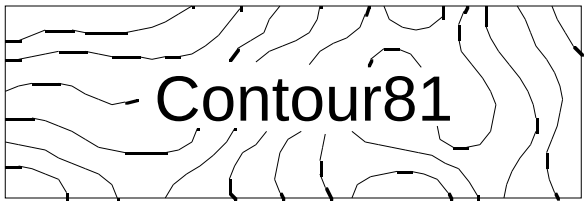

for the Macintosh II

Version 1.1

an easy-to-use application for
generation of contour plots
and three-dimensional surfaces

Technical Software Systems
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About Technical Software Systems

Technical Software Systems, located in northern New Jersey, is committed to providing quality low-cost microcomputer software tools for engineers and scientists. We specialize in scientific programming for the MS-DOS and Macintosh environments. Our background includes extensive experience in numerical analysis and simulation, civil engineering and systems-level programming. Please contact the address on the cover page for information regarding new technical software products or custom application development in these fields.

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What is **Contour81** and who would use it?

Contour81 is an application that creates contour maps and pictures from lists of three-dimensional data. A **contour map** is a two-dimensional picture of a surface defined by a set of data points. The points would usually be elevations of a physical location, such as a planned construction site. A survey crew would go to the site and essentially return with (among other things) a list of "points". Each one of these points would specify the elevation of some location at the site. Then, an engineer or draftsperson would have to plot the points and draw **contour lines** according to general rules of thumb. These contour lines would then represent locations at which the elevation was constant. A person could walk along the line and not move up or down with respect to a reference elevation at all. The site engineer can look at this contour map and calculate the volumes of various areas defined by the contour lines. In the case of site development, this tells him or her how much earth must be moved from one place to another in order to change the topography of the location into an acceptable form. A hydrologic engineer could look at the map and tell where flood areas would occur and the way that water would move around the site in a rainstorm. For example, water always seeks the lowest level as quickly as possible. Therefore it would flow perpendicular to the contour lines (the **gradient**), because that is the quickest way for it to change its elevation. Another type of contour map might be a scientist's plot of the electric potential (voltage) in an area of space. Then the contour lines would define **equipotentials**, a loose definition of these being lines that a charged particle could move on without changing its energy. In this example, if we draw lines perpendicular to the contour lines, these represent the electric field.

In case you haven't guessed already, the process of drawing these contour maps by hand can be extremely tedious and time-consuming. Until the relatively recent advent of low-cost microcomputers, however, this was (and still is) the only way available to some technical people. This program provides the necessary mathematical and graphic power in an simple, low-cost application that adheres to the Macintosh™ User Interface Guidelines. We must assume that you are familiar with basic Macintosh operation and are knowledgeable about the meaning of your three-dimensional data and its analysis. You do not have to understand any of the mathematics behind the program if you do not wish to, but a full explanation of the process is provided for those who are interested. Please also note that the generation of hard copy from this program also requires the use of MacDraw™, AutoCAD™ or another program that can read and work with PICT or DXF™ files.

The **Contour81** program offers the following capabilities and features:

- It can handle up to 1,000 input points, and it can generate a contour plot of up to 20,000 vectors. Input comes from standard TEXT files.

- The dimensions of the contoured grid can be as great as 100 x 100, and up to 50 contour elevations can be plotted.

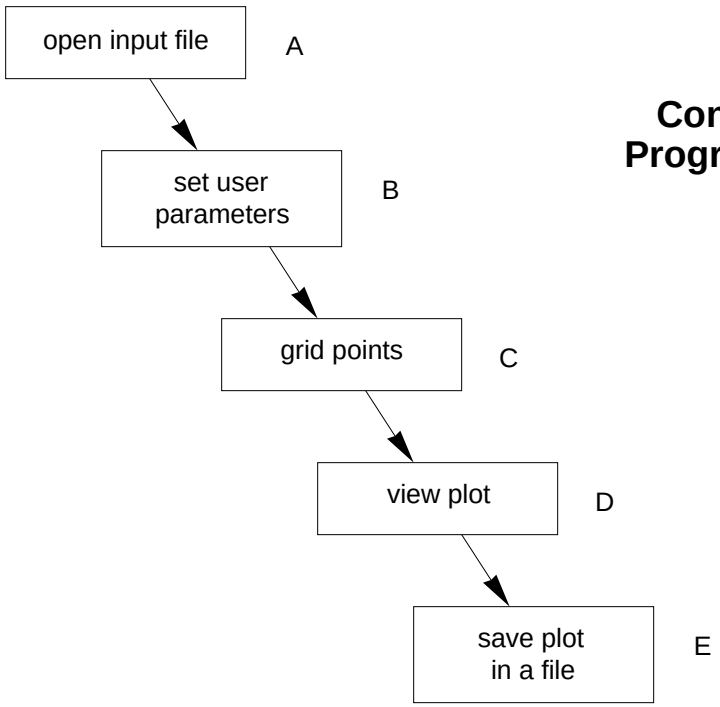
- The user has full control over the X and Y coordinates and limits, the Z values for contouring, and the appearance of the finished plot.

- A weighted least-squares approximation method is used along with inline MC68881 math coprocessor instructions for maximum speed and accuracy.

- It can generate regular contour plots ("plan view") or it can rotate the viewing angle and show a three-dimensional representation of the surface. If the appropriate color hardware is available the plots can be viewed and printed in color.

- Plots and plot information can be saved in PICT, DXF or TEXT format, and can then be transferred to the appropriate program for editing prior to printing or inclusion in a report. The TEXT format allows user programs to access the generated data.

- With the use of MacDraw or another graphics program that can import PICT files and drive a plotter, you can generate plots on standard technical sheets of large sizes (i.e. 24" x 36", 36" x 48").



The operation of **Contour81** is simple and can even be done by persons who have only a basic familiarity with the Macintosh. The paragraphs that follow demonstrate this process.

Step A - Getting the Data In

Before the program can be run, an "input file" must be prepared. This file must be of the following general form:

```
14.276 56.47 213.3
17.83 47.892 243.01
.
.
.
45.34 32.01 272.45
56.346 12.62 249.4
```

This input file has the following characteristics:

- It has 3 numerical values per line, representing the X, Y and Z coordinates of a point.
- The X, Y and Z values are separated by spaces only.
- Blank lines and lines that start with an asterisk (for comments) are ignored. Lines of any other form will keep the input file from being accepted by the program.

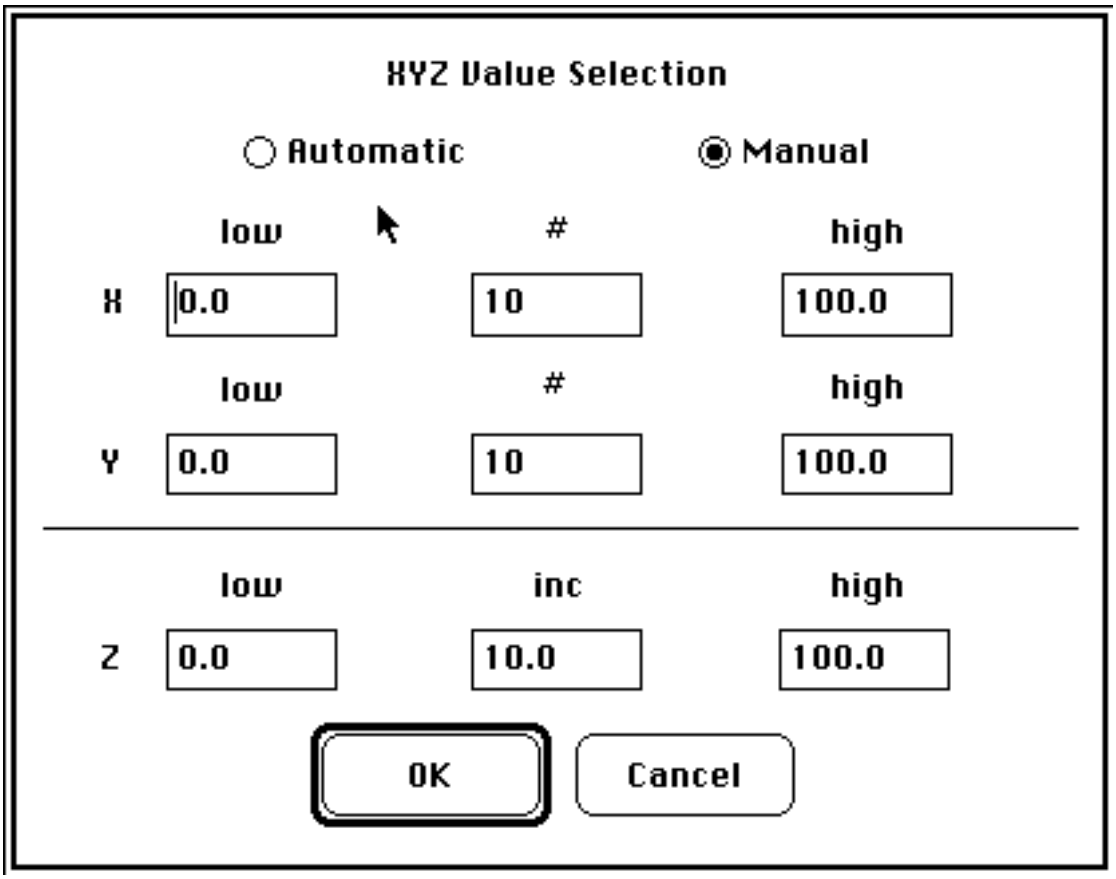
It may be created by MDS Edit™, MacWrite™ (saved under "Save As…" with the "Text Only" option selected), or any other application that can create files of type TEXT. If MS-Excel™ is used to save to a text file, it puts tabs in on the blank lines. **Contour81** can not accept this, so put an asterisk in column 1 of any blank line before saving it to a TEXT file.

Step B - Setting Grid Parameters

Now that a valid input file exists, the **Contour81** program can be executed. Double-click on the program icon. (If you have a hard disk you may drag the **Contour81** application icon to a folder on your hard disk and use it there.) After clicking on "OK" to remove the title screen, choose "Open input…" from the File Menu or type Option-O. Then choose the input file that you just created from this list. Now the program will read in your input file (this may take a few seconds) and the contouring process can begin.

Step C - Create the Contour Plot

After the input file is loaded in (the watch icon disappears), choose "Go" or type Option-G. The dialog box at the top of page 7 appears on your screen:

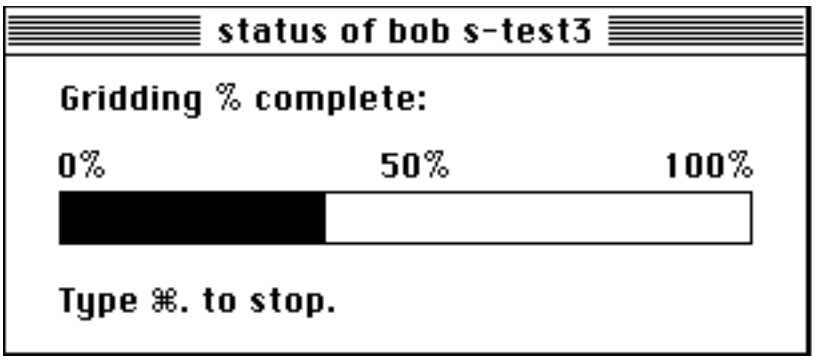


This is where you can set all the parameters that deal with the location and size of the contour map. Hitting the Automatic button will change the "low" and "high" values into values that come from the input file, i.e. the physical boundaries of that data. Of course, any of these items may be overridden by changing the appropriate number.

For X and Y, the number in the "low" column is the lowest coordinate that the contour map will be drawn over and the number in the "high" column is the highest coordinate. Using these numbers you can get a general plot of your area, then zoom in on spots of particular detail. The "#" field for X and Y is the number of grid squares, so a 10 x 10 grid would have 100 squares. Note that the time that **Contour81** takes to generate your contour plot will be proportional to the product of these 2 numbers. For more information on this see the Mathematics section of this manual.

The Z fields deal with the **contour values**. These are the values for which contour lines will be drawn. As with X and Y, the "low" and "high" fields signify the lower and upper bounds of this range. The "inc" field is slightly different here in that it represents the increment use to go from the "low" and "high" Z values. For example, if we set the Z "low" to 5.0, the Z "high" to 9.0 and the Z "inc" to 1.0, then we will get contour lines on our plot that represent Z values of 5.0, 6.0, 7.0, 8.0 and 9.0 and are labeled correspondingly. The Z "inc" value has no meaning when you generate a three-dimensional surface.

When you are satisfied with all of these settings, click OK or hit RETURN to begin the contouring process. If you change your mind, just click on the Cancel button and all of your changes will be discarded and all settings will revert back to their original values.



Once OK is chosen, a window like the one above appears and the contouring process begins. If you wish to learn more about this mathematical process, we encourage you to turn to the Mathematics section and read more about it. The thermometer-like status window shows the "percent complete" of the process. For a large input file and many gridding intervals this process can be quite lengthy, even on a Mac II. **Contour81** tries to achieve an optimum balance between simplicity of operation, speed and accuracy.

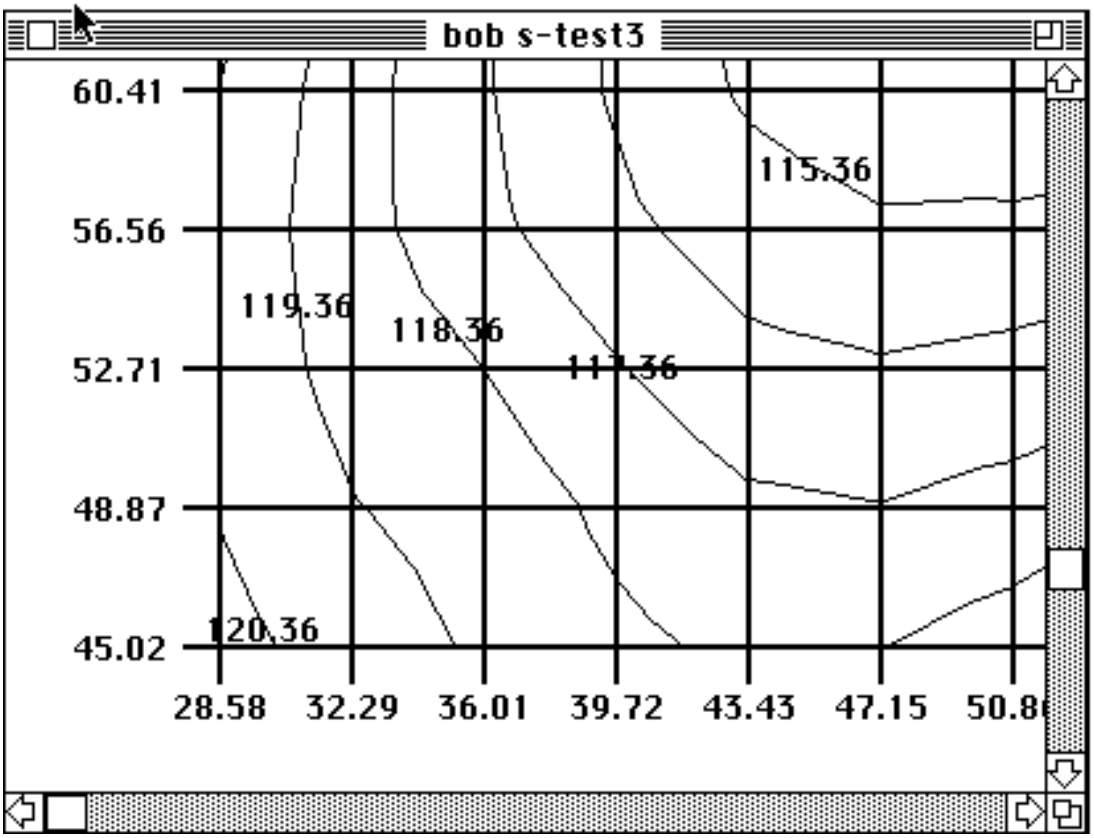
At the time of this writing, **Contour81** works under MultiFinder™, specifically the release included with System 6.0. During the gridding process it is usually possible to switch to another application and continue working. However, we have not tested it extensively with all other programs and we can not recommend its use in this manner for this reason.

If you wish to interrupt the process for any reason, hit Option-Period. The contouring process will be terminated.

Step D - View the Plot

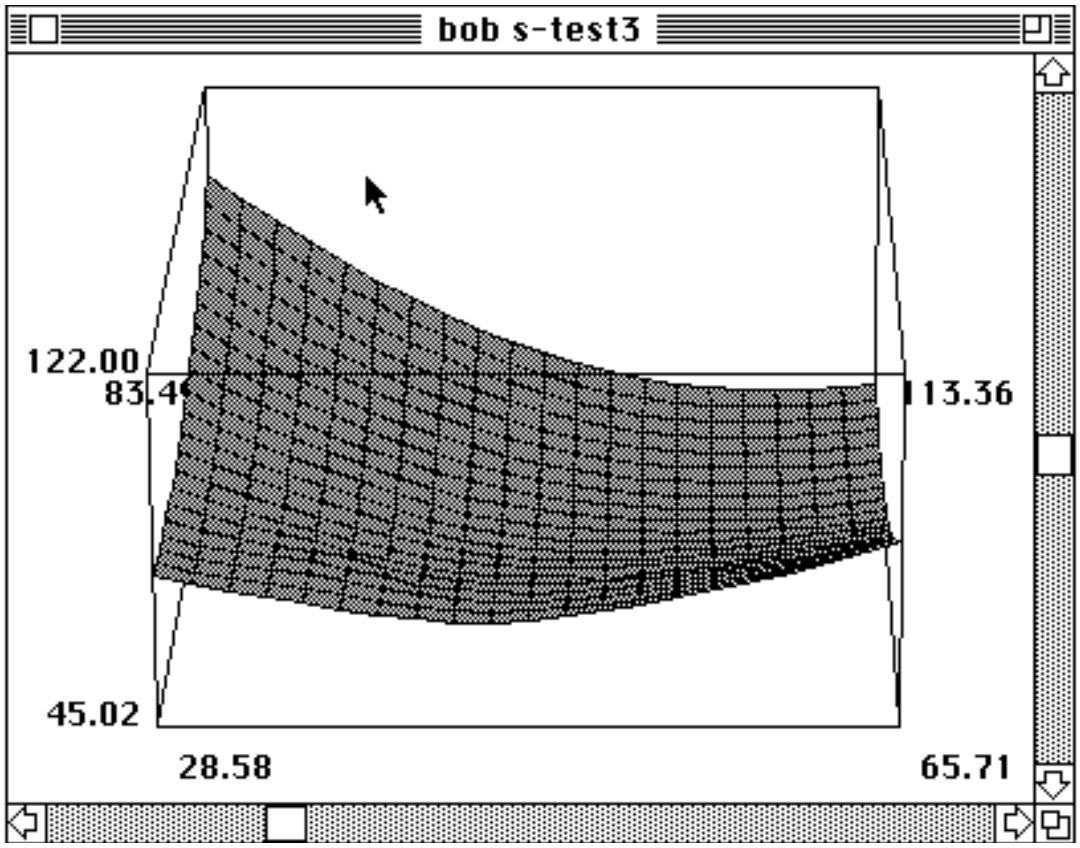
When the mathematical machinations are complete, **Contour81** will beep and display a dialog box informing you of this. If the internal vector storage limits of the program are exceeded, another dialog box will inform you of this fact also. If this occurs, the program will generate as much of the plot as it can. Reduce the size of your grid or the number of contour levels.

After a time period for generating the picture, your contour map or three-dimensional plot will now be displayed on the screen. Shown below are samples of program output:



This is a sample of the plot that results when you do not check the "Draw as terrain map" box under "Graph Options…". The contour lines are labeled with their elevations, and the grid and grid markings are placed over the plot. Since the plot will probably be

bigger than the screen, you can use the scroll bars and window sizing controls in the usual manner to view different parts of the plot. On the Mac II the contour lines and labels are in color with blue being the color of highest Z value and red being the lowest. Note that 256 color capability is not required to run **Contour81**, and in fact we recommend that you place your monitor in 16-color mode for speedier graphics.

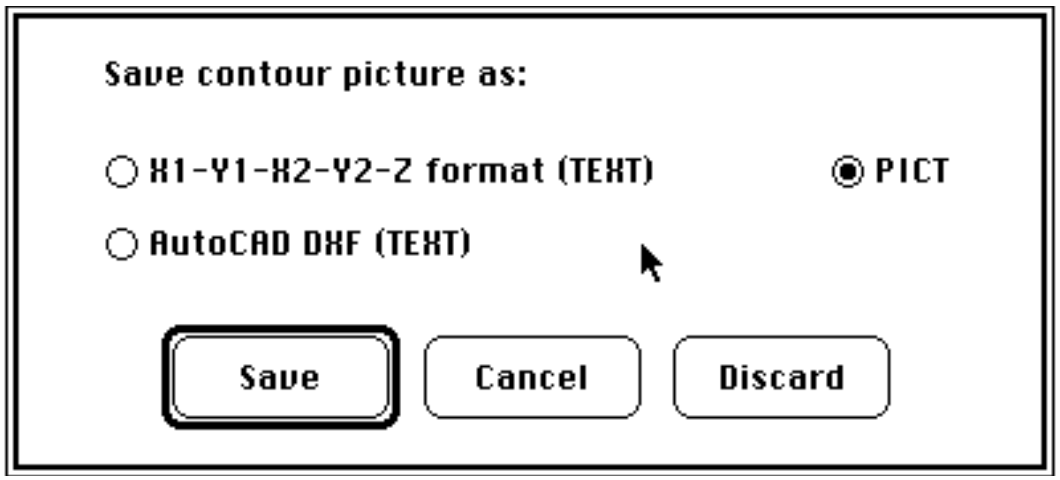


This is a sample of the plot that results when you check the "Draw as terrain map" box under "Graph Options…". On a Mac II, the color scheme is the same as on the previous plot. Here the computer has in effect interpolated a three-dimensional surface through all of your data points. The appearance of both the three-dimensional and "plan view" contour pictures can be modified by the user by accessing the "Graph Options…" choice under the Options Menu. Refer to the Special Options section for more information.

Step E - Saving the Plot

Contour81 interfaces to other programs through its capability to save contour and surface pictures into files. While you can certainly use the "Copy" feature from the Edit Menu to copy and paste a plot into another program (if the window is active), you should also save it in a file so that later you can bring the picture into one of the many graphics applications available. In the graphics program you can add notes, change the size of the picture, etc. prior to including the picture in a report or spreadsheet.

After you have finished viewing the contour plot, choose "Close" from the File Menu (or Option-W) or click on the window close box. The following dialog will be presented:



Choose the format of your choice and click the Save box or hit RETURN. The standard file dialog will prompt you for a file name and your plot will be saved under that name. The window will close and you may now generate a different type of plot, change some plotting parameters, load a different input file, or leave the program.

If any of the X and Y options on the "XYZ Value Selection" dialog (page 7) or any of the options on the "Weighting Function" dialog (page 14) are changed, the program will have to regrid the data.

Output Files

As stated in the Program Specifications section, **Contour81** allows you to save your plot in PICT format (a common format usable between all graphics programs), DXF format, which is the standard interchange format between CAD programs such as AutoCAD, or TEXT format. The TEXT format just creates a text file of vectors (if you drew a plan view plot) or elevations at grid points (if you chose a three-dimensional surface). Examples of these 2 TEXT output formats are below.

If you have chosen to generate a plan view contour plot, this is a listing of a sample output file produced by the "X1-Y1-X2-Y2-Z" option on the "Save contour picture as:" dialog. Starting with the third line and listed in order from left to right are the X and Y coordinates of the beginning point of a contour line, the X and Y coordinates of its end point, and its Z value:

```
* TEXT file created by Contour81 V1.1
* input file: bob s-test3   date: 10/ 8/1988   time: 15:32:22
  35.668    79.993    35.483    79.643   120.360
  36.006    80.703    35.668    79.993   120.360
  34.622    81.077    33.862    79.643   121.360
  34.622    81.077    35.541    83.008   121.360
  35.779    83.490    35.541    83.008   121.360
  .
  .
  39.321    80.056    39.106    79.643   118.360
  39.719    80.922    39.321    80.056   118.360
  38.121    81.299    37.257    79.643   119.360
  38.121    81.299    38.589    82.319   119.360
```

If you have chosen to generate a three-dimensional surface picture, the following is a listing of the output produced by the "X-Y-Z" option on the "Save contour picture as:" dialog. Starting with the third line and listed in order from left to right (on the next page) are the X, Y and Z coordinates of each grid point.

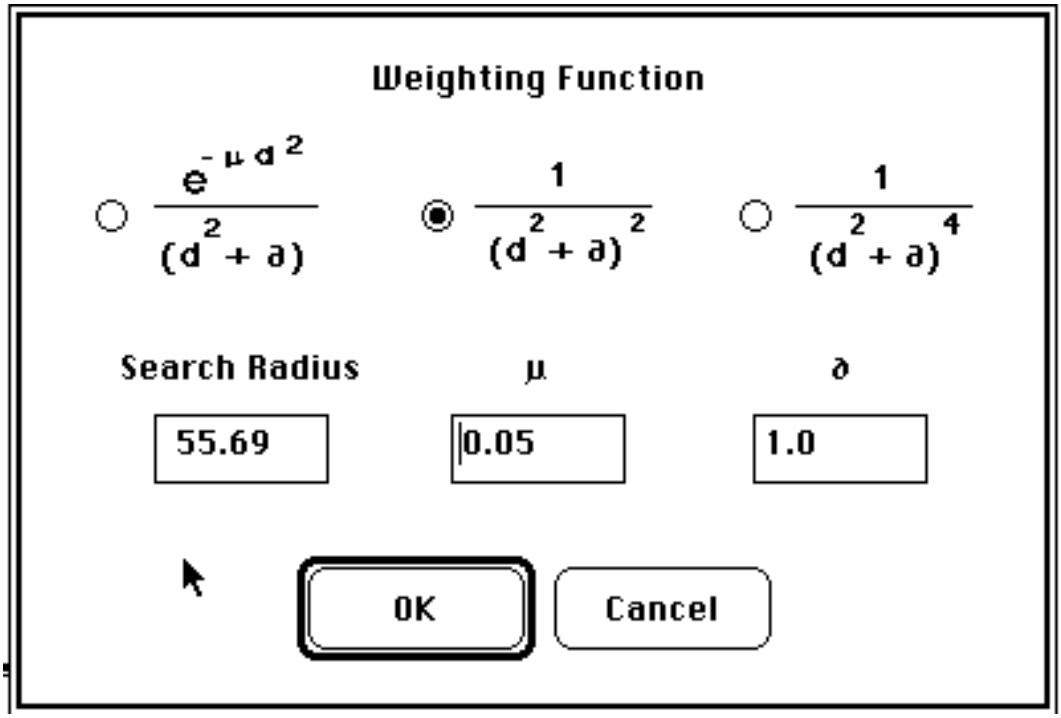
```
* TEXT file created by Contour81 V1.1
* input file: bob s-test3   date: 10/ 8/1988   time: 15:33: 7
  28.580    45.020   120.717
  28.580    48.867   120.294
  28.580    52.714   120.081
  28.580    56.561   120.111
  28.580    60.408   120.381
  28.580    64.255   120.864
  28.580    68.102   121.551
  .
  .
  32.293    45.020   119.871
  32.293    48.867   119.413
  32.293    52.714   119.006
  32.293    56.561   118.747
  32.293    60.408   118.789
```

These files are of type TEXT and can be viewed with MDS Edit or MacWrite. The capability to create these files was provided so that **Contour81** can interface with user-written programs for other types of data analysis.

The PICT file option is the output format option that will probably be used most often. Once a picture has been saved as a PICT file, almost any graphics application can be used to load it and make modifications. However, most of these "object-type" graphics programs do not support colored "regions", which means that the colors that are given to surface patches in a three-dimensional plot will be ignored. Try loading the PICT file into a "paint-type" program that supports color, such as PixelPaint™.

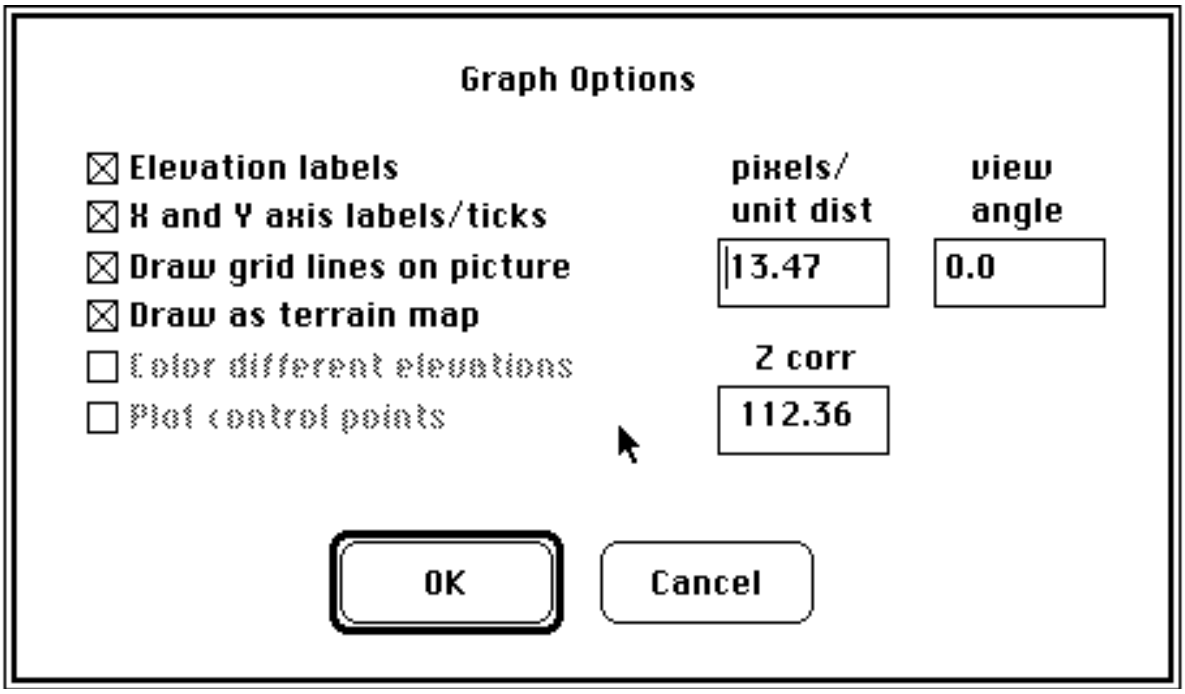
The DXF format option is included for the benefit of those who have access to the CAD power of AutoCAD or other programs that can access DXF files (on the Macintosh or MS-DOS™ machines). The contour plots are stored in color 7 on layer "0". The plan view plot is comprised of 3DLINEs and the three-dimensional surface plot is stored as 3DFACEs.

Next to the Edit Menu on the menu bar can be found the Options Menu. Under the Options Menu are three menu choices. The first choice is "XYZ values…" and choosing it results in a dialog similar to the one on page 7. The second choice from the top is "Weighting…" and it offers the following dialog:



The options in this dialog probably won't have to be changed very often, but they are provided for extra flexibility. The three functions along the top are the weighting functions that the program uses when gridding points. Simply put, the weighting function controls the amount of influence that other points have on the interpolated value at a given point. It is always a function of the distance (**d**) between the other points and the grid point in question. **μ** and *∂* are constants used to avoid any points of discontinuity. They should always be on the order of the inverse of the square of the average distances between nearby data points. The search radius is the maximum distance around a grid point to search for points to use in that grid point's interpolation. By experimenting with the weighting functions you will be able to see the different effects they have on a contour map of a given set of points.

The last choice on the "Options" Menu is "Graph Options…" In this dialog are the controls for the graphic output of the program, including the type and size of a graph and options for that type of graph.



On the left side of the dialog are the check boxes for the different types of pictures and additions. We purposely added these options because even though a user could certainly bring the PICT file into MacDraw or some other program and make all sorts of modifications, that would still take some time which could be saved by adding or removing the objects beforehand. The first box is "Elevation labels". This controls whether or not the elevations of the contour lines will be printed on the contour lines themselves. Remove the check if you do not want these labels. The second box, "X and Y axis labels/ticks", controls whether or not the axes will be labeled and small tick marks drawn at these labeling points. Remove the check if you do not want these additions. Third is "Draw grid lines on picture". This controls whether or not the grid lines will be printed. The grid lines go from side to side of the plot and coincide with the tick marks, axis labels and grid points. Remove the check if you do not want these grid lines.

The fourth option is used to indicate whether a three-dimensional "terrain map"-type surface plot should be drawn or if a "plan view" contour plot is desired. Note that the first three options have no effect on a "terrain map" plot because no exact contours are really distinguishable.

If color hardware is available, the fifth check box, "Color different elevations" can be selected. If it is selected then all plots will take advantage of color on the screen to represent different elevations. PICT files will also be saved with color information inside. On a machine that does not support color it will be impossible to select this option. The sixth option on the left controls whether the points in the input file will be plotted as small dots inside circles. Check the box if you are generating a plan view contour plot and you want this addition.

The "pixels/unit dist" entry controls the size of a plan view contour plot. The larger the number, the larger the picture. It also has no effect on a three-dimensional plot. It is set at startup to give a plot that fills the screen. The "view angle" option simply controls the angle of viewing for a three-dimensional plot. An entry of 0.0 will give a viewpoint directly overhead, while an angle of 90.0 will generate the picture as if you were standing at 0.0 elevation looking in the positive Y direction. An angle of 70 usually gives a good-looking plot.

The last option, "Z corr" is a Z correction to subtract from the base elevation of a three-dimensional plot. Normally it will be automatically set to the minimum contour level, and rarely needs to be changed. Increasing it will move the surface downward and vice versa. The user is encouraged to experiment with all of the above graphic options and determine the type of plot he or she wants to generate, keeping in mind that the full editing power of commercial graphics applications is always available.

The algorithm behind **Contour81** involves a certain amount of higher mathematics, but it is not beyond the reach of anyone with a technical education. The basic process is as follows: First, setup a rectangular grid according to the user input of the number of grid points in each direction and the values of x_{min}, x_{max}, y_{min} and y_{max}. Then calculate the z values of each grid point through interpolation of the input data points. Once this has been done we can treat each grid square as a four-sided figure in three-dimensional space. Since we also have a list of the contour values, we can easily draw any contour lines for this figure because they will be (if they exist) just the intersections of the figure and the planes parallel to the x-y plane at the contour value heights.

The idea behind the interpolation is to use the relative distances and directions of the data points to evaluate the coefficients of a quadratic polynomial to act as an approximation to the surface in that region. This second-order polynomial has the general form:

$$F(x, y) = a_{00} + a_{10} x + a_{01} y + a_{20} x y + a_{11} x^2 + a_{02} y^2$$

An additional requirement of ours will be that the data points that are closer to the grid point in question should "carry more weight" than points farther away. More explicitly, we wish to minimize the value of S in the following equation:

$$S = \sum_{i=1}^{n} (F(x_i, y_i) - z_i)^2 \; w((x_i - a)^2 + (x_i - a)^2)$$

with w(x) being a weighting function that gives us the desired effect, such as $w(x) = \exp(-d^2) / d^2$. Other functions are on the Weighting Functions dialog. To do this we must use the above equation to solve six equations for the six unknowns a_{mn}. **Contour81** does this through the use of Gaussian elimination with scaled partial pivoting.

At this point we have a "mesh" of our interpolated grid points. This is all that is necessary to draw a three-dimensional "terrain map" plot. To draw a contour map we now need only to calculate the occurrences of our contour levels as lines that traverse these grid squares.

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This manual was written on an Macintosh II computer with MacWrite II software.

Technical Support

Technical Software Systems apologizes for the fact that at this time it is unable to offer telephone support for this product. The absence of this type of support is reflected in the shareware nature of the software. However you can reach us for any questions by writing to the above address or by contacting the following electronic mail addresses:

Internet: rxk9228%njitx.decnet@njitc.njit.edu
GEnie: R.KOZLOWSKI1

Thank you for using and purchasing this software.