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Information accumulation system by inheritance and diffusion

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ABSTRACT

This paper suggests a new model, called as the IAS (Information Accumulation System), for the description of the dynamic process that people use to accumulate their information (knowledge or opinion) for specific issues. Using the concept of information, both the internal and the external mechanism of the opinion dynamics are treated on a unified frame. The information is quantified as a real number with fixed bounds. New concepts, such as inheritance and differential absorption, are incorporated in IAS in addition to the conventional diffusive interaction between people. Thus, the dynamics of the IAS are governed by following three factors: inheritance rate, diffusivity and absorption rate. The original set of equations was solved with an agent based modeling technique. In addition, the individual equations for each of the agents were assembled and transformed into a set of equations for the ensemble averages, which are greatly reduced in number and can be solved analytically. The example simulations showed interesting results such as the critical behavior with respect to diffusivity, the information polarization out of zero-sum news and the dependence of the solutions on the initial conditions alone. The results were speculated in relation to today's modern society where the diffusivity of information has been greatly increased through the internet and mobile phones.

1. Introduction

In this study, the term 'information' can mean the knowledge of a specific field or the opinion on a specific issue. The amount of information owned by an individual is continually changing. In some instances existing information may decay out with time, while other information may persist for a long time. New information may also be generated through the creativity or new experiences of individuals. A wide class of papers exploring consensus and opinion dynamics models focuses on how information (or opinion) spreads among individuals within a given system. The Ising model [1,2], the Sznajd model [3,4] and the continuous opinion models [5–7] are a few well known examples that illustrate this phenomenon. Basically, in opinion dynamics an individual updates his opinion in two different mechanisms, which are the internal and the external mechanism. The internal mechanism represents the recirculation of the existing opinion/information within the system. On the other hand the external mechanism describes the information from the source outside the system and reflects the effects of mass media or public broadcasting [8,9]. Today, the diffusivity of information among individuals is greatly increased by the widespread use of the internet and mobile phones.

This paper is motivated by a new social phenomenon: the candle vigils frequently taking place in South Korea, which the authors think might have some connection to the increase in the diffusivity of information. This paper does not attempt to simulate such phenomena directly, but suggests that at least some of these new instances show two observations that were not fully accounted for in existing opinion dynamics models. The first observation is related to peoples' attitude to

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selective hearing. Supporters of one of the two competing theories may be deaf to clues that appear to support the other theory. This can be partly explained using the concept of the confidence bound in existing opinion dynamics models [5–7], which states that a person will accept another person's opinion if it is close enough to their own. The first observation means that it is the person, not the opinion, which determines the confidence bound. The second observation is that the mass media can have a significant effect on the formation of public opinion. This viewpoint is nothing new; we make this point only because we found very few papers dealing with the effect of mass media [8,9], usually known as the external mechanism. One of the obstacles in treating the external mechanism may be that there are no systematic ways to define the relative importance of the two sources of information: internal and external. Based on these two observations, this study suggests a new dynamic model for the simulation of the information accumulation process in an individual and/or a group of interacting individuals. A new general equation is proposed and is applied to a couple of example problems. An agent based modeling (ABM) technique is used as the primary method to find the solution and analytical equations are derived for an approximate averaged behavior of the individuals in the system.

2. The model

Information in this study can mean news, knowledge or opinion. It is assumed that the information can be represented as a real number. In addition, color coding is used to denote the sign of the number. BLUE and RED information represent positive and negative information, respectively. The purpose of this study is to suggest a model that describes the information accumulation process in an individual or agent. The model is called the Information Accumulation System (IAS). To explain the basic concepts of IAS, consider a system composed of N agents that include agents a and b. We describe the change in information using discrete time steps. Let us denote the current level of information at time step i as $y_{a,i}$ and $y_{b,i}$, for agents a and b, respectively. In IAS, an agent accepts his information from the following three types of sources: himself, neighboring agents in the system and external sources. Each of these sources is related to the following basic concepts of IAS: inheritance, diffusion and news, respectively.

Agent a carries part of his previous information, $\tau y_{a,i}$, to the next time step. The factor τ denotes the *inheritance rate*. The most common form of inheritance will be through personal memory. Part of the information is lost during the inheritance due to imperfect memory. For later use, we define the *volatility* $\Delta \equiv 1 - \tau$. The inheritance term is a unique feature of IAS. Most of the existing models do not consider this inertial effect that the agents might have. The only exception the authors found in the literature was the model in which the inheritance mechanism is incorporated in a limited sense that the agent adheres to his *initial opinion* to a certain degree [10]. In this paper, inheritance does not mean that an agent remembers his opinion at time step $i = 0$, but rather his opinion from the previous time step as explained above.

The diffusion in IAS reflects the interactions between agents. Two agents are involved in the interaction, for example, the sender b and the receiver a. Upon interaction, the sender b sends part of his information, $\omega_b y_b$, to a potential receiver. Here ω denotes the *diffusivity*, reflecting the 'loudness of the voice' of the sender. The actual information absorbed by the receiver is, in general, different from the one sent by the sender and is expressed as $\lambda_a \omega_b y_b$. Here, λ will be called the *absorption factor*. Usually λ takes a value between 0 and 1. Note that the diffusivity is tied to the sender while the absorption factor is tied to the receiver. A differential absorption hypothesis is adopted in this study. People tend to hear what they want to hear. A familiar concept in the literature is that of the bounded confidence [5–7]. The concept of inflexibility can be realized by setting $\lambda = 0$ [11]. In relation to the differential absorption, the color of the agent is defined in this study as the color of the information the agent prefers. For example, a BLUE agent would absorb the information as it is ($\lambda = 1$) when it is BLUE, but only a fraction of it when it is RED ($\lambda = 0.3, 0.5$, etc.). The color of an agent never changes once it is defined.

The diffusion is the most important concept in the opinion dynamics literature. The USDF (United we Stand, Divided we Fall) rule in the Sznajd model (3), the local majority rule in discrete opinion models (1) and the rule of compromise in continuous models [5–7] are just different implementations of diffusion interactions. As the IAS is a kind of continuous model, it is worthwhile to mention the difference between the diffusion terms of existing continuous models and that of the IAS. In existing continuous models the interactions always take the form of a compromise, but in IAS the interaction, as defined above, can result in a synergy. In IAS, the interaction is a synergy when the colors of the current information of the two agents under interaction are the same. Basically, under the compromising interaction of the existing models, the total information of the system is conserved. On the contrary, the synergetic interaction in the present model results in an increase in the total information of the system. This kind of increase may cause a problem in a continuous model, that is, the information can grow infinitely, which is not acceptable in the real sense. This could be part of the reason why the existing continuous models depend only on the compromise. In reality we can easily find examples in which the system-wise information can increase with time. For example, we can consider the process of the teaching. Needless to say, a successful teaching interaction will result in a synergy, increasing the total information, or knowledge in this case, of the system. The problem of the information burst is successfully overcome in IAS by the introduction of the concept of saturation, which will be explained later.

The inheritance and the diffusion reflect the internal mechanism of IAS, which is nothing more than a recirculation of the existing information that is not new to the system. On the other hand, news reflects information that is newly brought into the system. News can be generated through creativity or new experiences of an individual or of the system as a whole. Mutation could be a kind of news to a biological system where the genetic information is maintained mainly through the mechanism of inheritance. News is also a kind of information and assumed to be quantified.