Trajectories of Individual WWW Usage: Implications for Electronic Commerce

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Abstract
The number and variety of Web sites offering information, commerce and services has multiplied since 1995. The number of users making use of the Internet and the Web has also grown tremendously. Yet at the level of the individual, little is known about the trajectory of change over time in number of visits to Web sites. Drawing upon recent advances in semi-parametric, group-based statistical modeling, we examine whether there are distinctive clusters of such trajectories. Using longitudinal data from 1995-1998 on visits to distinctive Web sites, we provide answers to these questions. We find that WWW users can be clustered into four groups with distinct trajectories of use. These groups achieve saturation in their extent of Web usage as measured in the number of distinct Web sites they visit over time. We also develop demographic profiles of these different user groups. These results have important implications for Internet marketing.

1. Introduction
With the advent of commercialization in the Internet, the WWW has become a marketplace. Visits at given Web sites are considered an important measure of market share and success, and indeed, many Web sites have enjoyed a steady increase in the number of visits. Our study reveals that this increase is due to the immense growth in the number of WWW users rather than an increase in WWW usage at the individual level.

In view of the exponential growth in Web sites available (see figure 1), it is reasonable to expect that this increase in number of Web sites has increased individual WWW usage at least among some groups of people. To test this hypothesis we made use of a new statistical method [13] developed for psychologists to assist in the identification of groups of individuals with similar
A major finding of the HomeNet project was that demographic factors – generation, race, and gender – rather than socioeconomic factors – income and education – or psychological factors – like social extraversion and attitudes towards computing – were the major factors that influence use. The fact that neither household income nor education predict Internet use, does strongly suggest that if economic barriers to Internet access were removed, people across socioeconomic lines would use the Internet. However, gender, race, and generation were all strong predictors of Internet use in the sample. For example, teenagers turned out to be much heavier users than their parents, and among teenagers, boys are heavier users than girls. Through detailed monitoring of family's Internet use, periodic surveys, and interviews with family members, the HomeNet project measures the demand for and impact of electronic communication and telecommunication services over time. Documents about HomeNet are at http://homenet.andrew.cmu.edu/Progress.

3. A Semiparametric, Group-Based Approach for Analyzing Developmental Trajectories

A trajectory describes the pattern of change of a behavior over time. [13] demonstrates a distinct semiparametric, group-based approach for modeling trajectories. This group-based modeling approach assumes that the population is composed of a mixture of distinct groups defined by their trajectories. For example, do some groups of people follow a trajectory of exponential growth in Web sites visited while others display a pattern of initial growth followed by steady decline? The resulting trajectories are compared to the overall trend in the number of Web sites, which multiplied exponentially in the period of observation.

Section two briefly describes our data, the HomeNet project at Carnegie Mellon University. Section three describes the semi-parametric, group-based statistical methodology and its application to the HomeNet data. Section four presents the results of the analysis. Finally, section 5 discusses the implications for electronic commerce.

2. The HomeNet project at Carnegie Mellon

HomeNet is a field trial at Carnegie Mellon University whose aim is to understand people’s use of the Internet at home. Starting in 1995, it provided families with hardware and Internet connections and carefully documented their usage of on-line services such as electronic mail, computerized bulletin boards, chat groups, and the World Wide Web. The number of individuals in the project grew from 156 in early 1995 to 339 in early 1998. Specifically, the HomeNet data is assembled from five sources: [9]

- Computer-generated use records of electronic traffic, newsgroups read and posted to, Web sites visited, and time on the Internet
- Pretrial, bimonthly, and post trial questionnaires
- An archive of HomeNet newsgroup messages
- A log of help requests
- Home interviews

A developmental trajectory describes the developmental course of a behavior over time. Here we apply this method for the first time to the ‘development’ of WWW usage. We focus on the analysis of the number of distinctive Web sites accessed over time as a measure of the user’s interest in the World Wide Web. The method allows us not only to identify groups of different levels of usage, it also identifies distinctive trajectories of the development of Web usage over time. It identifies for example, whether some groups of people follow a trajectory of exponential growth in Web sites visited while others display a pattern of initial growth followed by steady decline. The resulting trajectories are compared to the overall trend in the number of Web sites, which multiplied exponentially in the period of observation.

A major finding of the HomeNet project was that whereas the applications in developmental psychology were aimed at identifying distinctive developmental patterns in behaviors like hyperactivity, our objective is to use this method for the purpose of identifying distinct groups of “developmental trajectories” of WWW usage. To do this the method was applied to data from the HomeNet project at Carnegie Mellon University [9]. The HomeNet project has collected data on individual Internet usage and demographics from a panel of users from 1995 onwards, when the Net became popular.

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The precision of an individual’s assignment to a specific group. The pitfalls of constructing groups with subjective classification procedures, such as overfitting – creation of trajectory groups that only reflect random variation – are avoided. The data themselves are used to identify the number of groups that best fits the data and the shape of the trajectory for each group. Finally, the data also provide an estimate of the proportion of the population whose measured behavior conforms most closely to each trajectory group.

The method can handle three different data types - count, binary, and psychometric scale data. However, for the purpose of this article which analyzes a count of distinctive Web sites visited, we focus on count data only. The count data is assumed to be generated by an underlying Poisson process. Specifically, for each group $j$, it’s rate of Internet usage in week $t$ following installation of the Internet connection, $\lambda_{jt}^\prime$, is assumed to follow a third order polynomial:

$$\log(\lambda_{jt}) = \beta_0 + \beta_1\text{week}_t + \beta_2\text{week}^2_t + \beta_3\text{week}^3_t \quad (1)$$

The shape of the trajectory can vary by suitably setting $\beta_0, \beta_1, \beta_2,$ and $\beta_3$, the model’s coefficients. They are superscripted by $j$ to denote that the coefficients are not constrained to be the same across the $j$ groups. This flexibility allows for easy identification of population heterogeneity not only in the level of behavior at a given week but also in its development over time. The parameters of interest - $\beta_0, \beta_1, \beta_2,$ and $\beta_3$ - are the product of maximum-likelihood estimation. For a detailed derivation of this likelihood see [13].

The selection of the model that fits the data best involves: (a) determination of the optimal number of groups to compose the mixture and (b) determination of the appropriate order of the polynomial used to model each group’s trajectory, where order refers to the degree of the polynomial used to model the group’s trajectory. For example, a second-order trajectory is defined by a quadratic equation, a first-order trajectory is defined by a linear equation in which $\beta_2$ and $\beta_3$ are set equal to zero, and a zero-order trajectory is defined by a flat line in which $\beta_1, \beta_2$ and $\beta_3$ are set equal to zero. We follow the lead of [3] and use the Bayesian information criterion (BIC) as a basis for selecting the optimal model. For a given model, BIC is calculated as follows:

$$\text{BIC} = \log(\text{L}) - 0.5 \times \log(\text{n}) \times (k) \quad (2)$$

where $L$ is the value of the model’s maximized likelihood, $n$ is the sample size, and $k$ is the number of parameters in the model. [8] recommend selection of the model with the maximum BIC. Since BIC is always negative, the maximum BIC will be the least negative value.

Once the model that fits the data best is found, for each individual $i$ the probability of membership in group $j$ can be calculated on the basis of the individual’s longitudinal pattern of behavior. Furthermore, demographic factors that distinguish the populations of the various trajectory groups can be identified easily.

The software used to estimate these models is a customized SAS procedure that was developed with the SAS product SAS/TOOLKIT. Note that this software assists the user in all the necessary steps of modeling the data: It helps finding the model that fits the data best by calculating BIC scores, it estimates the parameters for a given model, and it computes the probabilities of group membership for each given individual as well as the demographic factors that discriminate the various groups. Furthermore, it uses the SAS/GRAPH software for visualization of the trajectories. The procedure is a program written in the C programming language and is designed to interface with the SAS system to perform model fitting. It accommodates missing data. Thus, individuals with incomplete assessment histories do not have to be dropped from the analysis. Also, time between assessment periods do not have to be identical across participants. The software is available on request and is described in detail in [7].

4. Developmental Trajectories of WWW usage in the HomeNet data

Figure 2 depicts the average utilization for the entire sample over the study period. Observe that in contrast to the exponential growth in Web sites available as shown in figure 1, there is in actually a large decline in the average number of distinctive Web sites accessed. However, this population average maybe concealing important heterogeneity across subgroups. In particular, it is possible that there are some groups of heavy users, non-users, moderate users etc, that balance each other out. Different groups of people may exhibit different kind of behavior.
The group of ‘non-users’ was composed of individuals who, but for a few visits to Web sites immediately after the start, basically did not use the WWW throughout the observation period. This group accounts for estimated 49.9% of the sampled population. The saturation level of ‘non-users’ is close to zero, indicating that this group did not find the WWW useful, following a short period of ‘surfing around’ or ‘exploring’ the Web. The second group of individuals – moderate users - start WWW usage at a higher level and follow a downward path in WWW usage to a point of saturation between 3 and 4 distinctive Web sites per week. This group is estimated to constitute 35.5% of the population. Among the population that actually uses the WWW (group 1 excluded) it accounts for 70.9% of the population.

The third group - heavy users - initiate WWW usage at a high level between 25 and 30 distinctive Web sites per week. However, thereafter for the period of observation their utilization steadily declines. Their saturation point cannot be estimated, however, it seems to be somewhere below 10 distinctive Web sites per week. This group accounts for 10.2% of the overall population or 20.4% of the WWW users.

Table 1: Group percentages

<table>
<thead>
<tr>
<th>Group Percents</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>non-users</td>
<td>49.9%</td>
</tr>
<tr>
<td>moderate users</td>
<td>35.5%</td>
</tr>
<tr>
<td>heavy users</td>
<td>10.2%</td>
</tr>
<tr>
<td>very heavy users</td>
<td>4.3%</td>
</tr>
</tbody>
</table>

Figure 2: Average number of distinctive Web sites accessed at a given week

We applied the method described in the previous section to those HomeNet data on individual WWW usage to test for the presence of such heterogeneity. We consider the trajectories ‘learning curves’ of WWW usage. Our purpose is to test whether the obvious changes in the WWW between 1995 and 1998, such as rapid increase of the number of Web sites available, commercialization of the Net and the advent of banner ads, have a positive impact on these ‘learning curves’. All of the sampled households initiated their WWW usage in this period of dramatic change in the Internet.

Based on the Bayesian information criterion we find that WWW users can be clustered into four groups with distinct trajectories of use. The four-group model has the polynomial orders of 2, 2, 2, and 3 for the groups 1, 2, 3, and 4 respectively. Figure 3 depicts the results of the analysis of the HomeNet data. It displays the actual and predicted trajectories of the four groups which we label “very heavy users”, “heavy users”, “moderate users”, and “non-users”. Also, because the utilization rates of the latter two groups are so much lower than the former two groups, figure 4 is included showing only learning curves of the moderate- and non-user groups. The solid lines represent actual behavior and the dashed lines represent predicted behavior. Table 1 reports the estimated proportion of the population belonging to each of these groups.

![Figure 2: Average number of distinctive Web sites accessed at a given week](image)

![Figure 3: Number of distinctive Web sites accessed at a given week](image)

\[\text{Equation 1}\]

\[\text{Expected values are computed as the mean behavior of all persons assigned to the various groups identified in estimation. As described below, the assignments are based on the posterior probability of group membership.}\]
Finally, a ‘very heavy user’ group was identified and is estimated to make up 4.3% of the overall population or 8.6% of the WWW using population in the HomeNet sample. This group consists of users who started at a very high level, nearly 70 sites per week and who, aside from some modest temporary increases and decreases, settle into a usage rate of about 50 sites per week.

In summary, all the groups achieve a saturation in their extent of Web usage as measured by the average number of distinctive Web sites visited per week. This saturation level is independent of the number of Web sites available. For 49.9% of the population called ‘non-users’, this saturation level is close to zero. For ‘moderate users’ who account for 70.9% of the people who actually use the WWW, this saturation level is about 4 distinctive Web sites per week. ‘Heavy users’ tend to visit nearly 10 distinctive Web sites per week. A minority of very heavy users has a saturation level that is about 50 distinctive Web sites per week.

The method allows direct testing of whether trajectories predicted by theory are actually present in the population. The hypothesis of finding at least some groups that follow the overall trend of increasing number of distinctive site visits cannot be confirmed. On the contrary, all the groups follow a downward path, indicating that, after a period of ‘surfing around’ and ‘exploring’ the WWW users seem to focus on a limited number of sites. This is particularly the case for the large group of ‘moderate users’. Apart from the group of ‘heavy users’, given clusters of users do not change behavior much over time. The increase of available Web sites did not lead to an increase of WWW usage on the individual level. There is no evidence for an upward trend. This is of particular interest if one considers the dramatically increasing number of banner ads in the Web, which are supposed to trigger a higher number of visits to distinctive Web sites. This does not seem to be the case for the three year long trajectory groups identified in the analysis. Note that there might be individuals who actually show an increasing WWW usage pattern. However, our analysis reveals that this group, if it exists, is not large enough to form a distinctive group of individuals.

As a next step we analyzed which demographic factors characterize the identified clusters and developed profiles of these different user groups. One major finding of former analysis of the HomeNet data was that social demographics – generation, race, and gender – rather than socioeconomic and psychological factors – like income, social extraversion and attitudes toward computing – were the major determinants of use [9]. Therefore we focused on variables such as gender, race and position in the family rather than income and education. Tables 3 shows the demographic differences across the various groups.

The summary statistics reveal that individuals in the groups that use the WWW heaviest tend to be younger, male, and white. Teenagers, particularly boys, use the Internet substantially more than their parents. The group of heavy users and very heavy users consists mostly of sons and daughters. Conversely, the group that make little use of the WWW (‘non-users’) is disproportionately comprised of adult females and minorities. These result agrees with [9].
increase in WWW usage in terms of visits to distinctive Web sites. The effectiveness of banner ads, which are supposed to trigger a higher number of visits to distinctive Web sites, might be questioned. This confirms existing sources of consumer response data on banner ads that propagate that with increasing exposure to passive banner ads, the probability that a consumer will click on it becomes close to zero [2].

An important question is why users reach saturation? Apart from what can be best described as a ‘learning experience’, where users explore the Web first and reach saturation points afterwards, insights can be gained from research that has been conducted on cognitive processing limits of individuals. The increasing number of Web sites available in general and the increasing number of hits after querying a search engine in particular is in this regard what is commonly referred to as ‘information overload’. Early research [10] dealt with this issue in a general way. More recent research [4,5] links individual processing limits to online behavior, although it deals with computer mediated communication in a narrower sense by focusing on media that require a higher level of interaction, such as Email and IRC. Generally speaking, a way to deal with information overload is clearly to change or restrict behavior so that information becomes manageable, which indirectly anticipates the saturation we found. However, a deeper analysis of cognitive processing limits of individuals using the WWW is beyond the scope of this paper and is a topic that requires further research.

Given cognitive processing limits of individuals, our finding of saturation in number of Web sites visited on a weekly basis has potentially important implications for personalized WWW search engines and personalized recommender systems. Given an individual ‘capacity’ for WWW usage, such systems could help to find the best mix of Web sites. On the other hand, personalized search engines and recommender systems can trigger an increase in the number of Web sites visited by offering Web sites that better match the user’s interests. In this regards, such systems help to make information manageable, even in a world of information overload.

Apart from identifying groups of developmental trajectories, which lead to different points of saturation, we discovered distinctive demographic factors that distinguish these groups. Our findings confirm results of previous work on the HomeNet project, we find that race, gender, age, and role in the family are major correlates of WWW use in general and saturation level in particular. The identification of demographic factors that characterize the clusters of developmental trajectories enables much more personalized marketing. In this non-users tend to be older, female, and minorities. Marketing efforts of commercial Web sites should be concentrated on customers who fit into the profile of moderate users, heavy users, or very heavy users.

5. Conclusion: Implications for electronic commerce

In this analysis we have examined the per weekly trajectories of visits to distinctive Web sites over a 156 week period. It is important to keep in mind that individuals do not necessarily visit the same distinct Web sites from week to week. Indeed, there might be considerable churn in the specific Web sites visited from week to week. In this case, there would be limited overlap over time in the identities in the specific Web sites visited. However, the basic idea of saturation of WWW usage still holds under the assumption of constant churn over time.

The relevant implication for electronic commerce on the WWW are the following: The study reveals that, due to a saturation point in WWW access behavior, the number of visits at a given Web site is unlikely to be increased on the individual level. On average, the growth of visits at Web sites is rather a result of an increasing number of WWW users than a result of increased usage on the individual level. This leads to the conclusion that there exists, for each given individual, a fixed level of preferred WWW usage, which is independent of the number of Web sites offered. On the individual level, the competition for WWW users seems to be a zero sum game. On average, winning a user for one Web site means loosing this user to another site. Means of WWW commercialization such as the advent of banner advertisements, which became common in the WWW during the period of our study, does not seem to lead to an increase in WWW usage in terms of visits to distinctive Web sites. The effectiveness of banner ads, which are supposed to trigger a higher number of visits to distinctive Web sites, might be questioned. This confirms existing sources of consumer response data on banner ads that propagate that with increasing exposure to passive banner ads, the probability that a consumer will click on it becomes close to zero [2].

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### Table 3: Overview of characteristics of users in the various groups

<table>
<thead>
<tr>
<th></th>
<th>all users</th>
<th>non-users</th>
<th>moderate users</th>
<th>heavy users</th>
<th>very heavy users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>100%</td>
<td>49.9%</td>
<td>35.5%</td>
<td>10.2%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Adult</td>
<td>59.3%</td>
<td>63.2%</td>
<td>57.5%</td>
<td>51.5%</td>
<td>41.7%</td>
</tr>
<tr>
<td>Female</td>
<td>55.1%</td>
<td>61.6%</td>
<td>54.2%</td>
<td>39.4%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Minority</td>
<td>29.8%</td>
<td>39.7%</td>
<td>19.8%</td>
<td>15.2%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Position:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mom</td>
<td>26.8%</td>
<td>31.6%</td>
<td>25.0%</td>
<td>18.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Dad</td>
<td>19.5%</td>
<td>16.1%</td>
<td>25.0%</td>
<td>21.2%</td>
<td>8.3%</td>
</tr>
<tr>
<td>Daughter</td>
<td>23.6%</td>
<td>23.0%</td>
<td>25.8%</td>
<td>18.2%</td>
<td>25.0%</td>
</tr>
<tr>
<td>Son</td>
<td>18.9%</td>
<td>16.7%</td>
<td>17.5%</td>
<td>33.3%</td>
<td>33.4%</td>
</tr>
<tr>
<td>Other</td>
<td>11.2%</td>
<td>12.6%</td>
<td>6.7%</td>
<td>9.1%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Avg. age</td>
<td>30.7</td>
<td>31.6</td>
<td>30.6</td>
<td>28.3</td>
<td>25.2</td>
</tr>
</tbody>
</table>
Groups of people follow trajectories for visits to particular commercial Web sites as well. Further research is necessary to analyze the usage pattern of individuals for these sites. Counts of buy orders at a given commercial Web site are undoubtedly data that should be analyzed in further research. Furthermore, demographic factors that discriminate clusters of trajectories on particular commercial Web sites are likely to change from one Web site to the next.

In general, the rejection of the hypothesis of increasing WWW usage in terms of distinctive Web sites visited becomes important when the growth in terms of numbers of people accessing the WWW slows down. Then, competition among WWW companies for WWW market share is likely to become fiercer.

Relatedly, the issue of churn has to be analyzed in more detail. If indeed there is considerable churn, users maybe effectively visiting different Web sites at random. Alternatively, and we believe more plausibly, they maybe visiting Websites that are functionally related, e.g. vacation sites. If in fact this is the case, we need to develop methods for modeling churn, which take into account the possibility that Web sites maybe in some sense complements and substitutes to each other.

Finally, the patterns of WWW usage we found for usage data from 1995-1998 may be different for more recent data. Note that the HomeNet project focuses on individuals at home. A significant part of the population accesses the Internet at work. Therefore, further research is necessary in order to confirm those patterns for all groups of users in the WWW and for data from 1998 on.

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