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1 Introduction

VOSviewer is a computer program for creating maps based on network data and for visualizing and exploring these maps. The main features of VOSviewer can be summarized as follows:

- *Creating maps based on network data.* Maps can be created based directly on the adjacency matrix of a network, but it is also possible to create maps of publications, authors, or journals based on bibliographic coupling, co-citation, or co-authorship networks extracted from Web of Science or Scopus data. Term maps can be created directly based on a text corpus. Maps are created using the VOS mapping technique and the VOS clustering technique.¹
- *Visualizing and exploring maps.* Two visualizations are provided, the network visualization and the density visualization. Zooming and scrolling functionality allows maps to be explored in full detail, which is essential when working with large maps containing hundreds or even thousands of items.

Although VOSviewer is intended primarily for analyzing bibliometric networks, the program can in fact be used to create, visualize, and explore maps based on any type of network data.

VOSviewer is written in the Java programming language, which means that it runs on most hardware and operating system platforms. VOSviewer can be obtained from www.vosviewer.com. The program can be used freely for any purpose.

This manual is concerned with version 1.6.2 of VOSviewer. The manual is organized as follows. We first introduce the user interface of VOSviewer in Chapter 2, we then explain the file types used by VOSviewer in Chapter 3, and finally we discuss some advanced topics in Chapter 4. For additional information about VOSviewer, we refer to a paper that we have written (Van Eck & Waltman, 2010). In this paper, a general introduction to VOSviewer is provided. Also, the technical implementation of specific parts of the program is discussed in considerable detail. Similar information, including a step-by-step tutorial, can also be found in a recent book chapter (Van Eck & Waltman, 2014).

¹ Together, these two techniques provide a unified framework for mapping and clustering. For more information about the techniques, we refer to Van Eck, Waltman, Dekker, and Van den Berg (2010) and Waltman, Van Eck, and Noyons (2010).

2 User interface

The main window of VOSviewer is shown in Figure 1. As can be seen in the figure, the main window consists of the following five panels:

- *Main panel.* In this panel, a selected area in the currently active map is shown. The zoom and scroll functionality of VOSviewer can be used to select the area in the currently active map that is shown in the main panel.
- *Options panel.* This panel can be used to change the way in which the currently active map is shown in the main panel.
- *Information panel.* In this panel, information about an item in the currently active map can be shown.
- *Overview panel.* In this panel, an overview of the currently active map is shown. A rectangular frame is displayed in the overview panel to indicate the area in the currently active map that is shown in the main panel.
- *Action panel.* This panel can be used to undertake all kinds of actions, such as creating a new map, opening or saving an existing map, making a screenshot, finding an item, and constructing or transforming a map.

VOSviewer provides two visualizations, which are referred to as the **network visualization** and the **density visualization**. As shown in Figure 1, the **Network Visualization** and **Density Visualization** tabs can be used to switch between the two visualizations.

In the next sections, we discuss the five panels of VOSviewer in more detail.

To get some hands-on experience with VOSviewer, we encourage the reader to use the map file `journal_map.txt`, which is distributed together with VOSviewer. This file can be used to reproduce the figures in this chapter. The file contains a map of 232 journals in the fields of economics, management, and operations research (for more details, see Van Eck & Waltman, 2010). To open the map, press the **Open** button on the **Action** tab in the action panel, select the map file `journal_map.txt`, and press the **OK** button.

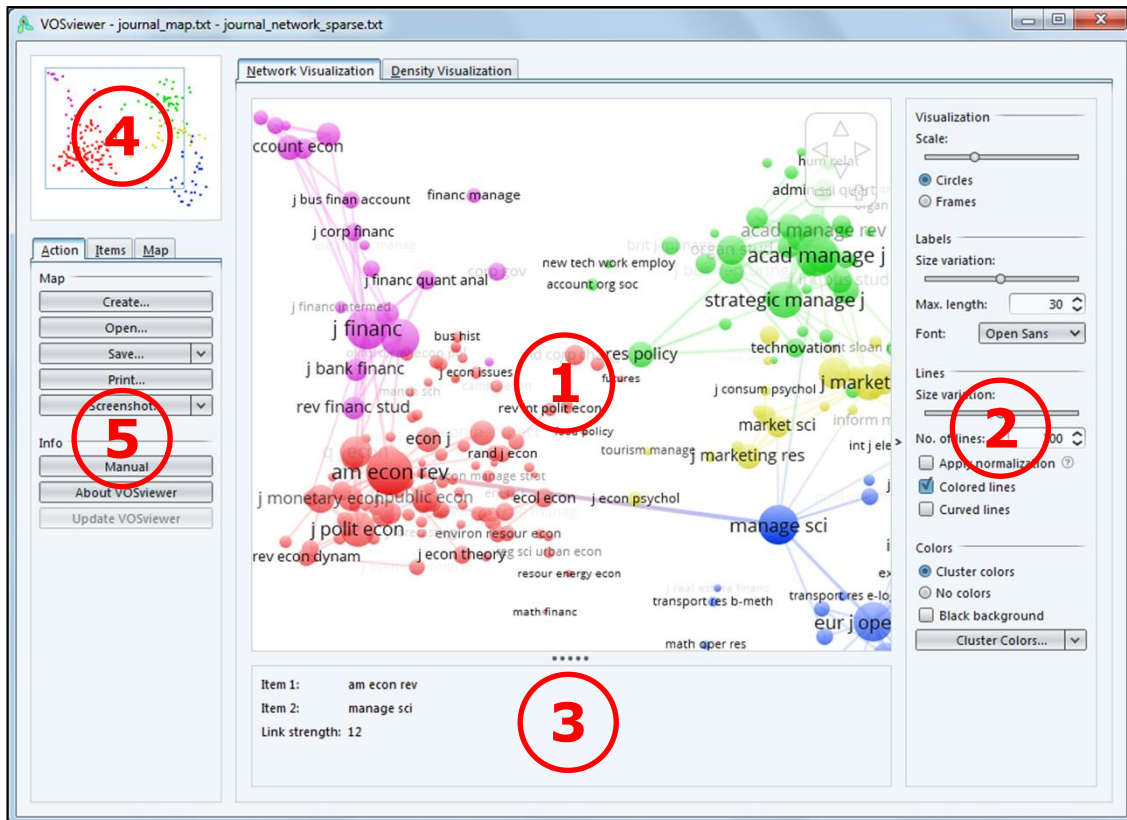


Figure 1. The main window of VOSviewer. The numbers indicate (1) the main panel, (2) the options panel, (3) the information panel, (4) the overview panel, and (5) the action panel.

2.1 Main panel

As can be seen in Figure 1, the main panel of VOSviewer is used to show a selected area in the currently active map. The zoom and scroll functionality of VOSviewer can be used to determine which area in the currently active map is shown. The way in which the currently active map is shown depends on whether the network visualization or the density visualization is selected.

We first consider the network visualization. When the network visualization is selected, items are indicated by their label and, by default, also by a circle. For each item, the font size of the item's label and the size of the item's circle depend on the weight of the item.² The color of the circle of an item can be determined in a

² The weight of an item is determined by the *weight* or *normalized weight* column in a map file (see Section 3.1). When a new map is created without providing a map file with a *weight* or *normalized weight* column, the weight of an item is set equal to the total strength of all links of the item. When an existing map is opened without providing a map file with a *weight* or *normalized weight* column, all items in the map are given the same weight.

number of different ways. If items have been assigned to clusters, the color of the circle of an item can be determined by the cluster to which the item belongs. If scores have been given to items, the color of the circle of an item can be determined by the item's score, where by default colors range from blue (low score) to green (average score) to red (high score).³ A third possibility is to determine the color of the circle of an item by the color of the item as specified in a map file (using the *red*, *green*, and *blue* columns; see Section 3.1). The options panel can be used to switch between the different ways of coloring items. We note that for some items the label may not be visible. This is done in order to avoid overlapping labels. Also, by default, no lines between items are displayed. However, this can be changed in the options panel. An example of the network visualization is shown in Figure 2.

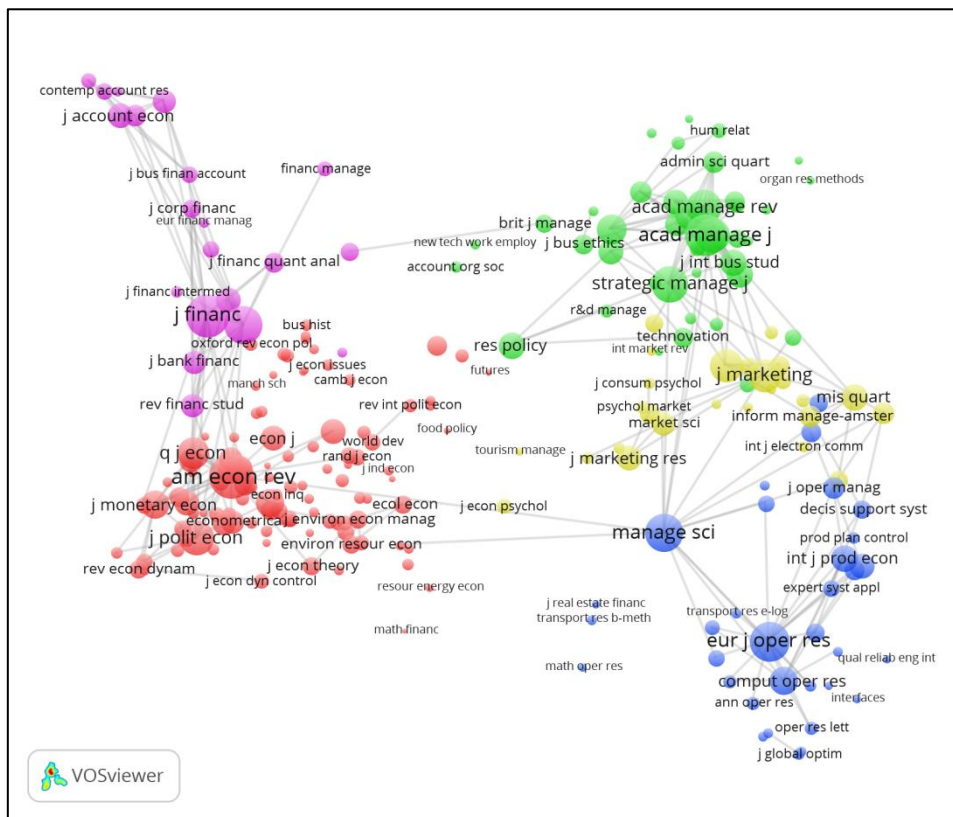


Figure 2. The network visualization.

³ If colors are determined by the scores of items, a color bar is shown in the lower right corner of the main panel. This color bar indicates which colors correspond with which scores.

We now consider the density visualization. There are in fact two variants of the density visualization. We first discuss the item density visualization, followed by the cluster density visualization. The options panel can be used to switch between the two variants of the density visualization. We refer to Van Eck and Waltman (2010) for a detailed discussion of the technical implementation of the density visualization.

In the item density visualization, items are indicated by their label in a similar way as in the network visualization. Each point in a map has a color that depends on the density of items at that point. By default, this color is somewhere in between red and blue. The larger the number of items in the neighborhood of a point and the higher the weights of the neighboring items, the closer the color of the point is to red. Conversely, the smaller the number of items in the neighborhood of a point and the lower the weights of the neighboring items, the closer the color of the point is to blue. An example of the item density visualization is shown in Figure 3.

The cluster density visualization is available only if items have been assigned to clusters. The cluster density visualization is similar to the item density visualization except that the density of items is displayed separately for each cluster of items. In the cluster density visualization, the color of a point in a map is close to the color of a certain cluster if there are a large number of items belonging to that cluster in the neighborhood of the point. Like in the item density visualization, items with high weights count more heavily than items with low weights. An example of the cluster density visualization is shown in Figure 4.

To facilitate the detailed examination of a map, VOSviewer offers zoom and scroll functionality. In the main panel, zooming and scrolling can be done in the following three ways:

- *Using the mouse.* To zoom in, move the mouse upwards while keeping the right mouse button pressed. Conversely, to zoom out, move the mouse downwards while keeping the right mouse button pressed. As an alternative, the mouse wheel can be used to zoom in and out. To scroll through a map, move the mouse while keeping the left mouse button pressed.
- *Using the navigation buttons in the upper right corner of the main panel (see Figure 1).* Use the plus and minus buttons to zoom in and out. Use the arrow buttons to scroll through a map.
- *Using the keyboard.* Use the plus and minus keys to zoom in and out. Use the arrow keys to scroll through a map.

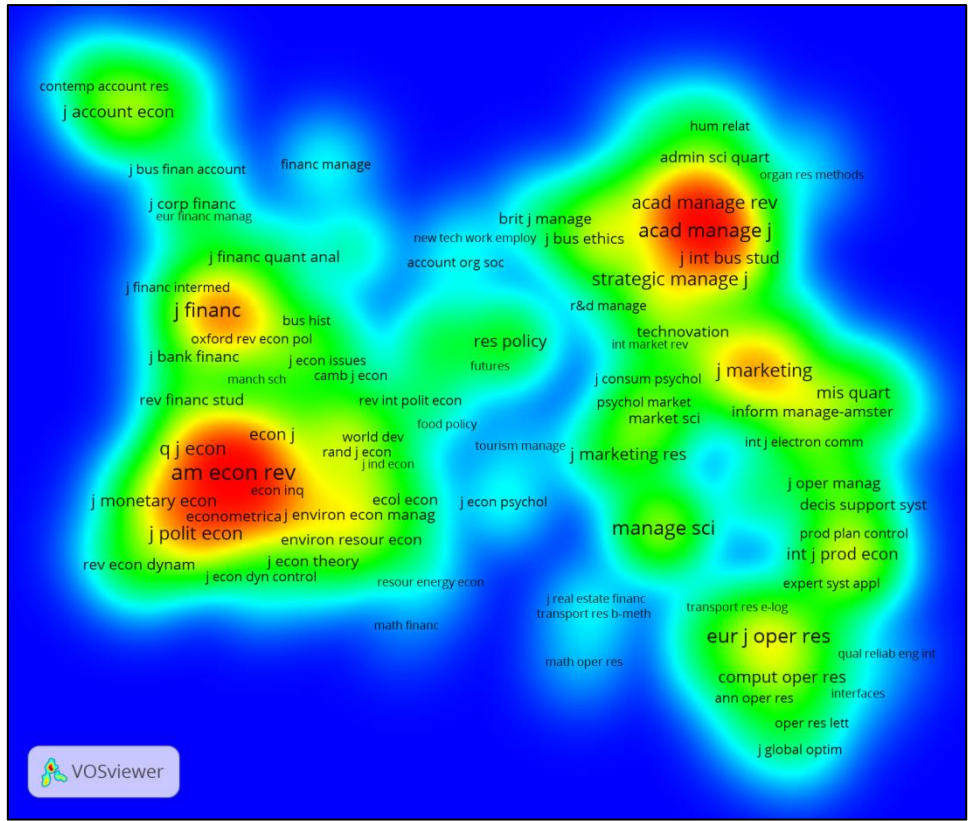


Figure 3. The item density visualization.

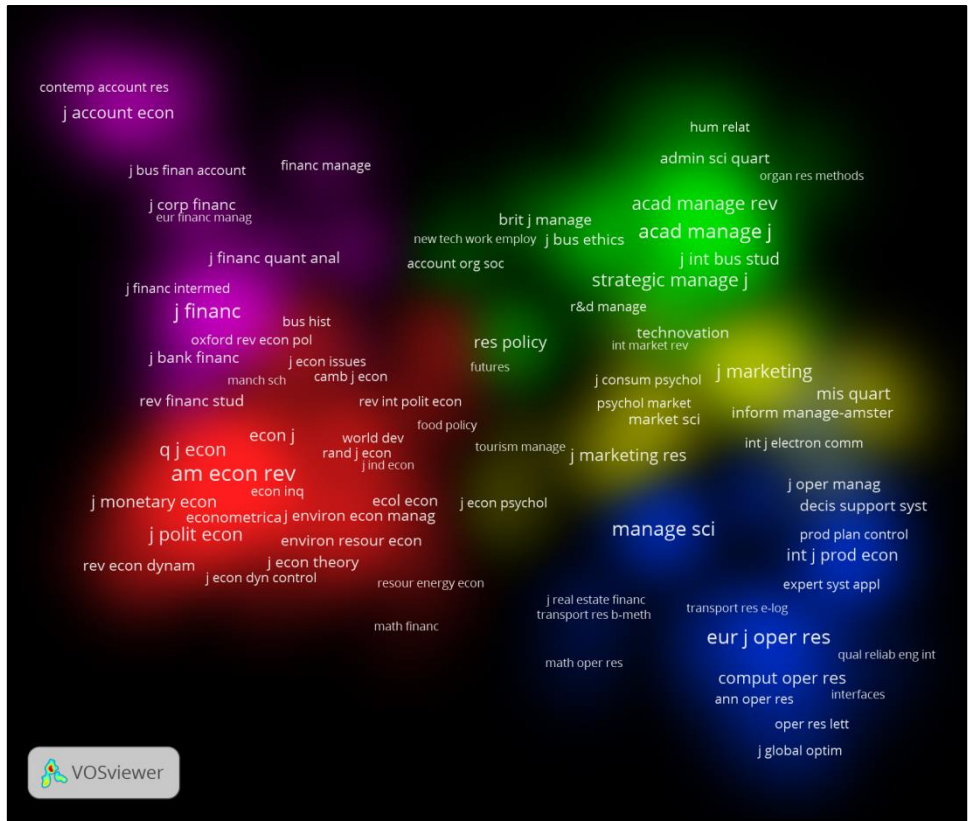


Figure 4. The cluster density visualization.

2.2 Options panel

The options panel can be used to change the way in which the currently active map is shown in the main panel. The network visualization and the density visualization each have their own options. Some of the options are not always available. The options panel shows only the options that are relevant given the currently available map data.

When the network visualization is selected, the following options may be available:

- **Visualization.**
 - **Scale.** This slider determines the size of the font used to display the labels of items in the main panel. The **Scale** slider also determines the thickness of the lines used to display links between items.
 - **Weights.** Items sometimes have more than one weight. The **Weights** drop down list then determines the weights based on which the currently active map is shown in the main panel.
 - **Circles** and **Frames.** These radio buttons determine how items are indicated in the main panel. If the **Circles** radio button is selected, items are indicated both by their label and by a circle. If the **Frames** radio button is selected, items are indicated by their label displayed within a rectangular frame.
- **Labels.**
 - **Size variation.** The higher the weight of an item, the larger the font that is used to display the item's label in the main panel. The **Size variation** slider determines the strength of this effect.
 - **Max. length.** This text box determines the maximum length of a label displayed in the main panel. If the length of a label exceeds the maximum length, the last part of the label is not displayed.
 - **Font.** This drop down list determines the font that is used to display the labels of items in the main panel.
- **Lines.**
 - **Size variation.** The stronger the link between two items (based on either the unnormalized link strength or the normalized link strength), the thicker the line that is used to display the link in the main panel. The **Size variation** slider determines the strength of this effect.

- **No. of lines.** This text box determines the maximum number of links to be displayed in the main panel using lines. If the number of links in the network exceeds the maximum number of links to be displayed, only the strongest links (based on either the unnormalized link strength or the normalized link strength) are displayed.
 - **Apply normalization.** This check box determines whether links are displayed based on their unnormalized link strength or their normalized link strength.
 - **Colored lines.** This check box determines whether links are displayed using gray lines or colored lines.
 - **Curved lines.** This check box determines whether links are displayed using straight lines or curved lines.
- **Colors.**
 - **User defined colors, Cluster colors, Score colors, and No colors.** These radio buttons determine how items are colored in the main panel and the overview panel. If the **User defined colors** radio button is selected, each item has its own color as specified in a map file (using the *red*, *green*, and *blue* columns; see Section 3.1). If the **Cluster colors** radio button is selected, items are colored based on the cluster to which they belong. If the **Score colors** radio button is selected, items are colored based on their score. If the **No colors** radio button is selected, all items are colored in gray.
 - **Black background.** This check box determines whether the main panel has a white or a black background color.
 - **Scores.** This drop down list is available only if the **Score colors** radio button is selected. Items sometimes have more than one score. The **Scores** drop down list then determines the scores that are used to color items in the main panel and the overview panel.
 - **Cluster Colors.** This button is available only if the **Cluster colors** radio button is selected. The button offers four options:
 - **Edit.** This option is the default choice. Choose this option to edit the current cluster colors in the **Edit Cluster Colors** dialog box.
 - **Import.** Choose this option to import cluster colors from a cluster colors file (see Section 3.4).

- **Export.** Choose this option to export the current cluster colors to a cluster colors file (see Section 3.4).
- **Restore original.** Choose this option to restore the original cluster colors.
- **Score Colors.** This button is available only if the **Score colors** radio button is selected. The button offers four options:
 - **Set range.** This option is the default choice. Choose this option to bring up the **Set Score Colors Range** dialog box. This dialog box can be used to change the minimum and maximum score that determine how scores are mapped to colors. By default, scores less than or equal to the minimum score are mapped to blue, scores equal to the average of the minimum and the maximum score are mapped to green, and scores greater than or equal to the maximum score are mapped to red.
 - **Import.** Choose this option to import score colors from a score colors file (see Section 3.4).
 - **Export.** Choose this option to export the current score colors to a score colors file (see Section 3.4).
 - **Restore original.** Choose this option to restore the original score colors.

When the density visualization is selected, the following options may be available:

- **Visualization.**
 - **Scale.** This slider determines the size of the font used to display the labels of items in the main panel.
 - **Kernel width.** This slider determines the value of the kernel width parameter. We refer to Van Eck and Waltman (2010) for more information about this parameter.
 - **Weights.** Items sometimes have more than one weight. The **Weights** drop down list then determines the weights based on which the currently active map is shown in the main panel.
 - **Item density** or **Cluster density.** These radio buttons determine whether the item density visualization or the cluster density visualization is selected.
- **Labels.** These options are identical to the ones provided when the network visualization is selected.
- **Colors.**

- **White background.** This check box is available only if the cluster density visualization is selected. The check box determines whether the main panel has a black or a white background color.
- **Density Colors.** This button is available only if the item density visualization is selected. The button offers three options:
 - **Import.** This option is the default choice. Choose this option to import density colors from a density colors file (see Section 3.4).
 - **Export.** Choose this option to export the current density colors to a density colors file (see Section 3.4).
 - **Restore original.** Choose this option to restore the original density colors.
- **Cluster Colors.** This button is available only if the cluster density visualization is selected. The button offers four options:
 - **Edit.** This option is the default choice. Choose this option to edit the current cluster colors in the **Edit Cluster Colors** dialog box.
 - **Import.** Choose this option to import cluster colors from a cluster colors file (see Section 3.4).
 - **Export.** Choose this option to export the current cluster colors to a cluster colors file (see Section 3.4).
 - **Restore original.** Choose this option to restore the original cluster colors.

2.3 Information panel

In the information panel of VOSviewer, information about an item in the currently active map can be shown. For example, when the mouse cursor is moved over the label of an item in the main panel, information about the item will be shown in the information panel. If item descriptions have been provided (using the *description* column in a map file; see Section 3.1), the description of the item will be shown. If no item descriptions have been provided, the label of the item will be shown and possibly also the weight of the item, the number of the cluster to which the item belongs, and the score of the item.

Information about a link between two items can also be shown in the information panel. When the mouse cursor is moved over a line between two items,

information about the link between the items will be shown in the information panel. The labels of the items and the strength of the link will be shown.

2.4 Overview panel

In the overview panel of VOSviewer, an overview of the currently active map is shown. Each item in the map is indicated by a small colored dot. A rectangular frame is displayed in the overview panel to indicate the area in the currently active map that is shown in the main panel. By left-clicking in the overview panel, the area in the currently active map that is shown in the main panel can be changed.

2.5 Action panel

The action panel of VOSviewer can be used to undertake all kinds of actions. The panel consists of three tabs: The **Action** tab, the **Items** tab, and the **Map** tab. These tabs are discussed in Subsections 2.5.1, 2.5.2, and 2.5.3.

2.5.1 Action tab

The **Action** tab can be used to perform a number of basic actions. The following buttons are available on the **Action** tab:

- **Map.**
 - **Create.** Use this button to create a new map. The button brings up the **Create Map** wizard. There are three ways in which a new map can be created using this wizard:
 - **Create a map based on a network.** This option requires the adjacency matrix of a network. The adjacency matrix indicates which pairs of items in the network are linked to each other, and for each pair of linked items it indicates the strength of their link. The matrix can be read from a network file. In addition to a network file, a map file may also be provided. The map file may for example contain labels and descriptions of items. We refer to Sections 3.1 and 3.2 for a detailed discussion of map files and network files. Instead of a map file and a network file, it is also possible to use Pajek files⁴ or a GML file.

⁴ Pajek is a well-known computer program for social network analysis (De Nooy, Mrvar, & Batagelj, 2011). It is available at <http://pajek.imfm.si/doku.php>. VOSviewer supports Pajek matrix, network, partition, and vector files.

- **Create a map based on bibliographic data.** This option requires bibliographic data. The data can be read from Web of Science, Scopus, or PubMed files. Using this option, it is possible to create maps of scientific publications, scientific journals, researchers, or research organizations based on bibliographic coupling relations (i.e., multiple items citing the same publication), co-citation relations (i.e., multiple items being cited by the same publication), or co-authorship relations (i.e., multiple items co-authoring the same publication).
- **Create a map based on a text corpus.**⁵ This option requires a text corpus. The corpus is stored in a corpus file. A corpus file is a text file that contains on each line the text of a document. This text is assumed to be in English. Using natural language processing techniques, VOSviewer extracts terms from the corpus file, where a term is defined as a sequence of nouns and adjectives (ending with a noun). Based on the extracted terms, VOSviewer creates a term map. This is a map in which terms are located in such a way that the distance between two terms provides an indication of the number of co-occurrences of the terms. In general, the smaller the distance between two terms, the larger the number of co-occurrences of the terms. Two terms are said to co-occur if they both occur on the same line in the corpus file. In addition to a corpus file, a scores file may also be provided. A scores file is a text file that contains on each line the score of a document. Based on the scores in a scores file, VOSviewer calculates a score for each term in the term map. The score of a term equals the average score of the documents in which the term occurs. In the network visualization, colors can be used to indicate the scores of terms. It is also possible to create a term map based on Web of Science, Scopus, or PubMed files instead of a corpus file. In that case, terms are extracted from the titles and abstracts of scientific publications.
- **Open.** Use this button to open an existing map. The button brings up the **Open Map** dialog box. Map data can be read from a map file. The map file must contain coordinates of items. The file may also contain, for example, labels, descriptions, weights, scores, and cluster numbers of items. In addition to a map file, a network file may also be provided. The network file contains the adjacency matrix of a network. Based on this matrix, lines

⁵ We refer to Van Eck and Waltman (2011) for more information about this option.

between the items in a map can be displayed. Instead of a map file and a network file, it is also possible to use Pajek and GML files. For a detailed discussion of map files and network files, we refer to Sections 3.1 and 3.2.

- **Save.** This button offers three options:
 - **Save map.** This option is the default choice. Choose this option to save the currently active map in a map file. Map files are discussed in Section 3.1. Instead of a map file, it is also possible to use a Pajek or GML file.
 - **Save network.** This option can be chosen only if the adjacency matrix of a network is available. Choose this option to save the adjacency matrix in a network file. Network files are discussed in Section 3.2. Instead of a network file, it is also possible to use a Pajek or GML file.
 - **Save normalized network.** This option can be chosen only if the adjacency matrix of a network is available. Choose this option to save the normalized adjacency matrix in a network file. Normalization of an adjacency matrix is discussed in Subsection 2.5.3. Network files are discussed in Section 3.2. Instead of a network file, it is also possible to use a Pajek or GML file.
- **Print.** Use this button to print a screenshot of the main panel.
- **Screenshot.** This button offers three options:
 - **Save to file.** This option is the default choice. Choose this option to save a screenshot of the main panel. The screenshot resembles the main panel as closely as possible. However, the navigation buttons in the upper right corner of the main panel are not shown in the screenshot. If the **Optimize labeling** check box in the **Screenshot Options** dialog box (see below) is checked, the number of labels visible in the screenshot is optimized. This means that some labels not visible in the main panel may be visible in the screenshot. Screenshots can be saved in a number of graphic file formats. For most applications, we recommend the PNG format. Some formats, such as EPS, PDF, and SVG, use vector graphics when saving a screenshot. This has the advantage that the screenshot can be resized without loss of quality. We note that Figures 2 to 4 were obtained using the screenshot functionality of VOSviewer.

- **Copy to clipboard.** Choose this option to copy a screenshot of the main panel to the clipboard. The screenshot can for example be pasted into a Word document or a PowerPoint presentation.
- **Screenshot options.** Choose this option to bring up the **Screenshot Options** dialog box. This dialog box can be used to change some screenshot-related settings of VOSviewer. The **Scaling** drop down list determines the resolution (i.e., the number of pixels) of a screenshot. The resolution is calculated relative to the resolution of the main panel. Using a scaling of 100%, screenshots have the same resolution as the main panel. Using the default scaling of 200%, screenshots have a resolution that is twice as high (i.e., twice as many pixels horizontally and vertically) as the resolution of the main panel. The **Scaling** drop down list has no effect on screenshots that are saved in a file format that uses vector graphics. The **Optimize labeling** check box determines whether the number of labels visible in a screenshot is optimized. Optimizing the number of labels visible in a screenshot means that some labels not visible in the main panel itself may be visible in a screenshot of the main panel. The **Include border** check box determines whether a border is included around a screenshot.
- **Info.**
 - **Manual.** Use this button to open the VOSviewer manual. This requires an internet connection.
 - **About VOSviewer.** This button brings up the **About VOSviewer** dialog box. This dialog box provides some general information about VOSviewer, such as the version number, a copyright notice, a license text, the address of the VOSviewer web site, and a list of software libraries used by VOSviewer.
 - **Update VOSviewer.** This button is available only if a new version of VOSviewer is available. Use this button to open the VOSviewer website. The new version of VOSviewer can then be downloaded from the website.

2.5.2 Items tab

The **Items** tab provides a list of items in the currently active map. By default, a list of all items in the map is provided. However, a filter can be used to restrict the list to a subset of the items in the map. To do so, enter a filter string in the **Filter** text box. This yields a list of all items whose label contains the filter string.

The **Group items by cluster** check box determines how items are listed. If the check box is unchecked, items are simply listed alphabetically. If the check box is checked, items are first grouped by cluster and then listed alphabetically within each cluster.

By double-clicking on an item on the **Items** tab, the item is shown in the main panel.

2.5.3 Map tab

The **Map** tab can be used to construct or transform a map. Maps are constructed using the VOS mapping technique and the VOS clustering technique.⁶ The **Map** tab can also be used to change the parameters of these techniques. The following parameters and controls are available on the **Map** tab:

- **Parameters.**
 - **Mapping attraction** and **Mapping repulsion.** These parameters influence the way in which items are located in a map by the VOS mapping technique. The **Mapping attraction** parameter must have an integer value between -9 and +10. The **Mapping repulsion** parameter must have an integer value between -10 and +9. The value of the **Mapping repulsion** parameter must be lower than the value of the **Mapping attraction** parameter. For most purposes, our recommendation is to work with the default parameter values.
 - **Clustering resolution.** This parameter determines the level of detail provided by the VOS clustering technique. The parameter must have a non-negative value. The larger the value of the parameter, the larger the number of clusters that will be obtained. Our recommendation is to try out different values for the parameter and to use the value that yields the level of detail considered most satisfactory for the particular application at hand.
 - **Min. cluster size.** This parameter determines the minimum cluster size used by the VOS clustering technique. Each cluster produced by the VOS clustering technique must consist of the minimum number of items specified by this parameter. The **Min. cluster size** parameter can be useful to simplify the clustering solutions obtained from the VOS clustering technique by getting rid of small and uninteresting clusters.

⁶ We refer to Van Eck et al. (2010), Waltman and Van Eck (2013), and Waltman et al. (2010) for more information about these techniques.

- **Advanced Parameters.** This button brings up the **Advanced Parameters** dialog box. This dialog box can be used to change a number of more advanced parameters of the VOS mapping and clustering techniques. These parameters are discussed below.
- **Run.** The **Run** button is available only after a new map has been created (using the **Create** button on the **Action** tab in the action panel). The button can be used to run the VOS mapping and clustering techniques. The radio buttons determine whether both techniques are run or only one of them.
- **Rotate/flip.**
 - **Rotate.** Use this button to rotate the currently active map. The **Degrees to rotate** parameter determines the number of degrees by which the map will be rotated.
 - **Flip Horizontally.** Use this button to flip the currently active map in horizontal direction.
 - **Flip Vertically.** Use this button to flip the currently active map in vertical direction.

As mentioned above, the **Advanced Parameters** dialog box can be used to change a number of more advanced parameters of the VOS mapping and clustering techniques. The following parameters are available:

- **Normalization.**
 - **No normalization.** If this radio button is selected, no normalization of the adjacency matrix of a network is performed. In general, we do not recommend this option.
 - **Normalization method 1.** If this radio button is selected, normalization method 1 is used for normalizing the adjacency matrix of a network. This is the default normalization method. This method uses the so-called association strength measure (Van Eck & Waltman, 2009).
 - **Normalization method 2.** If this radio button is selected, normalization method 2 is used for normalizing the adjacency matrix of a network. This is an alternative normalization method. The difference between normalization method 1 and normalization method 2 is somewhat technical, and we will therefore not discuss it here.
 - **Use LinLog/modularity normalization.** If this check box is checked, normalization is performed in the same way as in the LinLog mapping

technique and the modularity clustering technique. For more information about these techniques, we refer to Newman (2004) and Noack (2007, 2009).

- **Random number generator.**
 - **Fixed seed.** This text box determines the seed of the random number generator used by the optimization algorithms of the VOS mapping and clustering techniques. The seed must be a non-negative integer.
 - **Do not use fixed seed.** If this check box is checked, the random number generator used by the optimization algorithms of the VOS mapping and clustering techniques does not have a fixed seed. Instead, each time the VOS mapping and clustering techniques are run, a different seed will be used, possibly leading to different results.

- **Mapping.**
 - **Random starts.** This parameter determines the number of times the optimization algorithm of the VOS mapping technique is run. Each time the optimization algorithm is run, a different mapping solution may be obtained. The best mapping solution obtained in all runs of the optimization algorithm will be used as the final mapping solution. The larger the value of the **Random starts** parameter, the more accurate the final mapping solution that will be obtained.
 - **Max. iterations.** This parameter determines the maximum number of iterations performed by the optimization algorithm of the VOS mapping technique. The larger the value of the parameter, the more accurate the mapping solution that will be obtained. In general, the default value of the parameter works well and does not need to be changed.
 - **Initial step size, Step size reduction, and Step size convergence.** These are technical parameters of the optimization algorithm of the VOS mapping technique. The parameters must have values between 0.000001 and 1. The smaller the value of the **Step size convergence** parameter, the more accurate the mapping solution that will be obtained. In general, the default values of the parameters work well and do not need to be changed.

- **Clustering.**
 - **Random starts.** This parameter determines the number of times the optimization algorithm of the VOS clustering technique is run. Each time the optimization algorithm is run, a different clustering solution may be

obtained. The best clustering solution obtained in all runs of the optimization algorithm will be used as the final clustering solution. The larger the value of the **Random starts** parameter, the more accurate the final clustering solution that will be obtained.

- **Iterations.** This parameter determines the number of iterations performed by the optimization algorithm of the VOS clustering technique. The larger the value of the parameter, the more accurate the clustering solution that will be obtained. In general, the default value of the parameter works well and does not need to be changed.

3 File types

The two primary file types used by VOSviewer are the map file and the network file. Map files and network files are simple text files that can easily be viewed and edited using a text editor (e.g., Notepad) or a spreadsheet program (e.g., Excel). Map files and network files consist of multiple columns. Hence, each line in a map file or a network file contains multiple pieces of information. Different pieces of information on the same line are separated from each other by a comma, a semicolon, or a tab. If a piece of information (e.g., the label of an item) itself contains a comma or a semicolon, the whole piece of information needs to be enclosed within double quotes.

We discuss map files and network files in more detail in Sections 3.1 and 3.2. Four additional file types, the thesaurus file, the cluster colors file, the score colors file, and the density colors file, are discussed in Sections 3.3 and 3.4. We note that all example files mentioned in this chapter are distributed together with VOSviewer.

3.1 Map file

A map file is a text file that contains information about the items in a map. Each line in a map file corresponds with an item. The only exception is the first line. This is a header line that indicates what is contained in each of the columns of a map file. Below, we list the columns that can be used in a map file. For each column, we provide the column header and we specify what the column contains.

<i>id</i>	The ID of an item. Items need to have an ID only if a map file is used in combination with a network file.
<i>label</i>	The label of an item.
<i>sublabel</i>	The sublabel of an item. In the main panel, the sublabel of an item is displayed below the item's ordinary label. Sublabels are displayed in a smaller font.
<i>description</i>	The description of an item. The description of an item is used to provide information about the item in the information panel. HTML formatting can be used in this column.
<i>url</i>	The URL of an item. This column can be used to associate a web page with an item. Clicking on the label of an item in the main panel will cause the web page associated with the item to be opened in a web browser.
<i>x</i>	The horizontal coordinate of an item.
<i>y</i>	The vertical coordinate of an item.
<i>weight</i>	The weight of an item. Only non-negative numbers are allowed in this column. The higher the weight of an item, the more prominent the item is presented in the

	main panel.
<i>normalized weight</i>	The normalized weight of an item. Only non-negative numbers are allowed in this column. The higher the normalized weight of an item, the more prominent the item is presented in the main panel. The default presentation of an item is obtained by setting the item's normalized weight to 1.
<i>score</i>	The score of an item. In the main panel and the overview panel, items can be colored based on their scores, with by default colors ranging from blue to green to red.
<i>cluster</i>	The number of the cluster to which an item belongs. Only integers between 1 and 1000 are allowed in this column.
<i>red</i>	The red component of the color of an item. Only integers between 0 and 255 are allowed in this column.
<i>green</i>	The green component of the color of an item. Only integers between 0 and 255 are allowed in this column.
<i>blue</i>	The blue component of the color of an item. Only integers between 0 and 255 are allowed in this column.

In a map file, one always uses only a subset of the above columns. The order in which the columns are used is not important.

There are a number of restrictions on the columns that are used in a map file:

- There must be an *id* column or a *label* column. (If there is no *label* column, the ID of an item is used as the item's label.)
- If there is a *sublabel* column, there must be a *label* column as well.
- The *x* and *y* columns must be used together.
- The *red*, *green*, and *blue* columns must be used together.
- The *weight* column and the *normalized weight* column cannot be used together.

For an example of a map file, see the file `journal_map.txt`.

3.2 Network file

A network file is a text file that contains the adjacency matrix of a network. The adjacency matrix of a network is a square matrix that indicates for each pair of items in the network the strength of the link between the items. The strength of a link is given by a non-negative number. If there is no link between two items, the strength of the link between the items equals zero. VOSviewer works with symmetric adjacency matrices. If a network file contains an asymmetric adjacency matrix, VOSviewer will make the matrix symmetric by averaging corresponding elements on both sides of the main diagonal.

A network file has either a full format or a sparse format:

- *Full format.* The entire adjacency matrix, including elements that are equal to zero, is stored in the network file. The file consists of n lines and $n + 1$ columns, where n denotes the number of items in the network. The element in the i th row and the j th column of the adjacency matrix is stored on the i th line and in the $(j + 1)$ th column of the network file. The first column of the network file contains IDs of items. This column indicates for each row and column of the adjacency matrix the ID of the corresponding item. For an example of a network file in full format, see the file `journal_network_full.txt`.
- *Sparse format.* Only the non-zero elements of the adjacency matrix are stored in the network file. The file consists of two or three columns. The first two columns contain IDs of items. The third column contains the non-zero elements of the adjacency matrix. This column indicates the strength of the link between the items referred to in the first two columns. If there is no third column, the strength of the link between the items referred to in the first two columns always equals one. In the case of a symmetric adjacency matrix, it is sufficient to store only half of the matrix (either the upper triangular part or the lower triangular part) in the network file. For an example of a network file in sparse format, see the file `journal_network_sparse.txt`.

A network file is usually used in combination with a map file. For each item ID in the network file, there must then be a corresponding item ID in the map file.

3.3 Thesaurus file

A thesaurus file is a text file that can be used in the following situations:

- When creating a map based on Web of Science or Scopus files (see Subsection 2.5.1), a thesaurus file can be used to merge different variants of a source title, an author name, an organization name, or a cited reference. This may for example be useful when the name of a researcher is written in different ways in different publications (e.g., with first initial only and with all initials). A thesaurus file can then be used to indicate that different names in fact refer to the same researcher.
- When creating a map based on a corpus file (see Subsection 2.5.1), a thesaurus file can be used to merge synonyms into a single term. This may be useful not only for merging different terms referring to the same concept, but also for merging different spellings of the same term (e.g., *behavior* and

behaviour). It may also be useful for merging an abbreviation of a term with the term itself.

Each line in a thesaurus file contains a label and indicates an alternative label that replaces the original label. The only exception is the first line. This is a header line that indicates what is contained in each of the columns of a thesaurus file. A thesaurus file must have two columns: A *label* column and a *replace by* column. The *label* column contains a label. Depending on the situation (see above), a label may represent a source title, an author name, an organization name, a cited reference, or a term. The *replace by* column contains an alternative label that replaces the original label. The *replace by* column may also be empty. In that case, the original label is not replaced by an alternative one, but instead the original label is simply ignored. When creating a map based on a corpus file, this allows a thesaurus file to be used as a kind of stop word list. A thesaurus file may for example indicate that certain uninteresting terms (e.g., *copyright* and *Elsevier* in the case of a corpus of abstracts of scientific publications) should be ignored. For examples of thesaurus files, see the files `thesaurus_authors.txt` and `thesaurus_terms.txt`.

3.4 Cluster colors file, score colors file, and density colors file

A cluster colors file is a text file that contains the colors of clusters. Each line in a cluster colors file corresponds with a cluster. The only exception is the first line. This is a header line that indicates what is contained in each of the columns of a cluster colors file. A cluster colors file must have four columns: A *cluster* column, a *red* column, a *green* column, and a *blue* column. The *cluster* column contains cluster numbers. Only integers between 1 and 1000 are allowed in this column. The *red*, *green*, and *blue* columns contain the red, green, and blue components of the colors of clusters. Only integers between 0 and 255 are allowed in these columns. For an example of a cluster colors file, see the file `cluster_colors.txt`.

A score colors file is similar to a cluster colors file except that instead of a *cluster* column it has a *color value* column, with values between 0 and 1. If scores have been given to items, items can be colored by transforming their scores into color values and by matching these color values with the color values in the *color value* column of the score colors file. Exact matching of color values is usually not possible, and in that case the colors in the score colors file are interpolated. For an example of a score colors file, see the file `score_colors.txt`.

A density colors file is identical to a score colors file. In the item density visualization, the color of a point in a map is determined by transforming the

density of items at that point into a color value and by matching this color value with the color values in the *color value* column of the density colors file. Exact matching of color values is usually not possible, and in that case the colors in the density colors file are interpolated. For an example of a density colors file, see the file `density_colors.txt`.

4 Advanced topics

In this chapter, some advanced topics are addressed. We first consider the use of command line parameters (Section 4.1). We then discuss how a map can be made available on the internet (Section 4.2) and how the amount of memory available to VOSviewer can be increased (Section 4.3).

4.1 Using command line parameters

VOSviewer supports a large number of command line parameters. These parameters can for example be used to automatically open a map when VOSviewer is started or to override some of the default settings of VOSviewer. The command line parameters supported by VOSviewer are listed below.

Command line parameters for opening or creating a map

<code>gml</code>	Use this parameter to specify a GML file. Based on this file, a map will be opened or created when VOSviewer is started.
<code>map</code>	Use this parameter to specify a map file (see Section 3.1). The map in this file will be opened when VOSviewer is started.
<code>network</code>	Use this parameter to specify a network file (see Section 3.2). An adjacency matrix will be read from this file when VOSviewer is started. The adjacency matrix can be used to display lines between the items in a map or to create a new map.
<code>pajek_network</code>	Use this parameter to specify a Pajek network (or matrix) file. Based on this file, a map will be opened or created when VOSviewer is started.
<code>pajek_partition</code>	Use this parameter to specify a Pajek partition file. Cluster numbers of items will be read from this file when VOSviewer is started.
<code>pajek_vector</code>	Use this parameter to specify a Pajek vector file. Weights of items will be read from this file when VOSviewer is started.

Command line parameters for creating a term map based on a corpus file

<code>corpus</code>	Use this parameter to specify a corpus file. Based on this file, a term map will be created when VOSviewer is started.
<code>counting_method</code>	Use this parameter to specify the counting method to be used in the creation of the term map (1 for binary counting and 2 for full counting).
<code>min_n_occurrences</code>	Use this parameter to specify the minimum number of occurrences a term must have to be included in the term map.
<code>n_terms</code>	Use this parameter to specify the number of terms to be included in the term map. VOSviewer will select the terms that seem most relevant.
<code>scores</code>	Use this parameter to specify a scores file. In the creation of the term map, this file will be used to calculate a score for each term.

thesaurus Use this parameter to specify a thesaurus file (see Section 3.3). In the creation of the term map, this file can be used to merge synonyms into a single term.

Visualization-related command line parameters

black_background Use this parameter to have a black background color in the network visualization.

circles_frames Use this parameter to specify how items will be indicated in the network visualization (1 for circles and 2 for frames).

cluster_colors Use this parameter to specify a cluster colors file (see Section 3.4). Cluster colors will be imported from this file when VOSviewer is started.

colored_lines Use this parameter to display links using colored lines in the network visualization.

curved_lines Use this parameter to display links using curved lines in the network visualization.

density Use this parameter to specify whether the item density visualization or the cluster density visualization will be selected in the density visualization (1 for item density visualization and 2 for cluster density visualization).

density_colors Use this parameter to specify a density colors file (see Section 3.4). Density colors will be imported from this file when VOSviewer is started.

kernel_width Use this parameter to specify the initial value of the **Kernel width** slider in the options panel.

label_size_variation Use this parameter to specify the initial value of the **Size variation** slider for labels in the options panel.

line_size_variation Use this parameter to specify the initial value of the **Size variation** slider for lines in the options panel.

max_label_length Use this parameter to specify the initial value of the **Max. length** text box in the options panel.

max_score Use this parameter to specify the initial value of the **Max. score** text box in the **Set Score Colors Range** dialog box.

min_score Use this parameter to specify the initial value of the **Min. score** text box in the **Set Score Colors Range** dialog box.

n_lines Use this parameter to specify the initial value of the **No. of lines** text box in the options panel.

normalized_lines Use this parameter to display links based on their normalized (instead of their unnormalized) link strength in the network visualization.

scale Use this parameter to specify the initial value of the **Scale** slider in the options panel.

score_colors Use this parameter to specify a score colors file (see Section 3.4). Score colors will be imported from this file when VOSviewer is started.

visualization Use this parameter to specify which visualization will be selected when

VOSviewer is started (1 for the network visualization and 2 for the density visualization).

- `white_background` Use this parameter to have a white background color in the cluster density visualization.
- `zoom_level` Use this parameter to specify the initial zoom level in the main panel. The zoom level must have a value of at least 1. The higher the zoom level, the more the main panel will be zoomed in on the center of a map.

Miscellaneous command line parameters

- `encoding` Use this parameter to specify the character encoding that is used by VOSviewer to read and write text files. For a list of the available encodings, see <http://docs.oracle.com/javase/6/docs/technotes/guides/intl/encoding.doc.html>. If this parameter is not used, VOSviewer will attempt to automatically determine the correct encoding when reading a text file (which in some cases may result in the use of an incorrect encoding), while it will use the default encoding when writing a text file.
- `file_location` Use this parameter to specify the folder that is used by VOSviewer as the default file location.
- `no_clustering` Use this parameter to indicate that no clustering must be performed when VOSviewer is started. This parameter can for example be used together with the `pajek_network` parameter. A map will then be opened or created based on a Pajek network file, but no clustering of the items in the map will be performed.
- `view_only` Use this parameter to start VOSviewer in the view only mode. In this mode, the **Run** button on the **Map** tab in the action panel is not available.

To use the above command line parameters, VOSviewer needs to be run from the command line. When using the Windows executable of VOSviewer, this can for example be done as follows:

```
VOSviewer -map map.txt -visualization 2 -zoom_level 2.5
```

In this way, VOSviewer will be started and the map in the map file `map.txt` will be opened. Also, the density visualization will be selected, and the main panel will be zoomed in on the center of the map. When instead of the Windows executable of VOSviewer the VOSviewer JAR file is used, VOSviewer can for example be run in the following way:

```
java -jar VOSviewer.jar -map map.txt -visualization 2 -zoom_level 2.5
```

We note that some command line parameters cannot be used together. For example, the `map` and `pajek_network` parameters and the `map` and `corpus` parameters cannot be used together. On the other hand, some parameters can only be used in combination with another parameter. The `pajek_partition` parameter for example can only be used in combination with the `pajek_network`

parameter. Similarly, the `counting_method` parameter can only be used in combination with the `corpus` parameter.

4.2 Making a map available on the internet

Suppose one wants to make a map available on the internet. One way to do this is simply by making a map file and a network file (or only a map file) available on the internet. To open the map, one then needs to take two steps. In the first step, the map file and the network file are downloaded from the internet. In the second step, VOSviewer is started and the downloaded map file and network file are used to open the map.

The above two-step approach is not very convenient, and therefore an alternative approach is available as well. In this alternative approach, a map can be opened in VOSviewer directly from a web page. The alternative approach works as follows. A map file and a network file (or only a map file) need to be made available on the internet. Suppose these files are located at

```
http://www.example.com/map.txt
```

and

```
http://www.example.com/network.txt
```

The map can then be made available on a web page by creating a hyperlink that points to

```
http://www.vosviewer.com/vosviewer.php?map=http://www.example.com/map.txt&network=http://www.example.com/network.txt
```

Using this hyperlink, the map can be opened directly in VOSviewer.

We note that all command line parameters discussed in Section 4.1 can also be used in a hyperlink. For example, to open a map, to select the density visualization, and to zoom in on the center of the map, the following hyperlink can be used:

```
http://www.vosviewer.com/vosviewer.php?map=http://www.example.com/map.txt&network=http://www.example.com/network.txt&visualization=2&zoom_level=2.5
```

4.3 Increasing the availability of memory

When using VOSviewer to work with large maps (e.g., maps containing several thousands of items), the memory requirements can be quite substantial. VOSviewer will produce an out of memory error if there is not enough memory available. The availability of memory can be increased by running the VOSviewer

JAR file from the command line and specifying the amount of memory that needs to be available. For example, if 1000 MB of memory needs to be available, the VOSviewer JAR file can be run as follows:

```
java -Xmx1000m -jar VOSviewer.jar
```

When working with large maps, VOSviewer may also produce a stack overflow error. To prevent this error from occurring, the stack size needs to be increased. This can be done by running the VOSviewer JAR file from the command line in the following way:

```
java -Xss1000k -jar VOSviewer.jar
```

In this case, the stack size is set to 1000 KB, but other values are possible as well.

References

- De Nooy, W., Mrvar, A., & Batagelj, V. (2011). *Exploratory social network analysis with Pajek* (2nd ed.). Cambridge University Press.
- Newman, M.E.J. (2004). Fast algorithm for detecting community structure in networks. *Physical Review E*, 69, 066133.
- Noack, A. (2007). Energy models for graph clustering. *Journal of Graph Algorithms and Applications*, 11(2), 453–480.
- Noack, A. (2009). Modularity clustering is force-directed layout. *Physical Review E*, 79, 026102.
- Van Eck, N.J., & Waltman, L. (2009). How to normalize cooccurrence data? An analysis of some well-known similarity measures. *Journal of the American Society for Information Science and Technology*, 60(8), 1635–1651.
- Van Eck, N.J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523–538.
- Van Eck, N.J., & Waltman, L. (2011). Text mining and visualization using VOSviewer. *ISSI Newsletter*, 7(3), 50–54.
- Van Eck, N.J., & Waltman, L. (2014). Visualizing bibliometric networks. In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), *Measuring scholarly impact: Methods and practice* (pp. 285–320). Springer.
- Van Eck, N.J., Waltman, L., Dekker, R., & Van den Berg, J. (2010). A comparison of two techniques for bibliometric mapping: Multidimensional scaling and VOS. *Journal of the American Society for Information Science and Technology*, 61(12), 2405–2416.
- Waltman, L., & Van Eck, N.J. (2013). A smart local moving algorithm for large-scale modularity-based community detection. *European Physical Journal B*, 86(11), 471.
- Waltman, L., Van Eck, N.J., & Noyons, E.C.M. (2010). A unified approach to mapping and clustering of bibliometric networks. *Journal of Informetrics*, 4(4), 629–635.