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Experimental analysis of self-organizing team's behaviors

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ABSTRACT

This paper is focused on the study of self-organizing team's behaviors which are dependent on the interaction rules and the decision factors of team members. The self-organizing team's behavior means that team members work unconditionally with one of the three work attitudes (diligence, average, and shirking). A small-world network is suggested as the basic relationships of team members. Different from the traditional models, Reciprocators encourage their friends if they work diligently and punish them if they shirk work. It is supposed that team member's decision of choosing work attitude depends on four decision factors, *humanity*, *herd instinct*, *rationality*, and *follower tendency*. Firstly, all of the four decision factors' weights are supposed as 0.25. Multiple experiments were conducted to analyze the behavior of a team by a multi-agent experiment system. It is found that, in order to increase the fraction of diligent team members, different strategies should be used under different Reciprocators' fractions. Increasing Reciprocators' fraction is beneficial to the increase of diligent members; however, the increase rate will slow down after an inflexion (here it means the inflexion of Reciprocators' fraction). After the previous experiments study, extended experiments were developed to work on the influence of the four factors' different weights. A self-adaptive algorithm is suggested to achieve the four decision factors' weights. The results of self-adaptive algorithm have different influences on the team's behaviors under different fractions of Reciprocators. Finally, influences of members' different relationships are studied by other experiments. It is also proved that the fraction of diligent members is not dependent on the structure of team members' relationships. The results demonstrate that the self-organizing team's behavior can be significantly influenced by its scenario while managing a self-organizing team.

1. Introduction

The essence of self-organization is that a system spontaneously arranges its components or elements in a purposeful (non-random) manner, under appropriate conditions but without being guided or managed by an outside source. Self-organization is usually associated with more complex, non-linear phenomena, rather than with the relatively simple processes of structure maintenance of diffusion. The self-organizing behavior of social animals suggests that self-organization should be expected in human society. Usually the growth of social networks is fueled by social contexts and ideology of all participants in the network.

Due to the social networks' complexity and non-linearity, this work is focused on the study of self-organizing team's behaviors by a multi-agent system. A multi-agent system (MAS) is a system composed of multiple interacting intelligent agents. Multi-agent systems can be used to solve problems which are difficult for an individual agent or monolithic system. Social structures are appropriate to be modeled by multi-agent systems.

Bowles and Gintis (2004) offered a model of cooperation and punishment that is called *strong reciprocity*, where Reciprocators only punish shirkers. In our work, a team consists of three types of members, *Reciprocators, Cooperators and Selfish*. It is supposed that Reciprocators encourage the diligent team members besides punishing shirkers. Additionally, it is assumed that each team member has one of the three categories of work attitudes, diligence, average, and shirking, and a small-world network (Watts & Strogatz, 1998) is suggested as the relationship network of all members.

Under the assumptions described above, this paper works on the self-organizing behaviors of a 100-team members' social network. In this model, the typical self-organizing behavior is that multiple members work diligently with high cost without being guided or managed by others. This paper also assumes that member's decision is dependent on four factors, *humanity*, *herd instinct*, *rationality*, and *follower tendency*. All the four decision factors' weights are supposed as 0.25 at first. By a multi-agent experiment system, the relation between the Reciprocators' fraction and the

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team's behaviors was found by these experiments. Increasing Reciprocators' fraction is beneficial to the increase of diligent members; however, the increase rate will slow down after an inflexion (here it means the inflexion of Reciprocators' fraction). Extended experiments were developed to work on the influence of the four factors' different weights. A self-adaptive algorithm is suggested to achieve the four decision factors' weights. The results of self-adaptive algorithm have different influences on the team's behaviors under different Reciprocators fraction. Finally, influences of members' different relationships are studied in this work too.

The rest of the paper is organized as follows. The related literature is reviewed in Section 2 and then the social model is developed in Section 3. A series of experiments are conducted in Section 4. Four propositions under different experiments are generated and a detailed result analysis is presented in Section 4. Finally, the conclusions are summarized and future work is suggested in Section 5.

2. Review of the related research

Self-organization is more and more concerned in the literature and industrial practice. This paper is related to small-world network, self-organizing mechanism, artificial society and multi-agent systems.

Many researchers are carrying out study of small-world networks after Watts and Strogatz (1998). Deng, Zhao, and Li (2007) introduced a new type of network growth rule and proposed and evolved the network model to investigate the node deleting on the network structure. It was found that the network structure was significantly transformed with the introduction of node deleting. Li, Lin, and Liu (2007) showed that two scientific collaboration networks were small-world networks. Many other researchers worked on social networks with small-world networks. Toivonen, Onnela, Saramäki, Hyvönen, and Kaski (2006) presented a model for an undirected growing network which reproduced these characteristics, with the aim of producing efficiently very large networks to be used as platforms for studying social dynamic phenomena. Jun, Kim, Kim, and Choi (2006) considered a firm's profit maximization problem when the demand for the product was created by referrals between consumers connected in a small-world network. His work demonstrated that contrary to human's anticipation, the firm's profit smoothly (not rapidly) approached the profit in the complete network as the rewiring probability increases, but that per consumer profit was saturated to a finite non-zero value when the rewiring probability was near zero, implying a small-world transition. Yang, Lu, Xie, Chen, and Zhuang (2007) reported a detailed study of a competitive relationship network of certified Independent Software Vendors, which showed some prominent scale-free structural properties and complex dynamical behaviors.

Self-organizing networks are pervasive in communication systems too. Liu, Yuan, Shan, Ren, and Ma (2008) focused on the driving forces behind individual evolutions of network components. Understanding forces underlying the evolution of networks should enable informed design decisions and help to avoid unwanted surprises, such as congestion collapse. Dressler (2008) and Theoleyre and Valois (2008) worked on the self-organizing mechanism for communication systems. In their papers, solutions for the medium access control and the network layer were analyzed and discussed. Crowston, Li, Wei, Eseryel, and Howison (2007) provided the empirical evidence about how free open source software development teams self-organized their work, specifically, how tasks were assigned to project team members. Wagner and Leydesdorff (2005) tested the hypothesis that international collaboration was a self-organizing network. In proposing a self-organizing view of manufacturing enterprises, Tharumarajah (2003) attempted to shed some light on the underlying processes and general mechanisms for the design and operation of self-organizing enterprises.

Artificial society is another important theory for this study. Gintis, Bowles, Boyd, and Fehr (2003) presented the evidence supporting strong reciprocity as a schema for predicting and understanding altruism in humans. Dominique et al. (2004) supported the hypothesis that people derived satisfaction from punishing norm violations and that the activation in the dorsal striatum reflected the anticipated satisfaction from punishing defectors. Bowles and Gintis (2004) offered a model of cooperation and punishment which was called *strong reciprocity*: where team members profited from mutual adherence to a social norm, strong Reciprocators obeyed the norm and punished its violators, even though as a result they received lower payoffs than other team members, such as Selfish team members who violated the norm and did not punish, and pure Cooperators who adhered to the norm but free-ride by never punishing. Their agent-based simulations showed that, under assumptions approximating likely human environments over the 100,000 years prior to the domestication of animals and plants, the proliferation of strong Reciprocators when initially rare was highly likely, and that substantial frequencies of all three behavioral types could be sustained in a population. The strong reciprocity model is suggested as one of the assumptions in our study.

Similar to our paper, other papers are studied in this field by a multi-agent approach. Fitoussi and Tennenholtz (2000) presented the notions of minimal and simple social laws, which captured two basic criteria for selecting among alternative (useful) social laws by multi-agent systems. Ormerod (2007) used an agent-based model to show that information appeared to flow across a small-world network. Little and McDonald (2007) simulated agents harvesting a renewable resource, and examined the effect of agents in different social networks on their ability to exploit the resource under different levels of uncertainty. Robins, Pattison, Kalish, and Lusher (2007) introduced the exponential random graph (p^*) models for social networks in his paper. Lubbers and Snijders (2007) described an empirical comparison of four specifications of the exponential family of random graph models (ERGMs), distinguished by model specification (dyadic independence, Markov, partial conditional dependence) and, for the Markov model, by estimation method (Maximum Pseudo Likelihood, Maximum Likelihood). This was done by reanalyzing 102 student networks in 57 junior high school classes. These works may help us to elucidate the structural characteristics of self-organization in social networks.

Based on the literature review stated the above, the paper is focused on the research of self-organizing teams' behaviors. Multiple experiments were conducted to reveal that a team member chooses diligent work attitude by self-organization. Four propositions were suggested to improve the revenues of self-organizing teams.

3. A research model

Social networks can be highly clustered, like regular lattices, yet they have small characteristic path lengths, like random graphs. This category of networks is defined as small-world network (Watts & Strogatz, 1998). This paper is focused on the study of a social network with 100 nodes. A WS (Watts & Strogatz, 1998) small-world model (supposed rewiring probability $p = 0.05$, average degree $k = 4$) is suggested as the relation of these team members. This social network is shown in Fig. 1. All nodes (team members), whose path length to a special node (n_i) is one, are selected as friends of this special node (n_i) in Fig. 1.