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Knowledge diffusion in the collaboration hypernetwork

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HIGHLIGHTS

- A knowledge diffusion model based on the local-world hypernetwork is proposed.
- The preferential diffusion mechanism and the absorptive capability are introduced.
- The hypernetwork is more suitable for investigating the knowledge diffusion.

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ABSTRACT

As knowledge constitutes a primary productive force, it is important to understand the performance of knowledge diffusion. In this paper, we present a knowledge diffusion model based on the local-world non-uniform hypernetwork, which introduces the preferential diffusion mechanism and the knowledge absorptive capability α_j, where α_j is correlated with the hyperdegree $d_H(j)$ of node j. At each time step, we randomly select a node i as the sender; a receiver node is selected from the set of nodes that the sender i has published with previously, with probability proportional to the number of papers they have published together. Applying the average knowledge stock $\overline{V}(t)$, the variance $\sigma^2(t)$ and the variance coefficient $c(t)$ of knowledge stock to measure the growth and diffusion of knowledge and the adequacy of knowledge diffusion, we have made 3 groups of comparative experiments to investigate how different network structures, hypernetwork sizes and knowledge evolution mechanisms affect the knowledge diffusion, respectively. As the diffusion mechanisms based on the hypernetwork combine with the hyperdegree of node, the hypernetwork is more suitable for investigating the performance of knowledge diffusion. Therefore, the proposed model could be helpful for deeply understanding the process of the knowledge diffusion in the collaboration hypernetwork.

1. Introduction

Knowledge is playing an increasing important role in the economic development and social progress [1]. Many efforts contribute noticeably for improving the understanding of knowledge diffusion in all sorts of networks. For example, Allen [2], An and Kiefer [3] investigated the technology diffusion by an Ising model based on a very regular network. Steyer and Zimmermann [4] used random graph model to study technology diffusion. More recently, Cowan and Jonard [5], Kim and Park [6] compared the knowledge diffusion in regular, random and small-world networks, and found that the small-world network is the most efficient structure to diffuse the knowledge. Besides the small-world property [7], the scale-free property [8] is another topological structure of the social networks. Tang et al. [9,10], and Lin and Li [11] argued that the

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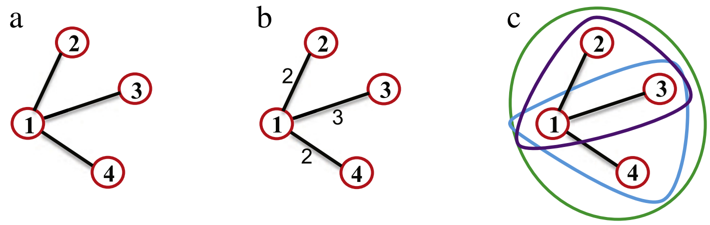

Fig. 1. (a) In a simple pairwise interaction network, the nodes (shown as red hollow circles) represent the authors and the edges represent the cooperative relationship between the authors. (b) In a complex weighted network, the nodes (shown as red hollow circles) represent the authors and the edge weight $e(i, j)$ represent the number of cooperation between the authors. $e(1, 2) = 2, e(1, 3) = 3$ and $e(1, 4) = 2$. (c) In a complex hypernetwork, the nodes (shown as red hollow circles) represent the authors and the hyperedges described by closed curves represent the co-authored papers. Node hyperdegree $d_H(i)$ is defined as the number of the hyperedge attached to node i. $d_H(1) = 3$, $d_H(2) = 2$, $d_H(3) = 3$ and $d_H(4) = 2$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

scale-free structure is more effective for knowledge diffusion. In addition, Guimerà et al. [12] proposed a model for the self-assembly of creative teams, and found that the emergence of a large connected community of practitioners could be described as a phase transition. Team assembly mechanisms determined both the structure of the collaboration network and team performance for teams derived from both artistic and scientific fields. In many literatures about knowledge diffusion [5,6,11,13], the knowledge absorption rate was set to a constant or a random number, which did not reflect the individual differences. In scientific collaboration networks, the knowledge diffusion mechanisms should take into account the following two aspects. One is that the probability of interaction between two authors is proportional to the number of papers they have published together. The other one is that the more papers one has published, the more knowledge one holds, and the stronger absorptive capability one owns. This is also consistent with the reality.

Simple pairwise interaction networks can only show the cooperative relationship between the authors, and cannot show the number of cooperation and the number of papers they have published [14,15]. Complex weighted networks can effectively show the number of cooperation between any two authors, but cannot show the number of papers any author has published. However, complex hypernetworks can well solve the above problems, in which a hyperedge can contain more than two nodes. Thus, it is useful to represent the collaboration network as a hypernetwork in which nodes represent authors and hyperedges represent papers that have been coauthored by the groups of authors [16–19]. For example, we want to describe the fact that author '1' co-published a paper with author '2' and '3', co-published a paper with author '3' and '4', and co-published a paper with author '2', '3' and '4'. It is represented by simple pairwise interaction network, complex weighted network and complex hypernetwork, respectively (see Fig. 1). Therefore, in this paper, we argue that the hypernetwork is more feasible to analyze the performance of knowledge diffusion. The reasons are as follows: firstly, people tend to diffuse knowledge by coauthoring papers in the scientific collaboration systems. However, by means of network science to investigate the performance of knowledge diffusion, one cannot know the information of papers. Secondly, the more any two authors collaborate, the greater the probability that the knowledge disseminate between them is. Thirdly, the more papers one has published, the more knowledge one holds, and the stronger absorptive capability one owns. The information also cannot be well expounded by means of network science. However, in the scientific collaboration hypernetwork, the hyperedges can represent the papers, the hyperdegree of a node can represent the number of the coauthored papers, and the number of the hyperedges encircling two specified nodes at the same time can represent the number of the two nodes cooperation. In addition, in practice, typically an individual only interacts with a very small proportion of the population, therefore the local world effect of the hypernetwork should be taken into account.

Inspired by the above ideas, this paper investigates the performance of knowledge diffusion in the local-world non-uniform hypernetwork (LWH) [18]. Based on the LWH, we present a knowledge diffusion model, which introduces the preferential diffusion mechanism and the knowledge absorptive capability α_j, where α_j is correlated with the hyperdegree $d_H(j)$ of node j. The knowledge growth amount of the recipient depends on his knowledge absorptive capability and the difference in knowledge stock between the sender and the recipient. At each time step, we randomly select a node i as the sender, and in probability p_j preferentially select a neighbor node j of node i as the recipient, where p_j is correlated with the number of cooperation C_{ij} between node i and node j. In the knowledge diffusion process, the node j absorbs part of the knowledge with the knowledge absorptive capability α_j. We compare the diversity of the behavior that the knowledge diffuses in the LWH model and the corresponding normal network model. Additionally, we further examine the effect of different hypernetwork sizes and different knowledge evolution mechanisms on the performance of knowledge diffusion.

The remainder of our paper is organized as follows. In Section 2, the knowledge diffusion model based on the LWH model is given. In Section 3, we introduce three measurements, i.e. the average knowledge stock $\overline{V}(t)$, the variance $\sigma^2(t)$ and the variance coefficient $c(t)$ of knowledge stock and numerically investigate the performance of knowledge diffusion. The conclusions and discussions are given in Section 4.