5 Affiliations

5.1 Introduction

Membership of an organization or participation in an event is a source of social relations. In organizations and events, people gather because they have similar tasks or interests and they are likely to interact. Members of a sports club, for instance, share a preference for a particular sport and play with or against one another. Directors and commissioners on the boards of a corporation are collectively responsible for its financial success and meet regularly to discuss business matters. Inspired by the sociology of Georg Simmel, groups of people that gather around one or more organizations and events are called **social circles**.

In previous chapters, we studied direct relations among people, such as the choice of friends, or among other social entities, e.g., trade relations between countries. Note that we studied relations among actors of one kind: relations between people or between organizations, but not between people and organizations. Now, we will focus on the latter type of relations, which are called affiliations. Data on affiliations can be obtained relatively easily and they are very popular in data mining.

Affiliations are often institutional or ‘structural’, that is, forced by circumstances. They are less personal and result from private choices to al lesser degree than sentiments and friendship. Of course, membership oin a sports team depends much more on a person’s preferences than detention in a particular prison ward, but even the composition of sports teams depends on circumstances and on decisions made by coaches and sports club authorities. Affiliations express institutional arrangements and since institutions shape the structure of society, networks of affiliations tell us a lot about society. People are often affiliated to several organizations and events at the same time, so they belong to a number of social circles, or, in other words, they are the intersection of many social circles. Society may be seen as a fabric of intersecting social circles.

Although membership lists do not tell us exactly which people interact, communicate, and like each other, we may assume that there is a fair chance that they will. Moreover, joint membership in an organization often entails similarities in other social domains. If, for example, people have chosen to become members in (or have been admitted to) a particular golf club, they may well have similar professions, interests, and social status. Different types of affiliations do not overlap in a random manner: social circles usually contain people who are clustered by affiliations to more than one type of organization. From the number or intensity of shared events, we may infer the degree of similarity of people. However, this argument can be reversed: organizations or events that share more members are also more close socially. A country club with many members from the local business elite can be said to be part of the business sphere.

In this chapter, we present a technique to analyze networks of affiliations which focuses on line values and we discuss three-dimensional displays of social networks.

5.2 Example

In political science, economy, and sociology, much attention has been paid to the composition of the boards of large corporations. Who are the directors of the largest companies and, in particular, which people sit on the boards of several companies? If a person is a member of the board of directors in two companies, he (women have seldom been found in these positions) is a multiple director, who creates an interlocking directorate or interlock between firms.

The network of interlocking directorates tells us something about the organization of a business sector. It is assumed that interlocking directorates are channels of communication between firms. In one board, a multiple director can use the information acquired in another board. Information may or may not be used to exercise power, depending on the role played by the director. If directors are elected because of their social prestige within a community, they serve the public relations of a firm, but they do not influence its policy: they fulfill a symbolic role. However, multiple directors who have executive power may coordinate decisions in several companies, thus controlling large sections of an economy. Then, interlocking directorates are power lines.

In this chapter, we use a historical example: the corporate interlocks in Scotland in the beginning of the twentieth century (1904-5). In the nineteenth century, the industrial revolution brought Scotland railways and industrialization, especially heavy industry and textile industry. The amount of capital needed for these large scale undertakings exceeded the means of private families, so joint stock companies were established, which could raise the required capital. Joint stock companies are owned by the shareholders, who are represented by a board of directors. This opens up the possibility of interlocking directorates. By the end of the nineteenth century, joint stock companies had become the predominant form of business enterprise at the expense of private family businesses. Families, however, still exercised control through ownership and directorships.

The data are taken from the book *The Anatomy of Scottish Capital* by John Scott and Michael Hughes. It lists the multiple directors of the 108 largest joint stock companies in Scotland in 1904-5: 64 non-financial firms, 8 banks, 14 insurance companies, and 22 investment and property companies (`Scotland.net`). The companies are classified according to industry type (see `Industrial_categories.clu`): 1 - oil & mining, 2 - railway, 3 - engineering & steel, 4 - electricity & chemicals, 5 - domestic products, 6 - banks, 7 - insurance, and 8 - investment. In addition, there is a vector specifying the total capital or deposits of the firms in 1,000 pound sterling (`Capital.vec`).

We listed 136 multiple directors, but we should note that two multiple directors (W.S. Fraser and C.D. Menzies) are affiliated with just one board so they are not multiple directors in the strict sense. The data files are collected in the project file `Scotland.paj`.

5.3 Two-mode and one-mode networks

By definition, affiliation networks consist of at least two sets of vertices such that affiliations connect vertices from different sets only. There are usually two sets, which are called **actors** and **events**, for example, directors (actors) and boards of corporations (events). Affiliations connect directors to boards, not directors to directors or boards to boards, at least not directly. Figure 1 shows a fragment of the interlocking directorates network in Scotland: a set of directors (green) and firms (yellow). Note that lines always connect a yellow and a green vertex, e.g., director J.S. Tait to the Union Bank of Scotland. This type of network is called a two-mode network or a bipartite network, which is structurally different from the one-mode networks, which we have analyzed thus far because all vertices can be related in a one-mode network.

In a **one-mode network**, each vertex can be related to each other vertex.
In a **two-mode network**, vertices are divided into two sets and vertices can only be related to vertices in the other subset.

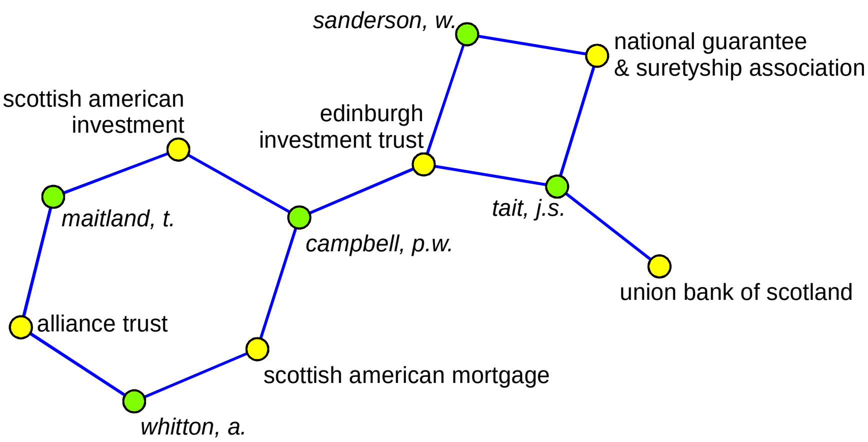


Figure 1 - A fragment of the Sottish directorates network.

We can describe the two-mode network of Scottish directorships in the usual manner by its number of vertices (108 firms and 136 multiple directors) and lines (356 affiliations or board seats), the number of components (16 isolated firms without multiple directors, three small components containing two firms, and one large component), and its degree distribution. Recall that the degree of a vertex is equal to the number of its neighbors if the network does not contain multiple lines and loops. This is the case in the directorships network, so the degree of a firm specifies the number of its multiple directors. This is known as the **size of an event**. The degree of a director equals the number of boards he sits on, which is called the **rate of participation** of an actor. Have a look at Figure 1 and determine the size of events and participation rates of its vertices.

In our description of a two-mode network, we must distinguish between actors and events, because simple measures such as degree have different meanings for actors and events. There are more complications: some structural indices must be computed in a different way for two-mode networks. Consider, for example, the concept of completeness, which we defined as the maximum possible number of lines in a network (see Chapter 3). In a one-mode network, this number is much higher than in a two-mode network because each vertex can be related to all other vertices in a one-mode network but it can only be related to part of the vertices in a two-mode network. As a consequence, the density of a two-mode network, which is the actual number of lines divided by the maximum possible number of lines, must be computed differently for one-mode and two-mode networks.

Techniques to analyze one-mode networks cannot always be applied to two-mode networks without modification or change of meaning. Special techniques for two-mode networks are very complicated and fall outside the scope of this book. So, what can we do? The solution commonly used, which we will follow, is to change the two-mode network into a one-mode network, which can be analyzed with standard techniques.

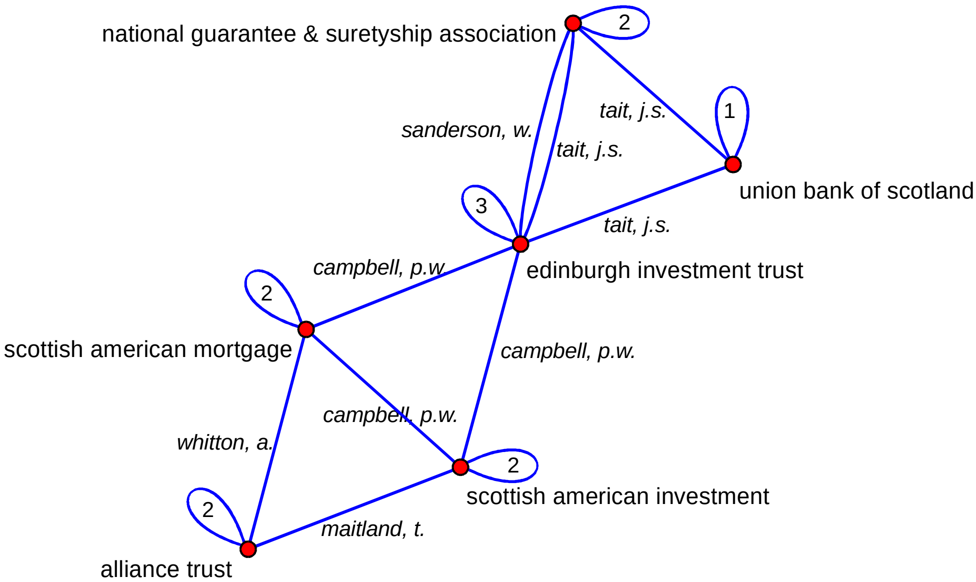


Figure 2 - One-mode network of firms created from the network in Figure 1.

We can create two one-mode networks from a two-mode network: a network of interlocking events and a network of actors which share membership or attendance to common events. Figure 2 shows the one-mode network of firms (events) which is derived from the network in Figure 1. It is constructed in the following way. Whenever two firms share a director in the two-mode network, there is a line between them in the one-mode network. J.S. Tait, for instance, creates a line between the Union Bank of Scotland and The Edinburgh Investment Trust because he sits on the boards of both companies. Since he is also on the board of the National Guarantee and Suretyship Association, he is responsible for lines between three firms. Each line can be labeled by his name. In addition, he creates a loop for each of these firms. The number of loops incident with a vertex shows the number of its neighbors in the two-mode network. In our example, it shows the number of multiple directors on the board of a firm: the size of the event. In short, the actors in the two-mode network become the lines and loops in the one-mode network of events.

From Figure 2, it is clear that firms can be connected by multiple lines, namely in the case that two firms share more than one director. The derived network, therefore, usually is not a simple network. Since it may also contain loops, you must take care when you interpret the degree of a vertex in a network derived from a two-mode network.

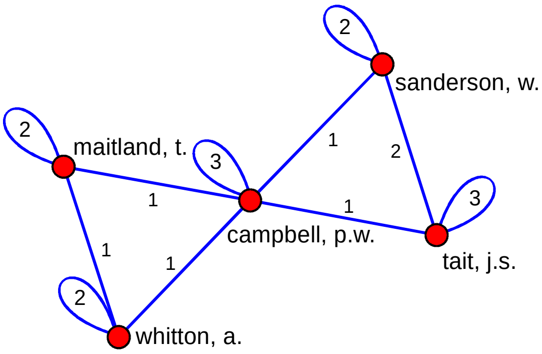


Figure 3 - One-mode network of directors derived from Figure 1.

Multiple lines can be replaced by a single line to obtain a **valued network** with a line value expressing the original number of lines between two vertices. Such a line value is called a **line multiplicity**. Figure 3 shows the valued network of directors (co-membership) which can be derived from the example in Figure 1. Now, the events of the two-mode network are represented by lines and loops in the one-mode network of actors. J.S. Tait meets W. Sanderson in board meetings of two companies. We are confident that you can trace the firms which are responsible for the lines in this network.

Although we stated that one-mode networks derived from two-mode networks can be analyzed with standard techniques, there is a risk of interpreting the results erroneously. A direct relation in a derived one-mode network is easy to interpret: it indicates that two boards have common directors or that two directors meet at one or more boards. Absence of a direct tie implies that two boards do not share a director, e.g., Alliance Trust and Edinburgh Investment Trust in Figure 2, or that two directors do not meet in a board, for instance, A. Whitton and J.S. Tait in Figure 3.

The interpretation of subgroups consisting of three or more vertices is more complicated in derived one-mode networks. Figure 2 contains three cliques of size three. Two cliques are due to directorships of one person, e.g., P.W. Campbell and J.S. Tait, but one clique is not: the clique of size three with Scottish American Mortgage, Alliance Trust, and Scottish American Investment exists thanks to the memberships of three directors (Campbell, Whitton, and

Maitland). In a valued network, this difference is not visible because the multiple lines labeled by names of directors are replaced by single lines with multiplicity values. When interpreting a derived valued network, restrict your conclusions about the number of shared persons (or events) to pairs of vertices. For threesomes and larger sets of vertices you can only conclude that they share one or more actors or events, but you do not know the actual number.

Application

Pajek has special facilities for two-mode networks. We advise to use the data format for two-mode data, which is an ordinary list of vertices and list of edges with the special feature that the list of vertices is sorted: the first part contains all vertices which belong to one subset and the remainder lists the vertices of the other subset. In our example (`Scotland.net`), vertices numbered 1 to 108 are firms and 109 to 224 are multiple directors. The first line of the data file specifies the total number of vertices and the number of vertices in the first subset, e.g., `*Vertices 244 108`. If Pajek opens a data file in this format, it automatically creates a partition which distinguishes between the first subset of vertices (class 1) and the second (class 2). This partition is labeled `Affiliation partition` in the Partition drop list

Net>Transform >2-Mode to 1-Mode >Rows, Columns

You need the affiliation partition to derive a one-mode network from the two-mode network. The submenu *Net>Transform* contains several commands to translate two-mode into one-mode networks. You can create a one-mode network on each of the two subsets of vertices. By convention, vertices of the first subset are called 'rows' and 'columns' refer to the second subset. These terms come from matrix notation, which we will discuss in Chapter 12. The subsets are defined by the affiliation partition. In our example, the first subset contains the firms, so the *Rows* command in the *2-Mode to 1-Mode* submenu will create a network of firms, provided that the two-mode network and affiliation partition are selected in the drop lists of the Main screen. The *Columns* command creates a network of directors.

Net>Transform >2-Mode to 1-Mode >Include Loops, Multiple lines

Check the option *Include Loops* before you derive a one-mode network if you want to know the number of affiliations per vertex in the new network. Depending on the subset you choose for induction, loops specify the participation rate of actors or the size of events. When the option *Multiple lines* is checked, the derived network will contain one line for each shared actor or event with labels of the events or actors which create the lines. If this option is not checked, a valued network without multiple lines is created with line values expressing line multiplicity. Usually, you do not want loops or multiple lines in the one-mode network, so we do not check these options now.

Info>Network >Line Values

There is an easy way to display the distribution of line values in Pajek, for example, line multiplicity in a derived one-mode network: execute the command *Line Values* from the *Info>Network* submenu. In a dialog box, you may either specify custom class boundaries or you may choose a number of classes of equal width. To obtain classes of equal width, type a number preceded by a #-sign in the dialog box. Usually, the number suggested by the dialog box serves the purpose.

Table 1 - Line multiplicity in the one-mode network of firms.

Line Values	Frequency	Freq%	CumFreq	CumFreq%
(... 1.0000]	229	83.5766	229	83.5766
(1.0000 ... 2.0000]	28	10.2190	257	93.7956
(2.0000 ... 3.0000]	7	2.5547	264	96.3504
(3.0000 ... 4.0000]	3	1.0949	267	97.4453
(4.0000 ... 5.0000]	1	0.3650	268	97.8102
(5.0000 ... 6.0000]	0	0.0000	268	97.8102
(6.0000 ... 7.0000]	0	0.0000	268	97.8102
(7.0000 ... 8.0000]	6	2.1898	274	100.0000
Total	274	100.0000		

Table 1 lists the multiplicity of the lines in the one-mode network of Scottish firms. The first class contains 229 lines with values up to and including one. Since there are no lines with multiplicity less than one, this class contains all lines with multiplicity one: the single lines. The next class contains lines with values higher than one, up to and including lines with value two. We assume that you will understand that all 28 lines in this class have multiplicity two; they refer to pairs of firms interlocked by two directors.

You can use the affiliation partition, which distinguishes between the two modes (actors and events), to select the vertices of one mode from a partition or vector associated with the two-mode network. The standard techniques for extracting one or more classes from one partition or vector according to another, which we presented in Chapter 2, can be used to this end.

Net>Partitions >Degree>Input

Partitions >Extract Second from First

Imagine, for example, that we want to know the degree of the firms in the two-mode network, which is equal to the number of their multiple directors (the size of the events). We compute the degree in the usual manner with the *Degree>Input* command in the *Net>Partitions* submenu. The partition created by this command does not distinguish between the firms and the directors, so we must extract the firms from it. We select the degree partition as the first partition in the *Partitions* menu because we want to extract the firms from it. Next, we select the affiliation partition as the second partition in this menu because it identifies the firms within the network. Finally, we extract class 1 (the firms) of the affiliation partition from the degree partition with the *Second from First* command in the *Partitions* menu. Now, we can make a frequency distribution (*Info>Partition*) of the degree of the firms. In the same way, we can translate partitions belonging to a two-mode network to a one-mode network derived from it.

5.4 M-slices

One-mode networks derived from two-mode affiliation networks are often rather dense. They contain many cliques, so we can analyze the structure of overlapping cliques or complete subnetworks if we want to detect cohesive subgroups (see Chapter 3, Section 3.6). In Chapter 12, additional techniques are presented which are useful for analyzing dense networks. In the present chapter, however, we will concentrate on a technique based on line multiplicity: *m-slice*s.

Multiple lines are considered to be more important because they are less personal and more institutional. From this point of view, we may define cohesive subgroups on line multiplicity rather than on the number of neighbors. The larger the number of interlocks between two firms, the stronger their tie, the more similar or interdependent they are. In Figure 4, for instance, the four gray firms share eight directors; they are connected by six lines of multiplicity eight (see Table 1). These firms are connected much more tightly than other firms, which are connected at a multiplicity level of five or less.

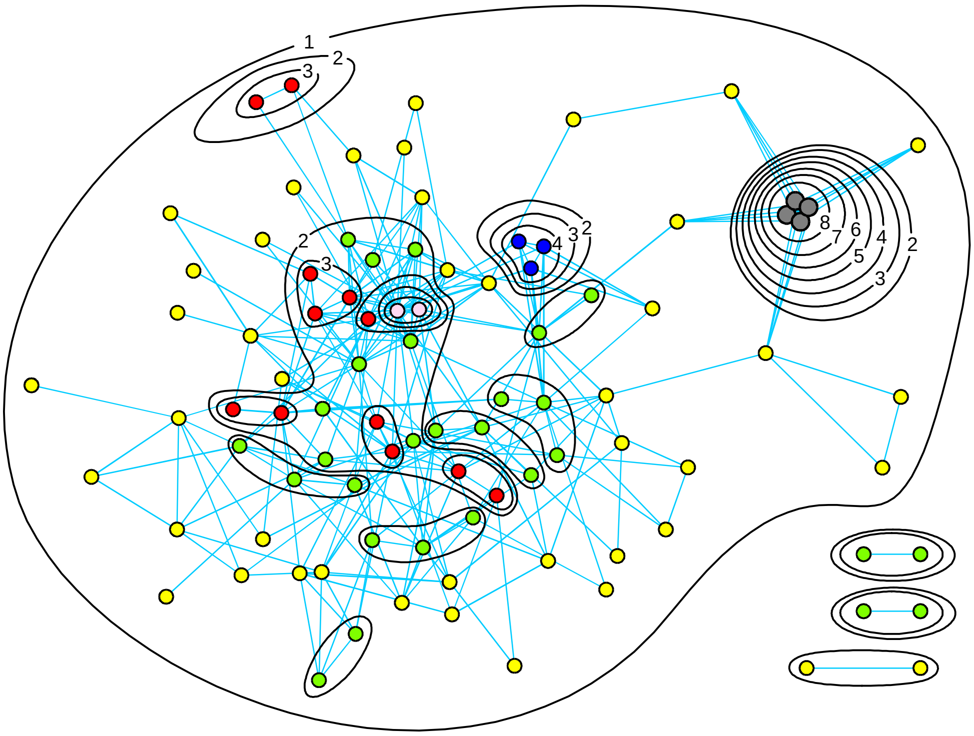


Figure 4 - *m*-slices in the network of Scottish firms (1904-5).

This brings us to the concept of an *m-slice*: a subnetwork defined by the multiplicity or value of lines. In an *m-slice*, vertices are connected by lines of multiplicity *m* or higher to at least one other vertex. This concept was introduced by John Scott, who called it an *m*-core, but we prefer to rename it because we reserve the term 'core' for a *k*-core.

An ***m*-slice** is a maximal subnetwork containing the lines with a multiplicity equal to or greater than *m* and the vertices incident with these lines.

An *m*-slice is similar to a *k*-core in several respects. A trivial point of resemblance concerns its notation. While a 2-core of a simple undirected network is a core in which vertices are connected to at least two neighbors, vertices in a 2-slice are connected by lines with multiplicity two or higher. Furthermore, *m*-slices are nested like *k*-cores. In Figure 4, we manually circled the vertices in the *m*-slices.

These contours show the nesting of cores: the (red) 3-slice is contained in the (green) 2-slice, which is nested in the (yellow) 1-slice. The number of contours which surround a vertex is equal to the multiplicity value defining the *m*-slice it belongs to.

Finally, note that a entire *m*-slice does not need to be connected, e.g., the 2-slice of the Scottish firms network contains several unconnected parts. Just like a *k*-core, an *m*-slice does not necessarily identify one cohesive subgroup. If you want to find the cohesive subgroups in a particular *m*-slice, that is, the vertices which are connected by lines of a particular minimum multiplicity, remove all lines with values lower than *m* and look for weak components. Each component contains vertices which are directly or indirectly linked by ties of a particular strength.

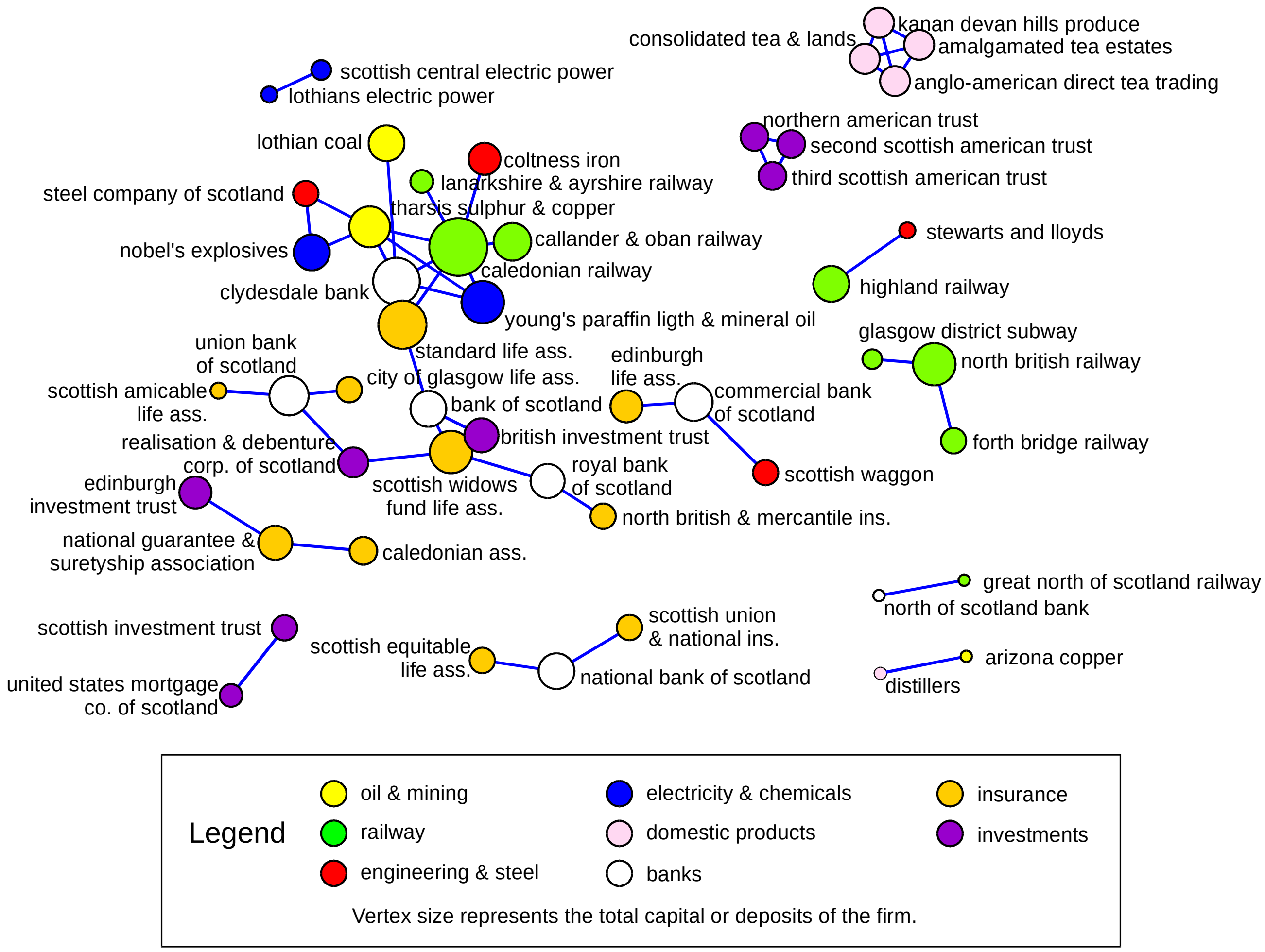


Figure 5 - 2-slice in the network of Scottish firms (1904-5).

Figure 5 shows the components within the 2-slice: several small components of firms of one type (domestic products, railways, electricity, investments) and one larger component consisting of a 'knot' of large firms dedicated to railways, engineering, steel, mining, and chemicals, and a 'tail' of financial institutes: banks, insurance and investment companies. In the large component, the wealthy Caledonian Railway occupies a pivotal position. We may conclude that plural interlocks interconnect financial organizations rather than that they link the financial sphere to the heavy industries or the production of consumer goods in this historical example.

Application

Net>Transform>Remove >lines with value>lower than

Net>Partitions>Degree >Input

Operations>Extract from Network>Partition

In Pajek, there are several ways for producing the *m*-slices in a valued network. If you want to obtain a particular *m*-slice, e.g., the 2-slice, we recommend to delete all lines with line values below *m* with the *Net>Transform>Remove>lines with value>lower than* command: enter the desired level of *m*, e.g., 2, in the dialog box issued by this command. Next, identify all isolated vertices with a degree partition (isolated vertices have zero degree) created with the command *Net>Partitions> Degree>Input*, and remove them with the *Operations>Extract from Network> Partition* command: extract classes one and higher in the degree partition.

Partitions >Extract Second from First

Vector>Extract Subvector

Draw >Draw-Partition-Vector

With the degree partition, you can also extract the non-isolated vertices from the partition of industrial classes (`Industrial_categories.clu`) and from the vector containing the capital or deposits of the firms (`Capital.vec`). Use the *Partitions>Extract Second from First* and *Vector>Extract Subvector* commands discussed in Chapter 2 (sections 2.4 and 2.5 respectively). If you draw the new network, partition, and vector (command *Draw>Draw-Partition-Vector*) and energize it, you obtain a sociogram similar to the one depicted in Figure 5.

Net>Partitions >Valued Core >Use max instead of sum

If you just want to know the *m*-slices to which the vertices belong, you may use the commands in the submenu *Net>Partitions>Valued Core*, provided that the network does not contain multiple lines or loops. Make sure that the option *Use max instead of sum* is checked in the submenu before you execute either the *First Threshold and Step* or *Selected Thresholds* command, which are two different ways to group continuous line values into classes. If you want *m* to represent classes of equal width, choose the command *First Threshold and Step* and choose *Selected Thresholds* otherwise. The latter command needs a vector for input, which is a little bit complicated, so we will not discuss it here.

Net>Partitions >Valued Core >First Threshold and Step

If you use the command *First Threshold and Step*, you must choose between *Input*, *Output*, and *All*. By now, you will be familiar with these options and you will know it is best to choose *Input* or *Output* when you are analyzing an undirected network. In a dialog box, you must specify the first threshold, which is the upper limit of the lowest class. Note that each class includes its upper limit. The default threshold, e.g. 0, is the correct choice if the network may contain isolated vertices. A second dialog box asks for the step value, which is the class width. It is one by default and this is a good value for *m*-slices because it creates a class for each consecutive multiplicity.

Now, Pajek creates a partition with class numbers corresponding to the highest *m*-slice each vertex belongs to. In addition, Pajek reports a frequency table with the distribution of vertices over *m*-slices (denoted by m). Note that loops (if present) are taken into consideration in the computation, so remove them from the network first, otherwise isolated vertices may be regarded as having one or more neighbors.

[Draw screen] Options >Values of Lines >Similarities

The *m*-slices partition can be drawn in the usual way. Since the idea of *m*-slices is that vertices with stronger ties are more similar, we recommend to use line values when you energize a network of *m*-slices. Lines with high multiplicity ought to be drawn shorter than lines with low multiplicity. In Chapter 4, we already presented the relevant option (*Options>Values of Lines>Similarities*). Tightly connected vertices in the double sense, viz. entertaining many lines and lines with high values, will be located closely together, e.g., the four gray vertices in Figure 4, which are the pink tea companies in Figure 5. These firms are a clique and each pair of firms is connected by eight directors. Actually, eight men sat on the boards of all four companies. No wonder that they are almost drawn on top of each other.

Export>SVG >Line Values >Nested Classes

Finally, Pajek offers a powerful tool to show *m*-slices interactively on the web with the *Export>SVG* submenu. Select the command *Nested Classes* from the submenu *Line Values* to obtain an HTML-file with a drawing of the network. If you open this file in an internet browser with the SVG plug-in installed (see Appendix 2 for details), you will see the sociogram and a set of checkboxes to its right. Each checkbox is associated with a class of lines, which you specified in a dialog box. If you deselect a checkbox, all lines with values up to and including the deselected class are removed from the picture as well as all vertices which are isolated when the lines are removed. This allows you to view the lines and vertices at different multiplicity levels interactively. The HTML-file `m-slices.htm` on the CD-ROM offers an example.

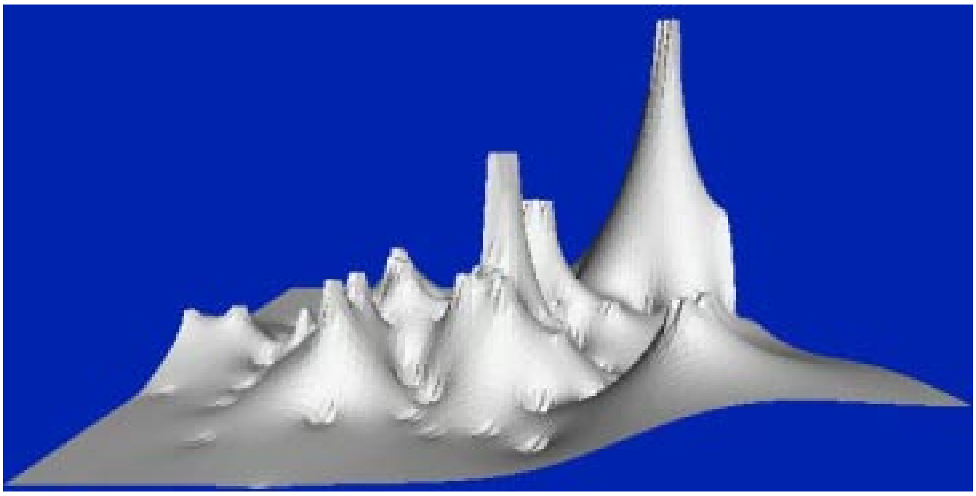


Figure 6 - *m*-slices in the network of Scottish firms modeled as a terrain.

5.5 The third dimension

Contours around *m*-slices resemble elevation lines on a hiker's map: crossing a contour means that you go up or down one *m*-slice as if you are climbing or descending a certain amount of meters in the mountains. Can we model the network as a landscape in which the elevation of a point matches the value of its *m*-slice? This can be done, as illustrated by Figure 6, but it involves techniques from geography which are not available in Pajek. Although we cannot obtain such a smooth picture easily, we can apply the principle of adding heights to points in a plane.

In previous chapters, we alluded to the possibility of drawing networks in three dimensions but we restricted ourselves to two dimensions. The third dimension is called the z-axis, which points from the plane of the Draw screen towards the person in front of the computer monitor. If we use the *m*-slice class numbers of vertices as their scores on the z-axis, the highest *m*-slice peaks out of the plane. If computer screens were flexible, a three-dimensional drawing of the *m*-slices in the network of Scottish firms would change its surface to the landscape of Figure 6 and we would be able to feel *m*-slices with our fingertips.

As it is, we have to be satisfied with a faint sensation of depth, which is caused by the size of vertices and the darkness of vertex labels in a two-dimensional drawing. Nearby vertices are drawn larger and distant vertex labels are gray rather than black. When we rotate the network, we get a better view of the 'landscape' of *m*-slices (Figure 7), which is clearly dominated by the gray peak of the 8-slice.

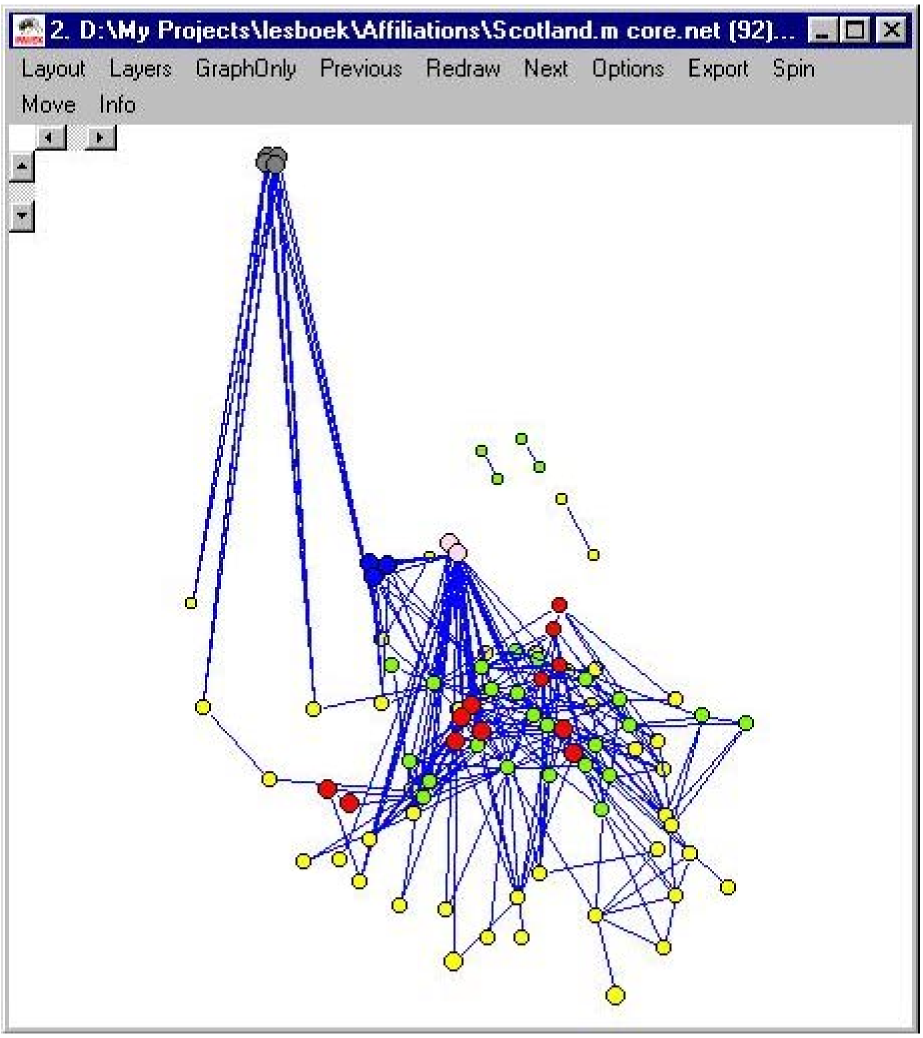


Figure 7 - *m*-slices in three dimensions.

The third dimension offers another opportunity to visualize social networks. Instead of using a predetermined set of values as z-scores (heights), e.g., values of *m*-slices, we can energize a network in three dimensions, allowing the *Energy* procedure to locate vertices in a three-dimensional space in order to optimize the length of lines. Sometimes, a third dimension helps to detect patterns, for instance a 3D drawing of the Scottish firms networks separates the different red 3-slices better than a two-dimensional drawing (Figure 9) but the results are often disappointing. Our graphical devices can handle two-dimensional representations much better than three-dimensional models.

Application

First, let us have a look at the coordinate system of Pajek (Figure 8). Imagine that the light gray square is the Draw screen. As we have seen before, the x-value defines the horizontal location of a vertex (from left to right) and its y-value specifies the vertical position (from top to bottom). The z-value of a vertex defines its protrusion from the background of the Draw screen. The arrows indicate the direction of positive rotations around the axes.

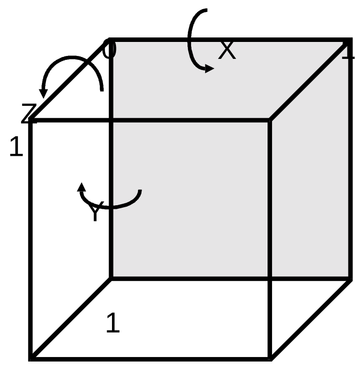


Figure 8 - Coordinate system of Pajek.

Layers>Type of Layout

Layers>In z direction

You can 'lift' the *m*-slices out of the plane of the screen with the *Layers* menu in the Draw screen. First, optimize the drawing using line values as similarities (see previous section) to make sure that vertices in an *m*-slice are drawn closely together. Also, make sure the *m*-slices partition is active and displayed in the draw screen, otherwise the *Layers* menu is not available. Next, choose option *3D* from the *Type of Layout* submenu and the *Layers* menu will show a command which displays the layers in the z direction. On execution of the *In z direction* command, nothing seems to happen but if you take a closer look, you will see that some vertices are drawn larger than others and some vertex labels are gray instead of black. You are looking at the 'peaks' from above, which does not give much sense of relief.

Options >ScrollBar On/Off

When you rotate the structure, peaks and lowlands are more apparent. Toggle the *ScrollBar On/Off* option in the *Options* menu to add two scrollbars to the top left of the Draw screen (see Figure 7). Press the buttons on the vertical scroll bar to rotate the network around the x-axis, which will raise or lower the peaks, and continue until you are satisfied with your view. Now you can see that the gray 8-

slice is towering high above the rest of the network. If the Draw screen is active, you can use the x, y, and z keys on your keyboard to spin the network around the x, y, and z axis respectively. Use capitals X, Y, and Z for rotation in the opposite direction.

Spin menu

You can also rotate the three-dimensional structure in any direction you wish with the *Spin* menu, but this is slightly more complicated because you have to choose the axis of rotation (command *Normal*) and the angle of rotation, which you must enter in a dialog box displayed by the *Spin around* command. When you ask for a rotation over 360 degrees (or just press s or S if the Draw screen is active), you will see the network revolve for your eyes. This allows you to inspect the network from all angles.

Layout>Energy > Fruchterman Reingold >3D

Three-dimensional optimization is accomplished with the command *3D* in the *Layout>Energy>Fruchterman Reingold* submenu. Figure 9 offers a view of the main component of Scottish firms after three-dimensional optimization. The colors of the vertices indicate their *m*-slice. Now, we can see that there are several small (red) 3-slices rather than one large core.

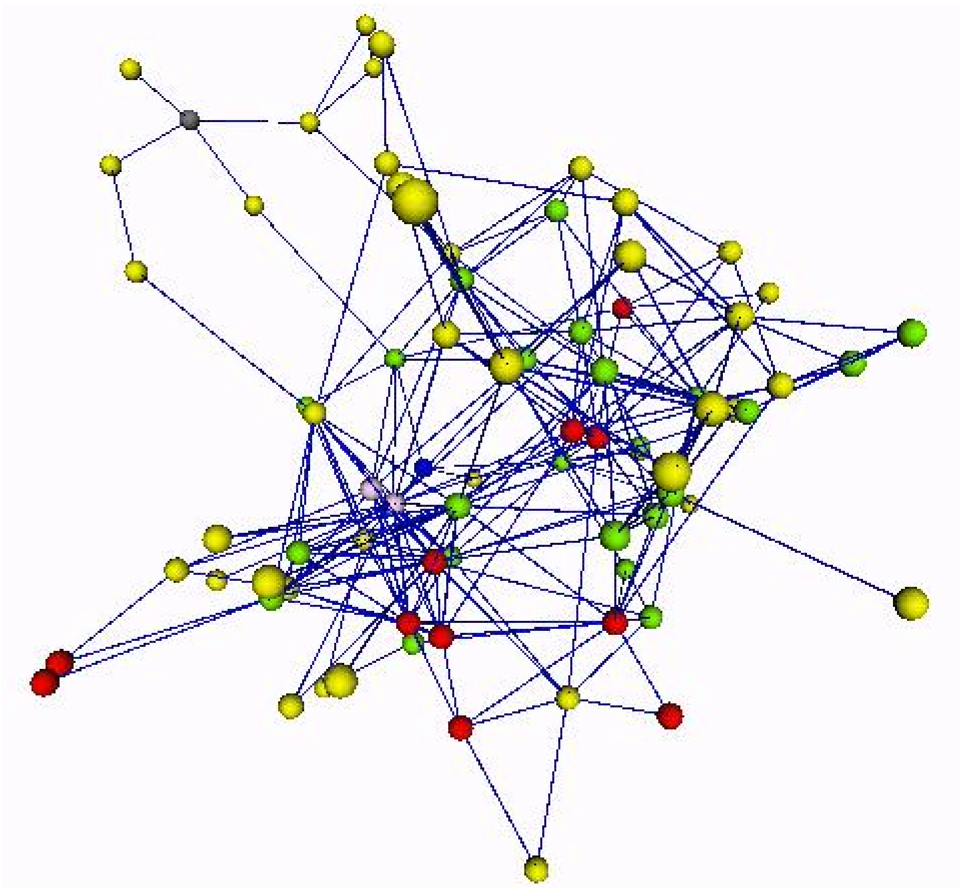


Figure 9 - VRML model of *m*-slices in the largest component of Scottish firms.

Export>VRML

Figure 9 is a Virtual Reality Markup Language (VRML) model, which can be displayed and manipulated by an internet browser provided that a special plug-in is installed (for details see Appendix 2). You can rotate and move through the structure as if it is part of a video game, but you need a fast computer and graphics card for smooth operations. The file `m-slice.wrl`, which was created by Pajek with the *Export>VRML* command, contains the model shown here.

5.6 Summary

Affiliation networks are typically two-mode networks, in which persons are related to organizations. The structure of these networks may be analyzed with standard network techniques, but several structural concepts have to be redefined or must be interpreted differently when applied to two-mode networks. Therefore, network analysts usually focus on the one-mode person-by-person or organization-by-organization network which can be derived from a two-mode affiliation network.

Derived one-mode networks tend to be rather dense, since all people affiliated to one organization are interrelated in the derived network of persons and all organizations which share a particular person are completely connected in the derived network of organizations. Researchers apply the techniques of overlapping cliques and *m-slice*s to networks derived from affiliations. Overlapping cliques identify relatively dense sections of the network and *m*-slices identify clusters of persons or organizations which are related by multiple lines, e.g., firms which share a certain number of directors.

Finally, this chapter introduces three-dimensional displays. We can use the third dimension to represent predetermined values by layers, e.g., the multiplicity level of *m*-slices, which turns a sociogram into a landscape, or we can use all three dimensions to energize a network. In subsequent chapters, we will encounter more applications of the third dimension but it should be noted that two-dimensional sociograms are often easier to interpret.

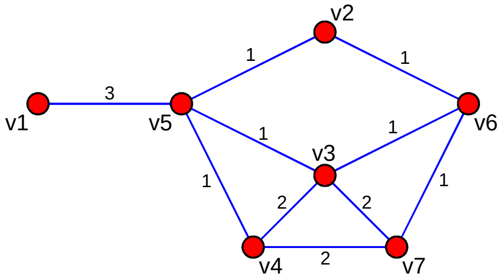
5.7 Exercises

1 Add the names of the firms to the lines of the one-mode network of directors in Figure 3 (Section 5.3).

2 Which of the following statements is correct? Justify your choice.
   a Each affiliation network is a two-mode network.
   b Each two-mode network is an affiliation network.

3 In Figure 4 (Section 5.4), what is the multiplicity of the relation between the two pink vertices?
   a we do not know
   b 4
   c 5
   d 5 or higher

4 The sociogram below depicts a one-mode network of firms derived from affiliations between multiple directors and firms. Which of the following interpretations can be incorrect?



a Three directors sit on the boards of v1 and v5 simultaneously.

b No director sits on all four boards of firms v2, v3, v5, and v6.

c Two directors sit on the boards of v3, v4, and v7 simultaneously.

d No director sits on the boards of v1 and v4 simultaneously.

5 Add contours of *m*-slices to the sociogram of Exercise 4.

6 Create a three-dimensional energized drawing of the information network in San Juan Sur, which you analyzed in the assignment of Chapter 3 (`SanJuanSur_deathmessage.net`). Which family-friendship groupings (`SanJuanSur_deathmessage.clu`) are nicely clustered in this image?

5.8 Assignment

In Hollywood, composers of soundtracks work on a freelance basis. For each movie, a producer hires a composer and negotiates a fee. The earnings of composers is highly skewed: a handful of composers earn a lot whereas most of them have moderate or low revenues. This is characteristic of artistic labor markets.

Why do some composers earn much more money than their colleagues in Hollywood? Let us assume that there are two hypotheses:

1. A successful composer works for the same producer(s) on a regular basis whereas less successful composers do not.
2. The most successful composers all work for the top producers who are responsible for the most expensive movies.

The network `Movies.net` contains the collaboration of 40 composers and the 62 producers who produced a minimum of five movies in Hollywood, 1964-1976. This is a 2-mode network: a line between a composer and a producer indicates that the former created the soundtrack for the movie produced by the latter. The line values indicate the number of movies by one producer for which the composer created the music in the period 1964-1976. The partition `Movies_top_composers.clu` identifies the five top composers each of whom earned 1.5% or more of the total income of Hollywood movie score composers in the 1960s and 1970s.

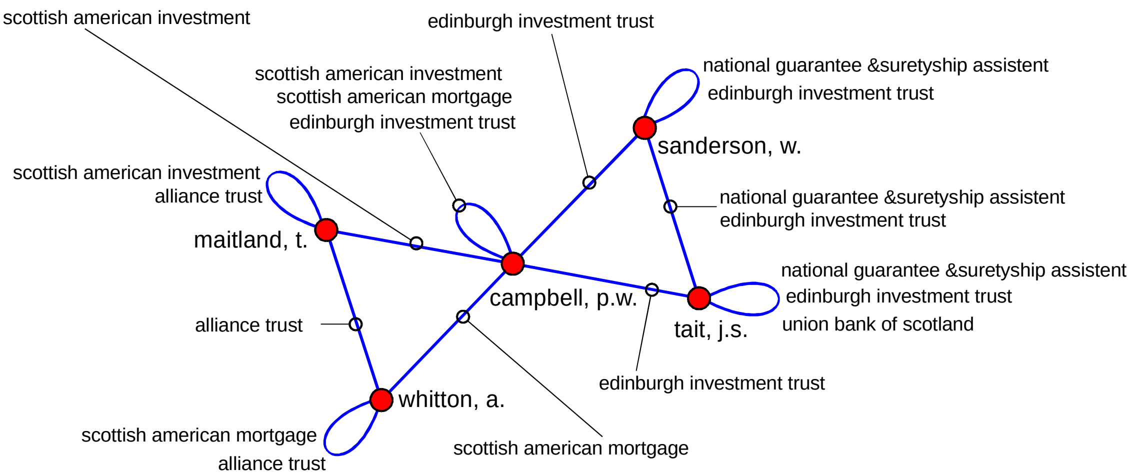
Analyze the 2-mode network in order to test hypothesis 1. Then, create a 1-mode network of composers and see whether it corroborates or falsifies hypothesis 2.

5.9 Further Reading

- Georg Simmel stated his ideas about social circles in *Soziologie. Untersuchungen über die Formen der Vergesellschaftung* (Berlin: Duncker & Humblot, 1908), which was translated by Kurt H. Wolff as *The Sociology of Georg Simmel* (New York: The Free Press, 1950). Charles Kadushin used this concept and adapted it to network analysis in his book *The American Intellectual Elite* (Boston: Little, Brown and Company, 1974), using the technique of overlapping cliques.
- In the paper 'Analysing interlocking directorates: theory and methods', published in the journal *Social Networks* (vol. 1 (1979) issue 4, p. 1-36), Meindert Fennema and Huibert Schijf survey research on interlocking directorates. Our example is taken from John Scott & Michael Hughes, *The anatomy of Scottish capital: Scottish companies and Scottish capital, 1900-1979* (London: Croom Helm, 1980).
- Stanley Wasserman and Katherine Faust discuss affiliation networks and some advanced techniques in Chapter 8 of their book *Social Network Analysis: Methods and Applications* (Cambridge: Cambridge University Press, 1994).
- The data of the assignment are taken from Robert R. Faulkner, *Music on Demand. Composers and Careers in the Hollywood Film Industry* (New Brunswick: Transaction Books, 1983).

5.10 Answers

1 The sociogram should look like this (do not forget the loops!):

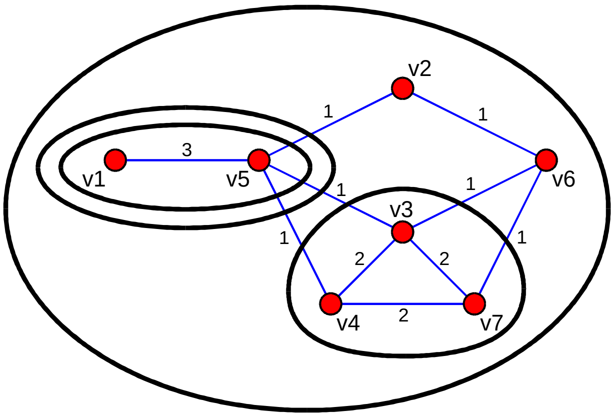


2 Answer a is correct, since affiliations are relations between people and organizations or events, there must be two subsets which cannot be linked internally. Heterosexual love relations constitute a two-mode network but not an affiliation network, so answer b is not correct.

3 Answer c is correct. There are exactly five contours around the pink vertices, so their multiplicity level is five.

4 Interpretation c can be incorrect since it is possible that firms v3 and v4 share other directors than firms v3 and v7 and firms v7 and v4. The other interpretations can be correct.

5 Your answer should look like the sociogram below. Do not forget to draw two contours around the 3-slice (left) and to include a contour for the 1-slice, that is, the component, otherwise the level of multiplicity does not correspond to the number of contours.



6 Energize the network with *Fruchterman Reingold>3D* and spin it around. You will see that all family-friendship groupings are clustered quite well in the three-dimensional model, with the exception of the light green family-friendship grouping consisting of families f5, f14, f17, f25, f58, and f69, which are scattered in the middle of the sphere.