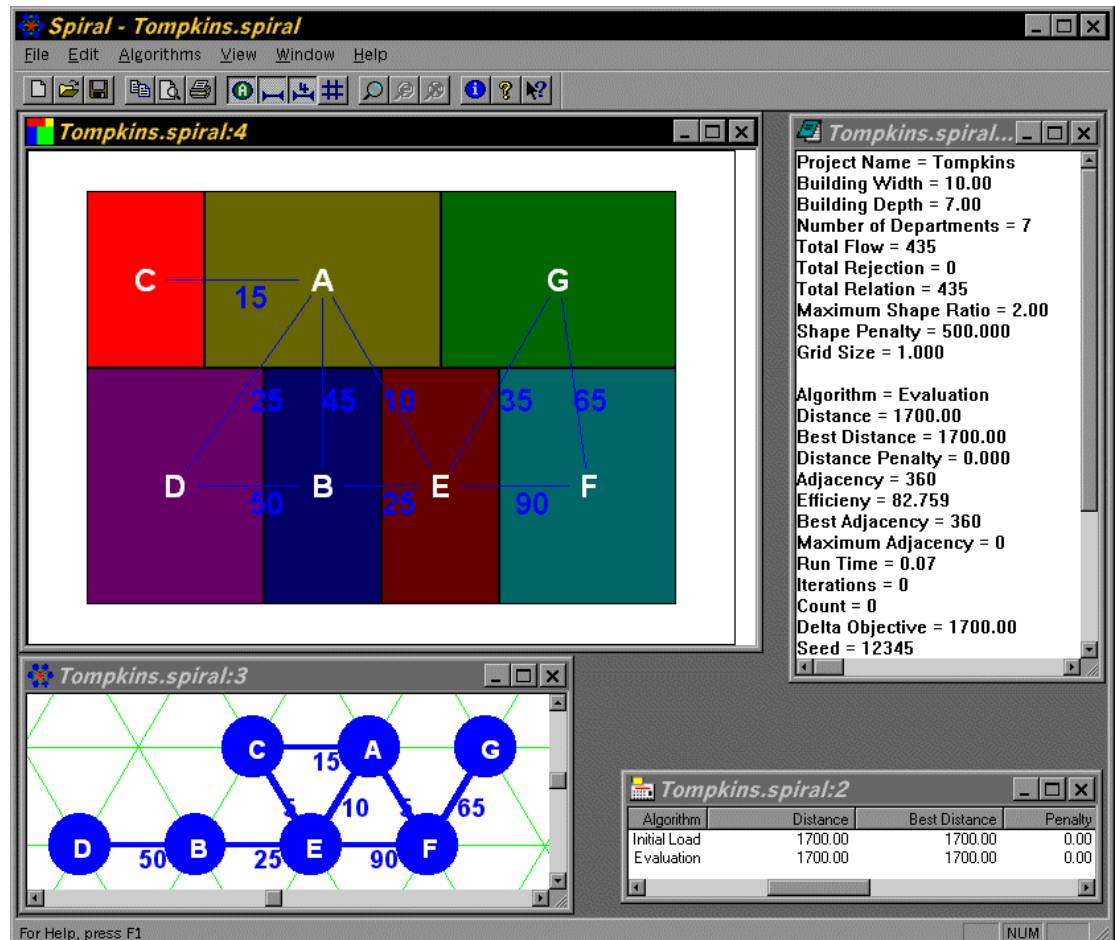# Spiral

User's Manual

By Marc Goetschalckx

Spiral User's Manual, Version 4.012, May 4, 2000
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Version

Version 4.012, May 4, 2000.

Chapter 1. Installation

Installing Spiral

To install **Spiral** you must run the **Setup** program on the distribution disk. The exact method of executing the **Setup** program depends on the version and type of Windows operating system that is installed on your computer.

Copying the files from the distribution disk to your computer or executing the program from a file or application server is not sufficient to run **Spiral**. Several dynamic link libraries, such as the **Scientif** application library, and active-x controls, such as the grid control, are required for the proper execution of the **Spiral** program and must be registered on your computer. The **Setup** program copies and registers these libraries and controls during its installation process.

To remove the **Spiral** application completely and safely from your computer see the instructions in the section on Removing **Spiral**.

Installation Instructions for Windows NT 4.00 and Windows 95 and 98

1. Insert the distribution disk 1 into the floppy or CD-ROM disk drive **a:**.

2. In the **Control Panel**, select **Add/Remove Programs** and then press the **Install/Uninstall** tab.

3. The Windows operating system will search for the installation program on the floppy or CD-ROM drives **a:** and will identify **a:\setup.exe** as the installation program.

4. Press **Finish** to start the installation procedure.

5. Follow the instructions of the SETUP program.

If your floppy or CD-ROM disk drive is not drive **a:**, substitute the appropriate disk drive letter with colon for **a:** in the above instructions.

Alternatively, you can also install **Spiral** using the installation instructions for Windows NT version 3.51.

Installation Instructions for Windows NT 3.51

1. Insert the distribution disk 1 into the floppy or CD-ROM disk drive **a:**.

2. In the Windows Program Manager, select the **Run** command from the **File** menu.

3. In the Command Line box type:

   a:\setup

4. Choose **OK** to start the installation procedure.

5. Follow the instructions of the SETUP program.

If your floppy or CD-ROM disk drive is not drive **a:**, substitute the appropriate disk drive letter with colon for **a:** in the above command.

Installation Notes

Write Access Privileges

When installing to a Windows NT system, make sure that you have write access privileges to the directory where **Spiral** will be installed and to all the files in this directory and its subdirectories. You must also have write access privileges to the \Winnt\System32 directory and the *scienmfc.dll* file in that directory. We recommend that you install **Spiral** while being logged on as administrator.

Grid Control grid32.ocx

Several commands, such as the **All Relations** command of the **Edit** menu, require that the active-x grid control *grid32.ocx* is present and registered on the computer that is executing the **Spiral** program. The automated **Setup** program copies and registers the grid control during its installation process. If you run **Spiral** from a file or application server, the control must be installed on every client computer. Many commercial applications use the same grid control, so it might already be installed on your computer. To verify the presence and registration of the grid control, open the Tompkins project, which is provided on the distribution disk, and execute the **All Relations** command. If the two-dimensional relationship matrix is not shown, the grid control is not installed or registered. In that case run the **Setup** program to install **Spiral** and the grid control on this computer.

Removing Spiral

You can remove the **Spiral** program and its application libraries from your computer, as well as remove its keys from the **Registry**. The exact method of removing **Spiral** depends on the version and type of Windows operating system that is installed on your computer.

Since the removal procedure actually deletes files from your computer, some of which may be system level libraries or common controls, it is strongly recommended that you make a complete backup of all the files on your computer before proceeding with the removal procedure.

To install **Spiral** on your computer see the instructions in the section on Installing **Spiral**.

Removal Instructions for Windows NT 4.00 and Windows 95 and 98

Select the **Add/Remove Programs** command in the **Control Panel** of your computer. **Spiral** will be listed as one of the applications that can be automatically removed. Select **Spiral** and press **Add/Remove**. All the files specific to **Spiral**, such as the executable program file, the application help file and the **Scientif** application library, will be removed from your computer. All keys associated with **Spiral** will also be removed from the **Registry**. Common libraries, such as the Microsoft Foundation class library and the Microsoft C runtime library will not be removed. **Spiral** project files that you created in different directories will not be removed either.

Removal Instructions for Windows NT 3.51

During installation, an icon to remove **Spiral** from your computer was placed in the same program group that you selected for the **Spiral** program. Press this **Uninstall** icon. All the files specific to **Spiral**, such as the executable program file, the application help file and the **Scientif** application library, will be removed from your computer. All keys associated with **Spiral** will also be removed from the **Registry**. Common libraries, such as the Microsoft Foundation class library and the Microsoft C runtime library will not be removed. **Spiral** project files that you created in different directories will not be removed either.

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Chapter 2. Tutorial

Creating a Small Tutorial Project

Following are the step by step instructions to create a small project and design its layout in an interactive manner. For large projects it might be more convenient to create the necessary data files outside **Spiral** with a file editor capable of creating pure ASCII files and then to import the project from these data files.

Spiral follows the standard Windows graphical user interface (GUI) conventions. This tutorial will focus on the features unique to the **Spiral** program and assumes that you are familiar with the Windows environment and the execution of Windows applications. More information on the Windows user interface can be found in the Windows User's Guide.

More detailed explanations and instructions can be found in the sections on the Project Data and Design Algorithms. A summary of all the available actions in **Spiral** can be found in the section on the Command Reference. A list of traditional and World Wide Web (WWW) references for further reading is given in the Reference section. Finally, we will be using the classical Tompkins layout example in this tutorial and the data for this project are summarized in the section on Sample Projects.

Steps to Be Done Before Starting A New Project

Create a project directory

Determine in which directory you want to save this new project. It is strongly recommended that you use a separate directory for each project. If necessary, create this directory on your hard drive. Note that some versions of the Windows operating environment allow you to create this directory from the **Save As** dialog box while executing the **Spiral** program. **Spiral** is compatible with long file names and directory names.

Defining a New Project

Create a new project

Select the **New** command from the **File** menu or press the **New** button on the toolbar. The **New** dialog window will be shown. The **New** dialog window for this project is illustrated in Figure 2.1. Enter a project name with a maximum of 63

characters. Only letters, digits, spaces, and underscores are allowed in the project name. Enter the building width and building depth of the rectangular building. The building width and depth are displayed horizontally and vertically on the screen, respectively. For this tutorial project, enter "Tutorial", ten, and seven for project name and building width, and depth, respectively. Press **OK** and a new project without any departments will be created.

Note that any data item of this project can be changed later on from inside the project with commands from the **File** and **Edit** menu. You can also get context sensitive help for any dialog window by pressing the Help button when the dialog windows is displayed.
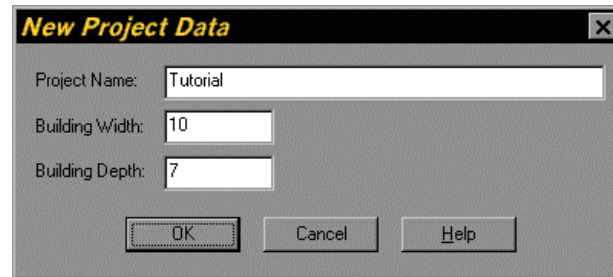

Figure 2.1. New Dialog Window for the Tutorial Project

Display all Views simultaneously

The **Spiral** program shows four cascaded views of the new project. Select the **Tile** command from the **Window** menu to display all the views simultaneously.

Each view has individual characteristics and display attributes. The type of view is indicated by an icon in the top left corner of the title bar of each view. The four view types are 1) project **Notes** view, 2) algorithm **Statistics** view, 3) hexagonal adjacency **Graph** view, and 4) block **Layout** view. Changing the attribute of one view does not affect the same attribute in other views.

Displaying the hexagonal and rectangular grids

Select the third view, which displays the hexagonal adjacency graph, by either clicking on its title bar or from the **Window** menu. Toggle the display of hexagonal adjacency graph in this view by selecting the **Grid** command from the **View** menu or by pressing the **Grid** button on the toolbar. You can also display the hexagonal adjacency graph by pressing the shortcut keys **Ctrl+Alt+G**.

Set the grid size for this project equal to one with the **Grid Size** command of the **Edit** menu. The Grid Size dialog box for this tutorial project is illustrated in Figure 2.2. Enter one for the grid size. Press **OK** and the tutorial project will use this new grid size.
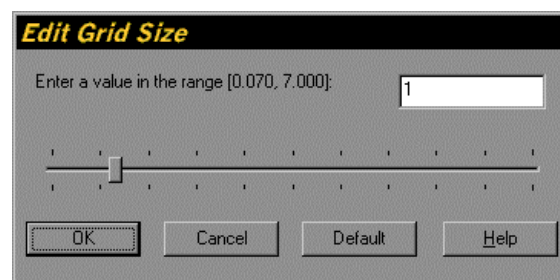

Figure 2.2. Edit Grid Size Dialog Box

If you have selected to display the grid in the layout view, then this view is updated to reflect the new grid size. All project data items, such as the grid size, have a single value that is used by all the views.

Select the fourth view, which displays the block layout, by either clicking on its title bar or from the **Window** menu. Toggle the display of rectangular grid in this view by selecting the **Grid** command from the **View** menu or by pressing the **Grid** button on the toolbar. You can also display the rectangular grid by pressing the shortcut keys **Ctrl+Alt+G**.

The different views of the current project at this time are illustrated in Figure 2.3. If you wish you can also display the orthogonal grid in the fourth or layout view in the same manner. Observe that the view titles indicate that this is a new project that not has been saved yet.
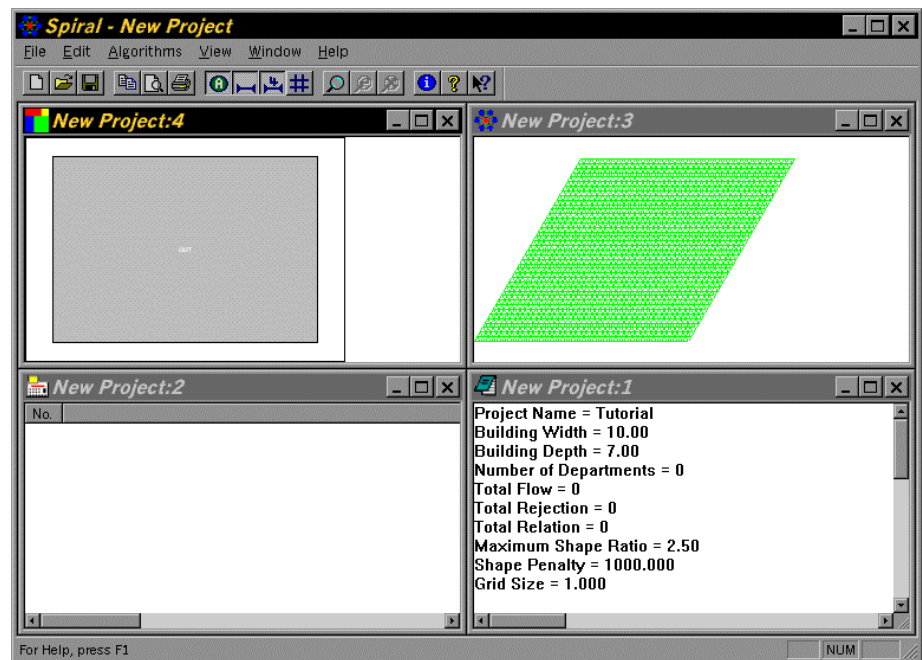
Figure 2.3. Initial Views for the New Project

Saving the new project for the first time

Save the current project with the **Save As** command from the **File** menu. In the **Save As** dialog box, select the directory where you want to save the project file. Specify a name for the project data file, which by default has the *spiral* extension. The **Save As** dialog box for this tutorial project is illustrated in Figure 2.4. Press **OK** and the file for the current project will be saved to disk.

Some versions of the Windows operating environment will truncate the default *spiral* extension to the three letters *spi*, so we recommend that you explicitly add the *spiral* extension to the file name in the Save As dialog window when saving a project for the first time.
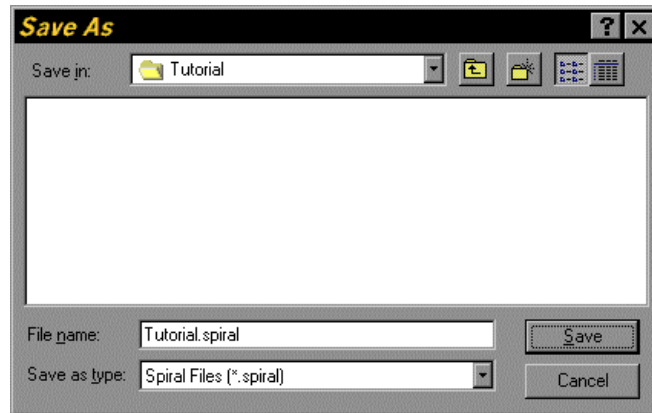
Figure 2.4. Save As Dialog Box for the Tutorial Project

The different views of the current project at this time are illustrated in Figure 2.5. Observe that the titles of the views have changed from New Project to Tutorial to indicate that this project has been saved.
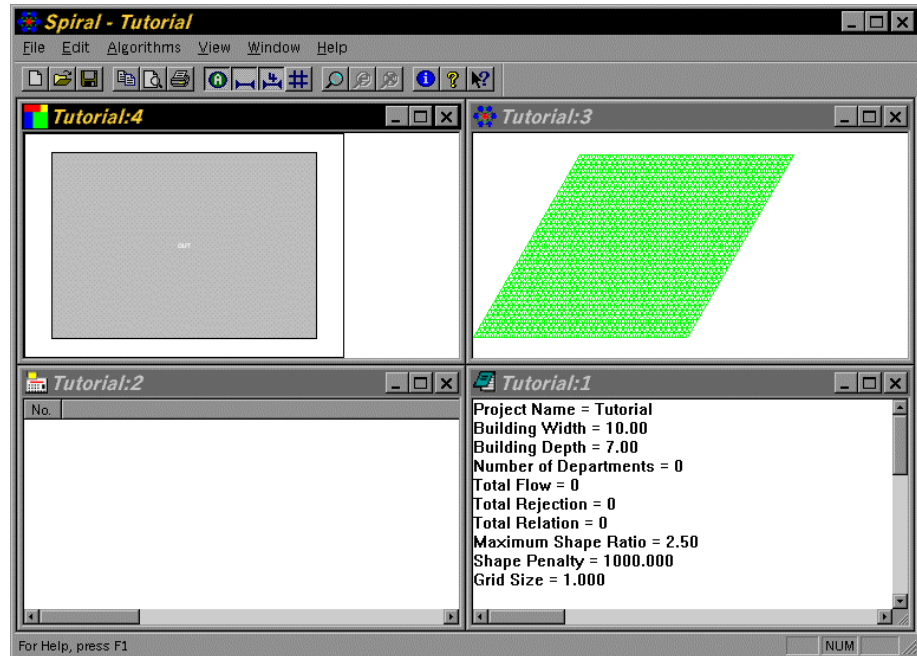
Figure 2.5. Initial Views for the Tutorial Project

Changing Project Information with the Properties Command

The project title and other project information can be changed with the **Properties** command of the **File** menu. The properties of the tutorial project are illustrated in Figure 2.6.

Figure 2.6. Project Properties Dialog for the Tutorial Project

At this time the project has neither departments nor department relationships. The number of departments in the project and the sum of all relationships are always shown in the **Notes** view.

Adding Departments to a Project

Adding a Department

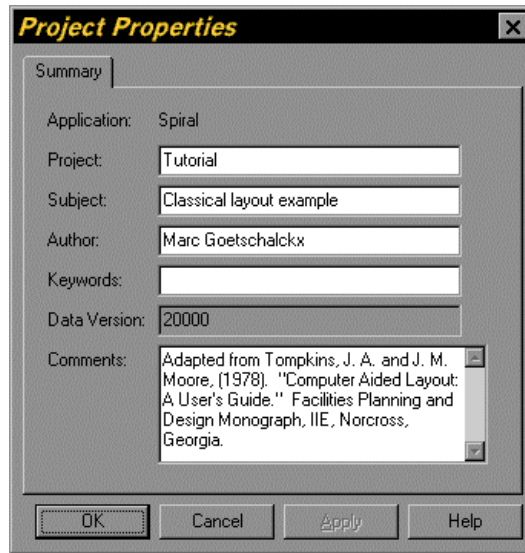Add one by one the departments to the current project by selecting the **Add Department** command from the **Edit** menu. The **Add Department** dialog box will be displayed.

Since we are defining a new department, only the items on the page with the **Input** tab are relevant. Enter the label of the department as the single letter A, enter the name of the department as "Receiving", and set the area of the first department to 12. The maximum shape ratio has been set to its default 2.5 value and we will leave it unchanged. Set the layout position to free, and set the area and border color of the department to palette colors green and black, respectively. The **Add Department** dialog window for the first department is shown in Figure 2.7.

If you press **OK** in the **Add Department** dialog box, the department will be added to the project with its current attributes. If you press **Cancel** the department will not be added to the project.
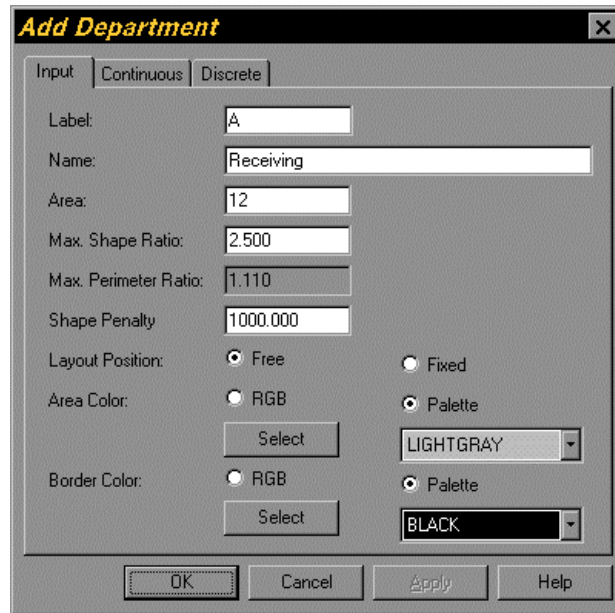
Figure 2.7. Add Department Dialog for the Tutorial Project

Department Data Limits

The following limits apply to the department data. More detailed information on project data and their limits can be found in the section on the project database description. The department label can be at most seven characters long. The department name can be at most 63 characters. Only letters, digits, and underscores are allowed in the department label. The label must be unique for this department in the project. Only letters, digits, spaces, and underscores are allowed in the department name. The department name can contain a description of the department function. The department area must be smaller than or equal to the building area and be expressed in units compatible with the building dimensions, i.e., if the building dimensions were given in feet then the department areas must be given in square feet. The shape factor is the maximum ratio of length to width or width to length of the department. The maximum value for the shape factor is 99 but more realistic values are less than five. The shape penalty is the rate at which departments that exceed the maximum shape ratio get penalized in the block layout objective function. Any nonnegative value will do, but enter 1,000 for this project.

Setting the layout position to free will later on allow the department to be moved in the layout improvement steps.

Specifying the display color for a department

The area and border colors of the department are only used in the display of the block layout, not in the display of the hexagonal adjacency graph. The colors can be either the predefined palette colors or any color for which you have specified the RGB values. You select this option by clicking either the **RGB** or **Palette** buttons. You can specify the RGB values by clicking the **Select** button underneath the **RGB** button. The **Color** dialog box is displayed, which allows you to select from a set of colors or to set the RGB values directly. The **Color** dialog box is illustrated in Figure 2.8. Using palette colors is slightly more efficient than using RGB colors in the display of departments.

The **Color** dialog box is a common dialog window and its exact appearance depends on the version of your Windows operating environment, the version of the Microsoft runtime libraries, and the number of colors or color depth of your Windows display.
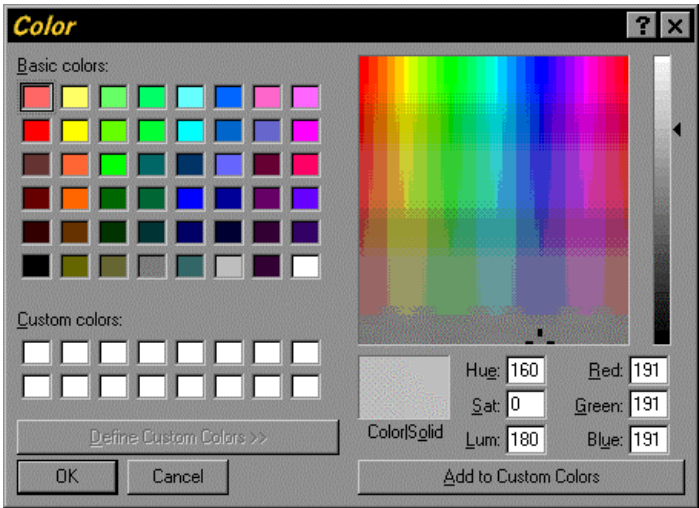
Figure 2.8. Common Color Dialog Box

Continue adding departments to the project until the project contains seven departments. The department data are given in Table 2.1. All departments have a layout position that is free and have a BLACK border color.

Table 2.1. Department Data for the Tutorial Project

Label	Name	Area	Area Color
A	Receiving	12	GREEN
B	Milling	8	CYAN
C	Press	6	RED
D	Screw	12	MAGENTA
E	Assembly	8	YELLOW
F	Plating	12	OCEAN
G	Shipping	12	FOREST

Selecting a department by its label for editing

At this time, you can edit the data for any department in the project. The department to be edited can be selected by its label with the **Department by Label** command from the **Edit** menu. A drop down list box with the labels of all the currently defined departments will be shown. The **Select Department** dialog box is illustrated in Figure 2.9.

Figure 2.9. Select Department by Label Dialog Box

Select department D. Press **Ok** to edit the selected department or **Cancel** to cancel the Select Department dialog box and not to edit any department.

Editing the date of a department

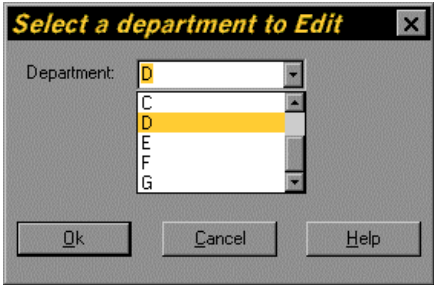When you press **OK**, the **Edit Department** dialog box will be shown. This dialog box is illustrated in Figure 2.10.
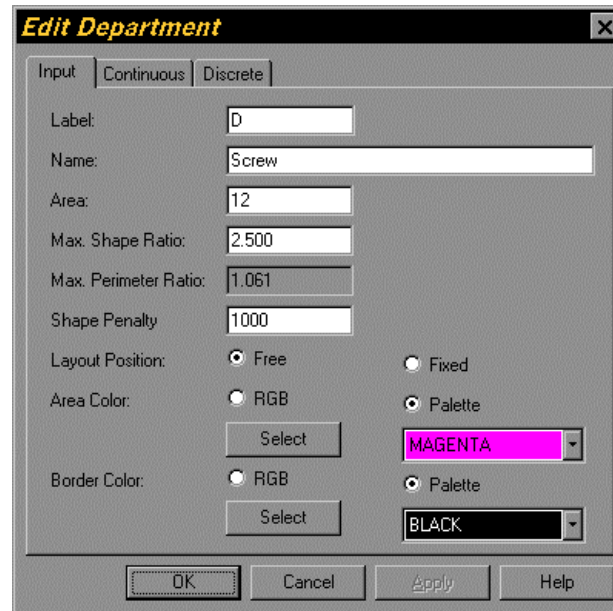

Figure 2.10. Edit Department Dialog Box

Since we are still entering and editing initial department data, only the **Input** page of the **Edit Department** dialog box is relevant. Change the name of department D from "Screw" to "Drilling". Since at this time no adjacency graph or block layout have been created, the department data on the **Continuous** page is still zero. The data on the **Discrete** page shows the number of unit squares in this department based on the current Grid Size. You can change the grid size with the **Grid Size** command from the **Edit** menu.

Deleting a department from the project

You can also completely delete a department from the project with the **Delete Department by Label** command from the **Edit** menu.

Saving the project

Save the current version of the tutorial project by selecting the **Save** command from the **File** menu or by pressing the **Save** button on the toolbar.

Adding Department Affinities to a Project

Selecting a relationship between two departments

At this time, we will enter all the affinities between departments or relationships to the project. Select the **All Relations** command from the **Edit** menu. The **Select a Relation** dialog will be shown, which displays the relations in a two dimensional array. The initial Select a Relation dialog is shown in Figure 2.11. Initially all

relations will be zero. Edit the relation between two departments by clicking on the corresponding element in the array. You can also move the cursor to the desired relation with the arrow keys and click the **Edit** button or press the **Alt-E** key.
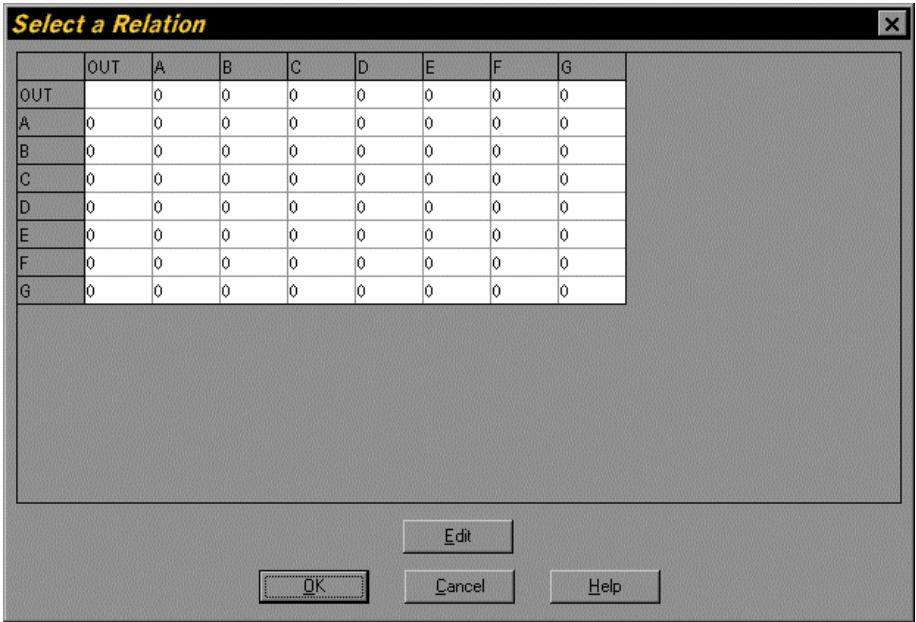
Figure 2.11. Initial Select a Relation Dialog of the Tutorial Project

Editing a relationship between two departments

Edit the relation between departments A and B. The **Edit Relation** dialog will be shown. Set the relationship value to 45. The Edit Relation dialog is shown in Figure 2.12. Press the **OK** button to accept the new value for the relationship between departments A and B.
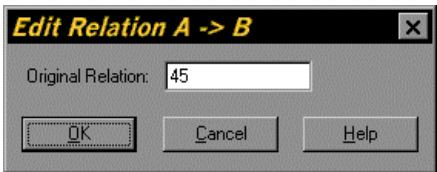
Figure 2.12. Edit Relation Dialog for the Tutorial Project

Repeat this for all the non-zero relationships shown in Table 2.2. The relationship values are shown in Figure 2.13. Press the OK button to accept all the changes to the relationships.

Table 2.2. Relationship Data for the Tutorial Project

Department	Department	Relation
A	B	45
A	C	15
A	D	25
A	E	10
A	F	5
B	D	50
B	E	25
B	F	20
C	E	5
C	F	10
D	E	35
E	F	90
E	G	35
F	G	65

Select a Relation

|	OUT	A	B	C	D	E	F	G
OUT		0	0	0	0	0	0	0
A	0	0	45	15	25	10	5	0
B	0	0	0	0	50	25	20	0
C	0	0	0	0	0	5	10	0
D	0	0	0	0	0	35	0	0
E	0	0	0	0	0	0	90	35
F	0	0	0	0	0	0	0	65
G	0	0	0	0	0	0	0	0

Edit   OK   Cancel   Help

Figure 2.13. Select a Relation Dialog Window for the Tutorial Project

Saving the project

Save the current version of the tutorial project by selecting the **Save** command from the **File** menu or by pressing the **Save** button on the toolbar.

Setting Department Shape Constraints and Penalty

Changing the maximum shape ratio for all departments in the project

Departments with long and narrow shapes are often not acceptable in layouts. The shape ratio of a department is the length to depth ratio of the smallest rectangle completely enclosing the department. While each department has its own maximum

shape ratio depending on its function, we can specify the maximum allowable shape ratio for all the departments in this particular project with a single command. Select the **Max Shape Ratio** command from the **Edit** menu. The **Edit Maximum Shape Ratio** dialog will be shown. This dialog is illustrated in Figure 2.14. Set the maximum value to two. Press Ok to accept the new value.

When maximum shape ratio is changed with the **Max Shape Ratio** command of the **Edit** menu, the maximum shape ratio of all current departments and the default maximum shape ratio for all future departments is also set to this value. Use the **Department** command to change the maximum shape ratio for individual departments.

The perimeter ratio is the ratio of the current perimeter length of a department divided by the perimeter length of a square department with the same area. For rectangular departments there exists a one to one correspondence between the shape ratio and the perimeter ratio. The perimeter ratio is an output-only variable and you cannot set it.
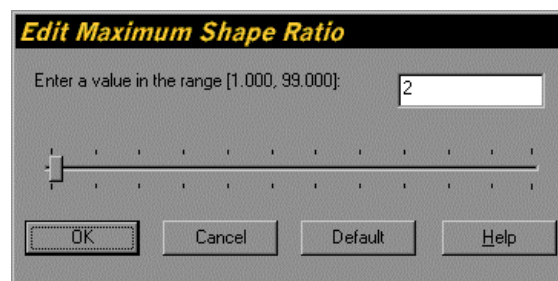
Figure 2.14. Edit Maximum Shape Ratio Dialog for the Tutorial Department

Setting the shape penalty for all departments in the project

If the shape ratio of a department violates its maximum allowable shape ratio for that department, then a penalty should be added to the distance score of the layout. Let s_i be the shape ratio, let S_i be the maximum allowable shape ratio, and let p_i be the shape penalty of department i, then the total shape penalty for all departments P that will be added to the distance score is equal to

$$P = \sum_{i=1}^{N} p_i \cdot \max\{0, s_i - S_i\} \tag{2.1}$$

Select the **Shape Penalty** command of the **Edit** menu to specify the shape penalty. The Shape Penalty dialog will be shown. The Shape Penalty dialog is shown in Figure 2.15. Enter a new value of 1000 for the penalty and press Ok to accept this value.

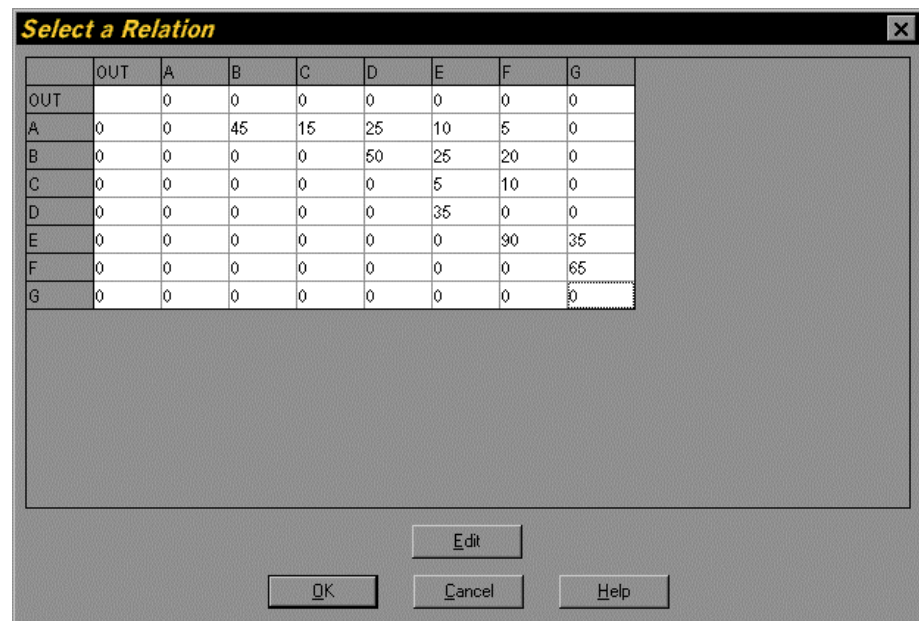*Figure 2.15. Shape Penalty Dialog for the Tutorial Project*

Saving the project

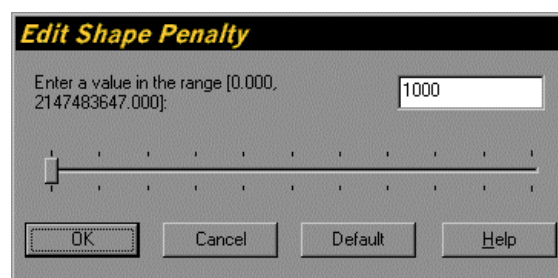Save the current version of the tutorial project by selecting the **Save** command from the **File** menu or by pressing the **Save** button on the toolbar.

At this time all project input data haven been specified. The next step is to design the hexagonal adjacency graphs and block layouts for this project.

Designing Adjacency Graphs and Block Layouts

Setting Algorithm Parameters and Output Log File

Several parameters apply both to the adjacency graph and block layout algorithms.

Setting the file and display level of reporting

You can specify the amount of information shown on the screen and printed to the Output Log file during algorithm execution by setting the Report Level. To set the Report Level execute the **Report Level** command from the **File** or **Edit** menu. The **Report Level** dialog will be shown. The Report Level dialog is shown in Figure 2.16. There are six possible levels, range from zero for no pauses and no information to the log file, to five for numerous pauses and extensive details to the log file. Select level three for uninterrupted algorithm execution. Press **Ok** to accept the new level.
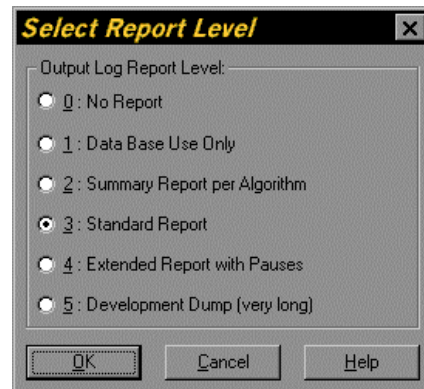
Figure 2.16. Report Level Dialog

Specifying a Algorithm Log File

Spiral will save the results of any algorithm in a log file, if such a file has been defined for the project. To specify a log file execute the **Output Log** command from the **File** menu. The **Output Log** dialog will be shown. The Output Log dialog is illustrated in Figure 2.19. Specify the name and location of the output log file and press **Ok** to accept the new values. The output log file has by default the extension *.log* and is a pure ASCII file. The amount of information written to the output log file for each algorithm depends on the Report Level.

Figure 2.17. Open Output Log Dialog for the Tutorial Project

Specifying a maximum time limit for algorithm execution

During the execution of algorithms, the program will periodically check if the algorithm has been computing longer than the allowable run time. If the limit has been exceeded, then the algorithm will be terminated and no results of the algorithms will be retained. To set the maximum amount of execution time for an algorithm, select the **Time Limit** command from the **Edit** menu. The **Time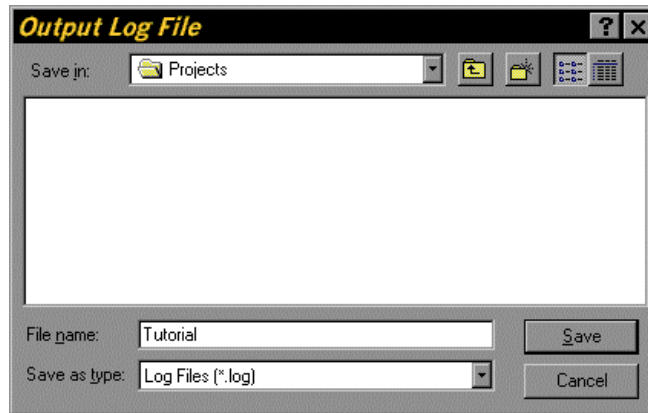 Limit** dialog window will be shown. The Time Limit dialog box is shown in Figure 2.18. Enter a limit of 120 seconds, which is more than sufficient for this small tutorial project. Press **Ok** to accept the new value.
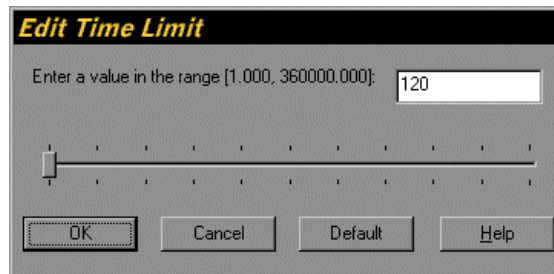
Figure 2.18. Time Limit Dialog

Specifying a random number seed

Several algorithms must make random choices at certain points during their execution. For example, the graph construction algorithms randomly select the location for a department node from a list of equivalent locations, and the layout simulated annealing improvement algorithms pick randomly the next departments that are considered for an exchange. These random choices are made based on the next pseudo-random number. The sequence of these random numbers depends on the starting number of the sequence, which is called the seed. When started from the same state, algorithms will generated the same solution if it has been given the same seed. You can set the random number seed by executing the **Seed** command from the **Edit** menu. The **Seed** dialog will be shown. The Seed dialog is shown in Figure 2.19. Set the seed to 12345. Press **Ok** to accept the new value.

Figure 2.19. Seed Dialog

Creating Adjacency Graphs

The **Select Graph** command of the **Algorithms** menu displays the **Select Graph** dialog box which lets you specify the settings for the algorithm that will create a planar hexagonal adjacency graph for the current project. These algorithms are called graph algorithms. You must specify three algorithm settings: relationship tuple, improvement st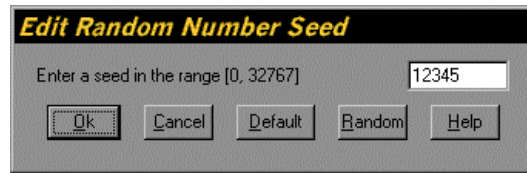ep procedure and tuple, and location tie breaker. The **Graph Algorithm Selection** dialog box is shown Figure 2.20. Select the Binary, Steepest Descent with Two Exchange and Centroid Seeking settings. When you press **OK** the graph algorithm will be executed with the current settings. If you press **Cancel**, no algorithm will be executed.

Figure 2.20. Select a Graph Algorithm Dialog

Creating Block Layouts

The **Select Layout** command of the **Algorithms** menu displays the Select Block Layout Algorithm dialog window, which lets you specify settings for the algorithm that will create a block layout for the current project. These algorithms are called layout algorithms. You must first specify three algorithm settings: building orientation, exchange improvements, and space allocation method. The Select Block Layout Algorithm dialog window is shown Figure 2.21. Select the Up orientation and Steepest Descent with Two Exchanges improvement procedure and select the Layered space allocation method. Because of its extensive computations this command might take a long time to complete. When you press **OK** the block layout algorithm will be executed with the current settings. If you press **Cancel** then no algorithm will be executed.
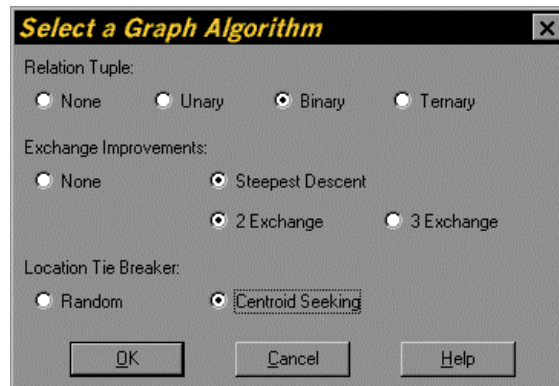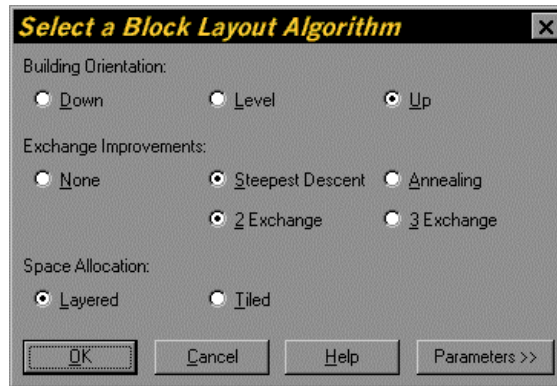
Figure 2.21. Select a Layout Algorithm Dialog

Sensitivity Analysis and Evaluating Graphs and Layouts

Evaluating the current layout or graph

You manual modify the data with the Department and **Relation** commands. To evaluate the impact of you changes you use the **Evaluate** command of the Algorithms menu. The Evaluate command computes the adjacency score of the adjacency graph and the distance score and adjacency score of the block layout if these have been created. It displays the distance score without shape penalty, called the flow distance score, for the block layout in the Delta Objective field. The results are displayed in the **Notes** and **Statistics** views. The Evaluate command is most frequently used after you have edited interactively the relationships after you have dragged a department in the adjacency graph to a new location. The Evaluate command does not create a new graph or block layout, but rather computes the cost of the current graph and layout based on the current relationship values. The command also displays in a dialog window the total distance score, the flow distance score, and the total shape penalty for the current layout. It also displays for each department the actual area, shape ratio, and perimeter ratio. The Evaluate dialog window is illustrated in Figure 2.22.
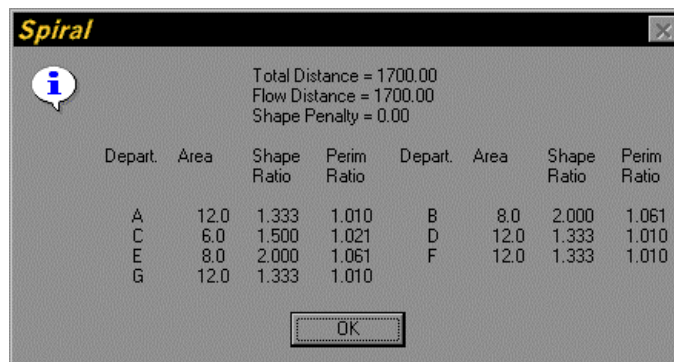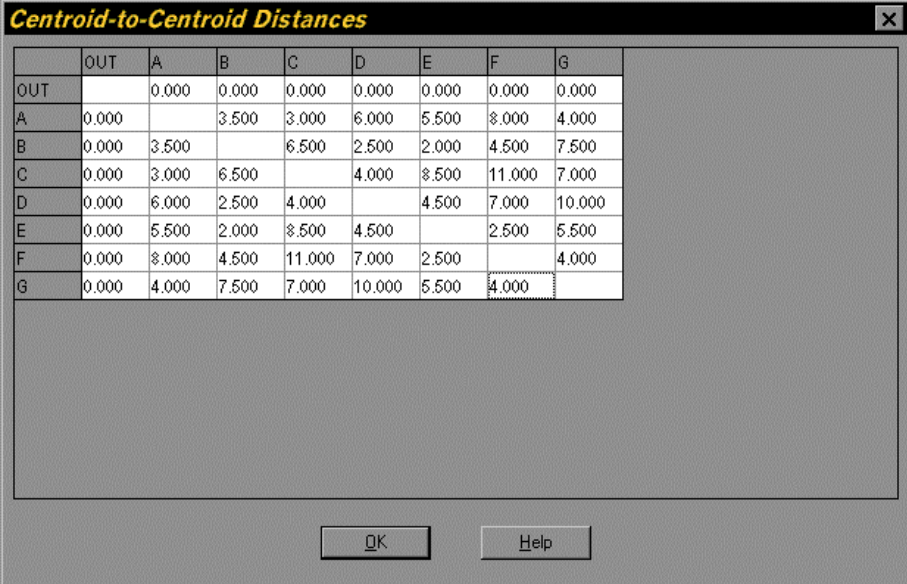
Figure 2.22. Evaluate Dialog Window

Displaying the current distances between department centroids

You can also display the individual centroid-to-centroid distances between each pair of departments with the Display Distances command of the Algorithms menu. The Display Distances dialog window will be shown as is illustrated in Figure 2.23. You can also display the product of the flow distance multiplied by the flow intensity between every pair of departments with the Display Flow-Distance Cost command of the Algorithms menu.
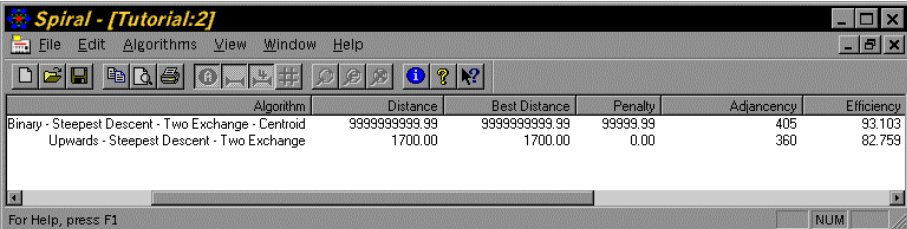
Figure 2.23. Display Distances Dialog Window

Displaying a history of algorithm statistics

The **Statistics View** displays the history of algorithm statistics. This view can be printed to the default printer with the **Print** command of the **File** menu. Move and size this window to suit your taste. The result of the graph and layout algorithm that you have executed so far is illustrated in Figure 2.24. The corresponding Graph view and Layout view are shown in Figure 2.25.

Figure 2.24. Algorithm Statistics View for the Tutorial Project
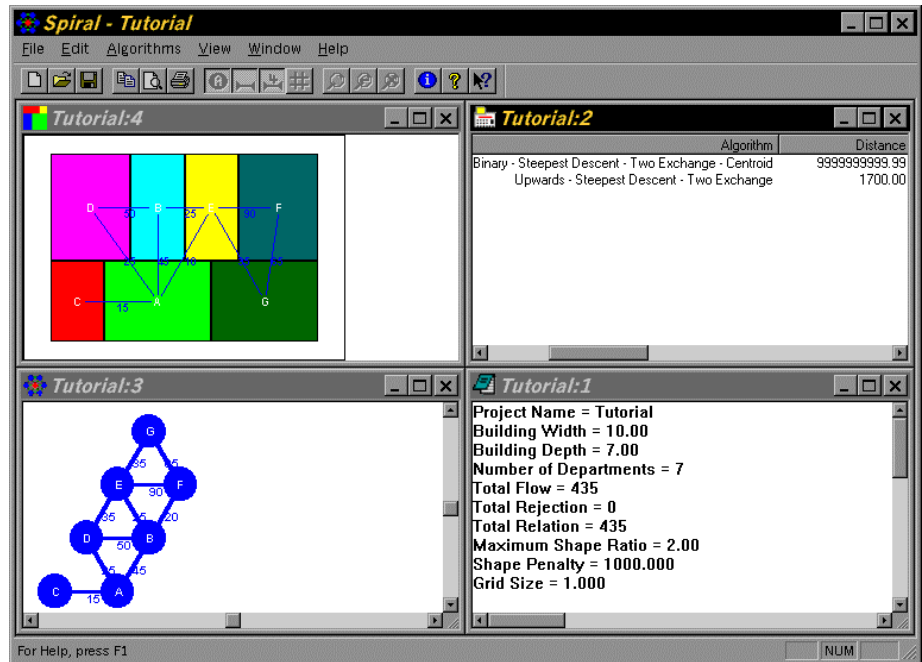
Figure 2.25. Final Views for the Tutorial Project

Using Spiral Graphs and Layouts in Other Windows Programs

The results of the **Spiral** design algorithms can be used in other Windows programs in basically three ways. Unless otherwise indicated, the actions described below can be executed on all four of the **Spiral** views. First, we will print the **Spiral** views to any installed printer, then we will copy and paste **Spiral** views into other Windows applications. Finally, the current project can be send as an attachment to an electronic mail message, if you have an active mail client installed on your computer.

Printing Spiral Views

Selecting and specifying print options

Select the printer on which you wish to print the **Spiral** views with the **Print Setup** command of the **File** menu. This command presents a **Print Setup** dialog box, where you specify the printer and its connection. This printer and these options will then be used by all subsequent **Print** operations. The same changes can also be made from the main Windows **Control Panel**. The printer must have been previously installed from the Windows **Control Panel** or **Print Manager**. The **Print Setup** dialog box is illustrated in Figure 2.26.

The **Print Setup** dialog box is a common dialog box and its exact appearance depends on the version of your Windows operating environment.

Figure 2.26. Print Setup Dialog Box

Previewing the image that will be printed

You can preview the image that will be printed by selecting the **Print Preview** command from the **File** menu. When you choose this command, the main window will be replaced with a **Print Preview** window in which one or two pages will be displayed in their printed format. The toolbar of the Print Preview window offers you options to view either one or two pages at a time; move back and forth through the document; zoom in and out of pages; and initiate a print job. The **Print Preview** dialog box is illustrated in Figure 2.27.

The **Print Preview** dialog box is a common dialog box and its exact appearance depends on the version of your Windows operating environment.

Figure 2.27. Print Preview Window

Specifying print options and printing a view

You can also directly select the view that you wish to print and then execute the **Print** command from the **File** menu. This command presents a **Print** dialog box, where you may specify the range of pages to be printed, the number of copies, the destination printer, and other printer setup options. If you press **OK** the selected view will be printed. For graph or layout views of large projects, printing such a complex view might require substantial processing times. The **Print** dialog box is illustrated in Figure 2.28.

The **Print** dialog box is a common dialog box and its exact appearance depends on the version of your Windows operating environment.
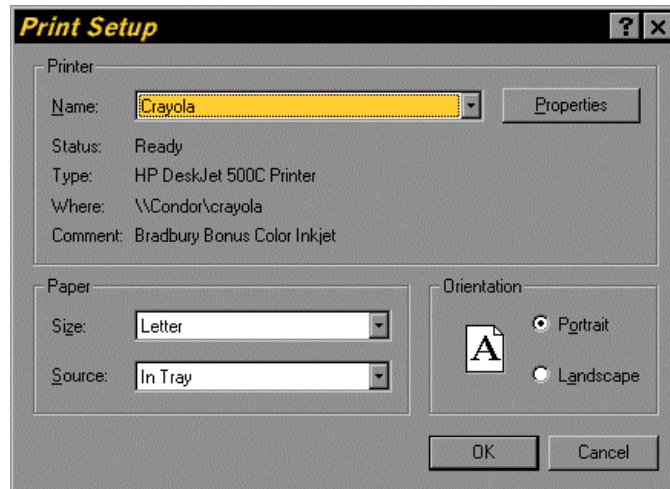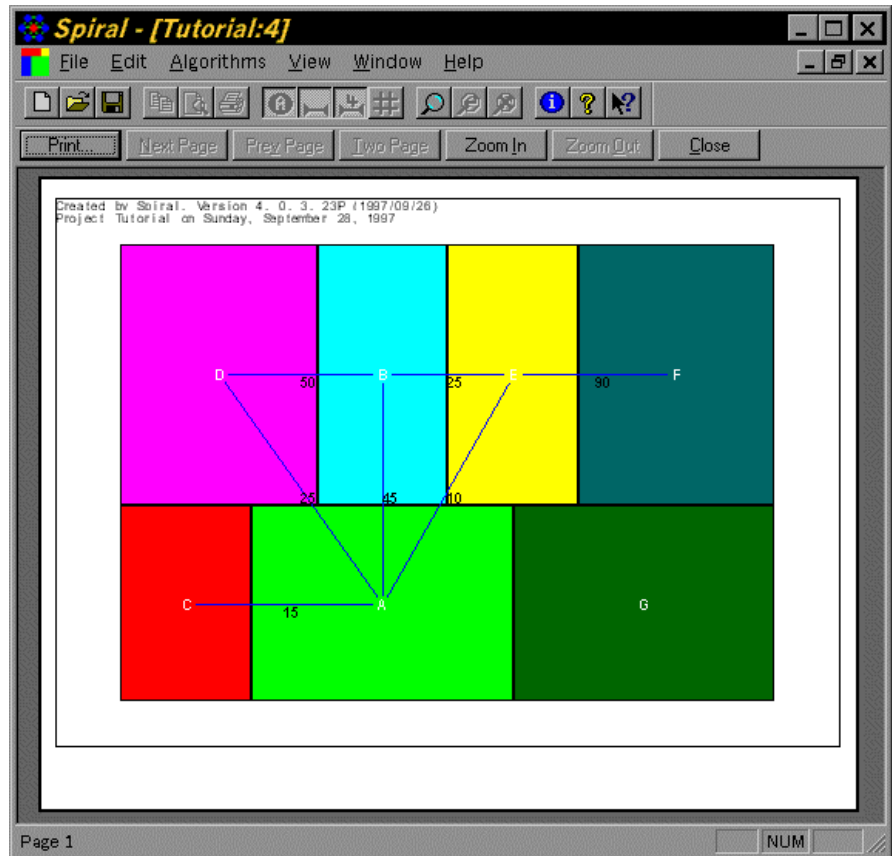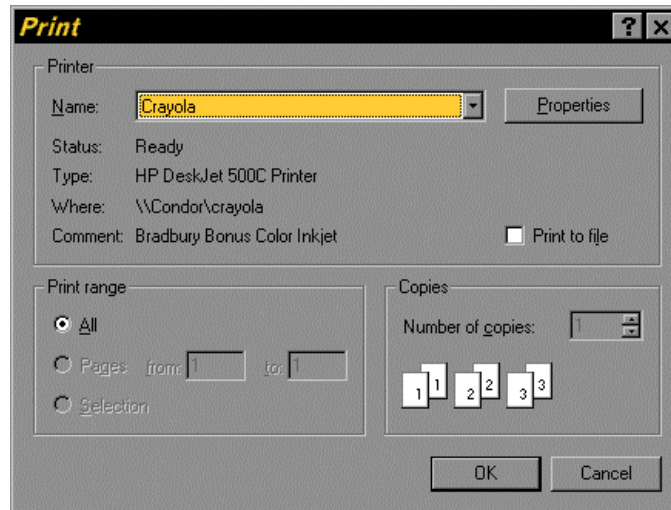
Figure 2.28. Print Dialog Box

Copying and Pasting Spiral Views with the Clipboard

To paste the contents of one of the **Spiral** views in another application, select the view that you wish to paste then execute the **Copy** command from the **Edit** menu. For the **Graph** and **Layout** views, the section of the graph or layout currently displayed in the view will be copied in graphical format to the clipboard. For the **Notes** and **Statistics** views, all the text, whether it is currently displayed or not, will be copied in text format to the clipboard. For the **Notes** and **Statistics** a header will generated which indicates the version of the **Spiral** program, the name of the project and the date the view was copied to the clipboard.

Copying a view to the clipboard

Select in turn the **Notes**, **Statistics**, **Graph**, and **Layout** view and execute the **Copy** command from the **Edit** menu. After each copy operation either activate the clipboard and verify its contents or paste the clipboard data into an application that accepts graphical data, such as Microsoft Word.

Select in turn the **Notes** and **Statistics** view and execute the **Copy** command from the **Edit** menu. After each copy operation either activate the clipboard and verify its contents or paste the clipboard data into an application that accepts text data, such as Microsoft Excel.

Capturing a screen image of a view

If you want to use a screen shot from one of the **Spiral** views, maximize this view and then capture the view with the **Alt-PrintScreen** command. For all views, the section of the graph, layout, or text currently displayed in the view will be copied in graphical format to the clipboard. No header indicating the **Spiral** version or the project data will be added to the image on the clipboard. You can use the same techniques if you want a screen shot from the main **Spiral** window as it is currently displayed. The same technique can also be used to capture images of the various dialog boxed used by **Spiral** to the clipboard. In this case, obviously the dialog box cannot and does not have to be maximized.

Select in turn the Notes, Statistics, Graph, and Layout view and maximize this view. Execute the **Alt-PrintScreen** command. After each copy operation activate the clipboard and verify its contents or paste the clipboard data into an application that accepts graphical data, such as Microsoft Word.

Sending the saved project as an electronic mail attachment

You can send the current layout project as an attachment to an electronic mail message, if you have an active mail client installed on your computer. The currently saved project will be sent, so you should save the project before sending it.

Select the **Send** command from the **File** menu to activate your mail client and to send the saved version of the current project as an attachment.

This concludes the tutorial. Further information on the project data can be found in the Project Data chapter, further information on the design algorithms can be found in the Design Algorithms chapter. A complete list of all commands is given in the Command Reference chapter. You can also find more information in the references given in the References chapter. Finally, the data used in the tutorial correspond to the classical layout example in Tompkins and Moore (1978) and are listed in the appendix Sample Projects.

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Chapter 3. Project Data

Specifying and Editing Project Data

Project Data

Every project has a number of data items associated with for which there is only one value per project.

Project Title

Every project has a title, assigned to it when the project was created with the **New** command or when the projected was read from an external ASCII file with the **Import** command. Both these commands are on the **File** menu. The project title should be a maximum of 63 characters and should contain only letters, digits, spaces, and underscore characters. The term project name is used synonymously with project title.

The project title can be changed with the **Summary Info** command of the **File** menu.

Note that the **Import** command does not allow a project title to contain spaces. A project title that is first exported and then imported again will be truncated at the first space character.

Building Width

The building width refers to the horizontal dimension of the building ground plan. It must be in units compatible with the department **areas**. The building always has a rectangular shape. The building area is computed as the product of the building width and building depth. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet.

The building width of a project is set when the project is created with the **New** command or when the project is read from an external ASCII file with the **Import** command of the **File** menu. The building width can be modified at any time by the **Building Dimensions** command of the **Edit** menu.

Building Depth

The building depth refers to the second dimension of the building ground plan (which will be displayed vertically on the screen). It must be in units compatible with the department **areas**. The building area is computed as the product of the building width and building depth. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet.

The building depth of a project is set when the project is created with the **New** command or when the project is read from an external ASCII file with the **Import** command of the **File** menu. The building depth can be modified at any time by the **Building Dimensions** command of the **Edit** menu.

Report Level

The Report Level controls the level of detail written to the **Output Log** file and the number of pauses during algorithm execution. There are six levels ranging from zero to five, which generate increasingly more detailed output and frequent algorithm pauses.

Levels of Detail

There are six levels of detail and pauses for reporting:

0. NONE generates no output per algorithm and does not halt the algorithm execution. This level is used when maximum execution speed and minimal reporting is desired.

1. DATABASE generates one line of strictly numerical output per algorithm. No titles or headers are included. This level is primarily used to create a data base file, which can then be manipulated in a spreadsheet or statistical analysis program.

2. SUMMARY displays the total cost plus the algorithm run time. It is useful if you is only interested in the final results. This level of output should be used if you is interested in performing timing studies. Higher level of details corrupt timing results due to user interaction delays and graphics creation delays.

3. STANDARD generates the total cost for each of the algorithm components. The program runs without interruption until the complete algorithm is finished. If you have selected ALL, then the program runs uninterrupted for the 18 different combinations.

4. EXTENDED displays the total cost during each of the algorithm modules and the run time so far. The program halts frequently to allow you to observe the algorithm process.

5. DEVELOP generates extremely detailed output plus a very large number of intermediate results. This mode is only useful for debugging purposes or to observe the most detailed workings of the algorithms. The output is extremely long for large problems.

The Report Level can be modified at any time with the **Report Level** command of the **Edit** menu. It can also be changed by pressing the Report Level button of the Pause dialog window, when an algorithm is paused. The algorithm will then use this new report level for the rest of its execution.

Department Data

For the following data items, each department can have a different individual value.

Label

The department label can consist of at most seven characters. Only letters, digits, and underscores are allowed in the department label. The label must be unique for this department in the project.

Name

The department name can be at most 63 characters. Only letters, digits, spaces, and underscores are allowed in the department name. The department name can contain a description of the department function.

Note that the **Import** command does not allow a department name to contain spaces. Department names that are first exported and then imported again will be truncated at the first space character.

Area

The department area is desired area for the department. The area must be smaller than the building area. The sum all department areas must be less than or equal to the building area, which is equal to the product of **building width** and **building depth**. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet.

You specify the required area for the department. However, various algorithms might create a department with either a continuous or discrete area that is smaller or larger than the specified area.

Layout Position

The status of a department can be set to have either free or fixed location. Setting the layout position to free will later on allow the department to be moved in the block layout improvement steps. Setting the layout position to fixed will prevent this department to be part of a department exchange in the block layout improvement steps.

However, other departments may move around this particular department, causing the location of this department to be moved even though it is fixed. For example, if a department is fixed and located on the perimeter of the adjacency graph, the department may still move to the center of the block layout caused by a sequence of exchanges involving other departments. There is currently no status switch that keeps a department exactly in its original location in the block layout.

Shape Ratio

The department shape ratio is the maximum of the length to width and width to length ratios of the smallest rectangle enclosing the department. Let l_i and w_i be the length and width of the smallest rectangle enclosing the department, then the shape ratio s_i is given by

$$s_i = \max\left\{ \frac{l_i}{w_i}, \frac{w_i}{l_i} \right\} \tag{3.1}$$

For rectangular departments the smallest rectangle enclosing the department is of course the department itself. For example the shape ratio of a square department is one and the shape ratio of a three by one rectangular department is equal to three.

The shape ratio is an output variable, computed by the program based on the current shape of the department. If the department shape ratio exceeds **the maximum shape ratio** then the shape adjusted distance score is the sum of the normal distance score and the excess of the department shape ratio over the maximum shape ratio multiplied by the **shape penalty**.

Perimeter Ratio

The perimeter ratio of a department is the ratio of the current perimeter length divided by the perimeter of a square department with the same area. Let p_i and a_i be the perimeter and area of department i, respectively, the perimeter ratio c_i is then given by:

$$c_i = \frac{p_i}{4\sqrt{a_i}} \tag{3.2}$$

For example the perimeter ratio of a square is one and the perimeter ratio of a four by one rectangle is equal to 1.25. A higher value indicates a department with a more convoluted shape.

For rectangular departments, the perimeter can be expressed in function of the width and length of the department as:

$$c_i = \frac{2(l_i + w_i)}{4\sqrt{a_i}} \tag{3.3}$$

The perimeter ratio is an output variable, computed by the program based on the current shape of the department.

For rectangular departments there exists a one to one correspondence between the perimeter and shape ratio of a department. Let s_i be the shape ratio of a department, then this relationship is given by:

$$c_i = \frac{s_i + 1}{2\sqrt{s_i}} \tag{3.4}$$

The equivalent values for the most practical range of the shape and perimeter ratio are given in the following table.

Table 3.1. Equivalent Values of Shape and Perimeter Ratios for Rectangular Departments

Shape	Complexity
1.5	1.02
2.0	1.06
2.5	1.11
3.0	1.15
3.5	1.20
4.0	1.25
5.0	1.34
6.0	1.43

Maximum Shape Ratio

The maximum shape ratio is the limit value for the **shape ratio** of a department before it gets penalized in the shape adjusted distance score. The acceptable value of the maximum shape ratio depends on the department function, so different departments can have different maximum shape ratios. If the department shape ratio exceeds the maximum shape ratio then the shape adjusted distance score is the sum of the normal distance score and the excess of the department shape ratio over the maximum shape ratio multiplied by the **shape penalty**. Let s_i be the shape ratio of department i, let S_i be the maximum shape ratio of the department, and let p_i be the shape penalty, then the total shape penalty for all departments P that is added to the distance score is equal to

$$P = \sum_{i=1}^{N} p_i \cdot \max\{0, s_i - S_i\} \tag{3.5}$$

The term shape factor is also commonly used for shape ratio. The acceptable value of the maximum shape ratio depends on the department function, so different departments can have different maximum shape ratios.

Only the block exchange algorithms use the maximum shape ratio to penalize block layouts to avoid excessively narrowly shaped departments. The Maximum Shape Ratio is an input parameter set by the user. You can use the **Department** command from the **Edit** menu to set the maximum shape ratio of individual departments. You can use the **Max. Shape Ratio** command of the **Edit** menu to set the maximum shape ratio of all departments simultaneously.

Shape Penalty

The Shape Penalty is the factor by which the excess of the department's **shape ratio** over the **maximum shape ratio** gets multiplied if it exceeds the maximum shape ratio and this product gets added to the distance score to yield the shape adjusted distance score. The purpose of the shape penalty is to avoid long and narrow departments. A higher shape penalty will tend to make departments more like squares. A low or a shape penalty equal to zero will allow more long and narrow departments. The shape penalty cannot be negative. The penalty of exceeding the maximum shape ratio depends on the department function, so different departments can have different shape penalties.

Only the block exchange algorithms use the shape penalty to penalize block layouts to avoid excessively narrowly shaped departments. The Shape Penalty is an input parameter set by the user. You can use the **Department** command from the **Edit** menu to set the maximum shape ratio of individual departments. You can use **the Shape Penalty** command of the **Edit** menu to set the maximum shape ratio of all departments simultaneously.

Maximum Perimeter Ratio

The Maximum Perimeter Ratio is the limit value for the **perimeter ratio** of the department.

For rectangular departments there exists a one to one correspondence between the perimeter ratio of a department and the shape ratio. In **SPIRAL** the maximum perimeter ratio is computed from the **Maximum Shape Ratio** assuming rectangular departments and only used as an output variable, i.e., it is displayed as information for the user.

Importing Externally Generated Layouts

The current version of the **Spiral** program can import data files created by the **Export** command of the **Spiral** program with the **Import** command of the **File** Menu. The description of the data files for this version of **Spiral** is given next.

A project is completely described by two files. The first file is the **Project Data** file that holds all the scalar information about this project. The second file is the **Department Data** file that contains all department and relationship data.

The easiest way to import an externally generated layout is to execute the following steps:

1. define the project interactively inside **Spiral**

2. generate any layout

3. export the project

4. modify the generated files to represent the external layout

5. import the modified files and evaluate the layout

Project Data File

The Project Data file can be created with any editor or word processor capable of generating pure ASCII files. Word processors usually insert special formatting codes into their regular document files, such as page breaks, which cannot be read by the **SPIRAL** program, so special care should be taken when using a word processor to generate a pure ASCII file. The project file also should not contain any blank lines. Once an input file has been created, it can be used repeatedly by the **Spiral** program.

Each line in the input file is associated with a single data item and contains two fields. The first field is the description or name of the data item. The name of the item is enclosed in square brackets and may not contain any spaces. The second field is then the value of the item to be used. The two fields are separated by one or more space or tab characters. For example:

```
[data_version]           20002
[project_name]           Furniture
[number_of_departments]  10
[department_file_name]   Furniture.dep
[building_width]         10.0
[building_depth]         7.0
[number_of_layout_rows]  3
[number_of_layout_cols]  4
[seed]                   12345
[tolerance]              0.00010
[time_limit]             120.0
[number_of_iterations]   20
[report_level]           2
[max_shape_ratio]        2.5
[shape_penalty]          500.0
```

Data Version

The first item is the data version of the current project. The data version is an integer number larger than 20000 generated by **Spiral** during the **Export** command.

Project Name

The next item is the name of the current project. This name should be a maximum of 15 characters and should contain only letters, digits, and underscore characters.

In the version 4.0 of **Spiral** or higher the name of this data field has been changed to **Project Title** and its size expanded and space characters are allowed. However, the old name of **Project Name** still should be used in export and import files and it should not contain any spaces.

Number of Departments

The second item is the number of departments in this problem. The minimum number of departments is one. The maximum number of departments depends on the version of the **SPIRAL** program. For industrial versions the limit is 255 departments. For educational versions the limit is 10 departments.

Department File Name

The third item is the name of the department data file, which contains the department names, codes, and interdepartmental relationships, respectively. A path must precede the file name if it is not in the current directory or in the data path. An example of a department data file is the file FURN.DEP that holds the department information. This file is included in the appendix and on the distribution diskette. This file must be created outside the **SPIRAL** program with an editor capable of generating pure ASCII files.

Building Width

The building width refers to the horizontal dimension of the building ground plan. It must be in units compatible with the department areas. The building always has a rectangular shape. The building area is computed as the product of the building width and building depth. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet.

Building Depth

The building depth refers to the second dimension of the building ground plan (which will be displayed vertically on the screen). It must be in units compatible with the department areas. The building area is computed as the product of the building width and depth. The building area is computed as the product of the building width and building depth. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet.

Seed

The graph construction algorithms often need to make a random choice among several alternative locations for the current department. This random choice is made

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based on pseudo random numbers, generated from an initial seed. An algorithm will always make the same random choices if it is given the same random seed, and hence will create the same adjacency graph. The seed has to be a positive number in the range of [1,32767]. If a seed of zero is given, then the computer will pick a random seed based on the computer clock.

Tolerance

At the current time the tolerance parameter is not used in the program.

Time Limit

The maximum time limit is the maximum amount of time a single algorithm is allowed to execute. The time limit is expressed in seconds. Currently, the time limit is only used to terminate the two and three exchange algorithms if they have exceeded the time limit after one complete iteration, i.e. after all possible two or three exchanges have been tested. So it is possible that the execution time of the improvement algorithm is actually larger than the time limit specified. The time limit is also used to terminate combination algorithms such as All Graph, All Layout, and All Combo Algorithms if the combination algorithm has exceeded the time limit after a component algorithm.

Number of Iterations

The graph construction and improvement algorithms often need to make a random choice among several equivalent locations to place the next department. Different replications of the same algorithm can thus provide different adjacency graphs. The higher the number of replications, the more likely a good adjacency graph will be constructed. Of course, more replications require more computation time. The default number of replications is equal to 20. In version 4.0 or higher of SPIRAL, the name of this field has been changed to **Number of Replications**.

Report Level

Report level is the level of detail the program will use in generating output reports. There are six levels of detail, ranging from 0 through 5. The higher the report level the more information is written to the Output Log File and the more frequent halts during program execution.

Number of Layout Rows

The number of layout rows is the number of horizontal layers in the rectangular layout. This value should be set to zero for a new problem unless the user wants to specify a given layout.

Number of Layout Cols

The number of layout columns is the maximum number of departments in any horizontal layer or row of the rectangular layout. This value should be set to zero for a new problem unless the user wants to specify a given layout.

Maximum Shape Ratio

The maximum shape ratio is the limit value for the shape ratio of a department before it gets penalized in the shape adjusted distance score. The department shape ratio is the maximum of its length to width and width to length ratios. For example the shape ratio of a square is one and the shape ratio of a three by one rectangle is equal to

three. If a department shape ratio exceeds the maximum shape ratio then it will get penalized. If the department shape ratio exceeds the maximum shape ratio then the shape adjusted distance score is the sum of the normal distance score and the excess department's shape ratio over the maximum shape ratio times the shape penalty. The term shape factor is also commonly used for shape ratio. The acceptable value of the maximum shape ratio depends on the department function, so different departments can have different maximum shape ratios. Only the block exchange algorithms use the maximum shape ratio to penalize block layouts to avoid excessively narrowly shaped departments.

Shape Penalty

The shape penalty is the factor by which a department shape ratio gets multiplied and this product gets added to the shape adjusted distance score to avoid long narrow departments. A higher shape penalty will tend to make departments more like squares. A low or zero shape penalty will allow more long narrow departments. The shape penalty cannot be negative.

The next paragraphs describe the contents and formatting of the Department Data File.

Department Data File

The department data file can be created with any editor or word processor capable of generating pure ASCII files. Word processors usually insert special formatting codes into their regular document files which cannot be read by the **Spiral** program, so special care should be taken when using a word processor to generate a pure ASCII file. The department data file also should not contain any blank lines.

In the first section of the department data file, there is one line per department and on each line there are eight fields. The fields are the facility code, grid x coordinate, grid y coordinate, area, layout x column, layout y row, color, and name of the department, respectively. An example is given in the next table, where the column header line is not part of the department data file.

Table 3.2. Sample Department Data Line

Code	Grid X	Grid Y	Area	Layout X	Layout Y	Color	Name
SA	5	4	4	3	1	RED	Sawing

Label

The facility label may be a maximum of seven letters, digits, and underscore characters, and cannot contain any spaces.

Grid X and Y Coordinates

The grid x and y coordinates of the department are the column and row coordinates of the department circle in the underlying hexagonal grid. For a new project these coordinates must be set to zero.

Area

The next field is the department area, which must be smaller than the building area. The sum all department areas must be equal to the building area, which is equal to the product of building width and depth. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building

depth and width are expressed in feet then the building and department areas must be expressed in square feet.

Layout X and Y Origin and Size

The layout x and y coordinates of the department are the column and row coordinates of the department rectangle in the rectangular block layout. For a new project these coordinates must be set to zero unless the user wants to specify a given layout. The y coordinate indicates the row or horizontal layer in the block layout, starting with one for the bottom row and increasing for higher layers. The x coordinate indicates the position of the department in a particular layer or row, starting with one for the leftmost position and increasing towards the right.

Color

The next field contains the color in which the department block will be drawn in the block layout. The list of valid colors is given in Table 3.3. In version 4.0 or higher of **SPIRAL** the color of a department can be one of the palette colors here specified or a RGB color.

Table 3.3. Allowable Colors for Edges and Departments

BLACK	DARKGRAY
BLUE	NAVY
GREEN	FOREST
CYAN	OCEAN
RED	BROWN
MAGENTA	PURPLE
YELLOW	OLIVE
WHITE	GRAY

Name

The last field on each line contains the department name. The department name can be at most 31 characters long and cannot contain any spaces or tab characters. In version 4.0 or higher of the **SPIRAL** program, the department name may contain space characters, but any department name that is imported will be truncated at the first space character.

Relations

In the second section of the department data file, there is one line per non-zero interdepartmental relationship. Each line contains three fields. The fields are the from department, the to department codes, and the relationship between the from and to departments. The department codes must have been defined in the first section of the data file or must be equal to OUT, which indicates a relationship with the outside. The relationship can be positive or negative in the range [-32767, 32767]. To indicate the end of the list of non-zero relationships, the last line in the department data file must contain the following dummy relationship:

OUT   OUT   0

The program will convert the asymmetric relationships to one symmetric one, i.e. the relationships from department 1 to department 2 and from department 2 to department 1 are added together to form a single relationship between departments 1 and 2.

Corner Coordinates

If a layout has been created when the file was exported or if an externally generated layout is to be imported, the third section contains the coordinates of the corner points of each department. Since a department has a rectangular shape, each department has exactly four corner points. For each department, there are five lines. The first line contains the number of corner points and must be equal to four. The next four lines contain the x and y coordinates of the four corners of the department. The coordinates can be fractional numbers. The department shape based on the coordinates of its corners must be a rectangle with horizontal and vertical sides.

```
4
2.000    0.000
6.000    0.000
6.000    3.000
2.000    3.000
```

Importing Data Files from Previous Versions

The current version of the **Spiral** program can import data files created by the previous version 3.63 of the **Spiral** program with the **Import** command of the **File** Menu.

A project is completely described by two files. The first file is the **Project Data** file that holds all the scalar information about this project. The second file is the **Department Data** file that contains all department and relationship data.

The differences in the data files for this previous version of **Spiral** compared to the current version are given next.

The **Project Data** file does not contain a [data_version] field. Projects imported from the previous versions of **Spiral** will get internally the data version 363 assigned.

The **Department Data** file does not contain the corner coordinates of the departments, even if the project has been exported whit a layout. The last line in the Department Data file is always the terminating line of the relationships "OUT   OUT   0".

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Chapter 4. Design Algorithms

Introduction

General Model and Algorithm Characteristics

Systematic Layout Planning or SLP

The following definitions are based upon the Systematic Layout Planning method or SLP by Muther (1973). The major steps in SLP are shown in Figure 4.1.
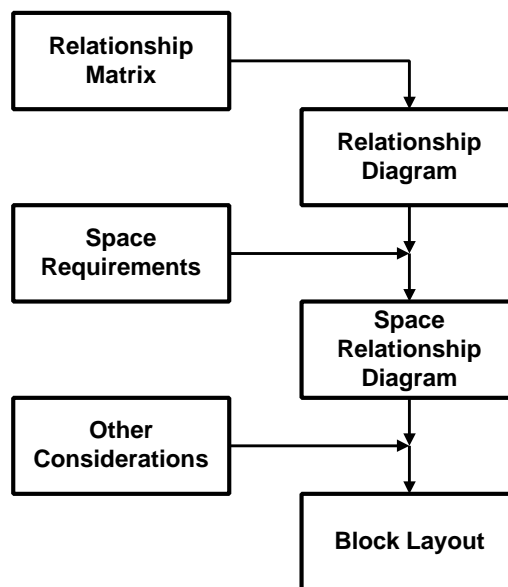

Figure 4.1. SLP Block Diagram

A relationship chart is the quantitative matrix containing the level of interaction between pairs of departments. The more positive the element in the matrix the stronger two departments interact and, in general, the closer to each other they should be located. The more negative the relationship the stronger two departments are incompatible with each other and, in general, the farther apart they should be located.

A relationship diagram is a spatial arrangement of the departments to represent the relationship data in a graphical way. This diagram is also called an adjacency graph. When the space requirements for the departments are added to this relationship diagram, then a space relationship diagram has been constructed.

Finally, any number of other considerations and constraints, that are not captured in the relationship data or the space data, can be incorporated in the space relationship diagram to generate a layout alternative. Hence, the spatial relationship diagram is not a layout, because it does not incorporate other considerations such as building shape and area and department shape constraints.

Model and Algorithm Classification and Hierarchy

The theoretical layout models and their solution algorithms can be classified and organized based upon the properties shown in Figure 4.2. Graph based models generate an adjacency graph, while area based models generate a conceptual block layout. Primal models maintain a feasible solution while attempting to obtain an optimal solution. Dual models maintain an optimal solution while attempting to obtain a feasible solution. In discrete area models the departments and building are composed of a number of equal sized unit squares. In continuous area models the dimensions of the building and departments can have fractional values.
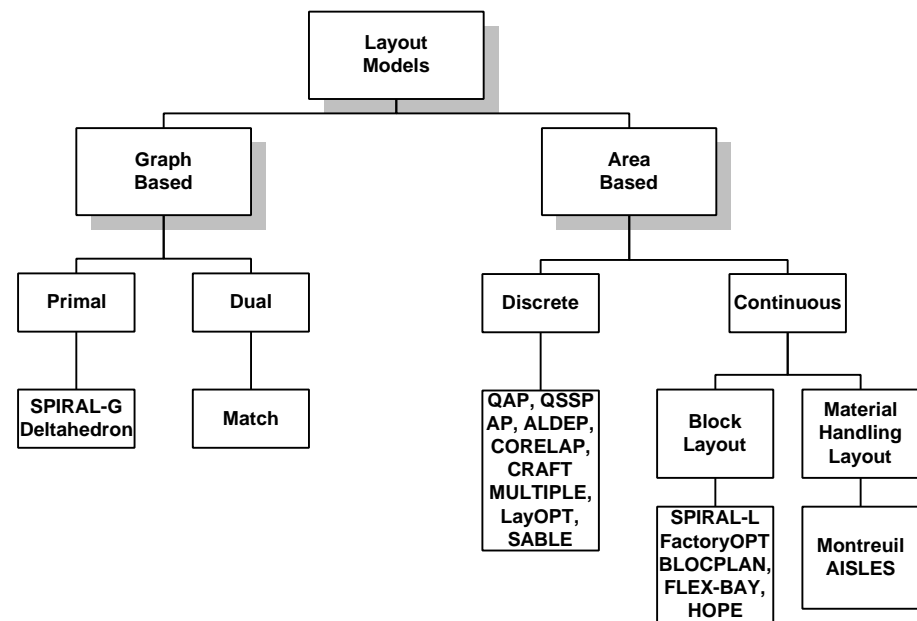
```
                        Layout
                        Models
          ┌───────────────┴────────────────┐
       Graph                             Area
       Based                             Based
    ┌─────┴─────┐              ┌───────────┴───────────┐
  Primal      Dual          Discrete              Continuous
    │           │              │              ┌────────┴────────┐
SPIRAL-G     Match       QAP, QSSP         Block          Material
Deltahedron              AP, ALDEP,        Layout         Handling
                         CORELAP,            │            Layout
                         CRAFT            SPIRAL-L           │
                         MULTIPLE,        FactoryOPT      Montreuil
                         LayOPT,          BLOCPLAN,       AISLES
                         SABLE            FLEX-BAY,
                                          HOPE
```

Figure 4.2. Theoretical Layout Models Hierarchy

The completed block layout can be represented as a graph. Similarly, the original relationship matrix can be represented as a complete undirected graph, where each department corresponds to a node and pairwise relationships form the edges. The *adjacency graph* is constructed from the relationship diagram by deleting all edges between non-adjacent departments, i.e. an edge is included in the adjacency graph if and only if the two departments are adjacent. The adjacency graph is thus a subgraph of the relationship diagram.

The block layout graph and the adjacency graph are related, in fact they are dual graphs. The relationship diagram can be constructed from the block layout by placing a node inside each department and by drawing the connecting relationship edge if and only if the two departments are adjacent, i.e. have a common wall. The

resulting adjacency graph is *planar*. A graph is planar if it can be drawn in a two-dimensional plane without crossing edges.

From an adjacency graph a block layout can be constructed if and only if the adjacency graph is planar, see Seppanen and Moore (1970). The concepts of layout graph, adjacency graph and their dual relationship are shown in Figure 4.3.
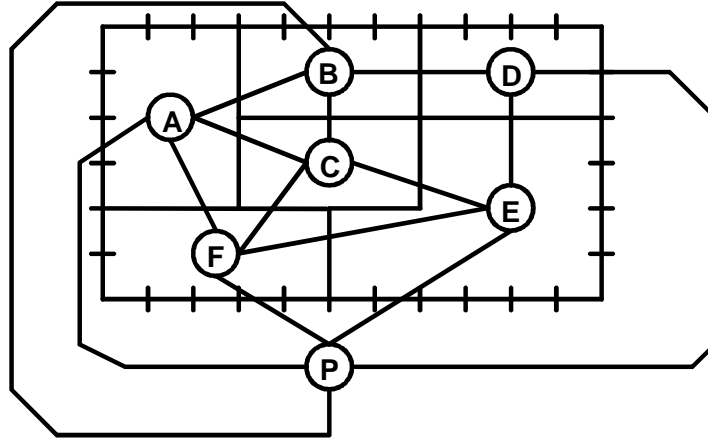

Figure 4.3. Adjacency Graph and Layout as Dual Graphs

The graph theoretic models are concerned with determining the best relative location of departments, ignoring the complexities of department and building shape and area. Their objective is to maximize the adjacency score. But in order to construct a block layout, the adjacency graph must be planar. Hence the problem is to extract a planar subgraph out of the relationship diagram, so that its edge weight is maximized and the graph is planar. This problem is called the Maximum (Weight) Planar Subgraph Problem (MPSP). This problem is NP-Complete and cannot be solved for practical problem size in reasonable amount of computer time.

SPIRAL Algorithm Characteristics

The **SPIRAL** algorithm consists of two major steps, denoted by **SPIRAL G** and **SPIRAL L** in Figure 4.2. In the first step, the fundamental principle of the **SPIRAL** algorithm is to grow a high weight, planar, hexagonal adjacency graph in a greedy fashion. In the second step, this graph is converted into a block layout with all rectangular departments and with material handling aisles parallel to one of the hexagon axes.

The **SPIRAL** program contains a collection of algorithms. These algorithms either construct a planar hexagonal adjacency or create a block and are called graph and layout algorithms, respectively.

You have the option of selecting one single design algorithm to be executed next or to select the execution of all possible combinations of algorithms. If you choose the latter, the program will execute a number of algorithms in sequential order. It also maintains the best adjacency score, the best efficiency, and the best shape adjusted distance score obtained by the algorithms for this project.

Graph Algorithms

The **SPIRAL** algorithm grows the relationship diagram in a crystalline, spiraling fashion. The original, manual form of this algorithm was first mentioned in Reed

(1967). It relied completely on the insight of the engineer. A more sophisticated version that incorporates relationships with the outside, neighborhood improvement steps, and is based on hexagonal graphs is given in Goetschalckx (1986, 1992).

The **SPIRAL** technique constructs a guaranteed planar graph with high adjacency score based on an underlying hexagonal grid. The hexagonal grid where each department has six neighboring departments is illustrated in Figure 4.4. A typical adjacency graph created by **SPIRAL** is shown in Figure 4.5.
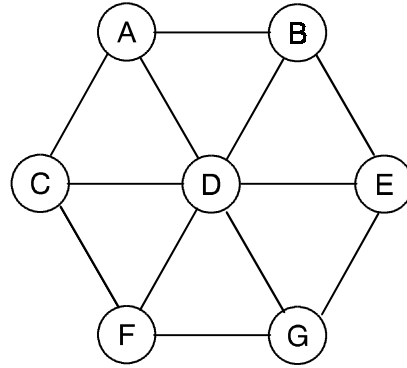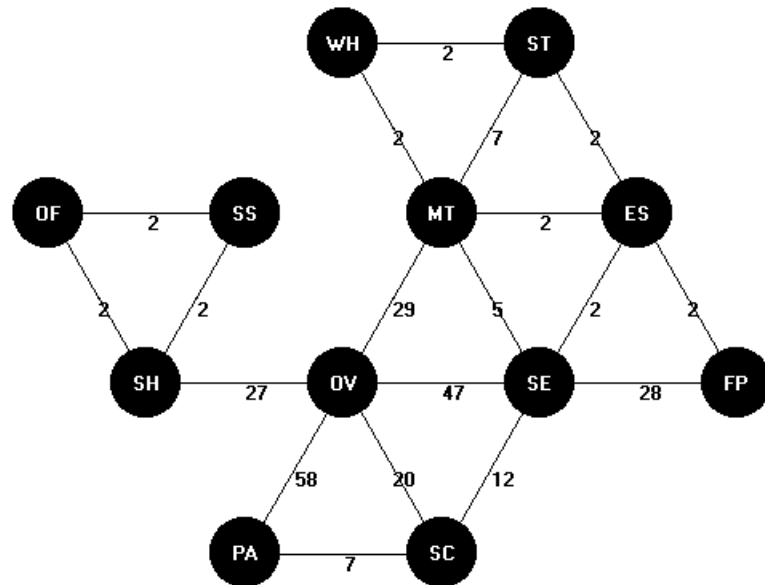

Figure 4.4. Hexagonal Grid Illustration

*Figure 4.5. **SPIRAL** Adjacency Graph Illustration*

The objective is to maximize the adjacency score based on a qualitative or numerical relationship chart. Departments are represented by standard, size independent symbols such as squares or circles. The data requirements are either a qualitative letter or quantitative relationship chart. The **SPIRAL** algorithm is one of the manual techniques to construct an adjacency graph or relationship diagram based upon a quantitative relationship matrix or flow matrix. The **SPIRAL** technique grows the graph in a crystalline manner by adding the department, which has the highest adjusted relationship, next to the graph so that the graph adjacency score is

maximized. As such the manual **SPIRAL** algorithm is an example of a greedy, heuristic construction procedure.

In the first phase, the **SPIRAL** technique attempts to construct a good relationship diagram. The quality of the relationship diagram is measured by the adjacency score. Hence, the objective is to maximize the positive flow or relationships between adjacent departments and to minimize the negative flow or relationships between adjacent departments. Observe that later on the objective is to minimize the shape adjusted distance score of the final block layout.

Departments are entered in the hexagonal adjacency graph based on their adjusted relationship. The relationship tuple indicates on how many departments the adjusted relationship is based. Possible options are null, unary, binary, and ternary. The departments then enter the graph by decreasing adjusted relationship. The null tuple indicates that the next department will be chosen at random, without any regard to its relationships with other departments. The unary adjusted relationship sums the relationships of a department with all other departments. The binary adjusted relationship is the relationship between the current department and one other department. The ternary adjusted relationship is the relationship between the current department and two other departments.

Next, the relationships with the outside are incorporated. A department with a high positive spiral relationships will tend to be located early on in the procedure and hence on the inside of the graph. Similarly, a department with a small positive or a negative spiral relationship will tend to be located late and hence towards the perimeter of the graph. To incorporate the relationships with the outside in a consistent manner each spiral relationship is adjusted by subtracting the relationship of the departments in the tuple with the outside. For example, the adjusted unary, binary, and ternary spiral relationship (denoted by the subscript adj) are computed from the original relationships in the relationship matrix (denoted by the subscript orig) as:

$$r_{adj}(i) = \sum_{j=1}^{M} r_{orig}(i,j) - r_{orig}(i,0) \tag{4.1}$$

$$r_{adj}(i,j) = r_{orig}(i,j) - r_{orig}(i,0) - r_{orig}(j,0) \tag{4.2}$$

$$r_{adj}(i,j,k) = r_{orig}(i,j) + r_{orig}(i,k) + r_{orig}(j,k)$$
$$-r_{orig}(i,0) - r_{orig}(j,0) - r_{orig}(k,0) \tag{4.3}$$

M is the total number of departments in the layout and *0* indicates the artificial outside department.

After the original graph is constructed three possible improvement steps can be executed. The options are none, two exchange, and three exchange. None does not execute an improvement step. Two exchange attempts to improve the graph in a steepest descent manner by attempting two department exchanges. It computes the savings generated by removing two departments out of the graph and swapping their position. The savings are based on an increase in the adjacency score. The exchange with the largest savings among all possible combinations of two departments is determined and if these savings are positive then those two departments are exchanged. The process repeats until no further improvements can be made. Three exchange attempts to improve the graph in a steepest descent manner by attempting three department exchanges. It computes the savings generated by removing three departments out of the graph and swapping their position. The savings are based on an increase in the adjacency score. The exchange with the largest savings among all

possible combinations of three departments is determined and if these savings are positive then those three departments are exchanged. The process repeats until no further improvements can be made. Computational processing time increases sharply with the amount of improvement processing.

When locating a department in the partial adjacency graph often alternative positions are possible. Two possible tie breaker rules can be used. The first one is random which places the department randomly in one of the alternative positions based on a random number. The second one is centroid seeking which places the department in the position closed to the centroid of the current (partial) adjacency graph. If there are still alternative positions after the first tie breaker then a position is chosen at random. For further information see Goetschalckx (1992).

In the case of the hexagonal grid, an upper bound on the adjacency score of the graph can be computed based on the following integer programming formulation, where o (zero) represents the artificial outside department:

$$\text{Max.} \quad \sum_{i=1}^{N-1}\sum_{j>i}^{N} r_{ij}x_{ij} + \sum_{i=1}^{N} r_{io}y_i \tag{4.4}$$

$$\text{s.t.} \quad \sum_{j=0}^{i-1} x_{ji} + \sum_{j=i+1}^{N} x_{ij} = 6 \qquad\qquad i = 1..N \tag{4.5}$$

$$y_i \le x_{oi} \qquad\qquad i = 1..N \tag{4.6}$$

$$x_{oi} \le 6y_i \qquad\qquad i = 1..N \tag{4.7}$$

$$y_i \in \{0,1\} \qquad\qquad i = 1..N \tag{4.8}$$

$$x_{ij} \in \{0,1\} \qquad\qquad i = 1..N-1, j = i+1..N \tag{4.9}$$

$$x_{oi} \ge 0 \qquad\qquad i = 1..N \tag{4.10}$$

The following notation is used:

x_{ij} is 1 if departments i and j are adjacent, 0 otherwise. For the artificial outside department x_{ij} represents the number of times department i is adjacent to the outside perimeter.

y_i is 1 if department i is adjacent to the outside, 0 otherwise.

r_{ij} is the binary relationship between departments i and j.

The formulation maximizes the adjacencies between departments and between a department and the outside (4.2), subject to the constraint that each department must have exactly six neighbors (4.3). These neighboring departments can be the artificial outside department. If a department has at least one outside department as a neighbor the relationship with the outside is satisfied and included in the objective function (4.4) and (4.5). All the adjacencies are binary variables, except the adjacencies with the outside department which are linear (4.6), (4.7) and (4.8).

The value of the formulation lies in the fact that it provides bound on the optimal solution quality and on the maximum deviation of the heuristic solutions. The value returned by the algorithm in **SPIRAL** is the solution of the linear relaxation of the above formulation. In a linear relaxation all variables that originally were restricted to be either zero or one now can take any value between zero and one. In other words:

$$\text{s.t.} \quad 0 \le x_{ij} \le 1 \qquad\qquad i = 1..N-1, j = i+1..N \tag{4.11}$$

$$0 \le y_i \le 1 \qquad\qquad i = 1..N \qquad\qquad (4.12)$$

To Create a Hexagonal Adjacency Graph

If you want to execute a single graph algorithm select the **Select Graph** command. If you want to execute all graph algorithms in sequence and retain the graph with the highest adjacency score, select the **All Graphs** command. Because of its extensive computations this last command might take a long time to complete.

To Compute an Upper Bound on the Graph Adjacency Score

You can compute the maximum adjacency score any graph can obtain for the current project by executing the **Graph Upper Bound** command.

Block Algorithms

In the second phase, **SPIRAL** converts the hexagonal adjacency graph into a rectangular block layout. The building has to be rectangular and all department shapes will also be rectangular. **SPIRAL** constructs the block layout based upon layers. Each layer corresponds to all departments on an axis of the hexagonal adjacency graph. Once the departments in a layer are determined, the area of this layer and the shape of each department in the layer can be computed. The **SPIRAL** algorithm attempts to improve the resulting block layout by using two and three department interchanges.

Building Orientation

The building orientation indicates to which of the possible three axes of the adjacency graph the building width dimension is parallel. The adjacency graph has three main axes, horizontal or level, 60 degrees upward, and 60 degrees downwards of the horizontal level. The block layout construction algorithms will create a layout by putting departments in rows, where the rows are parallel to the building width dimension. Departments whose positions in the adjacency graph are on the same axis will be placed in the same row in the block layout.
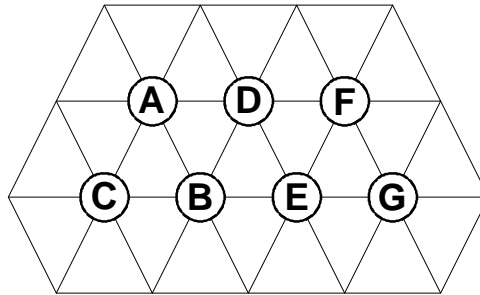

Figure 4.6. Main Axes of Adjacency Graph

Layout Improvement

After the original block layout is constructed four possible improvement steps can be executed. The options are none, steepest descent exchange and annealing exchange. Each exchange improvement procedure can be based either on exchanging two or three departments at a time.

None does not execute an improvement step.

Steepest Descent exchange attempts to improve the graph in deterministic and greedy manner by attempting two or three department exchanges. The exchange with the largest savings among all possible combinations of two or three departments is determined and if these savings are positive then those two or three departments are exchanged. The process repeats until no further improvements can be made.

Two Exchange attempts to improve the layout in a steepest descent manner by attempting two department exchanges. It computes the savings generated by removing two departments out of the graph and swapping their position. The savings are based on a decrease in the shape adjusted distance score. **Three Exchange** attempts to improve the graph in a steepest descent manner by attempting three department exchanges. It computes the savings generated by removing three departments out of the graph and swapping their position. The savings are based on a decrease in the shape adjusted distance score.

Annealing Exchange attempts to improve the graph in stochastic, non steepest descent manner by attempting two or three department exchanges. There exists an analogy between the optimization method of simulated annealing and the laws of thermodynamics, specifically with the way in which liquids freeze and crystallize or metals cool and anneal. The algorithm computes the savings generated by removing three departments out of the graph and swapping their position. The savings are denoted by S. The savings are based on a decrease in the shape adjusted distance score. The three departments are chosen at random. If the savings are positive then the exchange is made. If the savings are negative, i.e. the distance score after the exchange is higher, then the exchange can still be made with a certain probability depending on the how long the simulated annealing algorithm has been executing. This time by convention is called the temperature of the annealing process and is denoted by T. The probability of an exchange based on savings S, denoted by $P(S)$ is then computed as:

$$P(S|S > 0) = 1$$
$$P(S|S \leq 0) = e^{S/T}$$

(4.13)

During the algorithm execution the temperature T is systematically reduced. This allows early on exchanges with large negative savings. As the temperature is lowered, the number of such exchanges and the size of the allowed negative savings are gradually reduced. The objective of these non-improving exchanges is to avoid a steepest descent into a local minimum. The process repeats until no further improvements can be made.

For further information on two and three exchanges see Goetschalckx (1992). For further information on simulated annealing see Kirkpatrick et al. (1983) and Vechi and Kirkpatrick (1983).

Computational processing time increases sharply with the amount of improvement processing.

Space Allocation

The **Layered** space allocation method divides the building area in strips or layers parallel to the orientation of the building. All departments located on an axis of the hexagonal adjacency graph parallel to the building orientation are assigned to a single layer. The algorithm then assigns department areas from left to right in each layer. The Layered method has the advantage that it creates natural material handling aisles in the building.

The **Tiled** space allocation method divides the building area into a set of non-overlapping rectangular departments. The position of the department rectangles is derived from the hexagonal adjacency graph. The Tiled space allocation method recursively divides a partial building area along all possible vertical and horizontal rows and columns of the hexagonal adjacency graph and keeps the best layout generated so far. The Tiled space allocation method has more flexibility than the Layered space allocation method and on the average will yield layouts with a lower distance score. However, the resulting layout may not have the structure that aligns departments along parallel material handling aisles.

The Tiled space allocation method will always generate layouts with a score that is not larger than the score of layouts generated with the Layered space allocation method if no improvement exchanges are allowed. Because the improvement exchanges are heuristic algorithms, the Layered method may generate a layout with lower distance score than the Tiled space allocation method for individual project instances. Because the Tiled method examines many more alternatives than the Layered method, it requires substantially longer computation times.

To Create a Block Layout

If you have already created a graph, then you can create a block layout next. If you want to execute a single layout algorithm, select the Select **Layout** command. If you selected the Tiled space allocation method, generating even a single layout for large projects might take a long time to complete. If you want to execute all block layout algorithms in sequence and retain the block layout with the minimum shape adjusted distance score, select the **All Layouts** command. Because of its extensive computations this last command might take a long time to complete.

Finally, if you want to execute all graph algorithms and for each graph algorithm execute all layout algorithms, select the **All Graphs and Layouts** command. Because of its extensive computations this command may take a long time to complete.

To Evaluate the Current Graph and Layout

If you have made some changes to the project data, the current graph or the current layout, then you can evaluate quickly the effect of these changes by executing the **Evaluate** command. This command does not create a new graph or layout but merely evaluates the current graph and or layout.

Parameters

Setting several algorithm parameters can modify the execution of the various algorithms. Not all algorithms use all parameters.

Maximum Replications...

The graph algorithms create random adjacency graphs when breaking ties for the location of department nodes in the adjacency graphs. When graph algorithms are executed again with a different seed, a different graph might be generated. The layout improvement algorithms based on simulated annealing select random pairs of departments to be tested for possible exchange. Different replications of the same algorithm can thus provide different adjacency graphs or block layouts. The higher the number of replications, the more likely a high quality block layout will be

constructed. But this comes at an increase in computation time. You can set the maximum number of replications the graph algorithm executes with the **Max. Replications** command of the **Edit** menu.

Seed...

Several design algorithms use random numbers to make arbitrary decisions. The graph algorithms use random numbers to break ties in locating department nodes in the adjacency graph. The layout improvement algorithms based on simulated annealing use random numbers to select the next two departments to be tested for a possible exchange. The sequence of random numbers is determined by its starting point, called the seed. An algorithm will always produce the same results if you select the same algorithm options and set the same random number seed. You can set the random number generator seed with the **Seed** command of the **Edit** menu.

If an algorithm has executed multiple replications then the seed reported in the **Statistics** and **Notes** windows is the seed that yielded the best graph or layout among all the replications. An algorithm that does not use random numbers or that only executes one replication will always return the same seed as it was started with.

In order to repeat the results for an algorithm, you must set the seed to the value reported at the completion of the algorithm and set the number of replications to one. Then run the algorithm again with all other parameters unchanged.

The actual random numbers are generated from the seed with a standard pseudo random number generation process. This process is dependent on the combination of processor and compiler, so computers with different processors and compiler version may give different random number sequences. **SPIRAL** has no control over this process.

Time Limit...

This command allows the user to set the maximum time a single algorithm is allowed to run or for the maximum time in seconds an algorithm can execute a particular step. Once the time limit has been reached the algorithm is terminated.

Tolerance...

The Parameters menu's Tolerance Command queries the user for the new relative tolerance. The algorithm terminates, if the current solution is within the relative tolerance of current best solution. This parameter cannot be modified by the user at the current time, but is set to 0.001.

Report Level...

You can control the level of detail the program will use in generating output reports and the number of pauses during algorithm execution by setting the report level. The output reports are written to the **Output Log** file, if this one has been defined. The **Report Level** command of the **Edit** menu displays the **Report Level** dialog box which allows you to set the report level. There are six levels ranging from 0 to 5, which increasingly generate more detailed reports and cause more frequent execution stops.

Statistics

Adjacency Statistics

If all departments have been located then the adjacency and efficiency of the graph are computed. To score the graph, the sum of all **p**ositive relationships between **a**djacent departments will be denoted by *PA*. The sum of all **n**egative relationships between non-adjacent or **s**eparated departments will be denoted by *NS*. The sum of all **p**ositive relationships between non-adjacent or **s**eparated departments will be denote by *PS*, and the sum of all **n**egative relationships between **a**djacent department will be denoted by *NA*. The adjacency (*A*) and efficiency (*e*) are then computed as

$$A = PA + NA \tag{4.14}$$

$$e = \frac{PA - NS}{PA + PS - NS - NA} \tag{4.15}$$

The efficiency has its numerator all relationships that are desirable, namely positive adjacent and negative separated ones. It has in the denominator the sum of all relationships. The efficiency is thus a measure of the quality of the adjacency graph with values between 0 and 1 and invariant with respect to the magnitude of the relationships. A diagram which maximizes the adjacency will also maximize the efficiency since the numerator of the efficiency is equal to adjacency minus the constant *(NS + NA)*.

Distance Statistics

The shape adjusted distance score *D* is computed as the sum of the flow distance score and the shape penalties. The flow distance score itself is composed of the internal and the external flow distance score. The internal flow distance score is equal to the sum of the products of the rectilinear distance between the centroids of two departments and the relationship between those departments. In other words, if the centroids of two departments are located at coordinates (x_i, y_i) and (x_j, y_j) then the rectilinear centroid to centroid distance is given by:

$$d_{ij}^R = |x_i - x_j| + |y_i - y_j| \tag{4.16}$$

The external flow distance score is equal to the sum of the shortest rectilinear distance of the centroid of the department to the perimeter of the building multiplied by the relationship of that department with the outside. In other words, if the origin of a department is denoted by *(x, y)*, its size by *(w, l)*, and the building dimensions by *(W, L)*, then the rectilinear distance between the department and the perimeter is given by

$$d_{io}^R = \min\{x + w/2, y + l/2, W - x - w/2, L - y - l/2\} \tag{4.17}$$

The total flow distance is then equal to

$$D = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} d_{ij}^R \cdot r_{ij} + \sum_{i=1}^{N} d_{io}^R \cdot r_{io} \tag{4.18}$$

For each individual department the shape ratio is denoted by s_i, the maximum shape ratio is denoted by S_i, and the shape penalty is denoted by p_i. The shape adjusted distance score *SD* is then equal to:

$$SD = D + \sum_{i=1}^{N} \max\{0, s_i - S_i\} \cdot p_i \qquad (4.19)$$

The shape adjusted distance score is reported at the end of the algorithms. If you are only interested in the flow distance score, you can compute this score by evaluating the layout with the **Evaluate** command of the **Algorithms** menu. The flow distance score is reported as the Delta Objective value and also shown in the Evaluate dialog window.

Examples

Tompkins Example

This section illustrates the construction algorithm for hexagonal adjacency graphs that has been implemented in the **SPIRAL** program.

Consider a layout project with seven departments. The space requirements and the flow from-to-chart are given below. The flow chart is based on the number of trips per day with an electric platform truck. This example was originally presented in Tompkins and Moore (1978).

Table 4.1. Departmental Data

	A	B	C	D	E	F	G	Function	Area
A		45	15	25	10	5		Receiving	12,000
B				30	25	15		Milling	8,000
C					5	10		Press	6,000
D		20			35			Lathing	12,000
E						65	35	Assembly	8,000
F		5			25		65	Plating	12,000
G								Shipping	12,000

The first step converts the asymmetric matrix into a symmetric one. The sum of all relationships is equal to 435.

Table 4.2. Symmetric Department Relationship Data

	A	B	C	D	E	F	G	Function	Area
A		45	15	25	10	5		Receiving	12,000
B				50	25	20		Milling	8,000
C					5	10		Press	6,000
D					35			Lathing	12,000
E						90	35	Assembly	8,000
F							65	Plating	12,000
G								Shipping	12,000

Step two creates the **SPIRAL** relationships, which in this case is easy since there are no outside relationships, and step three ranks the relationships by non-increasing value.

Table 4.3. Ranked Relationships

Index	Pair	Value	Index	Pair	Value	Index	Pair	Value
1	EF	90	8	BE	25	15	AG	0
2	FG	65	9	BF	20	16	BC	0
3	BD	50	10	AC	15	17	BG	0
4	AB	45	11	AE	10	18	CD	0
5	DE	35	12	CF	10	19	CG	0
6	EG	35	13	AF	5	20	DF	0
7	AD	25	14	CE	5	21	DG	0

In step four the departments are placed in the relationship diagram in such way as to maximize the sum of adjacent flows.

The flow EF is the largest, hence departments E and F are placed next to each other.
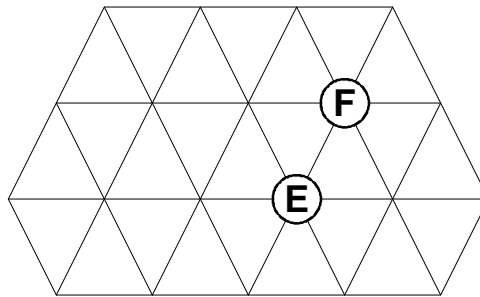
Figure 4.7. Partial Hexagonal Adjacency Graph with 2 Departments

The largest relationship with an anchor department already located is now FG. Department G will be located adjacent to department F, but there exist alternative locations. Department G has both positive flows with departments F and E, so it is placed adjacent to both. There still exists a tie between locations left or right of departments E and F, which is broken arbitrarily.
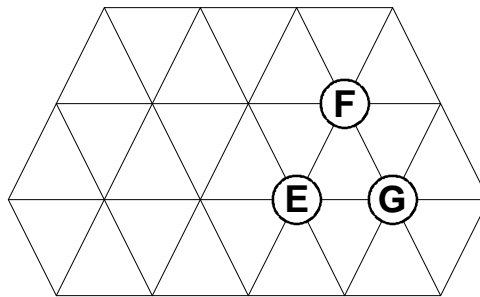
Figure 4.8. Partial Hexagonal Adjacency Graph with 3 Departments

The next largest relationship with a department already in the layout is relationship DE. Department D will be placed adjacent to department E, but there exist alternative locations. Checking down the list shows that department D has no further relationship with any of the already located departments and the tie is thus broken arbitrarily.
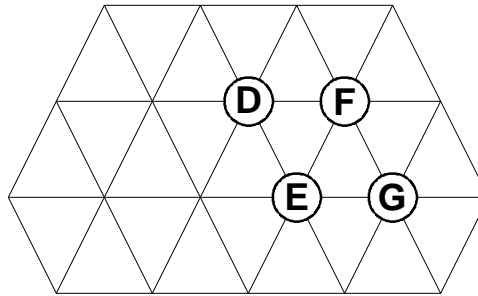
Figure 4.9. Partial Hexagonal Adjacency Graph with 4 Departments

The next largest flow with an already located department is BD. Department B will be placed adjacent to department D. To break the tie, the first located department down the list with a relationship with B is department E. Hence department B will be located in the unique location adjacent to D and E.
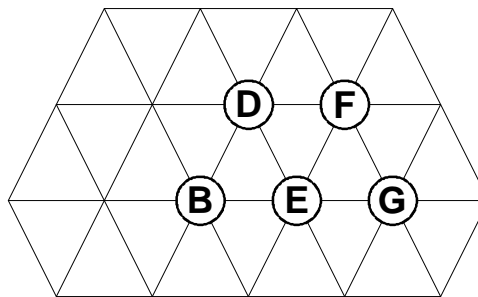
Figure 4.10. Partial Hexagonal Adjacency Graph with 5 Departments

The largest flow is now AB. Department A has positive flows with departments B, D and E in that order. There is a single unique location adjacent to departments B and D, so department A is placed adjacent to departments B and D.
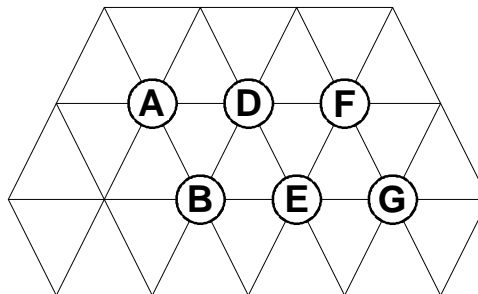
Figure 4.11. Partial Hexagonal Adjacency Graph with 6 Departments

The largest flow is now AC. Department C has positive flows with departments A, F and E. It cannot be adjacent to A and to either F or E, so it is placed in an arbitrary location adjacent to department A.
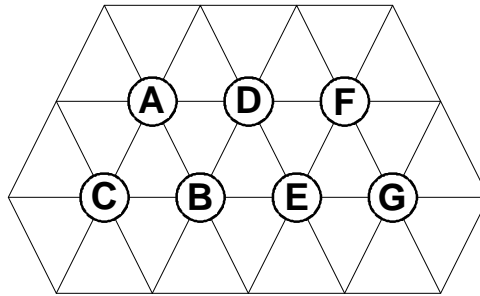
Figure 4.12. Complete SPIRAL Hexagonal Adjacency Graph

Since all the relationships are positive, the evaluation is done immediately with the original adjacency matrix. The adjacency matrix is multiplied element by element with the symmetric relationship matrix to generate the adjacency score.

Table 4.4. Adjacency Matrix

	A	B	C	D	E	F	G
A		1	1	1			
B			1	1	1		
C							
D					1	1	
E						1	1
F							1
G							

The adjacency score is equal to 385. The efficiency is then equal to 385/435 or 89 %.

If random location ties are broken differently, then the diagram of Figure 4.13 is generated. Its efficiency is equal to 405 / 435 = 93 %.
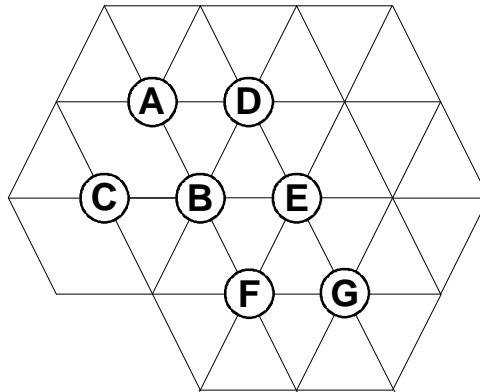
Figure 4.13. Alternative SPIRAL Hexagonal Adjacency Graph

When the layout construction algorithm is executed on the adjacency graph of Figure 4.12 with a level main axis and no improvement steps, then the block layout shown in Figure 4.14 is created.
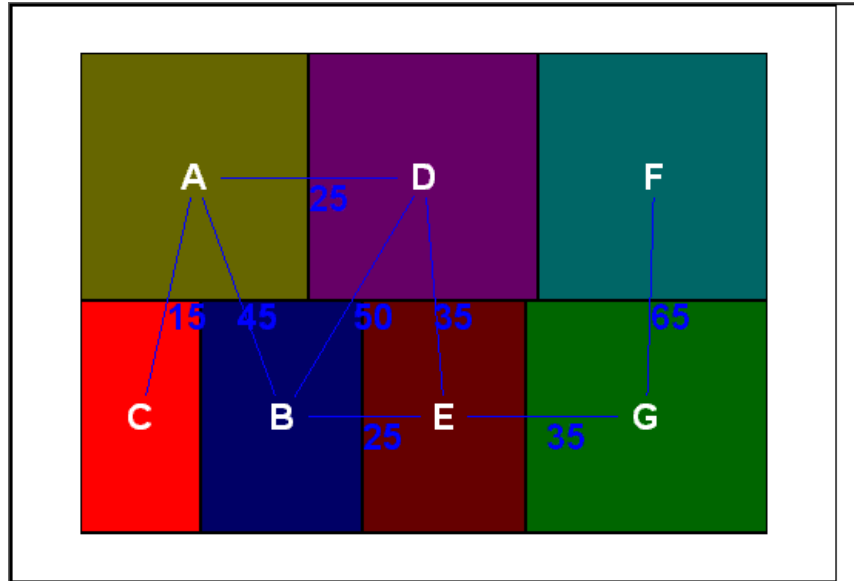
Figure 4.14. SPIRAL Block Layout

The rectilinear centroid-to-centroid distance score is equal to 2171. Since all departments have a shape ratio smaller than their maximum shape ratio, which is equal to two for all departments, the shape adjusted distance score is equal to the flow distance score.

Autoparts Example

The company produces stamped metal parts, to be used in automotive assembly, from sheetmetal coils. The plant consists of five major departments. Some of the parts have to be treated with corrosion resistive paint and then dried in an oven. Forklift trucks are used for all material handling transportation operations in the plant. A summary of the department data is given in Table 4.5. The number of truck trips per week between each pair of departments and between each department and the outside is given in Table 4.6. The building dimensions are 200 by 120 feet.

Table 4.5. Department Data for the Autoparts Example

Label	Function	Area	Maximum Shape Ratio	Shape Penalty
SHI	Shipping	4,000	3.0	15,000
REC	Receiving	2,000	3.0	10,000
STA	Stamping	10,000	1.5	25,000
PAI	Painting	6,000	2.0	50,000
STO	Steel Coil Storage	2,000	4.0	10,000
OUT	Outside			

Table 4.6. Material Handling Trips for the Autoparts Example

	OUT	SHI	REC	STA	PAI	STO
OUT			50			
SHI	300					
REC				15		35
STA		240			60	
PAI		60				
STO				35		

We will first create a hexagonal adjacency graph and block layout following the SPIRAL methodology. For the graph construction phase, we will use the binary relationships, not use improvement interchanges, and break location ties by the centroid-seeking rule. For the graph, we will show first the symmetrical adjusted relationships in a two-dimensional matrix. We then will show the sorted list of adjusted binary relationships. Third, we will show the adjacency graphs after we have added each department. Finally, we will compute and show the adjacency and efficiency score of the final graph.

We first convert the asymmetrix material handling trips to a symmetric relationship table, where all relationships are shown above the main diagonal.

Table 4.7. Symmetric Relationships for theAutoparts Example

	OUT	SHI	REC	STA	PAI	STO
OUT		300	50			
SHI				240	60	
REC				15		35
STA					60	35
PAI						
STO						

Next the adjusted binary relationships, that incorporate the relationships with the outside, are computed. Because several departments have positive relationships with the outside, many of the adjusted relationships are negative.

Table 4.8. Binary Adjusted Relationships for the Autoparts Example

	SHI	REC	STA	PAI	STO
SHI		-350	-60	-240	-300
REC			-35	-50	-15
STA				60	35
PAI					0
STO					

The adjusted binary relationships are then sorted in decreasing order.

Table 4.9. Sorted Binary Adjusted Relationships for the Autoparts Example

Index	Dept. 1	Dept. 2	Relation	Index	Dept. 1	Dept. 2	Relation
1	STA	PAI	60	6	REC	PAI	-50
2	STA	STO	35	7	SHI	STA	-60
3	PAI	STO	0	8	SHI	PAI	-240
4	REC	STO	-15	9	SHI	STO	-300
5	REC	STA	-35	10	SHI	REC	-350

The first two departments to enter the hexagonal adjacency graph are the two departments in the first element of the list, i.e. STA and PAI. They are placed at random in two adjacent vertices of the hexagonal grid.
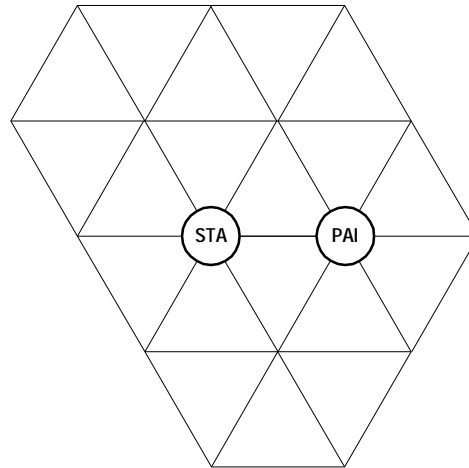

Figure 4.15. Adjacency Graph with 2 Departments for the Parts Example

The next relationship selected must have one department in the graph and one department not in the graph. These departments are called the anchor department and the new department, respectively. The anchor department also must have an open adjacent grid position. Element two of the list satisfies all those conditions: department STA is in the graph, department STO is not, and department STA has an empty adjacent grid position. All empty grid positions adjacent to the anchor department are possible locations for the new department, and because of the relationship selection rule there exists at least one open adjacent grid position. The grid position with the highest adjacency score based on the original symmetric relationships is selected. Ties are broken by the centroid-seeking rule, i.e. the new department is located in the open grid location adjacent to the anchor department that tied for the highest adjacency score and that is closest to the centroid of the current adjacency graph. Department STO has only a relationship with department STA, and thus all open grid positions adjacent to department STA are tied. There are three grid position closest to the centroid of the graph and the one above the centroid is selected at random.
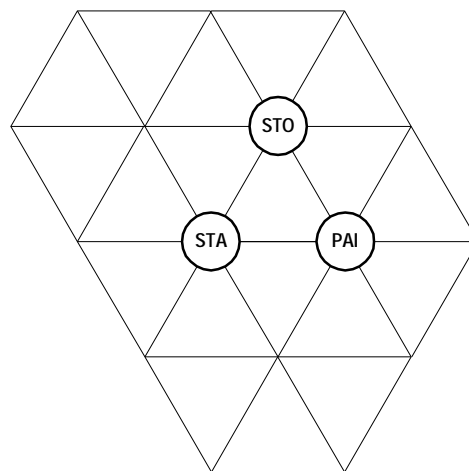
Figure 4.16. Adjacency Graph with 3 Departments for the Autoparts Example

Element four is the next relationship selected from the list. Department STO is in the graph, department REC is not, and department STO has an open adjacent grid position. Deparment REC has a positive relationship with departments STA and STO and so the open grid position adjacent to both those department is the selected location for department REC.
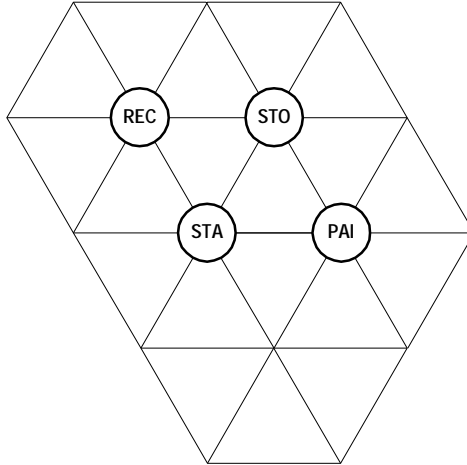
Figure 4.17. Adjacency Graph with 4 Departments for the Parts Example

Department SHI is the only remaining free department. Element seven is the next selected relationship, since department STA is in the graph, deparment SHI is not in the graph, and department STA has an open adjacent grid location. All open grid positions adjacent to department STA are candidate locations. Since department SHI has positive relationships only with departments STA and PAI, it will be located in the open grid location adjacent to those two departments.
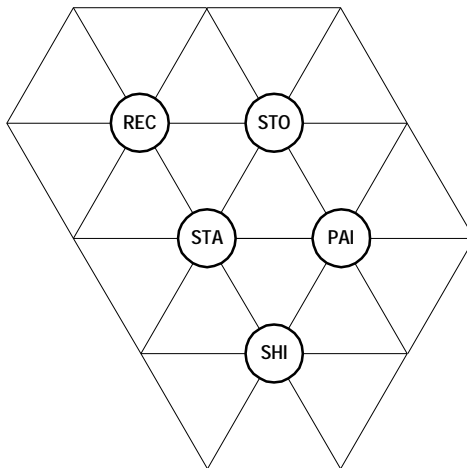
Figure 4.18. Adjacency Graph with 5 Departments for the Parts Example

To compute the adjacency score, we construct the adjacency matrix for the graph above.

Table 4.10. Adjacency Matrix for the Autoparts Example

	OUT	SHI	REC	STA	PAI	STO
OUT		1	1	1	1	1
SHI				1	1	
REC				1		1
STA					1	1
PAI						1
STO						

The adjacency matrix is then multiplied element by element with the symmetrical relationship matrix and the sum of the product is computed. The sum is equal to 795. Since the sum of the absolute values of all relationships is also equal to 795, the efficiency of the above graph is equal to 100 %.

For the block layout phase, we will use the graph axis with the most departments in the graph as the building orientation, not use improvement interchanges, and use the layered space allocation method. For the layout phase, we will first show the layout drawn to scale with all departments properly dimensioned. Next, we will show all distances in a two-dimensional matrix of which we will only fill in the upper half. Third, we will compute and show the inter-department distance score and the distance score with the outside. Fourth, we will compute and show the shape penalty score for each individual department and the total shape penalty. Finally, we will compute and show the shape adjusted distance score.

The graph axis with the most departments is oriented downwards. The conceptual block layout with the layered space allocation method is shown in the next figure.
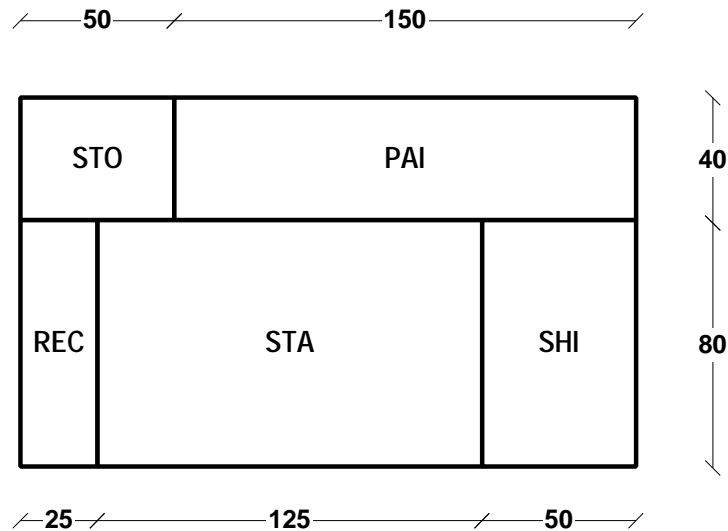
Figure 4.19. Block Layout for the Given Graph for the Autoparts Example

Table 4.11. Distance Matrix for the Autoparts Example

	OUT	SHI	REC	STA	PAI	STO
OUT		25.0	12.5	40.0	20.0	20.0
SHI			162.5	87.5	110.0	210.0
REC				75.0	72.5	72.5
STA					97.5	122.5
PAI						100.0
STO						

The distance matrix is then multiplied element by element with the symmetrical relationship matrix and the sum of the products is computed. This sum is the flow distance score and is equal to 49,525, of which 41,400 is between two departments and 8,125 is between departments and the outside.

Table 4.12. Penalty Shape Computations for the Autoparts Example

Dept.	Actual Shape	Maximum Shape	Delta Shape	Penalty Rate	Shape Penalty
SHI	1.6	3	0	15000	0
REC	3.2	3	0.2	10000	2000
STA	1.5625	1.5	0.0625	25000	1563
PAI	3.75	2	1.75	50000	87500
STO	1.25	4	0	10000	0

The total shape penalty is computed as the sum of the individual department shape penalties and is equal to 91,063. The total shape distance score for the layout is computed as the sum of the flow distance score and the shape penalty and is equal to 140,588.

The block layout without exchange improvements, the best block layout with the layered space allocation method, and the best block layout with the tiled space allocation method are shown in the next three figures. The distance statistics for the three layouts are shown in the next table.
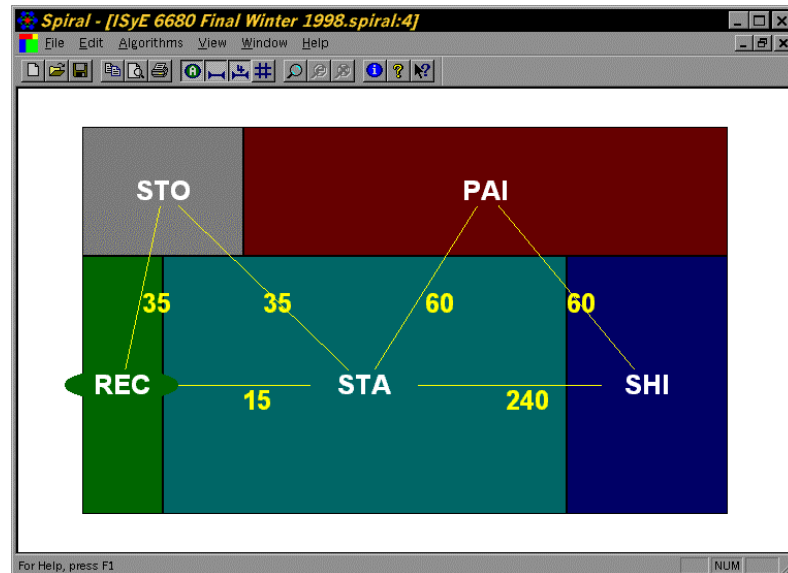
Figure 4.20. Unimproved Block Layout for the Given Graph for the Parts Example
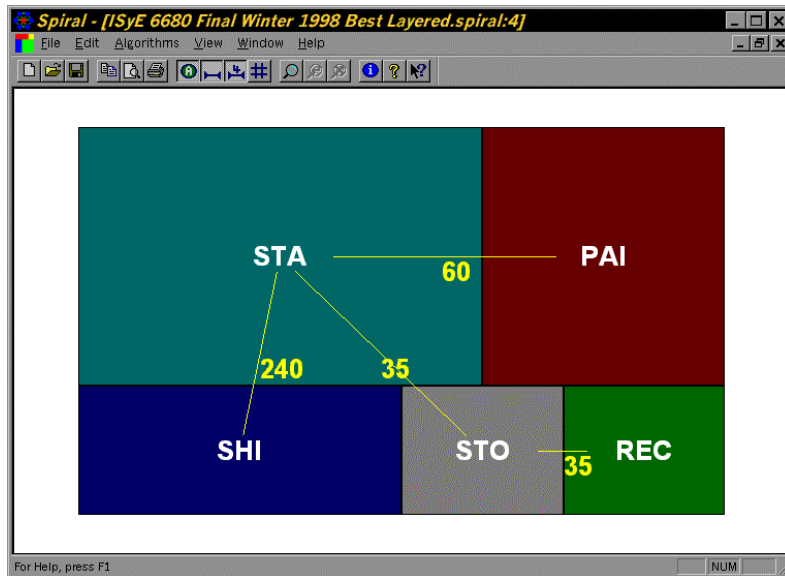
Figure 4.21. Best Layered Block Layout for the Given Graph for the Parts Example
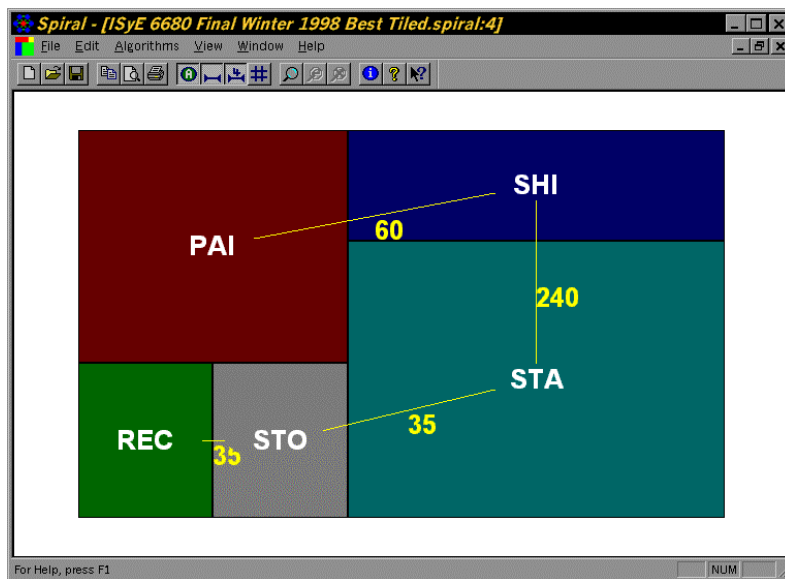
Figure 4.22. Best Tiled Block Layout for the Given Graph for the Parts Example

Table 4.13. Distance Statistics for the Parts Example

	Unimproved	Best Layered	Best Tiled
Flow Distance	49,525	49,375	43,169
Shape Penalty	91,063	1,563	6,042
Shape Distance	140,588	50,938	49,211

While the computer can provide evaluations of the different layouts based on centroid-to-centroid distances, it remains up to the user to decide which layout is best suited for their particular layout project.

Chapter 5. Command Reference

Menu Overview

An overview of the **Spiral** program menu structure is shown in Table 5.1.

Table 5.1. **Spiral** *Menu Structure*

File	Edit	Algorithms	View	Window	Help
New...	Add Department	Select Graph...	Department Labels	New Notes View	Help Topics...
Open...	Delete Department	All Graphs	Edge Labels	New Statistics View	About SPIRAL...
Close	Delete Department by Label…	Graph Upper Bound	Edges...	New Graph View	
Save	Department	Select Layout...	Grid	New Layout View	
Save As...	Department by Label...	All Layouts	Label Size...	Cascade	
Import...	Relation...	All Graphs and Layouts	Node Colors...	Tile	
Export	Relation with Outside	Synchronize Graph	Edges Display...	Arrange Icons	
Send...	All Relations	Evaluate	Zoom	Toolbar	
Properties...	Building Dimensions	Display Distances	Zoom Previous	Status Bar	
Output Log...	Max. Shape Ratio…		Zoom Original		
Close Log	Shape Penalty…		Redraw		
Print...	Grid Size…				
Print Preview...	Report Level				
Print Setup...	Seed				
Exit	Max Replications				
	Time Limit				
	Copy				

Several commands have shortcut keys so that you can easily control the program with the keyboard. Several commands are also shown on the toolbar, to allow easy program control with the mouse.

Figure 5.1. **Spiral** *Toolbar*

File Menu

The **Spiral** program requires the project data before any algorithm can be executed. The projects are managed with the commands on the **File** menu.

New

The **New** command of the **File** menu allows you to interactively create a new facilities design project.

If there is a project currently open and if it has been modified, then the program will display the **Save Changes** dialog window and ask if you wish to save those changes, discard the changes, or if you wish to abort the creation of new project. The **Save Changes** dialog window is illustrated in Figure 5.2.

The command displays the **New** dialog window, which is illustrated in Figure 5.3. To save the new project use the **Save As** command. To open a previously saved project use the **Open** or **Import** commands.

To create the new project with the values shown in the dialog window press the **OK** button. When this project is created it has no departments and all relationships will be equal to zero. If you press **Cancel**, no new project will be created.

New Project Shortcuts

Toolbar:

Keys: CTRL+N

Save Changes Dialog Window

Figure 5.2. Save Changes Dialog Window

New Project Dialog Window
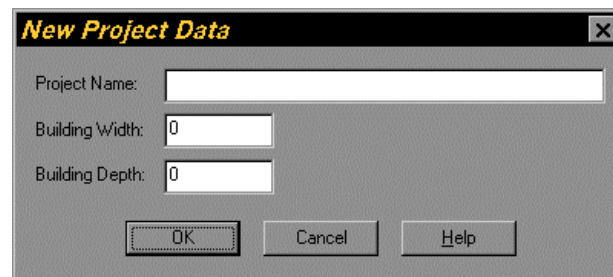
Figure 5.3. New Project Dialog Window

New Project Data Items

Project Title

The project title refers to the title of the project to be used in reports and printouts. It consists of a maximum of 63 alphanumeric, spaces, or underscore characters. Punctuation marks, or tab characters are not allowed. The title is also included in the project **Properties**. The term project name is used synonymously with project title.

Further information can be found in the **Project Data** section under **Project Title**.

Building Width

The building width refers to the horizontal dimension of the building ground plan. It must be in units compatible with the department areas. The building always has a rectangular shape. The building area is computed as the product of the building width and building depth. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet. The width of the building is displayed along the horizontal axis on the screen.

Further information can be found in the Project Data section under **Building Width**

Building Depth

The building depth refers to the second dimension of the building ground plan (which will be displayed vertically on the screen). It must be in units compatible with the department areas. The building area is computed as the product of the building width and building depth. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet. The depth of the building is displayed along the vertical axis on the screen.

Further information can be found in the Project Data section under **Building Depth**

Open

The **Open** command allows you to read a previously saved project.

The program will read the corresponding **Project Data File**. Starting with version 4.0 of the **Spiral** program, the **Project Data File** is a binary file that can no longer be viewed or manipulated outside the **Spiral** program. Use the **Import** command to import project data created with previous versions of the **Spiral** program or with the **Export** command. The default extension for **Spiral** project files is *.spiral*. The command then displays the **Open** dialog window, which is illustrated below in Figure 5.4.

As all applications using the Scientif support library, the **Spiral** application can only open one project at the time. If there is a project currently open and if it has been modified, then the program will display the **Save Changes** dialog window and ask if you wish to save those changes, discard the changes, or if you wish to abort the opening of another project or the creation of new project. The **Save Changes** dialog window is illustrated in Figure 5.2.

However, you can still compare two projects side by side by opening a second copy of the **Spiral** application itself, opening the second project with this copy of **Spiral**, and then arranging the two application windows on your desktop.

Open Project Shortcuts

Toolbar:

Keys: CTRL+O

Open Project Dialog Window
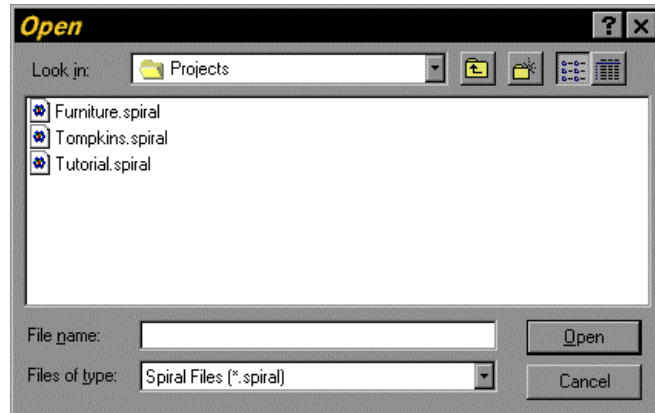
Figure 5.4. Open Project Dialog Window

Close

The **Close** command of the **File** menu allows you to close the current project.

If the current project has been modified, then the program will display the **Save Changes** dialog window and ask if you wish to save those changes, discard the changes, or if you wish to abort the closing of the current project. The **Save Changes** dialog window is illustrated in Figure 5.2.

Save

The **Save** command of the **File** menu will save the current project data in the **Project Data File**. If no file name for the current **Project Data File** has been defined, then the **Save** command will execute as the **Save As** command.

Save Project Shortcuts

Toolbar:

Keys: CTRL+S

Save As...

The **Save As** command of the **File** menu will query you for the file name of the **Project Data File** with the **Save As** dialog window. If you press the **Save** button the current project will then be saved as if the **Save** command was executed.

Save As Dialog Window
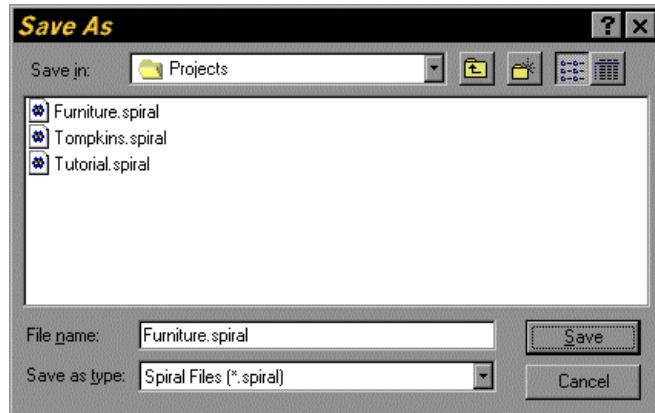
Figure 5.5. Project Save As Dialog Window

Save As Data Fields

File Name

Spiral is compatible with long file and directory names that follow the Windows conventions. Some versions of the Windows operating environment will truncate the default *spiral* extension to the three letters *spi*, so we recommend that you explicitly add the *spiral* extension to the file name in the Save As dialog window.

File Type

Starting with version 4.0 of the **Spiral** program, the **Project Data File** is a binary file that can no longer be viewed or manipulated outside the **Spiral** program. Use the **Export** command to create a set of ASCII files that contain the major data for the current project. These files can then be manipulated outside the **Spiral** program with an ASCII text editor and then imported again into the **Spiral** program using the **Import** command.

Import...

The **Import** command of the **File** menu allows you to read project data saved in ASCII files with a version of the **Spiral** program earlier than 4.0, created with the **Spiral Export** command, or created manually outside the **Spiral** program with an ASCII editor.

Starting with version 4.0 of the **Spiral** program, the **Project Data File** is a binary file that can no longer be viewed or manipulated outside the **Spiral** program. Use the **Open** command to read project data files created with the **Save** command of version 4.0 or higher of **Spiral**. The default extension for **Spiral** project files is *.spiral*, the default extension for the Spiral project files of previous versions or exported data files is *.dat*.

The command then displays the **Open** dialog window, which is illustrated in Figure 5.4. The program will read the corresponding **Project Data File** (**.dat*) and **Department Data File** (**.dep*).

The **Project Data File** and the **Department Data File** can be created with any text editor or word processor capable of generating pure ASCII files or with the

Export command. Since word processors usually insert special formatting codes into their regular document files, which cannot be read by the **Spiral** program, special care should be taken when using a word processor to generate a pure ASCII file. The project data file also should not contain any blank lines. Once these input files have been created, they can be used repeatedly by the **Spiral** program.

Export...

The **Export** command of the **File** menu will save the current project data in a set of ASCII files. The program will create the corresponding **Project Data File** (**.dat*) and **Department Data File** (**.dep*). Once these data files have been created, they can be read by the **Spiral Import** command and by an ASCII editor. Not all program settings will be saved, but only the major project, department, and relationship data.

Starting with version 4.0 of the **Spiral** program, the **Project Data File** created by the **Save** command is a binary file which can no longer be viewed or manipulated outside the **Spiral** program. Use the **Open** command to read project data files created with the **Save** command of version 4.0 or higher of **Spiral**. The default extension for **Spiral** project files is *.spiral*, the default extension for the Spiral project files of previous versions or exported data files is *.dat*.

Export Dialog Window
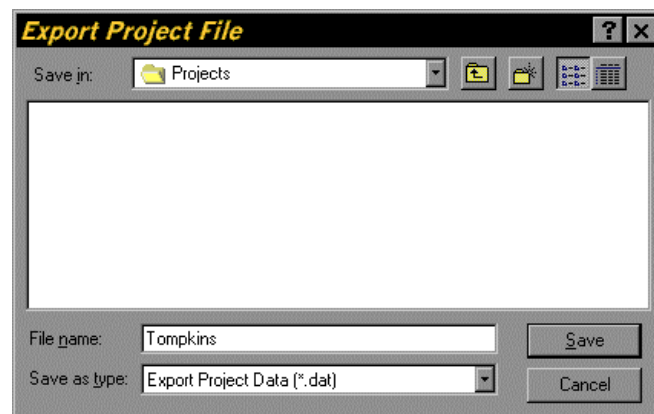
Figure 6. Export Dialog Window

Send...

The **Send** command of the **File** menu uses the electronic mail application installed on your computer to send the saved version of the current project as an attachment to an electronic mail message. It is recommended that the current project first be saved before using the **Send** command. The exact execution of this command will depend on which electronic mail application has been installed on your computer. This command will not be enabled if you do not have an electronic mail client installed on your computer.

Properties...

The **Properties** command of the **File** menu allows you to add project information, such as authors, subjects, and comments to the current project. The **Properties**

command displays the **Properties** dialog window for the current document. You can provide additional information in this dialog window about the current project.

Properties Dialog Window

Figure 5.7. Properties Dialog Window

Properties Data Items

Application

The name of the application creating this dialog window. In this case, **Spiral**. You cannot change this data field.

Project

The project title. This is the only place where the title of the current project can be changed after it has been initially entered in the **New Project** dialog window or was imported from the **Project Data** file. The project title can contain letters, digits, spaces, and underscore characters.

Further information can be found in the **Project Data** section under **Project Title**.

Subject

The subject of the current project.

Author

The author of the current project.

Keywords

A list of one or more keywords describing this project.

Data Version

The data version of the current project. You cannot change this data field. It is displayed for information purposes only.

Comments

You can enter comments about the current project.

Output Log

The **Output Log** command of the **File** menu allows you to specify the file name for the log file created and used by the **Spiral** program. **Spiral** writes the results and intermediate information generated by the various design algorithms to the **Output Log file**. The amount of information written to the **Output Log File** depends on the level of detail selected with the **Report Level** command in the **Edit** menu. The file and all of its previous contents will be erased every time the **Output Log** command is executed. To select another log file or to restart the current log, execute the **Output Log** command again. To stop recording algorithm results without deleting the log file itself, use the **Close Log** command of the **File** menu.

Output Log Dialog Window
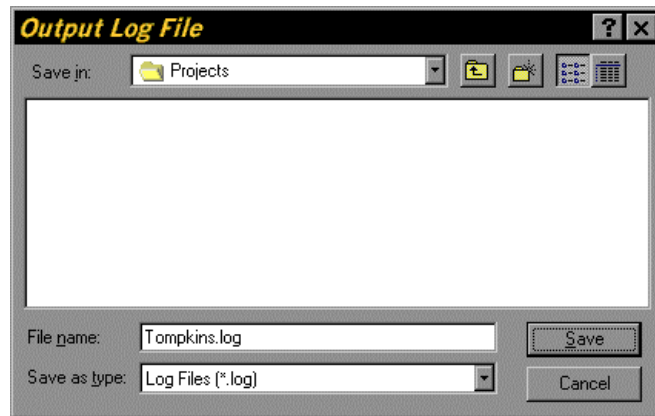
Figure 5.8. Output Log Selection Dialog Window

Close Log

Use this command to close the current output log. No further information or algorithm results will be written to the output log, but the output log file itself will not be deleted. Reopening the same log file with the **Output Log** command will erase all the information in the log file, since the Output Log command always creates a new file.

Print

Use this command to print a document. This command presents a **Print** dialog window, where you may specify the range of pages to be printed, the number of copies, the destination printer, and other printer setup options.

You can also copy the all views to the clipboard with the **Copy** command of the **Edit** menu and then paste the views in other Windows applications.

Print Shortcuts

Toolbar:

Keys: CTRL+P

Print Dialog Window
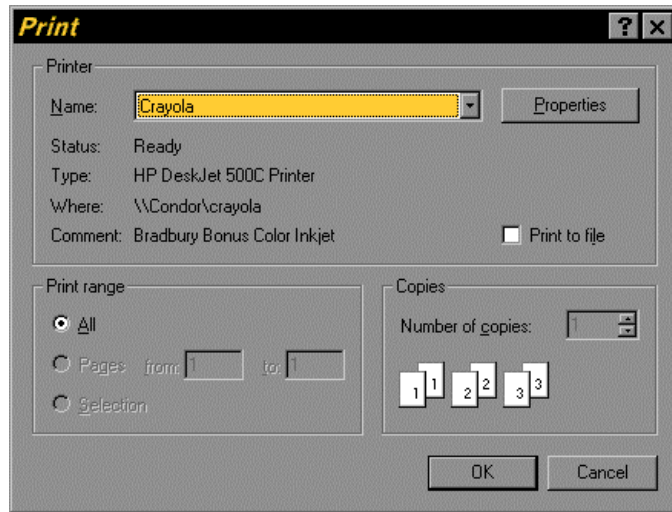
Figure 5.9. Print Dialog Window

Print Data Items

The following options allow you to specify how the current view should be printed:

Printer

This is the active printer and printer connection. Choose the Setup option to change the printer and printer connection.

Setup

Displays a **Print Setup** dialog window, so you can select a printer and printer connection.

Print Range

Specify the pages you want to print:

Table 5.2. Print Range Options

Option	Legend
All	Prints the entire document.
Selection	Prints the currently selected text.
Pages	Prints the range of pages you specify in the From and To boxes.

Copies

Specify the number of copies you want to print for the above page range.

Collate Copies

Prints copies in page number order, instead of separated multiple copies of each page.

Print Quality

Select the quality of the printing. Generally, lower quality printing takes less time to produce.

Print Progress Dialog

The Printing dialog window is shown during the time that **Spiral** is sending output to the printer. The page number indicates the progress of the printing.

To abort printing, choose **Cancel**.

Print Preview

Use this command to display the active view as it would appear when printed. When you choose this command, the main window will be replaced with a **Print Preview** dialog window in which one or two pages will be displayed in their printed format. The toolbar of the Print Preview window offers you options to view either one or two pages at a time; move back and forth through the document; zoom in and out of pages; and initiate a print job.

Print Preview Shortcuts

Toolbar:

Print Preview Window
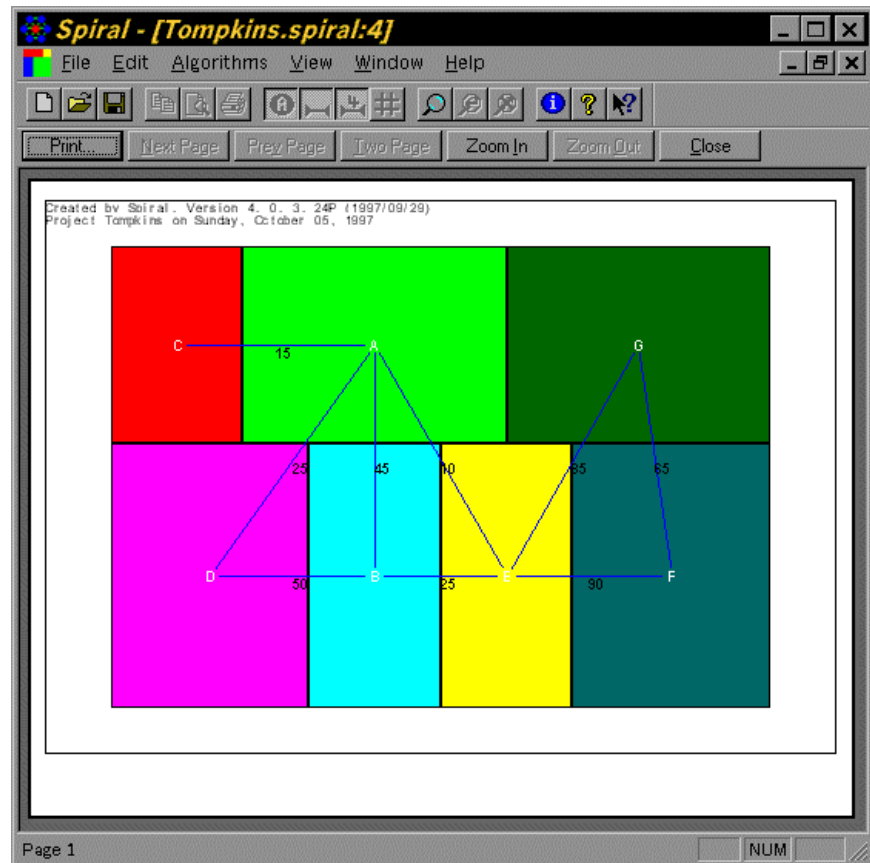
Figure 5.10. Print Preview Window

Print Preview Commands

The print preview toolbar offers you the following options:

Print

Bring up the print dialog window, to start a print job.

Next Page

Preview the next printed page.

Prev Page

Preview the previous printed page.

One Page / Two Page

Preview one or two printed pages at a time.

Zoom In

Take a closer look at the printed page.

Zoom Out

Take a larger look at the printed page.

Close

Return from print preview to the editing window.

Print Setup

Use this command to select a printer and a printer connection. This command presents a **Print Setup** dialog window, where you specify the printer and its connection. This printer and these options will then be used by all subsequent **Print** commands. The same changes can also be made from the main Windows Control Panel.

Print Setup Dialog Window
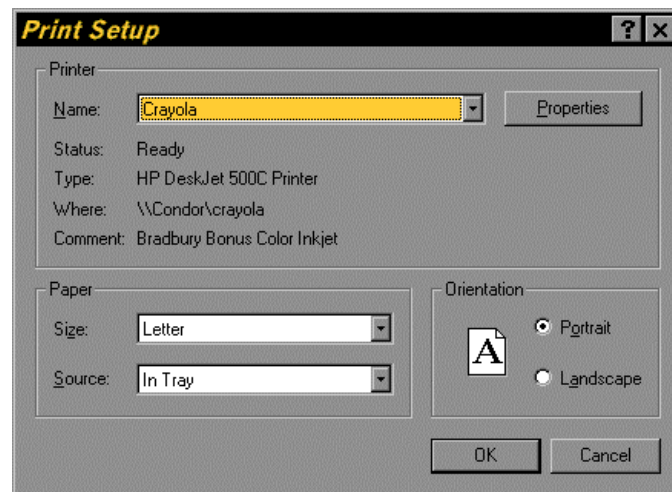
Figure 5.11. Print Setup Dialog Window

Print Setup Data Items

The following options allow you to select the destination printer and its connection.

Printer

Select the printer you want to use. Choose the Default Printer; or choose the Specific Printer option and select one of the current installed printers shown in the box. You install printers and configure ports using the Windows Control Panel.

Orientation

Choose Portrait or Landscape.

Paper Size

Select the size of paper that the document is to be printed on.

Paper Source

Some printers offer multiple trays for different paper sources. Specify the tray here.

Options

Displays a dialog window where you can make additional choices about printing, specific to the type of printer you have selected.

Network...

Choose this button to connect to a network location, assigning it a new drive letter.

Most Recently Used Files

Every time a project is saved, **Spiral** adds the fully qualified path and file name of the project data file to the list of the most recently used (MRU) files. The eight most recently used files are listed in the **File** Menu and saved in the Registry between sessions. You can bypass the **Open** command and open one of those projects directly by clicking on its file name.

Exit

The **Exit** command of the **File** menu terminates the **Spiral** program.

If there is a project currently open and if it has been modified, then the program will display the **Save Changes** dialog window and ask if you wish to save those changes, discard the changes, or if you wish to abort the termination of the application. The **Save Changes** dialog window is illustrated in Figure 5.2.

The **Spiral** program can be terminated in the same way as all Windows programs by double clicking on the system menu box or by selecting the **Exit** command.

Edit Menu

All the data items of the current project can be modified while executing the **Spiral** program. Most of the data items can be edited with commands from the Edit menu. Some overall project characteristics can be changed with commands on the File menu. Finally, some algorithm parameters can be changed with the commands on Algorithms menu.

Add Department

The **Add Department** command of the **Edit** menu allows you to interactively add a department to the current layout project. The command displays the **Add Department** dialog window in which the department data can be entered. Choose **OK** to add the department with the entered department data. Choose **Cancel** to cancel the dialog window and *not* to add the new department.

The new department will have all relations equal to zero with the other departments and the outside. You can change the relations with the **Relation** and **Relation with Outside**, or **All Relations** commands.

Add Department Dialog Window

The **Add Department** dialog window contains three pages, each selected by a one of the tabs: **Input**, **Continuous**, and **Discrete**. When you are adding a department, only the input page is relevant. You can view the continuous and

discrete department data pages after all the required data on the input page have been entered.
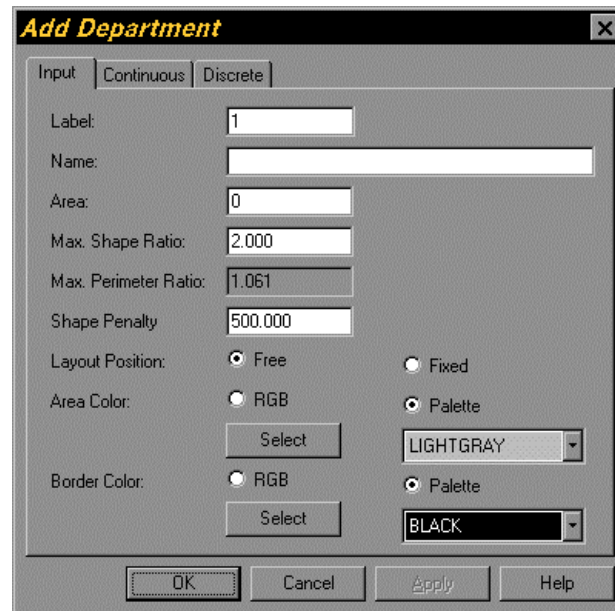
Figure 5.12. Add Department Dialog Window

Add Department Data Items

The data items are identical to those for editing a department. See the **Department Data Items** for further information.

Delete Department

The **Delete Department** command of the **Edit** menu allows you to interactively delete a department from the current layout project. The command displays the **Delete Department** dialog window in which the department data can be reviewed. If you press **Ok** you will be asked to confirm the deletion of the department, since deleting the department will permanently remove all the data associated with this department from the project. If you press **Cancel**, the department will not be deleted from the project.

Delete Department Dialog Window
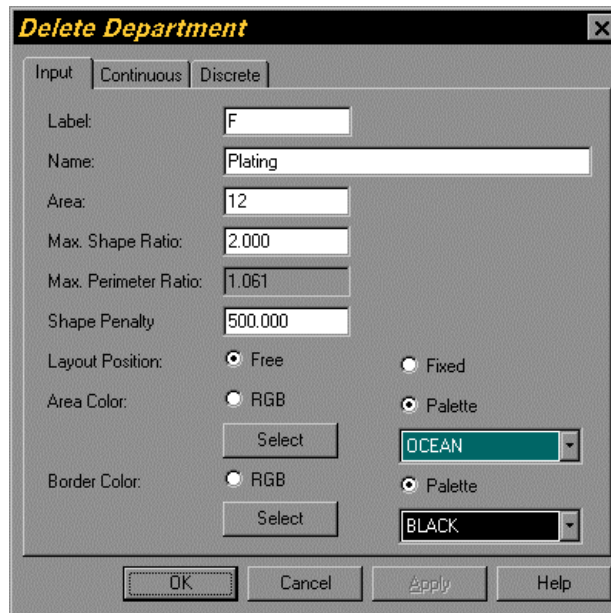
Figure 5.13. Display of Department to be Deleted Dialog

Confirm Delete Department Dialog Window
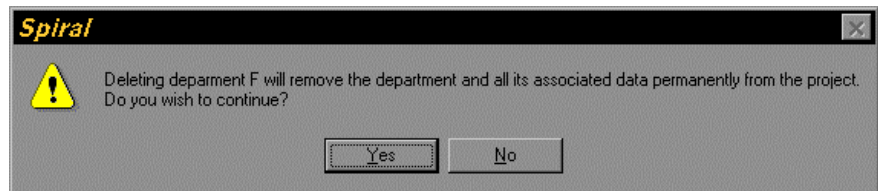
Figure 14. Confirm Deletion of a Department Dialog Window

Delete Department Data Items

The data items are identical to those for editing a department. See the **Department Data Items** for further information.

Delete Department by Label

The **Delete Department by Label** command of the **Edit** menu will display a list with all the labels of the departments in the current project. The **Select Department by Label** dialog window is illustrated in Figure 5.15. After a department has been selected with its label, the department data can be deleted just like in the **Delete Department** command by pressing the **Ok** button. While the **Delete Department** dialog is shown, choose **OK** to retain the delete department and choose **Cancel** to cancel the dialog window and not to delete the department. In either case, you are returned to the **Select Department by Label** dialog window and can then select the next department to be deleted by its label. Pressing the **Cancel** button will terminate the department selection dialog window.

Select Department to Delete by Label Dialog Window
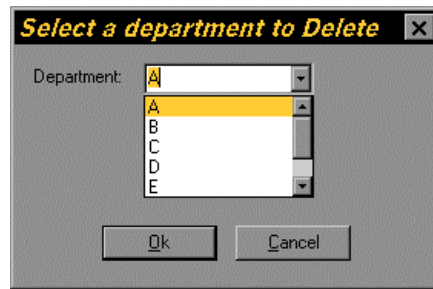
Figure 5.15. Select a Department to Delete by Its Label Dialog

Department

The **Department** command of the **Edit** menu allows you to change the data of a single department. After you have selected the command from the menu, the cursor changes to a selection arrow and you can select the department by clicking the left mouse button while the cursor is over the department node or area. Alternatively, you can select the department to be edited immediately without using the menu by moving the cursor on top of the node or area of the department you want to edit and then clicking the right button of the mouse and selecting Edit from the context sensitive menu. Finally, you can also select a department for editing by its label with the **Department by Label** command. The command displays then the **Select Department by Label** dialog window.

The **Edit Department** dialog window is contains three pages: **Input**, **Continuous**, and **Discrete**. The Input page contains the initial department data, the Continuous page contains the data related to continuous algorithms. Finally, the Discrete page contains the data when the department consists of unit squares.

Edit the department data. Choose **OK** to retain the edited department data. Choose **Cancel** to cancel the dialog window and *not* to change the department data.

Edit Department Dialog Window (Input Page)

Figure 5.16. Edit Department Dialog Window (Input Page)

Edit Department Data Items (Input Page)

Label

The department label can consist of at most seven characters. Only letters, digits and underscores are allowed in the department label. The label must be unique for this department in the project.

Name

The department name can be at most 63 characters. Only letters, digits, spaces, and underscores are allowed in the department name. The department name can contain a description of the department function.

Area

The department area must be smaller than or equal to the building area and be expressed in units compatible with the building dimensions, i.e., if the building dimensions were given in feet then the department areas must be given in square feet. The area on the Input page is the specified area for the department. Various algorithms might create a department with either a continuous or discrete area that is smaller or larger than the specified area.

Layout Position

Setting the layout position to free will later on allow the department to be moved in the block layout improvement steps. Setting the layout position to fixed will prevent this department to be part of a department exchange in the block layout improvement steps. However, other departments may move around this particular department, causing the location of this department to be moved even though its position is fixed. For example, if a department is fixed and located on the perimeter of the adjacency graph, the department may still move to the center of the block layout caused by a

sequence of exchanges involving other departments. There is currently no status switch that keeps a department exactly in its original location.

Max. Shape Ratio

The Maximum Shape Ratio is the limit value for the shape ratio of a department before it gets penalized in the shape adjusted distance score. The department shape ratio is the maximum of the length to width and width to length ratio of the smallest rectangle that completely encloses the department. For example the shape ratio of a square is one and the shape ratio of a three by one rectangle is equal to three. If a department shape ratio exceeds its maximum shape ratio then it will get penalized. If the department shape ratio exceeds the maximum shape ratio then the shape adjusted distance score is the sum of the flow distance score and the department shape ratio excess over the maximum shape ratio times the **Shape Penalty**. The term shape factor is also commonly used for shape ratio. The acceptable value of the maximum shape ratio depends on the department function, so each department can have a different maximum shape ratio. Only the block exchange algorithms use the maximum shape ratio to penalize block layouts to avoid excessively narrowly shaped departments.

Use the **Max. Shape Ratio** command of the **Edit** menu to change the maximum shape ratio for all departments simultaneously.

Max. Perimeter Ratio

The Maximum Perimeter Ratio is the limit value for the ratio of the department perimeter divided by the perimeter length of a square department with the same area. For example the perimeter ratio of a square is one and the perimeter ratio of a four by one rectangle is equal to 1.25. A higher value indicates a department with a more convoluted shape.

For rectangular departments there exists a one to one correspondence between the perimeter ratio of a department and the shape ratio. In **Spiral** the maximum perimeter ratio is computed from the Maximum Shape Ratio and only used as an output variable, i.e., it is displayed as information for the user.

Shape Penalty

The Shape Penalty is the factor by which the excess of the department's shape ratio over the maximum shape ratio for this department gets multiplied if it exceeds the maximum ratio and this product gets added to the shape adjusted distance score to avoid long narrow departments. A higher shape penalty will tend to make departments more like squares. A low or zero shape penalty will allow more long and narrow departments. The shape penalty cannot be negative. The acceptable value of the shape penalty depends on the department function, so each department can have a different shape penalty. Only the block exchange algorithms use the shape penalty to penalize block layouts to avoid excessively narrowly shaped departments.

Use the **Shape Penalty** command of the **Edit** menu to change the shape penalty for all departments simultaneously.

Area and Border Color

The area and border colors of the department are only used in the display of the block layout, not in the display of the hexagonal adjacency graph. The colors can be either the predefined palette colors or any color for which you have specified the RGB values. You select this option by selecting either the **RGB** or **Palette** options.

Using palette colors is slightly more efficient than using RGB colors in the display of departments. You can select one of the palette colors from the dropdown list. The list of predefined palette colors is given in Table 5.3.

Table 5.3. Palette Colors for Department Area and Border

BLACK	DARKGRAY
BLUE	NAVY
GREEN	FOREST
CYAN	OCEAN
RED	BROWN
MAGENTA	PURPLE
YELLOW	OLIVE
WHITE	GRAY

You can specify the RGB values by clicking the **Select** button underneath the **RGB** button. The **Color** dialog window is displayed, which allows you to select from a set of colors or to set the RGB values directly. The **Color** dialog window is illustrated in Figure 5.17.

The **Color** dialog window is a common dialog window and its exact appearance depends on the version of your Windows operating environment, the version of the Microsoft runtime libraries, and the number of colors or color depth of your Windows display that are currently installed on your computer.
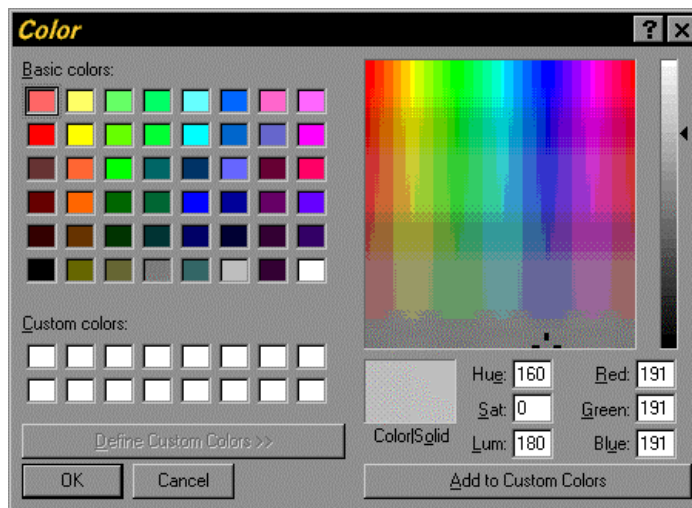
Figure 5.17. RGB Color Selection Dialog Window

Edit Department Dialog Window (Continuous Page)

Figure 5.18. Edit Department Dialog Window (Continuous Page)

Edit Department Data Items (Continuous Page)

Grid X and Y

The grid x and y coordinate indicate the location of the department node in the hexagonal adjacency graph. The y-axis is oriented downwards and left along the axis of the hexagonal graph, i.e., y coordinates increase from the top of the screen to the bottom. The x coordinates increase from left to right.

Layout X and Y

The layout x and y coordinate indicate the location of the department in the two-dimensional layout matrix. The y-axis is oriented downwards, i.e., y coordinates increase from the top of the screen to the bottom. The x coordinates increase from left to right.

Origin X and Y

The origin x and y of a departments are the horizontal (width) and vertical (depth) coordinates of the top left corner of the department relative to the top left corner of the building. The x coordinate increases from left to right, the y coordinate increases from top to bottom of the screen. The coordinates are real numbers, i.e. they can have fractional values. The department located in the top left corner of the building has by definition origin x and y coordinates equal to (0, 0). The units are the same as for the building dimensions.

Extent X and Y

The x and y extent of a department are the horizontal (width) and vertical (depth) dimensions of the smallest rectangle that completely encloses the department. For rectangular shaped departments this is equal to the department dimensions. The

dimensions are real numbers, i.e. they can have fractional values. The units are the same as for the building dimensions.

Centroid X and Y

The x and y centroid coordinates of a department are the horizontal and vertical coordinates of the center of gravity of the department. For rectangular shaped departments the centroid is located halfway between the two boundaries. The coordinates are real numbers, i.e. they can have fractional values. The units are the same as for the building dimensions.

Area

Some algorithms might create a department with a continuous area smaller (or larger) than the specified area. The actual continuous area is computed and shown on this page.

Perimeter

The actual perimeter length of the department is shown on this page.

Shape Ratio

The shape ratio of a department is the maximum of the depth to width and width to depth ratio of the smallest rectangle that completely encloses the department. For example the shape ratio of a square is one and the shape ratio of a three by one rectangle is equal to three.

Perimeter Ratio

The perimeter ratio of a department is the ratio of its actual perimeter length divided by the perimeter length of a square department with the same area. For example the perimeter ratio of a square is one and the perimeter ratio of a four by one rectangle is equal to 1.25. A higher value indicates a department with a more convoluted shape. For rectangular departments there exists a one to one correspondence between the perimeter ratio of a department and the shape ratio. In **Spiral** the perimeter ratio is only displayed as information for the user.

Edit Department Dialog Window (Discrete Page)
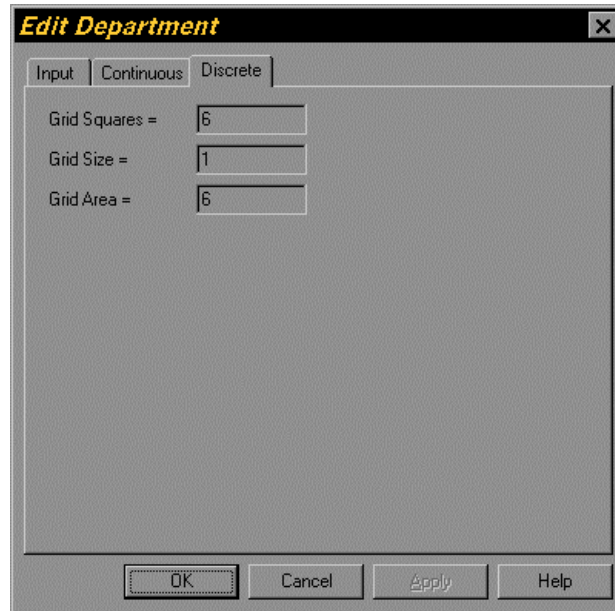
Figure 5.19. Edit Department Dialog Window (Discrete Page)

Edit Department Data Items (Discrete Page)

Grid Squares

The number of unit squares in the department. This number will be an integer number, equal to the department area divided by the square of the grid size and then rounded to the nearest integer if necessary.

Grid Size

The grid size determines the number of unit squares in a department and the building. The grid size is equal to the length of the side of the unit square. The units are the same as for the building dimensions.

Grid Area

The grid area of a department is equal to its number of unit squares multiplied by the unit square area, which is equal to the square of the grid size. Because of round off effects the discrete grid area of a department might not be exactly equal to its specified area. The grid area must be expressed in units compatible with the building dimensions, i.e., if the building dimensions were given in feet then the grid area must be given in square feet.

Department Context Menu

You can also display and execute commands from the department context menu by clicking the right button of the mouse when the cursor is over the department area in the layout view or over the department node in the graph view. Right clicking on a department and then selecting an action is equivalent to selecting an action from the Edit menu and then left clicking on a department.

Dragging a Department Node

You can also change the position of the department node in the adjacency graph directly by moving the cursor onto the node symbol of the department you want to move and then pressing and holding down the left button of the mouse. The department node will then track or follow the cursor as long as you keep the left button of the mouse depressed. To stop dragging the department node release the left button of the mouse. The department node will be placed in the nearest vertex position of the hexagonal adjacency graph if this position is unoccupied by another department. If you drag the department node outside the world coordinate boundary box or if its new vertex position is occupied, then the department node will be returned to its original location.

Fixing the Location of a Department in the Block Layout

You can fix the graph and layout position of a department. This prevents a department from being part of an adjacency graph or block layout improvement exchange. However, a department may still move in the block layout because other departments move around it in a sequence of exchange improvements. There is currently no foolproof method or status switch that keeps a department exactly in its original location in a block layout.

For example, follow these steps in order to fix the shipping department in the back of the layout and the office department in the front of the layout. First, move the node corresponding to the shipping department to the highest row in the adjacency graph and the node corresponding to the office department to the lowest row in the adjacency graph. Then, set the status of both departments to be fixed in place. Finally, set the layout construction procedure to use the level building orientation and not to attempt any improvement exchanges. The shipping department will be at the back of the block layout and the office will be at the front. If you allow exchange improvements, the shipping and office departments may still be at the back and front, respectively, but this is not assured.

Department by Label...

The **Department by Label** command of the **Edit** menu will display a list with all the labels of the departments in the current project. The **Select Department by Label** dialog window is illustrated in Figure 5.20. After a department has been selected with its label, the department data can be edited just like in the **Department** command by pressing the **Ok** button. While the **Edit Department** dialog is shown, choose **OK** to retain the edited department data and choose **Cancel** to cancel the dialog window and *not* to change the department data. In either case, you are returned to the **Select Department by Label** dialog window and can then select the next department to be edited by its label. Pressing the **Cancel** button will terminate the department selection dialog window.
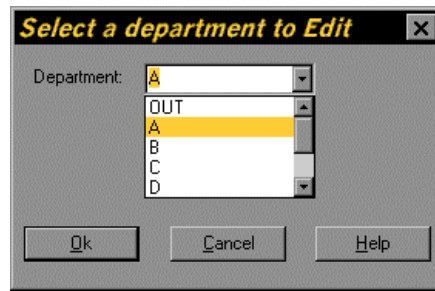
Select Department by Label Dialog Window

Figure 5.20. Select to be Edited Department by Label Dialog Window

Relation

The **Relation** command of the **Edit** menu allows you to interactively change the original asymmetric relation between two departments. Select the **Relation** command and the cursor will change to an up arrow in the graph and layout views. Move the cursor on top of the node or area of the first department and click the left button of the mouse. Then move the cursor on top of the node or area of the second department and click the left button of the mouse again. The **Edit Relation** dialog window will be shown. The relation dialog window is illustrated in Figure 5.21.

Edit the relation value. Click on **OK** to accept the modifications that you have made to the relation. If you click on **Cancel** then all the modifications that you made to the relation will be discarded and the relation will not be modified.

Alternatively, you can select the relation to be edited by holding down the Ctrl key and clicking the right mouse button while the cursor is over the first and second department. A third way to select the relation to be edited is to click the right mouse button while the cursor is on the relationship edge itself. The context sensitive menu for edges will be shown, from which the edit command can be selected. This latter method works only for nonzero relationships in the upper right triangle of the relationship matrix.

To edit the relation of a department with the outside, use the **Relation with Outside** command. If you have incorrectly selected the first node of the relation, select the **Relation** command again to start anew with the first node.

Edit Relation Dialog Window
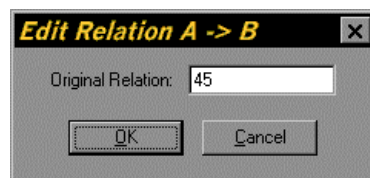
Figure 5.21. Edit Original Relation Dialog Window

Relation with Outside

The **Relation with Outside** command of the **Edit** menu allows you to interactively change the original asymmetric relation between a department and the outside. Select the **Relation with Outside** command and the cursor will change to an up

arrow in the graph and layout views. Move the cursor on top of the node or area of the department and click the left button of the mouse. The **Relation** dialog window will be shown. The **Edit Relation** dialog window is illustrated in Figure 5.22.

Click on **OK** to accept the modifications that you have made to the relation with the outside. If you click on **Cancel** then all the modifications that you made to the relation with the outside will be discarded and the relation will not be modified.

Edit Relation with Outside Dialog Window
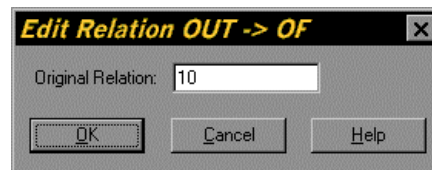
Figure 5.22. Edit Original Relation with Outside Dialog Window

All Relations...

Use this command to display or edit all the original, asymmetrical relations between the departments. The command will display the **All Relations** dialog window, which allows the modification of the relations. The All Relations dialog window is illustrated in Figure 5.23.

This dialog window shows the original, asymmetrical relations between the departments. Each row represents an origin department and each column represents a destination department. You can use the scrollbars to move around the relationship matrix, if there are more departments than can be displayed simultaneously in the dialog window. You can also move the arrow keys to move around the relationship matrix.

Click on any relationship and you will be able to modify that relation with the **Edit Relation** dialog window. You can also click on the **Edit** button or press **E** or **Alt E** to edit the currently selected relationship, which is indicated by a thin black border. You can edit a relation as many times as you want and as many relations as you want.

When you have finished editing the relations, click on **OK** to accept the modifications that you have made to the relations. If you click on **Cancel** then all the modifications that you have made to the relations will be discarded and none of the relations will be modified.

Edit All Relations Dialog Window

Edit a Relation

	OUT	SA	RE	FR	UP	FS	CU	SE	SH	OF	ST
OUT		0	45	0	0	0	0	0	55	10	0
SA	0	0	22	35	1	0	0	0	0	-17	0
RE	0	0	0	2	1	12	4	0	0	4	10
FR	0	0	0	0	28	0	0	0	0	-17	1
UP	0	0	0	0	0	0	6	14	42	3	4
FS	0	0	0	0	0	0	35	9	2	3	0
CU	0	0	0	0	0	0	0	16	0	3	0
SE	0	0	0	0	0	0	0	0	0	3	1
SH	0	0	0	0	0	0	0	0	0	4	4
OF	0	0	0	0	0	0	0	0	0	0	3
ST	0	0	0	0	0	0	0	0	0	0	0

Edit

OK   Cancel

Figure 5.23. Edit All Original Relations Dialog Window

Building Dimensions...

The **Building Dimensions** command of the **Edit** menu allows you to change the dimensions of the building. The **Building Dimensions** dialog window will be shown.

Click on **OK** to accept the modifications that you have made to the building width and depth. If you click on **Cancel** then all the modifications that you made to the building dimensions will be discarded and the building dimensions will not be modified.

Building Dimensions Dialog Window

Edit Building Dimensions

Building Width: 10

Building Depth: 7

OK   Cancel   Help

Figure 5.24. Edit Building Dimensions Dialog Window

Building Dimensions Data Items

Building Width

The building width refers to the horizontal dimension of the building ground plan. It must be in units compatible with the department areas. The building always has a rectangular shape. The building area is computed as the product of the building width and building depth. The building and department areas should be expressed in

compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet.

Building Depth

The building depth refers to the second dimension of the building ground plan (which will be displayed vertically on the screen). It must be in units compatible with the department areas. The building area is computed as the product of the building width and building depth. The building and department areas should be expressed in compatible units to the building width and depth, i.e., if the building depth and width are expressed in feet then the building and department areas must be expressed in square feet.

The building area, which is computed as the product of the building width times the building depth, must be larger than or equal to the sum of all the department areas before a layout construction algorithm can be executed.

Max. Shape Ratio...

The **Max. Shape Ratio** command of the **Edit** menu allows you to change the maximum shape ratio simultaneously for all departments. The **Maximum Shape Ratio** dialog window will be displayed.

Click on **OK** to accept the modifications that you have made to the maximum shape ratio. The Maximum Shape Ratio of all departments will be set to this new value. If you click on **Cancel** then all the modifications that you made to the maximum shape ratio will be discarded and the maximum shape ratio will not be modified. If you want to the change the Maximum Shape Ratio of a single department, use the **Department** command for that department.

Maximum Shape Ratio Dialog Window
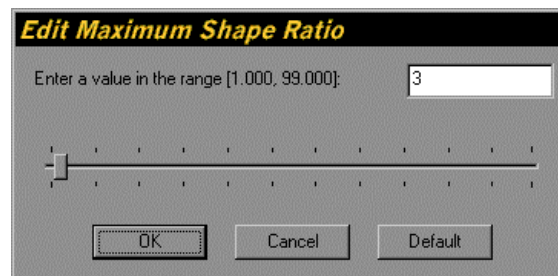
Figure 5.25. Maximum Shape Ration Dialog Window

Maximum Shape Ratio Data Items

The Maximum Shape Ratio is the limit value for the shape ratio of a department before it gets penalized in the shape adjusted distance score. The department shape ratio is the maximum of the length to width and width to length ratio of the smallest rectangle that completely encloses the department. For example the shape ratio of a square is one and the shape ratio of a three by one rectangle is equal to three. If a department shape ratio exceeds its maximum shape ratio then it will get penalized. If the department shape ratio exceeds the maximum shape ratio then the shape adjusted distance score is the sum of the flow distance score and the department shape ratio excess over the maximum shape ratio times the **Shape Penalty**. The term shape

factor is also commonly used for shape ratio. The acceptable value of the maximum shape ratio depends on the department function, so each department can have a different maximum shape ratio. Only the block exchange algorithms use the maximum shape ratio to penalize block layouts to avoid excessively narrowly shaped departments.

The perimeter ratio is the ratio of the current perimeter length of a department divided by the perimeter length of a square department with the same area. For rectangular departments there exists a one to one correspondence between the shape ratio and the perimeter ratio. The Maximum Perimeter Ratio is computed from the Maximum Shape Ratio and is an output only variable, it cannot be set by you.

Shape Penalty...

This **Shape Penalty** command of the **Edit** menu allows you to change the shape penalty for all departments simultaneously. The shape penalty is the factor by which the excess of the department's shape ratio over the **Max. Shape Ratio** gets multiplied if it exceeds the maximum ratio and this product gets added to the shape adjusted distance score to avoid long narrow departments. A higher shape penalty will tend to make departments more like squares. A low or zero shape penalty will allow more long and narrow departments. The shape penalty cannot be negative.

Click on **OK** to accept the modifications that you have made to the shape penalty. If you click on **Cancel** then all the modifications that you made to the shape penalty will be discarded and the shape penalty will not be modified.

Shape Penalty Dialog Window
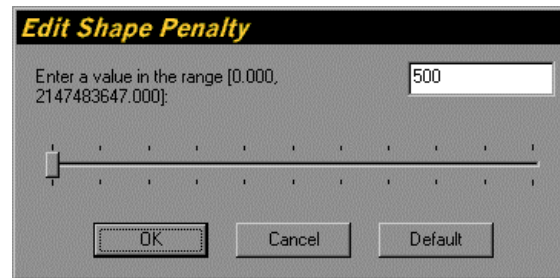
Figure 5.26. Shape Penalty Dialog Window

Shape Penalty Data Items

If the shape ratio of a department violates the maximum allowable shape ratio, then a penalty will be added to the flow distance score of the layout. Let s_i be the shape ratio of department i, and let S_i be the maximum shape ratio and let p_i be the shape penalty, then the total shape penalty for all departments P that is added to the flow distance score is equal to

$$P = \sum_{i=1}^{N} p_i \cdot \max\{0, s_i - S_i\} \tag{5.1}$$

Grid Size...

This **Grid Size** command of the **Edit** menu allows you to change the grid size. The grid size determines the number of unit squares in a department and the building.

The grid size is equal to the length of one side of the unit square. The discrete area of a department is equal to its number of unit squares times the square of the grid size. Because of round off effects the discrete area of a department might not be exactly equal to its continuous area.

Click on **OK** to accept the modifications that you have made to the grid size. If you click on **Cancel** then all the modifications that you made to the grid size will be discarded and the grid size will not be modified.

Grid Size Dialog Window
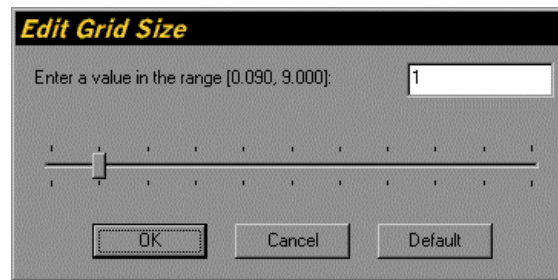
Figure 5.27. Grid Size Dialog Window

Report Level...

The **Report Level** command of the **Edit** menu displays the **Report Level** dialog window, which allows you to set the level of detail written to the **Output Log** file and the number of pauses during algorithm execution. There are six levels ranging from 0 to 5, which generate increasingly more detailed output and algorithm pauses.

Click on **OK** to accept the modifications that you have made to the report level. If you click on **Cancel** then all the modifications that you made to the report level will be discarded and the report level will not be modified.

Report Level Dialog Window
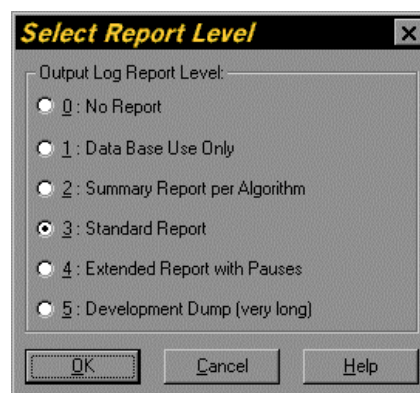
Figure 5.28. Report Level Dialog Window

Report Level Data Items

Levels of Detail

There are six levels of detail and pauses for reporting:

0. NONE generates no output per algorithm and does not halt the algorithm execution. This level is used when maximum execution speed and minimal reporting is desired.

1. DATABASE generates one line of strictly numerical output per algorithm. No titles or headers are included. This level is primarily used to create a data base file, which can then be manipulated in a spreadsheet or statistical analysis program.

2. SUMMARY displays the total cost plus the algorithm run time. It is useful if you is only interested in the final results. This level of output should be used if you is interested in performing timing studies. Higher level of details corrupt timing results due to user interaction delays and graphics creation delays.

3. STANDARD generates the total cost for each of the algorithm components. The program runs without interruption until the complete algorithm is finished. If you have selected ALL, then the program runs uninterrupted for the 18 different combinations.

4. EXTENDED displays the total cost during each of the algorithm modules and the run time so far. The program halts frequently to allow you to observe the algorithm process.

5. DEVELOP generates extremely detailed output plus a very large number of intermediate results. This mode is only useful for debugging purposes or to observe the most detailed workings of the algorithms. The output is extremely long for large problems.

Algorithm Executing Pause

If you have selected a report level higher than three, the algorithms will pause at certain points during their execution and give you the option to continue the execution, abort the execution, or to change the report level. The **Pause Algorithm** dialog window will be shown. Choose Continue to continue the algorithm execution, Abort to terminate this algorithm, or Report Level to bring up the **Report Level** dialog window.

Pause Algorithm Dialog Window

Figure 5.29. Pause Algorithm Dialog Window

Seed...

The **Seed** command of the **Edit** menu displays the **Seed** dialog window, which allows you to set the new seed for the random number generator. Several algorithms use the random numbers to make random choices during their execution. The graph algorithms use random numbers to break ties in locating department nodes in the adjacency graph. The layout improvement algorithms based on simulated annealing use random numbers to select the next two departments to be tested for a possible exchange. An algorithm that uses the random numbers will always produce the same identical results if you select the same algorithm settings and set the same random

number seed. The algorithm most likely will yield a different result for different random number seeds.

Click on **OK** to accept the modifications that you have made to the random number seed. If you click on **Cancel** then all the modifications that you made to the random number seed will be discarded and the random number seed will not be modified.
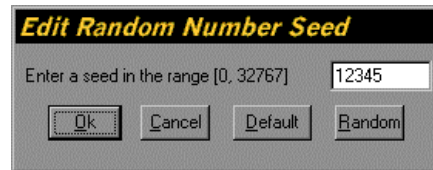
Seed Dialog Window

Figure 5.30. Seed Dialog Window

For further information on the function of this dialog window see the **Seed** command. For a detailed explanation of the seed parameters see the **Seed Data Items**

Seed Data Items

Any positive seed value between 1 and 32767 is a valid starting seed for the random number generator. If a zero seed value is specified, the computer will create a random seed based on the computer clock.

Default

The default value for the seed is equal to one. This is the seed value when the program is originally started.

Random

If a value of zero is entered for the seed, then the program will select a random seed based upon the computer clock.

Max. Replications...

This **Max. Replications** command of the **Edit** menu allows you to change the maximum number of replications of an algorithm. The default number of replications is equal to 20.

Click on **OK** to accept the modifications that you have made to the maximum number of replications. If you click on **Cancel** then all the modifications that you made to the maximum number of replications will be discarded and the maximum number of replications will not be modified.

Maximum Replications Dialog Window
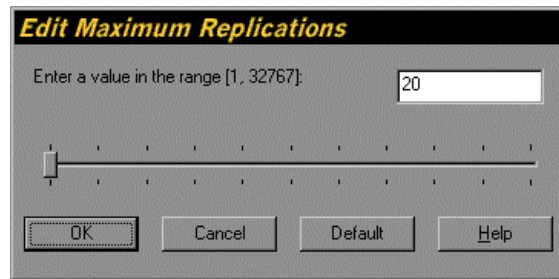
Figure 5.31. Maximum Replications Dialog Window

Maximum Replications Data Items

The graph construction algorithms often need to make a random choice among
several equivalent locations to place the next department. Similarly, the layout
improvement algorithms based on simulated annealing select random pair of
departments to be tested for possible exchange. Different replications of the same
algorithm can thus provide different adjacency graphs or block layouts. The higher
the number of replications, the more likely it is that a good adjacency graph or block
layout will be constructed. Of course, more replications require more computation
time.

Time Limit...

The maximum time limit is the maximum amount of time a single algorithm is
allowed to execute. The time limit is expressed in seconds. Click on **OK** to accept
the modifications that you have made to the time limit. If you click on **Cancel** then
all the modifications that you made to the time limit will be discarded and the time
limit will not be modified.

If an algorithms exceeds the time limit, then you will asked either to abort or continue
the algorithm with the Time Expiration dialog window. At that time you have also
the option to set a new time limit.

Time Limit Dialog Window
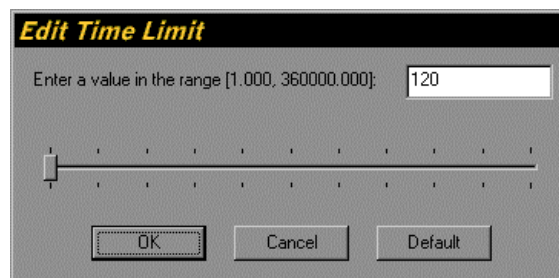
Figure 5.32. Time Limit Dialog Window

Time Limit Data Items

Currently, the time limit is only used to terminate the two, three and annealing
exchange algorithms if they have exceeded the time limit after one complete iteration,
i.e. after all possible two or three exchanges have been tested or when the annealing

temperature is decreased. So it is possible that the execution time of the improvement algorithm is actually larger than the time limit specified. The time limit is also used to terminate combination algorithms such as **All Graph**, **All Layout**, and **All Graph and Layout Algorithms** if the combination algorithm has exceeded the time limit after a component algorithm. Finally, the time limit is also used to terminate the **Graph Upper Bound** algorithm, which checks periodically if the time limit has been exceeded.

Time Limit Expiration Dialog Window
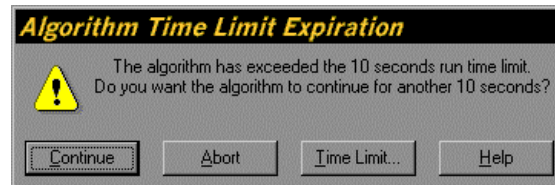
Figure 5.33. Time Limit Expiration Dialog Window

Copy

The **Copy** command of the **Edit** menu copies the contents of the currently active view to the Windows Clipboard. The contents can then be pasted into other Windows applications such as CAD to design the layout in further detail. The Graph and Layout views copy the view as currently displayed to the clipboard. The Notes and Statistics views copy all the data in text format to the clipboard.

Copy View Shortcuts

Toolbar:

Keys: CTRL+C

Algorithms Menu

Select Graph...

The **Select Graph** command of the **Algorithms** menu displays the **Select Graph** dialog window which lets you specify settings for the algorithm that will create a planar hexagonal adjacency graph for the current project. These algorithms are called graph algorithms. You must specify three algorithm settings: relationship tuple, improvement step procedure and tuple, and location tie breaker.

The **Graph Algorithm Selection** dialog window is shown Figure 5.34. When you press **OK** the graph algorithm will be executed with the current settings. If you press **Cancel**, no algorithm will be executed.

Select Graph Dialog Window
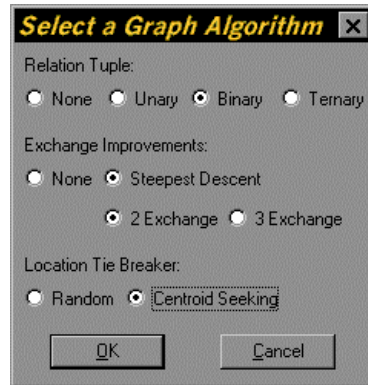
Figure 5.34. Graph Algorithm Selection Dialog Window

For further information on the function of this dialog window see the **Select Graph** command. For a detailed explanation of the graph algorithm parameters see the **Select Graph Data Items**

Select Graph Data Items

Relationship Tuple

The relationship tuple indicates on how many departments the adjusted relationship is based. Possible options are null, unary, binary, and ternary. The departments then enter the graph by decreasing adjusted relationship. The null tuple indicates that the next department will be chosen at random, without any regard to its relationships with other departments. The unary adjusted relationship sums the relationships of a department with all other departments. The binary adjusted relationship is the relationship between the current department and one other department. The ternary adjusted relationship is the relationship between the current department and two other departments.

Graph Improvement

After the original graph is constructed three possible improvement steps can be executed. The options are none, or steepest descent exchange with two exchange or three exchange.

None does not execute an improvement step.

Two Exchange attempts to improve the graph in a steepest descent manner by attempting two department exchanges. It computes the savings generated by removing two departments out of the graph and swapping their position. The savings are based on an increase in the adjacency score. The exchange with the largest savings among all possible combinations of two departments is determined and if these savings are positive then those two departments are exchanged. The process repeats until no further improvements can be made.

Three Exchange attempts to improve the graph in a steepest descent manner by attempting three department exchanges. It computes the savings generated by removing three departments out of the graph and swapping their position. The savings are based on an increase in the adjacency score. The exchange with the largest savings among all possible combinations of three departments is determined

and if these savings are positive then those three departments are exchanged. The process repeats until no further improvements can be made.

Computational processing time increases sharply with the amount of improvement processing.

Department Location Tie Breaker

When locating a department in the partial adjacency graph often alternative positions are possible. Two possible tie breaker rules can be used. The first one is Random, which places the department randomly in one of the alternative positions based on a random number. The second one is Centroid Seeking that places the department in the position closest to the centroid of the current (partial) adjacency graph. If there are still alternative positions after the first tie breaker then a position is chosen at random.

For further information see Goetschalckx (1992).

All Graphs

The **All Graphs** command of the **Algorithms** menu creates a planar hexagonal adjacency graph for the current project by executing all possible combinations of graph algorithm settings and retaining the adjacency graph with the highest adjacency score. In other words, it runs four relationship tuple times three improvement steps times two tie breakers for a total of 24 algorithms. For each combination of options the algorithm is run for the maximum number of iterations. The best adjacency graph is retained and displayed at the conclusion of the algorithm. Because of its extensive computations this command might take a long time to complete.

Graph Upper Bound

The **Graph Upper Bound** command of the **Algorithms** menu computes the upper bound or maximum value of the hexagonal adjacency score for the current project.

The formulation maximizes the adjacencies between departments and between a department and the outside, subject to the constraint that each department must have exactly six neighbors. These neighboring departments can be the artificial outside department. If a department has at least one outside department as a neighbor the relationship with the outside is satisfied and included in the objective function. In the original formulation all the adjacencies are binary variables, except the adjacencies with the outside department that are integer. To compute the graph upper bound all integer and binary variables are relaxed to their continuous equivalent, i.e. a linear relaxation is used. For further information see the formulation in **Graph Algorithms** and Goetschalckx (1992).

Since the computation of the upper bound may require a significant amount of time, the program allows you to limit the maximum execution time with the **Time Limit** command of the **Edit**.

Select Layout...

The **Select Layout** command of the **Algorithms** menu displays the **Layout Algorithm Selection** dialog window, which lets you specify settings for the algorithm that will create a block layout for the current project. These algorithms are called layout algorithms. You must first specify three algorithm settings: building orientation, exchange improvement step, and space allocation method. The **Layout**

Algorithm Selection dialog window is shown Figure 5.35. Because of its extensive computations this command might take a long time to complete.

When you press **OK** the block layout algorithm will be executed with the current settings. If you press **Cancel** then no algorithm will be executed.
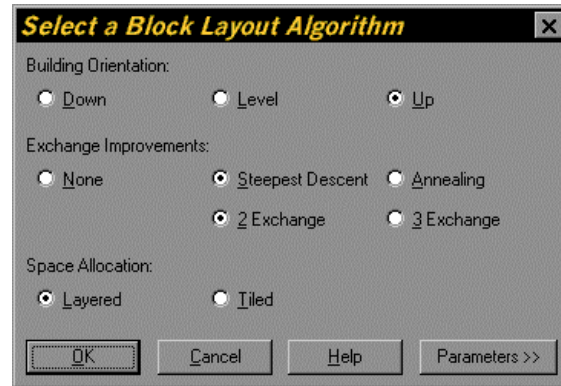
Select Layout Dialog Window

Figure 5.35. Layout Algorithm Selection Dialog Window

Select Layout Data Items

Building Orientation

The building orientation indicates to which of the possible three axes of the hexagonal adjacency graph the building width dimension is parallel. The adjacency graph has three main axes, horizontal or level, 60 degrees upward, and 60 degrees downwards of the horizontal level. The block layout construction algorithms will create a layout by putting departments in rows, where the rows are parallel to the building width dimension. Departments whose positions in the adjacency graph are on the same axis will be placed in the same row in the block layout.

Exchange Improvements

After the original block layout is constructed five possible improvement steps can be executed. The options are none, steepest descent two exchange and three exchange, and annealing exchange two exchange and three exchange.

None does not execute an improvement step.

Steepest Descent exchange attempts to improve the graph in deterministic and greedy manner by attempting two or three department exchanges. The exchange with the largest savings among all possible combinations of two or three departments is determined and if these savings are positive then those two or three departments are exchanged. The process repeats until no further improvements can be made.

Two Exchange attempts to improve the layout in a steepest descent manner by attempting two department exchanges. It computes the savings generated by removing two departments out of the graph and swapping their position. The savings are based on a decrease in the shape adjusted distance score. **Three Exchange** attempts to improve the graph in a steepest descent manner by attempting three department exchanges. It computes the savings generated by removing three departments out of the graph and swapping their position. The savings are based on a decrease in the shape adjusted distance score.

Annealing Exchange attempts to improve the graph in stochastic, non steepest descent manner by attempting two or three department exchanges. It computes the savings generated by removing three departments out of the graph and swapping their position. The savings are based on a decrease in the shape adjusted distance score. The two or three departments are chosen at random. If the savings are positive then the exchange is made. If the savings are negative, i.e. the shape distance score is higher, then the exchange can still be made with a certain probability depending on the how long the simulated annealing algorithm has been executing. The process repeats until no further improvements can be made.

For further information on two and three exchanges see the Block Layout section in the Algorithms chapter and Goetschalckx (1992). For further information on simulated annealing see Kirkpatrick et al. (1983) and Vechi and Kirkpatrick (1983).

Computational processing time increases sharply with the amount of improvement processing. Since the computation of the upper bound may require a significant amount of time, the program allows you to limit the maximum execution time with the **Time Limit** command of the **Edit** menu or by pressing the Parameters button.

Space Allocation

The **Layered** space allocation method divides the building area in strips or layers parallel to the orientation of the building. All departments located on an axis of the hexagonal adjacency graph parallel to the building orientation are assigned to a single layer. The algorithm then assigns department areas from left to right in each layer.

The **Tiled** space allocation method divides the building area into a set of non-overlapping department rectangles. The position of the department rectangles is derived from the hexagonal adjacency graph. The Tiled space allocation method has more flexibility than the Layered space allocation method and will yield on the average layouts with a lower distance score. However, the resulting layout may not have the structure that allows parallel material handling aisles. There is no guarantee that the Tiled space allocation method will yield a lower distance score than the Layered space allocation method for a particular layout project. Because the Tiled method examines many more alternatives than the Layered method, it requires substantially longer computation times.

Parameters

All layout improvement parameters can be set by pressing the Parameters button. The **Exchange Parameters** dialog window will be shown.

Set Layout Parameters

The pages with the shape, time, and annealing parameters of the Layout Parameters dialog window are shown in Figures 5.36, 5.37, and 5.38, respectively. Click on **OK** to accept the modifications that you have made to the layout algorithm parameters. If you click on **Cancel** then all the modifications that you made to the layout algorithm parameters will be discarded and the layout algorithm parameters will not be modified.

Further information on the annealing algorithm to construct block layouts can be found in the **Block Layouts** section of the Design Algorithms chapter.

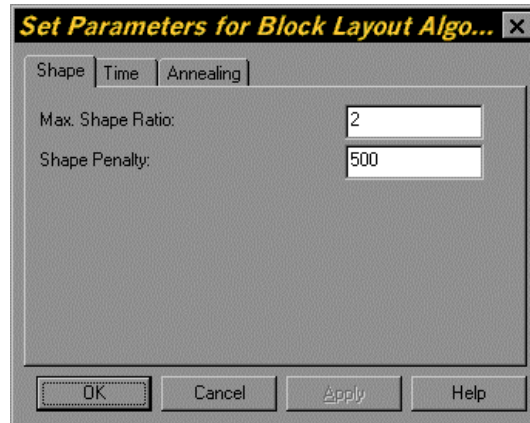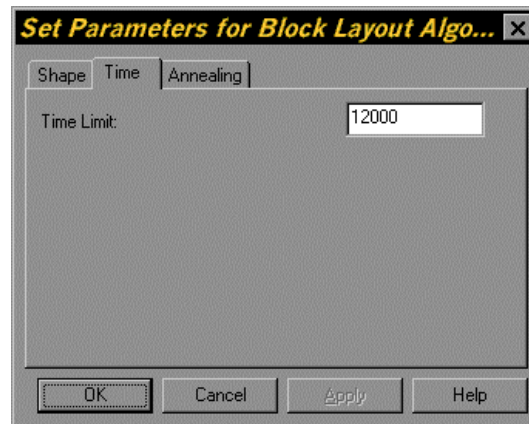### *Layout Parameters Dialog Window (Shape Page)*

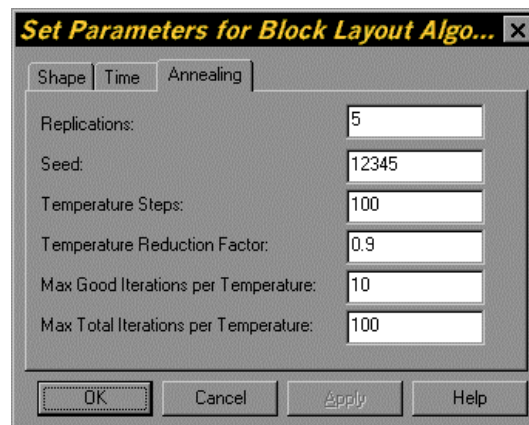*Figure 5.36. Layout Improvement Parameters Dialog (Shape Page)*

For further information on the function of this dialog window see the **Set layout Parameters** command. For a detailed explanation of the graph algorithm parameters see the **Layout Parameters Shape Page Data Items**.

Layout Parameters Data Items (Shape Page)

Max. Shape Ratio

The maximum shape ratio is the limit value for the shape ratio of a department before it gets penalized in the shape adjusted distance score. The department shape ratio is the maximum of the length to width and width to length ratio of the smallest rectangle that completely encloses the department. For example the shape ratio of a square is one and the shape ratio of a three by one rectangle is equal to three. If a department shape ratio exceeds its maximum shape ratio then it will get penalized. If the department shape ratio exceeds its maximum shape ratio then the shape adjusted distance score is the sum of the flow distance score and the department shape ratio excess over the maximum shape ratio times the **Shape Penalty**. The term shape factor is also commonly used for shape ratio. The acceptable value of the maximum shape ratio depends on the department function, so different departments can have different maximum shape ratios. Only the block exchange algorithms use the maximum shape ratio to penalize block layouts to avoid excessively narrowly shaped departments.

The maximum shape ratio can also be set for all departments simultaneously with the **Max. Shape Ratio** command of the **Edit** menu.

Shape Penalty

The Shape Penalty is the factor by which the excess of the department's shape ratio over the **Max. Shape Ratio** gets multiplied if it exceeds the maximum ratio and this product gets added to the shape adjusted distance score to avoid long narrow departments. A higher shape penalty will tend to make departments more like squares. A low or zero shape penalty will allow more long and narrow departments. The shape penalty cannot be negative.

If the shape ratio of a department violates the maximum allowable shape ratio, then a penalty will be added to the flow distance score of the layout. Let s_i be the shape ratio of department *i*, and let S_i be the maximum shape ratio and let p_i be the shape

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penalty, then the total shape penalty for all departments *P* that is added to the flow distance score is equal to

$$P = \sum_{i=1}^{N} p_i \cdot \max\{0, s_i - S_i\} \tag{5.2}$$

The shape penalty can also be set for all departments simultaneously with the **Shape Penalty** command of the **Edit** menu.

Layout Parameters Dialog Window (Time Page)

Figure 5.37. Layout Improvement Parameters Dialog (Time Page)

For further information on the function of this dialog window see the **Set layout Parameters** command. For a detailed explanation of the graph algorithm parameters see the **Layout Parameters Time Page Data Items**.

Layout Parameters Data Items (Time Page)

Time Limit

The maximum time limit is the maximum amount of time a single algorithm is allowed to execute. The time limit is expressed in seconds.

The Time Limit can also be set with the **Time Limit** command of the **Edit** menu.

Layout Parameters Dialog Window (Annealing Page)

Figure 5.38. Layout Improvement Parameters Dialog (Annealing Page)

For further information on the function of this dialog window see the **Set layout Parameters** command. For a detailed explanation of the graph algorithm parameters see the **Layout Parameters Annealing Page Data Items**.

Layout Parameters Data Items (Annealing Page)

Replications

The layout improvement algorithms based on simulated annealing select random pair of departments to be tested for possible exchange. Different replications of the same algorithm can thus provide different adjacency graphs or block layouts. The higher the number of replications, the more likely a high quality block layout will be constructed. Of course, more replications require more computation time. The default number of replications is equal to 20.

The number of replications can also be set with the **Max. Replications** command of the **Edit** menu.

Seed

The new seed for the random number generator. The layout improvement algorithms based on simulated annealing use random numbers to select the next two departments to be tested for a possible exchange. An algorithm will always produce the same identical results if you select the same algorithm settings and set the same random number seed. Any positive seed value between 1 and 32767 is a valid starting seed for the random number generator. If a zero seed value is specified, the computer will create a random seed based on the computer clock.

The seed can also be set with the **Seed** command of the **Edit** menu.

Temperature Steps

The maximum number of steps for each replication. A higher number of steps gives each algorithm more opportunities to improve the layout.

Temperature Reduction Factor

The factor by which the current temperature is multiplied to yield the next temperature. The factor must fall between zero and one. The lower or closer to zero the factor is, the faster the algorithm is forced to settle for a layout solution. The higher or closer to one the factor is, the more steps the algorithm has to find the layout solution.

Max. Good Iterations per Temperature

The maximum number of improving iterations for each temperature step. When the number of improving iterations exceeds this bound, the temperature is reduced to the next lower level.

Max Total Iterations per Temperature

The maximum number of iterations, improving and non-improving, for each temperature step. When the number of iterations exceeds this bound, the temperature is reduced to the next lower level.

All Layouts

The **All Layouts** command of the **Algorithms** menu creates a block layout for the current project by executing all possible combinations of block layout algorithm settings. In other words its runs three side orientations times five improvement steps time two space allocation methods for a total of 30 algorithms. The block layout with the lowest shape adjusted distance score is retained and displayed at the conclusion. Because of its extensive computations this command may take a long time to complete. The Tiled space allocation method is especially computation time intensive, and its execution can be disabled with the **Execute All Layouts** dialog window, which is illustrated below. When you press **Yes** all possible combinations of layout algorithms will be executed for the current adjacency graph. If you press **No**, no algorithm will be executed.
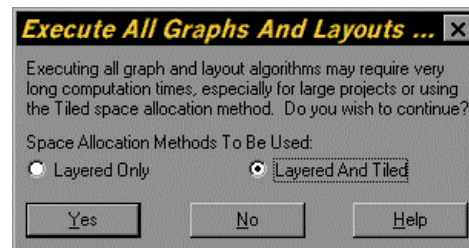
Execute All Layout Algorithms Dialog Window
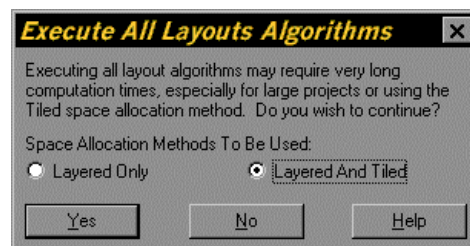
Figure 5.39. All Layout Algorithms Configuration Dialog Window

For further information on the function of this dialog window see the **All Layouts** command. For a detailed explanation of all layout algorithms parameters see the **Execute All Layout Algorithms Data Items**.

Execute All Layout Algorithms Data Items

Space Allocation Method

The **Layered** space allocation method divides the building area in strips or layers parallel to the orientation of the building. All departments located on an axis of the hexagonal adjacency graph parallel to the building orientation are assigned to a single layer. The algorithm then assigns department areas from left to right in each layer.

The **Tiled** space allocation method divides the building area into a set of non-overlapping department rectangles. The position of the department rectangles is derived from the hexagonal adjacency graph. The Tiled space allocation method has more flexibility than the Layered space allocation method and will yield on the average layouts with a lower distance score. However, the resulting layout may not have the structure that allows parallel material handling aisles. There is no guarantee that the Tiled space allocation method will yield a lower distance score than the Layered space allocation method for a particular layout project. Because the Tiled method examines many more alternatives than the Layered method, it requires substantially longer computation times. It therefore can be disabled during the execution of all layout algorithm combinations.

All Graphs and Layouts

The **All Graphs and Layouts** command of the **Algorithms** menu creates a planar hexagonal adjacency graph for the current project by executing all possible combinations of graph algorithm settings. In other words its runs four relationship tuples times three improvement steps times two tie breakers for a total of 24 algorithms. For each combination of settings the algorithm is run for the maximum number of iterations. For each combination of graph algorithm settings all possible combinations of block layout algorithm settings are executed. In other words its runs three side orientations times five improvement steps time two space allocation methods for a total of 30 algorithms. The total number of combo algorithms is then 24 times 30 or 720 algorithms. The block layout with the lowest shape adjusted distance score is retained and displayed at the conclusion. Because of the extensive computations this command will take a very long time to complete.

The Tiled space allocation method is especially computation time intensive, and its execution can be disabled with the **Execute All Graph and Layouts** dialog window, which is illustrated below. When you press **Yes** all possible combinations of graph and layout algorithms will be executed. If you press **No**, no algorithm will be executed.

Execute All Graph and Layout Algorithms Dialog Window

Figure 5.40. All Layout Algorithms Configuration Dialog Window

For further information on the function of this dialog window see the **All Graphs and Layouts** command. For a detailed explanation of all layout algorithms parameters see the **Execute All Graph and Layout Algorithms Data Items**.

Execute All Graph And Layout Algorithms Data Items

Space Allocation Method

The **Layered** space allocation method divides the building area in strips or layers parallel to the orientation of the building. All departments located on an axis of the hexagonal adjacency graph parallel to the building orientation are assigned to a single layer. The algorithm then assigns department areas from left to right in each layer.

The **Tiled** space allocation method divides the building area into a set of non-overlapping department rectangles. The position of the department rectangles is derived from the hexagonal adjacency graph. The Tiled space allocation method has more flexibility than the Layered space allocation method and will yield on the average layouts with a lower distance score. However, the resulting layout may not have the structure that allows parallel material handling aisles. There is no guarantee that the Tiled space allocation method will yield a lower distance score than the Layered space allocation method for a particular layout project. Because the Tiled method examines many more alternatives than the Layered method, it requires

substantially longer computation times. It therefore can be disabled during the execution of all graph and layout algorithm combinations.

Synchronize Graph

The **Synchronize Graph** command of the **Algorithms** menu creates a new hexagonal adjacency graph based on the current block layout. During normal operation, the block layout is created based on the current hexagonal adjacency graph. The improvement procedures of the block layout algorithms may rearrange the departments in the block layout. However, the location of the department nodes in the adjacency graph has not changed. If you want to perform some sensitivity analysis based on the current layout, you first must rearrange the graph to correspond to the layout since sensitivity analysis uses the graph. This command will synchronize the graph with the location of the departments in the block layout. You can then further manipulate the graph interactively.

Evaluate

The **Evaluate** command computes the adjacency score of the adjacency graph or the shape adjusted distance score and adjacency score of the block layout if these have been created. It displays the distance score without shape penalty, called the flow distance score, for the block layout in the Delta Objective field. The results are displayed in the **Notes** and **Statistics** views. This command is most frequently used after you have edited interactively the relationships or after you have dragged a department in the adjacency graph to a new location. The **Evaluate** command does not create a new graph or block layout, but rather computes the cost of the current graph and layout based on the current relationship values. If a block layout has been created, the command also displays in a dialog window the total distance score, the flow distance score, and the total shape penalty for the current layout. It also displays for each department the actual area, shape ratio, and perimeter ratio. If only an adjacency graph has been created, the command displays the adjacency score, the sum of the absolute values of all relations, and the efficiency score of the current graph. The **Evaluate** dialog windows are illustrated in Figures 5.41 and 5.42, respectively when a block layout or a adjacency graph only have been created.

Evaluate Dialog Window (Layout Page)
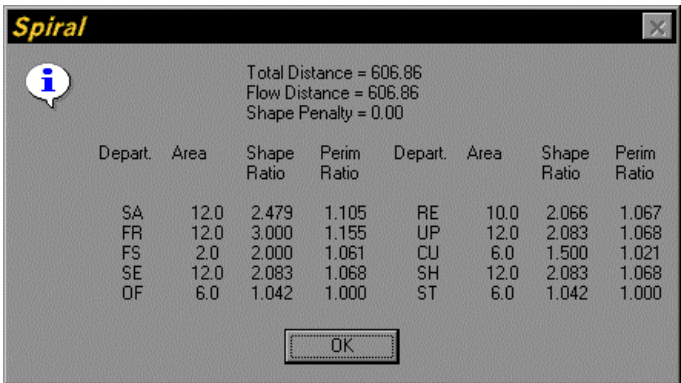
Figure 5.41. Evaluate Layout Dialog Window

For further information on the function of this dialog window see the **Evaluate** command.
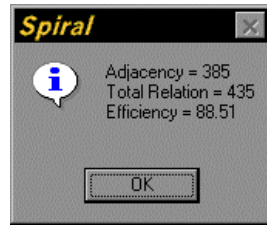
Figure 5.42. Evaluate Graph Dialog Window

For further information on the function of this dialog window see the **Evaluate** command.

Display Distances

The Display Distances command displays a two dimensional grid with the centroid-to-centroid distances between each pair of departments and between a centroid of a department and the outside. This command does not compute a new layout or new distances, but merely displays the current distances in detail. The **Display Distances** dialog window is illustrated in Figure 5.43.

If the centroids of two departments are located at coordinates (x_i, y_i) and (x_j, y_j) then the rectilinear centroid-to-centroid distance is given by:
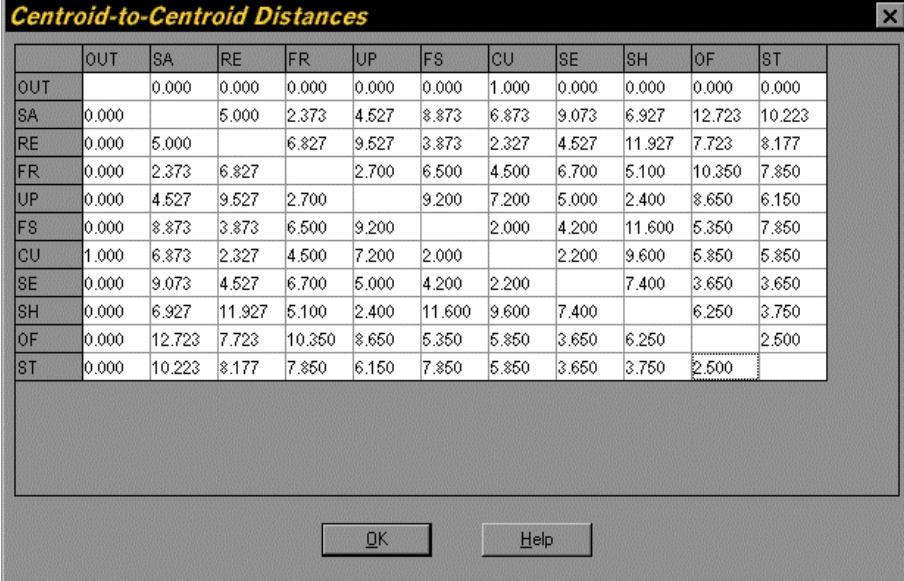
$$d_{ij}^R = |x_i - x_j| + |y_i - y_j| \tag{5.3}$$

If the origin of a department is denoted by *(x, y)*, its size by *(w, l)*, and the building dimensions by *(W, L)*, then the rectilinear distance between the department and the perimeter is given by

$$d_{io}^R = \min\{x + w/2, y + l/2, W - x - w/2, L - y - l/2\} \tag{5.4}$$

Further information can be found in the section on **Distance Statistics** of the Design Algorithms chapter. See also the **Display Flow-Distance Costs** command to display material handling costs in the current layout and the **All Relations** command to display the departmental relationships.

Display Distances Dialog Window

	OUT	SA	RE	FR	UP	FS	CU	SE	SH	OF	ST
OUT		0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
SA	0.000		5.000	2.373	4.527	8.873	6.873	9.073	6.927	12.723	10.223
RE	0.000	5.000		6.827	9.527	3.873	2.327	4.527	11.927	7.723	8.177
FR	0.000	2.373	6.827		2.700	6.500	4.500	6.700	5.100	10.350	7.850
UP	0.000	4.527	9.527	2.700		9.200	7.200	5.000	2.400	8.650	6.150
FS	0.000	8.873	3.873	6.500	9.200		2.000	4.200	11.600	5.350	7.850
CU	1.000	6.873	2.327	4.500	7.200	2.000		2.200	9.600	5.850	5.850
SE	0.000	9.073	4.527	6.700	5.000	4.200	2.200		7.400	3.650	3.650
SH	0.000	6.927	11.927	5.100	2.400	11.600	9.600	7.400		6.250	3.750
OF	0.000	12.723	7.723	10.350	8.650	5.350	5.850	3.650	6.250		2.500
ST	0.000	10.223	8.177	7.850	6.150	7.850	5.850	3.650	3.750	2.500	

Figure 5.43. Display Distances Dialog Window

For further information on the function of this dialog window see the **Display Distances** command.

Display Flow-Distance Costs

The Display Flow-Distance Costs command displays a two dimensional grid with the centroid-to-centroid distances between each pair of departments and between a centroid of a department and the outside multiplied by the relationship between those two departments. This command does not compute new flow-distance costs, but merely displays the current costs in detail. The **Display Flow-Distance Costs** dialog window is illustrated in Figure 5.44.

See also the **Display Distances** command to display rectilinear centroid-to-centroid distances in the current layout and the **All Relations** command to display the departmental relationships.

Display Flow-Distance Costs Dialog Window

Figure 5.44. Display Flow-Distance Costs Dialog Window

For further information on the function of this dialog window see the **Display Flow-Distance Costs** command.

Aborting an Executing Algorithm

While the algorithms are executing, they will display the **Abort Algorithm** dialog window. The algorithms check at certain points during their execution if you have pressed the Abort button and, if so, will terminate at that time.

Note that for computationally intensive algorithms, there may be a significant delay between the moment you press the Abort button and the moment the algorithm checks for the button press. This is especially true for computers with single or slow processors.

Since the algorithm did not run to completion, the reported scores for the graph and layout may be incorrect. It is strongly recommended that you execute immediately the **Evaluate** command from the **Algorithms** menu if you plan to use the graph or layout shown to ensure that the correct adjacency score and distance scores are computed for this graph and layout.

Abort Algorithm Dialog Window

Figure 5.45. Abort Algorithm Dialog Window

View Menu

All settings and switches in the View menu apply only to the currently active view. The equivalent setting in other views will not be affected by the commands of this menu.

Department Labels

The **Department Labels** command is a toggle switch that displays or hides the department labels.

The size of the displayed labels can be set with the **Label Size** command from the **View** menu

Department Labels Shortcuts

Toolbar:

Keys: CTRL+ALT+L

Edges

The **Edges** command is a toggle switch that displays or hides the relationship edges. Which edges are displayed is specified with the **Edges Display** command.

Edges Shortcuts

Toolbar:

Keys: CTRL+ALT+E

Edge Labels...

The **Edge Labels** command is a toggle switch that displays or hides the labels of the relationship edges. Which labels are displayed is specified with the **Edges Display** command. The edges themselves have to be displayed before the edge labels can be displayed. The display of the edges is controlled with the **Edges** command.

Edge Labels Shortcuts

Toolbar:

Keys: CTRL+ALT+D

Grid

The **Grid** command is a toggle switch which displays or hides the hexagonal grid in the **Graph** view and the rectangular, unit square grid in the **Layout** view. This grid is primarily of use when you want to add departments to the project or when you want to adjust the created graph manually, since department nodes can only be located on the vertices of the hexagonal grid. The size of the unit squares in the **Layout** view can be changed with the **Grid Size** command of the Display menu.

Grid Project Shortcuts

Toolbar:

Keys: CTRL+ALT+G

Label Size...

The **Label Size** command allows the user to specify the size of the text labels used to identify the departments and the edges. Windows displays the labels in a font size that most closely matches the desired label size.

The display of the department and edge labels is controlled by the **Department Labels** and **Edge Labels** command of the View menu, respectively.

Click on **OK** to accept the modifications that you have made to the label size. If you click on **Cancel** then all the modifications that you made to the label size will be discarded and the label size will not be modified.

Label Size Dialog Window
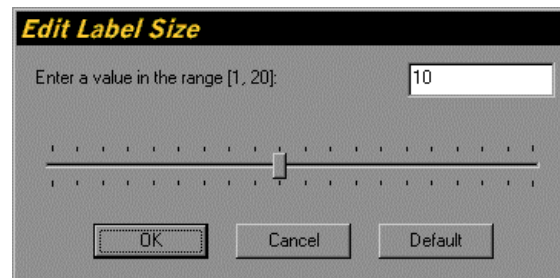
Figure 5.46. Edit Label Size Dialog Window

Node Colors...

The **Node Colors** dialog window allows the selection of the colors to draw the internal and external nodes in the adjacency graph. A node is external if it has at least one adjacency with the outside, internal if it is not adjacent to the outside at all. The colors have to be selected from the list of valid colors given in Table 5.4. The standard colors are RED for the internal nodes and BLUE for the external nodes. The **Node Colors** selection dialog window is shown in Figure 5.47.

Click on **OK** to accept the modifications that you have made to colors used to display nodes in the adjacency graph. If you click on **Cancel** then all the modifications that you made will be discarded and the node colors will not be modified.

Node Colors Dialog Window
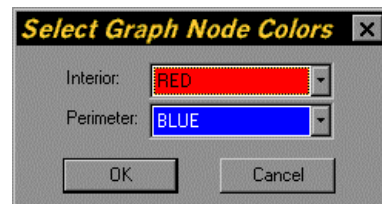
Figure 5.47. Edit Graph Node Colors Dialog Window

For further information on the function of this dialog window see the **Node Colors** command. For a detailed explanation of all layout algorithms parameters see the **Node Colors Data Items**.

Node Colors Data Items

Table 5.4. Allowable Colors for Edges and Departments Nodes

BLACK	DARKGRAY
BLUE	NAVY
GREEN	FOREST
CYAN	OCEAN
RED	BROWN
MAGENTA	PURPLE
YELLOW	OLIVE
WHITE	GRAY

Edges Display...

The **Edges Display** command allows the selection of displaying the edges, the edge labels, the edge widths, and the edge colors. You select to display none, all, or only adjacent relation edges between the facilities. You also select to display the original or adjusted relationships as edge labels or no edge labels. You can select the width of all the edges to thin or to be proportional to the relationship between the department pairs. Finally, you select the colors used to display edges with positive and negative relationships. The **Edges Display** election dialog window is shown in Figure 5.48.

Click on **OK** to accept the modifications that you have made to which edges will be displayed. If you click on **Cancel** then all the modifications that you made will be discarded and which edges will be displayed will not be modified.

The adjusted interdepartmental relation is used in the graph construction procedures to incorporate relations with the outside. For further information see the **Graph Algorithms** section in the Design Algorithms chapter.

The dialog window allows the selection of the colors to draw the positive and negative edges in the graph and block layout. The colors have to be selected from the list of valid colors given in Table 5.4. The standard colors are FOREST for the positive edges and BROWN for the negative edges.

Edge Display Dialog Window
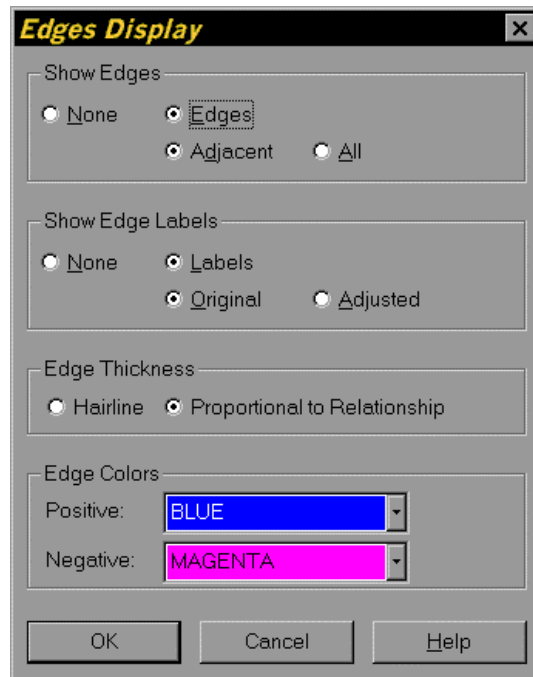
Figure 5.48. Edge Display Dialog Window

For further information on the function of this dialog window see the **Edges Display** command.

Zoom

The **Zoom** command allows you to select a rectangular portion of the current **View** window and to enlarge that rectangular region so that it will fill the complete **View** window. After the command has been selected you start a rubber band bounding rectangle by pressing and holding down the left mouse button in any graph or layout view. The rectangle will shrink or grow following the cursor until you release the left mouse button. The **Zoom** operation preserves the length to width aspect ratio of the **View** window. The zoom option is most useful to display the graph or layout in more detail. The full, original **View** can be displayed by using the **Zoom Original** command. The previous **View** screen can be viewed by using the **Zoom Previous** command.

Zoom Shortcuts

Toolbar:

Keys: CTRL+ALT+Z

Zoom Previous

The **Zoom Previous** command displays again the previous **View** window before the last **Zoom** command was executed.

Zoom Previous Shortcuts

Toolbar:

Keys: CTRL+ALT+P

Zoom Original

The **Zoom Original** command displays the original, full **View** window before any **Zoom** command was executed for the current case.

Zoom Original Shortcuts

Toolbar:

Keys: CTRL+ALT+O

Redraw

The **Redraw** command of the **Display** menu redraws the currently active view immediately, be it either a Graph View, Layout View, Notes View or Statistics View. It is used primarily to remove any remaining screen artifacts created by either a zoom operation on the current view or dragging a department in the current view.

Redraw Shortcuts

Keys: CTRL+R

Windows Menu

The **Windows** menu allows the opening, closing, arrangement, and selection of the **Graph** Views, the **Layout** Views, the **Notes** Views, and the **Statistics** Views. In addition, the windows can be tiled and cascaded in standard Windows fashion as described in the Windows User's Guide.

New Notes Window

The **New Notes View** command displays a new window showing the overall, aggregate project data. This view can be printed to the default printer with the **Print** command of the **File** menu. This window can be moved and sized to suit your taste.
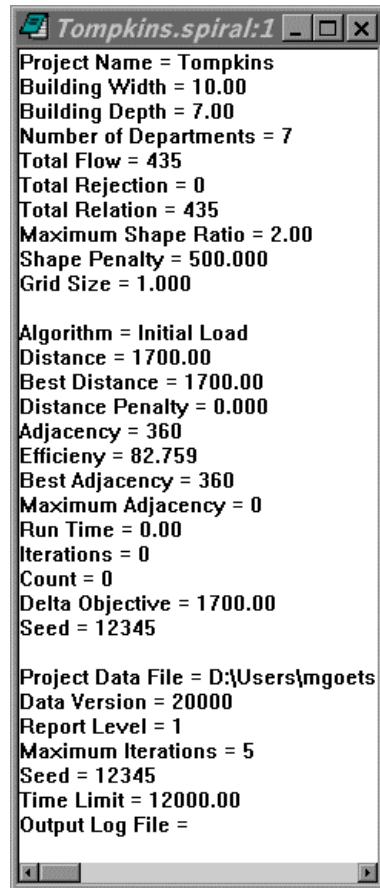
Figure 5.49. Notes View

For further information on the function of this dialog window see the **New Notes Window** command.

New Statistics Window

The **New Statistics View** command displays a new window showing the history of algorithms statistics. This view can be printed to the default printer with the **Print** command of the **File** menu. This window can be moved and sized to suit your taste.

Figure 5.50. Statistics View

For further information on the function of this dialog window see the **New Statistics Window** command.

New Graph Window

The **New Graph View** command adds a new window that displays the hexagonal adjacency graph of the current project. The display options for the new view are the standard options. You can then modify these options in the normal fashion described under the **Display** menu. Each **View** window can be moved and sized to suit your taste.
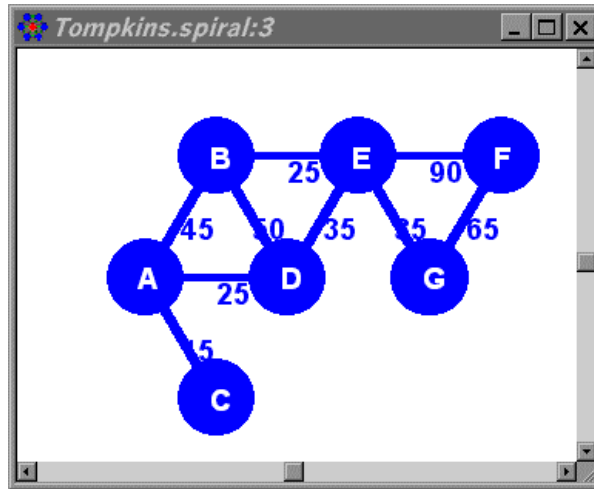
Figure 5.51. Graph View

For further information on the function of this dialog window see the **New Graph Window** command.

New Layout Window

The **New Layout View** command adds a new window that displays the block layout of the current project. The display options for the new view are the standard options. You can then modify these options in the normal fashion described under the **Display** menu. Each **View** window can be moved and sized to suit your taste.
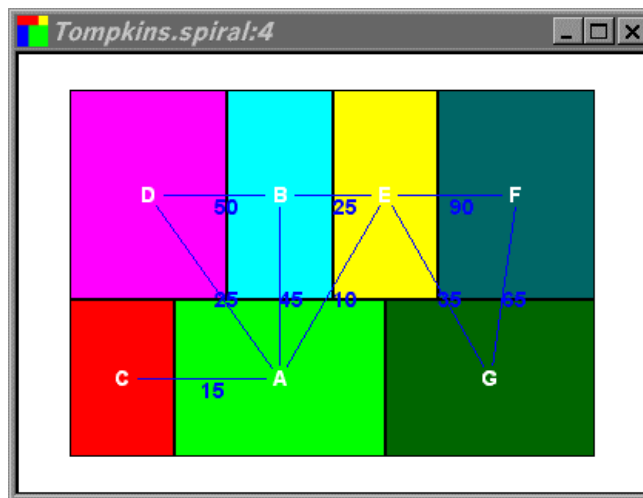
Figure 5.52. Layout View

For further information on the function of this dialog window see the **New Layout Window** command.

Cascade

This command cascades or arranges all child views in an overlapping manner, with the currently active child view on top.

Tile

This command tiles or arranges all child views in a non-overlapping manner, attempting to make each view window the same size.

Arrange Icons

This command arranges all icons of child views that have been minimized at the bottom of the **Spiral** window.

Opened Windows

You can activate any of the opened view windows by clicking on its name in the Window menu or by clicking anywhere in the window area. When you activate a window it displayed on top of all other child view windows.

Toolbar

This command toggles the display of the toolbar of the **Spiral** program. The toolbar contains short cut buttons to the most commonly used commands. When the mouse point is held immobile for a short time on any button of the toolbar a tool tip which gives the buttons functions will be displayed.

*Figure 5.53. **Spiral** Toolbar*

The toolbar is dockable, i.e. it can be moved to any part of the application window and be reshaped. There exists an error in Microsoft Foundation Classes (MFC) that does not display the last row of buttons in the toolbar correctly, if the toolbar is not a single horizontal or vertical strip of buttons. We are in process of developing a work around for this particular display error.

*Figure 5.54. Dockable **Spiral** Toolbar*

Status Bar

This command toggles the display of the status bar at the bottom of the **Spiral** window. The Status Bar displays a description of the currently highlighted command and the status of the keyboard.

For Help, press F1	CAP	NUM	

Figure 5.55. Status Bar

Help Menu

Help Topics

This command displays the Contents page of the **Spiral** interactive help system as shown in Figure 5.56.

The **Spiral** program contains an interactive help system. The instructions in the help system always take precedence over those in the printed User's Manual. The Help system can be started from the **Help** menu or by pressing F1.

Help Topics Window
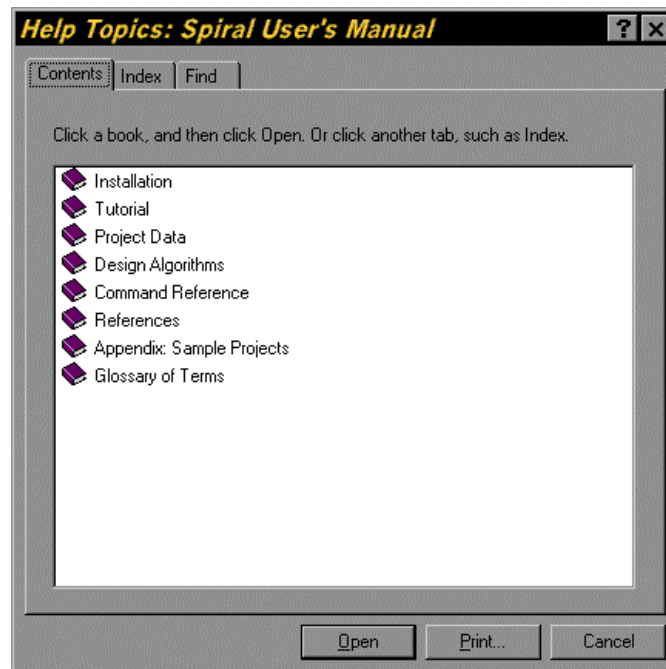
Figure 5.56. Help Contents Window

For further information on the function of this dialog window see the **Help Topics** command.

Help Shortcuts

Toolbar:

Keys: CTRL+H
        F1

Context Sensitive Help

You can request help for a specific topic by pressing SHIFT-F1 or by clicking the button for context sensitive help in the toolbar. The **Spiral** application is placed in Help mode. You can then specify the topic by a mouse click on a menu command or an area of the screen or by the key stroke(s) for a menu command. The help file will be opened on that particular topic.

Pressing the Esc button while the application is in Help mode will cancel the Help mode and return the application to its normal operation.

Pressing the Help button in the various dialog windows will also activate the context sensitive help for that dialog window. Usually, an image of the dialog window will be shown. Browse one page back to display the help on the dialog window.

Context Sensitive Help Shortcuts

Toolbar:

Keys: Shift+F1

About Spiral

The **About** command of the **Help** menu shows the **About Spiral** dialog window with the **Spiral** program and the **Scientif** library information. This information includes the name, version, date, and copyright. It also shows the program and library icon. The **About Spiral** dialog window is illustrated it Figure 5.57.

About Spiral Dialog Window
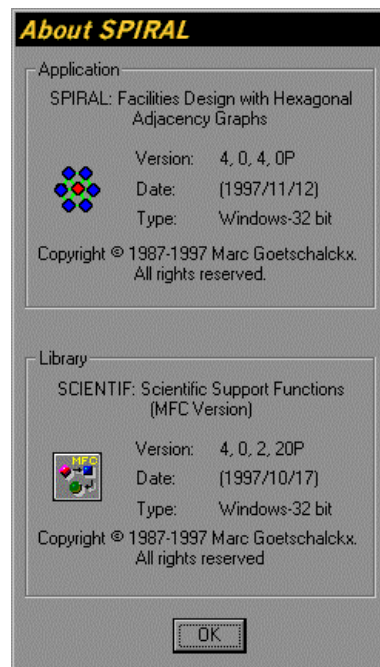
Figure 5.57. About Dialog Window

For further information on the function of this dialog window see the **About Spiral** command.

About Shortcuts

Toolbar:

Keys: CTRL+I

This page left intentionally blank.

References

Book and Journal References

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World Wide Web Sites

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17. Facilities Planning and Design Division, Institute of Industrial Engineers. www.iienet.org/index.htm

18. Material Handling Institute. www.mhia.org

Appendix: Sample Projects

Tompkins (Tutorial Project)

This project was first described in Tompkins and Moore (1978). The project file *Tompkins.spiral* will be copied to the Projects directory by the installation program.

The **Project Data** and **Department Data** files are listed below, but are no longer included on the distribution disk. The files correspond to the Tompkins project when no graph or layout has been created.

Export files created by versions of **Spiral** less than 4.0 have an implicit data version of 3.63 and do not contain department corner coordinates.

Tompkins.dat Project Data File Example

[data_version]	20000
[project_name]	TOMPKINS
[number_of_departments]	7
[building_width]	10
[building_depth]	7
[department_file_name]	TOMPKINS.DEP
[seed]	6821
[tolerance]	0.00010
[time_limit]	120
[number_of_iterations]	20
[report_level]	2
[max_shape_ratio]	2.00
[shape_penalty]	500.00

Tompkins.dep Department Data File Example

A	0	0	12	0	0	Green	Receiving
B	0	0	8	0	0	Cyan	Milling
C	0	0	6	0	0	Red	Press
D	0	0	12	0	0	Magenta	Screw
E	0	0	8	0	0	Yellow	Assembly
F	0	0	12	0	0	Ocean	Plating
G	0	0	12	0	0	Forest	Shipping
A	B	45					

```
A       C       15
A       D       25
A       E       10
A       F       5
B       D       50
B       E       25
B       F       20
C       E       5
C       F       10
D       E       35
E       F       90
E       G       35
F       G       65
OUT     OUT     0
```

Furniture

This project was first described in Montreuil et al (1987). The project file *Furniture.spiral* will be copied to the Projects directory by the installation program.

The **Project Data** and **Department Data** files, as exported by the current version of **Spiral**, are listed below and are included on the distribution disk, but are not copied to your computer during the installation process.

Note that the data version of files exported by the current version of **Spiral** is 20000 or higher. The files have been exported after a layout has been created for the project and the number of corners and the location of the corners of each department are given in the file.

Furniture.dat Project Data File Example

```
[data_version]              20000
[project_name]              Furniture
[number_of_departments]     10
[building_width]            10.000000
[building_depth]            9.000000
[department_file_name]      Furniture.dep
[max_shape_ratio]           2.000000
[shape_penalty]             500.000000
[number_of_layout_rows]     3
[number_of_layout_cols]     4
[report_level]              1
[number_of_iterations]      10
[seed]                      11463
[time_limit]                120
```

Furniture.dep Department Data File Example

SA	21	21	12.0	3	3	Red	Sawing
RE	21	20	10.0	3	2	Yellow	Receiving
FR	20	20	12.0	2	3	Cyan	Framing
UP	23	21	12.0	1	3	Green	Upholstery
FS	22	22	2.0	3	1	Brown	Fab_Storage
CU	22	21	6.0	2	1	Olive	Cutting
SE	23	22	12.0	2	2	Forest	Sewing
SH	23	20	12.0	1	2	Magenta	Shipping
OF	22	20	6.0	1	1	White	Offices
ST	21	19	6.0	4	1	Gray	Storage
SA	RE	22					
SA	FR	35					
SA	UP	1					
SA	OF	-17					
RE	OUT	45					
RE	FR	2					
RE	UP	1					
RE	FS	12					
RE	CU	4					
RE	OF	4					
RE	ST	10					
FR	UP	28					
FR	OF	-17					
FR	ST	1					
UP	CU	6					
UP	SE	14					
UP	SH	42					
UP	OF	3					
UP	ST	4					
FS	CU	35					
FS	SE	9					
FS	SH	2					
FS	OF	3					
CU	SE	16					
CU	OF	3					
SE	OF	3					
SE	ST	1					
SH	OUT	55					
SH	OF	4					
SH	ST	4					
OF	OUT	10					
OF	ST	3					
OUT	OUT	0					

4
6.667 5.400
10.000 5.400
10.000 9.000
6.667 9.000
4
7.059 2.000
10.000 2.000
10.000 5.400
7.059 5.400

```
4
3.333    5.400
6.667    5.400
6.667    9.000
3.333    9.000
4
0.000    5.400
3.333    5.400
3.333    9.000
0.000    9.000
4
6.000    0.000
7.000    0.000
7.000    2.000
6.000    2.000
4
3.000    0.000
6.000    0.000
6.000    2.000
3.000    2.000
4
3.529    2.000
7.059    2.000
7.059    5.400
3.529    5.400
4
0.000    2.000
3.529    2.000
3.529    5.400
0.000    5.400
4
0.000    0.000
3.000    0.000
3.000    2.000
0.000    2.000
4
7.000    0.000
10.000   0.000
10.000   2.000
7.000    2.000
```

Glossary of Terms

ASCII

ASCII is an acronym in computer science for American Standard Code for Information Interchange. It is a standardized coding scheme that assigns numeric values to letters, numbers, punctuation marks, and certain other characters. By standardizing the values used for these characters, ASCII enables computers and computer programs to exchange information. ASCII provides for 256 codes divided into two sets of 128 each. The standard ASCII character set consists of the first 128 codes. The first 32 values of standard ASCII are assigned to communication and printer control codes, i.e., non-printing characters, such as backspace, carriage return, and tab, that are used to control the way information is transferred from one computer to another or from a computer to a printer. The remaining 96 codes are assigned to common punctuation marks, the digits 0 through 9, and the uppercase and lowercase letters of the Roman alphabet. Since ASCII characters just consists of characters, numbers, and punctuation marks and none of the special formatting codes associated with word processors, most programs are able to read ASCII files. Common synonyms are "DOS text" or "text".

GUI

GUI is the abbreviation for graphical user interface. **Spiral** follows the conventions of the standard Windows user interface.

MRU

MRU is the abbreviation for Most Recently Used. Most applications display a list of most recently used files in their **File** menu to allow quick access to the project and document files that have been recently saved.

RGB

RGB is an acronym for Red-Green-Blue and it denotes a color described by three numbers for its red, green, and blue components, respectively. Windows allows values from 0 to 255 for each component for a total of more than 16.7 million colors.

Scientif

Scientif is a library containing common scientific functions used in Windows programs. The current implementation is *scienmfc.dll*, which is the 32 bit dynamic link library required to run the **Spiral** application program. **Scientif** in turn requires a 32 bit Windows operating system, which is denoted by Win32. The safest location for *scienmfc.dll* is in the directory where **Spiral** was installed. For the 32 bit Windows NT operating system *scienmfc.dll* can also be placed in the system32 directory of the directory where Windows NT has been installed. Usually this directory is *c:\winnt\system32*. For the Windows 95 and 98 operating systems *scienmfc.dll* can also be placed in the system directory of the directory where Windows 95 or 98 has been installed. Usually this directory is *c:\windows\system*. The automated **Setup** program with its default selections will place all the application and library files in the appropriate directories.

Setup

Setup is the automated, Windows based installation program which copies the **Spiral** program, help, libraries, and example data files to your hard disk. In addition, it installs **Spiral** in the selected program group on your desktop. The **Setup** program file is *setup.exe* and it is located on the first distribution diskette or CD-ROM.

SLP

SLP is the abbreviation of the Systematic Layout Planning method developed by Muther (1973) to create conceptual block layouts. The method successively adds complicating data categories until a block layout has been generated.

Win32

Spiral is a 32 bit Windows program and as such requires a 32 bit version of the Windows operating environment, denoted by Win32. Current implementations of Win32 are Windows NT (all versions), Windows 95 (all versions), and Windows 98 (all versions). This version of **Spiral** is no longer compatible with the 32 bit extensions Win32s to the 16 bit Windows 3.1.

WWW

WWW is the acronym for the World Wide Web and denotes the collection of sites on the Internet that contain a large variety of information.

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