

Introduction
to
Ultra Fractal

Instructor Guide



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Introduction

The area of fractal geometry is a relatively new one that has generated interest in many areas. While being fundamentally mathematical, the aesthetic beauty of fractals appeals to artists and people not traditionally drawn to math. Fractals typically are generated using a computer, so more technically oriented people can find them intriguing, too.

This unit is an introduction to the fractal-generating software, “Ultra Fractal.” The intended users are undergraduate students at the University of Advancing Computer Technology. The instruction has been developed such that it could be delivered to any student at the University, irrespective of their major, by any of the faculty in the mathematics area. The unit has been written to be approximately 4 hours long, covering two 2-hour class periods.

Objectives

1. Students generate images of Mandelbrot and Julia fractals.
2. Students demonstrate the techniques for saving and exporting fractal image and parameter files.
3. Students demonstrate the use of formulas and inside and outside colorings in creating fractal images.
4. Students demonstrate the use of gradients and layering in manipulating fractal images.

Students will also learn:

- what are fractals
- what differentiates fractals and non-fractal shapes
- about Mandelbrot and Julia sets
- about other types of fractals
- how to use anti-aliasing to improve their fractal images

At the conclusion of the instruction, the students will have a basic introduction to “Ultra Fractal,” a program that is currently available to all students at the University.

Organization

The material is organized into 4 lessons. Each lesson is designed to be delivered in one hour (50 clock minutes) of classroom time. The lessons consist of small lectures, demonstrations, and opportunities for the students to try out the material for themselves.

Materials

The “Introduction to Ultra Fractal” unit consists of a complete set of instructor and student materials, as well as additional material about Ultra Fractal:

- **Instructor Guide:** Contains instructional procedures to use with each lesson, reproducible exercises and quiz, instructor background information about fractals, and a glossary. The unit contains one color copy of the Instructor Guide.
- **Student Guide:** Contains 25 pages of instructional text and practice opportunities. The unit contains 15 black and white copies.
- **Supplemental material on CD-ROM:**
 - **Ultra Fractal program:** The latest release, version 2.05. This is the same version that is available from www.ultrafractal.com. See that site or the Ultra Fractal Information on page 20 of this guide for more information on installing the program.
 - **Sample images:** Over 40 sample images created by artists who work with Ultra Fractal. The images are saved in fractal file (ufr), parameter (upr), and image (jpg) formats. The jpg files can be viewed with any standard image processing program or web browser.
 - **Electronic copies of the Student and Instructor Guides, in Microsoft Word format.**

Instructor Background Information

This unit was designed such that it can be taught without any special knowledge about fractals. However, if you would like additional information before you teach the unit, or at times during the unit, you can refer to the Instructor Background Information starting on page 15 of this guide. General information about fractals is presented, along with specific information about the Mandelbrot set and about the Ultra Fractal program.

Lesson 1: What Are Fractals?

Preparation

- Read “What Are Fractals?” in the Student Guide (pages 3 – 5).
- Read “What Are Fractals?” (page 16 – 18) and, “The Mandelbrot and Julia Sets” (page 19) in the Instructor Guide.
- Open Ultra Fractal.
- Prepare the “lesson 1” folder on the CD-ROM for access.

Materials

- Student Guide

Procedures

- A. Introduction
 - Distribute the student materials.
 - Open Ultra Fractal.
 - Show some or all of the images in the “Sample Images” folder on the CD-ROM.
 - Explain that the students will learn how to use Ultra Fractal to create similar images.
- B. Demonstrate the smooth nature of the circle.
 - Open the “circle zoom” fractal.
 - Zoom in by pressing the F9 key repeatedly. Zoom out by pressing the F10 key.
- C. Demonstrate the fractal nature of the Mandelbrot set.
 - Open the “mandelbrot zoom” fractal in the “lesson 1” folder.
 - Zoom in by pressing the F9 key repeatedly. Zoom out by pressing the F10 key.
 - Alternatively, use the zoom box (see page 9 of the Student Guide) to zoom into any point of your choosing, or simply move the cursor to an interesting spot in the image and double-click.
- D. On the white board, demonstrate iterating and how a sequence can be bounded or divergent.
 - Use $f(z) = z^2 + c$ with the initial $z = 0$.
 - For divergent examples, use $c = 1, 2,$ or larger integer.
 - For bounded examples, use $c = 0$ or $c = -1$.
- E. Demonstrate the effect of increasing the number of iterations.
 - Open the “mandelbrot iteration” fractal.
 - On the “Formula” tab, repeatedly double the “Maximum Iterations” up to 128 or so, for the students to see the effect.

Lesson 2: Using Ultra Fractal

Preparation

- Read “Using Ultra Fractal” in the Student Guide (pages 6 – 14).
- Read “Ultra Fractal Information” in the Instructor Guide (pages 20 – 21).
- Visit the Ultra Fractal website (www.ultrafractal.com) for additional information.
- Prepare the “lesson 2” folder on the CD-ROM for access.
- Open Ultra Fractal.

Procedures

A. Introduction

- Show some or all of the images of Mandelbrot and Julia fractals in the “Lesson 2” folder on the CD-ROM.
- Explain that, in this lesson, the students will learn how to use Ultra Fractal to create similar images.

B. Administer tutorial on creating a Mandelbrot set fractal.

- Demonstrate creating a new fractal and loading the “Mandelbrot” formula.
- Show how to size the image.
- Save the fractal file, allowing the students time to do so. Check to see if everyone’s fractal opened properly.
- Demonstrate the use of the zoom box.
- Save the fractal parameters, allowing the students time to do so. Check to see if everyone’s parameters loaded properly.
- Demonstrate entering parameters into the Location tab.
- Export the image to a JPEG file, allowing the students time to do so. Check to see if everyone’s image exported properly.

C. Discuss Julia sets and switching from Mandelbrot to Julia sets.

- Briefly discuss the relationship between the Mandelbrot set and Julia sets.
- Show how to use the Switch feature to generate a Julia set from a Mandelbrot set.

D. Conduct exercise, “Creating Mandelbrot and Julia Fractals.”

- Distribute handout.
- Circulate among the students to check progress and answer questions.

Lesson 3: Other Fractal Types

Preparation

- Read “Other Fractal Types” in the Student Guide (pages 15 – 17).
- Open Ultra Fractal. Select “Options...” from the “Options” menu. On the “Previews” tab, check the boxes, “Use size from original window,” “Use gradient from original window,” and, “Use color settings from original window.”
- Prepare the “lesson 3” folder on the CD-ROM for access.

Procedures

A. Introduction

- Show some or all of the images in the “Sample Images” folder on the CD-ROM.
- Explain that, in this lesson, the students will learn how to use Ultra Fractal to create images other than the Mandelbrot and Julia set fractals.

B. Demonstrate the effect of changing powers on the Mandelbrot fractal.

- Open the “mandelbrot” fractal from the “lesson 3” folder.
- On the Formula tab, change the real part of the “power” parameter to 3, 4, 5, etc. Discuss the symmetry of the Mandelbrot set for various powers.
- Use various non-zero values of the imaginary part of the “power” parameter. Discuss the branch cuts in the fractal.
- Use the “Switch” mode to generate sample Julia sets, as desired.

C Show the “Newton’s Method” fractal.

- Briefly discuss Newton’s Method.
- Open the “newtons method” fractal. The colors relate to the solution found. Discuss how the fractal structure relates to the method finding different solutions.
- On the Formula tab, change the “Degree” parameter from 3 to 4, 5, 6, etc. Discuss the number of arms present for each degree.

D Show the “Phoenix” fractal.

- Open the “phoenix mandelbrot” fractal. Show how the Phoenix is a variation of the Mandelbrot.
- On the Formula tab, roll over the formula-specific parameter boxes with the cursor. Show how hints are displayed.
- Change various parameters and see the effect on the image. Zoom in if desired.

E Show the “General Tent” fractal.

- Open the “general tent mandelbrot” fractal.
- On the Formula tab, emphasize how parameters are entered and how to use the drop-down menus.

Lesson 4: Rendering Images

Preparation

- Read “Rendering Images” in the Student Guide (pages 18 – 25).
- Open Ultra Fractal. Select “Options...” from the “Options” menu. On the “Previews” tab, check the boxes, “Use size from original window,” “Use gradient from original window,” and, “Use color settings from original window.”

Procedures

- A. Administer tutorial on loading a coloring formula.
 - Create the “basic julia” fractal by following the directions on page 18 of the Student Guide.
 - Show how to load the “Basic” coloring from the “lkm” folder on the Outside tab.
 - Change the “color by” parameter to “polar angle.”
 - Check to see if everyone’s fractal is colored properly.
- B. Administer tutorial on using the gradient editor.
 - Open the gradient editor, using the “basic julia” image with the “polar angle” coloring.
 - Show how to cycle the colors through the “Position” parameter.
 - Show how to change the colors and locations of the control points.
 - Demonstrate loading pre-existing and random gradients.
 - Check to see if everyone is following along.
- C. Administer tutorial on layering, found on pages 22 – 23 of the Student Guide.
 - Create the bottom layer.
 - Create the top layer.
 - Select the merge mode.
 - Check to see if everyone’s fractal is colored properly.
- D. Administer the quiz. Depending on the time, you may have the students perform the quiz right then in class, or at their leisure within the next day.

Reproducible Masters

- “Creating Mandelbrot and Julia Fractals” exercise
- “Experimenting with Formulas and Colorings” exercise
- Quiz
- Quiz answer key

Creating Mandelbrot and Julia Fractals

Here's your chance to experiment with Mandelbrot and Julia fractals.

1. Create a zoom into the Mandelbrot set. On the Location tab, set the Center to $0/1$ (Re/Im) and the Magnification to 1. Zoom in repeatedly by pressing F9. How far in can you go? (When the image stays blocky and doesn't refine, you've run out of computer precision.) Export this image as a JPEG file. View this image in a web browser or an image-processing program to verify that you exported it properly.
2. There's a small copy of the Mandelbrot set centered around $-1.9990958/0$ (Re/Im). Can you find it? You may need to increase the Maximum Iterations on the Formula tab as you zoom in. Save this as a fractal file (.ufr). Open this file to verify that you saved it correctly.
3. Create a Mandelbrot set image and zoom in to an interesting spot of your own choosing. Zoom in to a magnification of at least 1 million (1000000 or $1e6$), increasing the maximum iterations if necessary. Then, choose a spot in that image and generate the corresponding Julia set. Is there any resemblance between the zoom of the Mandelbrot set and the Julia set? Save the parameters for this Julia set as a .upr file. Reload these parameters to verify that you saved them correctly.

Experimenting with Formulas and Colorings

Now you can try out what you've learned about formulas and coloring methods. Be sure to save any images that you like to your own disk, either as parameters (upr) or as fractal files (ufr).

1. Create an image using the "General Tent Mandelbrot" formula (in the "lkm" folder) and the "Statistics" coloring (in the "lkm" folder) for the Inside pixels. Be sure to try various settings for the "r type" parameter in the formula and "statistic" parameter in the coloring.
2. Take the "layering.ufr" image from the layering example and play with different gradients for both layers. Vary the merge mode and opacity for the top layer until you find a combination that you like.
3. Trade images with someone else. See if you can improve their image and if they can improve yours.

Introduction to Ultra Fractal

Quiz

1. Create a Mandelbrot fractal with the following characteristics. Any item that is not specified is to be left at the default value. Save the fractal file as “Mandelbrot.ufr” and email it to the instructor. Export the image as “Mandelbrot.jpg” with the default quality setting and email the image to the instructor.

Formula

- “Mandelbrot” from “standard” folder
- Periodicity Checking: off
- Maximum Iterations: 2500
- Power (Re/Im): 2.01/0
- Bailout value: 1000

Location

- *Start* with these parameters:
 - Center (Re/Im): -1.7578/0
 - Magnification: 300
 - Rotation angle: 90
- Then, zoom in to create an image where a small Mandelbrot fills the window. The magnification must be *at least* 1 million (1000000).

Gradient

- “Royal” from “standard” folder
- Invert it
- Rotate it to a position of 50.

Image

- Width: 640 pixels
- Height: 480 pixels

2. Create a Julia fractal with the following characteristics. Any item that is not specified is to be left at the default value. Save the parameters as “Julia” in “julia.upr” and email that file to the instructor.

Formula

- “Julia” from “standard” folder
- Drawing Method: Multi-pass Linear
- Periodicity Checking: off
- Maximum Iterations: 243
- Julia seed (Re/Im): -0.044662513/0.643849337
- Power (Re/Im): 2/0

Location

- Center (Re/Im): 0.1560925/ 0.7658098
- Magnification: 110
- Rotation angle: 286

Inside

- “Range Lite” from “lkm” folder
- range center: 0.56
- range width: 0.01
- color by: last mag

Outside

- same coloring as Inside

Gradient

- “45/225” from “lkm” folder

Image

- Width: 500 pixels
- Height: 400 pixels

Introduction to Ultra Fractal

Quiz Answer Key

1. Create a Mandelbrot fractal with the following characteristics. Any item that is not specified is to be left at the default value. Save the fractal file as “Mandelbrot.ufr” and email it to the instructor. Export the image as “Mandelbrot.jpg” with the default quality setting and email the image to the instructor.

Formula (5 points)

- “Mandelbrot” from “standard” folder
- Periodicity Checking: off
- Maximum Iterations: 2500
- Power (Re/Im): 2.01/0
- Bailout value: 1000

Award 1 point each for:

- fractal file named properly
- fractal file emailed (or otherwise handed in) properly
- image file (.jpg) named properly
- image file emailed (or otherwise handed in) properly

Location (2 points)

- Start with these parameters:
 - Center (Re/Im): -1.7578/0
 - Magnification: 300
 - Rotation angle: 90
- Then, zoom in to create an image where a small Mandelbrot fills the window. The magnification must be *at least* 1 million (1000000).

To check the ufr file, save it to disk from email. Within Ultra Fractal, open it by choosing “File / Open,” and select the appropriate folder and file. Check the “Formula,” “Location,” and “Image” tabs to verify that the specifications were met.

The image should resemble this:

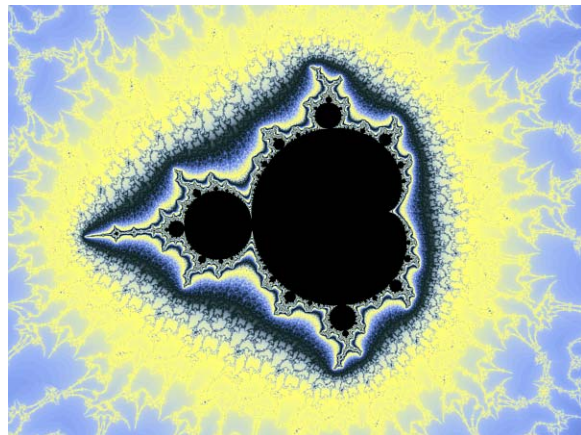
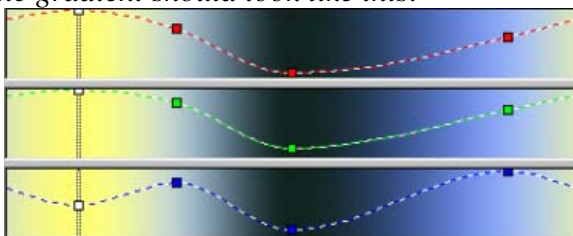
Image (2 points)

- Width: 640 pixels
- Height: 480 pixels

Gradient (2 points)

- “Royal” from “standard” folder
- Invert it
- Rotate it to a position of 50.

The gradient should look like this:



2. Create a Julia fractal with the following characteristics. Any item that is not specified is to be left at the default value. Save the parameters as “Julia” in “julia.upr” and email that file to the instructor.

Formula (7 points)

- “Julia” from “standard” folder
- Drawing Method: Multi-pass Linear
- Periodicity Checking: off
- Maximum Iterations: 243
- Julia seed (Re/Im): -0.044662513/0.643849337
- Power (Re/Im): 2/0

Location (4 points)

- Center (Re/Im): 0.1560925/0.7658098
- Magnification: 110
- Rotation angle: 286

Inside (4 points)

- “Range Lite” from “lkm” folder
- range center: 0.56
- range width: 0.01
- color by: last mag

Outside (4 points)

- same coloring as Inside

Gradient (1 point)

- “45/225” from “lkm” folder

Image (2 points)

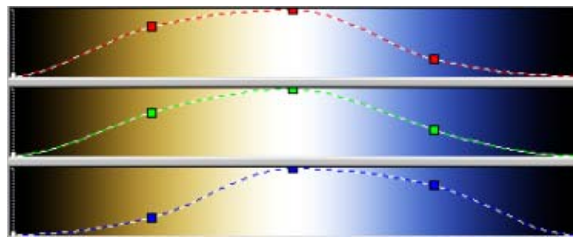
- Width: 500 pixels
- Height: 400 pixels

Award 1 point each for:

- parameter file named properly
- parameter file emailed (or otherwise handed in) properly

To check the upr file, save it to disk from email. Within Ultra Fractal, choose “File | Browse | Parameters...” Click the “Add File” icon and select the correct folder and file. Verify that the parameter set is named “Julia”, and click on it in the browser to load it. Check the “Formula,” “Location,” “Image,” “Inside” and “Outside” tabs to verify that the specifications were met.

The gradient should resemble this:



And the image should resemble this:



Instructor Background Information

- What Are Fractals?
- The Mandelbrot and Julia Sets
- Ultra Fractal Information

What Are Fractals?

(This material was taken from the Fractalus website, www.fractalus.com. It is © Damien M. Jones.)

This is a simple question with a very complicated (and very long) answer. A technical answer, while accurate, doesn't help much because it uses other fractal speak jargon that few people understand, so I won't even give that definition here.

The simple answer is that a fractal is a shape that, when you look at a small part of it, has a similar (but not necessarily identical) appearance to the full shape. Take, for example, a rocky mountain. From a distance, you can see how rocky it is; up close, the surface is very similar. Little rocks have a similar bumpy surface to big rocks and to the overall mountain.

A Simple Example

This concept of self-similarity can be a little hard to come to grips with, but it's a fundamental part of fractals. So take a look at this first image—from a Julia set, a very simple fractal type. I've highlighted a small box near the left side (it's a little faint). The portion of the image in that box is shown in the second image, below. That image also has a small box highlighted, and that area is shown in full in the third image.

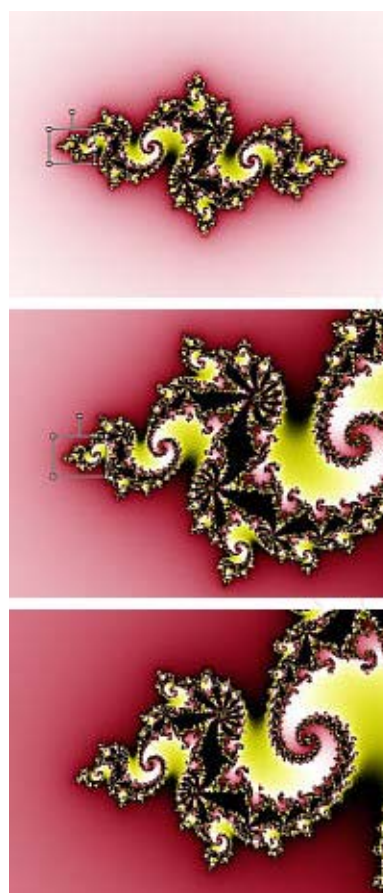
You can see in these images that smaller areas of the fractal shape look very much like the larger, full-size image. With Julia fractals, you can continue this enlarging ("zooming") process as often as you like, and you will still see the same sort of details and shapes at very tiny sizes that you see on the full-size image. This is what is meant by self-similarity.

Now of course, with something so rigidly self-similar, there's not really much point in zooming in. After all, everything is the same; small detail looks like large detail. So while it's interesting that fractals are self-similar, if this is all there is to it, there isn't much point.

Not Quite So Similar

Fortunately for fractal enthusiasts, that isn't all there is to it. Many fractal types get wildly different as you zoom in. They're still self-similar, but they're not rigidly self-similar.

This is what makes fractal exploration so intriguing. The features you see as you zoom are always changing—teasing you with a little bit of familiarity, and tantalizing you with new and unexpected twists. With just a single fractal shape, you can explore forever and never see everything it has to offer. The further you zoom, the more likely you are seeing something that



nobody has ever seen before. And with modern computers, it's very easy to zoom and zoom and zoom. With just a few clicks you can have zoomed so far that the original fractal image is larger than the sun.



Take, for example, the zoom sequence on the left. Starting with the upper left image, the center of each image was magnified tenfold. Whereas the Julia image looked virtually identical as it was zoomed, this Mandelbrot image shows new variations as the magnification increases. (Because of the small size of these images, it may not be obvious that each image is a magnification of the previous one, but they are.)

How It All Works

The basic technique of these fractals can actually be explained without resorting to confusing mathematical equations and jargon. It's rather simple, really.

First, give every point on the screen a unique number. Now take that number and stick it into a formula; you'll get a result from the formula. Take that result and stick it back into the formula. Keep doing this and watch what happens to the numbers you get. Color each point based on what happens.

That's it. Really—that's it. Now, with most formulas it probably won't do much of interest, but with the formulas used in fractal creation, some interesting things happen. Sometimes the numbers you get by feeding the results of a formula back into the formula (iterating) explode into enormous numbers, that just keep getting bigger and bigger. Those points get colored one way. Other times, the numbers "home in" on a number, getting closer and closer to it. They get colored a different way.

The interesting thing—and the reason fractals work at all—is that sometimes, just a tiny little change in the number you start with can completely change what happens as you keep iterating the number. And the boundary between numbers that explode and numbers that home in is complicated and twisted—it's the shape of the fractal.

The Enormous Task at Hand

Calculating fractals this way involves a lot of work. A small fractal image—perhaps only 640x480—contains over 300,000 points. Each of those points may require running a number through the fractal formula more than 1,000 times. This means the formula has to be computed more than three hundred million times. And that's a mild example. Extreme images (such as poster-size fractals) can involve more than one trillion calculations.

Fortunately for the impatient among us, modern computers are fast enough to do the job in a few minutes. Large fractals might take hours or days, but exploring fractals has never been easier.

Where To Go From Here

As I stated at the outset, fractals are a huge topic. All I've even talked about here are one particular type of fractals (escape-time fractals), but there are many other types as well. Unfortunately, the further you look into fractals, the more math you will need to know. There are very few fractal-related books or web pages that don't get into heavy mathematics. I've attempted to assemble some pages here that will get you started on the mathematics behind fractals in an accessible fashion, but there is no hiding the fact that it is math.

The Mandelbrot and Julia Sets

The Mandelbrot Set

The Mandelbrot Set is a set of points in the complex plane. For each complex number c , a sequence of iterates (the orbit of c) is formed by iterating the function $f(z) = z^2 + c$:

$$z_0 = 0$$
$$z_n = z_{n-1}^2 + c, \text{ for } n = 1, 2, 3, \dots$$

If $|z_n|$ remains bounded as n goes to infinity, then c is a member of the Mandelbrot set (also termed an “inside” point). Otherwise, $|z_n|$ goes to infinity, c is outside of the Mandelbrot set, and c 's orbit diverges.

The Mandelbrot set is named after Benoit Mandelbrot, who discovered it while working at IBM in the 1970s. Mandelbrot was studying the slightly different, but dynamically similar function $z^2 - c$, which he called his “ μ map.” In practice, images of the Mandelbrot set are generated in c -space, showing the c values that are in the set. The initial value of z is set to 0, as 0 is the critical point for this function.

Julia Sets

Mandelbrot's work was inspired by the work of Gaston Julia. Julia studied the dynamics of iterated rational functions in the complex plane in the early 1900s. He won the French equivalent of the Nobel Prize for his work, but his work was soon forgotten and languished until Mandelbrot's rediscovery of it.

The (standard) Julia set uses the same function as the Mandelbrot set, but differs in the initialization. The orbit is formed based on the initial value of z , z_0 ; c is a parameter. In practice, the horizontal and vertical coordinates of the pixel are scaled into the real and imaginary parts of z_0 . The parameter c is a user input. The function $f(z) = z^2 + c$ is iterated, as with the Mandelbrot set. If the orbit does not diverge, then z_0 is part of the Julia set for that particular c . Each value of c has its own Julia set.

Part of Mandelbrot's contribution was in discovering how his set “cataloged” all the Julia sets for the same function. If c for a particular Julia set is outside of the Mandelbrot set (for example, $c = 1$), then the Julia set is a “dust,” a collection of isolated points. If c is taken from the interior of the Mandelbrot set (for example, $c = -1$), then the Julia set has a definite interior. Points on the edge of the Mandelbrot set (for example, $c = i$) have dendritic Julia sets, infinitely thin connected lines with no interior.

Ultra Fractal Information

(This material was taken from the Ultra Fractal website, www.ultrafractal.com. It is © Frederik Slijkerman.)

Ultra Fractal is a versatile fractal plotter for Windows 95/98/NT/2000. Ultra Fractal allows you to open any number of fractals at the same time. A fractal consists of one or more layers, which are merged in Photoshop-like fashion. Each layer has its own fractal formula, location, and coloring algorithms. You can write your own fractal formulas, coloring algorithms and transformations, and Ultra Fractal will compile them on-the-fly. Besides being powerful, Ultra Fractal also offers a friendly user interface and extensive online help to help you to get started quickly.

Features

- MDI design, allowing you to open multiple documents (fractals, gradients, and formula files) at the same time
- Multi-threading, which makes the application more responsive while calculating fractals, and takes full advantage of multi-processor systems (Windows NT only)
- True-color (24-bit) fractals, with dithering in 256-color and high-color modes
- Multiple layers per fractal, with all Photoshop merge modes
- Formula compiler, compatible with Fractint 19.6, 2-6 times faster, with new advanced features
- Custom fractal formulas
- Custom coloring algorithms
- Custom geometric transformations to create your own coordinate mappings
- Easy-to-use gradient editor for color designing
- Built-in formula editor
- Fractint PAR and MAP import
- Export to BMP, JPEG, PNG, PSD (with layers) and TGA images
- Render to disk feature to create poster-size images (up to 100,000x100,000 pixels) with anti-aliasing
- Batch render feature to render an entire parameter set to disk
- Browsers to manage your parameter/formula/coloring/transformation collection

System requirements

Basically, Ultra Fractal can run on any computer with Windows 95, 98 or NT installed. For good performance, it is recommended to use at least an Intel Pentium processor (Ultra Fractal will be much slower on AMD K5/K6 and Cyrix processors). Pentium II or III processors are even better, of course. The new AMD K7 Athlon processor seems to be the best choice for fractal calculations now.

An accelerated PCI video card is strongly recommended. To work comfortably, your display should be set to at least 800x600 resolution in high-color (65536 colors), but 1024x768 with true-color (16777216 colors) is much better.

The minimum amount of memory (RAM) you need is 16 MB, but if you want to create large images or use a lot of layers, you need more, such as 32 MB or 64 MB.

Installing Ultra Fractal on your hard drive takes only a few megabytes, but some extra space for storing fractals and rendered images won't hurt. Make sure there is still enough free disk space (about 50 MB) for Windows to use as virtual memory.

Glossary

anti-aliasing: Refining the image by adding sub-pixels during the rendering, and averaging their colors to achieve the final pixel color.

aspect ratio: Ratio of an image's width to its height.

bailout value: How large a number must become before the iteration ceases and the pixel is declared to be "outside."

complex number: A number with two parts, the real and imaginary parts, used in the calculation of fractal images.

control point: A point used to specify the colors that compose the gradient.

export: To save the fractal image only, without saving the underlying information.

formula, calculation: A small program used to compute the fractal shape, chosen from the "Formula" tab.

formula, coloring: A small program used to compute the distribution of colors in an image, chosen from the "Inside" and "Outside" tabs.

fractal: A shape characterized by infinite detail, typically made of small copies of the original shape, and generated by iteration.

gradient: The set of colors used to render a fractal image.

inside: A point or pixel whose sequence of iterated numbers does not grow to be larger than the bailout value. Also, the tab used for setting the coloring parameters for inside pixels.

iteration: A step in creating the orbit for a pixel. The previous step's formula output is used as the input for the formula in then next step.

Julia set: A fractal created from the same formula as the Mandelbrot set, but with different initializations. Each point in a Mandelbrot set fractal has its own Julia set fractal.

layer: A single, independent fractal, which is combined with other layers to create a finished image.

magnification: How big the entire set would be, compared to the view in the current window.

Mandelbrot set: One of the most famous fractals, discovered by Benoit Mandelbrot.

merge mode: How the current layer is combined with the stack of layers below it.

opacity: The degree to which the current layer interacts with the stack of layers below it.

orbit: The sequence of complex numbers that is generated for each pixel during the iteration.

orbit trap: Monitoring the orbit and coloring the pixel according to some characteristic of the orbit.

outside: A point or pixel whose sequence of iterated numbers grows to be larger than the bailout value. Also, the tab used for setting the coloring parameters for outside pixels.

parameters: The “recipe” for generating a fractal, stored in a upr file.

render to disk: To create a fractal image in “batch” mode, without direct interaction.

switch: To generate a Julia set based on the cursor location in a corresponding Mandelbrot set image.

ufr: A binary file containing a fractal’s parameters and image data.

upr: A text file used for storing a fractal’s parameters.

zoom box: A rectangular outline used to control the location of a new fractal view.