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Dynamic patterns of academic forum activities

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HIGHLIGHTS

- The dynamic pattern of academic forum activity is first to be investigated.
- There exists a power-law scaling between the visiting frequency and corresponding visitors.
- The Heaps' law is found in the expansion process of academic forum.
- The exploration, preferential return and memory effect drive the academic forum activity.

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ABSTRACT

A mass of traces of human activities show rich dynamic patterns. In this article, we comprehensively investigate the dynamic patterns of 50 thousands of researchers' activities in *Sciencenet*, the largest multi-disciplinary academic community in China. Through statistical analyses, we found that (i) there exists a power-law scaling between the frequency of visits to an academic forum and the number of corresponding visitors, with the exponent being about 1.33; (ii) the expansion process of academic forums obeys the Heaps' law, namely the number of distinct visited forums to the number of visits grows in a power-law form with exponent being about 0.54; (iii) the probability distributions of time intervals and the number of visits taken to revisit the same academic forum both follow power-laws, indicating the existence of memory effect in academic forum activities. On the basis of these empirical results, we propose a dynamic model that incorporates the exploration, preferential return with memory effect, which can well reproduce the observed scaling laws.

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1. Introduction

It has been deemed that complicated factors are affecting the dynamic patterns of human activities, such as the priority of task [1–4], individual interest [5–7], memory effects [8–14], deadline effects [15], social contacts [16–21], and so on. Thanks to the rapid development of information technology, massive traces of human activities are provided both in real and virtual social systems. Thus, many experts simultaneously devote themselves to modeling and understanding human dynamics (or dynamical patterns) involved with the aforementioned factors. Large amounts of empirical results on human dynamics have been reported in various fields [16,22–28], which are usually characterized by the heavy-tailed distribution

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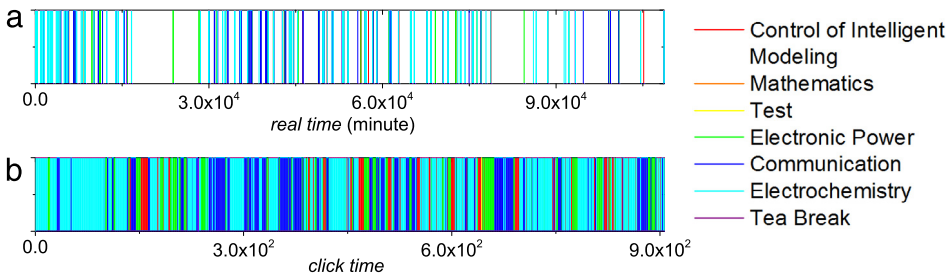

Fig. 1. (Color online) A typical visitor's transition process on academic forums along with (a) real time and (b) click time, suggesting a heterogeneous dynamic pattern that commonly exists in other online human dynamics [25]. The colored vertical line denotes the different academic forums.

of inter-event times and the power-law scaling law. They also achieve a number of relevant practical applications ranging from information spreading [29–32], decision making [33] to advertising [34,35] and recommendation [36–38].

Although diverse human activities from various fields have been widely studied, researchers' activities in academic forums are rarely concerned and still not clearly understood as they usually accompanies with many endogenous and exogenous factors, including the individual preference (or interest) and professional background, the quality of a forum, the content of a post, and so on. Moreover, human interest transitivity in virtual social systems is not wholly identical with the movement in the human spatial mobility in real world though some studies demonstrate that there are some analogies between them [8,39,40]. To fill this gap, we obtain a data set sampled from *Sciencenet* (http://www.sciencenet.cn/) that contains the academic forum activities of many Chinese researchers and probe the dynamic patterns of these academic forum activities through empirically analyzing both the expansion and exploration processes implying with human interest transitivity.

Thus, in this paper, we observe novel dynamic patterns of academic forum activities characterized by the following statistical features: (i) the power-law relation between the frequency of visits to an academic forum and the number of corresponding visitors; (ii) the Heaps' law [41] in the expansion process, namely the number of distinct visited forums power-law grows with the number of visits; (iii) the memory effect. We further propose a dynamic model that well reproduces the empirical observations in comparison with the previous model in absence of individual preference.

2. Experimental data and concepts

Sciencenet is the largest multi-disciplinary academic community in China, which contains a blog system, a bulletin board system (BBS, consisting of 60 academic forums), and a virtual social network of researchers. Our data set keeps track of activities in the BBS between October/1/2007 and July/7/2011, composed of 366,524 records from 49,578 researchers. Each record includes researcher ID, academic forum ID, posting/reviewing topic ID, and timestamp with resolution of minute. Table A.1 presents the names, the visiting frequencies (i.e, total visits from all researchers), and the number of visitors (i.e., researchers) of the 60 academic forums, ranked in the descending order of visiting frequencies (see in Appendix).

At the aggregated level, as shown in Table A.1, both the number of visits and the number of visitors are heterogeneously distributed among academic forums. While at the individual level, the visiting behavior is also heterogeneous, indicated by the burstiness that a visitor usually stays in an academic forum for long time and then glances over several ones. Fig. 1 shows the transition process of a typical real visitor in academic activities, with two different scales: (a) real time (minute) and (b) click time. Note that the click time indicates the order of the number of visits (browsing actions). The colored vertical lines represent different academic forums.

To conceptualize the academic forum activities, as shown in Fig. 2, we illustrate the transition process of two example visitors, with visiting sequences shown in the first rows of Fig. 2(c) and (d). And, We show the measurements for investigating their dynamic patterns as follows:

(1) $S(n)$, describes the expansion process of a visitor, namely the number of distinct academic forums along with the number of visits (i.e., browsing action) n. For example, as shown in Fig. 2(c), for a browsing order of academic forums with 10 actions, $\{A, B, B, A, C, D, A, A, A, A\}$, the $S(n)$ is $\{1, 2, 2, 2, 3, 4, 4, 4, 4, 4\}$. Thus, it can be analogy to random walk that the number of diverse subdisciplines can be mapped into the visiting sites and the browsing actions are served as the steps.
(2) $\Delta S(n)$, represents the exploration process of a visitor, namely the number of new academic forums (i.e., the incremental process of $S(n)$).
(3) τ and Δn, respectively indicate the real time interval and the click time (i.e., browsing actions) interval. Here, τ depicts that how *long* the individual will return to the same academic forum after she/he previously browses it and Δn means how many *actions* one individual will take between she/he sequentially visits the same academic forum.

3. Empirical results

For all 60 academic forums, we first study the relation between the number of visits to an academic forum (denoted by F) and the number of corresponding visitors (denoted by P). Fig. 3(a) and (b) show the heterogeneous distribution of F

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