Response time of internauts

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Abstract

A new experiment measuring the dynamical response of the Internet population to a “point-like” perturbation has been performed. The nature of the perturbation was that of an announcement, specifically a web-interview on stock market crashes, which contained the URL to the author’s articles on the subject. It was established that the download rate obeys the relation \( \approx \frac{1}{t} \) in qualitative agreement with previously reported results.

1 Introduction

There can be little doubt that the World-Wide-Web (WWW) provides one of the most efficient methods for retrieving and distributing information. As such, it is believed to carry an enormous potential with respect to sale and marketing of all kinds of products and is thus of great economic interest to most companies.

A very different aspect of the WWW is that it constitutes a quite unique example of a fast evolving social ecology which can be studied in real time. There are many examples of self-organising systems in society and Nature, where “less intelligent” individuals interact creating a “more intelligent” whole. Examples are ant hills, flashing colonies of fire-flies, fish schools, the stock market, cities, ... A rather troublesome feature with all these systems is that they are in general difficult to probe. This is not so with the WWW. The fact that it is computer-based and access is unrestricted provides a rather unique opportunity to study in real time a fast evolving ecology of heterogeneous intelligent agents.

Most studies of the WWW have until now focused on the more easily accessed statistical properties, such as the connectivity of the WWW, e.g., the distributions of outgoing and incoming links [1]. However, little is known about the internaut population’s response to some external or internal event. With respect to commercial exploitation of the WWW, as well as other applications, it is obviously the response of the internaut population to some new piece of information which is of interest and not the topology or connectivity of the underlying network itself. A rather unique experiment has previously been reported in this journal [2], which studies exactly this response. The purpose of the present paper to present the results of a similar experiment thus increasing the evidence for a self-similar relaxation rate [2].

The paper proceeds as follows. In the next section, we briefly review the previous experiment. In section 3, the nature of the present experiment is presented and the results compared with those of the previous experiment. In section 4, a physical setting for the observations is presented. Last section concludes.
2 A previous experiment

An interview with the author and co-worker Didier Sornette on a subject of broad public interest, namely stock market crashes, was published on the 14th of April 1999 in the leading Danish newspaper JyllandsPosten [3]. The text included the URL's to the author’s papers [4] and was published both in the paper version and the electronic version on the WWW of the newspaper, the latter restricted to subscribers. The URL to the search engine of the Los Alamos preprint server, which also contains the author’s paper on the subject, was included as well.

Subsequently, the cumulative number of downloads \( N(t) \) of papers from [4] was recorded, see figure 1. It was found that \( N(t) \) obeyed a relation

\[
N(t) = \frac{1}{1-b}(t/t_0)^{1-b} + ct,
\]

over a time period of one hundred days corresponding to a download rate

\[
\frac{dN(t)}{dt} = \frac{t_0^{b-1}}{t^b} + c.
\]

The last term accounts for a constant background taking into account features unrelated to the perturbation caused by the interview. From a fit with eq. (1) to the data, see figure 1, it was found that \( b \approx 0.6, t_0 \approx 0.8 \) minutes and \( c \approx 0.8 \) days\(^{-1} \).

3 The present experiment

The Nasdaq crash culminating on Friday the 14th of April 2000 caught many people with surprise and shook the stock market quite forcefully. As always, many different reasons for the crash were given ranging from the anti-trust case against MicroSoft to an “irrational exuberance” of the participants on the stock market. The author and co-worker Didier Sornette had also bid for the cause [5], which was made public on Monday the 17th of April 2000 on the Los Alamos preprint server. As a result, a forty minute interview with the author called “The World (Not) According to GARCH” was published on Friday the 26th of May 2000 on a “radio website” [6]. As in the experiment presented in section 2, the URL to the author’s papers [4] was announced making it clear that work on stock market crashes in general and the recent Nasdaq crash in particular could be found using the posted URL. The URL of the Los Alamos preprint server was not included on this occasion. As in the previous experiment, the the number of downloads of papers as a function of time from the appearance of the interview was recorded.

A few a priori important differences between the two experiments should be held forward. The web-interview appeared on a single web-site and only a single source was provided for the download of the author’s papers. In the experiment described in the previous section, the interview was published in the electronic as well as the paper version of the newspaper JyllandsPosten. Hence, it was initially not freely available, since you either had to buy the newspaper or be a subscriber. A stronger response to the web-interview should be expected due to an audience which is much more oriented towards the subject than the average Danish newspaper reader. Furthermore, since the web-interview was in English it had potentially a larger audience than its Danish counter-part.

In figures 2 and 3, the cumulative number of downloads \( N(t) \) as a function of time \( t \) after the appearance of the interview are shown on a linear and semi-logarithmic scale. The error-bars are simply taken as the square-root of \( N(t) \). The data is over \( \approx 60 \) days surprisingly well-captured by the relation

\[
N(t) = a \ln (t/t_0) + ct,
\]

with \( a \approx 583, t_0 \approx 0.80 \) days and \( c \approx 2.2 \) days\(^{-1} \), corresponding to a download rate

\[
\frac{dN(t)}{dt} = \frac{a}{t} + c.
\]
Thus, we again obtain a power law relaxation of the download rate, however, with a different exponent. After ≈ 60 days, we see how the data breaks away from the fitted line. The reason is the appearance of [4] on the Social Science Research Network server (http://WWW.SSRN.COM) causing a second perturbation*. Hence, the experiment became influenced by a second perturbation of non-negligible impact and was consequently halted after 69 days.

4 Interpretation of results

The results shown in figures 1, 2 and 3 suggests that the rate of downloads is that of a power law with a constant background

\[ \frac{dN (t)}{dt} = \frac{a}{b^x} + c. \]  

(5)

where \( b \) is not universal† Such power law dependence of the rate of “events” are found in other areas of Physics. Two well-known examples are Omori’s law for the rate of aftershocks as a function of time elapsed since the main event [7] and relaxation of spin glasses subjected to a magnetic field [8].

At time \( t \) after the appearance of the interview, the internaut community consists of two populations, namely those who have not downloaded a paper from [4] and those who have. The transition from the first state to the second demands the crossing of some threshold specific to each internaut. We thus imagine that the announcement of the URL plays the role a “field” to which the internaut population is subjected and study the relaxation process by monitoring the number of downloads as a function of time since the field was applied. Within this frame-work [2], we may view the process as a diffusion process in a random potential, where the act of downloading is similar to that of a barrier-crossing in the Trap model [8] of spin glasses. In this model, the distribution of trapping times \( \tau_i \) is a power law

\[ P (\tau) \propto \tau^{-(1+x)}, \]  

(6)

where \( x \) depends of the experimental conditions, e.g., \( x = T/T_g \) for a spin glass where \( T_g \) is the temperature of the glass transition. For \( x < 1 \), the mean trapping time \( \langle \tau \rangle \equiv \int_0^\infty \tau P (\tau) \ d\tau \) diverges and, as a consequence, the time needed for the system to relax is infinite. This is known as “weak breaking of ergodicity” in terms of spin glasses and is the hallmark of “aging” in anomalous relaxation processes.

For finite times we may proceed as follow. The parameter \( x \) is determined by

\[ \langle \tau \rangle = \int_{\tau_{\text{min}}}^{\tau_{\text{max}}} \frac{\tau}{\tau^{1+x}} d\tau \sim \Delta t_{\text{max}}^{1-x}, \ x < 1. \]

The maximum \( \tau_{\text{max}} \) is typically given by [8]

\[ N \int_{\tau_{\text{max}}}^\infty \frac{d\tau}{\tau^{1+x}} \sim 1, \]

where \( N \) is the number of barrier crossings, i.e., the number of downloads. Hence,

\[ \tau_{\text{max}} \sim N^{\frac{1}{x}}, 0 < x < 1 \]

Thus \( t = N (\Delta t) \sim N^{\frac{1}{x}} \), which finally gives

\[ N \sim t^x \Rightarrow \frac{dN (t)}{dt} \sim t^{x-1} \]  

(7)

*That a second advertisement of [4] had appeared on SSRN became quite evident when the author started receiving e-mail requests for preprints citing SSRN as information source.

†In the present context, \( b \) varies with e.g., the subject and the language of the interview.
In the case of the second experiment, the logarithmic growth of $N(t)$ formally corresponds to the case $x = 0$. However, in the present framework this case correspond to $x \ll 1$, which gives the same behaviour up to first order. Comparing relation (7) with (2) and (4), we find $1 - b = x < 1$ in both experiments. This means that the longer since the last download, the longer the expected time till the next one [9]. In other words, any expectation of a download that is estimated today depends on the past in a manner which does not decay. That the relaxation exponent $b$ is less than one has an important consequence, namely non-stationarity and “aging” in the technical sense of a breaking of ergodicity [8].

Within the proposed framework, one may speculate on the nature of the “field” created by the interview and its effect on the internaut population. Obviously, the act of downloading is a consequence of a) that the information of the URL is available to the internaut and b) that the knowledge of the URL results in a download by the internaut. The first contribution relates to how information spreads through the internaut population, the second to a “response-time” specific to each individual internaut. However, these two contributions are consequences of the same underlying processes, since the spread of information on the WWW is a consequence of the individual internaut’s decision to post a link, send e-mails, ... which again is governed by the internauts’ response-times. In fact, no download would take place if

1. nobody decided to visited the site where the URL was posted.
2. nobody decided to read/listen to the interviews.
3. nobody decided to use the URL after understanding the subject.
4. nobody decided to download after using the URL.
5. nobody decided to to tell others about the interview and URL.
6. nobody decided to use the URL after being told about it and the interview.
7. ...

These considerations strongly suggest that eq. (6), and consequently eq. (7), reflects the variation in response-time of internauts when confronted with a new piece of information. Furthermore, if the contributions of 5) and 6) are negligible this suggest that in the absence of deadlines internauts (humans) have a power law distribution of waiting times before deciding to act on a new piece of information. Each individual thus has a “psychological barrier” which must be crossed in order for the individual to act and the time needed to cross this barrier is power law distributed throughout the internaut (human) population.

5 Concluding remarks

The two rather unique experiments presented here in both cases shows a self-similar dynamical response of the internaut population to a perturbation, even though a priori the nature of the perturbations were quite different. Specifically, we have presented two experiments where the rate of downloads $N(t)$ from a site obeys a power law

$$\frac{dN(t)}{dt} \sim t^{-b}.$$ as a function of time $t$ after an advertisement on the WWW of that site’s URL.

In Physics, the fundamental approach for studying a given system is to introduce a well-controlled perturbation on the system and then study e.g., its response function, its susceptibility and its relaxation dynamics. In the social fields, it is generally impossible to control the effective perturbation, since it has its origin in a variety of complex sources with unknown internal interactions as well as with
the system itself. It is therefore very difficult to study the response of a social system in a controlled manner. Here, we have discussed two quite unique cases of a perturbation of a social self-organising system, which is controlled enough to allow the use of a Physics methodology. It uses a point-like perturbation and then measures the relaxation of the system as a function of time by monitoring a single site. This as well as the fact that the announcements (perturbations) were focused on a quite visible problem (financial crashes) of interest to a broad class of people produces a large impact compared to the background and makes the two experiments very “clean”.

In summary, we have reported two unique experiments in real time where the dynamical relaxation of the internaut population on the WWW in response to a point-like perturbation exhibits a slow power law decay similar to what have been observed for earthquake aftershocks and relaxation of spin glasses in the glass phase. In both experiments, a power law relaxation was obtained thus quantifying the internaut population response to a “perturbation”, i.e., the impact of an advertisement on the internaut population. With respect to applications, it is obviously the impact of some new piece of information on the internaut population which is of interest and not the topology and connectivity of the network as such. By heuristic arguments, it was argued that the power law response of the internaut population is a fingerprint of the psychological processes initiated by the reception of new information and ending with the triggering of some action based on this new information. Specifically, the two experiments suggest that in the absence of deadlines the response-time of internauts (humans) to new information have a power law distribution throughout the population. The existence of such a fat-tailed distribution of response-times of “agents” has quite important implications for the modelling of social systems such as the financial markets.

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Figure 1: Cumulative number of downloads $N$ as a function of time $t$ from the appearance of the newspaper interview on Wednesday the 14 April 1999. The fit is $N(t) = \frac{a}{(1-b)t^{1-b}} + ct$ with $b \approx 0.58$. 

\[
\text{eq. (1): } \frac{1}{(1-b)(t/t_0)^{1-b}} + ct
\]
eq. (3): \( f(x) = a \log(t/b) + ct \)

Figure 2: Cumulative number of downloads \( N(t) \) as a function of time \( t \) from the appearance of the Web-interview on Friday the 26 May 2000. The fit is \( N(t) = a \ln(t/\tau) + ct \).

Figure 3: Cumulative number of downloads \( N(t) \) as a function of time \( t \) from the appearance of the Web-interview on Friday the 26 May 2000. The fit is \( N(t) = a \ln(t/\tau) + ct \).