Physica A 388 (2009) 961–966

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Opinion formation in a social network: The role of human activity

Andrzej Grabowski

Central Institute for Labour Protection - National Research Institute, 00-701 Warsaw, Poland

ARTICLE INFO

Article history:
Received 22 September 2008
Received in revised form 19 November 2008
Available online 3 December 2008

PACS:
89.75.Da
89.75.Hc
89.65.Ef

Keywords:
Complex systems
Human dynamics
Dynamic phenomena in complex networks

ABSTRACT

The model of opinion formation in human population based on social impact theory is investigated numerically. On the basis of a database received from the on-line game server, we examine the structure of social network and human dynamics. We calculate the activity of individuals, i.e. the relative time devoted daily to interactions with others in the artificial society. We study the influence of correlation between the activity of an individual and its connectivity on the process of opinion formation. We find that such correlations have a significant influence on the temperature of the phase transition and the effect of the mass media, modeled as an external stimulation acting on the social network.

1. Introduction

Studying the statistical properties of social (e.g. friendship) networks remains a challenge. It is possible to assess the form of degree distribution with a survey, as in the case of the web of human sexual contacts [1]. However it is much more difficult to learn about other important properties of networks, because there is no data on their entirety. A survey often provides data on a small sample only.

Progress in information technology has made it possible to investigate the structure of the social networks of interpersonal interactions maintained over the Internet, e.g. e-mail networks [2], web-based social networks of artificial communities [3] and blog networks [4]. However there is still an unexplored area of research. In recent years on-line games have become increasingly popular and have attracted an increasing number of players, who interact in the large virtual world of Massive Multiplayer Online Role Playing Games (MMORPGs).

MMORPG is a network game in which players enter a virtual world as characters they have invented — gaining virtual life. This virtual world takes the form of a game server connected to the Internet, on which accounts are registered for users who log in through special game client programs. The rules allow players to create more than one character on one account, with each of those characters having its own personality (further in the text we refer to such characters as individuals). Thousands of people can play on one server – they become a virtual society – so they share the common culture, area, identity, and interactions in the network of interpersonal relationships.

The aim of our work is to investigate the influence of human social activity on dynamic phenomena in a social network. In the present work, we use data on a social network consisting of 6×10^3 individuals. It is a giant component of a network of individuals who interact in the large virtual world of the aforementioned MMORPG [5]. On the basis of playing time, we calculate the activity A of individuals, i.e. the relative time devoted daily to interactions with others. On the basis of human activity calculated as above, we investigate the process of opinion formation in a real social network. For modeling of the

E-mail address: angra@ciop.pl.

0378-4371/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.physa.2008.11.036

process of opinion formation, in the case of two possible states (i.e., the positive or negative answer to a certain question), the Ising-based models are used by many authors [6–14]. The Ising model was first introduced to describe interactions between fermions which are arranged in an array and are placed in an external field [15], and since then still attracts great interest among physicists. It was found that cooperative behavior, which arises from direct interactions between components of the system can be successfully described in different systems (eg. biological, economical and social systems) using Ising-like models.

2. Statistical properties of the network

Basic network measures of the whole network and the Giant Component (*GC*) [16] are presented in Table 1. This network consists of 28 011 individuals, but for many of them, the number of connections k equals zero. This means that those characters have no friends on their lists. Most individuals with $k = 0$ are abandoned characters who do not appear in the virtual world and who have therefore lost all their contacts with those still active, or are new characters. *GC* contains almost all individuals whose degree is greater than zero (6065 characters); only 252 individuals with $k > 0$ do not belong to *GC* (i.e. only 4%).

The average path length $\langle l \rangle$ in *GC* is similar to that in a random graph. A high value of the clustering coefficient and a short average path length $\langle l \rangle$ are characteristic features of social networks [16]; they are typical for small-world networks. The degree distribution of the network has the form $P(k) \sim k^{\eta-1} \exp(-\xi k^{\eta})$, where $\xi = 1.40 \pm 0.05$ and $\eta = 0.35 \pm 0.02$ ($R^2 = 0.99$). Hence, in the network under investigation, degree distribution decays as a stretched exponential for large k (see Fig. 1(a)).

The local clustering coefficient $C(k)$ is negatively correlated with the degree of the node k, showing the existence of the power law $C(k) \sim k^{-\alpha}$ with $\alpha = 0.44 \pm 0.02$ ($R^2 = 0.98$). A slightly lower value of the exponent α has been observed in other social networks, 0.33 [3] and 0.35 in a network consisting of over one million nodes [17]. The power-law relation $C(k)$ is similar to the relationship in hierarchical networks [18]. However it has been recently shown [20] that most observed degree dependence of the clustering coefficient follows from degree mixing patterns.

In the network under investigation, the greater the k, the greater the average degree of nearest neighbors k_{NN}. Hence, the network is assortatively mixed by degree; such a correlation has been observed in many social networks [19]. In social networks it is entirely possible, and it is often assumed in sociological literature that similar people attract one another. The relation $k_{\mathrm{NN}}(k)$ can be approximated with the power-law relation $k_{\mathrm{NN}}(k) \sim k^{0.18\pm0.01}$ ($R^2 = 0.93$). A similar value of the exponent (0.2) has been found in other social networks [17]. However, it was recently shown that such correlations can be explained by modularity and a heavy-tailed degree distribution [21].

On-line games like MMORPGs offer a great opportunity to investigate human dynamics [22], because much information about individuals is registered in databases. Knowing the accumulative time spent by the user in the virtual world T_{G} and the lifespan T_{L} (i.e. the number of days from the time the individual was created to the date of last logging), we can calculate the average time devoted daily to interactions in the virtual environment. By dividing this average time by 24 h we obtain the activity A of a character. Thus, the activity A_{i} denotes the probability that an i-th character exists in the virtual world.

$$A = \frac{T_{\mathrm{G}}}{24 T_{\mathrm{L}}}. \tag{1}$$

The value of activity relates to the whole lifespan of an individual. However the activity is not biased by the lifespan of an individual, because the average time devoted daily for playing the game is approximately independent on T_L. It should be noted that we have found similar results (e.g. lack of correlations between A and T_L) analyzing the behavior of 5×10^6 players in the web-service www.xfire.com. The activity of a character is positively correlated with its degree, and the results can be approximated with the power law

$$A(k) \sim k^{\eta} \tag{2}$$

where $\eta = 0.35 \pm 0.02$ (see Fig. 1(a)). The activity distribution $P(A)$ is exponential: $P(A) \sim \exp(-\mu A)$, where $\mu = 12.0 \pm 0.2$; $R^2 = 0.98$ (see Fig. 1(b)).

3. The process of opinion formation

Let us describe the effect of social activity on the phenomenon of opinion formation. Each individual is influenced by the local field h_i, which depends on interactions with k_i neighbors and external stimulation I:

$$h_i(t) = -S_i(t) A_i \left(\sum_{j}^{k_i} A_j S_j(t) + I \right) \tag{3}$$

where $S_i = \pm 1$ — state of i-th individual, k_i — number of neighbors of i-th individual, A_i — activity of i-th individual. The external stimulation I may be regarded as a global preference towards one of the opinions stimulated by mass-media, government policy etc.