Hierarchical Social Network Analysis Using a Multi-Agent System: A School System Case

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ABSTRACT

The quality of K-12 education has been a major concern in the nation for years. School systems, just like many other social networks, appear to have a hierarchical structure. Understanding this structure could be the key to better evaluating student performance and improving school quality. Many studies have been focusing on detecting hierarchical structure by using hierarchical clustering algorithms. The authors design an interaction-based similarity measure to accomplish hierarchical clustering in order to detect hierarchical structures in social networks (e.g. school district networks). This method uses a multi-agent system, for it is based on agent interactions. With the network structure detected, they also built a model, which is based on the MAXQ algorithm, to decompose the funding policy task into subtasks and then evaluate these subtasks by using funding distribution policies from past years and looking for possible relationships between student performances and funding policies. For the experiment, the authors used real school data from Bexar county’s 15 school districts in Texas. The first result shows that their interaction-based method is able to generate meaningful clustering and dendrograms for social networks. Additionally the authors’ policy evaluation model is able to evaluate funding policies from the past three years in Bexar County and conclude that increasing funding does not necessarily have a positive impact on student performance and it is generally not the case that the more is spent, the better.

Keywords: Education Quality, Hierarchical Clustering, Multi-Agent Systems, School District Networks, Social Network Analysis

1. INTRODUCTION

The quality of K-12 education has been a very big concern for years. Many studies have been conducted in the field. There are also many factors that have been studied, such as, school choice (Bettinger 2005; Lubienski & Lubienski 2006), school size (Slate & Jones 2005), teacher quality (Rockoff 2004; Harris & Sass, 2007), school/school district administrator quality (Meier et al. 2003; Clark 2010), funding (Crampton 2009; Anderson 2011), etc. Because

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previous research in this field mostly studied the impact of one or two of those factors on school performance, the results they provide can be limited.

A social network is a set of people (or organizations or other entities), which are represented by nodes, connected by a set of socially meaningful relationships, which are represented by edges (Wellman 1997). A school district system, which is a set of many different actors, such as students, teachers, principals, school staffs etc., is a social network. There might be underlying community structure within a network, which is the division of network nodes into groups within which network connections are dense (Newman and Girvan 2003).

Social network analysis has been an emerging field in recent years. It views social relationships in terms of nodes (agents) and edges (ties). Research has shown that social networks play a critical role in determining the way problems are solved, organizations are run, etc. (Andrighetto et al. 2009).

A multi-agent system (MAS) is a set of autonomous and interactive entities called agents (Guessoum et al. 2003). Multi-agent system and social network analysis share some similarities (e.g. agents, relationships, etc.). Much research has successfully combined these two together (Grant 2009; Ma et al. 2009). In multi-agents simulations, when agents communicate with each other or work together on a common goal, agents are often organized into networks. For a survey on networks, see Newman (2003).

It is often very important to find underlying structure for social networks in order to better understand how they work. Hierarchical clustering algorithms can find multi-level clustering for a network. They are further divided into two classes: agglomerative algorithms and divisive algorithms. Agglomerative or bottom-up algorithms start with each node in its own singleton cluster, and at each step merge these clusters into larger ones until all clusters are merged into one big cluster (Schaeffer 2007).

School systems contain many actors or agents that interact with each other. They form social networks. According to Fortunato (2010), social networks often have an underlying hierarchical community structure, and finding these community structures is very important for understanding inherent structures for complex social networks (Wakita and Tsurumi 2007). Thus hierarchical clustering algorithms can be useful and appropriate methods to detect multi-level structures of networks (Fortunato 2010). The first step for any hierarchical clustering algorithm is to decide what the similarity between two nodes or clusters is. Because a school system consists of many interacting agents (actors), for example, students and teachers, it is regarded as an interaction-based system. Therefore we use the interaction level between two nodes or clusters to be the similarity measure. Once the hierarchical structure of school system is detected, it can be used to help evaluate policies that may affect student performance.

The purpose of this work is to study structures of social networks with a focus on social interactions by detecting underlying hierarchical structures. The detected structure of social networks is then used to help evaluate their organization performance. We first want to detect hierarchical community structure in social networks by using an agglomerative hierarchical algorithm. Existing agglomerative hierarchical algorithms usually calculate similarity or dissimilarity between two clusters by using some measure of distance between pairs of observations. We, however, develop a method that calculates similarity based on social interactions between pairs of agents because social networks are essentially multi-agent systems. Then we would like to study the factors that affect organization performance with the help of organization structure. In the school system network, how funding is distributed in the school system is a very important matter; however, research in the field has not been able to draw any sound conclusions yet. We design and implement a funding evaluation model that examines the relation between funding policy and school performance. We want to consider as many factors that may affect school quality as possible, but, because of the limitation of available data, we currently take student test...
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