Mining and Analysis of Periodic Patterns in Weighted Directed Dynamic Network

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ABSTRACT

Periodic patterns are mined individually on structural and weight aspects of an interaction in a dynamic network. However, these interactions possess a direction aspect too. Moreover, some applications require patterns on both aspects i) on direction and ii) on weight of directed interactions for a better understanding of their behaviour. To the authors’ knowledge, no such work is available that mines both types of periodic patterns in a single run. To overcome this limitation, the authors propose a framework to mine periodic patterns on both the aspects. The framework first mines periodic patterns on direction, and then only the edges present in the patterns obtained are considered further for patterns on weight of directed interactions. Further, the patterns are being analysed to develop a better understanding of the dynamic network. To do so, a set of six parameters explained later in the text is proposed to study the behaviour of interactions at microscopic level. The framework is tested on real world and synthetic datasets. The results highlight its practical scalability and prove its efficiency.

KEYWORDS

Dynamic Graph, Frequent Dynamic Graph, Periodic Dynamic Graph, Periodic Graph, Weighted-Directed Dynamic Graph

1. INTRODUCTION

With the recent technological advances, the amount of data being collected and stored is increasing at an exponential rate. The challenges and problems faced by applications involving the use of big datasets have been listed in Hassanien et al (2015). To analyse and extract valuable information out of the big data, data mining techniques are applied on such passive data, most of which is modelled in the form of a dynamic network consisting of sequence of graphs being evolved over time. A considerable amount of effort has been put in to study the evolution of interactions in a dynamic network (Apostolico et al., 2011; Borgwardt et al., 2006; Desikan & Srivastava, 2006; Duan et al., 2009; Gupta et al., 2014; Halder et al., 2013; Inokuchi et al., 2000; Lahiri & Wolf, 2010; Liu et al., 2009; Obulesu et al., 2014; Qin et al., 2011; Rasheed et al., 2011; Yang et al., 2014). Among these, a good amount of emphasis has been laid on interactions that exhibit frequent behaviour (Borgwardt et al., 2006; Inokuchi et al., 2000; Yang et al., 2014). Also, a substantial effort has been put in to study regular behaviour of interactions (Gupta et al., 2014; Qin et al., 2011).

However, an interaction tends to exhibit other important occurrence patterns, such as periodic patterns which repeat after a fixed interval of time. The first step to study periodic behaviour has been marked through the development of a model based on similarity of time sequences used for mining
periodic patterns (Srikant & Agrawal, 1996). Afterwards, Ozden et al. (1998) have constructed a model for discovery of association rules displaying regular cyclic variation over time. It has been followed by construction of a model (Han et al., 1999) for efficient mining of partial periodic patterns in a time series database. Later, an algorithm (Ma & Hellerstein, 2001) has been proposed for mining partially periodic event patterns with unknown periods. Subsequently, Berberidis et al. (2002) have proposed an approach to deal with datasets in which periodicity is not known in advance. Further, a model (Yang, 2003) has been introduced to mine asynchronous periodic patterns. Later, Lahiri & Wolf (2010) have proposed an algorithm to mine parsimonious periodic patterns on a dynamic network. Subsequently, an improvement (Apostolico et al., 2011) of the algorithm (Lahiri & Wolf, 2010) in terms of time complexity has been proposed and a noise resilient suffix tree based approach (Rasheed et al., 2011) has been provided to detect all periodic patterns in a time series and sequence database. Later, a new approach (Halder et al., 2013) has been given based on super graph for discovering periodic patterns. Further, a framework (Obulesu et al., 2014) has been proposed to find frequent and maximal periodic patterns in Spatiotemporal Databases having big data.

The above mentioned works analyze the periodic behaviour of interactions based on two aspects: 1) topology or structure (Apostolico et al., 2011; Halder et al., 2013; Lahiri & Wolf, 2010; Obulesu et al., 2014; Rasheed et al., 2013), and 2) weight on edges representing interactions (Lahiri & Wolf, 2010). But the focus has been laid on these aspects individually. However, many applications in real world have interactions with direction aspect as well and their behaviour is better understood when periodic patterns are mined on two aspects, i) direction and ii) weight. Here, weight aspect of interaction refers to weight on direction aspect. In the paper, weight on direction aspect is denoted as $dw$ aspect. Vital information is obtained by emphasizing on both direction and $dw$ aspect of interaction. Let us illustrate the meaning of $dw$ aspect and significance of mining periodic patterns on both the aspects with the help of following example. Consider a stock market network depicting relationships between opening and closing prices of various stocks. Let $S_1$ and $S_2$ be two vertices in a graph corresponding to two stocks. A directed edge exists from $S_1$ to $S_2$, if stock $S_1$ suffers a net loss over the entire week and stock $S_2$ gains profit. The weight on the edge represents the value of the net gain in switching from loss incurring stock to profit gaining stock. Let us limit the attention to one particular edge of the network between $S_1$ and $S_2$ and study its behaviour over a series of 10 timesteps. Suppose the observed sequence is $abcdb0bba$. Here, the non-bold character represents weight on edge from $S_1$ to $S_2$ and bold from $S_2$ to $S_1$. Also, the values of weights have been rounded off to integral values, as dollar is more significant than the cent and ‘0’ denotes the absence of edge, ‘a’ denotes a net gain value lying between 1-50, ‘b’ between 51-100 and so on. The periodic occurrence of edge between $S_1$ and $S_2$ based on $dw$ aspect is from $S_1$ to $S_2$ starting at timestep 2 with period 4. From the sequence, it is observed that considering only direction or $dw$ aspect individually results in either losing the information on the direction of gain or the value of net gain itself. But on considering both the aspects, it is inferred that switching in the direction from $S_1$ to $S_2$ which occurs periodically starting at timestep 2 and period 4, is profitable for the buyer and weight on the directed edge gives the value of net gain which for the above example is ‘b’.

From the above example it is clear that mining patterns on both, direction and $dw$ aspect provide significant information which would have not been conveyed if only one of these had been considered. However, existing algorithm (Lahiri & Wolf, 2010), called PSEMINER, returns periodic patterns only on a single aspect of interaction in a single run. Therefore, in this paper, a framework has been proposed based on the work of Lahiri & Wolf (2010) to mine periodic patterns on both direction and weight on direction ($dw$) aspect. The framework is called as Directed and DW Periodic Patterns Framework, DDWPPF. It constitutes the following components – i) a pairing function for assigning unique numbers, ii) a mapping procedure which associates weight component to edges exhibiting periodic pattern on direction aspects, iii) a modified version of existing algorithm (Lahiri & Wolf, 2010) for mining periodic patterns and iv) an inverse pairing function for converting the unique
Multi-Agent Active Services for Online Social Networks
Enrico Franchi, Agostino Poggi and Michele Tomaiuolo (2014). *Handbook of Research on Demand-Driven Web Services: Theory, Technologies, and Applications* (pp. 84-100).
[www.igi-global.com/chapter/multi-agent-active-services-for-online-social-networks/103664?camid=4v1a](www.igi-global.com/chapter/multi-agent-active-services-for-online-social-networks/103664?camid=4v1a)

Managing Online Customer Service Operations
David Barnes and Matthew Hinton (2007). *Utilizing and Managing Commerce and Services Online* (pp. 1-19).
[www.igi-global.com/chapter/managing-online-customer-service-operations/30688?camid=4v1a](www.igi-global.com/chapter/managing-online-customer-service-operations/30688?camid=4v1a)