

Attributes and Relations

2.1 Introduction

In Chapter 1, we argued that social network analysis focuses on social relations. A network is a set of vertices and lines. Both vertices and lines have characteristics that we may want to include in our analysis (e.g., the gender of people and the strength of their ties). As noted in Chapter 1, properties of relations are represented by line values in the network (e.g., first and second choices among girls in the dormitory). Now, we add characteristics of the vertices to the analysis. How can we use information on the actors to make sense of the social network?

In this chapter, we present techniques that combine relational network data and nonrelational attributes, such as psychological, social, economical, and geographical characteristics of the vertices in the network. The attributes enhance our interpretation of network structure and they enable us to study subsections of the network. In addition, we briefly discuss how to use the network position of vertices in statistical analysis; social network analysis and statistics are two complementary sets of techniques. After having studied this chapter, you will understand the basic data used in network analysis and you will be able to combine relational and non-relational data.

2.2 Example: The World System

Social network analysis can be applied to large-scale phenomena. In 1974, Immanuel Wallerstein introduced the concept of a capitalist world system, which came into existence in the sixteenth century. This system is characterized by a world economy that is stratified into a core, a semiperiphery, and a periphery. Countries owe their wealth or poverty to their position in the world economy. The core, Wallerstein argues, exists because it succeeds in exploiting the periphery and, to a lesser extent, the semiperiphery. The semiperiphery profits from being an intermediary between the core and the periphery.

The world system is based on a global division of labor. Countries in the core specialize in capital-intensive and high-tech production, whereas peripheral countries apply themselves to low-valued, labor-intensive

products or unprocessed, raw materials. Core countries import raw and less-processed products from the periphery and turn them into expensive high-tech products that are exported to countries in the core, semiperiphery, and periphery. In consequence, there is much trade among core countries, but little trade between countries in the periphery. The core dominates the world trade in a double sense: core countries are more often involved in trade ties than peripheral countries and the value of exports from core countries exceeds the value of imports because their products have higher added value. This is why core countries do very well economically.

Which countries belong to the core, semiperiphery, or periphery? In political economy, several attempts have been made to answer this question, some of which are based on social network analysis. The network analysts analyzed the structure of the trade relation and classified countries according to the pattern of their trade ties; for instance, the nations that trade with almost all other countries are classified as core countries. World trade statistics, which are widely available, offer the data required for this analysis.

In this chapter, we use statistics on world trade in 1994. We included all countries with entries in the paper version of the *Commodity Trade Statistics* published by the United Nations, but we had to add data on some countries for 1993 (Austria, Seychelles, Bangladesh, Croatia, and Barbados) or 1995 (South Africa and Ecuador) because they were not available for 1994. Countries that are not sovereign are excluded because additional economic data are not available: For example, the Faeroe Islands and Greenland or Macau, which belong to Portugal and Denmark respectively. In the end, the network contains eighty countries and most missing countries are located in central Africa and the Middle East or belong to the former USSR.

The arcs in our network represent imports into one country from another. We restrict ourselves to one class of commodities rather than total imports and we picked miscellaneous manufactures of metal, which represents high-technology products or heavy manufacture. We use the absolute value of imports (in 1,000 U.S.\$) but we did not register imports with values less than 1 percent of the country's total imports on this commodity. The network data are stored in the file `Imports-manufactures.net`.

In addition, we use several attributes of the countries in our analysis, namely their continent (`Continent.clu`), their structural world system position in 1994 (`World_system.clu`), their world system position in 1980 according to a previous analysis by Smith and White (`World_system-1980.clu`; see the reference in Section 2.10), and their gross domestic product per capita in U.S. dollars in 1995 (`GDP-1995.vec`). Note that in this chapter, we do not determine the world system position of the countries, we use results from an advanced structural technique called blockmodeling, which is presented in Chapter 12. The three world system positions in 1994 – core, semiperiphery, and periphery – are defined such that the core countries trade a lot of manufactures of metal among themselves and they export a lot to the countries in the semiperiphery, whereas the countries in the semiperiphery and periphery do not export a substantial amount of these manufactures.

2.3 Partitions

A partition of a network is a classification or clustering of the network's vertices. Each vertex is assigned to exactly one class or cluster (we use these words as synonyms); for example, one country is assigned to the core and another to the semiperiphery. A partition may contain a special class that collects the vertices we cannot classify because data are missing. Usually, the classes are identified by integers; for instance, a core country receives code 1 in the partition, and a country in the semiperiphery gets a 2. In this format, a partition is simply a list of nonnegative integers, one for each vertex in the network.

A *partition* of a network is a classification or clustering of the vertices in the network such that each vertex is assigned to exactly one class or cluster.

In network analysis, partitions store discrete characteristics of vertices. A property is *discrete* if it consists of a limited number of classes; for instance, we may code the continents of countries by digits such that African countries constitute class 1, Asian countries constitute class 2, and so on. Six classes will suffice. A classification contains a limited number of classes and most classes contain several vertices because we want the classes to represent groups of actors rather than single actors or nothing at all. Partitions, therefore, are very useful for making selections from a network to reduce its size and complexity. We discuss this in Section 2.4.

In some cases, the order of class numbers in a partition is arbitrary for instance, in the partition of nations according to continents: there is no compelling reason why African countries should have a lower class code than Asian countries. In other instances, however, the order is meaningful. For instance, it would be foolish to assign the semiperiphery to class 1, the core to class 2, and the periphery to class 3, because this would not correctly reflect the obvious ranking of the three classes. Finally, the class codes may represent “real” numbers, for instance, the number of lines incident with a vertex: all vertices in class 1 are incident with one line, vertices in class 2 are incident with two lines, and so on, so make sure that you attach the right meaning to class numbers!

Partitions may specify a *structural property* such as world system position, which is a result of network analysis or a characteristic measured independently of the network (e.g., the continent where a nation is located). We call the latter *attributes* of vertices.

Figure 17 displays the trade in manufactures of metal and their position in the world system in 1994. In line with the spatial connotations of the concepts of core, semiperiphery, and periphery, the core countries are placed in the center (black vertices), the semiperiphery constitutes the middle ring (gray vertices), and the peripheral countries (white vertices) are located on the outer ring. The intense trade ties among the countries in the core and between the core and semiperiphery are apparent, just like the relative absence of trade in manufactures of metal among countries in the periphery. We should, however, note that the impression of clear

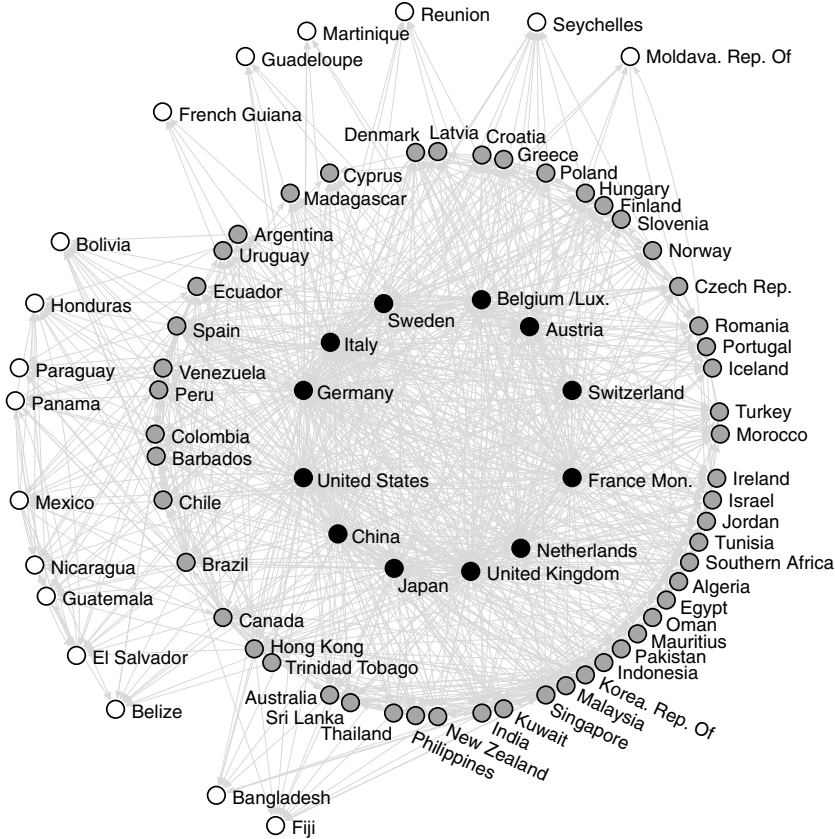


Figure 17. World trade of manufactures of metal and world system position.

boundaries between the three classes has deliberately been created by the researcher: this layout shows the world system positions rather than proves them.

Application

File>Partition>
Read

File>Partition>
Save

Partition
drop-down menu

In Pajek, partitions are a data object on their own, so they are accessible from a drop list once they are read (*File>Partition>Read*). Partitions are saved in files with the extension .clu (*File>Partition>Save*) and these files are just lists of nonnegative integers preceded by a line which specifies the number of vertices. The first integer represents a property of the first vertex (e.g., world system position), the second integer belongs to the vertex with serial number 2, and so on. You should change neither the sequence of vertices in a network nor the sequence of entries in a partition because this will destroy the compatibility of the partition and the network: vertices are then no longer associated with the corresponding classes.

File>Pajek
Project File

Although partitions can be stored separately, we can also save them with the network to which they belong. Pajek has a special data format – the project file – that may contain all networks, partitions, and other

Vertex	Val	Label
1	2	Algeria
2	2	Argentina
3	2	Australia
4	1	Austria

Figure 18. Edit screen with partition according to world system position.

data objects that belong together. You may, for example, read the world trade network and associated partitions and vectors from the project file *World_trade.paj* with the command *File>Pajek Project File>Read*. With the *Save* command from the same submenu, you can create your own project file, which contains all data (networks, partitions, and so on) at the time you save the project. We advise to open the project file *World_trade.paj* now.

If you edit it, it is easy to see that a partition consists of a series of integers. Choose the command *Edit* in the *File>Partition* submenu or simply click on the edit button at the left of the Partition drop-down menu (with the writing hand) to open the Edit screen (see Figure 18). The Edit screen contains three columns, which display the vertex number (*Vertex*), the class code (*Val*), and the vertex label (*Label*). The first vertex in the world trade network represents Algeria, which belongs to class 2 (semiperiphery), and the fourth vertex is Austria, part of the core (class 1). You may click on the class code to change it manually but you can also change the labels of vertices in the network. Note that the labels are displayed only if the associated network is selected in the Network drop-down menu.

*Editing Partition
Screen*

*File>Partition>
Edit*

The command *Partition* in the *Info* menu produces a frequency table of the classes in the active partition, which offers a quick way to inspect a partition. On execution, this command displays two dialog boxes. In the first box, which is similar to the dialog box associated with the *Info>Network>General* command (see Section 1.3.3), the user may request a listing of vertices with the highest or lowest class numbers. Type a positive integer to list vertices with the highest class numbers and type a negative integer to list vertices with the lowest class numbers. The second dialog box allows for suppressing classes in the table which occur seldom; for instance, type 5 in this dialog box to exclude classes with four vertices or less from the frequency tabulation.

Info>Partition

The *Info>Partition* command presents a table that lists the number of vertices in each class of the partition. In Table 1, we can see that twelve countries belong to the first class, which is 15 percent of all countries. The number 12 is the *frequency* (abbreviated to *Freq* in the table) with which class 1 occurs among the vertices. Pajek does not “know” that this

Table 1. *Tabular Output of the Command Info>Partition*

Class	Freq	Freq%	CumFreq	CumFreq%	Representative
1	12	15.0000	12	15.0000	Austria
2	51	63.7500	63	78.7500	Algeria
3	17	21.2500	80	100.0000	Bangladesh
SUM	80	100.0000			

class refers to the core. It can only help the interpretation of the meaning of the class by showing a representative of the class, that is, the label of a vertex that belongs to this class. Together, the core and semiperiphery contain sixty-three of the eighty countries (column CumFreq), which is 78.75 percent (CumFreq%).

Draw>
Draw
-Partition

Because partitions contain discrete classes, the class to which a vertex belongs can be represented by the color of the vertex. Each class is associated with a color (e.g., vertices in class 1 are yellow). It is easy to obtain a colored sociogram. First, make sure the right network and partition are selected in the drop-down menus of the Main screen, for example, the manufactures of metal network (`Imports-manufactures.net`) in the Network drop-down menu and the world position partition (`World-system.clu`) in the Partition drop-down menu. Next, execute the command *Draw-Partition* from the *Draw* menu (or press *Ctrl-p*). If the selected network and partition are compatible, that is, if the number of entries in the partition is equal to the number of vertices in the network, Pajek draws the network with vertex color determined by the partition.

Layout>Energy>
Kamada-
Kawai>Free

Move>Circles

In Figure 17, the circular layout was created in the following way. First, the layout was energized with the Kamada–Kawai energy command. This brought most core countries to the center and most peripheral countries to the margin of the sociogram. Then, manual movements of vertices was restricted to three circles and eighty positions on each of them with the *Circles* command in the *Move* menu. Finally, the countries were manually dragged toward the nearest position on the appropriate circle.

Then, what you get is a sociogram such as in Figure 17 in color. On your screen, the core countries are yellow, the countries in the semiperiphery are green, and the peripheral countries are red. Because this book is printed in black and white, we cannot reproduce the colors here but we stored all the color illustrations in a document (`illustrations.pdf`) on the Web site dedicated to this book (<http://vlado.fmf.uni-lj.si/pub/networks/book/>) so you can check the colors that you are expected to see on your screen.

Options>
Colors>
Partition
Colors

For black-and-white printing, a limited number of grays can replace color. Pajek offers a command to switch between colors and grays in the *Colors* submenu of the *Options* menu in the Draw screen: the command *Partition Colors*. On selection of this command, Pajek displays a dialog box such as that in Figure 19. It contains forty colored squares and the partition’s class numbers with which they are associated. For class numbers above 39, Pajek cycles through the first forty colors again: the vertex color of class 40 is equal to the color of class zero, and so on. Press the button labeled “Default GreyScale 1” to change the first five colors (classes

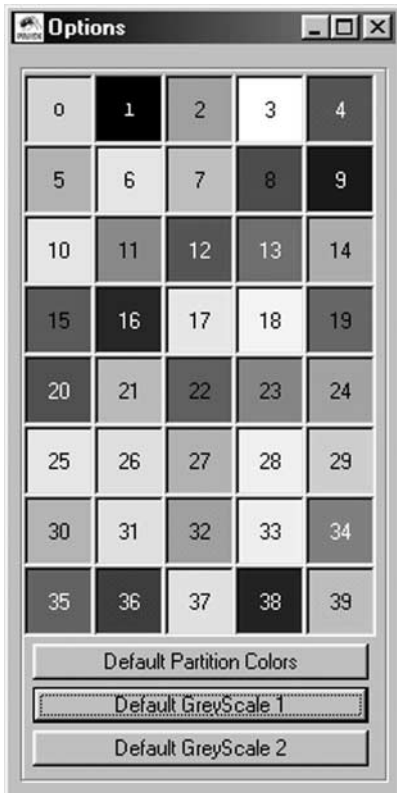


Figure 19. Vertex colors according to a partition in Pajek.

zero to four) into grays (this color scheme is represented in Figure 19) or the button “Default GreyScale 2” to change the first eleven colors into grays. The button “Default Partition Colors” resets the original colors. Unless stated differently, we use partition color scheme “GreyScale 1” in the sociograms printed in this book.

In addition, you can change the color of a particular class by means of the Partition Colors dialog box. If you want to change the color associated with a particular class, click on the square with the desired color and type the number of the class you want this color to be associated with in the dialog box that appears and Pajek will swap the colors. Press the button labeled “Default Partition Colors” if you want to restore the original colors of classes.

When colors or grays do not suffice, you may display the class numbers of the vertices in the vertex labels of a sociogram. Select the option *Partition Clusters* in the *Options>Mark Vertices Using* submenu in the Draw screen. Until you turn this option off, vertex labels in the Draw screen will begin with their class number between brackets, provided, of course, that a network and a matching partition are being drawn.

In Pajek, you can create a new partition that can be edited manually. In the *Partition* menu, the command *Create Null Partition* makes a new partition for the selected network. All vertices are placed in class zero. With the edit command, which was discussed previously (*File>Partition>Edit*),

*Options>Mark
Vertices
Using>Partition
Clusters*

*Partition>Create
Null Partition*

*Draw>Draw-
SelectAll*

you can assign vertices to other classes: just change their class numbers in the list. You can obtain the same result with the command *Draw-SelectAll* from the *Draw* menu in the Main screen (shortcut: *Ctrl-a*). This command creates a new partition and displays it in the Draw screen.

*Change the class
number of
vertices*

In the Draw screen, you can raise the class number of a vertex by 1 in the following way: click on the vertex with the middle mouse button – if available – or with the left mouse button while holding down the *Shift* key on the keyboard. If the cursor is not on a vertex, all class numbers are raised. Clicking a vertex while the *Alt* key is pressed subtracts 1 from the class number and clicking between vertices with the *Alt* key pressed lowers the class numbers of all vertices provided that they are larger than zero, which is the minimum value. In this way, you can easily create a partition that groups a small number of vertices.

*Layout>Energy>
Kamada-
Kawai>Fix
selected vertices*

In a sociogram with colored classes, it is very easy to move all vertices that belong to one class. Position the cursor *near* but not *on* a vertex, press the left mouse button and drag: all vertices in the class will move simultaneously. This is a very useful technique. In addition, the Kamada–Kawai energy procedure has a special command for energizing networks with class colors; you can restrict the automatic relocation to the vertices in class 0 with the *Fix selected vertices* command. If the partition does not contain vertices in class zero, Pajek issues a warning and it does not change the layout of the network.

menu Partition

menu Partitions

There are several ways to manipulate partitions, make a new partition or combine two partitions. We encounter most of these techniques in later chapters. Suffice it to say here that the commands that involve one partition are located in the *Partition* menu, whereas commands operating on two partitions can be found in the *Partitions* menu of the Main screen.

Exercise I

Open the original manufactures of metal trade network and energize the positions of the core countries only. What changes? Hint: create a new partition in which the core countries belong to class zero and the other countries to class one or higher and energize it with the *Fix selected vertices* command.

2.4 Reduction of a Network

Partitions divide the vertices of a network into a number of mutually exclusive subsets. In other words, a partition splits a network into parts. Therefore, we can use partitions to reduce a network in three ways: extract one part (local view), shrink each class of vertices into one new vertex (global view), or select one part and shrink neighboring classes to focus on the internal structure and overall position of this class (contextual view). We now discuss the three types of reduction.

2.4.1 Local View

The easiest way to reduce a network is to select one class of vertices. Of course, a mere selection of vertices is not very interesting; we must also

select all lines between them – and their loops eventually – if we want to inspect the structure of ties in this part of the network. This operation is called *subnetwork extraction* and its result is called an *induced subnetwork* that offers a *local view*.

To *extract* a subnetwork from a network, select a subset of its vertices and all lines that are only incident with the selected vertices.

If we want to examine the trade in manufactures of metal within South America, we can extract the subnetwork of South American countries, which is depicted in Figure 20. From the energized drawing, it is clear that Brazil occupies a central position, whereas French Guiana, Martinique, and Guadeloupe are isolated. Apparently, these islands trade with countries in other parts of the world. Finally, geography appears to be important within the continent, because neighboring countries are close in the network.

Application

To extract a subnetwork, we need a network and a partition that defines the sets (classes) of vertices that we want to extract. Therefore, the extraction commands are located in the *Operations* menu. In this section, we use the manufactures of metal trade network (`Imports_manufactures.net`) and the continents partition (`Continent.clu`).

To obtain a local view of the South American trade network, use the command *Partition* from the *Operations>Extract from Network* submenu. Because South America is the sixth class in the partition, select class 6 in the two dialog boxes that appear. Pajek produces a new network, which contains fifteen countries. Energize it to obtain a drawing similar to Figure 20.

*Operations>
Extract from
Network>
Partition*

It is very important to note that the original partitions do not fit the induced subnetwork because the subnetwork contains fewer vertices than

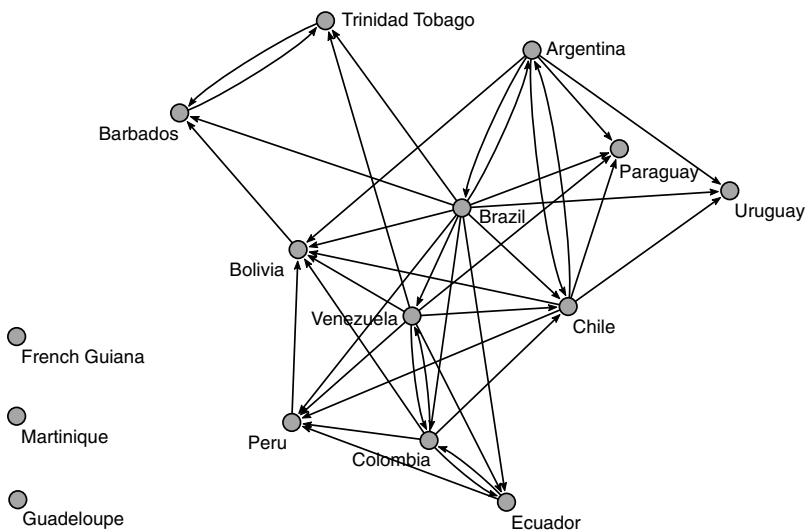


Figure 20. Trade ties within South America.

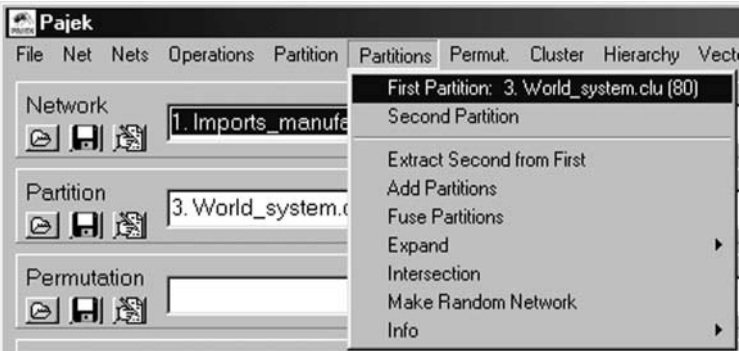


Figure 21. The *Partitions* menu.

the original vertices. This is a pity, because we may want to know, for instance, the world system position of the countries in the South American trade network. However, we can extract a new partition that matches the induced subnetwork in a few steps.

*Partitions>First
Partition*
Second Partition
*Extract Second
from First*

First, we must select the original partition that we want to translate to the induced subnetwork as the first partition in the *Partitions* menu. Make sure that the world system partition is selected in the Partition drop-down menu. Then, select command *First* in the *Partitions* menu. Nothing seems to happen but open the *Partitions* menu again and you will see the name of the world system partition in it (Figure 21). Second, select the partition that you used to extract the network – in our case the continents partition – as the second partition in the *Partitions* menu. You need this partition to identify the subset of vertices that must be extracted from the world positions partition. Finally, execute the command *Extract Second from*

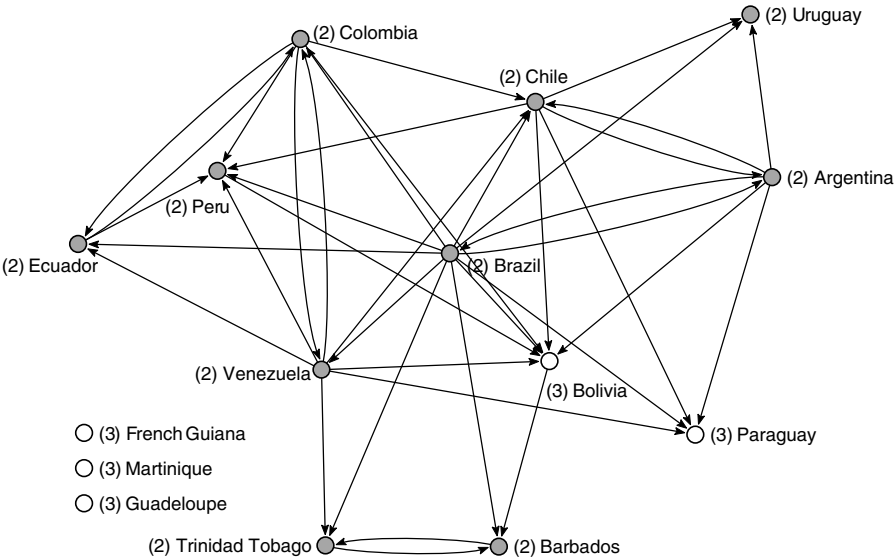


Figure 22. World system positions in South America: (2) semiperiphery and (3) periphery.

First from this menu. Dialog boxes will ask for the class numbers to be extracted and if you type 6 twice, Pajek produces a new partition for the fifteen South American countries. Figure 22 shows the South American trade network drawn with this partition.

2.4.2 Global View

Instead of zooming in on a particular region of the network, we may also zoom out to obtain a global view. Now, we are no longer interested in each individual vertex but we want to study relations between classes, for instance, continents. Which continents have strong trade ties? In this example, a global view of the network covers the whole world but we should note that a global view may also pertain to ties between groups in a local setting.

To *shrink* a network, replace a subset of its vertices by one new vertex that is incident to all lines that were incident with the vertices of the subset in the original network.

In network analysis, we obtain a *global view* by shrinking all vertices of a class to one new vertex. In our example, we shrink all countries within a continent to a new vertex that represents the entire continent (see Figure 23). Lines incident with shrunk vertices are replaced, for instance, all imports by South American countries from European countries are replaced by one new arc pointing from Europe to South America. Its line value is equal to the sum of all original line values. In the network of trade ties, line values indicate the value of imports expressed in

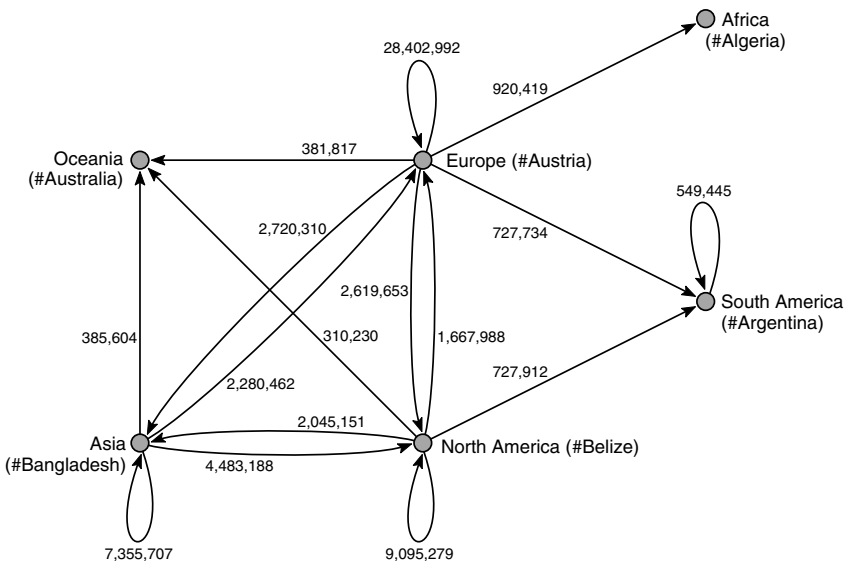


Figure 23. Trade in manufactures of metal among continents (imports in thousands of U.S.\$).

thousands of U.S. dollars (U.S.\$), so values of lines in the shrunken network represent the value of total imports of metal manufactures. Lines between shrunken vertices within one class, (e.g., trade in manufactures of metal within South America), are replaced by a loop.

Figure 23 shows the world trade network that is shrunk according to continents. To obtain a clear picture, we deleted arcs (total imports) with summed values below three hundred million U.S. dollars. We can see that South American countries import manufactures of metal with a total value of 729 million U.S. dollars from Europe but they do not export a substantial amount to Europe, so there is an asymmetrical trade tie between South America and Europe. The countries in Oceania and Africa are also importing rather than exporting. Trade within South America (549 million U.S.\$) is much higher than in Oceania and Africa but internal trade is at its highest in Europe.

Application

*Operations>
Shrink
Network>
Partition*

The command *Partition* in the *Operations>Shrink Network* submenu shrinks classes of vertices in a network according to the active partition, in this case, the continents partition. A dialog box asks for the minimum number of connections between clusters. This is the minimum number of lines that must exist between shrunken vertices to obtain a new line in the shrunken network. We recommend choosing 1 (the default value). In a second dialog box, you may choose a class of vertices that must not be shrunk to give them a contextual view. Shrink all classes to obtain a global view, so type any class number that is not present in your partition or accept the default value (zero). Finally, Pajek shrinks all classes except the selected class and adds the shrunken network to the Network drop-down menu.

*File>Partition>
Edit*

Pajek's *Shrink Network* command also creates a new partition – called shrinking – along with the new network identifying the classes in the partition that was used to shrink the original network. However, Pajek does not know the meaning of these classes, so it cannot assign meaningful new labels to shrunken classes. It chooses the label of the first vertex of a class that is shrunk and adds a pound sign (#) to obtain a label for the shrunken class. For example, Argentina happens to be the first South American country in the network, so the vertex that represents this continent carries the label “#Argentina” in the shrunken network. We added the names of continents to Figure 23 manually by editing the shrunken partition (“Shrinking”) with the *File>Partition>Edit* command (see Section 2.3).

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

In Figure 23, we removed lines with summed values below three hundred million U.S. dollars to obtain a clear picture. Lines with low values can be removed automatically with the command *Remove>lines with value>lower than* in the *Net>Transform* submenu. We entered 300000 as the threshold for this operation, because import values are measured in thousands of U.S. dollars.

In a shrunken network, a class of vertices is replaced by one new vertex; in our example, the Latin American countries are substituted by a new vertex representing this continent. Properties of the original vertices, such

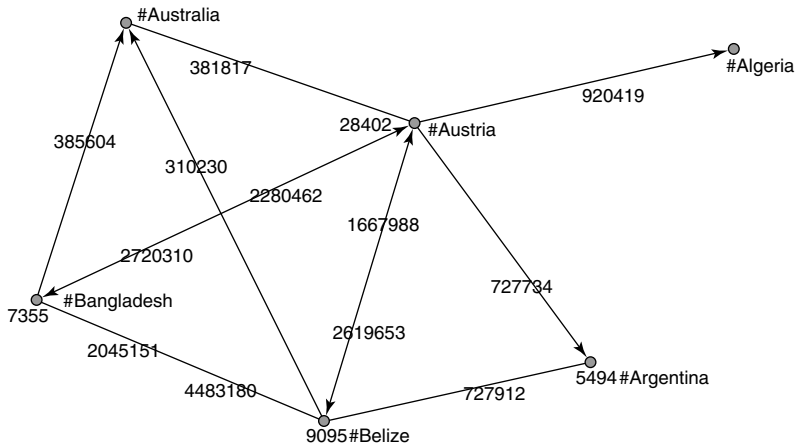


Figure 24. Trade among continents in the Draw screen.

as their world system position, are lost: it is impossible to assign the entire continent to a particular world system position. Therefore, it is impossible to use the data from a partition that was not used to shrink the network.

Note that the way a network is shrunk depends on the option selected in the *Options>Blockmodel – Shrink* submenu. By default, option 0 is selected, which means that the number of links in the original network is used to decide whether a new line is added to the shrunk network. This option causes Pajek to display the dialog box mentioned above. We advise not to select another option from this submenu until you understand blockmodeling, which is presented in Chapter 12.

[Main]
Options>
Blockmodel –
Shrink

Loops, which signify the trade within a continent in this example, cannot be drawn in the Draw screen. If the option *Options>Lines>Mark Lines>with Values* (shortcut *Ctrl-v*) has been selected, the line values are shown in the Draw screen (see Figure 24), including the values of loops, which are printed very close to the vertices. The value of a loop can be examined more closely if you right click a vertex in the Draw screen. Among the lines, which are then listed in the Editing Network dialog box, you can find the loop, for instance, the line from #Argentina to #Argentina. Its line value is 549445, which means that the total value of trade in manufactures of metal among South American countries amounted to 549,445,000 U.S. dollars.

[Draw]
Options>Lines>
Mark Lines>
with Values

2.4.3 Contextual View

A global view shows the position of South America in the world system and a local view clarifies the central position of Brazil within the South American trade network. But how do countries in this regional network relate to the rest of the world? From which continents do the isolated islands import their manufactures of metal? If you want to focus on one class of vertices (e.g., countries on one continent) and take into consideration aggregated ties to the “outside world,” you need a contextual view.

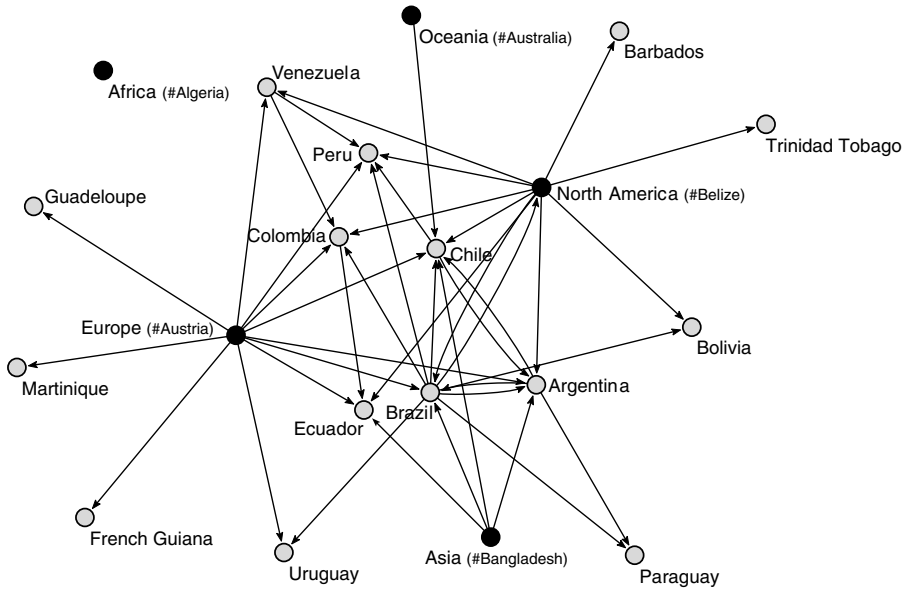


Figure 25. Contextual view of trade in South America.

In a *contextual view*, all classes are shrunk except the one in which you are particularly interested. In Figure 25, all countries are shrunk to continents (black vertices) except the South American countries (gray vertices). We removed ties between continents because we already know them from Figure 23 and we discarded trade in manufactures of metal with summed values under ten million U.S. dollars to obtain an intelligible drawing. This sociogram shows the South American countries in the context of world trade. Clearly, Africa and Oceania are not important trading partners to South American countries. The larger countries on the continent import from Europe and North America, but smaller countries are connected to either North America (Barbados, Trinidad and Tobago, Bolivia) or Europe (Uruguay, Guadeloupe, Martinique, and French Guiana). Former colonial ties surely play a part here.

There are many ways to extract or shrink a network and extraction and shrinking can even be combined. Subnetwork extraction and shrinking are important techniques to dissect a network and to obtain partial views of a network when its structure is too complicated to understand at a first glance.

Application

A contextual view is obtained by partially shrinking the network, so we can use the *Shrink Network* command. In the dialog box asking for the class that should not be shrunk, type the appropriate class number, namely class 6 for South America. Lines with summed values below ten million U.S. dollars can be removed automatically with the command *Remove>lines with value>lower than* in the *Net>Transform* submenu as discussed.

Operations>
Shrink
Network>
Partition

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

Lines between continents can be deleted automatically provided that you have a partition that identifies the continents in the shrunk network. You may create this partition manually with the commands described under *Application* in Section 2.3: create a null partition and assign the five shrunk continents to class 1. Now, you can execute the command *Operations>Transform>Remove Lines>Inside Clusters* to remove the lines between vertices in the continents class (class 1, enter 1 twice in the dialog box).

*Operations>
Transform>
Remove
Lines>Inside
Clusters*

Exercise II

Create a global view of the trade relation (manufactures of metal) between the core, semiperiphery, and the periphery. Explain the structural differences between the world system positions from this network.

2.5 Vectors and Coordinates

Partitions store discrete properties of vertices and vectors store continuous properties. In principle, a continuous property may take any value within a defined range; for instance, the surface of a country may take any value between zero square kilometers (or miles) and the total surface of the Earth. When two countries have different sizes, it is always possible to imagine a country that is smaller than one and bigger than the other.

In practice, of course, we do not care about differences in sizes of countries smaller than a square kilometer, but the principle is important: continuous properties are not meant to group vertices into classes, so they cannot be used to reduce a network by extraction or shrinking. Continuous properties express a particular and often unique value of a vertex, for instance, the wealth of a country indicated by its gross domestic product per capita. In practice, no two countries have exactly the same GDP per capita because it is equal to the quotient of the economic production of a country and the size of its population, both of which are usually figures that characterize no other country. Most quotients yield results with decimals, so a vector is not a list of integers but a list of real numbers.

A *vector* assigns a numerical value to each vertex in a network.

In our discussion of partitions, we have distinguished between structural indices and attributes. This distinction applies to continuous properties or vectors as well. In later chapters, we encounter several examples of vectors that represent structural features of vertices, for instance, their centrality (Chapter 6). GDP per capita of a country is an example of a continuous attribute that is measured independently of the network and added to the graph as additional data: it is a continuous attribute.

A special continuous property of a vertex is its location in a sociogram. Location is expressed by coordinates, real numbers that correspond with positions on one or more axes. For example, the two-dimensional Draw screen has two axes, a horizontal *x* axis and a vertical *y* axis. Both axes

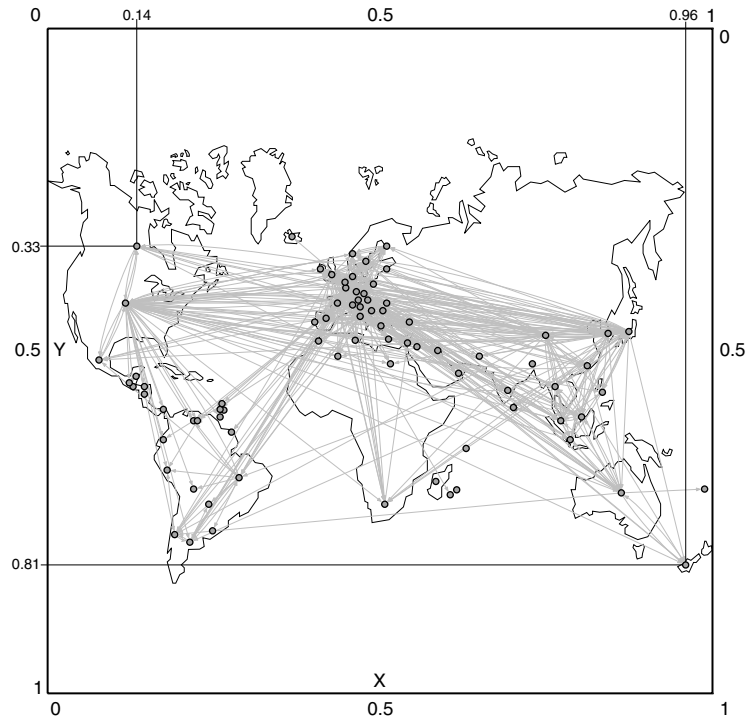


Figure 26. Geographical view of world trade in manufactures of metal, ca. 1994.

range from zero to 1 (see Figure 26). The position of a vertex in the Draw screen is determined by two coordinates (e.g., Canada is located at 0.14 on the x axis and 0.33 on the y axis).

Because coordinates are real numbers, they can be stored as vectors: one representing the location of vertices on the x axis and the other locations on the y axis. In Figure 26, we did something special: we made sure that locations in the Draw screen matched geographical locations on a map of the world projected behind the network (see Appendix 2 for details on how to produce this image). Now, vectors express geographical coordinates and we can see geographical patterns in a social network.

Application

File>Vector

Info>Vector

In Pajek, vectors have a drop-down menu of their own. A vector (e.g., the vector `GDP_1995.vec` containing GDP per capita in 1995) can be opened, edited, and saved like a network or a partition. Basic information can be gathered from the output of the *Info>Vector* command. When you execute this command, you can ask for a list of highest or lowest vector values. In a second dialog box, you can specify the number or boundaries of the classes of values that will be reported in the frequency distribution (Figure 27). Note that vector values are supposed to be continuous, so each value probably occurs only once. As a consequence, it is not informative to list each separate value as an entry in the frequencies table; values must be joined into classes. You may either list selected values that must be

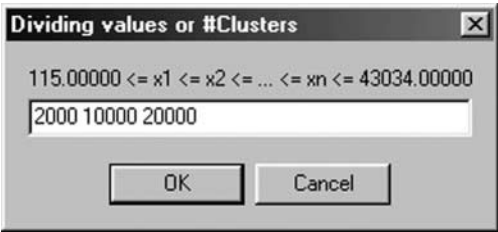


Figure 27. *Info>Vector* dialog box.

used as class boundaries (as in Figure 27) or specify the number of classes preceded by the pound (#) sign.

In the Report screen, the *Info>Vector* command outputs some statistics on the vector values; for instance, it tells us that GDP per capita ranges from 115 to 43,034 U.S. dollars, with an average of 10,249.9 U.S. dollars and standard deviation 10,834.7. Then it prints the requested frequencies table, which is shown in Table 2. The first entry of this table contains the twenty-two countries with GDP per capita ranging from the lowest value up to and including 2,000 U.S. dollars. The second entry contains the twenty-seven countries with GDP per capita over 2,000 U.S. dollars up to and including 10,000 U.S. dollars, and so on. In the first column, the round bracket means “from” and the square bracket means “up to and including.”

As we discussed before, partitions and vectors have different applications: partitions serve to select subsets of vertices from a network, whereas vectors specify numerical properties that can be used in calculations. Sometimes, however, you may want to change partitions into vectors or vice versa. It is very easy to convert a partition to a vector: just use the *Make Vector* command in the *Partition* menu. Note, however, that conversion may be meaningful only if classes in a partition express a quantity – if they are numbers that can meaningfully be added, subtracted, and so on.

*Partition>Make
Vector*

The translation of a vector into a partition is more complicated because you have to change real numbers into integers, which can be done in several ways in the *Vector>Make Partition* submenu. Truncation is the easiest way, which means that you drop the decimals from the real numbers in the vector to obtain integers that can be stored in a partition. A GDP per capita of 115 U.S. dollars up to but not including 116 U.S. dollars is changed to class 115 in a new partition. In the command name, *Abs* stands for absolute, which means that negative vector values are

*Vector>Make
Partition >by
Truncating (Abs)*

Table 2. *Distribution of GNP per Capita in Classes*

Vector Values	Freq	Freq%	CumFreq	CumFreq%
(... 2000]	22	27.5000	22	27.5000
(2000 ... 10000]	27	33.7500	49	61.2500
(10000 ... 20000]	15	18.7500	64	80.0000
(20000 ... 43043]	16	20.0000	80	100.0000
TOTAL	80	100.0000		

transformed into positive class numbers because partitions cannot hold negative integers.

*Vector>Make
Partition>by
Intervals>First
Threshold and
Step*

Another way to convert a vector into a partition is to recode vector values into classes of fixed width; for instance, recode GDP per capita into classes of 10,000 U.S. dollars. Use the command *by Intervals>First Threshold and Step* in the *Vector>Make Partition* submenu and specify the upper bound of the lowest class as the first threshold (e.g., 10000 for a class including a minimum value up to and including 10,000) and class width as the step (e.g., fill in 10000 again). Note that Pajek does not accept a comma separating thousands from hundreds.

*Vector>Make
Partition>by
Intervals>
Selected
Thresholds*

In the case of GDP per capita, a conversion of values to classes with fixed width is not very useful. GDP per capita is unevenly distributed, so many countries are lumped together in the lowest classes, whereas higher classes contain few countries. In this example, it is better to create classes of unequal width, namely narrow classes for low values and wider classes for higher values, with the command *Selected Thresholds* in the *Make Partitions by Intervals* submenu. In the dialog box, specify the boundaries between classes (e.g., 2000, 10000, and 20000). Just type the numbers separated by spaces and do not use $\leq$ as specified in the top of the dialog box. The $\leq$ sign means that all classes include the upper boundary.

*Draw>
Draw-Vector*

*Draw>
Draw-Partition-
Vector*

*[Draw]
Options>Size>
of Vertices*

In a sociogram, vector values are represented by the size of vertices if you use *Draw-Vector* or *Draw-Partition-Vector* from the *Draw* menu. The area of a vertex is proportional to its vector value. Note that GDP per capita ranges from 115 to 43,034 U.S. dollars, but in the *Draw* screen vertices usually have sizes between 2 to 4. If you draw a network with vector sizes ranging from 115 to 43034, vertices are so large that they do not fit in the screen. Pajek may issue a warning that it changes the size of the vertices. If vertices are still too large, you can adjust the vector values to get reasonable sizes in a drawing. The *Options>Size>of Vertices* command of the *Draw* screen offers the simplest way to achieve this. In the dialog box issued by this command, enter 0 to activate the *AutoSize* utility of Pajek, which computes optimal vertex sizes automatically.

In Figure 28, countries with higher GDP per capita have larger vertices, according to their vector values. We can see that the wealthiest countries are part of the core and strong semiperiphery, but note that geographical location is also important; Scandinavian countries have similar (high) GDP per capita, whether they belong to the core (Sweden) or to the semiperiphery (Norway, Denmark, Finland).

Representation of vector values by size of vertices is not useful for negative numbers, because negative size is meaningless. Pajek ignores negative signs of vector values when it computes the size of a vertex in a drawing. Vertices with large negative value are drawn as big as vertices with large positive value, which is quite misleading. Always check whether negative vector values exist with the *Info>Vector* command.

*Options>Mark
Vertices
Using>Vector
Values*

Vector values may also be displayed as vertex labels in the *Draw* screen: select the option *Vector Values* in the *Options>Mark Vertices Using* submenu. In most networks, the result is visually not very attractive but it is a good way to check the exact vector values of vertices in a drawing.

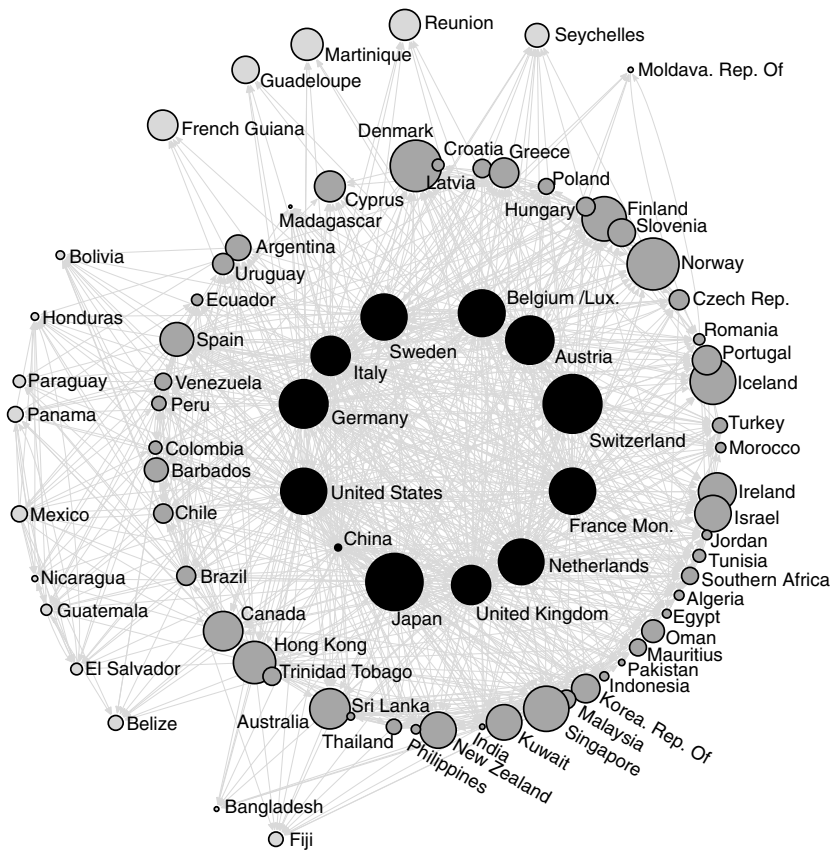


Figure 28. Trade, position in the world system, and GDP per capita.

In Section 2.4.1, we learned how to select a part of a network (e.g., the trade in manufactures of metal among countries of one continent) and how to reduce a partition to fit the extracted network. In a similar way, we can adjust vectors to induced subnetworks. Recall that we need a partition to extract a network; a partition of countries according to their continent is needed for extracting countries of one continent from the network. We can use the same partition for extracting the vector values, for instance, GDP per capita, of the selected countries. First, make sure that the partition which was used to reduce the network is selected in the Partition drop-down menu. Next, execute the command *Extract Subvector* in the *Vector* menu. Just like the command for extracting a partition, the *Extract Subvector* command asks the user to choose a class of vertices or range of classes which must be extracted: enter 6 to select South American countries. Finally, Pajek adds the reduced vector to the Vector drop-down menu.

*Vector>Extract
Subvector*

To obtain a global or contextual view, we shrink networks (see Sections 2.4.2 and 2.4.3). Recall that a class of vertices is replaced by one new vertex in a shrunken network; we replaced all countries belonging to the same continent by a vertex representing the continent. To use vector values associated with the original network (e.g., GDP per capita of a

*Vector>Shrink
Vector*

country) we must also shrink the vector. The command *Shrink Vector* in the *Vector* menu accomplishes this provided that you have selected the relevant vector and the partition that you want to use for the shrinking, namely *Continent.clu*. The command allows you to choose among taking the sum, mean, minimum, maximum, or median of the vertices in a class that will be shrunk. In the example of GDP per capita, it makes sense to calculate the mean or median GDP per capita on a continent.

As noted, coordinates of vertices can be thought of as vectors. In Chapter 1, we have learned that coordinates of vertices are saved in the network data file, so we do not need vectors to store the location of vertices. However, vectors of coordinates are useful if, for instance, you want to use coordinates from one network in another network with the same vertices, for instance, you have a network of trade in another product and you want to use the geographical coordinates from the manufactures of metal trade network.

*Net>Vector>Get
Coordinate*

*Operations>
Vector>Put
Coordinate*

You can save the present coordinates of the vertices as vectors with the *Get Coordinate* command in the *Net>Vector* submenu. You must create a vector of coordinates for each axis separately. The *Put Coordinate* command in the *Operations>Vector* submenu loads coordinates from vectors: one vector for each axis. In our example, geographical location of countries can be read from two vectors: *x-coordinates.vec* and *y-coordinates.vec*. Note that the save and load commands are listed in different menus. For saving coordinates, you need only a network, but for loading coordinates from a vector you need a vector to load from and a network to add coordinates to. Therefore, the load command is situated in the *Operations* menu.

*Options>
Transform>Fit
Area*

When you load coordinates from a file that was not created by Pajek, the Draw screen may be blank. This happens if the coordinates are not in the range between zero and 1. In this case, use the *Options>Transform>Fit Area* command in the Draw screen and Pajek will fit the sociogram to the size of the screen.

Exercise III

Shrink all countries to continents except the North American countries in the network of trade in metal manufactures. Remove the lines between the continents and trade ties with values under five million U.S. dollars (recall that line values reflect trade in thousands of U.S.\$). Draw the energized network with vertex sizes reflecting (mean) GDP per capita. Describe the structure that you see.

2.6 Network Analysis and Statistics

In this chapter, we use attributes of vertices in social network analysis; for instance, we compare GDP per capita of countries to their visual positions in the trade network. We find that countries in the core of the world trade system have higher GDP per capita than countries in the periphery. Thus, social network analysis handles relational data as well as attributes of vertices.

Attributes like GDP per capita are usually analyzed with statistical techniques. GDP per capita is compared, for instance, to population growth and level of education to find out which properties of countries are associated. GDP per capita is found to be higher in countries with a lower population growth and a higher level of education. Statistics offers a wide range of techniques to describe attributes and investigate the association between attributes, but it cannot handle relational data directly. If we are able to express structural properties of vertices as attributes or properties of actors, however, they can be included in statistical analysis.

The position of countries in the world system that we use here was calculated from the world trade network. It is stored in a partition, which can be used in statistical analysis. Continuous structural indices, such as vertex centrality (Chapter 6), can be stored as vectors. Partitions and vectors that store structural properties of vertices are the bridge between network analysis and statistics.

In this book, some examples of statistical analysis are given but are restricted to basic statistical techniques that are incorporated in Pajek. After all, this is not a course in statistics. Nevertheless, the link between statistics and social network analysis should be well understood, because the two techniques make up a powerful combination.

Application

One of the basic statistical techniques implemented in Pajek is the cross-tabulation of two partitions and some measures of association between the classifications represented by two partitions. Let us look at the world trade example. Our partition of positions in the world trade network was derived from the trade in manufactures of metal around 1994. In addition, we have at our disposal a classification of countries according to their position in the world system in 1980 that was proposed by Smith and White (*World-system-1980.clu*). To analyze the transition of countries between world system positions from 1980 to 1994, we can use simple statistical techniques.

First, we must select the two partitions that we want to compare. In Section 2.3, we learned how to do this. Select the partition with world system positions in 1980 (*World-system-1980.clu*) in the Partition drop-down menu and execute the command *First Partition* from the *Partitions* menu. Next, select the world system positions partition in 1994 (*World-system.clu*) and execute the command *Second Partition* in the same menu. When you open the *Partitions* menu now, you will see the names of the selected partitions in the menu. To obtain a cross-tabulation and measures of association, the selected partitions must refer to the same network: the same number of vertices in the same order. It is meaningless to compare partitions that do not refer to exactly the same vertices.

Second, select the *Info>Cramer's V, Rajski* command from the *Partitions* menu. Pajek will show a cross-tabulation and some measures of association in the Report screen. Table 3 contains the results of the *Info* command. In the cross-tabulation, the rows contain the four classes according to world system position in 1980: core countries in class 1, strong

*Partitions>First
Partition, Second
Partition*

*Partitions>Info>
Cramer's V,
Rajski*

Table 3. *Output of the Info Command*

Cramer's V, Rajski				
Rows: 1. World_system_1980.clu (80)				
Columns: 3. World_system.clu (80)				
	1	2	3	Total
1	10	1	0	11
2	1	16	0	17
3	0	15	0	15
4	0	4	5	9
TOTAL	11	36	5	52

Warning: 28 vertices with missing values excluded from cross tabulation!
Warning: 8 cells (66.67%) have expected frequencies less than 5!
The minimum expected cell frequency is 0.87!
Chi-Square: 66.2597
Cramer's V: 0. 7982
Rajski(C1↔C2): 0.3422
Rajski(C1→C2): 0.6827
Rajski(C1←C2): 0.4069

semiperiphery in class 2, weak semiperiphery in class 3, and periphery in class 4. The columns contain the three world system positions in 1994: core countries in class 1, semiperiphery in class 2, and periphery in class 3. Countries with an unknown world system position are automatically omitted by Pajek; their number is reported below the table. As a result, the first column represents eleven of the twelve countries in the core of the trade system in 1994. We do not know the world system position of China in 1980, so it is placed in class 9999998 in the `World_system_1980.clu` partition. Note that rows and columns are swapped when the first and second partition are exchanged in the *Partitions* menu.

From this table, we may conclude that the composition of the core has hardly changed between 1980 and 1994 (see the row and column of the cross-tabulation labeled “1”). The countries in the strong and weak semiperiphery in 1980 constitute the major part of the semiperiphery in 1994 (column 2), and four countries were promoted from the periphery in 1980 to the semiperiphery in 1994 (row 4, column 2).

Statistical indices of association tell us how strong the association is. Indices range from 0 to 1 and as a rule of thumb we may say that values between 0 and .05 mean that there is no association, values between .05 and .25 indicate a weak association, values from .25 to .60 indicate a moderate association, and values over .60 indicate a strong association.

In Pajek, two types of association indices are computed: Cramer's V and Rajski's information index. Cramer's V measures the statistical dependence between two classifications. It is not very reliable if the cross-tabulation contains many cells that are (nearly) empty, so Pajek issues a warning if this is the case. Rajski's indices measure the degree to which the information in one classification is preserved in the other classification. It has three variants: a symmetrical version, represented by (C1↔C2) in the output of Pajek, and two asymmetrical versions, which indicate the extent

to which the first classification can be predicted by the second ($C1 \leftarrow C2$) or the second classification can be predicted by the first ($C1 \rightarrow C2$).

In our example, Cramer's V is not very reliable because many cells have low expected frequencies. Rajske's information indices suggest that world system position in 1994 can be predicted quite well from the positions in 1980: Rajske $C1 \rightarrow C2$ is .68. The two world system positions are strongly associated.

Exercise IV

Determine the statistical association between the position of countries in the world system of trade in metal manufactures in 1994 and their GDP per capita in 1995. Hint: translate the GDP per capita vector into a partition with four classes: 0 to two thousand U.S. dollars, two to ten thousand U.S. dollars, ten to twenty thousand U.S. dollars, and twenty thousand and higher U.S. dollars.

2.7 Summary

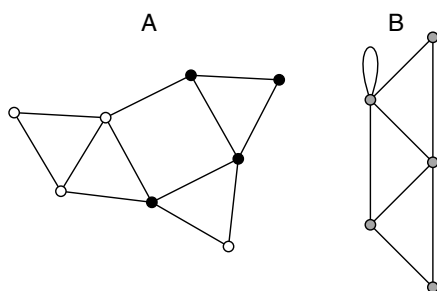
In this chapter, we used properties of vertices to find and interpret patterns of ties in a network. These properties are stored in partitions or vectors. Both partitions and vectors are lists of numbers, one number for each vertex in a network, but numbers in partitions refer to discrete classes, whereas vector values express continuous properties of vertices. Classes in partitions are represented by integers (e.g., countries on the African continent have code 1) and negative class numbers are not allowed. Vectors contain real numbers, which can be negative.

Social networks are often large and complicated. To understand network structure, it helps to study reductions of the network first. Partitions can be used to reduce a network in two ways: by extraction and by shrinking. Extraction is the selection of a subset of vertices from a network as well as the lines among these vertices. You can now concentrate on the structure of a part of the network, which is called a local view. In contrast, shrinking a network means that you lump together sets of vertices and lines incident with these vertices (e.g., you replace all African countries by one vertex representing the African continent). This yields a global view of the network if all classes are shrunk and a contextual view if one class of vertices is not shrunk. In all cases, classes of a partition define the subsets of vertices that are extracted or shrunk.

Properties of social actors that are not based on their structural position in a network are called attributes. They are added to a network to enhance the analysis and interpretation of its structure. Partitions and vectors, however, can also contain structural indices of vertices, which result from network analysis (e.g., the world system position of countries that is inferred from the trade network). These properties may be included in statistical analysis, so partitions and vectors are the nexus between social network analysis and statistics. In Chapter 3 techniques to compute structural properties of vertices in a network are discussed.

2.8 Questions

1. Which of the following statements is correct?
 - a. Each property of a vertex or a line is an attribute.
 - b. Each property of a vertex is an attribute.
 - c. Each nonrelational property of a vertex is an attribute.
 - d. Each nonrelational property of a line is an attribute.
2. There are two lists of numbers. Numbers in list A range from -1 to 1 and list B contains numbers between 1 and 10 . Which statements can be correct?
 - a. A and B are partitions.
 - b. A is a partition and B is a vector.
 - c. A is a vector and B is a partition.
 - d. A and B are vectors.
3. Suppose that the average population growth rate between 1990 and 1995 is available for the countries in the trade network, coded as $0 =$ negative growth, $1 = 0$ to 1.0 percent, $2 = 1.0$ to 3.0 percent, and $3 = 3.0$ percent and over. Would you use a partition or a vector for these data?
 - a. A partition because we cannot add or subtract the codes meaningfully.
 - b. A partition because percentages are recoded to integers.
 - c. A vector because negative population growth is possible.
 - d. A vector because percentages are “real” numbers.
4. What happens to the sociogram of a network if the order of numbers in the accompanying partition is changed?
 - a. Nothing changes in the sociogram.
 - b. Pajek does not draw the partition any longer.
 - c. Pajek uses other colors to draw the vertices.
 - d. Vertices are drawn in the wrong color.
5. Which of the following statements is correct about the networks below?



- a. A is extracted from B.
- b. B is extracted from A.
- c. A is shrunk from B.
- d. B is shrunk from A.

6. Which of the following statements is correct about the networks of Question 5?
- B is a contextual view of A.
 - A is a global view of B.
 - B is a local view of A.
 - A is a local view of B.

2.9 Assignment

Analyze the manufactures of metal trade network of Asian countries (local view) and their position with regard to other continents (contextual view). Does the structure of trade ties match the world system positions of countries, their prosperity (indicated by GDP per capita), and their geographical locations? Try to apply the theory of the world system, which was outlined in Section 2.2.

2.10 Further Reading

- In *The Modern World System: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century* (New York: Academic Press, 1974), Immanuel Wallerstein introduced the concept of a world system. The *Capitalist World-Economy* (Cambridge/Paris: Cambridge University Press & Editions de la Maison des Sciences de l'Homme, 1979) is a collection of essays that introduces the theory of a world economy. Bornschier and Trezzini ("Social stratification and mobility in the world system – Different approaches and recent research." In: *International Sociology* 12 (1997), 429–55) offer a summary of research traditions which use the concept of a world system or world economy.
- See Snyder and Kick ("Structural position in the world system and economic growth 1955–70." In: *American Journal of Sociology* 84 (1979), 1096–126) for the first (published) application of social network analysis to world systems theory and see Smith and White ("Structure and dynamics of the global economy – network analysis of international-trade 1965–1980." In: *Social Forces* 70 (1002), 857–93) for the research design followed here.
- Our data on imports are taken from the Statistical Papers. Commodity Trade Statistics [Series D Vol. XLIV, No. 1–34 (1994)] published by the United Nations and we gathered additional economic and demographic data from the Statistical Yearbook of the United Nations (Ed. 43, IVATION Datasystems Inc.). Imports of miscellaneous manufactures of metal are listed as SITC code 69 in the commodity trade statistics.

2.11 Answers

Answers to the Exercises

- I. If you want to fix the locations of the countries of the semiperiphery and periphery in the Draw screen, you must create a partition in which the core countries belong to class zero and the other countries to another class. The easiest way to achieve this is to create and draw a new empty partition with the *Draw>Draw-Select All* command in the Main screen. The Draw screen opens and shows the world trade network with all vertices in class zero (light blue). Pressing down the *Shift* key, click somewhere between the vertices to raise all class numbers to one. Then, zoom in on the core countries, dragging your mouse around them while pressing the right mouse button. After you have zoomed in on the core countries, lower their class number back to zero by clicking between the vertices while pressing the *Alt* key. Press Redraw in the Draw screen and you will see that the core countries are the only ones that belong to class zero in the partition. Now you have the right partition and you can select the *Energy>Kamada-Kawai>Fix selected vertices* command to optimize the location of the core countries with respect to the other countries. You will probably see that Japan is pulled toward the Latin American countries, Canada, and the Philippines, whereas Austria moves in the direction of the Eastern European countries (Czech Republic, etc.).
- II. Make sure that the partition with world system positions is active in the Partition drop-down menu and select the original trade network in the Network drop-down menu. Shrink the network with the *Operations>Shrink Network>Partition* command. The energized shrunk network may look like the sociogram depicted below (Figure 29), although the loops are not visible in the Draw screen.

The shrunk network shows several characteristics of the world system. First, the values associated with the loops reveal that trade between countries within one position of the world system decreases

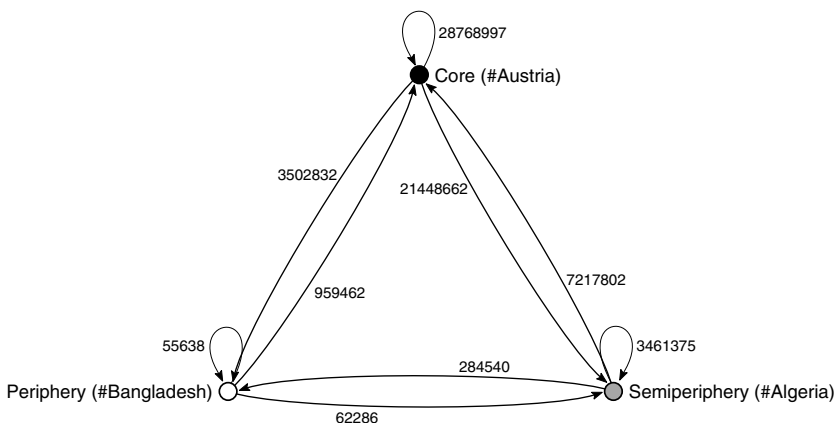


Figure 29. Aggregate trade in manufactures of metal among world system positions.

from core to periphery: from twenty-eight billion U.S. dollars within the core to fifty-five million within the periphery. Second, values of arcs between world system positions show asymmetries in world trade. Core countries export goods at a much higher value to the semiperiphery than vice versa and the semiperiphery exports more to the periphery than the other way around. The values of arcs indicate that the larger the difference in world system position, the larger the difference between exports and imports.

- III. In the partition according to continents, `Continent.clu`, the North American countries constitute class 4. Shrink the network according to this partition, entering 4 in the dialog box asking for the class that must not be shrunk. Now you have the contextual view of the North American countries, from which you can remove the lines among the shrunk continents (see Section 2.4.3) and the lines with values less than 5000 (command `Net>Transfrom>Remove>lines with value>lower than`). Make sure that you select the original partition according to continents again in the Partition drop list before you apply the `Vector>Shrink Vector>Mean` command to the GDP per capita vector. Finally, draw the shrunk network with vector values (command `Draw>Draw-Vector` in the Main screen) and energize it. The result should be similar to the sociogram depicted here (Figure 30). The United States occupies a central place in the trade of metal manufactures among the North American countries. South America and to a lesser extent Europe play an important part in the trade ties of the smaller countries on the North American continent.
- IV. You can extract a partition from the GDP vector with the `Make Partition>by Intervals>Selected Thresholds` command (see Section 2.5). Select the world system positions partition as the first partition in the *Partitions* menu and the GDP partition as the second. The `Info>Cramer's V, Rajski` command produces the table depicted below (Table 4). The table shows that the core countries have higher

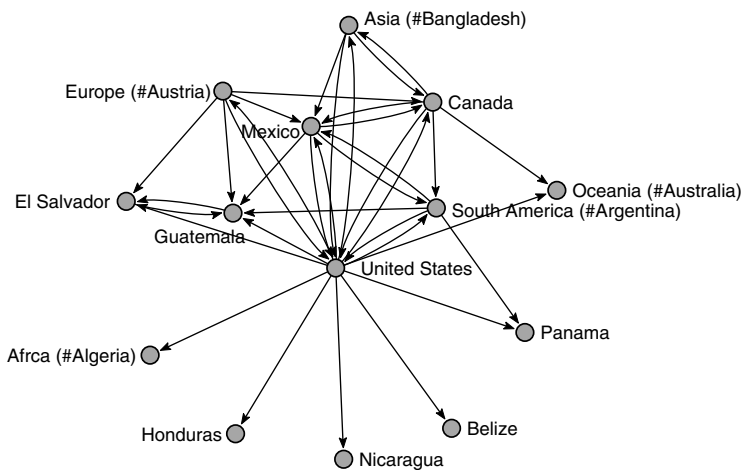


Figure 30. Contextual view of North American trade ties and (mean) GDP per capita.

Table 4. Cross-Tabulation of World System Positions (Rows) and GDP per Capita (Columns)

3. World_system.clu (80) / 4. From Vector 3 [2000 10000 20000] (80)					
	1	2	3	4	Total
1	1	0	2	9	12
2	13	21	10	7	51
3	8	6	3	0	17
TOTAL	22	27	15	16	80

Warning: 7 cells (58.33%) have expected frequencies less than 5!
The minimum expected cell frequency is 2.25!
Chi-Square: 31.5510
Cramer's V: 0.4441
Rajski(C1↔C2): 0.0962
Rajski(C1→C2): 0.1460
Rajski(C1←C2): 0.2200

GDP per capita (classes 3 or 4) than countries in the semiperiphery and periphery, which are found in the lower GDP classes. The association between world system position and GDP per capita, however, is weak according to Rajski's indices. The low GDP per capita of China, which is one of the core countries, is partly responsible for the moderate association.

Answers to the Questions in Section 2.8

1. Statement c is correct. Attributes (e.g., the continent of a country) are properties of vertices (viz., countries) and not lines, therefore statements a and d are incorrect. Recall that properties of lines are called line values. Properties that express the structural position of a vertex in a network (e.g., centrality) are distinguished from social, economic, psychological, and other characteristics that do not measure network position. We restrict the concept of an *attribute* to the latter, nonrelational, kind of property.
2. Statements c and d can be correct. List A contains negative numbers, so it must be a vector. List B contains positive numbers, so it is either a partition (if it contains integers) or a vector.
3. Statement a is the right choice. Aggregation of the percentages into four classes of unequal width implies that we cannot make meaningful calculations on the class numbers; for instance, add and divide class numbers of two countries. We cannot say that two countries have average population growth of 2.5. Classes of equal width, such as rounding to the nearest integer, would yield “real” numbers, which may safely be used in calculations. But this is not the case here (statement b). The properties of the original percentages no longer matter after they have been aggregated in classes, so statements c and d are incorrect.
4. Answer d is correct. Changing the order of numbers in a partition does not change the total number of entries or the class numbers. The number of entries of a partition must match the number of vertices in the network, otherwise Pajek does not draw the partition. Answer b is incorrect. Class numbers determine the colors used. Because they do

not change, the same colors are used (answer c is incorrect). The order of entries in a partition determines which class is assigned to which vertex: the class number in the first entry of a partition is assigned to the first vertex in the network, and so on. Changing the order of entries in a partition changes the links between vertices and entries with class numbers, so at least some vertices will be drawn in other colors (answer d).

5. Statement d is correct. Network B contains fewer vertices than network A, so B is extracted or shrunk from A and not the other way around (statements a and c). B is shrunk from A (statement d), because we find a loop in B but no loops in A and because there is no subset of five vertices in network A that are connected like B: three triangles which share a line with at least one other triangle. In fact, the white vertices in network A are shrunk to one new vertex, namely the vertex with the loop in network B.
6. Answer a is correct. B is shrunk from A, but not all vertices are shrunk: the black vertices are not shrunk (see answer to Question 5). A partially shrunken network offers a contextual view.