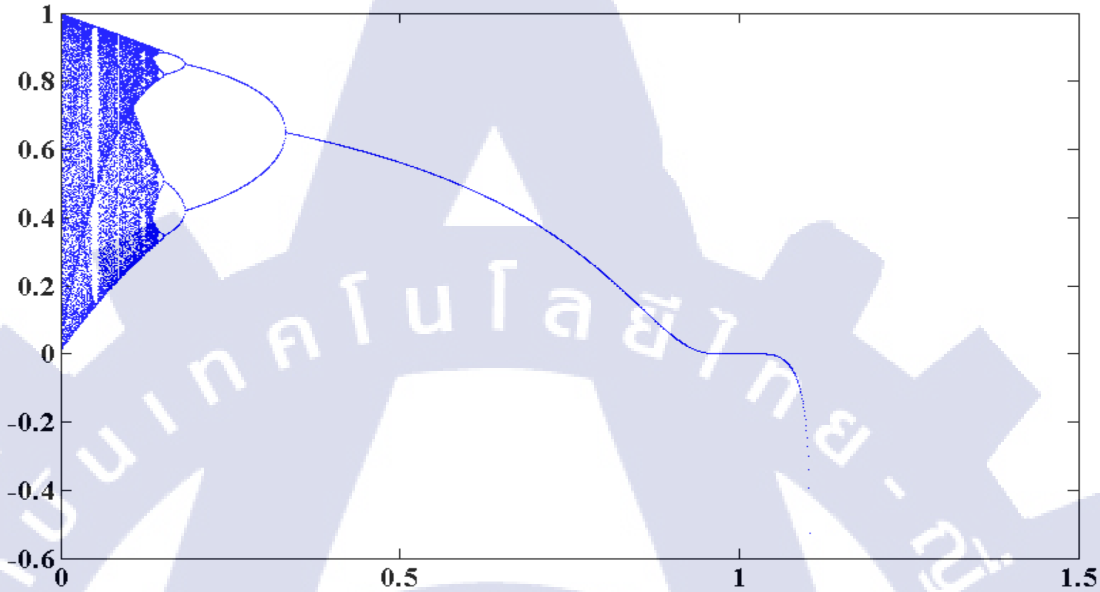

Figure 4.5 The period doubling bifurcation diagram of parameter b in the region of [0,1].

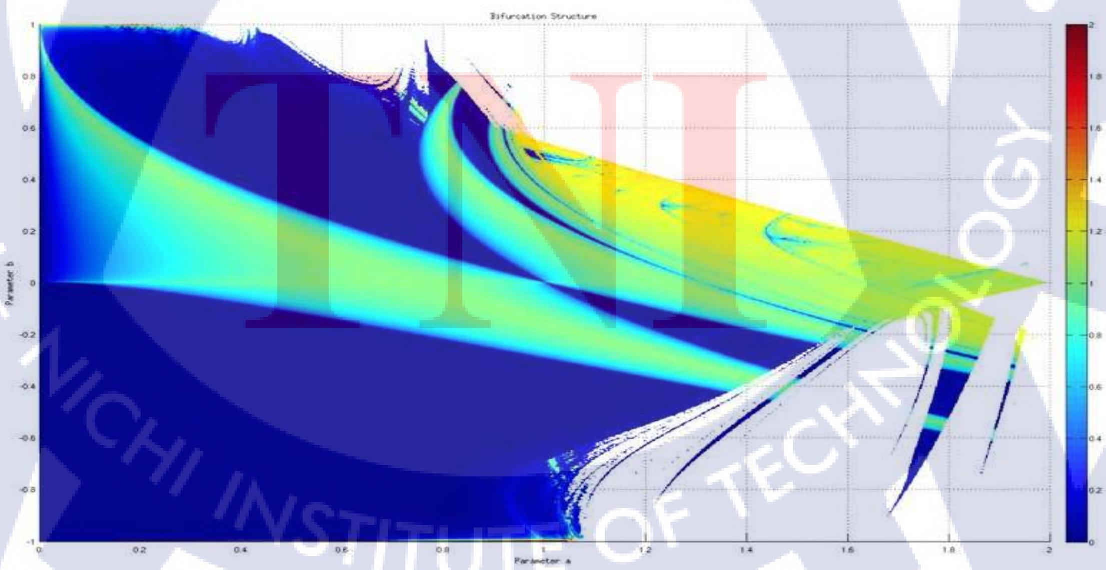

Figure 4.6 The bifurcation structure of parameter a versus b.

4.3 Proposed Exponentially Controller for Logistics Map

4.3.1 Generation of Chaotic Signals Using Microcontroller

The experimental results have been conducted using a cost effective Arduino with Atmel SAM3X8E ARM Cortex-M3 CPU as shown in Fig.4.5. The case where parameters a = 3.99 and b=0.1 was chosen as for demonstration. Fig. 4.8 shows the chaotic waveform generated from Arduino and Fig. 9.shows the Fast Fourier Transform (FFT) of the chaotic signal in Fig.4.8 showing a relatively flat spectrum over all frequency range. Other cases also exhibit the same characteristics in correspondence to the simulation results.

4.3.2 Randomess Tests

The National Institute of Standards and Technology (NIST) has provided a statistical tests suite in order to evaluate the randomness of binary sequences. This paper generates chaotic signals by the proposed two cases of the signum-based chaotic maps for 1,000,000 iterations and simply proceed a comparison with zero, i.e. bit “1” for any values that greater than zero and bit “0” for any values that smaller than zero. Subsequently, the NIST test suite from a special publication 800-22rev1a was realized using a typical 1,000,000 random bits. The test suite attempts to extract the presence of a pattern that indicates non-randomness of the sequences through probability methods described in terms of p-value. For each test methods, the p-value indicates the strength of evidence against perfect randomness hypothesis, i.e. a p-value greater than a typical confidence level of 0.01 implies that the sequence is considered to be random with a confidence level of 99%. The signal is 1-bit quantized at the fixed points, Table 4.1 summaries NIST test results, indicating that the generated sequences from both cases of chaotic maps pass all standard 15 tests.

Figure 4.7 Arduino with Atmel SAM3X8E ARM Cortex-M3 CPU

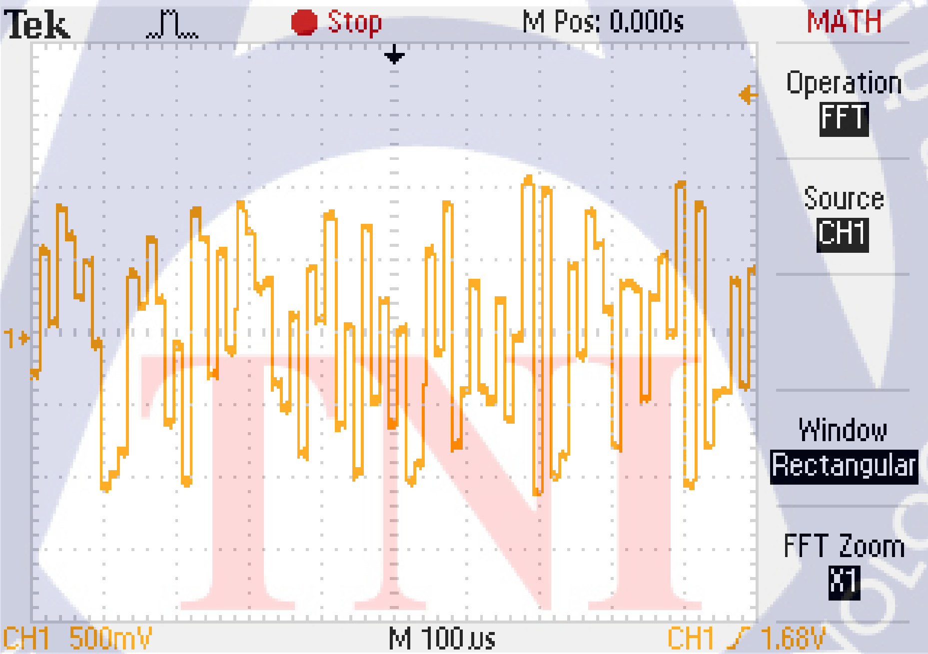

Figure 4.8 Chaotic waveform generated from Arduino.

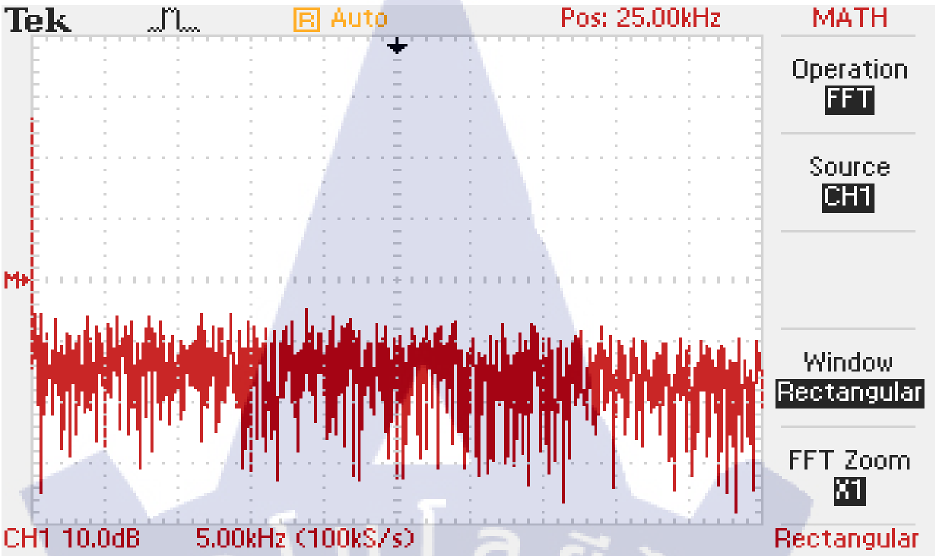

Figure 4.9 Fast Fourier Transfrom of the chaotic signal, showing a relatively flat spectrum over all frequency range.

Table 4.1 Summery of NIST test results of 1,000,000 bits.

Test Methods	***p*-values**	**Results**
Mono-bit	0.34927	Success
Frequency Block	0.40930	Success
Runs	0.29228	Success
Longest Run of Ones Block	0.85524	Success
Binary Matrix Rank	0.91190	Success
Discrete Fourier Transform	0.56938	Success
Non-overlapping Template Matching	0.99621	Success
Overlapping Template Matching	0.85515	Success
Universal Statistical	0.34322	Success
Linear Complexity	0.01986	Success
Serial	0.97677	Success
Approximate Entropy	0.58911	Success
Cumulative Sums	0.55185	Success
Random Excursions	0.34426	Success
Random Excursions Variant	0.20476	Success

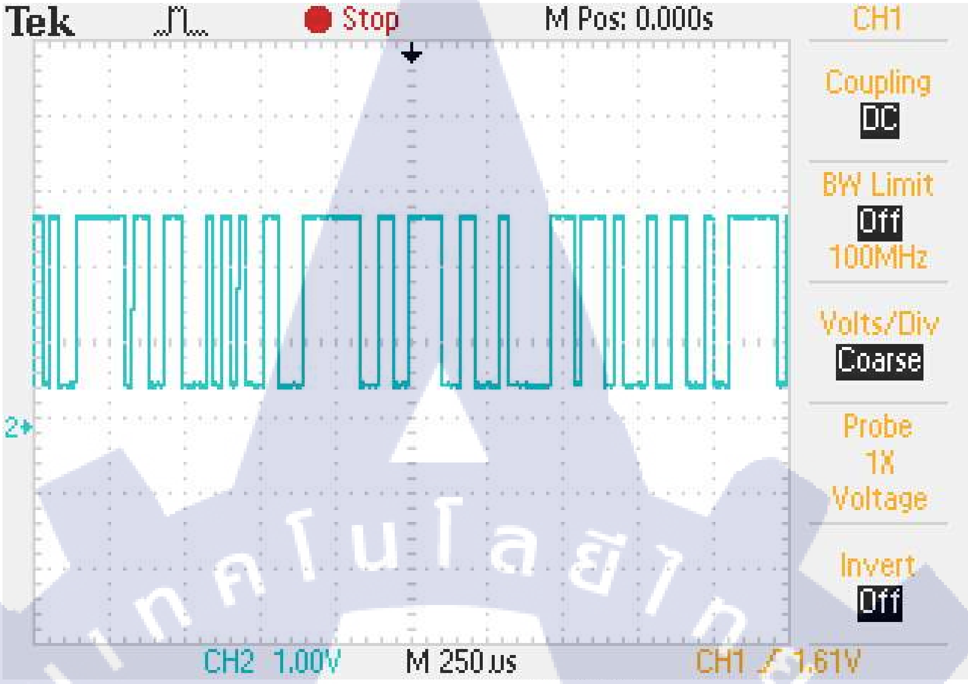

Figure 4.10 Illustration of the generated random bits

Fig.4.10 illustrated the random bits. It can be seen from Fig.4.9 that the digital bits that represented by 0-3.3V are random.

4.4 Proposed Implication to Organization Managements

This topic looks at the impact of Chaos theory to organization management and how basic and practice of management, as well as the role of managers and management guidelines for engaging in the practice of organization management. A current view of management theory stresses the changing nature of the external environment and the need to understand and address these external forces for change. Participation and the role of systems theory and the theory of organization to organization management process focused. Although some may see that we did not manage disasters that there is an overlap between the participation of management theory and emergency management. Management theory emphasizes the need for effective planning to ensure that the goals of the organization will be. Chaos and crisis management focuses on effective emergency response and recovery will depend on good planning. Creating a sustainable community and a common goal of both management and organization management. Management and disaster-related issues and concerns, along with strategies to improve emergency.

Chaos-Based Management Model

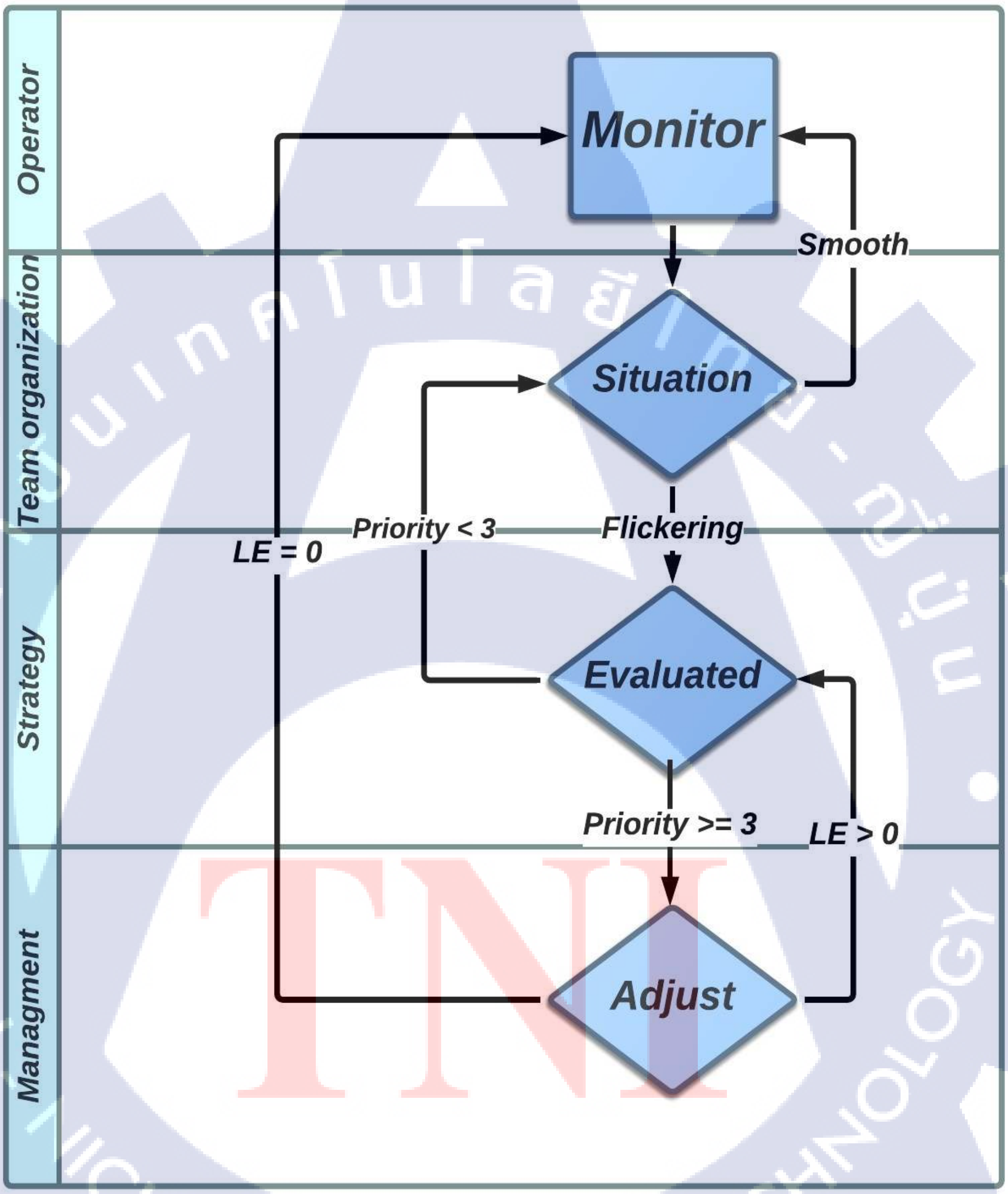

Figure 4.11 Chaos-Based Management Model

The organization management system can be explained in to 5 stages;

1. **Setup stage**

Use Equivalent characteristics of dynamical systems and organizations to frame the organization management system and Organization management Empirical model to set variable depended on each situation and mapping with the proposed exponential logistic map. And keep going to the next stage.

2. **Monitor stage**

Own responsibility by operator team, monitor the graph that Smooth or Flick. At smooth that's mean under normal circumstances but when the graph is flicking that mean the system start to become chaos. In dynamical systems, the transition to another stable state might not be definite. The system may oscillate around the saddle, jumping from the domain of one attractor to another. Matching early warning signs to category table is creating for use in this stage.

3. **Situation watching stage**

When systems start to become chaos, the way to make decision making process and possible to estimate the level of complexity of the organization management strategy, from which the occurrence of chaotic events can be inferred.

4. **Evaluated stage**

In this stage, after system become chaos. Yje key to use to make dicition making is the value of priority level. The suggested scale for determining tasks complexity may prevent underestimation of large complex organization management in to 5 Priority value level. And set the priority value to make an action.

5. **Adjust stage**

When the priority value >= Doable then the management team have to adjust the system to stable as soon as possible by use the *b* to control the chaotic.

Organization systems must believe that order will develop by operating under a clear core of values and vision kept in motion by continual organization. (Organization is the "strange attractor").

As members of complex, non-linear communication systems must be:

- Expect chaos.
- Delight in unpredictability.
- Accept yielding with uncertainty.

- Recognize the impossibility of identifying all initial conditions.
- Embrace participative management.
- Support individual autonomy.
- Allow the system to be self-organizing.
- Create a climate of risk-taking and empowerment.
- Embrace new information.
- Use self-referential techniques.
- Build strong relationships that will hold during times of turbulence.
- Plan for a variety of scenarios rather than specific objectives.

Chaos theory was recommended that even in the general theory of enterprise management systems must adapt to the complex changes and institutional learning institutions through a feedback system. Chaos theory states that only a small change in the initial conditions may have changed significantly in the long term behavior of the system is a classic example quoted by many to demonstrate a concept that is known as the Butterfly Effect

Change is constant although some events and circumstances in the organization cannot control other people. Chaos theory recognizes that change is inevitable and it is controlled. As organizations grow more complex and sensitive to the possibility for the event. And add a new level of energy to maintain complex and structured organization that uses more energy is needed to stabilize the system continues to evolve and change. Pairing organizations and dynamical system as show in Table 4.2.

Table 4.2 Equivalent characteristics of dynamical systems and organizations

Organizations	**Dynamical**
Organization	A set of dynamical systems
Complexity	Nonlinearity
Workflow	A dynamical system
Workflow algorithms	Time evolution equation
Regulations	Control parameters

Table 4.2 Equivalent characteristics of dynamical systems and organizations (Cont.)

Organizations	Dynamical
Initial condition	Initial condition
Variations in qualities and quantities	Bifurcation
Transacting workflows	Quasi-periodic
Critical	Chaotic
Crisis	Chaos

Determine the level of implications for management is in Table 4.3.

Table 4.3 Some implications of chaos theory concepts in management.

Concept	Implications for management	Effect level
Attractor	Setting values and principles as an attractor that project activities converge to it.	Strategic decisions
Bifurcation	Changing, if needed, values and principles of project to absorb new opportunities.	Strategic decisions
Fractality	Similarity of understanding about goals, values and end result at any dimension of project (teams, sub-teams and individuals)	Team organization
Butterfly effect	Intelligently considering impacts of changes in project conditions (people morale, requirements, results, work environments)	Strategic decisions

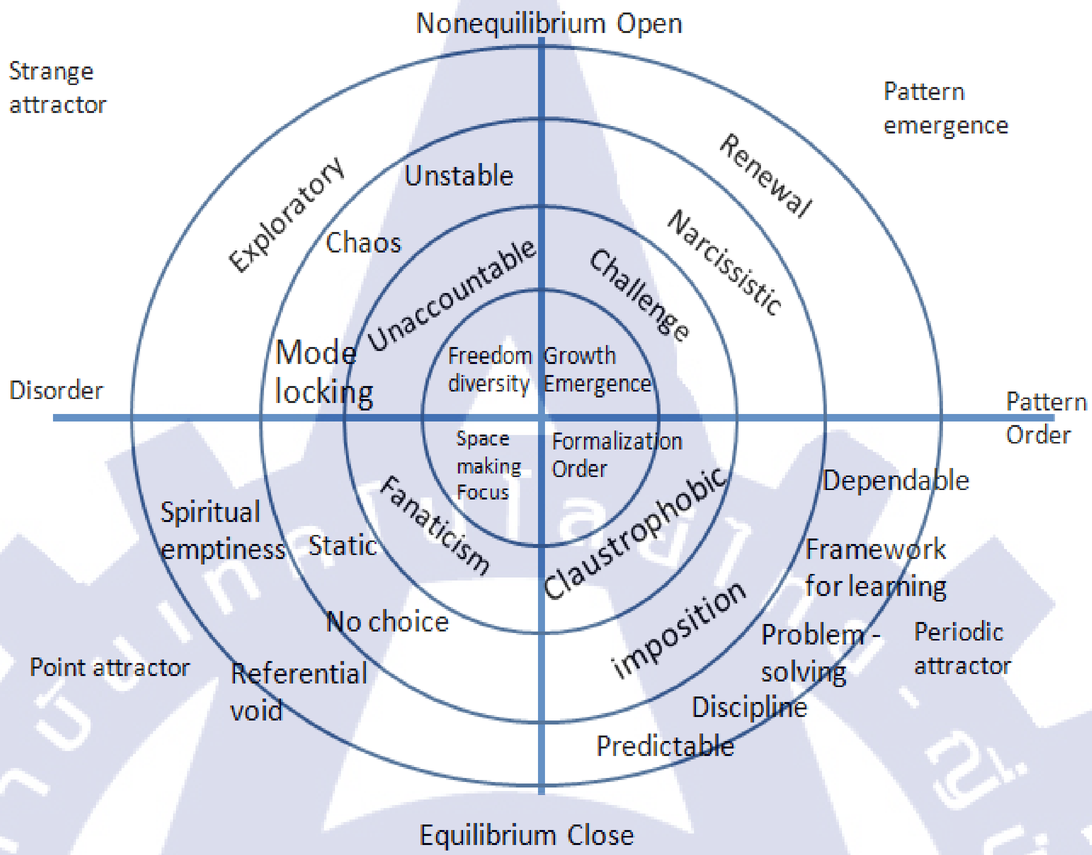

Figure 4.12 Organization Management Empirical Model

4.5 Investigation on Case Studies on the Chaos theory in Organization management

4.5.1 Critical organization management transitions

Organization management execution is a dynamic system that unfolds over time, and undergoes changes initiated from both internal and external causes. Such changes may be fluent and predictable but very often they are abrupt and seemingly unpredictable. However, there are early warning signs of an incoming qualitative change of a system, or the so called critical transition. The management team cognizant of the Chaos theory concepts may want to use this knowledge in order to detect the early signs of an incoming critical transition of organization management failure.

4.5.1.1 Alternative stable states

Dynamical systems may have multiple stable states in which they may operate over time. Change from one state to another is called critical transition or bifurcation. An example of alternative stable states during team cooperation may be productivity vs. no productivity.

When team members do their job, the productivity varies – there are periods of high productivity following by periods of lower productivity. When new thoughts and inspiration are lacking, the productivity may be decreased to almost a complete stop, a period of time where only limited amount of constructive work is done. Such change corresponds to the jump to another attractor within the phase space (Figure 1), where the ball is representing the current state of the team. When a team is cooperating in the domain of productivity attractor, there are rare periods of very high productivity, while most of the time the team productivity is average.

However, as the controlling parameter changes (lowering the level of available knowledge, inspiration, or insight into the problem being solved) the state of the team may cross the saddle into the domain of no-productivity attractor. Here the team productivity is low – the team procrastinates (Procrastination is practice of postponing duties and tasks or carrying out less urgent tasks prior to more urgent ones), uses inefficient tools or processes, is distracted by unimportant events, lacks self-reflection, runs in circles, etc.

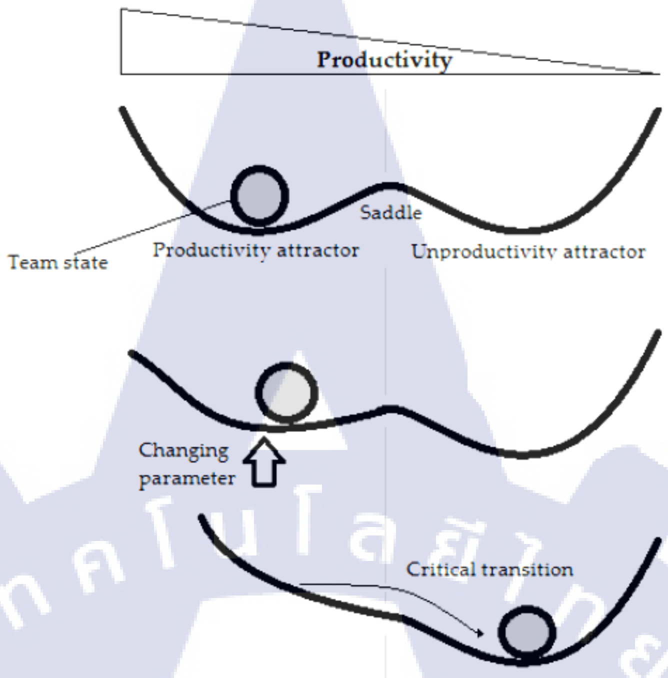

Figure 4.13 Critical transition of productivity

At the top of the saddle on Figure 4.13, there is a threshold. Once passed, it triggers a change of an attractor. When system is nearing the threshold in the region of the saddle, there could be early warning signs of upcoming bifurcation

4.5.1.2 Early warning signs of critical transitions.

Many complex systems have critical thresholds at which the system shifts abruptly from one state to another. Detecting early warning signs in real situations is notably more difficult than being presented in models. Often, identifying these signs is intuitively possible through “good/bad feeling” from situation, the Chaos theory suggests following early warning signs of an incoming critical transition.

4.5.1.2.1 Slower recovery from perturbations.

Around the bifurcation point, the system becomes very slow in recovering from even small perturbations. The closer the system gets to the bifurcation point, the slower and slower is the recovery from perturbations.

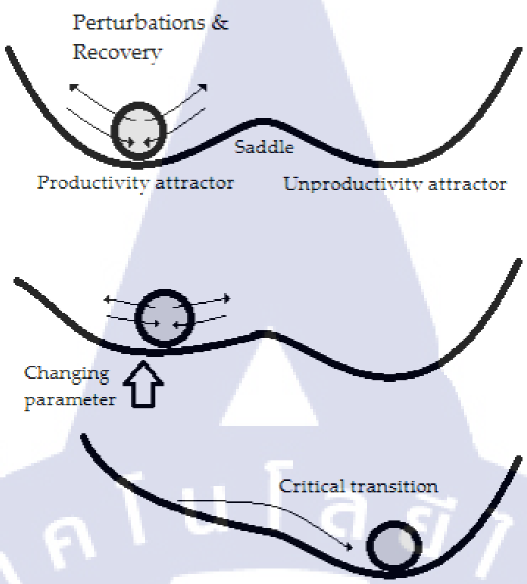

Figure 4.14 Slower recovery form perturbations

This slow recovery rate is illustrated on Figure 2 – in the domain of an attractor, the system returns to the equilibrium quickly (upper part of the figure). As the control parameter grows and the attractor becomes more shallow, the system returns to the equilibrium more and more slowly (middle part of the figure). Then a critical transition occurs (lower part of the figure). By studying the recovery rate, the distance of a system to the bifurcation point can be implied. In organization management, the management team may study the ability of the team to process tasks. If the team is getting gradually slower at accomplishing given tasks, then a critical transition to unproductive state is approaching.

4.5.1.2.2 Increasing autocorrelation

A slowdown of a recovery rate also means that the rate of system change is also slower. In other words, when approaching the bifurcation point, the system state is more and more similar to its past state – this is called the increasing autocorrelation. Observing the autocorrelation in a team cooperation means noticing the rate of a team change – when a team is getting stuck in a certain problem and the workflow is very slow, then a critical transition to unproductive state might be following.

4.5.1.2.3 Flickering

In dynamical systems, the transition to another stable state might not be definite. The system may oscillate around the saddle, jumping from the domain of one attractor to another. For instance, short periods of a headache interrupted by periods of pain absence might be the early warning signs of an incoming migraine. This phenomenon is called flickering. During the organization management, short periods of no productivity interrupting the normal productive workflow may be an early warning sign of a critical transition.

4.5.1.2.4 Increased spatial coherence

So far the identification of critical transitions was related to the observation of a system over time. There is also an early warning sign connected with the spatial configuration of a system. Studies of models and real life environments show that systems tend to produce spatial coherence together with resonance or synchronicity across scales (fractal pattern) prior to undergoing a critical transition into a new state. On the other hand, the system may also disintegrate its structure into individual uniform parts. A team gathered in one place and synchronized in their actions may be a sign of an incoming transition, e.g. making a breakthrough to so far unresolved problem. On the other hand, a team falling apart and members working isolated from each other may be a sign of slipping into an unproductive state.

Empirical studies of these early warning signs in real life complex systems are only beginning to emerge. As already mentioned, it is hard to identify them, and there are numerous false positive and negative signs, because the saddle point between two attractors is an unstable structure and there is no way to tell that an early warning sign is going to turn into a bifurcation.

4.5.1.3 Early warning signs of organization management strategy failure.

There is a lack of empirical studies identifying early warning signs (EWS) of critical transitions in organization management strategy from the Chaos theory perspective. However, there are several “traditional” empirical studies focused on identifying EWS of organization management failure. Some of these findings, concerning dynamics of organization management, are similar to those derived from theory of critical transitions. These similarities are presented by Table 4.4.

Table 4.4 Matching early warning signs to category

EWS determined by empirical studies	Category of EWS according to Chaos theory
Slow completion of work, poor team performance, inadequate skills	Slower recovery from perturbation / Increased autocorrelation
Rescheduling, frequently changing decisions, lack of commitment	Flickering
Deterioration of relationships between participants	Spatial coherence

Apart from this categorization related to Chaos theory, there are twelve dominant early warning signs of failures:

People- related risks

- Lack of top management support
- Weak management team
- No stakeholder involvement or participation
- Weak commitment of team
- Team members lack requisite knowledge and skills
- Subject matter experts are overscheduled

Process- related risks

- Lack of documented requirements and/or success criteria
- Lack of change management
- Ineffective schedule planning
- Communication breakdown among stakeholders
- Resources assigned to a higher priority project
- No business case for the project

With regard to the Chaos theory and critical transitions, the important process-related risk or early warning sign of the organization management failure is the inefficient change management. The management team familiar with critical transition concept may want to use this knowledge in order to prevent an unwanted bifurcation to occur, or to foster positive bifurcations.

4.5.1.4 Managing critical transitions

Critical transitions occur naturally in every dynamic system, including organization management. These transitions may be considered either good or bad, although a clear distinction is not straightforward. However, there are examples of critical transitions that are unwanted from the perspective of the organization management strategy, e.g. a transition to no productivity which increases the probability of organization management failure, as well as those welcomed transitions that bring in successes organization management strategy.

For managing critical transitions, there is no prescribed course of actions has to be taken. Each system is different and has to be insightfully studied for effective management of change. Natural systems are living, having their own dynamics and resilience. Therefore, one-time attempts to change the state of the systems may be inefficient. What is needed for triggering critical transitions is a systematical work on adjusting the resilience of a system.

4.5.1.4.1 Promoting positive transitions

Initiating a self-propagating shift from deteriorated state into a good state can be done by lowering the resilience of the unwanted state, which is unique for every studied system. It is also known from the network theory, that weak links lower the saddles between attractors which would help the transition to occur sooner. Promoting a good transition in organization management might be best illustrated with an example of an ineffective, procrastinating team. A sensitive analysis of situation based on discussion of team members may help the management team to determine why team is struggling to accomplishing organization management goal. His/her novel information, insights, or outside perspective may provide sufficient weak links for both lowering the resilience and the saddle between unproductive and productive attractors, promoting a positive critical transition.

4.5.1.4.2 Preventing negative transitions

When early warning signs begin to appear, the incoming critical transition may be prevented by keeping the system's resilience high. This may be done by increasing the fitness of the system. This could be accomplished by having actual, real-time information, by good distribution of knowledge, by good group cohesiveness, and by having optimal, both social and knowledge, network structure. Once it is known what factors influence the resilience of a system, maintaining high team resilience may be easier than trying to manage stochastic events (e.g. change of specification from customer, hardware fault, communication deficits, etc.). The ability to predict incoming critical transitions together with managing the resilience of the productive team might be a useful skill for the management team leading the modern organization management.

4.5.2 Managing organization management strategy at the edge of Chaos

In organization management strategy with increased complexity, skills and virtues (other than technical) become a differential factor. The manager must possess not only technical expertise, but also an intuition, own judgment, holistic/systemic thinking, the understanding of the social and emotional contexts. The quality of communication is both the key skill of organization management and the key process among organization management strategy participants that is directly correlated with the level of successes organization management strategy, because the quality of interaction influences the team self-organization process. Team interaction is by definition a nonlinear process, undergoing constant change – sometimes gradual, other times abrupt, as the system reaches the threshold of a critical transition. From this perspective, it is necessary to adjust the way how current tools are being used, as prediction of any dynamical system is possible only for a limited amount of time.

The experimental results of the impact of Chaos theory to organization management and how basic and practice of management, as well as the role of managers and management guidelines for engaging in the practice of organization management. A current view of management theory stresses the changing nature of the external environment and the need to understand and address these external forces for change. Participation and the role of systems theory and the theory of organization to organization management process focused.

4.5.2.1 Planning complex organization management strategy.

The traditional organization management strategy lifecycle is deterministic and relies on linear decision making model. Such approach to organization management strategy lifecycle is not realistic, as the reality of organization management is inherently nonlinear. As a result, the traditional organization management strategy lifecycle does not allow adaptation to incoming changes in the organization management, leading into the organization management failure according to the triple-constraint-based, criteria of organization success. This leads to a paradox of creating a fixed plan for a complex organization being delivered in conditions of unpredictability and ongoing change; and measuring performance of organization execution based on such plan.

Conventional organization management remains embedded in the technical and instrumental notion of organization management practice, i.e. it focuses on the scope of organization work (planning the sequence of tasks to be accomplished jointly) and on the communication management (meetings, monitoring, reporting of organization progress). Moreover, any incoming change is being covered by risk and change management, putting the management team in a continuous process called "fire fighting" – a firmly reactive position to any change, using sophisticated tools and techniques for its control, leading into prolonging of organization management strategy scope, consequently leading to the organization management failure according to the organization management triangle .

In order to deal with the discrepancy between traditional linear organization management strategy planning and the nonlinear reality of organization management, a better approach might be to adopt iterative re-planning of the organization management strategy scope after reaching every milestone. Agile methodology is already practiced in software development, resulting in three times more successful organization management strategy than the traditional waterfall method, according to The Standish Group.

4.5.2.2 Defining task complexity

The organization management is a dynamic system, which changes over time and it is often hard to predict. However, this apparent "randomness" is resulting from some ongoing underlying dynamic patterns, i.e. a chaotic behavior. Chaotic behavior in organization management environment can be defined as:

- An event which is unpredictable or disorderly
- An event that renews and revitalizes the process
- Small inputs leading to large consequences

- Similar patterns that take place across scales (fractal pattern)
- Decisions need to be made even in absence of all intended information

Chaotic events are, by definition, unpredictable. Calculating the level of chaos present in the organization management strategy is therefore not realistic. However, it is possible to estimate the level of complexity of the organization management strategy, from which the occurrence of chaotic events can be inferred. The suggested scale for determining tasks complexity may prevent underestimation of large complex organization management strategy:

1. **Trivial** (Priority Value = 1) – easy, well understood task, no research is expected, little effort, input is proportional to output.
2. **Simple** (Priority Value = 2) – requires preparation and possibly evaluation, but otherwise it is easy to deliver
3. **Doable** (Priority Value = 3) – can be challenging, requires research, prototyping, chaotic events are present
4. **Difficult** (Priority Value = 4) – requires significant preparation, hidden or unexpected difficulties are to be expected
5. **Very difficult** (Priority Value = 5) – the most complex task that can be reasonably accomplished in an iteration, high level of chaotic events is present

Using this scale for determining the complexity of a task might be useful for planning workflow in a the organization management, as it allows predicting how nonlinear dynamics influence the process of task delivery, i.e. how long would an iteration take. Good team management is important in order to manage the chaos present in organization management strategy because a team can be handled well than organization management environment. during critical transitions.

4.5.2.3 Team interaction management

A cooperating team interaction is a great illustration of the nonlinear nature of the organization management process. The team is embedded into a network of relationships and communication, subject to process of self-organization, where novel phenomena (solution, conflicts, attitudes, etc.) emerge spontaneously from the interaction.

The traditional role of the management team is to improve large scale processes, i.e. the sequence of actions involved in the organization management strategy as a whole. The Chaos theory suggests that management team should focus on how to improve small scale processes instead, i.e. on the quality of team cooperation. Here is where the professional concept becomes essential, because both technical and soft skills are important for efficient team management. The network science supports the notion that soft skills have significantly higher contribution to successful organization management than in the past.

Among other factors, a strong focus on improving the quality of team interaction embodies the following rules and principles

- Reading group dynamics and using it to improve cooperation
- Managing conflicts
- Promoting good relationships and team cohesiveness
- Showing respect and appreciation for others
- Being emphatic
- Fostering knowledge distribution
- Leveraging cross-functional team for improved stability of team network by interconnectedness and weak links
- Making the team responsible for their self-organization and auto correction
- Promoting self-reflection of the team – team members being aware of what they are doing
- Defining and maintaining a vision of how work should be done rather than setting up specific goals to be achieved
- Successful handling of anxiety among team members resulting from inherent uncertainty of organization management strategy
- Being ethical and moral

- Allowing a free and constructive dialog within the team in order to create an atmosphere allowing for novelty and emergence

The implementation of these principles may significantly improve the micro-scale self-organization processes and consequently the macro-scale processes as well based on the bottom-up logic of emergent phenomena

Empirical data gathered by examination of interviews with over 70 organization management strategy participants showed that in reality, management team deal with organization management complexity by using standard tools and techniques (Work Breakdown Structure, Critical Path Method, Program Evaluation and Review Technique, Gantt chart, etc.) in combination with a set of alternative skills and competencies that are not codified in the conventional recommendations, manuals, or best practice. Communication skills are frequently hailed as key competences in organization management that underpins both successful definition of work content (organization management scale) and control of the work including stakeholder management. Despite the fact that conventional organization management does not reflect the importance of managing team interaction quality, empirical studies show that management teams in field need communication and soft skills for improving the process of team cooperation in order to achieve success organization management

4.5.2.4 Summary – Comparison of linear and nonlinear approach to Organization management

The Chaos theory brings into the field of an organization management a change in perspective – delivery of an organization is not a straight line, it consists of oscillations, smooth curves, and abrupt breaks. It is important to realize that uncertainty or unpredictability of future events is a natural part of the organization execution process, although some critical transitions can be predicted by detection of early warning signals.

Many organizations may be sentenced to failure from the very beginning because success and failure criteria were based on linear assumptions. The reality is that all complex organizations are nonlinear and plans need to be redefined after reaching every milestone in order to maintain accuracy of estimations.

Organization is subject to an ongoing change that does not necessarily need to be controlled all the time, but taken as a part of the organization.

The Chaos theory also redefines the role of the management team from a “command and control” position into a participating team member, where the main focus is on improving the quality of team interaction. The change in perspective on organization execution presented by the Chaos theory may be better illustrated by a comparison of traditional and nonlinear approach to organization management in Table 4.5.

Table 4.5 Linear vs. nonlinear approach to organization management

Traditional (linear) approach	**Chaos theory (nonlinear) approach**
Organizations exist in equilibrium; therefore change is an abnormal process. The goal of management is to increase stability through planning, organizing, and controlling behavior.	Change and transformation are inherent qualities of organization execution. The goal of management is to increase learning and self-organizing in continuously changing contexts.
Organizational behavior is essentially linear and predictable, and results are proportional to causes.	Organizational behavior is inherently nonlinear, and results may be disproportional to the corresponding actions.
An organization can be completely defined in terms of its design, strategy, leadership, controls, and culture.	An organization is defined according to its underlying order and principles. These gave rise to a surface-level organizing structure, including design, strategy, leadership, controls, and culture.
Change should be controlled by minimizing uncertainty and tension, limiting information, and centralized decision making.	Change should be encouraged through embracing tension and increasing information flow.

Table 4.5 Linear vs. nonlinear approach to organization management (Cont.)

Traditional (linear) approach	Chaos theory (nonlinear) approach
Organizational success is based on maximizing resource utilization, to maximize profit and increase shareholder wealth.	Long-term organizational success is based on optimizing resource flow and continuous learning.
Management team's emphasis is on efficiency and effectiveness, improving large scale processes, monitoring organization and requesting reports.	Management team's emphasis is on improving quality of interaction in team, fostering knowledge creation and distribution, and supporting the team.
Management team's soft skills are of secondary importance, necessary for efficient transfer of information in organization. Technical skills have priority.	Management team should be a T-Shaped professional, soft skills are very important for both stabilizing the team network and for organization execution. Technical skills are of equal importance.

The shift from linear to nonlinear organization management approach is mainly a change in perspective, not in conception. This means that it is not necessary to develop new tools and techniques for executing the organization using the nonlinear approach. Rather changing the way the tools are being used may allow for a complex organization execution to meet adequately set success criteria.

4.6 Conclusion

This chapter has presented a new arbitrary power in the quadratic term in order to control stability of the system. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties are described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Ardino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain. The application in random-bit generator that passes all NIST standard tests is also involved. The proposed chaotic map offers an alternative maps and random bit generator for science applications such as in cryptography or in communications.

The Chaos theory in organization management is not about revolution, it is about synthesis of existing approaches, about reconciliation between technical knowledge and soft skills, both being equally important for managing complex organization.

Chapter 5
Conclusion

5.1 Introduction

The purpose of this chapter is to summarize the thesis research and suggest research and policy recommendations for further analysis. The first section of the chapter will discuss the objectives of the research and the methodology used to accomplish the analysis. A summary of the major results will be described. The second part of the chapter will discuss policy implications of the research and propose recommendations for further research both on the simulation results and experimental results.

5.2 Summary

The two objectives of this study were: to study a new arbitrary power in the quadratic term in order to control stability of the system ; and to apply a new arbitrary power in the quadratic term in order to control stability of the system into organization management

A typical logistic map has been utilized in a variety of applications such as in biological modeling and secure communications. Nonetheless, such a typical logistic map has only a single control parameter that sets all dynamic behaviors. This thesis therefore introduces a new arbitrary power in the quadratic term in order to control stability of the system. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties are described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Arduino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain. The application in random-bit generator that passes all NIST standard tests is also involved.

5.3 Conclusion

The aim of this thesis was to present Chaos theory as a general framework for introducing the shift from linear to nonlinear approach to organization management. A traditionally, organization management is based on linear thinking, while organization management strategy execution is inherently dynamic and nonlinear.

This leads to discrepancies between organization management theory and practice; and mainly to the paradox of measuring the performance of organization management strategy execution against a linearly created plan, resulting in high rate of organization management failure.

Theoretical part of the work provided general overview of the Chaos theory concepts. A synthesis of these concepts was provided by presenting the network theory, as all dynamic systems can be perceived as a network. Study of networks explains both structural and dynamical properties of complex systems, and allows for understanding their attributes and behavior.

Applying Chaos theory concepts in organization management is rather novel approach, with a limited number of publications and empirical research being conducted globally. However, in software development, the agile Methodology is getting increasingly popular. Aim of this thesis was not to present aspects of adopting this methodology. Instead of that, this work was focused on presenting nonlinear processes taking place in the organization management strategy execution; and on the importance of the management team role. In the chaotic organization environment, both technical and soft skills of the professional are needed for achieved.

In the analytical part, the Chaos theory concepts were applied to various aspects of team cooperation and organization management handling in order to provide practical examples how to nonlinear project management approach should be performed. General implications of the Chaos theory for organization management practice were also presented, with two dominant suggestions: a need for iterative planning after every milestone and the focus of management team on improving quality of team member’s interaction. Adopting these suggestions may lead into a significant Increase of organization management strategy success, as well as still manage the chaos situation in to stable as soon as possible.

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Appendices

```
% Henon Map : Bifurcation Logistic map
% IES LAB TNI, Bangkok, Thailand, 2015.

scale = 10000; % determines the level of rounding
maxpoints = 100; % determines maximum values to plot
N = 5000; % number of "r" values to simulate
a = 0; % starting value of "r"
b = 4; % final value of "r"... anything higher diverges.
rs = linspace(a,b,N); % vector of "r" values
M = 1000; % number of iterations of logistics equation

% Loop through the "r" values
for j = 1:length(rs)
   r=rs(j); % get current "r"
   y=zeros(M,1); % allocate memory
   y(1) = 0.00005; % initial condition (can be anything from 0 to 1)
   y(2) = 0.1;
   x(1) = 0.05;

   for i = 2:M, % iterate

      y(i+1) = r-y(i)^2;         %simplest logistic map Map r=[0 2]
      %y(i+1) = r*(1-y(i)^2);     %simple logistic map Map r=[0 1.4]
      %y(i+1) = r*y(i)*(1-y(i));  %logistics Map r=[0 4]
      %y(i+1) = r*sin(y(i));      %sine map r=[0 3.1]
      %y(i+1) = r*cos(y(i));      %cos map r=[0 2.5]

   end
   out{j} = unique(round(scale*y(end-maxpoints:end)));
end

% Rearrange cell array into a large n-by-2 vector for plotting
data = [];
for k = 1:length(rs)
   n = length(out{k});
   data = [data;  rs(k)*ones(n,1),out{k}];
end
```

```
% Plot the data
figure(99);clf
h=plot(data(:,1),data(:,2)/scale,'b.');
%g=title('y(i+1) = cos(r*y(i)+X)');
set(h,'markersize',1)
%set(g,'Visible','on');

% Henon Map : Bifurcation Structure
% IES LAB TNI, Bangkok, Thailand, 2015.


function Bifurcation_Structure
    clear all
    clc

    Parameter_Range_x    = [0, 4];
    Parameter_Range_y    = [0, 0.4];

    Number_Of_Sampling_x = 100;
    Number_Of_Sampling_y = 100;

    Step_x  = (Parameter_Range_x(2) - Parameter_Range_x(1)) / Number_Of_Sampling_x;
    Step_y  = (Parameter_Range_y(2) - Parameter_Range_y(1)) / Number_Of_Sampling_y;

    global r q
    for Count_x = 1: 1: Number_Of_Sampling_x + 1
        r = (Count_x - 1) * Step_x + Parameter_Range_x(1)
        for Count_y = 1: 1: Number_Of_Sampling_y + 1
            q = (Count_y - 1) * Step_y + Parameter_Range_y(1);
            [~, ~, DKY(Count_x, Count_y)] = Lyapunov_Exponents_2_Dimensional(50, 0.001, [0, 0]);
        end
    end

    % ----------------------- Map  Algorithm : RGB ------------------- %
    DKY_Max = real(max(max(DKY)))
    DKY_Min = real(min(min(DKY)))
    for Count_x = 1: 1: Number_Of_Sampling_x + 1
        for Count_y = 1: 1: Number_Of_Sampling_y + 1
            if DKY(Count_x, Count_y) > 0              % -    Choas   - %
                % # Gold      -> rgb(255, 215,   0) -> #ffd700           %
                % # Goldenrod -> rgb(218, 165,  32) -> #daa520           %
                Map(Count_x, Count_y, 1) = (255)*(1-(real(DKY(Count_x, Count_y))/DKY_Max));
```

```
            Map(Count_x, Count_y, 2) = (255)*(1-(real(DKY(Count_x, Count_y))/DKY_Max));
            Map(Count_x, Count_y, 3) = (255);
          elseif DKY(Count_x, Count_y) <= 0        % - Not  Choas - %
            Map(Count_x, Count_y, 1) = (255);
            Map(Count_x, Count_y, 2) = (255);
            Map(Count_x, Count_y, 3) = (255);
          else                                     % - Can't find - %
            Map(Count_x, Count_y, 1) = (255);
            Map(Count_x, Count_y, 2) = (255);
            Map(Count_x, Count_y, 3) = (255);
          end
        end

      end
      MapRGB(:, :, 1) = flipud(uint8(Map(:, :, 1)));
      MapRGB(:, :, 2) = flipud(uint8(Map(:, :, 2)));
      MapRGB(:, :, 3) = flipud(uint8(Map(:, :, 3)));
      % ----------------------------------------------------------------- %
      imtool(MapRGB)
      figure(1)
      surface((1: 1: Number_Of_Sampling_x + 1) * Step_x, (1: 1: Number_Of_Sampling_y + 1) * Step_y,
    real(DKY))
    end

    % Function Map : Henon Map
    % IES LAB TNI, Bangkok, Thailand, 2015.

    function Output = Function_Map(Input)
      global r q
      Output = zeros(size(Input));

      x_old = Input(1);
      x_now = Input(2);

      y_now = + x_old;
      x_new = - ((r.^2) * (x_now.^(1 + q))) + y_now + 1;

      Output(1) = x_now;
      Output(2) = x_new;
    end
```

```
% Function Map : Logistics Map
% IES LAB TNI, Bangkok, Thailand, 2015.

x0 = 0.5; % Initial condition
N  = 1000; % Number of iterations
r=3.8;
% Matrices in matlab cannot have zero index
x = zeros(N,1);
x(1) = x0;
 % compute the orbit and print out results
for i=1:N

 % Logistics Map
 %x(i+1) = r*x(i)*(1-x(i));

 % sine map
 x(i+1) = r*sin(x(i));

end
 % graph the orbit
plot(x);
xlabel('t'); ylabel('Xn');
hold on
```

```
% Lyapunov Exponent & Kaplan-Yorke Dimension
% Map Method :
%   [1] T. S. Parker and L. O. Chua, Practical numerical algorithms for chaotic systems, Springer?Verlag, New York, 1989.
%   [2] A. Wolf, J. B. Swift, H. L. Swinney, and J. A. Vastano, Determining Lyapunov exponents from a time series, Physica D
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IES LAB TNI, Bangkok, Thailand, 2015.

function [LE1, LE2, DKY] = Lyapunov_Exponents_2_Dimensional (Number_of_Iterates, Perturbation_Size, Initial_Conditions)

   n   = Number_of_Iterates; % Good at 10000
   eps = Perturbation_Size;  % Good at 0.001
   x   = Initial_Conditions;
   v1  = [1 ,0];
   v2  = [0 ,1];
   sum = [0, 0];

   for k = 1: 1: n
      v1(1) = v1(1) * eps;
      v1(2) = v1(2) * eps;
      v2(1) = v2(1) * eps;
      v2(2) = v2(2) * eps;

      v1(1) = v1(1) + x(1);
      v1(2) = v1(2) + x(2);
      v2(1) = v2(1) + x(1);
      v2(2) = v2(2) + x(2);

      v1 = Function_Map(v1);
      v2 = Function_Map(v2);
      x  = Function_Map( x);

      v1(1) = (v1(1) - x(1)) / eps;
      v1(2) = (v1(2) - x(2)) / eps;
      v2(1) = (v2(1) - x(1)) / eps;
      v2(2) = (v2(2) - x(2)) / eps;

      [norm, v1, v2] = GSR(v1, v2);

      sum(1) = sum(1) + log(norm(1));
      sum(2) = sum(2) + log(norm(2));
   end
   LE1 = sum(1) / k;
   LE2 = sum(2) / k;
   DKY = 1 + LE1 / abs(LE2);
end

function Output = Norm_Function(Input)
   Output = sqrt(Input(1).^2 + Input(2).^2);
```

```
end

function Output = Dot_Product(x, y)
   Output = x(1) * y(1) + x(2) * y(2);
end

function [norm, new_v1, new_v2] = GSR(v1, v2)
   norm(1) = Norm_Function(v1);
   v1(1)   = v1(1) / norm(1);
   v1(2)   = v1(2) / norm(1);
   Vector  = Dot_Product(v1, v2);
   x(1)    = v2(1) - Vector * v1(1);
   x(2)    = v2(2) - Vector * v1(2);
   norm(2) = Norm_Function(x);
   v2(1)   =  x(1) / norm(2);
   v2(2)   =  x(2) / norm(2);

   new_v1 = v1;
   new_v2 = v2;
end
```

```
% Henon Map : Lyapunov Exponent & Kaplan-Yorke Dimension
% IES LAB TNI, Bangkok, Thailand, 2015.

function Run_Lyapunov_Exponents_2_Dimensional
   clear all
   clc

   Parameter_Range    = [0, 1];
   Number_Of_Sampling = 1000;
   Step  = (Parameter_Range(2) - Parameter_Range(1)) / Number_Of_Sampling;

   global r q
   q = 1;
   for Count = 1: 1: Number_Of_Sampling + 1
      r = (Count - 1) * Step + Parameter_Range(1)
      Parameter(Count) = r;
      [LE1(Count), LE2(Count), DKY(Count)] = Lyapunov_Exponents_2_Dimensional(1000, 0.001,
[0, 0]);
   end
```

```
    subplot(1, 2, 1)
    plot(Parameter, DKY);
    xlabel(                    'Parameter a', 'FontSize', 16, 'FontName', 'Cordia New', 'FontWeight', 'bold');
    ylabel('Henon Map : Kaplan-Yorke Dimension', 'FontSize', 16, 'FontName', 'Cordia New',
'FontWeight', 'bold');
    grid on;

    subplot(1, 2, 2)
    plot(Parameter, LE1, Parameter, LE2);
    xlabel(                    'Parameter a', 'FontSize', 16, 'FontName', 'Cordia New', 'FontWeight', 'bold');
    ylabel(    'Henon Map : Lyapunov Exponents', 'FontSize', 16, 'FontName', 'Cordia New',
'FontWeight', 'bold');
    grid on;
end
```

A New Exponentially-Controlled Logistic Chaotic Map

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***Abstract*— The typical logistic map has been utilized in a variety of applications such as in biological modeling and secure communications. Nonetheless, such a typical logistic map has only a single control parameter that sets all dynamic behaviors. This paper therefore introduces a new arbitrary power in the quadratic term in order to control stability of the system. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties are described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Ardino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain.**

Keywords—Generalization, Robust Chaos, Absolute Value nonlinearity, Bifurcation, Lyapunov exponent.

I. Introduction

Chaotic system is typically a dynamic system that possesses some significant properties, involving the sensitive dependence on initial conditions and system parameters, the density of the set of all periodic points, and topological transitivity. In particular, a chaotic map is the lowest one-dimensional evolution function in a discrete-time domain that can exhibits chaotic behaviors. The simplest chaotic map may be a logistic map which realizes quadratic polynomials as nonlinearity [1], i.e.

$$x_{n+1} = a - x_n^2 \tag{1}$$

where a is a control parameter. The well-known variant of (1) that has been employed in a variety of applications [2-4] is in the form

$$x_{n+1} = ax_n(1 - x_n) \tag{2}$$

In other words, it can be considered in (2) that the equation comprises two terms, i.e. linear and nonlinear terms as follows

$$x_{n+1} = ax_n - ax_n^2 \tag{3}$$

This equation normally utilizes for a classic example of nonlinear dynamic system behaviors. Originally, the Logistic Map is a discrete-time demographic model analogous to the first logistic equation created by Pierre François Verhulst. The variable x_n is a number between zero and one that represents the ratio of existing population to the maximum possible population. The coefficient a is a number means the sum of the rate of reproduction and malnutrition. This equation models the distribution of human populations and estimates the increasing in populations of other species under limited circumstances.

The common feature found in both (1) and (2) is a single changeable parameter a that sets overall dynamic behaviors of the overall system. Conventionally, the adaptive control of logistic map was therefore proposed using additional controller [5], i.e.

$$x_{n+1} = ax_n - bx_n^2 + u_k \tag{4}$$

where a and b are two system parameters and u_k is a contoller. Recently, a generalized Logistic Map has been proposed in the form

$$x_{n+1} = ax_n^{\alpha}(1 - x_n^{\beta}) \tag{5}$$

where α and β are arbritrary power of the variable x_n. It can be considered from (4) and (5) that the equations are complicated in terms of atleast three parameters that contol both linear and nonlinar terms.

This paper therefore presents a new technique for controlling stability of the logistic map through the use of fractional power in the nonlinear term. The dynamic behaviors can be controlled effectively. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties will be described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Arduino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain.

II. Proposed Modified Logistic Map with Arbritary Power in Nonlinear Term

The proposed new technique for controlling stability of the logistic map through the use of fractional power in the nonlinear term is expressed as

$$x_{n+1} = ax_n(1 - x_n^{1-b}) \quad (6)$$

where a is a typical control parameter and b is a newly introduced parameter. Eq. (6) can be re-written as

$$x_{n+1} = ax_n - ax_n^{2-b} \quad (7)$$

It can be considered from (7) that the linear term (ax_n) is kept as original logistic map. However, the power of nonlinear term is reduced from 2 to frcational number. According to (8) the fixed point (x_p) can be found at

$$x_p = \left(\frac{1}{3-b}\right)^{\frac{1}{2-b}} \quad (8)$$

Generally, preliminary investigations of chaotic behaviors in chaotic maps can be achieved qualitatively and quantitatively through a bifurcation diagram and the Lyapunov Exponent (*LE*), respectively. The bifurcation diagram indicates possible long-term values, involving fixed points or periodic orbits, of a system as a function of a bifurcation parameter. The stable solution is represented by a straight line while the unstable solutions are generally represented by dotted lines, showing thick regions.

On the other hand, the *LE* is defined as a quantity that characterizes the rate of separation of infinitesimally close trajectories and is expressed as [5]

$$LE = \lim_{n\to\infty} \frac{1}{N} \sum_{n=1}^{N} \log_2 \frac{dx_{n+1}}{dx_n} \quad (9)$$

where N is the number of iterations. Typically, the positive *LE* indicates chaotic behaviors of dynamical systems and the larger value of *LE* results in higher degree of chaoticity. In this paper,

III. Simulation Results

A. Typical Logictic Map Characteristics

Dynamic behaviors of logistic map are investigated using MATLAB. Fig.1 shows an apparently chaotic waveform in time-domain where parameters were set at a = 3.99 and b = 0. It is seen from Fig.1 that the signal is random in both amplitude and frequency characteristics. Fig.2. shows the cobweb plot at a = 3.99 and b = 0.

The cobweb plot is typically used to investigate the qualitative behaviour of one-dimensional iterated functions. It can be seen in Fig.2 that a chaotic orbit shows a filled out area, indicating an infinite number of non-repeating values. Fig.3 show the period doubling bifurcation diagram in the region of [0,4] where chaos is induced from a gretaher than 3.5. Fig.5 shows the *LE* spectrum where chaos appears when *LE* is greater than zero.

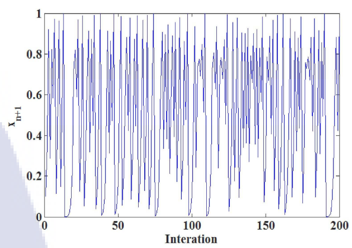

Fig.1. The pparently chaotic waveform in time-domain at a = 3.99 and b = 0.

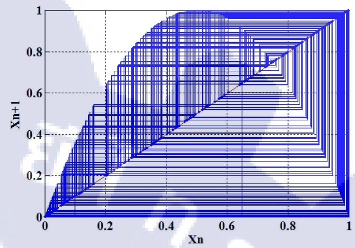

Fig.2. The cobweb plot at a = 3.99 and b = 0.

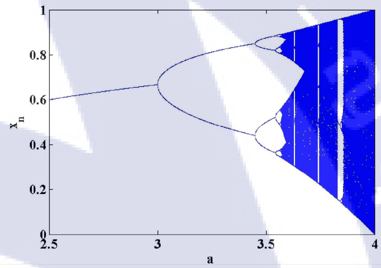

Fig.3. The period doubling bifurcation diagram in the region of [0, 4].

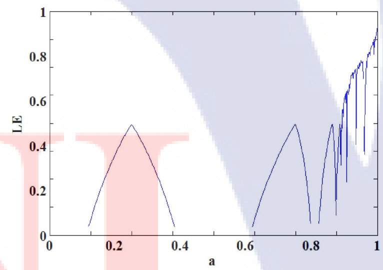

Fig.4 The *LE* spectrum where chaos appears when *LE* is greater than zero.

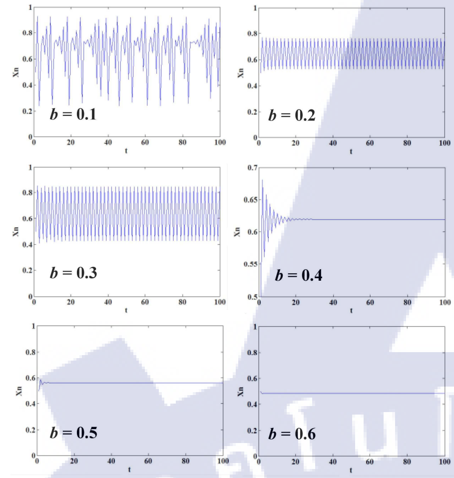

Fig.5. the time-domain waveforms of the modified logistic map at different value of the parameter *b*.

B. Dynamic Behaviors of the proposed Modified Logistic Map

Dynamic behaviors of the proposed modified logistic map can be investigated through the bifurcation of the parameter *b*. Fig.5.shows the period doubling bifurcation diagram of parameter *b* in the region of [0,1]. It can be seen that the bifurcation is inverse to the typical logistic map. In addition, the bifucation structure of parameter *a* versus *b* is shown in Fig.6. The system possesses relatively complex behaviors. In order to investigate the ability to control to behaviors, time domain waveforms are illustrated in Fig.7 It can be considered from Fig.7 that when the value of the parameter b is incresed, i.e. the power of the nonlinear term becomes fractional, the system become stable as indicated by the bifucation diagram shown in Fig.3 and the waveforms in Fig.7.

IV. Experimental Results

A. Generation of Chaotic Signals Using Microcontroller

The experimental results have been conducted using a cost effective Arduino with Atmel SAM3X8E ARM Cortex-M3 CPU as shown in Fig.6. The case where parameters a = 3.99 and b=0.1 was chosen as for demonstration. Fig. 7 shows the chaotic waveform generated from Arduino and Fig. 8. shows the Fast Fourier Transfrom (FFT) of the chaotic signal also showing a relatively flatspectrum over all frequency range. Other cases also exhibit the same characteristics in correspodance to the simulation results.

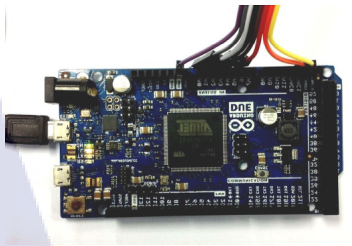

Fig.6 Arduino with Atmel SAM3X8E ARM Cortex-M3 CPU

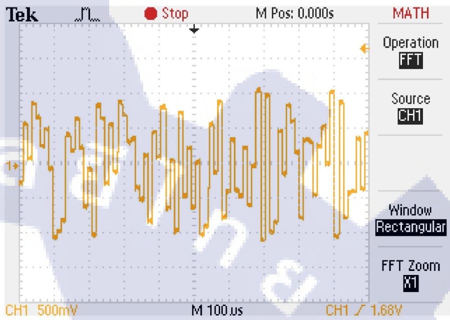

Fig.7. Chaotic waveform generated from Arduino.

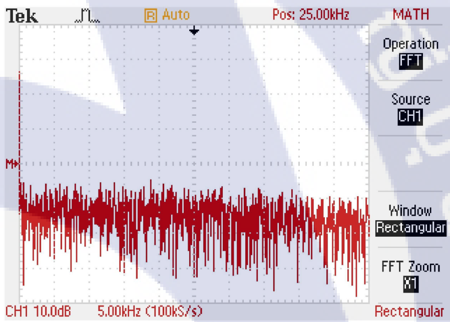

Fig.8 Fast Fourier Transfrom of the chaotic signal, showing a relatively flat spectrum over all frequency range .

V. Conclusion

This paper has presented a new arbitrary power in the quadratic term in order to control stability of the system. The additial arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties are described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Ardino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain. The application in random-bit generator that passes all NIST standard tests is also involved. The proposed chaotic map offer an alternative maps and random bit generator such as in cryptography or in communications

Acknowledgements

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References

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A Modified Simple Logistic Chaotic Map through Exponential Controller in Nonlinear Term

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Abstract— **A typical logistic map has been utilized in a variety of applications such as in biological modeling and secure communications. Nonetheless, such a typical logistic map has only a single control parameter that sets all dynamic behaviors. This paper therefore introduces a new arbitrary power in the quadratic term in order to control stability of the system. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties are described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Arduino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain. The application in random-bit generator that passes all NIST standard tests is also involved.**

Keywords—Generalization, Robust Chaos, Absolute Value nonlinearity, Bifurcation, Lyapunov exponent.

I. Introduction

Chaotic system is typically a dynamic system that possesses some significant properties, involving the sensitive dependence on initial conditions and system parameters, the density of the set of all periodic points, and topological transitivity. In particular, a chaotic map is the lowest one-dimensional evolution function in a discrete-time domain that can exhibits chaotic behaviors. The simplest chaotic map may be a logistic map which realizes quadratic polynomials as for its nonlinearity [1], i.e.

$$x_{n+1} = a - x_n^2 \tag{1}$$

where a is a single control parameter. The well-known variant of (1) that has been employed in a variety of applications [2-4] is in the form

$$x_{n+1} = ax_n(1 - x_n)\,. \tag{2}$$

In other words, it can be considered from (2) that the equation comprises two terms, i.e. linear and nonlinear terms as follows

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This equation normally utilizes for a classic example of nonlinear dynamic system behaviors. Originally, the Logistic map is a discrete-time demographic model analogous to the logistic equation first created by Pierre François Verhulst. The variable x_n is a number between zero and one that represents the ratio of existing population to the maximum possible population. The coefficient a is a number that means the sum of the rate of reproduction and malnutrition. This equation models the distribution of human populations, and estimates the increase in populations of other species under limited circumstances.

The common feature found in both (1) and (2) is a single controllable parameter a that sets overall dynamic behaviors of the overall system. Conventionally, the adaptive control of logistic map was proposed using additional controller [5], i.e.

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$$x_{n+1} = ax_n^{\alpha}(1 - x_n^{\beta}) \tag{5}$$

where α and β are arbitrary power of the variable x_n. It can be considered from (4) and (5) that the equations are complicated as there are three parameters that control both linear and nonlinear terms.

This paper therefore presents a new technique for controlling the stability of the logistic map through the use of fractional power in only a nonlinear term. The dynamic behaviors can be controlled effectively. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties will be described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Arduino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain.

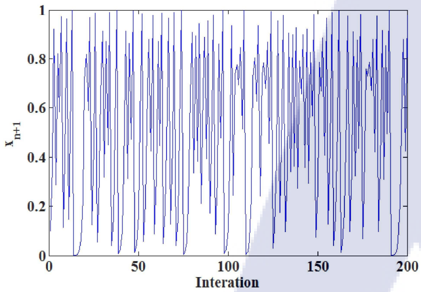

Fig.1. The apparently chaotic waveform in time-domain at $a = 3.99$ and $b = 0$.

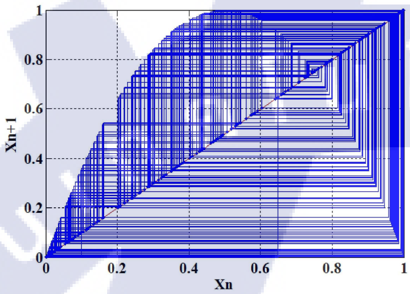

Fig.2. The cobweb plot at $a = 3.99$ and $b = 0$.

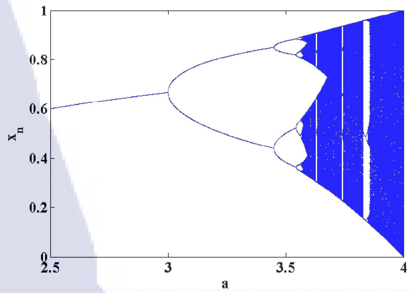

Fig.3. The period doubling bifurcation diagram in the region of [0,4].

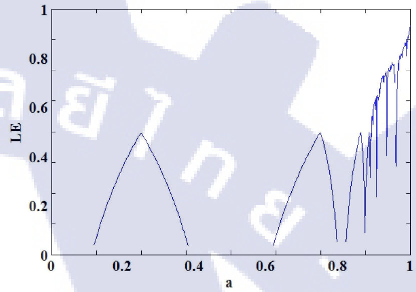

Fig.4 The *LE* spectrum where chaos appears when *LE* is greater than zero.

II. Proposed Modified Logistic Map with Arbritary Power in Nonlinear Term

The proposed new technique for controlling stability of the logistic map through the use of fractional power in the nonlinear term is expressed as

$$x_{n+1} = ax_n(1 - x_n^{1-b}) \tag{6}$$

where a is a typical control parameter and b is a newly introduced parameter. Eq. (6) can be re-written as

$$x_{n+1} = ax_n - ax_n^{2-b} \tag{7}$$

It can be considered from (7) that the linear term (ax_n) is kept as original logistic map. However, the power of nonlinear term is reduced from 2 to fractional number. According to (7) the fixed point (x_p) can be found at

$$x_p = \left(\frac{1}{3-b}\right)^{\frac{1}{2-b}} \tag{7}$$

Generally, preliminary investigations of chaotic behaviors in chaotic maps can be achieved qualitatively and quantitatively through a bifurcation diagram and the Lyapunov Exponent (*LE*), respectively. The bifurcation diagram indicates possible long-term values, involving fixed points or periodic orbits, of a system as a function of a bifurcation parameter. The stable solution is represented by a straight line while the unstable solutions are generally represented by dotted lines, showing thick regions. On the other hand, the *LE* is defined as a quantity that characterizes the rate of separation of infinitesimally close trajectories and is expressed as [5]

$$LE = \lim_{n\to\infty} \frac{1}{N}\sum_{n=1}^{N} \log_2 \frac{dX_{n+1}}{dX_n} \tag{8}$$

where N is the number of iterations. Typically, the positive *LE* indicates chaotic behaviors of dynamical systems and the larger value of *LE* results in higher degree of chaoticity. In this paper,

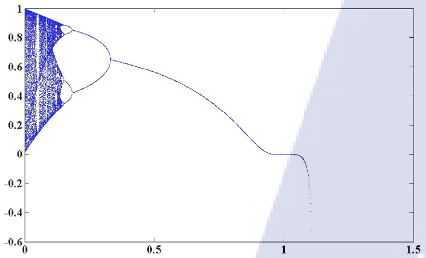

Fig.5. The period doubling bifurcation diagram of parameter *b* in the region of [0,1].

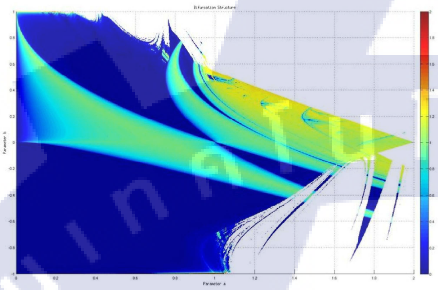

Fig.6. The bifurcation structure of parameter *a* versus *b*.

III. Simulation Results

A. *Typical Logictic Map Characteristics*

Dynamic behaviors of logistic map are investigated. Fig.1 shows an apparently chaotic waveform in time-domain at a = 3.99 and b = 0. It is seen from Fig.1 that the signal is random in both amplitude and frequency characteristics. Fig.2. shows the cobweb plot at a = 3.99 and b = 0. The cobweb plot is typically used to investigate the qualitative behavior of one-dimensional iterated functions. It can be seen in Fig.2 that a chaotic orbit shows a filled out area, indicating an infinite number of non-repeating values. Fig.3 show the period doubling bifurcation diagram in the region of [0,4] and Fig.5 shows the *LE* spectrum where chaos appears when *LE* is greater than zero.

B. *Dynamic Behaviors of the proposed Modified Logistic Map*

Dynamic behaviors of the proposed modified logistic map can be investigated through the bifurcation of the parameter b. Fig.5.shows the period doubling bifurcation diagram of parameter b in the region of [0,1]. It can be seen that the bifurcation is inverse to the typical logistic map. In addition, the bifurcation structure of parameter a versus b is shown in Fig.6. The system possesses relatively complex behaviors. In order to investigate the ability to control to behaviors, time

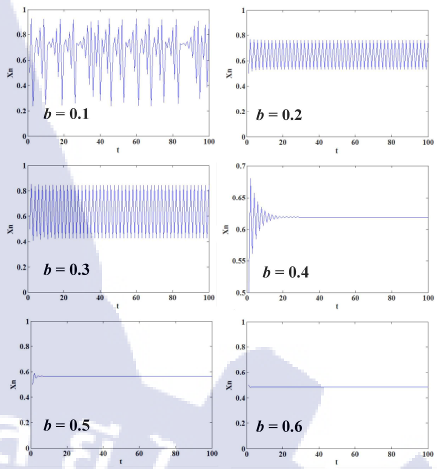

Fig.7. the time-domain waveforms of the modified logistic map at different value of the parameter *b*.

domain waveforms are illustrated in Fig.7 It can be considered from Fig.7 that when the value of the parameter b is increased, i.e. the power of the nonlinear term becomes fractional, the system become stable as indicated by the bifurcation diagram shown in Fig.5 and the waveforms in Fig.7.

IV. Experimental Results

A. *Generation of Chaotic Signals Using Microcontroller*

The experimental results have been conducted using a cost effective Arduino with Atmel SAM3X8E ARM Cortex-M3 CPU as shown in Fig.6. The case where parameters a = 3.99 and b=0.1 was chosen as for demonstration. Fig. 8 shows the chaotic waveform generated from Arduino and Fig. 9.shows the Fast Fourier Transform (FFT) of the chaotic signal in Fig.8 showing a relatively flat spectrum over all frequency range. Other cases also exhibit the same characteristics in correspondence to the simulation results.

B. *Randomess Tests*

The National Institute of Standards and Technology (NIST) has provided a statistical tests suite in order to evaluate the randomness of binary sequences. This paper generates chaotic signals by the proposed two cases of the signum-based chaotic maps for 1,000,000 iterations and simply proceed a comparison with zero, i.e. bit “1” for any values that greater than zero and bit “0” for any values that smaller than zero. Subsequently, the NIST test suite from a special publication 800-22rev1a [11] was realized using a typical 1,000,000 random bits. The test suite attempts to extract the presence of a pattern that indicates non-randomness of the sequences through probability methods described in terms of p-value. For each test methods, the p-value indicates the strength of evidence against perfect randomness hypothesis, i.e. a p-value greater than a typical confidence level of 0.01 implies that the sequence is considered to be random with a confidence level of 99%. The signal is 1-bit quantized at the fixed points, Table 1 summaries NIST test results, indicating that the generated sequences from both cases of chaotic maps pass all standard 15 tests.

Fig.8 Arduino with Atmel SAM3X8E ARM Cortex-M3 CPU

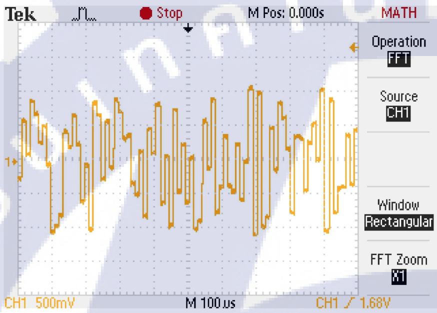

Fig.9 Chaotic waveform generated from Arduino.

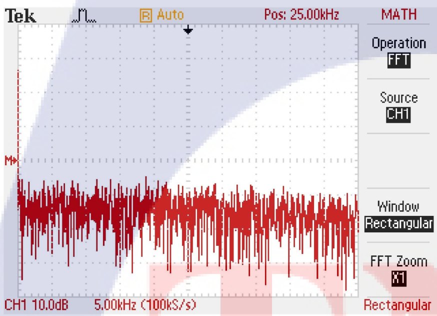

Fig.10 Fast Fourier Transfrom of the chaotic signal, showing a relatively flat spectrum over all frequency range .

TABLE I. SUMMARY OF NIST TEST RESULTS OF 1,000,000 BITS GENERATED FROM THE PROPOSED CHAOTIC MAPS.

Summary of NIST		
Test Methods	*p-values*	*Results*
Mono-bit	0.34927	Success
Frequency Block	0.40930	Success
Runs	0.29228	Success
Longest Run of Ones Block	0.85524	Success
Binary Matrix Rank	0.91190	Success
Discrete Fourier Transform	0.56938	Success
Non-overlappingTemplate Matching	0.99621	Success
Overlapping Template Matching	0.85515	Success
Universal Statistical	0.34322	Success
Linear Complexity	0.01986	Success
Serial	0.97677	Success
Approximate Entropy	0.58911	Success
Cumulative Sums	0.55185	Success
Random Excursions	0.34426	Success
Random Excursions Variant	0.20476	Success

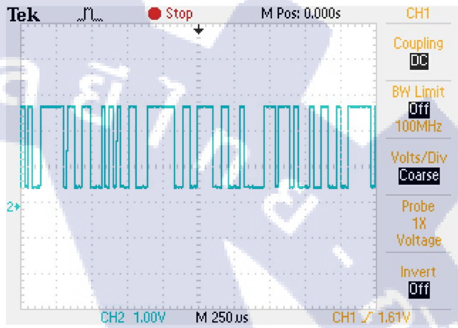

Fig.11 Illustration of the generated random bits

Fig.9 illustrated the random bits that generated from the case M1. It can be seen from Fig.9 that the digital bits that represented by 0-3.3V are random.

V. CONCLUSION

This paper has presented a new arbitrary power in the quadratic term in order to control stability of the system. The addition arbitrary power subsequently increases the degree of freedom of the logistic map and provides versatile responses as well as the flexibility of the system. Dynamic properties are described in terms of Cobweb plots, bifurcations, Lyapunov exponents, and chaotic waveforms in time domain. Experimental results utilize the Ardino microcontroller to generate chaotic waveforms with a relatively flat spectrum in frequency domain. The application in random-bit generator that passes all NIST standard tests is also involved. The proposed chaotic map offer an alternative maps and random bit generator for science applications such as in cryptography or in communications

ACKNOWLEDGEMENTS

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References

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A New Paradigm on Decision Making in E-Commerce in Thailand through a Combined Game and Chaos Theories

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ABSTRACT
This paper presents new paradigm on behaviors of decision making in E-commerce in Thailand through a perspective on game Theory and a chaos theory. As E-commerce is a multi-dimensional consideration, a single theory may not be sufficient for the overall perspective views in decision making. In this paper, game theory is suitable for decision making of E-commerce providers in order to set the strategy based on feedback information. However, chaos theory is suitable for describing customer decision making, especially the buying behaviors seems to be random in which the classical decision model cannot be described. The proposed new paradigm can be applicable for economics and managements in enterprise, especially business-to-customer types of entrepreneurs.

Categories and Subject Descriptors
J.1 [**Administrative Data Processing**]: Business, Financial, E-commerce, Government.

General Terms
Management, Performance, Design, Economics, Theory

Keywords
Random Behaviors, Customer Decision Making, Game Theory, Chaos Theory.

1. INTRODUCTION
The advancement in web-based technologies has continuously supported the growth of E-commerce in Thailand. Particularly, automation and delegation technologies have considerable effects on the future of E-commerce. Nowadays, the software has fully made E-commerce possible, for instance, the consumers can be able to conduct automated searches and consider price comparisons. These technologies can even perform decision making on behalf of individuals, negotiating with other programs, and participating in online markets. The opportunities to utilize the internet for business and comparison shopping have been increased significantly by technologies. In summary, an automated E-commerce creates new economics value not only by making business processes easier, but also by opening up new possibilities for market interactions.

According to the National Statistical Office (NSO) [1] of Thailand, information of percentage of E-commerce business by types of entrepreneurs has revealed in Figure 1. Most of E-commerce businesses were entrepreneurs engaged in Business-to-Customer (B2C) with 79.7% and Business-to-Business (B2B) with 19.3%. For those engaged in Business-to-Government (B2G) without E-Government, it was only about 1.0%. In terms of types of business, Figure 2 shows the percentage of E-commerce

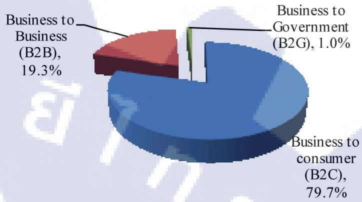

Figure 1. Percentage of E-commerce Business by Types of Entrepreneurs.

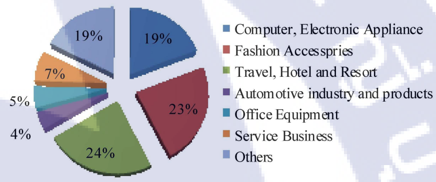

Figure 2. Percentage of E-commerce Business by Types of Business.

businesses. Considering the large scale of E-commerce businesses, it showed that the groups of industry were mostly travel, hotel and resort (24.0%), next were fashion industry, accessories and jewelry (23.3%), were on computer, electronic, appliance, and internet (19.2%), were service business (7.0%), were office equipment (4.99%), followed by automotive industry and products (4.1%), and other (17.5%), respectively.

In comparison to global scale, the average income for E-commerce of 20% comes from Asia and Pacific. In other word, this region has potentially shown a rapid growth of E-commerce. Thailand has been recognized as the highest growth of E-commerce in South-East Asia. Based on the report in the year 2013 [1], the value of E-commerce in Thailand is 473.3 Million Dollars and it is expected to be approximately 700 Million Dollars in 2016. Such a growth in E-commerce is due to the capability of accessing to internet, i.e. 33 million people in Thailand now. In addition, the important factor influencing the growth in E-commerce is the growth in smart phone market. In 2013, the growth rate of using smart phone is 132%, and 92% of Thai people always use the mobile phone. The statistics also indicates that 51% of Thai people make a business operation through E-commerce. Such numbers clearly explain that the impacts of E-commerce have aroused business developers to accelerate strategy for maximum benefits.

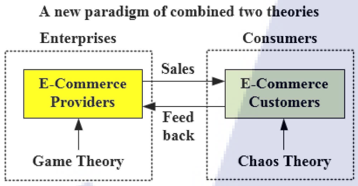

Figure 3. The proposed new paradigm of combined game theory and chaos theory.

According to such a rapid growth in E-commerce in Thailand, there is a significant need on a tool for decision making process for both E-commerce providers and customers. This paper therefore presents combined theories as a new paradigm for decision making. Game theory will be applied for enterprises, but the chaos theory will be applied for customers. A clear concept of this paper is to provide a new paradigm on E-commerce management theories from the viewpoints of both business providers and the consumers.

2. LITERATURE REVIEWS

On the one hand, game theory has extensively been studied for strategic decision making. In particular, the game theory is the mathematical models of conflict and cooperation between intelligent rational decision makers. Some papers relating game theory on decision making are as follows. Fernando Bernstein and et al. [2] has presented that consumers are generally better off with clicks-and-mortar retailers. If firms align with pure E-tailors to reach the online market, a prisoner's dilemma-type equilibrium may arise. Daewon Sun and et al. [3] have studied the properties of the optimal format to sell a product through the internet. Elliot Anshelevich and et al. [4] proposed progresses in prove bounds on the prices of anarchy and stability. Jing Yu and Bin Xu [5] have proved a numeric simulation that their proposed formulas can perfectly well reflect the realistic practice of merger and acquisition.

In addition, Yu Xiong [6] presented that both the dealer and the supply chain may benefit from the manufacturer's encroachment. Ursula F. Ott [7] indicates that there is considerably more potential for its refinements to be related to topics of uncertainty and dynamics in strategic interactions in International business. Qihui Lu and Nan Liu [8] presented the numerical analysis of the supplier and the retailer which are worse off in the Nash game than in the Stackelberg games. Wooje Cho and et al. [9] showed that in the duopoly market, even when customers are uninformed about quality, an investment-equilibrium exists. Finally, Salma Karray and Simon Pierre Sigué [10] have studied the properties of a partnership between a complementary product and independent product which is optimal when the price effect of the complementary product is large.

On the other hand, chaos theory is the study of dynamical system behaviors which are highly sensitive to initial conditions. Chaos theory has been applied for economics in variety of matters. Mouck [11] presented the capital markets research and real world complexity). Guégan [12] focused on the use of dynamical chaotic systems in economics and finance, and presented statistical tools which can be useful in practice to detect the existence of chaotic behavior inside real data sets. Barbora Volná [13] presented the

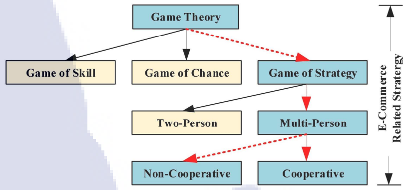

Figure 4. A diagram showing the taxonomy of game theory that relates to E-commerce system.

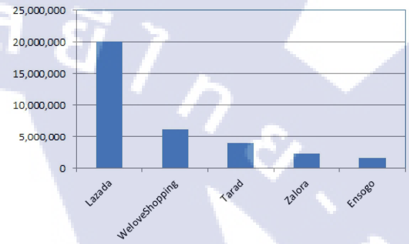

Figure 5. the ranking of E-Commerce in Thailand by page visits in January 2015[15].

existence of chaos in the plane R2 and its application in the fundamental macroeconomic equilibrium model called IS-LM model. In addition, Akio Matsumoto [14] has summarized in details regarding attractors, bifurcations and chaos, i.e. nonlinear phenomena in economics. As a result from considerations on both game theory and chaos theory, such two theories have strength in order to apply in E-commerce system as a new paradigm.

3. PROPOSED CONCEPTUAL MODEL

Figure 3 depicts the proposed conceptual model as a new paradigm of combined game theory and chaos theory. The new scenario focuses on the application of game theory to enterprises and chaos theory to customer behaviors, respectively. With reference to Figure 3, game theory reveals that it is suitable for E-commerce providers in order to set the strategy based on feedback information. However, the chaos theory is suitable for describing the customer decision making, especially the buying behaviors seems to be random in which the classical model cannot be described.

3.1 Proposed Game Theory for E-Commerce Providers

Figure 4 demonstrates the diagram showing the partial taxonomy of game theory that relates to E-commerce system. Nowadays, there have been a number of E-commerce providers and therefore the game theory should focus on the game of strategy in which multi-person are involved. The commonly-known Prisoner's Dilemma (two-person) might not be suitable to be applied to the current situation of E-commerce business as a number of providers have incredibly increased. This is due to the significant increase in smart phone markets and therefore people tend to purchase goods and services via mobile phone (M-Commerce), which is a novel existence in E-commerce markets. As for a concrete demonstration, Fig.5 shows the first five ranking of E-Commerce in Thailand by page visits in January 2015 [15]. According to Fig.5, the value of E-commerce in Thailand has been increasing dramatically reflected by amount of money flows. The application of game theory in multi-person system should consider on cooperative and non-cooperative strategies among competitors. Comparisons on advantage and disadvantages are as follows.

In terms of cooperative strategy, the customer base can be increased and therefore the channel for public relation can correspondingly be increased. The cooperative strategy helps support each other in terms of strength and weakness of each firm. Therefore, the brand is stronger and more creditable. In addition, the target of cooperative strategy in E-commerce system is clearer and hence no conflicts happen among competitors. Most importantly, cooperative strategy in E-commerce significantly reduces the operation costs.

For non-cooperative strategy, on the other hand, the operation and marketing strategy is deftness and flexible. Therefore, the decision making is faster, following the market trend. The enterprises can response to the real need of the target without any consideration from other companies. In addition, the firms can play the "price war" which can gain the maximum benefit for the own firm. In conclusion of game theory for E-commerce in Thailand, it seems to be that the non-cooperative strategy is more suitable due to the Thai culture which has a low completion. Additionally, Thai people are still concern about the monopoly market due to social space which still exists in Thailand.

3.2 Proposed Chaos Theory for E-Commerce Customers

Customer behavior is generally defined as activities that people undertake when obtaining, consuming and disposing of products and services. The businesses around the world recognize the consumer that is no longer the king, but rather a partnership. In essence, analysis of customer behaviors helps firms to know directly the impact of bottom line profits. The Consumer Decision Process (CDP) model is therefore a roadmap of consumers' minds that marketers and managers can use to help manage products, communications, and sale decisions. Typically, the one-time decision of a traditional model involves five-stage considerations, i.e. problem recognition, information search, alternative evaluation, purchase decision, and post-purchase behavior. However, such a model is a one-time decision, which is contrast to the current situation where a number of E-commerce providers are available with high competition.

This work therefore focuses on the random decision making of customers through the use of chaos theory. The chaos theory studies behaviors of dynamical systems which has high sensitivity on initial conditions. In other words, a response particularly referred to as the butterfly effect. Small differences in initial conditions results in dramatically diverging outcomes for such dynamical systems, rendering long-term prediction impossible in general. As for the sake of simplicity for understanding, the typical logistics map is demonstrated through the iteration $X_{n+1} = rX_n(1-X_n)$ where r is a control parameter. Figure 6 shows the bifurcation diagram of the Logistics Map and the Positive Lyapunov Exponent, indicating chaotic state. There are three cases for consideration of customer decision making as follows;

First, the stable state (a straight line) indicates the customers that really loyal to the brand. This group of customers will decide to

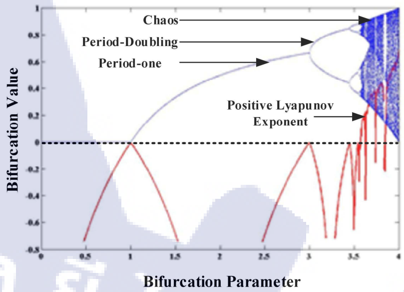

Figure 6. Bifurcation diagram of the Logistics Map and the Positive Lyapunov Exponent, indicating chaotic state

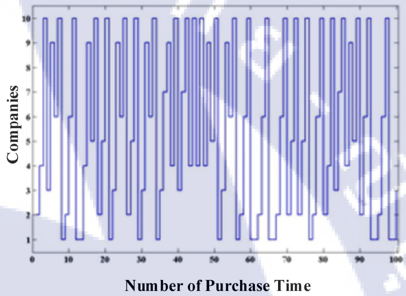

Figure 7. Examples of one customer who randomly buying products and services in different companies.

buy products and services only the brand that they prefer. Therefore, it is relative hard to change their behaviors to buy form other companies. In order to gain benefits from this group, the cooperative strategy among enterprises would be an alternative to expand the customer base.

Second, the period doubling state (Bifurcating) indicates the customers that are not really loyal to the brand. They might compare only some important factors such as prices and promotions. This group of customer should be realized by the enterprises as they are one of major groups that can be hold as a customer base.

Last, the chaotic state indicated by the thick area represent the group of customers that truly random buy goods and services without any considerations on brand and prices. Emotions and Public Relations (PR) are important factor to arouse this group of customers without any reasons. The viral marketing also affects the customer decision making in a random way. This group of customer is relatively difficult to handle due to they have no specific target and not loyal to any brand. Figure7 shows the examples of one customer who randomly buying products and services in different companies. It can be seen from Figure 7 that this customer buy 100 items with different companies modeled by the logistic map. It is apparent that most Thai people tend to have this kind of buying behaviors and it is chaotic behaviors.

4. CONCLUSION

This paper has presented the novel paradigm on a decision making in E-commerce in Thailand using a game Theory for the E-commerce business developers and a chaos theory for customer decision making. As E-commerce is a multi-dimensional consideration, a single theory may not be sufficient for the overall perspective views. For game theory, it is revealed that it is suitable for providers to set the strategy based on feedback information, which can be whether cooperative or non-cooperative strategies. However, the chaos theory is suitable for describing the customer decision making, especially the buying behaviors seems to be random in which the classical model of classical decision model cannot be described. Bifurcation diagram of the Logistics Map and the Positive Lyapunov Exponent were also demonstrated. The proposed new paradigm can be applicable for managements in enterprises, especially Business-to-Customer types of entrepreneurs.

5. ACKNOWLEDGMENTS

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