Physica A 415 (2014) 181–188

Contents lists available at ScienceDirect

Physica A

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

A two-layer team-assembly model for invention networks

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HIGHLIGHTS

- A model to replicate a two-layer network was developed.
- Data are obtained from Japan and US patents.
- The model can replicate inventor and company networks.
- The model uses only local information, which other models cannot do.

ARTICLE INFO

Article history:
Received 26 October 2013
Received in revised form 2 July 2014
Available online 7 August 2014

Keywords:
Network
Layer
Group
Patent
Inventor

ABSTRACT

Companies are exposed to rigid competition, so they seek how best to improve the capabilities of their innovations. One strategy is to collaborate with other companies in order to speed up their own innovations. Such inter-company collaborations are conducted by inventors belonging to the companies. At the same time, the inventors also seem to be affected by past collaborations between companies. Therefore, interdependency of two networks, namely inventor and company networks, exists.

This paper discusses a model that replicates two-layer networks extracted from patent data of Japan and the United States in terms of degree distributions. The model replicates two-layer networks with the interdependency. Moreover it is the only model that uses local information, while other models have to use overall information, which is unrealistic. In addition, the proposed model replicates empirical data better than other models.

1. Introduction

Companies increasingly need to maximize the capacity of innovations because of growing competition [1,2], and they consider the core of that capacity to be knowledge [3–5]. One strategy to acquire knowledge is to collaborate with other companies because collaborations enable companies to capitalize on external knowledge [6,7] and speed up innovations [3]. Commensurate with this, companies now place more importance on collaborations [8], and the number of co-patents between companies is increasing [9]. However, companies cannot unlimitedly acquire knowledge from other companies since they have different corporate cultures and unique tacit knowledge [10]. Therefore, companies must have a strategy to carefully choose their collaborators.

Much research has been done on generative models of collaboration networks in order to understand collaboration dynamics [11–14]. When inventors or authors of papers collaborate, it has been found that they can create higher quality work than those authored by solo authors [15]. Also, inter-organizational work has more impact than intra-organizational work [16]. These previous studies focused on one-layer networks.

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http://dx.doi.org/10.1016/j.physa.2014.07.076

Table 1
Overview of data sets: The range of years in which patents were applied for is labeled "Duration". The table lists the numbers of patents and companies that are included in the patents. Inventors working in companies were extracted.

	US	JP
Duration (year)	1963–1999	1994–2008
Total number of patents	2,923,922	1,967,361
Number of companies	33,515	72,841
Number of inventors in companies	285,418	829,052
Number of patents by multiple inventors	347,450	1,043,639
Total number of patents by companies	722,350	1,696,635
Number of patents by multiple companies	28,345	132,704

The collaborations in companies are conducted by individuals (i.e., developers or researchers) belonging to the companies. At the same time, the inventors seem to be affected by past collaborations between companies. Therefore, interdependency of two networks would be exist, i.e., individual and company networks.

Here, the author proposes a model of two-layer networks, where upper networks are expressed by aggregations of nodes and links belonging to lower networks. This model replicates networks extracted from patent data of Japan and the United States in terms of degree distributions. Although a lot of previous studies [17–25] have investigated two-layered networks, the proposed model can replicate the observed data better in degree distributions than those previous models. Also, the model only uses local information, while other models have to use overall information, which is an unrealistic set-up in complex networks.

This paper is organized as follows. The next section presents the data used in this study. In Section 3, the model is proposed, and how it can replicate the observed networks is verified. Finally, a summary is provided.

2. Data

Patents are useful for understanding what innovations occur over time [26]. Using a massive data set enables us to understand the tendency of innovations. Patent data from Japan (JP) and the United States (US) are used as data sets [4,27] in this paper.

The identifications (IDs) of rights holders and inventors are necessary to conduct this study. Assigning IDs to the rights holders is easy because their names and addresses give us sufficient information. Companies are extracted from the rights holders based on their names. The corporate statuses in the rights holders' names provide the information in the JP data set. The US data set contains information that has already been added. In contrast, inventors are identified by name, address, and company. The details of the process are explained in the Appendix.

Another process is conducted to connect each inventor with a company. An inventor is connected to a company, (1) if an inventor can be found on a patent applied for by a certain company, or (2) if an inventor can be found in patents jointly applied for by companies and there is only one common company in the companies. Since most Japanese inventors' addresses contain names of companies, that information is also used.

It has been more common for teams of inventors to apply for patents, and such patents statistically have better impact (more citations) than those authored by solo inventors [15]. However, it is less common for more than one company to jointly apply for patents. This is because no company can sell or license a patent jointly applied for without the consent of the others. Also, joint applications are more costly than other solutions such as solo applications with contracts for sharing benefits, and consequently, joint applications between companies are considered to be "second best" [8]. The number of patents jointly applied for by multiple companies accounts for 1.5% of all patents in the United States and 7.8% in Japan.

Table 1 summarizes the fundamental data from the two data sets with the number of patents, inventors, and companies. Fig. 1 shows how two-layer networks are created from the data sets. The left of Fig. 1 shows an example for three patents, five inventors, and three companies. One or more inventors apply for a patent, and each inventor works for a company. On the basis of the tripartite network on the left, we can create two different projected networks for the inventors and the companies. The inventor network is a network where every combination of inventors has a link if they have at least one patent in common. The company network is defined in the same way. If inventors who apply for a patent belong to different companies, the companies have a link.

Fig. 2 plots the cumulative probability distributions of degree. *Original* consists of the plots for the observed data. The other plots are the results of models explained in a later section. The figure plots the inventor and company networks for Japan and the US. A degree is a measure to count the number of links a certain node has. The figure indicates that the distributions for inventors decay faster than a power law. Previous studies found collaboration networks have the same distributions as those in this paper [11,28] or power laws [29]. The plots of the company networks seem to be fitted by lines, i.e., power-law distributions. A previous study already found that the collaboration networks of organizations in Japanese patents have power-law distributions [30].