Temporal data analysis for the good practice of competitive intelligence

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Abstract
The importance of managing dynamically a firm alliance portfolio has recently been demonstrated. In this study, taking as example the biopharmaceutical industry, we handle network data and visualization in ways that explicitly deal with its time-based nature. An algorithm called VisuGraph that allows graph display of evolving networks in a clockwise manner is used here to represent worldwide alliance networks as well as firms evolving portfolios. Using this analysis, we offer managers insights into the best ways to constantly check their local and global environment as well as their own position and its strategic relevance.

Keywords - network; algorithm; alliance; dynamics; biopharmaceutical industry, alliances

INTRODUCTION
One of the most important trends in industrial organization of the past quarter century has been the growth of interfirm alliances. These alliances are formed today with considerable ease across organizational and national boundaries. A recent survey found that alliances already account for anywhere from 6 percent to 15 percent of the market value of the typical company and that alliances are expected to account for 16 percent to 25 percent of median company value within five years and more than 40 percent of market value for almost one-quarter of companies. In current dollars, this means that for the advanced economies as a whole, alliances will represent somewhere between $25 trillion and $40 trillion in value within five years. In the biopharmaceutical and in the software sectors, dynamic alliance formation responds to technological shifts.
Firms are hence embedded into intricate meshes of business relationships. Terms such as the networked firm or the virtual organization have been increasingly used to describe an organizational form containing a network of firms.

The relevance of using complex network theories for studies of business partnerships has recently been demonstrated. In this study, taking as example the biopharmaceutical industry, we handle network data and visualization in ways that explicitly deal with its time-based nature. Using this analysis, we offer managers insights into the best ways to dynamically evaluate their local and global environment as well as their own position and its strategic relevance.

**TEMPORAL GRAPH VISUALIZATION**

Graph drawing addresses the problem of constructing geometric representations of graphs and has applications in many diverse fields, including biology, sociology, information systems, etc.

However, though considerable attention has been paid recently to the area of graph visualization, algorithmic work on network layouts has been devoted mostly to static graphs. In addition, criteria for assessing how ‘good’ a graph layout are ill-defined and different choices made in node or link placement can be used to emphasize different features and answer different needs. High graph density will also eventually lead to useless layout clutter, with ties and nodes obscuring each other.

Work in visual perception has also shown that the human being has a unified global configuration of elements or gestalt-perception of a scene, before paying attention to its details (Myers, 2000).

In the design of the VisuGraph package, still currently a working prototype, our main consideration has been to extend previous work to explicitly deal with the time-based nature of networks in a more versatile way and pay attention to global as well as local features of networks (Loubier and Dousset, 2007).

To illustrate the potential of this time-based analysis, we have analyzed the pace of dynamics of actual event data with the study of complex networks of business relationships as they evolve. We present several examples of temporal exploration of business news using for illustration the biopharmaceutical industry from the 7-year period between 2001 and 2007. Business news can be found in data bases such as Thomson Platinum or Windhover or obtained using open sources available on the World Wide Web, or a combination on both.
The data covers here a total of 8000 business news involving about 6000 firms. The data is used here essentially to demonstrate the potential of our dynamic graph visualization tool.

We use a novel technique for visualization of complex networks that evolve through time. Given a dynamic network, the layout algorithm produces a clock-wise representation of time-slices allowing for a combined view of the graph dynamics. Different types of graphs (subsets of the overall data) can be extracted and then viewed with this visualization tool.

Our graphs are undirected, node-weighted, and edge-weighted graphs. Vertices or nodes represent unique firms in our dataset and there is an edge between two vertices if the respective firms have signed a contract. Vertices can also represent countries. The weight of a vertex is determined by the number of contracts a firm/country has signed. The weight of an edge represents repeat alliances between two firms/countries.

Starting with a series of undirected graphs \( G_0 = (V_0,E_0) \), \( G_1=(V_1,E_1) \), ……., \( G_n=(V_n,E_n) \), the aim of the algorithm is to produce a series of layouts \( L_0, L_1,…..,L_n \), where \( L_i \) is a straight-edge drawing of \( G_i \). Vertices and edges between successive graphs \( G_{i-1} \) and \( G_i \) being added or disappearing. In an alliance database particularly, vertices or firms remain in the graph if they are active in making alliances and only new edges or alliances are taken into account on a yearly basis.

A key issue in dynamic graph drawing is the stability of the layouts that allow for the preservation of a mental map (Misue et al., 2007). Standard requirements from static graph layouts should also be satisfied, such as avoidance of node overlap and minimization of edge crossings, (Tufte, 2003) physical measurability of node’s value, Relativity between the reader cognitive and graph informational contribution.

It is thus essential that the global graph of reference is understandable and clear, allowing, without much cognitive effort, to locate each graph within the global graph. In order to maintain the mental map, the representation here rests on a programmed placing of the vertices, according to precise spatial reference markers corresponding to discrete time periods of one or more years, and using information from all layouts.

The reference markers, used thus to take into account the temporal dimension, are integrated into the graph layout to assist analysis (Loubier et al., 2007). We hence mimic the mechanism of an analog clock which uses a fixed numbered dial and moving hands to display the time. Analogous to the hour markers of a fixed numbered dial on a clock face, fixed temporal reference markers represent differentiated time periods numbered 1, …, \( i \), …, \( n \) in chronological order as in a 1- to 12-hour cycle, successive graphs \( G_{i-1} \) and \( G_i \) appearing within each fixed
period. The number of temporal reference markers corresponds therefore to the number of network snapshots. Vertices are akin to the moving short or long hour hands, their position being dictated by their presence or not within one (longer “hand”) or more (shorter “hand”) temporal markers and the number of linkages they make in each period.

Among the different classes of graph drawing algorithms, our algorithm builds on the class of force-directed layouts.

In that class, forces are applied to nodes according to the graph structure, and the layout is determined by convergence to a minimum stress configuration (Fruchterman and Reingold, 1991). In addition, our algorithm performs the following:

- Nodes/vertices and edges can be weighted, including in a temporal way. Nodes in particular can be displayed as histograms indicating the number of links they are making for each discrete time period (see Figure 1 as an example). Color is used to distinguish each period visualized on a node’s histogram. Weights are colored by different intensity depending on their value. The global activity of a node can thus be immediately assessed, contributing to mental mapping.

- Node placement takes into account temporal reference marks and the different graph layouts; linked vertices in only one period are placed close to the temporal reference marker corresponding to that period and therefore on the periphery of the graph while, at the other extreme, vertices equally active during all periods will be placed at the center of the network. In-between, vertices active in more than one period will be placed between temporal indicators.

  Additionally, nodes can be assigned weights that will influence node placement. A node linked to many nodes in a given period and less in others will be positioned more in the vicinity of the indicator of the period where it is most active (see Figure 2 as an example) but will nevertheless converge closer to the center of the graph display as the number of layouts it is present into increases.

- Global ‘clockwise’ network mapping or smooth transition from one temporal display to another (see Figure 3 as an example).

- A more versatile analysis of subsets of data of different kinds in a static or dynamic way.

- A filter can be applied on a graph to keep the strongest alliances.

- The k-core of a graph can be visualized (Fruchterman and Reingold, 1991).
• The transitivity in the neighborhood of any given individual node’s network can be measured (Alvarez-Hamelin et al., 2005).

**Figure 1.** Temporal representation of node degree, or number of alliances. We’ve used 8 temporal reference markers (yearly analysis starting in 2001 and ending beginning of 2008). The nodes represent three of the biggest pharmaceutical companies worldwide. In (a), the node has an uneven degree distribution while in (b), its number of links is constantly decreasing and in (c), the node has made about the same number of transactions each year. The transacting activity of these major firms is therefore extremely different.

**Figure 2.** Dynamic layout steps using VisuGraph. Four temporal markers (1 to 4) representing 4 discrete time periods in a major alliance biotech sector of the pharmaceutical industry are disposed in a clockwise manner. Nodes involved in only one period are placed on the periphery and closed to the fixed numbered markers of the “dial”. As nodes are involved in more periods they get closer to the center. Though the graph appears cluttered, it can be used rapidly in competitive intelligence to visualize the turn-over of nodes and immediately pick the dominant nodes in a sector (combined markers 1-2-3-4), emerging nodes in the latest period (markers 3-4 and fixed marker 4), ‘failed’ nodes (marker 1), etc, and their dynamics.
Figure 2 shows a global layout of an alliance network of a major sector of the biopharmaceutical industry. Nodes represent firms and links contracts.

A clockwise representation of a network using 4 snapshots corresponding to 4 discrete periods is made in Figure 3.

Figure 3. Four different temporal graphs are displayed separately. The histograms representing the nodes number of transactions per period, highlight only the number of transactions corresponding to a given graph display; the other bars on the histogram appear in grey in the background.

**ALLIANCE GRAPHS**

We have made here a rapid analysis of alliances in the biotechnology industry over 4 to 8 discrete time periods using the “clock” strategy. The analysis is not thorough and intends only to show the potential of mapping tools and simple dynamic visualization techniques.
We have therefore not gone into any details regarding the many different possible typologies of contracts or attributes of firms. A whole image of a major biotech sector of this industry has already been provided in Figure 2.

Figure 4 below shows that data can rapidly be obtained on any individual firm and give relevant information about its transaction dynamics.

Figure 4. Four different temporal graphs are displayed separately. The network of alliances made by the firm A (black arrow) is visualized using 4 temporal snapshots. We easily notice that firm A has made many alliances with major actors (at the center of the figure i.e. actors involved in most periods and transacting a lot) and with also some ‘minor’ actors in period 1 and 2 (closer to the temporal markers and with limited transacting activity).
Firm A is also strongly linked to Novartis and Novartis Vaccine and Diagnostic department (close to node and dark grey representation of weighted repeat link) and will be eventually acquired by this firm.

The same type of analysis can be made if we look at transactions between countries (Figure 5) and thus be rapidly alerted to the arrival of novel entrants in the industry that may change the balance of power between countries or continents as exemplified in Figure 5. Other data include looking at the countries a company may have invested into or the companies that are active in a given country, as shown in Figure 6, for example.

*Figure 5.* Interactions between countries using seven temporal markers.
**CONCLUSIONS**

We need to shift from static sampling methods to streaming actual event data which occur globally and at a very rapid pace in industries for example.

The generative processes of network formation, change, and dissolution need to be understood and predicted. Adapting static layout procedures to dynamic analysis of empirical complex networks is not an easy task. However, we’ve found our “clock” algorithm to be useful and a great help in grasping the underlying processes in dynamic networks.

We are also able to examine micro- and macro- level network processes. Of course other algorithms are needed that offer different solutions and will be specifically designed to interpret different types of networks, allowing for example the study not only of real event data such as examined here but also that of more abstract networks such as social networks of agents.
**BIBLIOGRAPHY**


