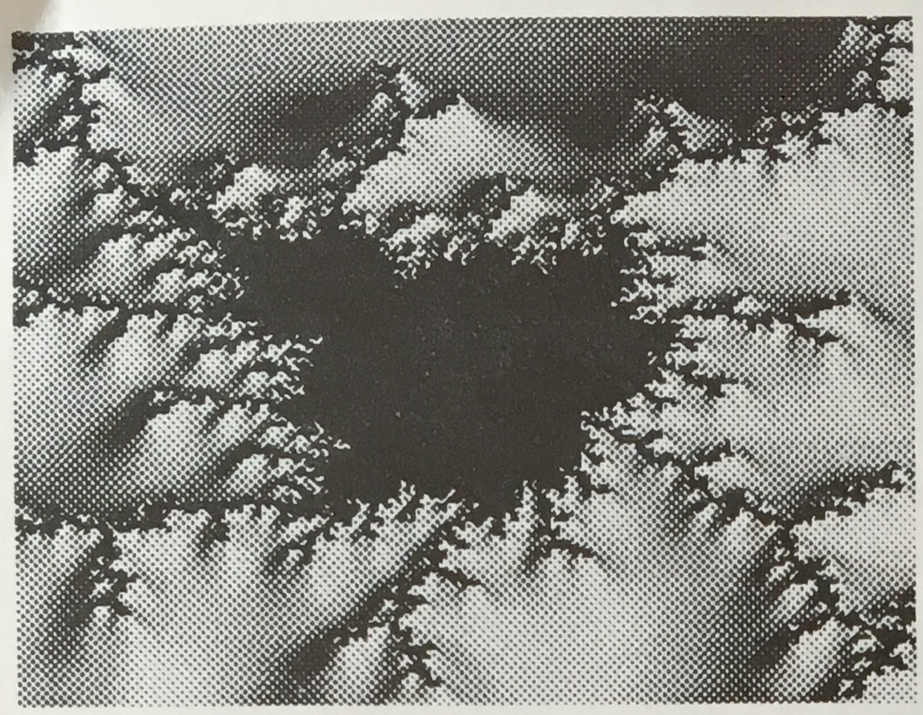

The Beauty of Fractals Lab

Graphics Software for the Macintosh

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Software written by

Thomas Eberhardt and Marc Parmet

With this program you can interactively explore the Mandelbrot set and its Julia sets **including 3D rendering**. Find your own fantastic zooms and artistic color maps. You can easily switch between 2D, 2.5D and 3D renderings. The algorithms are very fast in the sense that the predominant shapes of your images emerge very quickly. At that point you can already decide to initiate your next blow-up, or you may wish to save window coordinates for later processing of a fully computed high resolution image.

Features

- interactive computation of Mandelbrot and Julia sets
- 3D rendering of potential (and distance estimator) surfaces (*new*)
- six algorithms to choose from (*new*)
- see the predominant shapes immediately
- multiple windows
- can work in the background when you use the multifinder
- editor for color palettes included (*with many new features*)
- load and save images from and to disk (*now compressed format*)
- rectangular formats of images (*new*)
- tool icons and cursor info integrated into picture window (*new*)
- help facility and refinement tool (*with new features*)
- "Copy" and "Paste" allow you to insert the images into your favorite drawing program or word processor (as we did in this document which then was directly printed on a laser printer)

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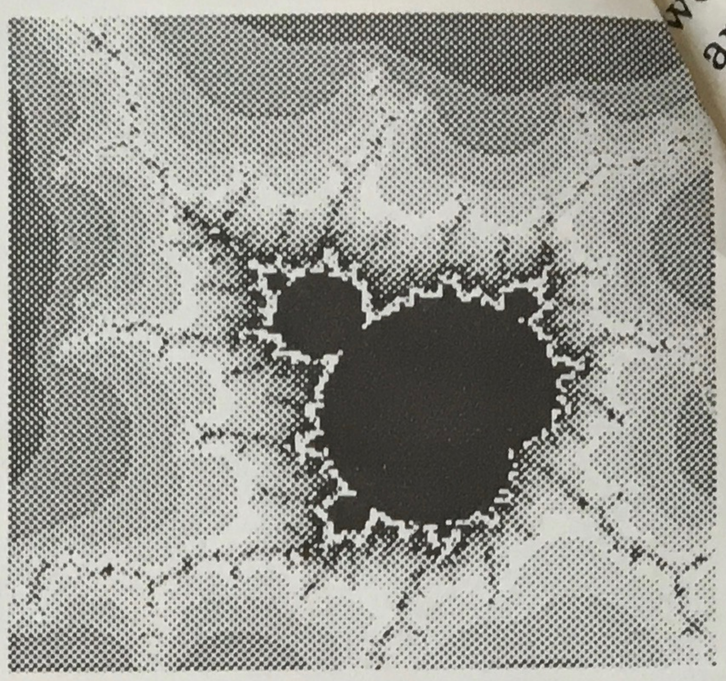
Menus



File Menu "**New**":

To open a new window select "New" from the file menu. You will get a dialog box which allows you to set all the necessary parameters.

File menu "**Again**":

This is another way to create a new picture window. But the dialog box already contains the parameters of the active picture window. This allows you to compute the same image again with possibly modified parameters.

File menu "**Open**":

Allows you to read (and display) previously saved pictures. If only parameters were saved, the image will be recomputed.

File menu "**Close**":

Allows you to close the active picture window.

File menu "**Save**":

This allows you to save the picture from the active window. You may save the complete picture (as far as it is drawn) or just the data describing the picture. The program will try to compress the data. This will save you a lot of disk space and it will take only a little more computer time. Note that older versions of the program (The Game of Fractal Images 1.x) will not be able to read these data files.

File menu "**Save as**":

This allows you to save the picture from the active window under a different name.

File menu "**Quit**":

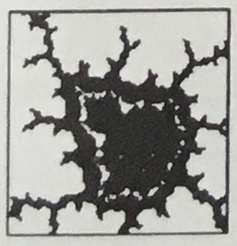
This is the end of the program.

Edit menu "**Undo**":

Allows you to undo changes made with the **Color Editor.**

Edit menu "**Cut / Clear**":

This allows you to delete color tables created with the **Color Editor.** Color tables which were cut out can be pasted in again.



Edit menu "**Copy / Paste**":

You may copy and paste **your pictures** into the Clipboard and the Scrapbook. In other words you can insert the picture into your favorite drawing program or

wordprocessor (as we did with this example). You may also copy and paste color maps between different images (simply activate the respective image window and return to the Color Editor). If the **Picture Info** window is active you can copy the text (and paste it into a word processor).

Edit menu "**Duplicate**":

This allows you to duplicate color tables created with the **Color Editor.** New (duplicated) tables can be modified without affecting the original.

Window menu "**Stack**":

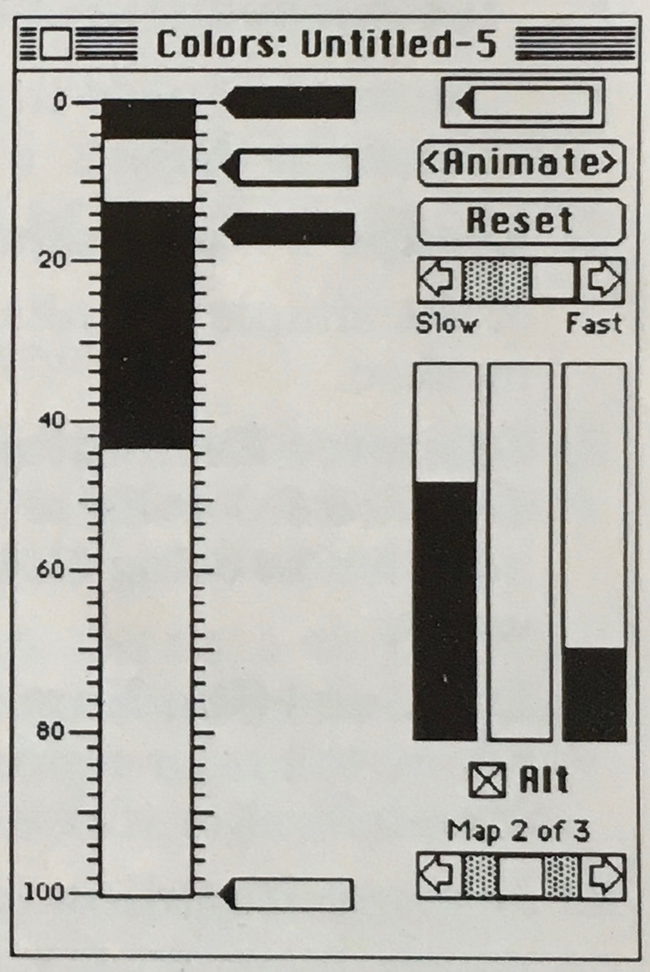
This will rearrange (stack) the displayed windows.

Window menu "**Picture Info**":

This will display some information on the active window. You can copy this information to any common word processor (etc.).

Window menu "**Color Editor**":

This item activates the color editor which assigns colors to the iteration count (escape time) of each point. You may add or remove color crayons. Simply pick the crayon shown in the upper right of the window and move it to the color bar (as you would do with tab markers in common word processors), or pick a crayon from the color bar and move it away. To change the color of the active (highlighted) crayon use the three color sliders for red, green and blue. You may also change colors by using the Macintosh Color Picker. To do this double click on the crayon.



A beautiful effect is obtained by the animation of the color table. You can run the animation forward and backward by moving the cursor from left to right (and back again) within the Animation-button. The speed of this color table animation can be selected by the corresponding slider. The Reset-button allows you to reset the color table.

The color editor can maintain several color tables for one image. The number of tables already defined is displayed in the lower right corner of the color editor window. The table selector allows you to switch between the tables. "Clear", "Cut", "Copy", "Paste" and "Duplicate" allow you to delete, duplicate or move color tables (from image to image). Interesting visual effects can be generated if the entries of two different color tables are alternately selected. If you check "Alt" this is done with two successively defined tables.

For the **Escape Time** or **Distance Estimator** algorithm the color spectrum on the left is scaled by the maximum number of iterations (it can also be mapped by a logarithmic function). By comparing the color spectrum with the computed image, one can determine the visible range of iteration counts in the image. The **Distance Shading** algorithm uses colors to represent distances. In this case the color spectrum is scaled by the image size. For all algorithms the number of color shades can be specified in the main dialog box.

Dynamic window menu for pictures:

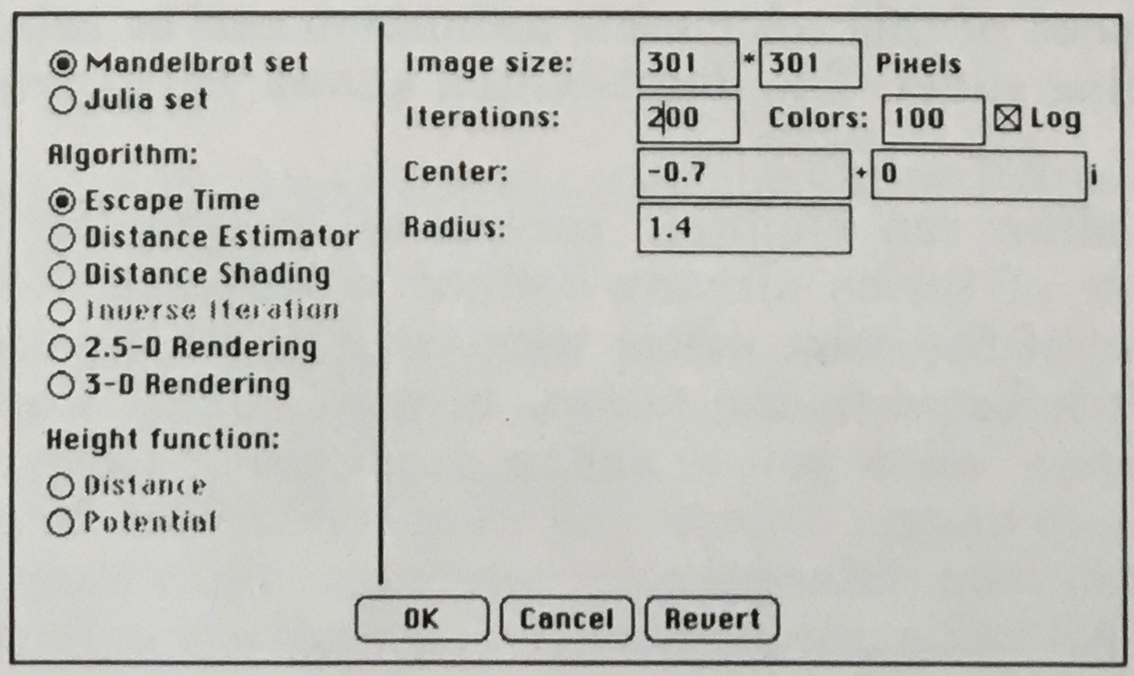
For all displayed picture windows an entry in the window menu is created. This provides an easy way to select a hidden window.

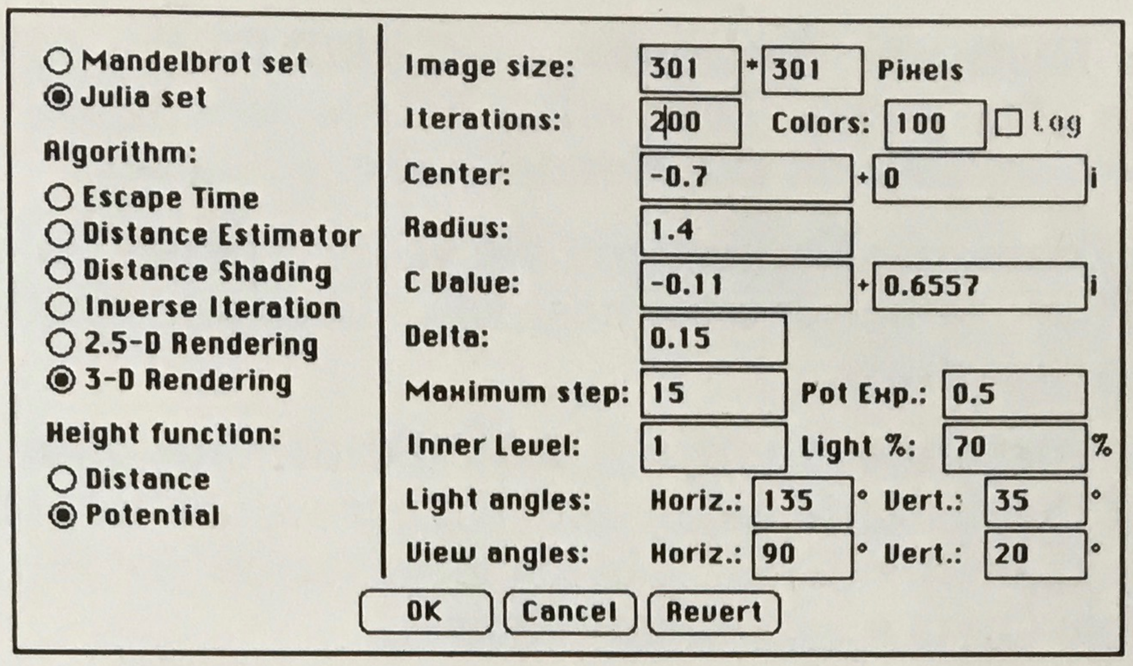
Main Dialog Box

The dialog box will allow you to select:

- the computation of the **Mandelbrot set** or a **Julia set**
- the method used to compute the picture, there are six of them:

1) **Escape Time**: Evaluates every point of the picture by iteration of the simple formula $z^2 + c$. This is a safe but sometimes slow method.
2) **Distance Estimator**: Estimates the distance to the Mandelbrot or (filled-in) Julia set and processes a whole disk at a time. In addition to being elegant and fast, this method is interesting to watch.
3) **Distance Shading**: Draws a continuously shaded color image where the color represents an estimate of the distance to the Mandelbrot or (filled-in) Julia set.
4) **Inverse Iteration** (only for Julia sets): This is a fast method which, however, gives only a black and white picture of the set. It computes a tree of pre-images under $z^2 + c$ and tries to omit certain inefficient subtrees.





5) **2.5D - Rendering**: This is a pseudo 3D-rendering. A distance or potential estimate is transformed into a height function. A fixed top view of the computed height field is displayed using a lighting model which can be modified by the user.

6) **3D - Rendering:** This is a full 3D-rendering of the same height field (as used in 5.). The viewpoint, viewing angles and the lighting can be changed by the user.

• the type of the **height function** (only for 2.5/3D - Rendering): potential of the Mandelbrot (or Julia) set or the distance to the computed set.

• the **size** (in pixels) of the picture to be computed.

• the range of complex numbers which will be covered: the center and the width (specified by the **radius**) of a square region which fits into the window specified by the "image size" parameter.

• the maximum number of **iterations** computed for a single point (both for Escape Time and Distance Estimator): for a global picture (overview) 100 is a good choice, for extreme blow-ups you will have to increase the number to 1000 (or even more) to see all the details.

• the (maximal) number of different **colors** used for the picture.

• check **logarithmic** mapping for the color table. The program uses the different colors to represent the escape time of a given point. If the maximal number of iterations is higher than the maximal number of colors the iteration count must be mapped into the given spectrum of colors. This is done nonlinearly if logarithmic mapping is checked (i.e., at the begining of the scale it is one to one but at the end many iterations can be mapped to one color), otherwise the complete range of possible iteration counts is simply scaled down linearly.

• (only for Julia sets) the **c-value** which determines the Julia set.

• (only for **Inverse Iteration**) the maximum number of times a pixel should be **hit** by the algorithm (10 seems fine).

• (only for **Distance Estimator** and **2.5/3-D**) the value "**delt** (in fractions of a pixel). This value determines which pixels ar colored to be very close to the Mandelbrot or Julia set.

• (only for **Distance Estimator**) the value "**recur**" (in fractions of a pixel). This value determines the smallest sized disk the algorithm tries to draw.

• (only for **Distance Shading, 2.5/3-D**) the **maximal step** size (in pixels) of the distance estimator. Higher values will increase the speed of the algorithm but if it is too large, some vertical strips will become visible (15 is a rather safe choice).

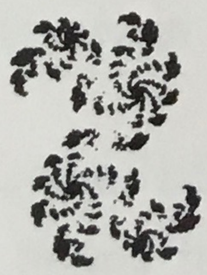
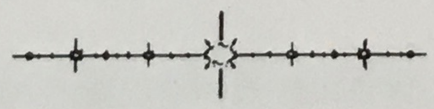
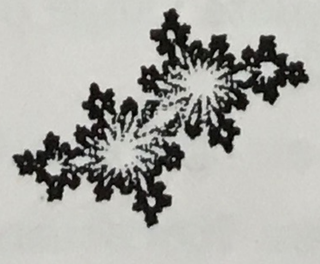
• (only for **Height Function Potential**) the value "**exp**". With this factor you can scale the height field with a proper power law (specify the exponent) to improve the visual balance of the height field and to maximize the dramatic effect of the fractal landscape.

• (only for **3-D**) the **inner level** (i.e., the height at which the Mandelbrot set is drawn). This allows you to give an interesting emphasis to the boundary of the Mandelbrot set. You can specify values from 1 to 0. A value near 1 (like 0.95) will result in images which show the boundary of the Mandelbrot set similar to a coastline, whereas a value of 1 will result in drawing the Mandelbrot set at the top level.

• (only for **3-D**) the **light** source ratio (any value between 0 and 100%). The value 0 will turn off the free light source whereas 100% will turn off the helmet lamp.

• (only for **2.5/3-D**) the position of the free **light** source. For 3-D there is a second light source which is exactly at the position of the viewer (like a helmet lamp). The free light source is "very far away" (like the sun). Therefore the position is specified by angles. A vertical angle of 90 degrees means light from the right hand side (along the x-axis) if we look into the direction of the y-axis (0 degree).

• (only for **3-D**) the **viewing direction**. If you specify a horizontal angle of 0 degrees you will look along the y-axis. A vertical angle of 90 degrees will result in a view right from the top.


Cursor Tools

Insert/Refine: Insert a new "seed" for the **Distance Estimator** algorithm by clicking at any point in the picture (just try it) and refine the picture starting with that point. Or (for all algorithms) select a part of the picture (drag the cursor with the mouse button pushed down to size the area of interest, press the option key to move it) for refinement.

Blow-up : Select "blow-up" windows. Drag the cursor with the mouse button pushed down to size the window - press the option key to move it. If you additionally press the command (apple) key the aspect ratio will be fixed to 1:1 or 4:3 (whatever is a better representation of the cursor action). When you release the mouse button the selected part of the picture will be recomputed in a new separate window. Before the computation is started, a dialog box (see above) will allow you to specify more parameters and options for the new window.

Julia-Set: Pick a c-value parameter from the Mandelbrot set for the computation of the corresponding Julia set. Additional parameters can be specified in the dialog box then a new window will be opened.

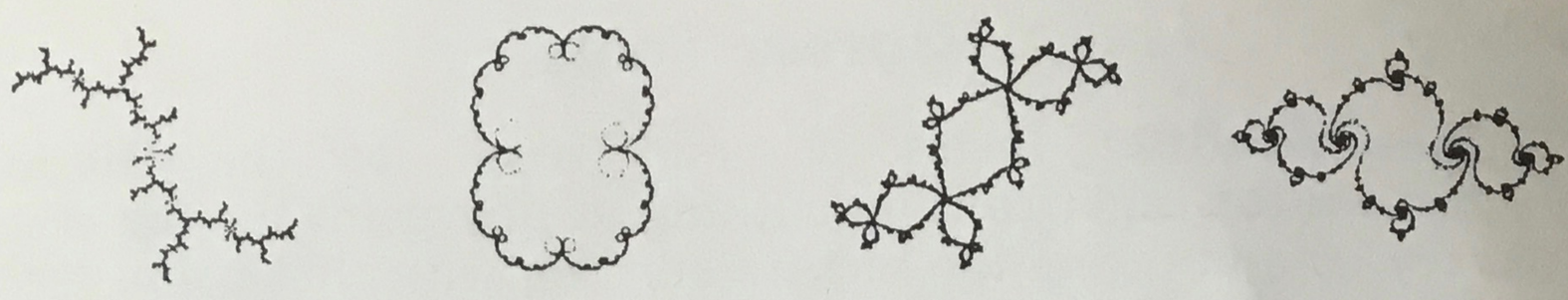
Orbits: Show the first forward iterates (orbit) of the initial value selected by the cursor. If you hold the cursor fixed at one point (mouse button down) the dynamics are shown by an animation of highlighted pixels.

Distance: show the guess of the distance estimator.

Hardware requirements

Macintosh II™ computer (running system 6.0.2 or later) with color or gray scale monitor (256 colors/shades) and one megabyte memory (two or more are preferred).

Note: On a 1 megabyte system it is advisable to use smaller windows (about 200 by 200 pixels) since otherwise you may be limited to only a few windows open at any time. Also as you proceed to work with the program, CPU memory may become partitioned into parts too small to hold the contents of a new window. In that case it is best to save your results on disk and to exit and to restart the program. The memory allocation by the MultiFinder is preset to a small value: 700 kilobyte. You can change this value if you select "Information" from the file menu of the Macintosh finder. The value "2000 kilobyte" is a good choice.



Help and Demo Facility

If you select "**Help**" from the apple menu you will find an extensive online documentation.

The built-in **Demo Facility** allows you to run the program in Demo Mode. Try exploring it by naming some of your picture files "Demo1", "Demo2", ... (they must reside in the same folder as the program) then start the program.

Background reading

- **The Science of Fractal Images**,
H.-O. Peitgen and D. Saupe (Eds.), Springer-Verlag, New York, 1988, 328 pp., 142 illus. in 277 parts, including 39 color plates, ISBN 0-387-96608-0

- **The Beauty of Fractals**,
H.-O. Peitgen and P. Richter, Springer-Verlag, New York, 1986, 199 pp., 184 figures in 221 separate illus., 40 color pages, ISBN 0-387-15851-0

- **Fractals for the Classroom**,
H.-O. Peitgen, H. Jürgens, and D. Saupe, Springer-Verlag, New York, 1990, 450 pages, ISBN 0-387-97041-0

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