Dual Acceptance of Web Diffusion: A Case of Clients and Servers

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This study introduces the concept of dual acceptance to the diffusion of innovation theory and calls for new modifications to the diffusion of interactive media in the particular case of the Web technology, a client/server architecture. The diffusion of Web clients and Web servers creates a dual acceptance phenomenon and crossed-reciprocal interdependence relationships, which stimulate and push the diffusion of Web technology in a faster pace. Mathematically, this study tests the saturation and growth models to the diffusion of these two entities. The preliminary findings imply a strong interdependent relationship during their diffusion process, and verify the hypothesis of dual acceptance.

Introduction

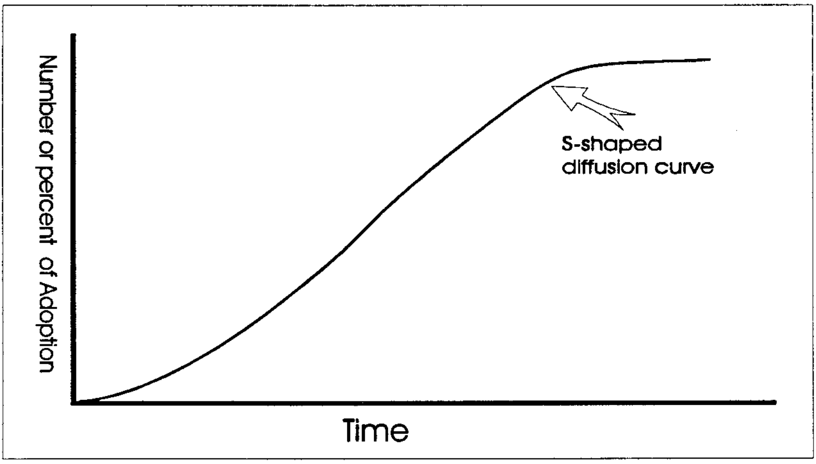
This paper introduces the concept of dual acceptance to the diffusion of innovation theory. Within the last three decades, diffusion theory has been widely applied to different fields in describing how a new knowledge, concept or innovation was adopted through certain channels over time among the members of a social system (Rogers 1995, 3). Researchers of diffusion theory usually have focused on time pattern of adoption, the categorization of adopters and the individual adoption process. The knowledge or innovations studied up to now have been focused on a single entity, and its rate of adoption usually followed a normal, bell-shaped curve when plotted over time on a frequency basis. With the recent fast development of computer networks and the introduction of client/server concept, traditional diffusion of innovation theory may fail to explain how Web technology, a particular case of client/server architecture, accelerate its diffusion with an exponential speed far before reaching its critical mass point.

In this paper, the author suggests that the traditional explanations of diffusion of innovations do not accommodate the client/server architecture, especially in the case of Web diffusion. The author calls for a modification to the diffusion theory by introducing the concept of dual acceptance, aiming to modify the existing theory in the case of client/server architecture.

Interactive Media

Interactive media, a relatively new term, first emerged in the 1980s. The main feature supporting interactive media is its interactivity, a potential possibility of a two-way communication in distance. Like face-to-face communication, interactive media contain the potential ability to "talk back," with a meaningful content and right timing. According to diffusion of innovations theory (Rogers 1995), the adoption of an innovation of interactive media in general includes three important features which are different from non-interactive media: different diffusion curves, critical mass point and reciprocal interdependence.

Figure 1. S-Shaped Curve



Different diffusion curves

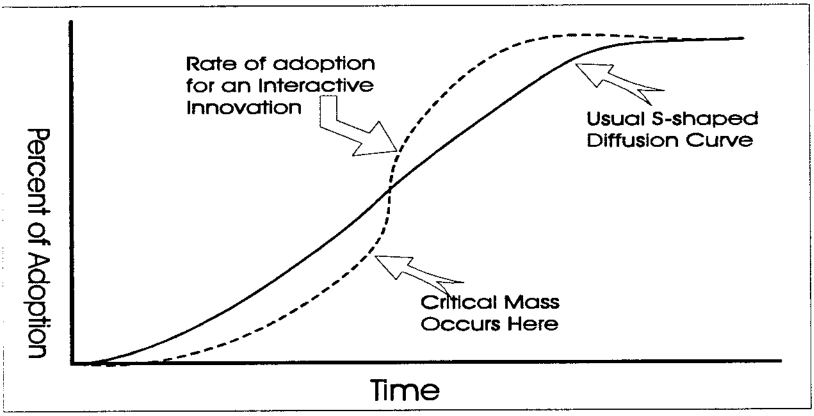
The adoption of a non-interactive innovation usually follows a normal, bell-shaped curve when plotted over time on a frequency basis.

If the cumulative number of adopters is plotted, the result is an S-shaped curve (see Figure 1). In the case of interactive media, the S-shaped curves are different in two ways from other S-shaped curves of traditional diffusion of innovations (Markus 1987, 494; Rogers 1995; Williams et al. 1988, 71). First, the rate of adoption of interactive media is comparatively slow at an early stage in the diffusion process; and second, it is also possible for an interactive medium not to achieve takeoff, and not to form an S-shaped curve as the utility of the whole innovation decreases when more participants drop out.

Critical Mass Point

The second important feature of diffusion of interactive innovations is critical mass (see Figure 2). According to the concept of critical mass, an interactive medium is of little value unless other individuals also adopt the system (Rogers 1995).

Figure 2. The Rate of Adoption for Usual Innovation and Interactive Innovation



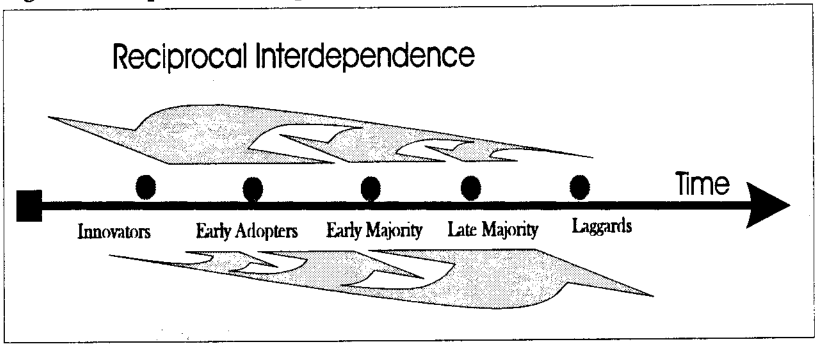
Source: Rogers 1995

It occurs because of the interactive quality of these new media which create a certain degree of interdependence in the adoption decisions of the members of a system (Williams 1988, 72). Mathematically, this is the point at which the diffusion curve begins to increase at an accelerated rate, defined as occurring at the point of 16 percent adoption, one standard deviation before the mean time of adoption in a system. In the real world, this assumption of 16% point, one standard deviation from the mean, has not been empirical verified.

Reciprocal Interdependence

The third feature is reciprocal interdependence (Markus 1987, 491). In the case of non-interactive innovations, the earlier adopters have a sequential interdependence effect on later adopters. As more and more individuals in a system adopt the non-interactive innovation, it is perceived as increasingly beneficial by future adopters. But in the case of interactive innovations, not only do earlier adopters influence later adopters, but later adopters also influence earlier adopters (see Figure 3), in a process of reciprocal interdependence. The benefits from each additional adoption of an interactive innovation increase not only for all future adopters, but also for each previous adopter (Markus 1987, 502).

Figure 3. Reciprocal Interdependence



Dual Acceptance

By introducing the concept of dual acceptance, the author suggests that the diffusion of Web technology is beyond general interactive media, and the concept of critical mass and reciprocal interdependence are not enough and accommodation to explain the diffusion of the Web.

Web technology, a non-traditional innovation and a new interactive medium (Huneycutt 1996, 11) created in the early 1990s, was developed and diffused at a speed of exponential growth. This special interactive medium offers a bi-directional channel between Web clients and Web Servers (Hoffman and Novak 1996, 50). On the one hand, the WWW is dramatically altering the traditional view of media' role, which is to inform, remind and persuade recipients. On the other hand, the Web has the potential to radically change the way businesses or organizations interact with their customers. The Web, which involves of a mechanism underlying its networking and hyperlink architecture, includes a high level of interaction between Web sites and Web clients during a communication process.

The concept of dual acceptance suggests that the diffusion pattern of the Web, a special case of client/server architecture, includes two distinct entities: Web servers and Web clients, respectively.

First, the interactivity of the Web occurs actually between clients and servers, not among servers or among clients, and this special feature of two distinct entities, clients and servers, creates a *new many-to-many communication model* for diffusion theory. Second, the diffusion of Web servers largely depends upon the diffusion of Web clients whereas the diffusion of Web clients depends upon the diffusion of Web servers, and this new feature of dual-entity diffusion creates a *dual-acceptance phenomenon*. Third, in a process of reciprocal interdependence, earlier Web client-side adopters influence later Web server-side adopters, and later Web server-side adopters influence earlier Web client-side adopters, and this bi-directional feature of reciprocal interdependence provides a feature of *crossed-reciprocal interdependence*.

A New Many-to-Many Model

In general, interactive media fulfill the many-to-many communication model because interactivity occurs between many adopters to many adopters. In contrast, the interactivity of the Web occurs between clients and servers. This special feature creates a new many-to-many model. In this model, the first "many" refers to "clients" and the second "many" refers to "servers." Clients of the Web interact with Web servers directly and Web servers interact directly with Web clients.

Dual-Acceptance Phenomenon

The new feature of the Web new communication model affects its diffusion pattern and creates a dual-acceptance phenomenon. The diffusion of Web servers largely depends upon the diffusion of Web clients, whereas the diffusion of Web clients largely depends upon the diffusion of Web servers. This phenomenon is called as "dual acceptance" of adoption. If there are only a few Web servers available on the Internet, using the Web is of little value to users. That is, the rate of adoption of Web clients actually depends upon the number (or the utility) of Web servers, not the number of Web clients. Similarly, if there are only a few Web clients on the Internet, creating a Web server is of little value to organizations or businesses. That is, the rate of adoption of Web servers depends upon the number of users (or the usage), not the number of Web servers.

Crossed-Reciprocal Interdependence

The reciprocal interdependence occurs only between Web servers and Web clients, not between clients or between servers. In a process of *reciprocal* interdependence, earlier Web client-side adopters influence later Web server-side adopters, and later Web server-side adopters influence earlier Web client-side adopters. On the one hand, the benefits from each additional Web server adoption do not increase directly for all future and previous Web server adopters, but for all future and previous Web client adopters. On the other hand, the benefits from each additional Web client adoption do not increase directly for all future and previous Web client adopters, but for all future and previous Web server-side adopters.

Markus (1987, 507) believed that traditional explanations of diffusion of innovations do not accommodate interactive media. Today, with these variants from interactive media, the Web itself is calling for a further modification to the critical mass aspects of diffusion theory. Several questions are not answered yet. For example, what is the relationship between the critical mass of clients' rate of adoption and servers' rate of adoption? Are these two points of critical mass different from general interactive media in terms of their timing of occurrence? Will the drop off of one side affect the rate of adoption of the other? Is the relationship between number of Web server adopters and number of Web client adopters a linear? More explorations are needed to answer these questions.

The purpose of this study is to mathematically and statistically test the concept of dual acceptance of client/server architecture, and explain the relationship between these two distinct entities, in the particular case of Web diffusion. Several mathematical models are used to describe and test the diffusion of the two entities, aiming to find the fitness of mathematical models and to empirically verify the concept of "dual acceptance."

Methodology

Mathematical Curves Estimation

It is possible and appropriate to illustrate S-shaped curves by using mathematics models when addressing the relationship between number of adopters and time serials. Mathematical models, which are based on the best fit between empirical data and model formula, are mostly used for forecasting purposes. Usually, parameters in a mathematical model are estimated by regression analysis methods. By building a visualized and steady model for the diffusion of Web technology, it becomes possible to use the mathematical model to forecast Web diffusion in the future and investigate the relationship of dual acceptance. Besides, with an appropriate model, several research questions addressed in the previous section may possibly be answered or explored, such as the relationship between Web servers' diffusion and Web clients' diffusion and the occurrence of critical mass point.

Based upon the fact that the diffusion pattern of innovations always forms an S-shaped curve through their adoption process, this study chooses five mathematics models of curve estimation for testing purposes. The typical approach using mathematical functions to describe and model the growth of adoption process is to use saturation models and growth curves. One of important features of saturation models and growth curves is that the increasing (growth) rate is a function of time. As time proceeds, the growth rate increases and the S-shaped curve is generated. However, an important feature built into saturation models but not to growth curves is the upper limit of the growth. As the remaining adopters become less and less, the growth rate is expected to be slow down when the rate of adoption reaches the saturation level of the diffusion in a certain social system. Since we do not really know the saturation level of Web servers and Web clients, this study tests both saturation models and growth curves. Namely, they are logarithmic, quadratic, cubic, exponential and logistic. Their regression equations are listed below:

(1) Logarithmic $Y = b_0 + b_1 \log t$

(2) Quadratic $Y = b_0 + b_1 t + b_2 t^2$

(3) Cubic $Y = b_0 + b_1 t + b_2 t^2 + b_3 t^3$

(4) Exponential $Y = b_0 e^{b_1 t}$

(5) Logistic $Y = \dfrac{1}{(1/u) + b_0 b_1^t}$

Data Source and Measurement

In order to proceed with the testing for mathematical models of Web diffusion, two different sets of data are required. The first set of data includes two variables: time series and number of Web servers at each time slot. The second set of data includes time series and number of Web clients at each time slot. The number of Web servers at each time slot has been roughly recorded by Matthew Gray of the Massachusetts Institute of Technology, who ran an application to ping each IP address on the Internet between 1992 and 1996, trying to find out the total number of Web servers running on the Internet. Since July 1995, Netcraft (http://www.netcraft.com/survey/) also ran surveys to count the total number of Web server on the Internet. The number of Web servers on the Internet is less controversial and is re-distributed by the Internet Society Organization (http://http://info.isoc.org). It is well believed that the data for the number of Web servers is valid and reliable (see Table 1).

Table 1. Data on the cumulative number of Web servers

Date	Number of Web servers
JUN 1992	4
NOV 1992	26
JAN 1993	50
JUN 1993	130
DEC 1993	623
JUN 1994	2738
DEC 1994	10022
JUN 1995	23500
NOV 1995	73500
Jan 1996	100000
Jun 1996	252000
July 1996	299403
Aug. 1996	342081
Sep 1996	397281
Oct 1996	462047
Nov 1996	525906
Dec 1996	603367
Jan 1997	646162
Feb 1997	739688
Mar 1997	883149
Apr 1997	1002612
May 1997	1044163
June 1997	1117255
July 1997	1203096
Aug 1997	1269800

Source: http://info.isoc.org/g26uest/zakon/Internet/History/HIT.html "WWW Growth."

On the contrary, there is less consensus about the number of Web clients at each time period. The estimations of the total number of Web clients vary and sometimes contradict each other partly due to three reasons. First, it is practically impossible and cost prohibitive to detect the total number of Web clients on the Internet. Second, a reliable and valid sampling technique has not been created for the best estimation of total number of Web clients on the Internet. Third, the definition of "Web clients" and measurements have not been standardized so the results have become inconsistent. See Hoffman et al. (1996) for the discussion of these potential problems. Before a standardized measuring method is available and accepted by the whole Internet society, the estimations of total number of Web clients on the Internet would always contradicted each other. As John Quarterman of MIDS (Matrix Information and Directory Services, Inc, (http://www.mids.org/mids/) says:

> The Internet is distributed by nature. This is its strongest feature, since no single entity is in control, and its pieces run themselves, cooperating to form the network of networks that is the Internet. However, because no single entity is control, nobody knows everything about the Internet. Measuring it is especially hard because some parts choose to limit access to themselves to various degrees.

The available data about total number of users on the Internet in each time period have never shown a consistent estimation even though all of them were derived from empirical studies. Table 2 illustrates the inconsistency of those estimations. In order to test the diffusion of Web clients, this study discarded those numbers which are inconsistent or contradict with others, and built a new table (see Table 3).

Table 2. Data on the cumulative number of Web clients (in Millions)

Date	Number of Web clients	Sources
Oct 1994	13.5 M	MIDS, http://www.mids.org/ids2/
Oct 1995	26.4 M	MIDS, http://www.mids.org/ids3/
1995	14.3 M	CommerceNet/Nielsen Internet Demographics Survey
Dec 1995	7.5 M	FIND/SVP, http://www.findsvp.com/
Dec 1995	17 M	Baruch College School of Public Affairs and polling company Louis Harris and Associates
Feb 1996	9.5 M	Find/SVP http://etrg.findsvp.com/
Feb 1996	5.8 M	O'Reilly & Associates?
1996	25.96 M	CommerceNet/Nielsen Internet Demographics Survey
April 1996	20 M	Business Week magazine
Dec 1996	31.4 M	International Data. http://www.idcresearch.com
1997	38.5 M	CommerceNet/Nielsen Internet Demographics Survey
April 1997	40 M	Business Week magazine
Nov 1997	56.85 M	IntelliQuest Information Group, Inc. 16 or older

Table 3. Data on the corrected cumulative number of Web clients

Date	Number of Web clients
OCT 1992	100*
Dec 1995	7.5 Million
Feb 1996	9.5 Million
APR 1996	20 Million
Dec 1996	31.4 Million
Nov 1997	56.85 Million

* This number is based on author's best guess.

Five mathematics models of curve estimation are tested for their goodness of fit to the diffusion of Web clients and Web servers. The procedure for the testing includes six steps. First, the observed data are plotted with variable "time slot" as X axis (independent variable) and variable "number of Web servers (or Web clients) " as Y axis (dependent variable). Variable "time slot" (X axis) is recoded from actual date to values of integer, ranged from 1, representing Oct. 1991, to 38, representing Nov. 1997. An interval of 1 in "time slot" represents 2 months, and total range of 38 represents 76 months. Second, all Betas and constants in regression equations are calculated for each mathematics model. Third, R Squares are calculated in order to detect the amount of variance explained by each model. Fourth, all significant levels (p-value) are calculated at 0.01 level in order to understand the possibility of chances for the fitness. Fifth, each model is then plotted against observed data to visually see the goodness of fit. All calculation processes are omitted here to save space but are available from the author upon requests. The results are displayed in Table 4 for Web servers and table 5 for Web clients.

Table 4. Statistical Analysis of Mathematical Models for Web Servers Diffusion

Model Name	R Square	P-value	Equation
Logarithmic	0.3	0.0135	Y=-439442+263197logX
Quadratic	0.88	0	Y=289687-65096X+2399X**2
Cubic	0.98	0	Y=-110677+54482X-5354X**2+136X**3
Exponential	0.99	0	Y=1.23(exp**(.41X))
Logistic	0.99	0	Y=1/(1/3000000000-.8116(.6638**X))

Table 5. Statistical Analysis of Mathematical Models for Web clients Diffusion

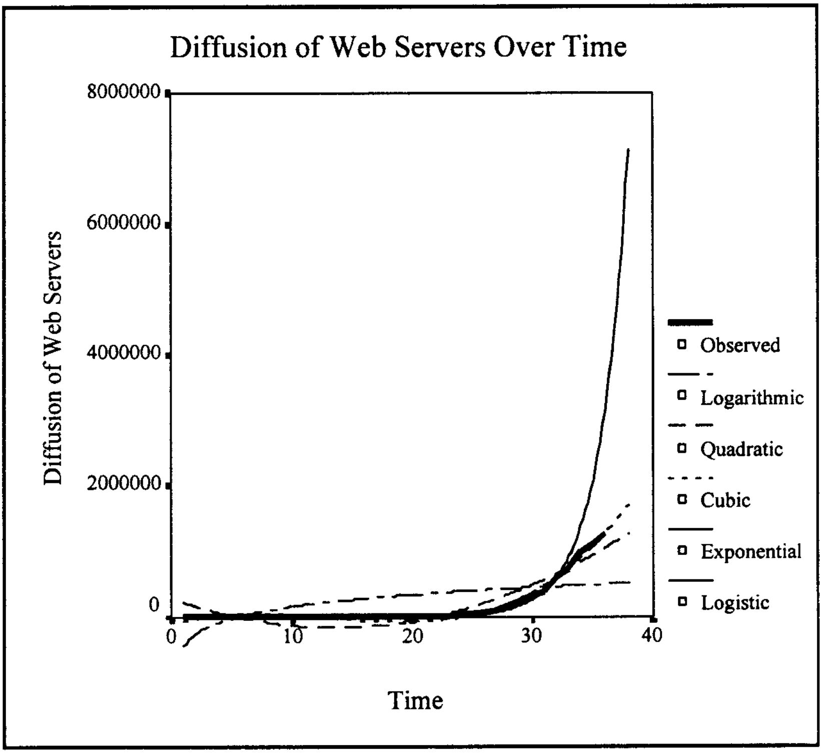
Model Name	R Square	P-value	Equation
Logarithmic	0.37	0.14	Y=-7934667+9547886logX
Quadratic	0.97	0.0011	Y=5566359-2237314X+93907X**2
Cubic	0.98	0.0049	Y=-859719-204691X-26786X**2+1887**
Exponential	0.95	0.0002	Y=.2.23(exp**(.52X))
Logistic	0.95	0.0002	Y=1/(1/3000000000+.0.45(.59**X))

Data Analysis

Diffusion of Web Servers

Several models are illustrated as below. Figure 4 is the plot of rate of adoption of Web servers (observed data) over time against hypothetical plots of logarithmic, cubic, quadratic, exponential and logistic. According to value of the amount of variance explained (R Square) and the p-value, the goodness of fit for quadratic, cubic, exponential and logistic functions is very high. However, visually, the models of exponential and logistic (both are overlapped) reach the takeoff point (critical mass) at about 33 and start to deviate the observed plot dramatically. On the contrary, the observed plot reaches its takeoff at about 25 point and follows the track of cubic model only. It seems that the cubic model explains the diffusion of Web servers better than others.

Figure 4. Plots of Diffusion of Web Servers against Hypothetical Models



Diffusion of Web Clients

Figure 5 is the observed plot of diffusion of Web clients over time against hypothetical plots of logarithmic, quadratic, cubic models. Figure 6 is for exponential and logistic models against observed plot. With very high values of R square, quadratic and cubic models explain the diffusion process of Web clients very well. Visually, Quadratic has the least deviation from the diffusion track of Web clients. According to the plot of observed data, the diffusion of Web clients reaches the takeoff point (critical mass) at about 28.

Figure 5. Plots of Diffusion of Web Users Against Hypothetical Models [1]

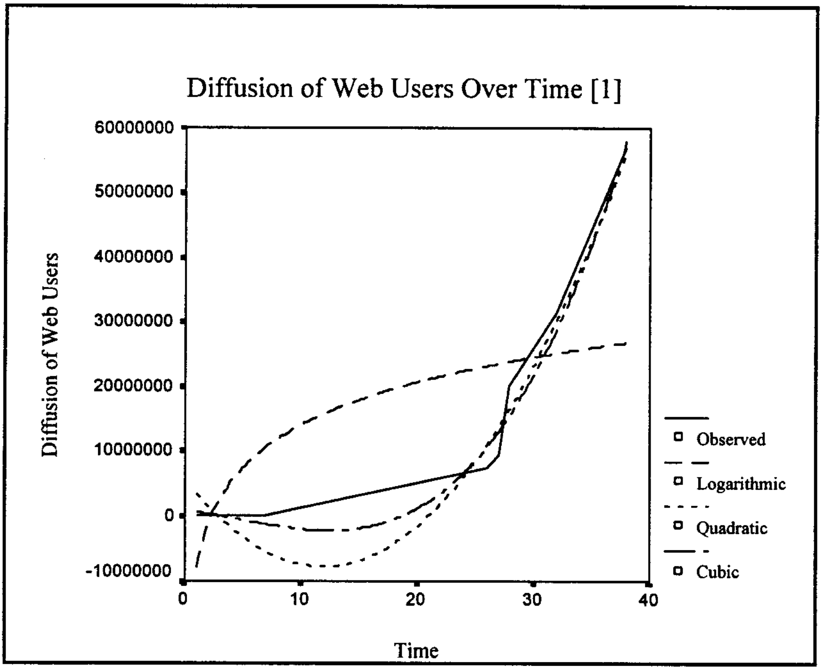
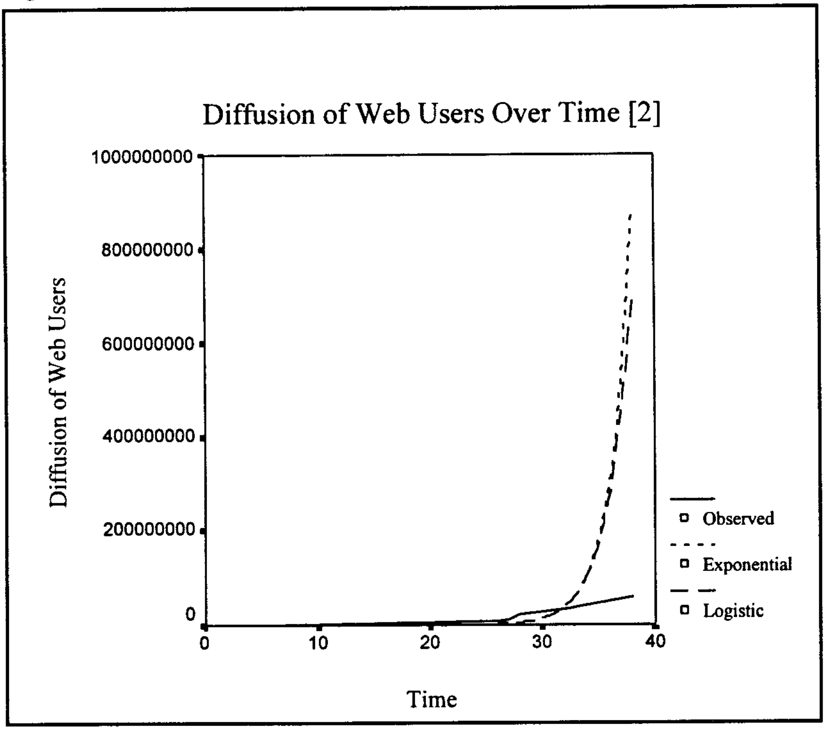


Figure 6. Plots of Diffusion of Web Users Against Hypothetical Models [2]



Discussion

With the limited availability of valid data set for total number of Web clients, this study still provides some useful preliminary findings to the concept of dual acceptance and crossed-reciprocal interdependence. They are summarized as following four points:

First, as appeared in the previous section, neither the diffusion of Web clients nor the diffusion of Web servers is "exponential", a term most people used to describe the fast diffusion pace of Web technology. Rather, the best term to describe the growth rate of Web servers is "cubic" while "quadratic" may be the best term for the diffusion of Web clients. If either Web clients or Web servers have grown exponentially, we should have had 10 times more users or servers by now.

Second, the data of this study have provided strong support for the concept of dual acceptance. The author argued that the diffusion of Web technology includes two distinct entities: Web servers and Web clients. The author also asserted that the rates of adoption of these two distinct entities are different and should be studied separately. The data analysis from the above mathematical testing and modeling process indicates that the S-shaped curve of the Web servers' diffusion is different from the S-shaped curve of the Web clients' diffusion. Not only do they own different plots of curves but also fit to different mathematical models while the statistical significance level is set at .001.

Third, the plots of diffusion of Web servers and Web clients are very different from traditional diffusion of innovations in terms of their critical mass point and S-shaped curves. Mathematically, the critical mass point occurs at 16% of adoption, one standard deviation from the mean while in the real world the critical mass point of diffusion of innovations are rarely known. From this study we found out that the diffusion of Web technology already had reached its critical mass point, if we consider the two takeoff points in both Web servers' diffusion and Web clients' diffusion are their critical mass points. Nevertheless, these two points are not yet close the 16% hypothetical point if we consider the saturation level in a global concept.

Fourth, this study also provides some possible explanations to the fast diffusion speed of Web technology. The special diffusion speed of Web technology may be caused by two new features of Web diffusion. First, it may be the new many-to-many communication model that actually facilitates the diffusion process and accelerates the rate of adoption. Second, it may be the interaction between these two entities, Web servers and Web clients, that motivate and stimulate the diffusion of Web technology to move in a faster pace.

In short, the diffusion of Web technology is a new concept which has not been sufficiently explored. This paper proposed the concept of dual acceptance, aiming to explain the diffusion of client/server architecture in the particular case of Web technology, and also to accommodate diffusion of innovation theory to the new distributed communication technology. Further research on this issue is needed to expand our knowledge about the dual acceptance of diffusion of innovations.

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