Chaos Theory as a Model for Interpreting Weblog Traffic

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Abstract

Weblogs are becoming increasingly popular and bloggers desire traffic. This study seeks to give an overall view of weblog systems including factors that affect weblog traffic. Key concepts of chaos theory are used to construct an interpretive framework to illustrate weblog traffic dynamics where interactions between a number of factors and weblog traffic are such that clear causal relationships cannot be established. Weblog systems tend to be non-linear, dynamic and deterministic. The sensitivity of weblog traffic to initial conditions is highlighted, which makes long term prediction impossible. Also, chaos theory suggests that weblog traffic exhibits "self-similar" dynamics. Implications are given for practitioners. Research opportunities are presented.

1. Introduction

Weblogs (or blogs) are a form of computer-mediated communication (CMC) technology that are becoming increasingly popular through which people can conveniently publish and establish networks online. Through weblogs, people express their personal ideas and opinions on news or entertainment. They can also share their experiences of life and work and participate through collaboration and discussion in the form of conversations (interrelated weblog posts and comments) [6]. Advanced blogging tools facilitate easy, fast and inexpensive web composition, which leads to broader adoption of weblogs.

Weblogs are becoming increasingly popular. According to Sifry (April, 2007) [23], founder and CEO of Technorati, blogsphere (the aggregate of all the blogs) doubled every 5-7 months from Quarter 2 2004 through Quarter 2 2006. About 120,000 new weblogs are created daily and approximately 17 postings are made per second in the 70 million weblogs worldwide. This flourishing weblog phenomenon has also attracted the attention of business. Phillip Windley, CIO for the state of Utah, launched a program that encourages 2,000 IT staffers and about 18,000 other state employees to use blogging software with the expectation that "if everybody just wrote every day [about things such as] 'Here's an interesting problem I had today,' and then we hook up a Google [Web search] appliance, we can create a state knowledgebase" (http://www.networkworld.com).

Firms have joined blogging in the form of corporate blogs, e.g., there were about 46 Fortune 500 companies including Microsoft, IBM and Google that had at least one public-facing corporate blog as of September 2006 (http://www.socialtext.net/bizblogs/index.cgi). Corporate blogs come out with their own specific purposes. Amazon.com uses a public blog to announce product enhancements and provide support. Disney practises the aim of knowledge sharing through an internal team blog. Boeing's vice president of marketing, Randy Baseler, gives Boeing's forecast of the airline market

and comments in his personal weblog to publicize their products.

These popular weblogs are read by thousands of people, with the implication that weblogs have the potential for advertising. Companies pay thousands of dollars to popular weblogs in the aim of advertisements. Online advertising is accepted in the model of cost-per-click, and thus, traffic is emphasized. A survey by InsightCN showed that 72.7% of bloggers in China wish to earn money through blog advertisements. They assume that advertisements thrive on wide readership, so traffic is important to these bloggers.

With the fact that blogging is becoming more and more popular, the blogsphere is growing rapidly and blogs have to face readership competition. In the blogging ecosystem, traffic distribution follows a power law distribution [22]. A small set of weblogs account for a majority of the traffic in the weblog world while the others typically have to suffer from poor readership, possibly used only by friends and family members. For weblogs with limited audiences, readership and communication are also very important motivators for bloggers [18]. In short, bloggers desire traffic.

So what are the characteristics of weblog traffic dynamics? What are the factors affecting weblog traffic? How do they affect it? This paper explores these questions through the lens of chaos theory from a systems perspective.

2. Literature

Weblog is defined as "frequently modified web pages in which dated entries are listed in reverse chronological sequence" [9]. As a CMC, most weblogs have the following common tools [9], [11]:

- Comment tools allowing readers/visitors to express their opinions on the weblog entry;
- Trackback capabilities informing bloggers of traffic to their original entries;
- Archives (storerooms of weblog entries) enabling visitors to find the historical contents;
- Permalinks allowing weblogs link posts with one another.

These tools offer technology features to facilitate interactions between bloggers and visitors, and also enhance conversations among bloggers. For example, through permalinks and comments, both the bloggers and readers can discuss their opinions on specific topics through an iterative cycle of postings and comments.

Weblog traffic comes from these interactions. Some famous weblog statistical web services such as Technorati (www.technorati.com) and Truthlaidbear (www.truthlaidbear.com) use inbound links, i.e., links from other weblogs, as the measure to compute popularity ranking, which is an indirect measurement of weblog traffic. The traditional web traffic statistical service Alexa (www.alexa.com) provides three measures: (1) Reach: the number of users, typically expressed as the percentage of all Internet users who visit a given site; (2) Page Views: the number of pages viewed by Alexa Toolbar users; and (3) Traffic Rank: based on the geometric mean of reach and page views over time.

In the academic field, the global flourishing blog phenomenon has attracted researcher attention, and studies about blogging have blossomed during the past few years. Weblog motivations have been explored. Among the thousands of weblogs created every day, many of them are motivated by different reasons: documenting one's life; providing commentaries and opinions; expressing deeply felt emotions; articulating ideas through writing; and forming and maintaining community forums, etc. Blog content is equally diverse, ranging from journals of daily activities to serious commentaries on important issues [19]. The distribution of blog types has been summarized according to their primary purpose as: personal journal, filter, k(nowledge)-log (blogs are created as environments for knowledge sharing), and mixed-purpose blog [9], [2]. Kumar et al. [14] conclude that the three layers in blogspace are explained in terms of geographic or demographic correlations, shared locations or shared interests, and bursts of activity. Conversational blogging practices have also been explored [6], [8]. These researchers have studied weblogs from the viewpoint of motivation, type and activity pattern.

A few researchers focus on weblog traffic. Du and Wagner examine weblog success from the technology perspective [5]. Also, visitation and interaction patterns between bloggers and visitors, and some specific technological factors have been explored [11]. These factors are studied through traditional linear analysis in a short period of time (e.g. several months or days). However, weblog traffic is affected by factors in other dimensions, such as external events (e.g. terrorist acts, political events) [10], contents, blogger's social relationships, etc. These factors do not affect weblog traffic in a simple linear relationship, which is beyond the traditional models. Thus, this paper borrows concepts from chaos theory, a theory that studies complex systems, to provide scaffolding for the explanation of weblog traffic in the long term.

3. Chaos Theory

Chaos theory was originally pioneered by Lorenz's work on the dynamics of turbulent flow in fluids, and developed in the science of physics. However, during the last 20 years, interest in chaos theory has grown among researchers from different fields, such as material science, organization and economics (e.g., [21], [15], [1], [3]). Systems characterized as complex, unpredictable, and irregular (with which traditional models, largely focusing on regularity and stability, are not able to deal) have been studied by chaos theory. More recently, attention has been given to information systems [17]. These studies apply chaos theory to complex systems in a variety of fields and the theory shows its power and attraction.

Chaos theory is "the qualitative study of unstable aperiodic behavior in deterministic non-linear dynamical systems" [12]. In non-linear systems, small inputs can sometimes lead to large outputs, and small disruptions in the initial conditions sometimes (but not always) make the system volatile and impose significant variances. Periods may be punctuated by sudden change, apparent patterns of behavior may disappear and new patterns unexpectedly emerge [17]. Chaos theory or Chaotic Systems Thinking (CST) gives an explanation of nonlinear systems which makes fundamental change and strikes a better understanding of the balance between order and disorder [1].

Chaotic Systems meet the following several criteria:

- **Non-linear:** Relationships between cause and effect are not constant, systems behavior responds to input non-linearly and in an unanticipated fashion. Small inputs can have large effects, and large inputs can result in no significant change [17]. Usually, non-linear systems cannot be analyzed by adding their respective components because the subsets of systems interact.

- **Dynamic**: Systems are unstable and shift between semi-stable states.

- **Deterministic**: Chaotic systems are dependent on their initial conditions, and they are seemingly random but actually don't lack order.

Table 1   Key concepts of chaos theory

| Concepts	Definition
Domain of interaction	Scope of forces of systems, space encompassing all behavior consequences.
Initial conditions	Set of initial states of systems at start period to be focused on.
Strange attractors	Subset of the domain space, patterns of systems behavior which are in a certain kind of order; extremely sensitive to disturbance; usually self-similar, independent of scale, which are termed "fractal."
Bifurcation	Process through which system behavior shifts between two states.
Iteration	Cycle of interaction that provides positive feedback to amplify initial conditions.
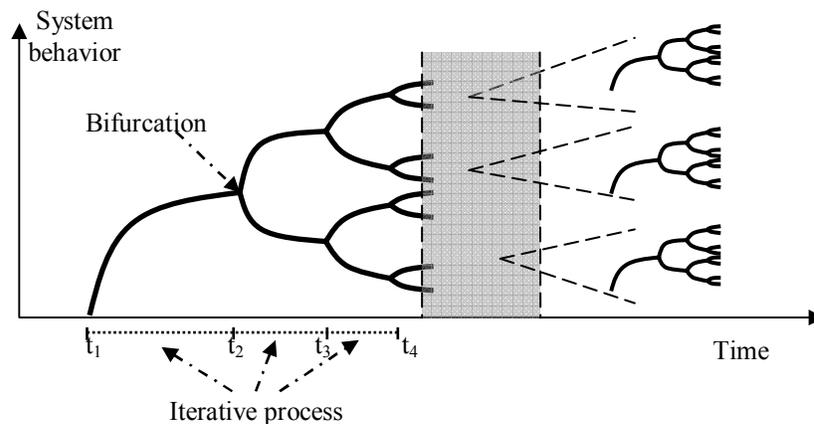
Figure 1   Structure of chaos process

3.1 Elements of Chaos Theory

Past studies ([17], [15], [24]) have suggested a number of key concepts of chaos theory that can be constructed into an interpretive framework. According to the context of our study, we provide definitions listed in Table 1, and illustrate the structure of chaos in Figure 1.

3.2 Suggestions Given by Chaos Theory

The following qualitative properties are often observed in chaotic systems:

1) Sensitivity to initial conditions. Small disturbances, through the iterative non-linear feedback which reinforces the original change, will exponentially accumulate and, as a result, lead to large fluctuations. Thus, chaotic systems are sensitive to initial conditions. In fact, two otherwise identical chaotic systems with slightly different initial conditions will eventually diverge greatly, no matter how small the difference of initial conditions is [12].

2) Fractal: scale invariance. System behavior can be generated through infinitely nested simple elements. Similar patterns are traced by a system whatever horizon is used to view it. Information between part and macrocosm is isomorphic.

4. Weblog System

4.1 Definition

This paper studies weblogs from a systems perspective as suggested by Wilber, that is, every chaotic system is composed of both an exterior (perceptible surface) and an interior (internal essence) [25]. Here, a weblog system is defined as a combination of the weblog, its environment (social environment and technology background) and blogger's behavior (social/off-blog interaction and online/on-blog communication). This paper suggests two dimensions to understanding weblog systems.

4.1.1 Internal vs. External. Weblogs act within both internal and external environments. A weblog is a CMC through which people conveniently interact with each other online; at the same time, weblogs feature in people's off-line/off-blog life, i.e., the real world. As Herring pointed out, the blogsphere has also been fertilized by a series of external events that have inspired blogging activity [10]. These activities are realized through technology-supported functions: permalinks and trackbacks enabling bloggers' online discussion and conversations, and comments enabling bloggers and readers frequent and deep interaction; thus, weblogs act in the real world. The bloggers communicate with their friends and families in the real world as well as with unknown readers on the Internet [18].

4.1.2 Objective vs. Subjective. Weblog systems exhibit both subjective and objective elements. Through technology-supported weblogs, people exchange their opinions on objective events and technology (objective), and people's interaction (subjective) through weblogs shows the power of technology and encourages technological development. Figure 2 illustrates a weblog system in the above two dimensions.

Based on the two dimensions in Figure 2, forces affecting weblog traffic come from three facets: the internal environment, external environment and interface (weblog and blogger). Forces may be from either of these three facets, or from a combination of the different facets. A categorization of forces influencing weblog traffic is given in Table 2.

4.2 Characteristics of Weblog Systems

Involved in the complex interactions between traffic and a number of forces, weblog systems have the following characteristics.

● **Non-linear.** Relationships between forces and weblog traffic are non-linear, e.g., the celebrity effect on the lead in the sharp jump of traffic; an example is the famous Chinese actress Xu Jinglei, who began her blog on 25 October, 2005. Her first post: "Shall I begin my blog career? Not prepared…Wait for me…not prepared… " received 448 comments and 107623 readings, while no links. Thousands of people read it just because she is popular, which soared her to the top in Technorati's ranking on 8th, May 2006. Yet, not all famous people's weblogs enjoy this "celebrity effect." That is, the factor of "celebrity" sometimes (but not always) has striking effects. The second point is that interactions exist among factors. An example is "celebrity" and "comments." Clearly, comments can increase the popularity of the weblog and hence the celebrity of the blogger; the increasing popularity of the weblog, in turn, brings more visits, and hence more comments. The third point is that interaction exists between factors and traffic, as evidenced that "weblog visits increased with the number of new comments and the increased visits were also coupled with more new comments" [11]. It seems that these complex interactions between weblog traffic and factors raise challenges to the methods of reductionism strategy in

traditional linear analysis.

● **Dynamic.** Weblog traffic can change every minute as a result of complex interactions. Figure 3 shows Matt Drudge's weblog (www.drudgereport.com) traffic in terms of reach in a five year strong period recorded by Alexa (www.alexa.com).

● **Deterministic.** Each factor has a specific effect on traffic. Given all the forces in a weblog system, the traffic is deterministic, i.e., in every minute it has a value of traffic. In other words, the future state of the weblog system is causally determined by the current and past states. This shows that there is some order behind the traffic's complex and seemingly random appearance.

In conclusion, a weblog system is a non-linear, dynamic and deterministic system. That leads to:

Proposition 1: **Weblog Systems are Chaotic.**

Table 2 A categorization of weblog system forces

|	Factors	Example
Internal	Technology	Blogging tools: typePad, Userland, iUpload
	Network quality	Network speed, brandwidth
	Conversation networks	Blogger "friends" through permalinks, comments, trackbacks
External	Events	Terrorist acts, political events, financial crisis
	Culture	Individualism/collectivism; independence/interdependence
	Social relationships and interactions	Classmates, friends, familiars Comments and discussion offline
Interface	Blogger's characteristics	Age, gender, education, celebrity
	Blog structure	Contents (quality, frequency of update) Personal information (contact, photos, etc.) Multimedia (images, videos, music), Page setup (tag box, trackback, external links, navigation bar, archive, profile, search engine, etc.) Other (blog age, advertisement, etc.)
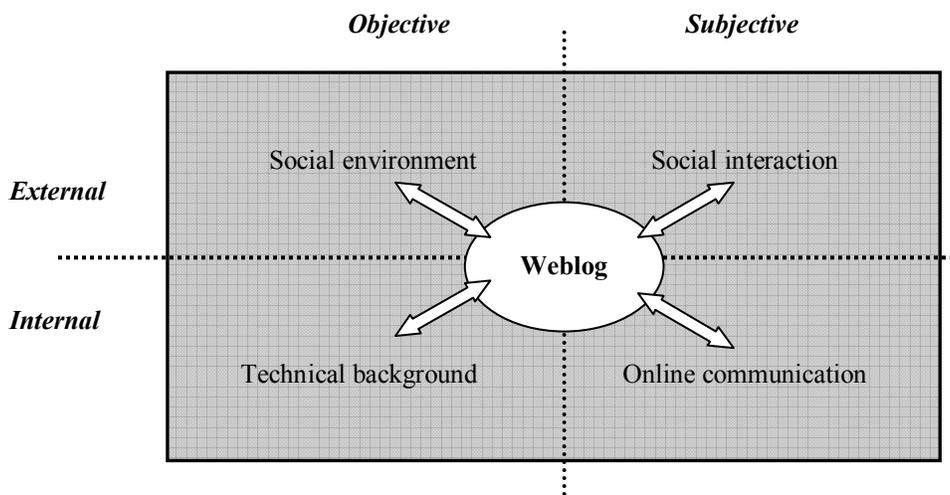
Figure 2   Weblog system in quadrants

4.3 Understanding Weblog Systems in the Chaos Theory Framework

It is noteworthy that the controllable forces of technology, conversational networks and aspects of blog structure have once been linearly statistically explored [5], [8], [11]. Past studies have focused on the characteristics of ease of use and usefulness of use of technology [4], as well as web site usability and design [20]. These are certainly important to blog traffic, as listed in our table. However, a weblog has its own features when compared with past CMC. A weblog is fertilized by events [10], it enhances communications in ways of on-blog/off-blog, and also (for this selective, peer-to-peer communication), its blogger's characteristics are important. Because of these factors which dramatically affect traffic non-linearly, chaos theory seems promising to help people's understanding. Thus, we apply chaos theory interpretively to weblog systems.

Initial conditions: Initial conditions are a set of weblog states affecting factors, as categorized in Table 2, at the starting point of the focal period. Given the repeated cycles of interactions between traffic and factors, very tiny disturbances in initial conditions can be amplified, and lead to large and unexpected fluctuations to traffic through an iterative process. Thus, the traffic is extremely sensitive to initial conditions especially in the long term. For different clusters of weblogs in terms of type (filter, k-log, personal journal, etc.), the degree of sensitivity to initial conditions differs. For example, personal journals may be more sensitive to blogger's social characteristics. Filters, especially "warblogs" and political weblogs, are especially sensitive to events.

Strange attractors: For weblog systems, a strange attractor is the traffic pattern which is a subset of the whole. Traffic could temporarily waver in this subset. In situations where most factors are static and do not act non-linearly, traffic may stay still or fluctuate in a narrow range; or some factors may attract a higher degree of attention and the traffic may jump up suddenly. In a short time period, it may still remain very large. However, these temporary patterns are fragile. Any "knock" on the internal, external or surface conditions may lead to the traffic moving to another pattern or a new strange attractor.

Bifurcation: A bifurcation in a weblog system is the traffic's sudden appearance of oscillations that shift between two values. The bifurcation process is usually caused by non-linear factors such as external

events or blogger characteristics. Familiar examples include a unique report of political events leading to a sudden jump of traffic, or a superstar's behavior in the real world causing people's attention to his/her weblog.

Iteration: Iteration is the process of cycles of interaction between weblog traffic and various factors. An example is the power law distribution and *an inequality suggested by Shirky* [22], those who garnered traffic early in the history of blogging for whatever reason will tend to continue to gain traffic over time in the iteration of "more traffic, much celebrity; much celebrity, more traffic."

4.4 Scale Invariance

A notion of chaos theory is that the patterns of system behavior are independent of scale, exhibiting fractal behavior. In other words, similar patterns could be expected in different scales. In Figure 3, similar layers of wrinkly appearance which are visually distinguishable (following studies in the stock market, using mathematical methods including time series to compute the "dimension of fractal" are expected for further validation) can be observed both at the 5 year level and the 1 year level. In fact, in accordance with the nature of fractals, if we record traffic every minute, it will be observed that whatever the horizon, similar patterns appear. That is, the traffic evolution over years will reflect monthly and daily evolution. What is more, one of the major achievements of chaos theory is its ability to demonstrate how a simple set of deterministic relationships can produce patterned yet unpredictable outcomes [15]. For our specific case, all the patterns can be generated through combination, nesting and iteration of the five fundamental patterns shown in Figure 4. Patterns a, b are mainly the factors when linear relationships are working; patterns d, e are the non-linear effects working; while pattern c is the result of all factors being generally static or effect of factors counteracting.

Figure 3 illustrates the self-similarity of patterns structure. For the whole period (Year 2002-2007), we observed it with the "time rule" of 1 year; the part period (Year 2006-2007), of 1 month. This behavior leads us to:

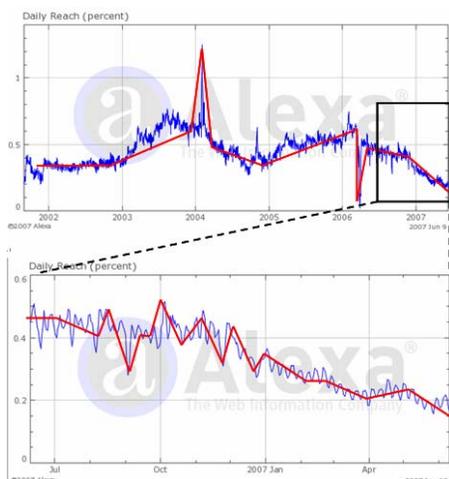*Proposition 2:* **Weblog traffic exhibits self-similar dynamics.**
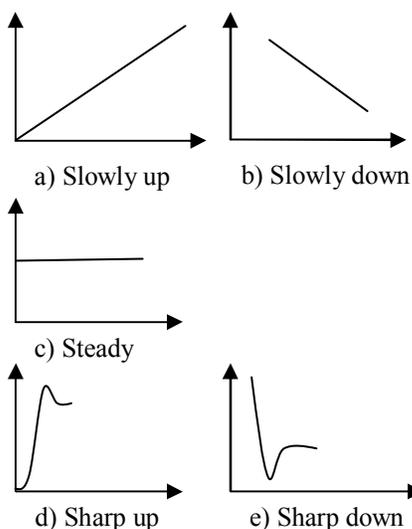
Figure 3   Self-similar dynamics

Figure 4   Fundamental patterns

4.5 Prediction in Short Term and Long Term

According to Proposition 2, traffic patterns are generated by the five fundamental ones exhibited in Figure 4. Given the condition at time "t", computer simulations can specify the weblog traffic at time "t+1" under a certain kind of deterministic algorithm (usually a linear relationship is used to approach non-linear relationships between factors and traffic). Through this step-by-step method from mathematics, forecasting is possible for a short period. However, in the long term, given the sensitive non-linear relationship between traffic and initial conditions, even a small change of the initial condition multiplied over time through iterations will cause large fluctuations. Also, weblog traffic evolves in a dynamic over time as a result of complex interactions among factors of interior, surface and exterior. It is impossible to do a quantitative study with our limited resources and IT technology, leading to:

Proposition 3: **Short term prediction is doable, while long term prediction is impossible.**

5.   Discussion, Implications, Limitations and Directions for Future Research

Chaos theory provides a means of understanding weblog traffic dynamics due to the complex interactions among factors that, based on our explanation, have implications for bloggers.

1) Use small changes to increase large effects through the iteration. Weblog traffic is sensitive to initial conditions and a small positive change may lead to unexpected returns. Bloggers are suggested to maintain details that make for sustained positive change. Examples include broadcasting their blogs everywhere (local communities, blog communities, etc.), and trying to write the content with resources from exact resources in every post.

2) Convert incidents into new opportunities through the effect of non-linear relationships. Weblog traffic sometimes responds abruptly to some factors (patterns d, e), which means opportunities for bifurcation—shifting abruptly to the pattern fluctuates on a much larger value level. It is suggested that bloggers should be prepared and actively make use of these opportunities. For example, they should trace events over time.

3) Be alert that any apparent current state is treated as temporary. Weblog traffic is dynamic, and impossible to predict because traffic is sensitive to initial conditions, which are changing all the time. New initial conditions and strange attractors may come out tomorrow or even in the next minute. Bloggers should be alert and diligently engage traffic competition in the fast growing blogsphere.

This is but a first attempt to study weblogs through the lens of chaos theory which originated and developed in the physics and mathematics contexts. Several limitations exist in this study. First, the study applies suggestions from chaos theory to weblogs. More mathematical consequences are warranted. In proposition 2, it is not sufficient to only visually represent fractals. A mathematical framework needs to be constructed to analyze the

7

similar patterns of weblog traffic in different time scales similar to the study on cotton and stock price curves. Second, more examples and cases for different weblog types (in terms of content, motivation, etc.) are needed to validate the propositions.

Despite these limitations, this constructed conceptual platform opens new avenues for future research, especially empirical studies to further provide directions for practice, including:

1) Categorizing blogsphere in terms of traffic dynamics progress patterns. As suggested by chaos theory, complexity could come from iteration of a set of simple deterministic patterns. In our study we identified five fundamental patterns in blog traffic dynamics. We could apply these patterns to identify blog traffic dynamics. For example, we collected 77 weblogs from the Top 100 on the 7th of June, 2007 from Technorati.com and analyzed traffic (in terms of rank in the whole internet) during the period (typically 2-5 years) that the rank was within the top 100,000. 32 (41.6%) of them (including 25 blogs) ranking in the top 50 exhibit the shape of progress. This is the cluster of successful ones, but what about the others in the weblog ecosystem? For different groups, the balance between chaos and order appearing in periods is different.

Determining the role, type and rank of weblogs in the ecosystem may lead to specific implications for strategy formation. A well-known example is Boeing's vice president of marketing, Randy Baseler, who chose to open up his blog the day before the Airbus A380 was formally introduced as a strong competitor of the Boeing A747. As the vice president of marketing, Randy saw the role of his blog as publicizing his product. He chose to strategically utilize the event so that attention would be given to Airbus's major competitor during the introduction of a new important product. Thus, his "celebrity effect" would garner large traffic and achieve his marketing goal.
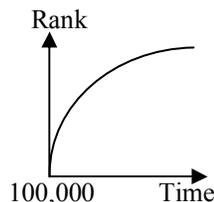

Figure 5 Traffic progress patterns of the success group

2) To understand the non-linear effect between external factors and weblog behavior, empirical relationships deserve exploration. For example, Krishnamurthy found that the daily number of posts increased while the number of links per post decreased in the week after the events of September 11, 2001 [13]. Through the accumulated understanding of external factors and their effect on weblogs (although precise prediction in the long term is still impossible), less uncertainty of weblog traffic prediction could be achieved.

3) Based on the general theoretical platform, potential studies and implications for practice could be suggested in specific contexts. For example, a corporate public-facing blog (which is built to support interaction with customers and publicly represent the company) traffic is partly an indicator that presents company perspectives for public attention and market position. Through chaos theory thinking, managerial implications are suggested. a) It would help to explore significant issues in the organization through watching bifurcations in the traffic. For example, if bifurcation occurs, what is the reason? An examination through the interaction between the posts and comments may give some clues. b) Through these accumulated experiences, a proactive orientation could be established before or during the coming of forces that cause bifurcation. Of course, this demands (and hence develops) an organization's ability to rapidly respond to changes and generate new knowledge.

6. Conclusions

This paper presents chaos theory as a framework for understanding weblog traffic dynamics over time as a result of complex interactions among factors. Based on chaos theory thinking, a weblog system is defined from two dimensions (internal vs. external, subjective vs. objective) according to its communication mechanism as a CMC. Affecting factors are categorized. By conceptualizing a weblog system as a chaotic system, propositions are drawn. While a weblog system exhibits a certain kind of deterministic order which enables short term prediction, long term forecasting is impossible and emergent fluctuations appear unexpectedly due to the traffic being sensitivity to initial conditions. Further, chaos theory suggests that weblog traffic evokes self-similar dynamics in terms of time scale, which signals that weblog traffic dynamics seem complex but do not lack order. There are many implications

for practice that suggest opportunities for future research.

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