Available online at www.sciencedirect.com
SCIENCE DIRECT®
Physica A 364 (2006) 537–543
PHYSICA A
www.elsevier.com/locate/physa

Discrete simulation of the dynamics of spread of extreme opinions in a society

Dietrich Stauffer*[,1], Muhammad Sahimi

Department of Chemical Engineering and Materials Science, University of Southern California, Los Angeles, California 90089-1211, USA

Received 20 June 2005; received in revised form 16 July 2005
Available online 15 September 2005

Abstract

We propose a discrete model for how opinions about a given "extreme" subject, about which various groups of a population have different degrees of enthusiasm for or susceptibility to, such as fanaticism, extreme social and political positions, and terrorism, may spread. The model, in a certain limit, is the discrete analogue of a deterministic continuum model suggested by others. We carry out extensive computer simulation of the model by utilizing it on lattices with infinite- or short-range interactions, and on symmetric and hierarchical (or directed) Barabási–Albert scale-free networks. Several interesting features of the model are demonstrated, and comparison is made with the deterministic continuum model.

Keywords: Terrorism; Agents; Lattices; Scale-free networks

1. Introduction

Given the current political climate around the globe, and the rise of extreme ideologies in some parts of the world, models that can provide insight into how such ideologies may spread in a society are clearly of great interest. In particular, given that, (1) the phenomenon of globalization has made interactions between people of various nations around the globe much easier than two decades ago, and (2) although extreme ideologies are usually advocated by very small fringe groups, they can survive and even thrive on certain time scales, it is important to understand the role of these two factors on the spread of an opinion or ideology about such antisocial behaviour as terrorism.

The goal of the present paper is to suggest a model to study this problem, and understand its implications. Some simple models for terrorism or extreme opinions appeared a few years ago in the physics [1] and sociological [2] literatures. The present work was motivated by a deterministic continuum model on bioterrorism [3], but the model that we describe and simulate can also apply to opinion dynamics regarding, for example, the latest "Star Wars" movie, fashion, a political candidate running for office, or other questions

*Corresponding author.
E-mail addresses: stauffer@thp.uni-koeln.de (D. Stauffer), moe@usc.edu (M. Sahimi).
[1]Visiting from Institute for Theoretical Physics, Cologne University, D-50923 Köln, Germany.

0378-4371/$ - see front matter
doi:10.1016/j.physa.2005.08.040

and opinions with varying degrees of enthusiasm. Thus, we do not even try to define "terrorism" here, as the model that we consider is generic.

The population in our model consists of four parts, G, S, E, and F corresponding, respectively, to the general, susceptible, excited, and fanatic parts of the population. For simplicity, we use, hereafter, the same letters to denote the fractions of the total population belonging to each group. Members of the population can be convinced by acquaintances from the S, E, and F groups to move from the G group to S; from there by the E and F groups to change to E, and from there by members of the F group to change to F. Moreover, members of each of the three groups S, E, and F can change their opinions and go back directly to the general population G. The dynamics of a model based on such a partitioning of a population has been treated in the continuum limit [3] by a set of deterministic nonlinear differential equations, depending only on the *total* fractions G, S, E, and F. The continuum model can provide mathematically sufficient conditions for terrorism, or any other opinion about a certain subject, to die out at long times, implying that in the long-time limit everybody will belong to the general population G, while the fractions S, E, and F shrink to zero which, when it comes to terrorism, is a good omen for the world.

However, as is well-known in the statistical physics of complex systems, deterministic continuum models represent mean-field approximations to the actual problem which, although they allow for development of mathematical proofs for the existence or nonexistence of certain phenomena and provide us with a first guide, they are also unreliable. Such models can take into account neither the effect of fluctuations on the phenomena, nor the effect of the internet, fax machines, and satellite television which have made long-range interactions between people on very large scales possible. For example, in a phenomenon somewhat close to the present problem, biological species with two types of animals [4], deterministic differential equations predicted extinction, whereas proper discrete simulations on a square lattice did not predict the same phenomenon.

Therefore, the goal of the present paper is to carry out extensive simulation of a discrete model of opinion dynamics which, in a certain continuum limit, becomes similar to the deterministic continuum model proposed by Ref. [3]. We utilize Monte Carlo simulations of a population of individuals of various opinions. Such simulations may be called agent-based outside physics, but have been used in physics since half a century ago.

The plan of the paper is as follows. We first describe the deterministic continuum model which is based on a set of nonlinear differential equations. We then describe the discrete model which is developed by putting individuals on a half-filled 2D lattice, such that the individuals can be influenced by all other individuals. Then, we restrict the influence to the nearest neighbours. Finally, we replace the dilute 2D lattice by a scale-free network of the Barabási–Albert type [6]. The main point of the paper is not testing whether the model can provide quantitative predictions; rather, we deal only with the methods and how to implement them realistically. In particular we follow [3] in assuming that if $S = E = F = 0$ at some moment, then these group stay without members forever. Thus, one set of simulations corresponds to the opinion dynamics following one external event and does not include new external events to cause S, E, and F to become non-zero again.

2. The deterministic continuum model

In the deterministic continuum model, the fractions G, S, E, and F in the population of agents having the corresponding opinions, with $C = S + E + F = 1 - G$, change with time t as

$$\frac{\mathrm{d}S(t)}{\mathrm{d}t} = \beta_1 CG - \frac{\beta_2 S(E+F)}{C} - \gamma_1 S\,,$$

$$\frac{\mathrm{d}E(t)}{\mathrm{d}t} = \frac{\beta_2 S(E+F)}{C} - \frac{\beta_3 EF}{C} - \gamma_2 E\,,$$

$$\frac{\mathrm{d}F(t)}{\mathrm{d}t} = \frac{\beta_3 EF}{C} - \gamma_3 E\,,$$

where the various coefficients, β_1, γ_1, etc., are constant. Without loss of generality, we set $\beta_1 = 1$ since, otherwise, it can be absorbed in the time scale. We also set $\gamma_2 = \gamma_1$. Nevertheless, we still have not only the four parameters β_2, β_3, γ_1, and γ_3, but also the three initial concentrations $E(0)$, $S(0)$, and $F(0)$ which are relevant