Chapter 23
Contour Plots

A contour plot lets you quickly visualize level curves—curves along which a particular quantity is constant. Using Mathcad, you make a contour plot in the same way you make a surface plot: by passing a matrix of *z* values in which each row and column corresponds to a particular *x* and *y* value. This chapter describes how a matrix can be represented as a contour plot.

This chapter contains the following sections:

Creating a contour plot

  Basic steps in creating a contour plot; what the plot actually shows.

Resizing a contour plot

 Procedures for changing the size of contour plots.

Formatting contour plots

  Procedures for changing contour plots: formatting contours and axes and adding labels.

Creating a contour plot

To create a contour plot:

■ Define a matrix of values to plot. Mathcad will assume that the rows and columns represent equally spaced intervals on the axes. Mathcad then linearly interpolates the values of this matrix to form level curves. Such level curves can represent isotherms, isobars, equipotentials, streamlines, and many other physical phenomena.

■ Choose **Graph⇒Contour Plot** from the **Insert** menu. Mathcad shows a box with a single placeholder as shown below:
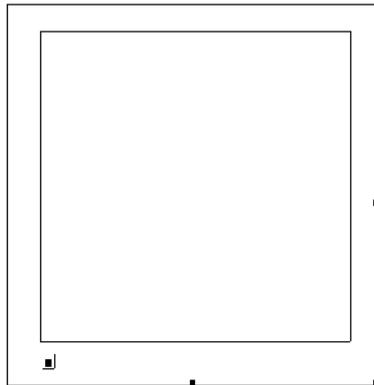
■ Type the name of the matrix in the placeholder. Just as with an equation, Mathcad will not process the contour plot until you click outside the region.

What you see is a visual representation of the matrix's level curves. Each level curve, or contour, is formed in such a way that no two cross. By default, the contours are labeled with their height above or below the *xy* plane. Mathcad plots the matrix by rotating it so that the (0,0) element is at the lower-left corner. Thus the rows of the matrix correspond to values on the *x*-axis, increasing to the right, and the columns correspond to values along the *y*-axis, increasing toward the top.

You can specify whether or not the contours are to be numbered, how many contours there are, and what labels and grid lines appear on the axes by formatting the contour plot. This is described in "Formatting contour plots" on page 536.

Level curves of a function of two variables

A typical contour plot shows the level curves of a function of two variables. To see such a plot, you must first create a matrix that holds the values of the function, then create a contour plot of that matrix. Here are the typical steps in plotting a function of two variables such as that shown in Figure 23-1:

■ Define a function of two variables.

- Decide how many points you want to plot in the x and y directions. Set up range variables i and j to index these points. For example, if you want to plot 10 points in each direction, enter:

$$i := 0 .. 9 \qquad j := 0 .. 9$$

- Define x_i and y_j as evenly as evenly spaced points on the x- and y-axes.

- Fill the matrix **M** with the values of $f(x_i, y_j)$.
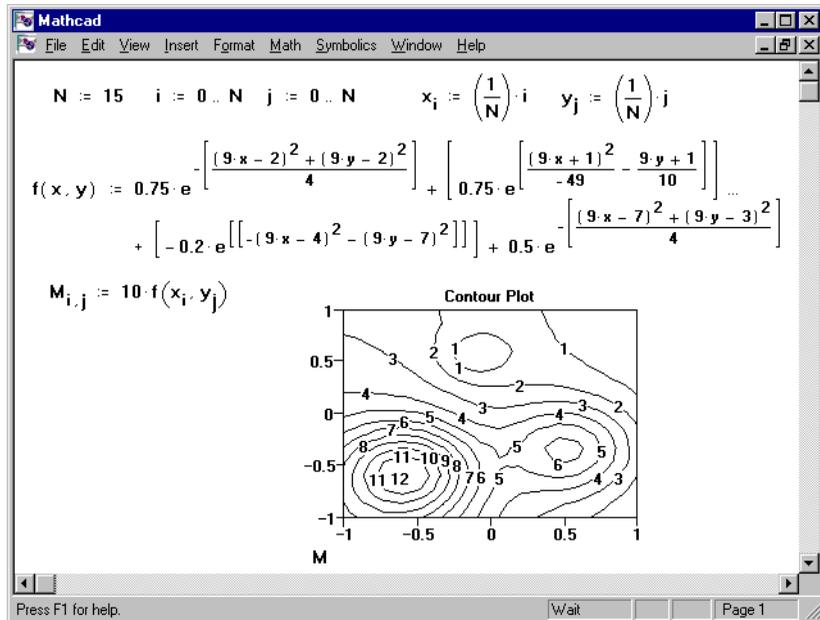
- Show **M** in a contour plot.

Figure 23-1: Contour plot of a function of two variables.

Note that if you plot a function as described here, the positive x-axis of the plot extends to the right and the positive y-axis extends toward the top of the window. Since the contour plot is created by putting the heights above the xy plane into a matrix, Mathcad has no way of knowing the actual values of the x and y axes. For this reason, the axes on contour plots are by default normalized to extend from 1 to -1. You can manually change the axis limits from these default values by choosing **Graph$\Rightarrow$3D Plot** from the **Format** menu with the contour plot selected or by double-clicking on the plot. Then set the values you want in the Min. Val. and Max. Val. text boxes on the Axes page.

Resizing a contour plot

To change the size of a contour plot, follow these steps:

■ Click in the contour plot to select it.

■ Move the mouse pointer to one of the three handles along the edge of the plot. The pointer will change to a double-headed arrow.
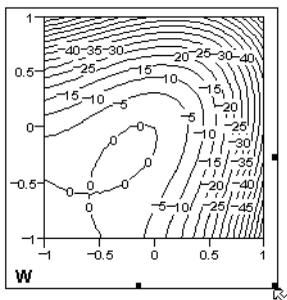
■ Press and hold down the mouse button. While holding down the button, move the mouse. The contour plot will stretch in the direction of motion.

■ Once the contour plot is the right size, let go of the mouse button.

■ Click outside the contour plot to deselect it.

Formatting contour plots

Mathcad gives you control over many of the visual characteristics of contour plots. These can be categorized in four groups:

■ Viewing characteristics: the type of plot being displayed.

■ Axis formatting: whether to show tick marks or grid lines on each axis.

■ Color and line formatting: whether the plot uses grayscale or color to show the height of a section and how the plot shows contours.

■ Title characteristics: how the plot will display titles.

To change any of these plot characteristics, start with the 3-D Plot Format dialog box:

■ Click on the plot to select it.

■ Choose **Graph⇒3D Plot** from the **Format** menu. Alternatively, double-click on the plot itself. Mathcad brings up the 3D Plot Format dialog box. The View Page

of this dialog box is shown below. The remaining three tabs take you to three additional pages.

- If necessary, click the tab for the page you want to work with.

- Change the appropriate characteristics in the dialog box.

- To see the effect of your changes *without* closing the dialog box, click "Apply."

- When you're finished, close the dialog by clicking "OK."
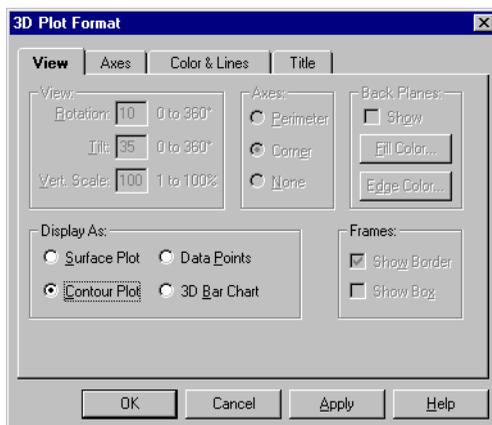
Changing your view of the contour plot

The View page of the 3D Plot Format dialog box lets you modify the general presentation of your plot.

To change your plot from a contour plot to another type of 3-D plot, click on the appropriate button in the Display As group. You can convert a contour plot into a Surface Plot or a 3D Bar Chart. These plot types are fully discussed in the corresponding chapters in this *User's Guide*. You can also display just the points making up the contours without displaying the contours themselves. To do so, click on Data Points. You can then change how the points look by using the Colors & Lines tab of this dialog box. For more information, see Chapter 25, "3D Scatter Plots."

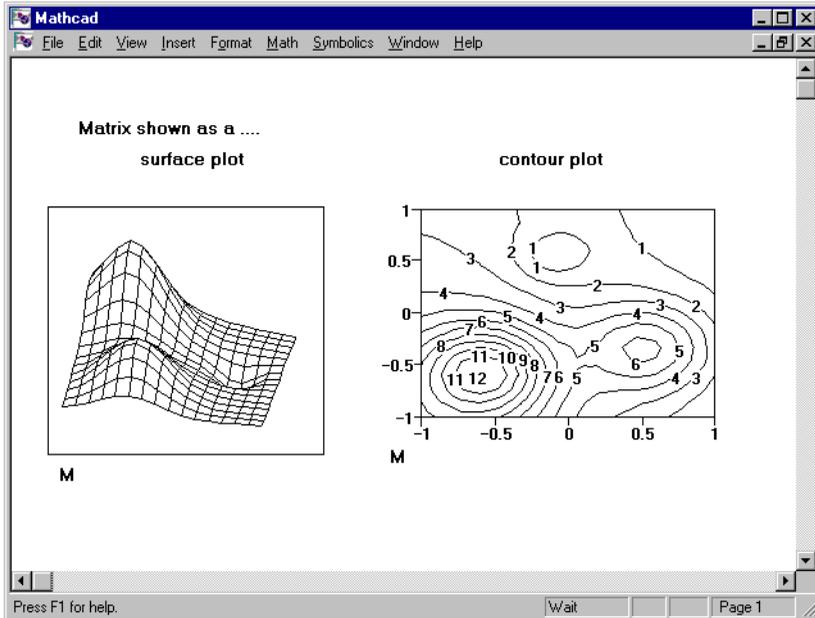Figure 23-2 shows the same matrix being plotted as a surface plot and as a contour plot.

Figure 23-2: Matrix shown as both a surface plot and as a contour plot.

Changing the shading of the contours

You can often make a contour plot communicate more effectively by using different colors to represent different values of *z*. Alternatively, if you intend to print on a black and white printer, you can achieve a similar effect by using different shades of gray to represent different values of *z*. Use the Color and Lines page of the 3D Plot Format dialog box.
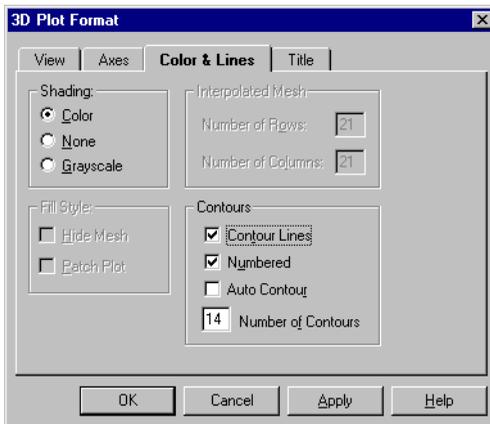
To specify the shading of your plot, click the appropriate button in the Shading group:

■ Color: The bands between contour lines are colored. The largest values of the matrix will be in red and the smallest values will be in blue. Intermediate values will range from yellow through green.

■ None: The bands between contour lines don't have any shading. Be sure the Contour Lines check box is checked or you won't see any contours at all.

■ Grayscale: The bands between contour lines are in shades of gray. The largest values of the matrix will be in white and the smallest values will be in black. Intermediate values will be in shades of gray.

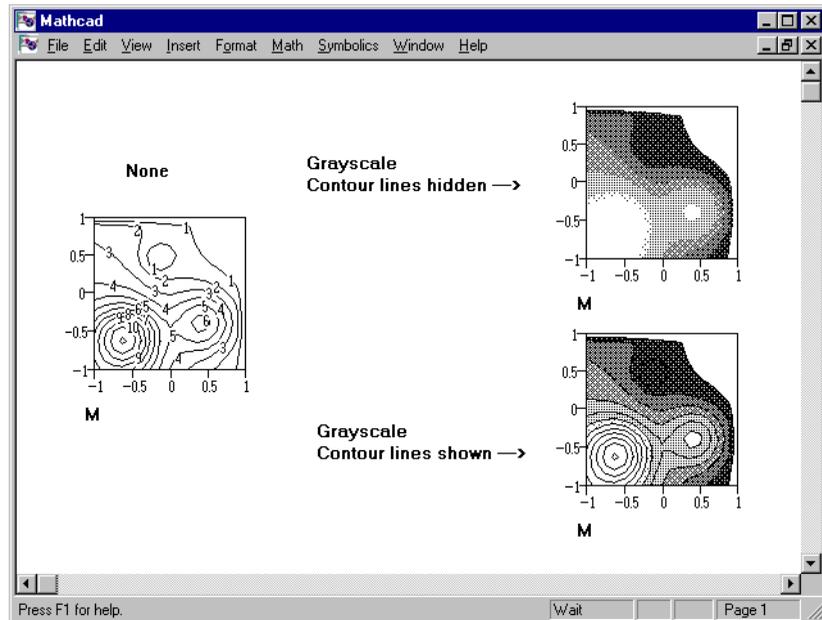Figure 23-3 shows the same contour plot displayed without shading and in grayscale.

Figure 23-3: No shading and grayscale versions of a contour plot.

Besides varying the colors of a contour plot, you can also choose to hide the contours themselves. If you've chosen to leave the surface without shading ("None"), you should have the contour lines showing. If the plot is colored or grayscale, you can hide the contour lines and let the colors or gray shades show the contours. To show or hide the contour lines, click Contour Lines to add or remove the checkmark. Figure 23-3 shows the same contour plot with the contour lines hidden and showing.

Contours can be numbered to indicate the value associated with that contour. To add or remove numbers on most contours, use the Numbered check box. Figure 23-4 shows the same contour plot with numbered and unnumbered contour lines. Note that Mathcad doesn't number every contour when to do so would result in overcrowding.
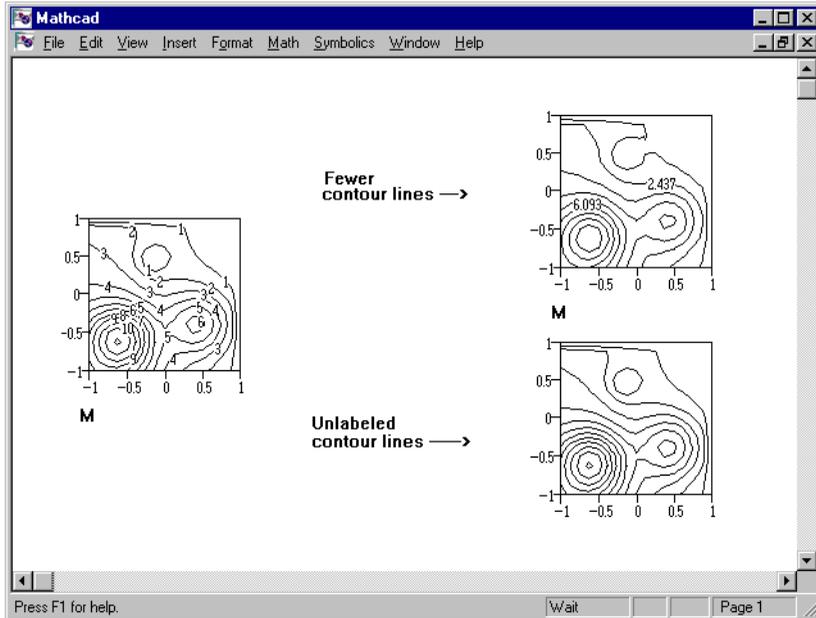
Figure 23-4: Changing the number of contours and turning off contour labeling.

To have Mathcad automatically select the number of contours to display, use the Auto Contour check box. When checked, Mathcad will automatically select the number of contours. When unchecked, you select the number of contours.

To specify the number of contours, enter an integer into the No. of Contours text box. This text box is only available when Auto Contour is unchecked. Figure 23-4 shows the same contour plot with contours automatically selected by Mathcad and with a specified number of contours.

Formatting the axes

The Axes page of the 3D Plot Format dialog box, shown below, lets you modify the format of the *x*- and *y*-axis of your plot. Each axis is described by its own set of check boxes and text boxes.
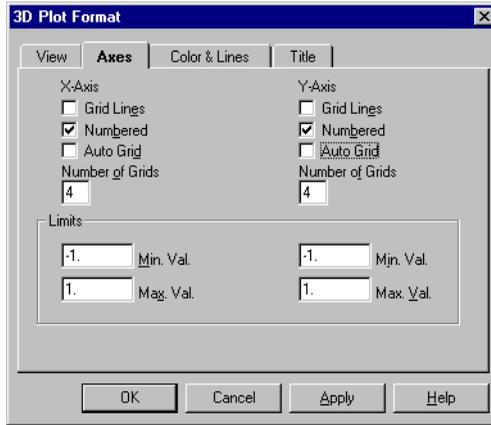
Mathcad generates grid lines on the plot at the same positions as the tick marks. To choose between seeing tick marks or grid lines on a selected axis, use the Grid Lines check box. When Grid Lines is checked, Mathcad adds grid lines to the plot. Figure 23-5 shows the same contour plot with and without grid lines.
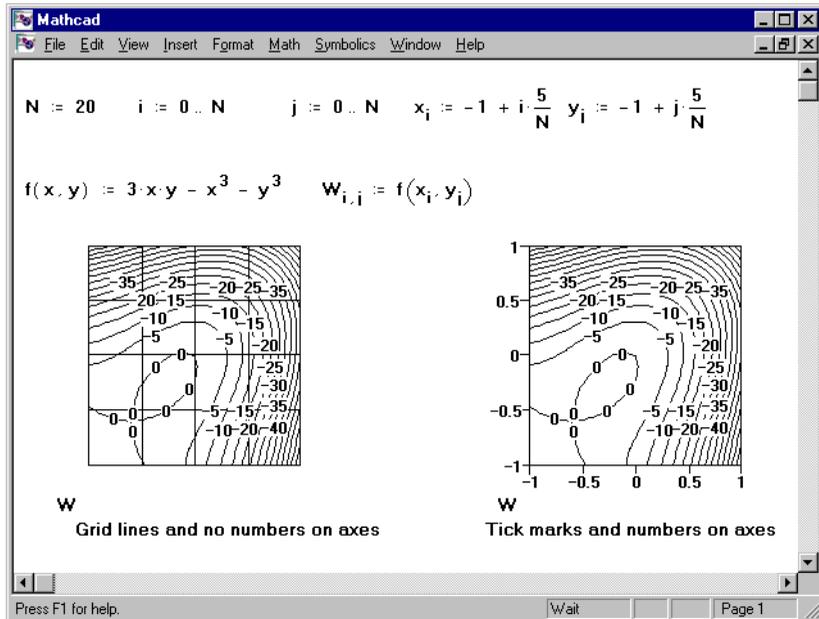

Figure 23-5: Effect of using the different options for tick marks.

To add or remove numbers for the tick marks on an axis, use the Numbered check box for that axis. The plot with grid lines in Figure 23-5 doesn't have numbers on the axes while the plot without grid lines does have them.

You can have Mathcad automatically select the number of grid intervals on an axis or you can specify the number yourself. Grid intervals are the spaces between tick marks or grid lines.

■ To have Mathcad select the number of grid intervals, use the Auto Grid check box. When Auto Grid is checked, Mathcad will automatically select the number of grid intervals on the specified axis.

■ To specify the number of grid intervals on an axis *yourself*, enter an integer from 1 to 99 in the No. of Grids text box. This text box is only available when Auto Grid is unchecked.

To set limits on the maximum or minimum values of the *x*- or *y*-axis, enter the limit in the Max. Val. or Min. Val. text box. However, since the surface of the plot is stored as rows and columns in a matrix, these numbers have no significance as coordinates. They affect the display only. By default, Min and Max are set to -1 and 1 respectively.

Labeling the contour plot

The Title page of the 3D Plot Format dialog box, shown below, lets you add and modify labels on your contour plot.
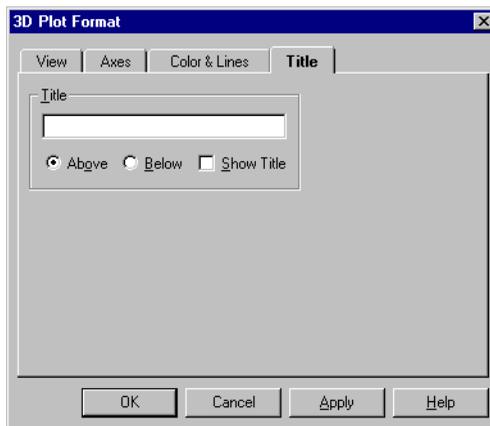
To add or edit a title for your contour plot:

■ Type the title for your plot into the Title text box.

■ To display the title, click on Show Title to insert a check. To conceal the title without deleting it, click on Show Title to remove the check.

■ To position the title, click on either the Above or Below button. Mathcad places the title either directly above or below your plot.

■ Click "OK" or "Close" to close the dialog box when you have finished.

To change the title's text or position, edit the information in the Title group as appropriate. To delete the title, highlight it in the text box and press [**Del**].

Figure 22-8 on page 532 shows how Mathcad positions a title on a 3D plot.