



Mandelbulber

Tutorial & User Manual

Version: 0.9.2 (18th, February 2017)

based on Mandelbulber Version 2.10

Download: <https://sourceforge.net/projects/mandelbulber/>

Project Website: <https://github.com/buddhi1980/mandelbulber2>

Forum: <http://www.fractalforums.com/mandelbulber/>

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1. What are fractals?

Fractals are objects with self-similarity, where the smaller fragments are similar to those on a larger scale. A characteristic feature is to have subtle details even at very high magnification.

1.1. Mandelbrot set

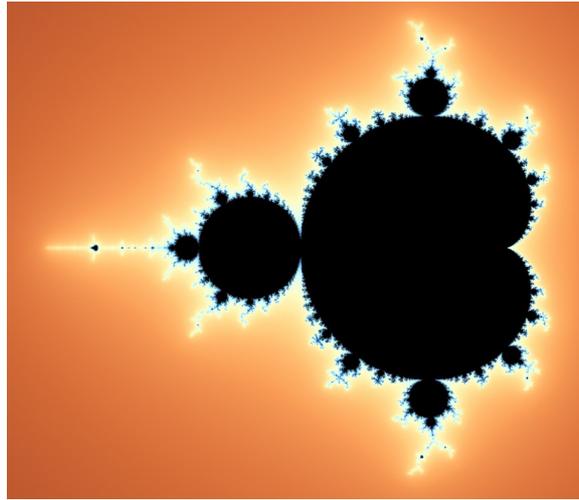


Illustration 1: Mandelbrot Set

This is a typical example of a two-dimensional fractal generated mathematically. This image is created with a very simple formula, which is calculated in many iterations:

$$z_{n+1} = z_n^2 + C$$

“z” is a complex number ($a + ib$), where $i =$ (imaginary number). The number is made of two parts : “a” the real part and “ib” the imaginary part.

“c” is the coordinates of the image point to be iterated.

In 2D, “z” is a vector containing two complex number coordinates , x and y, (these points represent the pixel location where x represents the real part of the number [a] and y represents the imaginary part of the number [b]). Because they are complex numbers, they can be positive or negative, but also there will still be a mathematical solution if a function requires the square root of a negative number.

Each original point (pixel position) is tested in the formula iteration loop, to determine if it belongs to the formula specific mathematical fractal set.

The initial value of point “z” is assigned to equal “c”, ($z_0 = c$), this parameter is then used repeatedly in the iteration loop.

$$z_{n+1} = z_n^2 + C \text{ -iteration-} \rightarrow z_{n+2} = z_{n+1}^2 + C \text{ -iteration-} \rightarrow z_{n+3} = z_{n+2}^2 + C \text{ etc.}$$



Termination conditions are applied to ensure the formula does not iterate to infinity. The most common conditions used are called Bailout and Maxiter. Maxiter is simply a condition to stop iterating when a maximum numbers of iterations is reached.

The Bailout condition stops the iteration loop if the formula transforms (moves) the point further than a set distance away from an "origin".

In the Mandelbrot formula, after each iteration, the modulus of a complex number is calculated; in other words, the length of the vector from the origin ($x = 0, y = 0$) to the current "z" point. This vector length is often called "r" for it is the radius from the center (origin) to the current "z" point.

In this example, when the length $r > 2$ (i.e Bailout = 2), the termination condition has been met, then the iteration process is stopped and the resulting image point is marked with a light color. When, after many repeated iterations, "r" is still less than 2, then it can be considered for simplicity that such a result will continue indefinitely. Iterations are therefore interrupted after a certain number of iterations (Maxiter). This point is marked on the image with black. This results in a "set" of points that do not reach bailout termination (black) and the rest of the points given lighter colors (dependent on a chosen coloring method).

1.2. 3D fractals

The three dimensional fractal type, the "Mandelbulb," is calculated from a fairly similar pattern to the Mandelbrot set. The difference is that the vector "z" contains three complex numbers (x, y, z) or four dimensions (x, y, z, w). As they are part of the "z" vector, they are denoted as ($z.x, z.y, z.z$). Examples being Hypercomplex numbers and quaternions.

They can also be created by modification of quaternions or by a specific representation of trigonometric vectors. Generally, common maths operators are used, e.g., addition, multiplication, squaring, and powers), and also conditional functions (e.g., if $z.x > z.y$, then $z.x = \text{something}$).

Some other types of 3D fractal objects are based on iterative algorithms (IFS - Iterated Function Systems). An example would be the famous Menger Sponge.

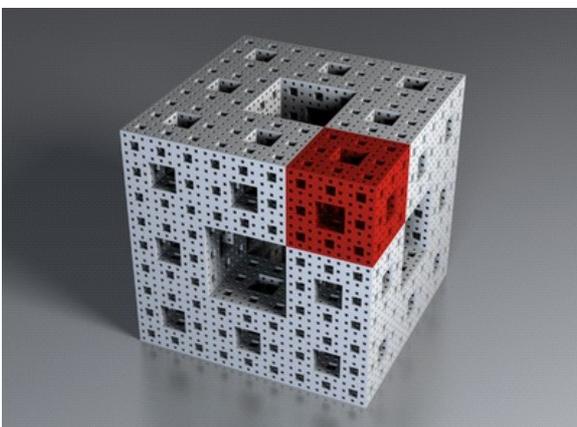


Illustration 2: Menger Sponge with highlighting of self similarity

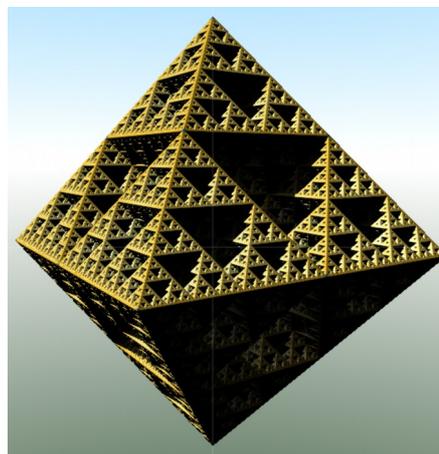


Illustration 3: Sierpinski pyramid



1.3. Mandelbulber Program

Mandelbulber is an easy to use, handy application designed to help you render 3D Mandelbrot fractals called Mandelbulb and some other kind of 3D fractals like Mandelbox, Bulbbox, Juliabulb, Menger Sponge, The following sections cover the program interface and give useful information about how to use it.

2. Distance Estimation

Distance Estimation (DE) is the calculation of an estimated distance from the given point to the nearest surface of the fractal. As suggested by the word 'estimate', it is an approximate value. It is calculated using simplified algorithms based on analytical (Analytical DE) or numerical (Delta DE) calculations of gradients.

DE is the most important algorithm required to render three-dimensional fractals within a reasonable time. It achieves a great reduction in the number of steps needed to find the exact area of the fractal while tracking a "photon" traveling toward the object along a ray (a simulated beam of light from the camera eye). A ray is generated for each pixel (1000 x 1000 resolution = 1,000,000 rays). They match FOV from the camera eye (i.e. they are not parallel.)

Without the DE calculation, the proximity of the photon to the fractal surface would need to be repeatedly calculated after each of many very small steps. For example, without an estimate of where the fractal surface is, you may need up to 10,000 steps to trace a ray of light, for every pixel of the image.

Using DE, the size of the steps along the ray of light can be increased, based on the calculated estimate of where the fractal surface should approximately be located. The process of moving along the ray and testing for the surface location is called ray-marching.

Ray marching looks like the illustration below. In each step, an estimation on the distance to the nearest fractal surface is calculated. The photon is moved along the ray by this distance. The next step is re-calculated based on the estimated distance. This distance is less so this time the Photon is moved a smaller distance. The ray-marching becomes more accurate closer to the surface of the fractal. The ray marching ceases when the photon becomes within a set "distance threshold" from the surface or after a maximum number of iteration if the option "stop at maximum iteration" is enabled.

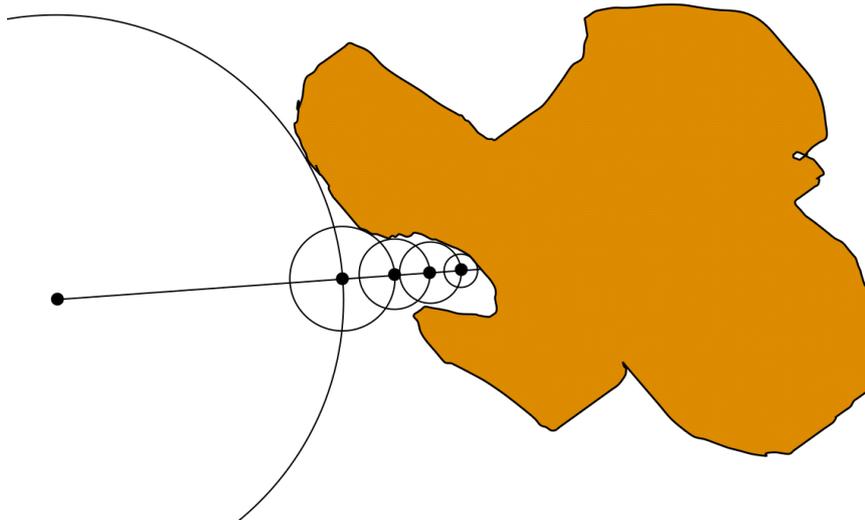


Illustration 4: Raymarching from the camera point along the ray close to the surface

Since the estimation contains some error (sometimes quite large), there is a risk that the step of moving the "photon" will be too large, and incorrectly it will flow into the surface of the fractal. This may result in visible noise in the rendered image.

To prevent this, the "photon" can be moved by the estimated distance multiplied by a number between 0 and 1 ("ray-marching step multiplier"). Steps are then smaller, so there is less risk of "overshooting" the surface, but the rendering time increases due to more steps being required.

Below is an example for a step multiplier of 0.5:

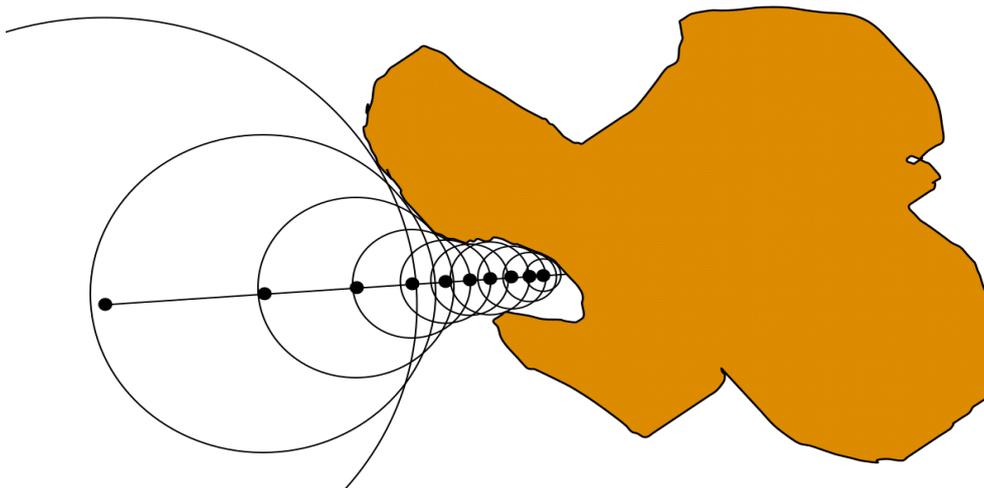


Illustration 5: Raymarching with step multiplier 0.5 produces high iteration count and good DE

Each formula is assigned a DE mode and function ("preferred"). In most cases the preferred mode is Analytical DE (fastest).

The preferred function is assigned based on whether the formula is transforming in a linear or logarithmic manner. These setting can be varied on the Render Engine tab.



Analytical DE mode is faster than Delta DE mode to calculate. However with some formulas only Delta DE mode will produce a good quality image. The DE modes can be used with either linear or logarithmic DE functions.

Example linear `out->distance = r / fabs(DE);`

Example logarithmic: `out->distance = 0.5 * r * log(r) / DE;`

The quality produced by the DE mode and function combinations is formula specific. The setting of formula parameters can also greatly affect the quality produced by the DE. In some cases the choice of fractal image is determined by what location and parameters can produce good DE quality.

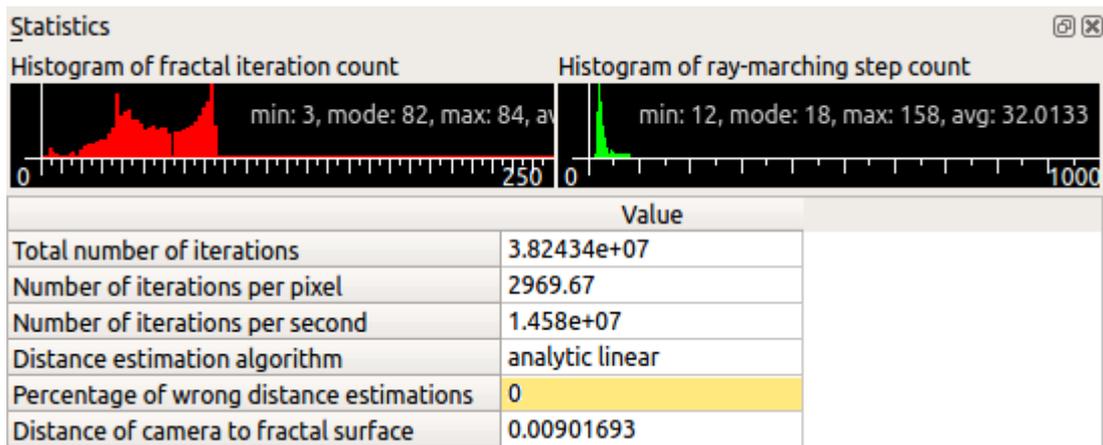


Illustration 6: Statistics Tab with histogram data

In the Statistics (enable in View menu) you can see Percentage of Wrong Distance Estimations ("Bad DE"). As a general rule less than 0.01 is good, but it is case specific and 3.0 sometimes is OK and 0.0001 sometimes is not.



3. Ray-marching - Maximum number of iterations vs. distance threshold condition

The ray marching distance threshold is the condition where the photon marching along the ray comes within a specified distance from the fractal surface and the ray-marching stops. This controls the size of the detail in the image, and is normally set to vary such that greater detail is obtained for the surface closest to the camera, (in the further regions of the fractal the distance threshold will be larger such that only bigger details are visible). Enabling “Constant Detail Size” on the Rendering Engine tab will make the distance threshold uniform.

There are two modes of stopping the ray-marching of each image pixel.

1st case: Stop ray-marching at distance threshold (“Stop at maximum iteration” is disabled).

2nd case: Stop ray-marching at point when a maximum number of iterations is reached (“Stop at maximum iteration” is enabled).

First important note: “Stop at maximum iteration” doesn't control the fractal iteration loop. The iteration loop always runs to achieve Bailout, (then if bailout is not reached the iteration stops at Maxiter.).

**Example for 1st case:**

Ray-marching stops at distance threshold. In most cases the fractal iteration loop stops on bailout condition, (because away from surface it is not possible to reach Maxiter).

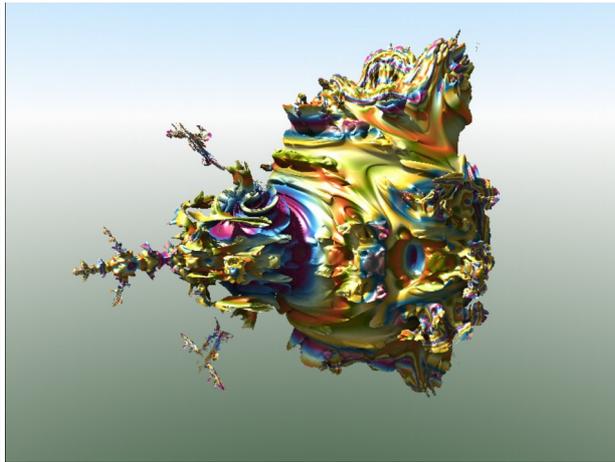


Illustration 7: Stop ray-marching at bailout

Example for 2nd case:

Ray-marching stops at the photon step when the maximum number of iterations is reached (ray-marching distance threshold is ignored). In many cases iteration loop stops on bailout condition (away from fractal surface), but on the fractal surface the maximum number of iterations is calculated (when bailout is not reached).

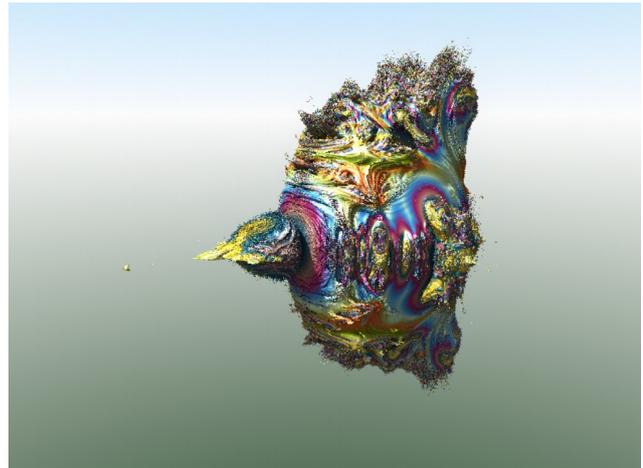


Illustration 8: Stop ray-marching at maxiter

Example for 1st case:

When maximum number of iterations is set to 4. Even if Maxiter is reached the ray-marching is continued until the ray marching distance threshold is reached.

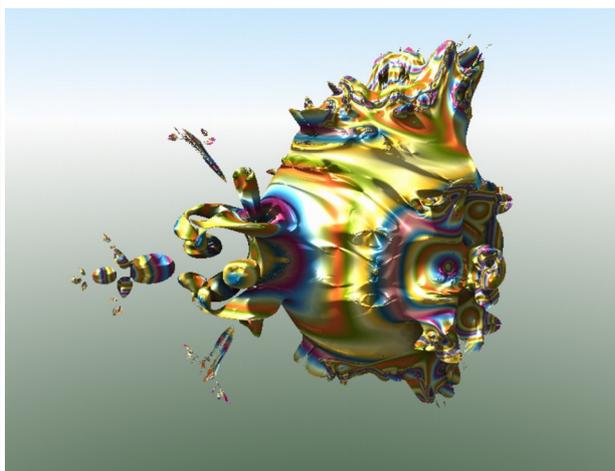


Illustration 9: Stop ray-marching at bailout with low bailout

Example for 2nd case:

When maximum number of iterations is reached, then ray-marching is stopped even if distance threshold is not reached.

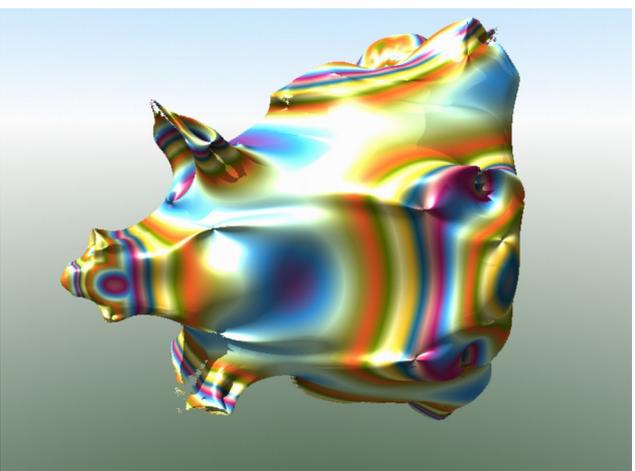


Illustration 10: Stop ray-marching at maxiter with low maxiter



4. Navigation

To set the current view there are two elements:

- **Camera** - represents a point where the camera is located
- **Target** - represents the point to which the camera is orientated with (i.e., the camera is always looking at the target.)

4.1. Camera and Target movement step

The relationship between the camera point and the target point can be altered manually by changing the numbers in the spin boxes, or by navigating with distance and rotation “steps” defined by the user.

For rotations, the camera is moved by the parameter **rotation step** (default 15 degrees). For movements of the camera and/or the target in a linear direction, the parameter **step** (default 0.5) is used. There are two modes for its use:

a) Relative step mode

The **step** for moving the camera and/or target in a linear direction is calculated relative to the estimated distance from the surface of the fractal. The closer to the surface that the camera is located, the smaller the step. This prevents movement of the camera beneath the surface of fractal, because very close to the surface, a step needs to be very small.

The actual step is equal to the distance from the fractal multiplied by the parameter **step**.

Example: If in this mode, the step is set at 0.5 and the nearest point of the fractal is 3.0, this camera will be moved 1.5 (no matter in which direction).

This mode is recommended in animations approaching the surface of the fractal.

b) Absolute step mode

Step movement of the camera and/or target is fixed. Therefore if the step is set at 0.5, the movement will be 0.5 in the direction of the arrow key or mouse pointer.

This mode is recommended for animation camera flying with a fixed (or strictly controlled) speed.



4.2. The camera and target functions

The screenshot shows the navigation dock interface with the following callout boxes:

- Enables automatic rendering of image after change of any fractal or effect parameter**: Points to the **Auto-refresh** checkbox.
- Mode selection of calculation of rotation angles**: Points to the **Relative step mode** dropdown menu.
- Resets the position of the camera so you can see the fractal, while maintaining the last angle of the camera.**: Points to the **Reset view** button.
- Setting the camera's distance to target. This will automatically update when navigating**: Points to the **Camera distance to target** slider.
- A step distance for moving the camera and/or the target.**: Points to the **step: 0,467735** input field.
- Calculation mode for movement step**: Points to the **Relative step mode** dropdown menu.
- Rotation step in degrees**: Points to the **rotation step: 5,00** input field.
- Camera rotation angles**: Points to the **yaw: 26,565**, **pitch: -16,60154**, and **roll: 0** input fields.
- Camera coordinates**: Points to the **Camera** coordinate input fields (x: 3, y: -6, z: 2).
- Target coordinates**: Points to the **Target** coordinate input fields (x: 0, y: 0, z: 0).
- Selecting the camera movement mode.**
- simultaneous movement of the camera and target
- only camera movement
- only target movement: Points to the **Move camera and target** dropdown menu.
- Moves the camera and/or target up, down, left, right, backwards and forwards, in linear directions by a given step**: Points to the directional arrow buttons.
- Rotates the camera by the rotation step**: Points to the rotation arrow buttons.
- Selection of camera rotation mode**
- camera rotation (target moves around the camera)
- strafing the camera around the target: Points to the **Rotate camera** dropdown menu.

Illustration 11: Navigation dock



4.3. Linear camera and target movement modes using the arrow buttons

A user can navigate by operating the arrow keys on the Navigation dock, with the user defined steps.

There are three modes for changing the relationship between camera and target.

a) Move camera and target mode

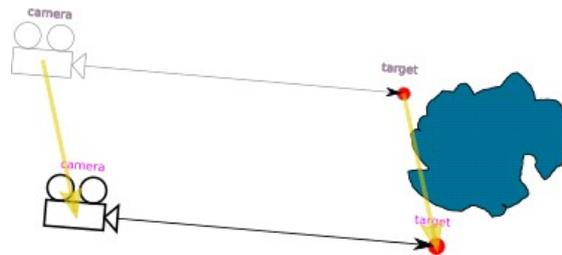


Illustration 12: Movement mode - camera and target

Moves both the camera and the target by the same distance in the same direction. The angle of camera rotation does not change.

b) Move camera mode

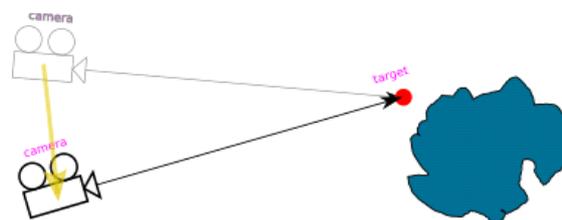


Illustration 13: Movement mode - camera

Moves only the camera and rotates it in respect to the motionless target.

c) Move target mode

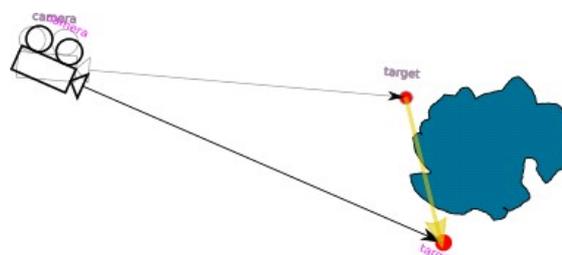


Illustration 14: Movement mode - target

Moves only the target while maintaining a fixed camera position. The camera rotates following the target. **Note:** In Relative Step Mode, the target is moved by distance related to distance of target to fractal surface. If target is inside the fractal (distance = 0), then this option will not work with Relative Step Mode.



4.4. Linear camera and target movement modes using the mouse pointer

A user can navigate in the render window with the user-defined **step** (absolute or relative) and the Mouse Click Function set to “Move the camera.”

a) Move camera and target mode

The target is moved to the point selected by the mouse. The camera is moved by a user defined step, and rotated.

In relative step mode, the camera is moved by distance equals to *distance_to_indicated_point* multiplied by *step* parameter.

In absolute step mode, the camera is moved by distance equals to *step* parameter.

b) Move camera mode

The camera is moved by the step (absolute or relative) in the direction of the mouse pointer, rotating the camera to look at the target. The target remains stationary.

c) Move target mode

The target is moved to the point selected by the mouse. The camera remains at the same point but rotates following the target.

4.5. Camera rotation modes using the arrow buttons

a) Rotate camera

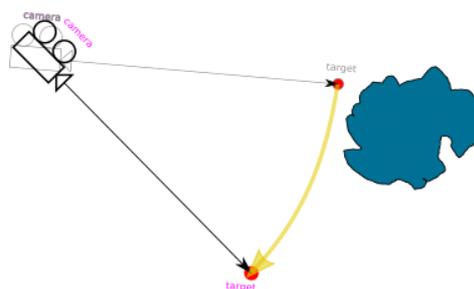


Illustration 15: Rotation mode – around camera

The camera is rotated by the rotation step around its axis and the target is moved accordingly. This is the standard mode for rotation of the camera.



b) Rotate around target

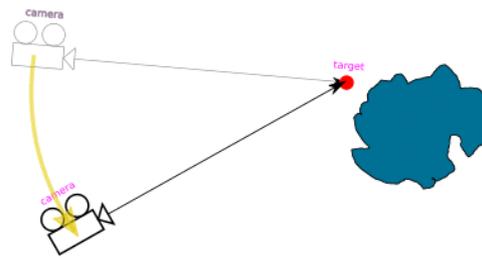


Illustration 16: Rotation mode – around target

The camera is moved around the stationary target by the rotation step, maintaining a constant distance to the target. The camera is rotated to look at the target.

4.6. Reset View

Camera Position is reset, by being zoomed out from the fractal but still maintaining the camera angles.

If the rotations are changed to zero before using Reset View, the camera will then be zoomed out from the target, and rotated to look down the y axis.

4.7. Calculation of rotation angles modes

a) Fixed-roll angle

In this mode, the angle gamma (roll) is constant. Pan the camera left or right always takes place around the global vertical Z-axis (not the render window vertical axis).

This mode can be likened to an aircraft's controls, where all turns are relative to the aircraft's axis, not the ground below. Rotate up / down raises / lowers the nose of the aircraft. Rotate left / right turns in the directions of the wings. Tilting the camera buttons



tilts the aircraft.

When the camera is pointing straight up or down, or when it is upside down in this mode, it is quite difficult to predict the result of the turn.

b) Straight rotation

The camera is rotated around its own local axis (local vertical axis is the render window vertical axis.)

This mode is a more intuitive way to rotate the camera, e.g., turn the camera left always give the visual effect of the camera rotating in that direction. The rotation angles are automatically converted so they are appropriate for the selected direction. This mode changes the gamma angle (roll).



4.8. Camera rotation in animations

With animation, the camera point and the target point can move independently following their own trajectories, with the camera always looking towards the target point. It is important to be aware that the rotation angle of the camera is the result of the camera coordinates and the target coordinates.

There are various ways of animating, depending on the objective.

The following example is a flight animation, with the camera trajectory approaching a location, with the camera rotating simultaneously so that the location is always observed, (as shown in the figure below). The camera positions represent three keyframes.

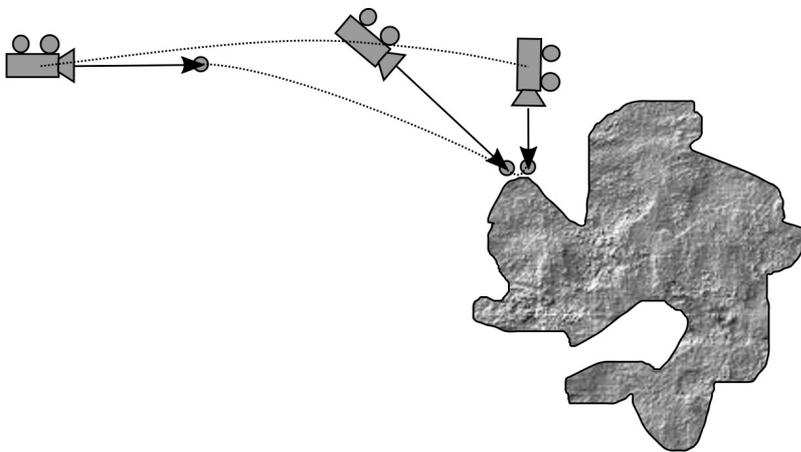


Illustration 17: Keyframe Animation with differing distances camera to target

Between the first and second keyframes, the camera and target both move large distances. But between the second and third keyframes, the camera moves a much greater distance than the target. This can sometimes lead to unexpected camera rotations between keyframes.

To compensate for this, on the Keyframe navigation tab use the button "Set the same distance from the camera for all the frames." This adjusts all keyframes by setting a constant distance between camera and target. It is important to note that the use of this function does not change the visual effect for the keyframes, and will help correct interpolation.

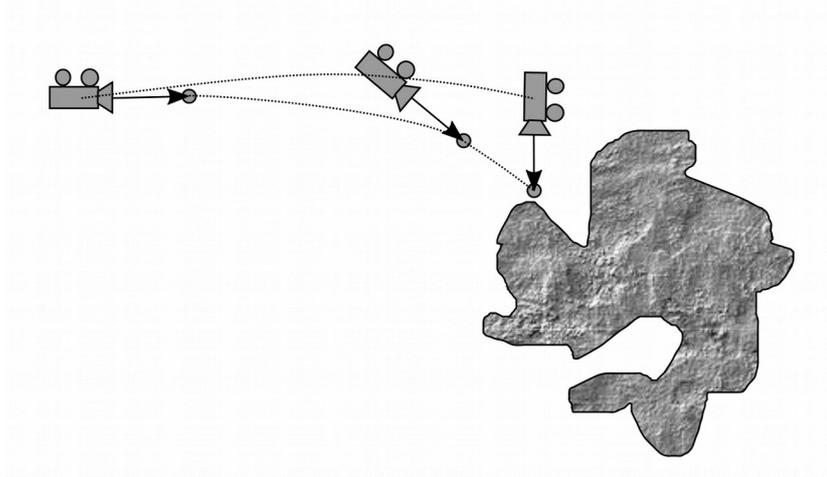
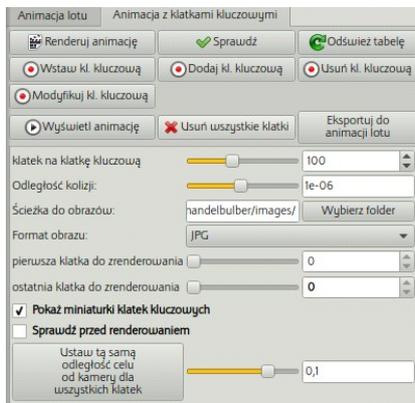


Illustration 18: Keyframe Animation with equal distances camera to target

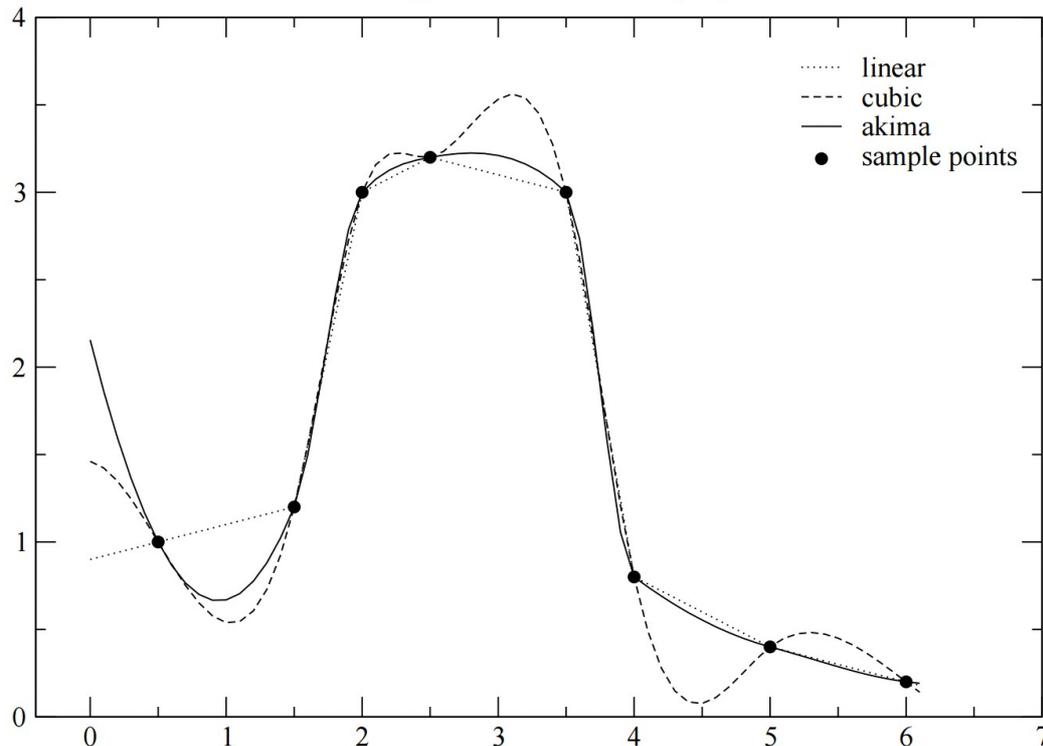


5. Interpolation

5.1. Akima interpolation

Comparison of the interpolation methods

methods applied to 8 random sample points



Catmull-Rom and Akima interpolation can both be used to get a “smooth” transition of a value over the keyframes. These methods can mostly be used interchangeably, where Akima stays closer to the points where as Catmull-Rom oscillates a little bit stronger. 5.2 applies to both interpolation forms.

5.2. Catmul-Rom / Akima interpolation - Advices

a) Collision

Fast approaching the obstacle may cause inadvertent drag to the camera towards the center of the object. It is recommended to maintain the principle that one keyframe does not reduce the distance to the object more than 5-times.

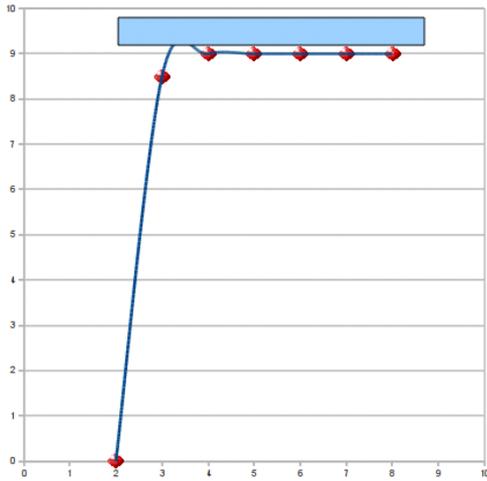


Illustration 19: Catmull-Rom - Collision with bad keyframes

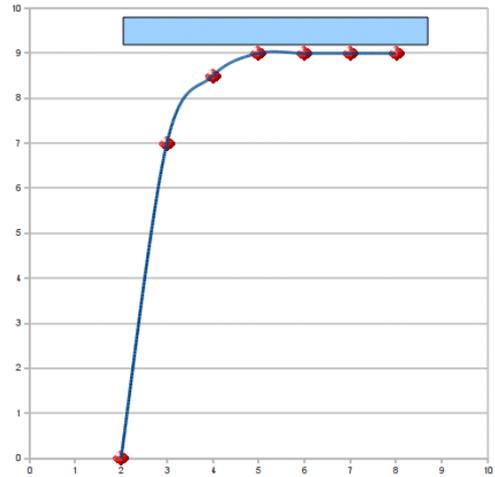


Illustration 20: Catmull-Rom - Collision averted with good keyframes

b) Fly through the gap

It is recommended to place a keyframe at the point where the camera flies through the gap

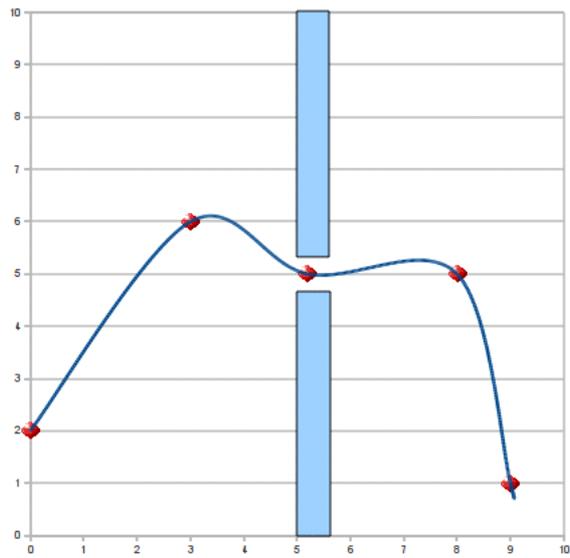
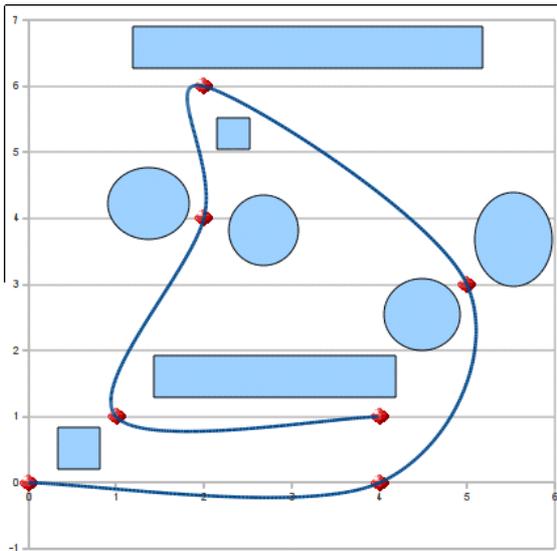


Illustration 21: Catmull-Rom - Fly through gap with keyframe in center of gap



c) Proper conduct cameras between objects



5.3. Changing interpolation types

To change the interpolation algorithm, right click on the parameter list and the options appear. In this example the main_formula_weight parameters have been changed from Akima to Linear. Interpolation type is color coded e.g. Linear parameters are highlighted in grey.

Animation

Flight animation | Keyframe animation

Render animation | Validate | Refresh table

Insert keyframe | Add keyframe | Delete keyframe

Modify keyframe

Show Animation | Delete all images | Export to Flight

frames per keyframe: 100

collision distance: 0,001

path for images: s/amazing_surf_anim/ | Select folder

image type: JPG

first frame to render: 0

last frame to render: 11000

Show keyframe preview thumbnails

Validate before render

Set the same camera target distance for all keyframes: 0,1

Keyframe previews	0	1	2	3
main_camera_x	-14,14195518597055	-14,1419975453347	-14,14198856136185	-14,141970890839...
main_camera_y	13,91296626507707	13,91300195967982	13,91306679269415	13,91319431236494
main_camera_z	-0,9134965954147...	-0,9121415921658721	-0,909691795933...	-0,904873306276...
main_target_x	-14,14195594362708	-14,14199830299123	-14,14198931901838	-14,14197164849555
main_target_y	13,91296626507707	13,91300195967982	13,91306679269415	13,91319431236494
main_target_z	-0,9134965954147...	-0,9121415921658721	-0,909691795933...	-0,904873306276...
main_camera_top_x	13,91296626507707	13,91300195967982	13,91306679269415	13,91319431236494
main_camera_top_y	-0,9134965954147...	-0,9121415921658721	-0,909691795933...	-0,904873306276...
main_camera_top_z	-14,14195594362708	-14,14199830299123	-14,14198931901838	-14,14197164849555
main_sweet_spot_h...	0,0000000000000000	0,0000000000000000	0,0000000000000000	0,0000000000000000
main_sweet_spot_v...	0,0000000000000000	0,0000000000000000	0,0000000000000000	0,0000000000000000
main_DOF_focus	0,0000000000000000	0,0000000000000000	0,0000000000000000	0,0000000000000000
main_aux_light_ena...	0,0000000000000000	0,0000000000000000	0,0000000000000000	0,0000000000000000
main_DOF_blur_opa...	0,0000000000000000	0,0000000000000000	0,0000000000000000	0,0000000000000000
main_DE_factor	0,6	0,6	0,6	0,6

Interpolation type

- None
- Linear
- Linear angle
- CatMulRom
- CatMulRom angle
- Akima
- Akima angle



6. NetRender

NetRender is a tool that allows you to render the same image or animation on multiple computers simultaneously. If you have multiple computers connected to an Ethernet network, you can greatly increase overall computing power.

One of the computers (server) manages the process of rendering. It sends a requests to the connected computers (clients) and collects the results of rendering. Other computers (clients) render different portions of the image and send it to the server. There can be only one server (master) but clients (slaves) can be any number. The more clients, the faster the rendering will be.

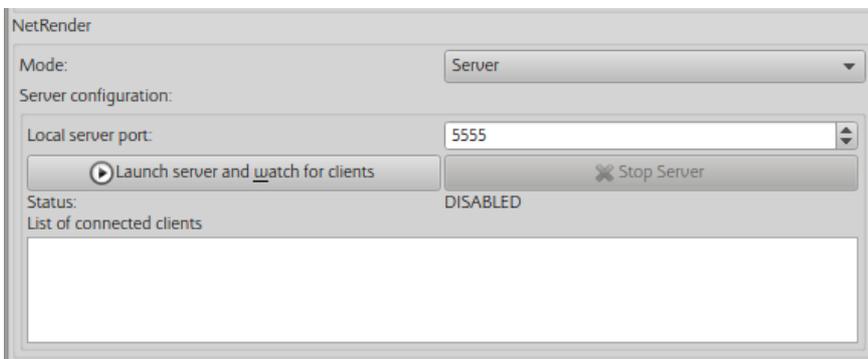
The Server is also the computer which renders the combined image .

The total number of CPUs (cores) used is the sum of server's CPUs cores + all client's CPUs cores.

6.1. Starting NetRender

a) Server configuration

On the computer which will be used as the Server, Mode is set to *Server*.



Local server port should be set to one which is not used by other applications, and is passed through routers (if any are used) and firewall. The default is 5555.

If settings are correct, press *Launch server and watch for clients* button to connect server to existing clients.

At this point, the server is ready to work

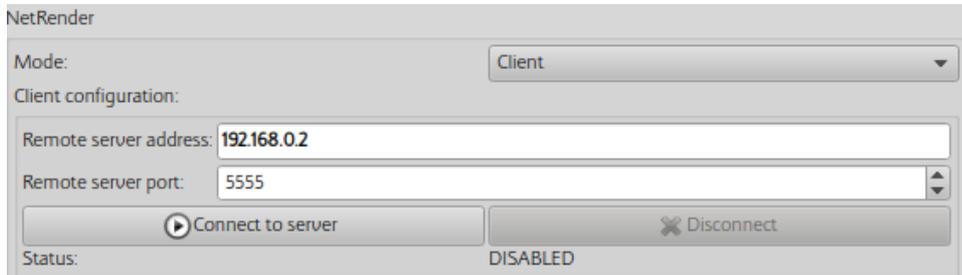
Alternative way to launch the server is to use command line. Example:

```
$ mandelbulber2 --server --port 5555 pathToFileToRender.fract
```



b) Configuring the clients

On the computers which will be used as Clients, Mode is set to *Client*

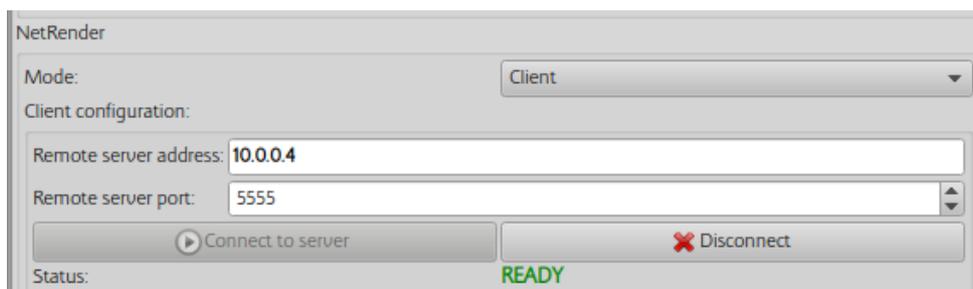


The remote server address must be set to the same as the Server computer which is running Mandelbulber in Server mode. The address can be given as an IP address or a computer name.

The remote server port number must be exactly the same as the setting on the Server.

Press *Connect to server* button to connect to the server

Once the connection is established correctly, the client application should show the status **READY**



Alternative way to establish NetRender client is to use command line:

```
$ mandelbulber2 --nogui --host 10.0.0.4 --port 5555
```

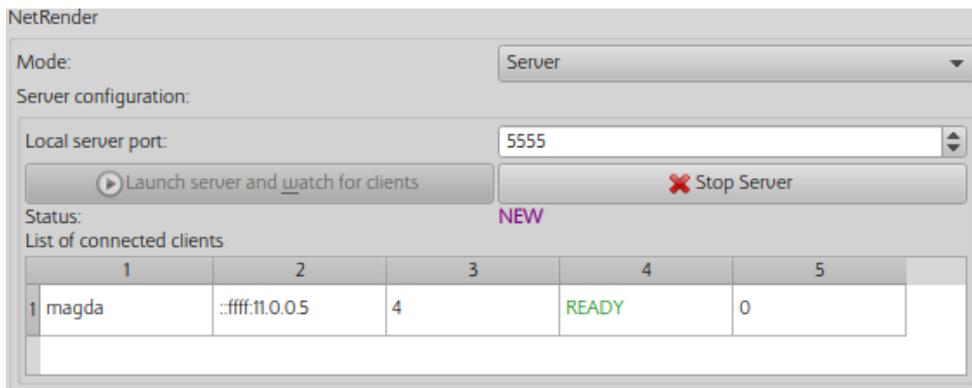
when connection is successfully established the program should return following message:

```
NetRender - Client Setup, link to server: 10.0.0.4, port: 5555
```

```
NetRender - version matches (2090), connection established
```

On the Server computer, in the table "List of connected clients" should be shown the name and address of the connected clients and the number of available processors (cores).

i.e magda computer has 4 cores and is **READY**.



c) Rendering

Only the Server can initiate rendering on the computers connected using NetRender. When the RENDER button is pressed on the server, all the connected computers commence rendering.

In the table "List of connected clients" in the column "Done lines" will be shown the number of lines the image rendered by each of the computers.

when rendering is finished, the Server computer, will display the complete image. On the Client computers, only that portion of the image which was rendered by that client will be displayed.



7. Q&A , Examples and Hints

Example of MandelboxMenger UI

Example settings

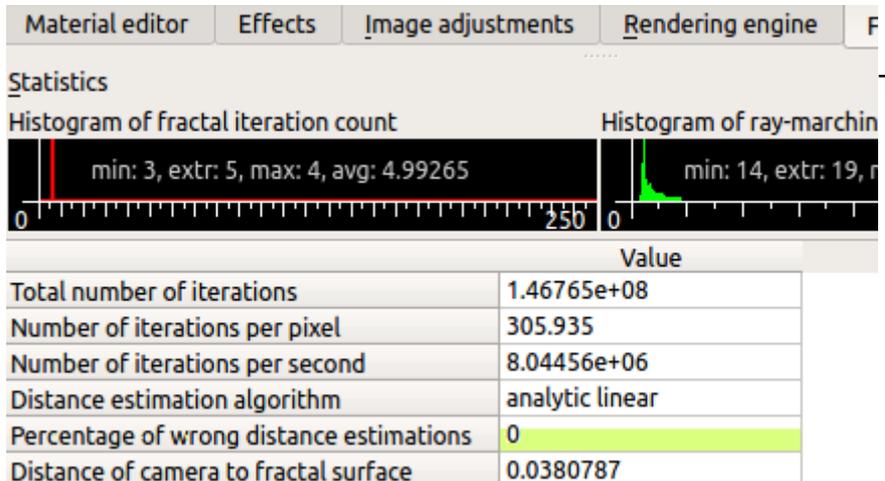
(copy to clipboard, then load in Mandelbulber using : File – Load settings from clipboard):

```
# Mandelbulber settings file
# version 2.08
# only modified parameters
[main_parameters]
ambient_occlusion_enabled true;
camera 1.872135433718922 -2.023030528885091 1.871963531652841;
camera_distance_to_target 0.005814178381115117;
camera_rotation -28.76425655707408 26.3550335393397 3.450283685696816;
camera_top -0.1604796308669786 -0.4174088010201082 0.894436236356597;
DE_factor 0.6;
dont_add_c_constant_1 true;
flight_last_to_render 0;
formula_1 91;
formula_2 61;
formula_iterations_2 5;
formula_start_iteration_2 4;
formula_stop_iteration_2 5;
fractal_constant_factor 0.9 0.9 0.9;
fractal_enable_2 false;
fractal_rotation 0 -90 0;
keyframe_last_to_render 0;
main_light_beta 44.34;
main_light_intensity 2;
mat1_coloring_palette_offset 12.83;
mat1_coloring_palette_size 255;
mat1_surface_color_palette fd6029 698403 fff59c 000000 0b5e87 c68876 a51c64 3b9fee d4ffd4 aba53c;
SSAO_random_mode true;
target 1.874642452030676 -2.018463533070165 1.874544631933419;
view_distance_max 28.58330790625501;
volumetric_fog_colour_1_distance 3.55841069795292e-06;
volumetric_fog_colour_2_distance 7.116821395905841e-06;
volumetric_fog_distance_factor 7.116821395905841e-06;
[fractal_1]
fold_color_comp_fold 0.3;
mandelbox_color -0.27 0.05 0.07000000000000001;
mandelbox_rotation_main 9 1.74 3;
mandelbox_scale -1.5;
transf_addCpixel_enabled_false true;
transf_int_1 12;
transf_scaleB_1 0;
transf_scaleC_1 0;
transf_start_iterations_M 4;
transf_stop_iterations_M 5;
```

1) In the example the MengerSponge part is run only on iteration 4. A single iteration of another fractal to make a hybrid is often the best practice.



2) In the Statistics (enable in View menu) you can see Percentage of Wrong Distance Estimations ("Bad DE") is 0, which is good!!. As a general rule less than 0.01 is good, but it is case specific and 3.0 sometimes is OK and .0001 sometimes is not.



The Raymarching step multiplier or "fudge factor" (Rendering Engine tab) is set at 0.6, which is good for a hybrid. If I change it to 0.7 the Percentage of Bad DE leaps up to 0.25 and you can see the areas of quality loss on your image.

Now if we disable the addCpixel Axis swap Constant Multiplier, we find we can now increase the Raymarching Step Multiplier to 0.9, and get a faster render and visually the same quality. So monitoring Percentage of Wrong Distance Estimations is a guide to managing quality. (Note when doing animations you may want to drop the Raymarching step down a bit to allow for what might happen between keyframes.)

3) MandelboxMenger Hybrids can behave a bit differently to a lot of hybrids, in the fact that the Percentage Bad DE often improves when you zoom in.



maximum view distance

Located : Rendering Engine - Common Rendering settings

It is important to optimize this setting to minimize render time. You can reduce until the furthest part of the 3D object(s) starts to disappear. However with animation an allowance should be made for changes between keyframes.

hint/note.

When navigating in Relative step mode, mouse click on spherical_inversion, camera zooms out, and maximum view distance becomes set on 280. If you don't reset it your render times will be increased.

Magic Angle Benesi Mag Transforms

In mathematics the Magic Angle = 54.7356° .

When rendering basic mag transforms the image does not render parallel to the standard x,y,z global axis. On the fractal dock, in "Global parameters" set y-axis rotation to 35.2644° ($= 90^\circ - 54.7356^\circ$). The fractal will then render parallel to the x-y plane.



Example of using Transform_Menger Fold to make Hybrid

```
# Mandelbulber settings file
# version 2.08
# only modified parameters
[main_parameters]
ambient_occlusion_enabled true;
camera -1.528388569045064 -1.23063017895654 -0.0251755516595821;
camera_distance_to_target 0.0004503351519815117;
camera_rotation -14.07789975269277 -44.28785609194563 3.773777260910995;
camera_top 0.2333184436621841 0.6598138513697914 0.7142885869084139;
DE_factor 0.7;
flight_last_to_render 0;
formula_1 1052;
formula_2 1010;
formula_3 1052;
formula_4 1009;
formula_iterations_1 5;
formula_start_iteration_4 45;
formula_stop_iteration_2 12;
formula_stop_iteration_4 5;
fractal_constant_factor 0.9 0.9 0.9;
fractal_enable_4 false;
hdr true;
hybrid_fractal_enable true;
keyframe_last_to_render 0;
main_light_alpha 2.6;
main_light_beta 1.59;
mat1_coloring_palette_offset 46.51;
mat1_coloring_palette_size 255;
mat1_coloring_random_seed 647723;
SSAO_random_mode true;
target -1.528310155903731 -1.230317492741513 -0.02549000429402527;
volumetric_fog_colour_1_distance 3.55841069795292e-06;
volumetric_fog_colour_2_distance 7.116821395905841e-06;
volumetric_fog_distance_factor 7.116821395905841e-06;
[fractal_1]
transf_addition_constantA_000 -0.071633 0 0;
transf_function_enabledy false;
transf_int_1 12;
transf_scale 0.5;
transf_scaleC_1 0;
transf_stop_iterations_1 2;
[fractal_2]
transf_scale3D_333 1.055556 1.027778 0.861111;
[fractal_3]
transf_function_enabledx false;
```

On this transform UI, the standard menger sponge formula is split into a start and end function. The simplest way to use this transform is in Hybrid Mode, having the menger fold transform in slots 1 & 3. In slot 2 place any linear type formula or transform. (ie more mengers, kifs, mboxes, amazing surf, folds, rotation , Benesi T1 etc).



In slot 1 disable the stop function and in slot 3 disable the start function, resulting in a standard menger sponge with something in the middle.

BTW in fact you can mix around with the start and stop functions have all enabled if you wish. Generally linear functions all work well together in making hybrids.

In Statistics, maximum is approx. 80 iterations. Generally hybrids take longer to render than standard formulas.

As well as adjusting formula parameters, you can use the iteration controls to tweak hybrids. In this example the first slot is set to repeat for 5 iterations before moving to slot 2. Slot 2 is set to stop at iteration 12, whereas slots 1 & 3 can continue to termination conditions are met (bailout or maximum number of iterations).

In the example above, slot2 of the hybrid sequenced ended at iteration 12. 12 was chosen because how it fitted into the iteration sequence, as follows:

Slot1 x 5

0,1,2,3,4 iteration numbers (note first iteration is iteration number 0.)

slot2

5

slot3

6

slot1 x 5

7,8,9,10,11

slot2

12 // last use of slot2

sequence continues slot1 x 5, slot3,to bailout.

So slot2 is used only twice in the iteration process. If I had entered 11 instead of 12 for slot2's stop_iterations, then the slot would have been used only once, if I entered 19 then it would run three times.



7.1. Q&A . How do you get different materials on different shapes?

This is how I have been doing it.

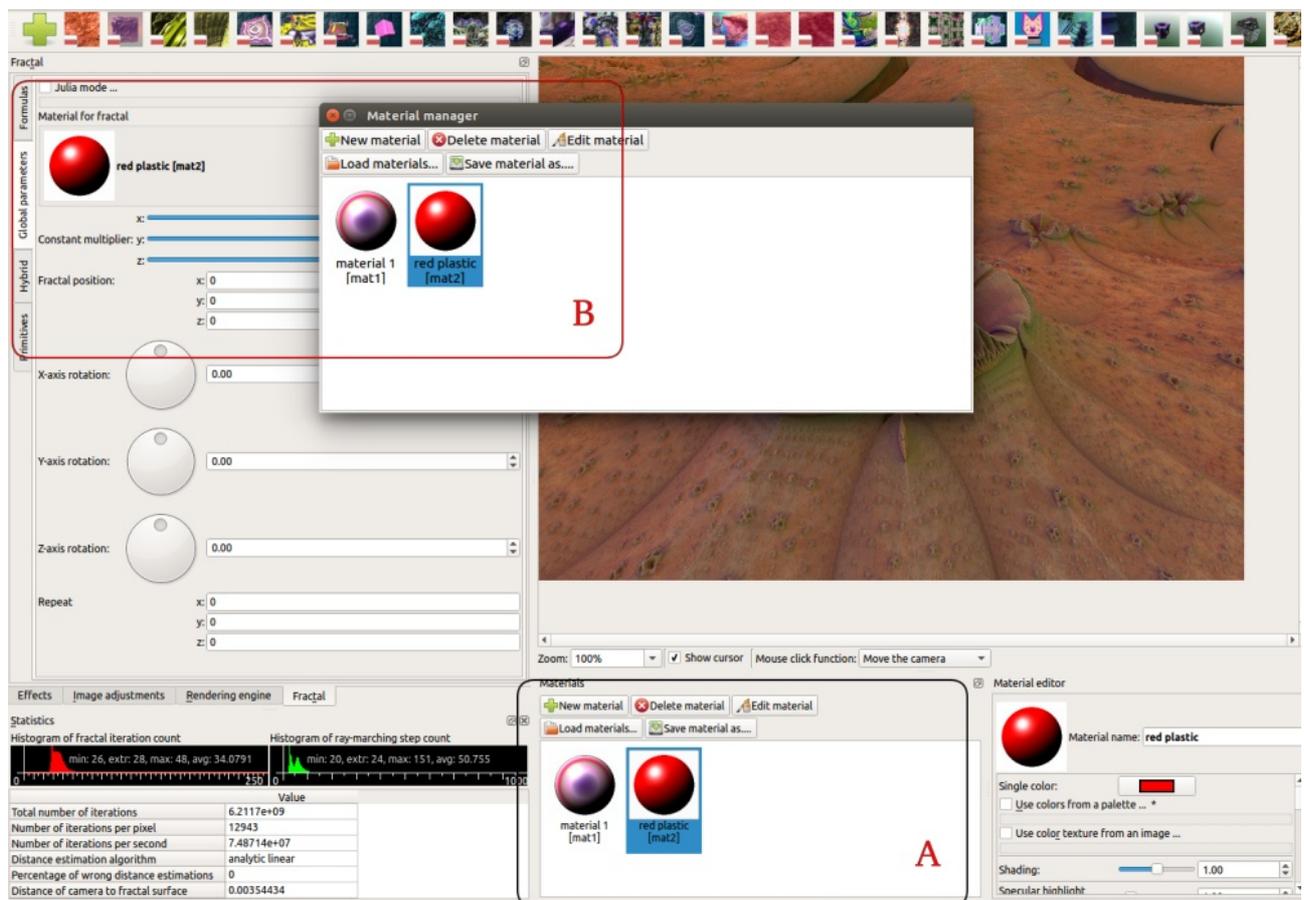
Rectangle at the bottom marked A.

This is where you start a new material or load an existing. The active material is highlighted in blue. Meaning it is active in the **material editor** where you create or modify the material.

Rectangle at top left marked B.

One way to use a material is to go to Global Parameters, click on the material preview image, and the **Material Manager** UI will appear with the materials you have loaded or created. Click on the one you want to use, then close that UI.

Similarly with primitives, click on the material preview image. And with Boolean Mode each fractal/transform has it's own material preview image when you scroll down.





8. Mandelbulber V2.10 Using “Anim By Sound” with multiple tracks

Note. The following “walk through” tutorial is for using Anim By Sound with multiple tracks. This tutorial is based on my initial experiments with Anim by Sound and may be revised as I gain more experience. The tutorial demonstrates using sound to animate a fractal offset parameter and the material color. The settings file also includes animation of some other parameters, and produces an animation just over a minute long, at 300 x 300, 45 minutes to render.

Animations can take many hours to render, so it is best when learning the controls, to keep it simple.

Choose fractals and/or primitives that render fast. Do not use slow effects like Volumetric Light or Multi Ray Ambient Occlusion.

I drop the resolution to 400 x 300 Detail Level 0.5, or 200 x 150 Detail Level 0.25.

The animation value of an object (or an effect) at each frame, is the sum of the parameter value, (generated from the keyframe animation table), and the sound value at that frame.

$$\text{animVal} = \text{paraVal} + \text{soundVal}.$$

This tutorial is about the basics of using soundVal to vary animVal. So I will keep paraVal constant and use only sound data to direct the animation of parameters.

A cool thing about using only soundVal (no keyframe animation) is that we can set up a trial with just two keyframes (beginning and end).

Note. You can create an audio file for the single purpose of directing animation, where the audio file is not used at all in the final song mix. You can use Anim by Sound to create silent videos.

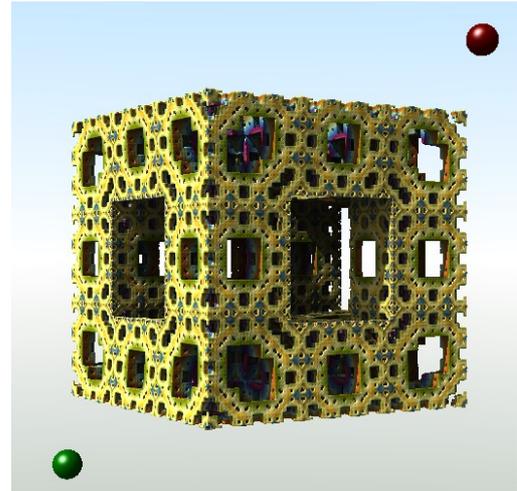
Keyframe animation requires changes to be made at keyframes. It is possible with Sound animation to make changes at any frame, (i.e. a change at any 1 / 30 of a second time interval, when at 30fps.)

*Previously, choreographing parameters with spreadsheets was very time consuming and I was limited to what I could achieve, so I stopped and have waited. **Anim by Sound** has made this process much more simpler, and has infinite possibilities.*

All files used in this example can be downloaded from mandelbulber.org

<http://cdn.mandelbulber.org/doc/audio/9%20tut.zip>

unzip and place “9 tut” folder in `home/mandelbulber/animations/`





8.1. Audio Files

The following formats are supported:

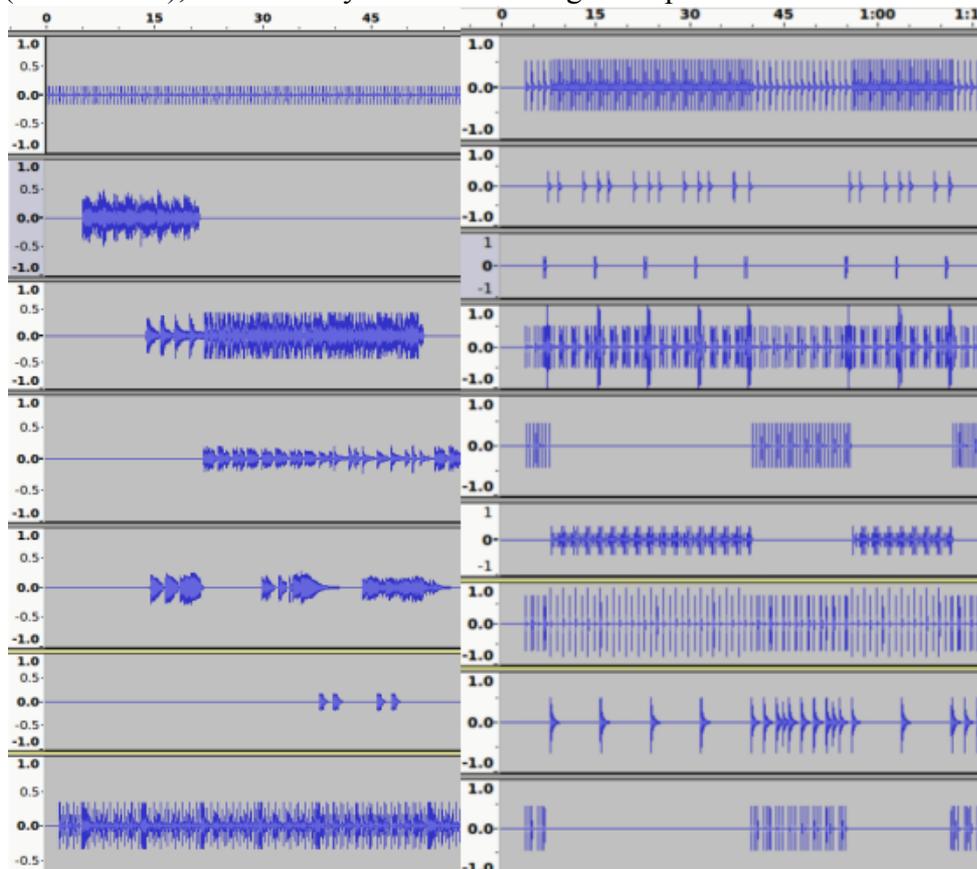
- *.wav (wave form audio format)
- *.ogg (Ogg Vorbis)
- *.flac (Free Lossless Audio Format)
- *.mp3 (MPEG II Audio Layer 3)

I used Hydrogen Drum Kit emulator to make all the individual drum track files. These are .wav files, which I converted to .mp3 for use with Mandelbulber. They are mono working files, when I make the video in VirtualDub I then use the final song mix .wav file.

The guitar tracks have also been recorded as .wav, and a .mp3 copy made to use with Mandelbulber. The audio file data is sampled at every frame point, the data is then converted to a *sound* number ranging between 0 (silent) and 1 (maximum) which can represent Amplitude or Pitch. This value is shown in the Sound Animation chart on the Audio Selector UI. We can use either the default Amplitude mode or choose Sound Pitch mode to animate.

For this example I used Pitch with lead guitar (melody line) creating the fractal movement, and Amplitude for a drum to alternate the color. The fractal shape will respond to the free flowing melody line and the color change as a repetitive rhythm event.

This is a screen-shot from Audacity showing some of the instrument tracks I had available. I only used one drum (a kick drum), but normally I would be using more percussion instruments.





8.2. Adding a parameter.

Firstly, have the Animation Dock open. (i.e. from menu select View - show animation dock.)

Then go to the dock or tab for the parameter you wish to animate (e.g. fractal, material, effect etc).

Right mouse click on the parameter field, and select Add to Keyframe Animation.

The parameter will then be listed in the keyframe animation table, with Anim By Sound in the next column.

The screenshot shows the Animation Dock interface with the 'Keyframe animation' tab selected. The interface includes several control buttons and a table of parameters.

Control Buttons:

- Render animation
- Validate
- Refresh table
- Insert keyframe
- Add keyframe
- Delete keyframe
- Modify keyframe
- Show Animation
- Delete all images
- Export to Flight

Parameter Settings:

- frames per keyframe: 7920
- frames per second: 30.0000
- collision distance: 1e-06
- path for images: ilber/animation/tut/

Keyframe Animation Table:

	Audio
main_camera_y	Anim By Sound
main_camera_z	Anim By Sound
main_target_x	Anim By Sound
main_target_y	Anim By Sound
main_target_z	Anim By Sound
main_camera_top_x	Anim By Sound
main_camera_top_y	Anim By Sound
main_camera_top_z	Anim By Sound
fractal0_transf_addition_constant_x	Anim By Sound
fractal0_transf_addition_constant_y	Audio loaded
fractal0_transf_addition_constant_z	Anim By Sound

Here I have chosen to animate parameter Menger_Mod1 offset y
fractal0_transf_addition_constant_y

i.e parameter name *transf_addition_constant_y*; from formula slot *fractal0*.

Parameters x & z are also added because this parameter is part of a vector3.

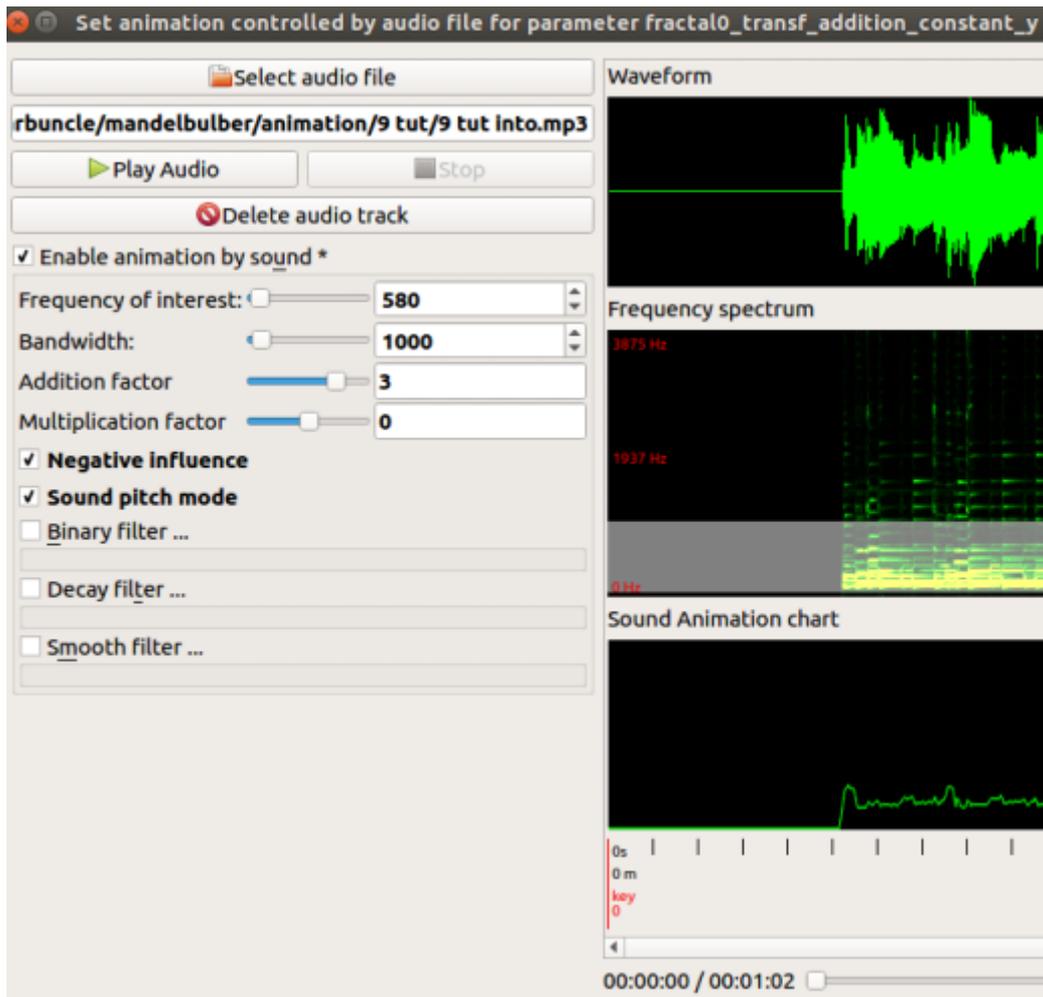


8.3. Loading the Audio File

Left mouse click on Anim By Sound and the Audio Selector UI will open. The name of the parameter will be in the description along the top.

Select an Audio file and three charts will appear.

Enable Animation by Sound and the options will appear.



Animation of a parameter is created by applying an addition-factor and/or a multiplication-factor.

$$\text{animVal} = \text{paraVal} + \text{soundVal}.$$

$$\text{soundVal} = (\text{paraVal} * \text{multiplication-factor} * \text{sound}) + (\text{addition-factor} * \text{sound})$$

It is less complicated when learning, to use only the addition factor, so we change multiplication factor to 0.0.



8.4. Using Sound Pitch mode.

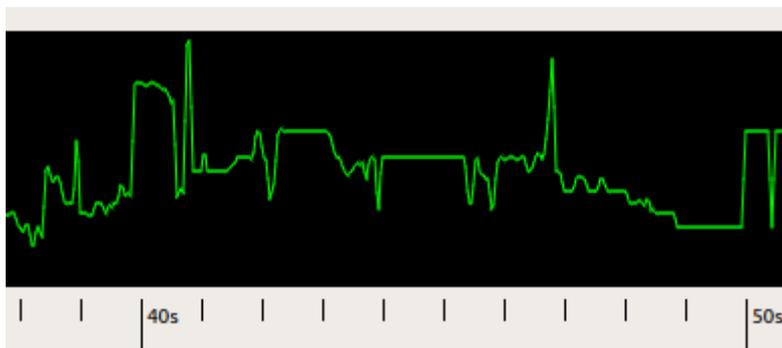
I set frequency at 580Hz and bandwidth to 1000Hz, this covers the range of the fundamental frequencies of my lead guitar notes (I am removing higher harmonic frequencies, although this may not be necessary).

Make further adjustment if the Sound Animation charts shows that the pitch is contained only in the top or bottom of the chart, (resulting from a melody line only using high notes or only using low notes.) Push the Play Sound button and check that the chart line is following the pitch of the audio track.

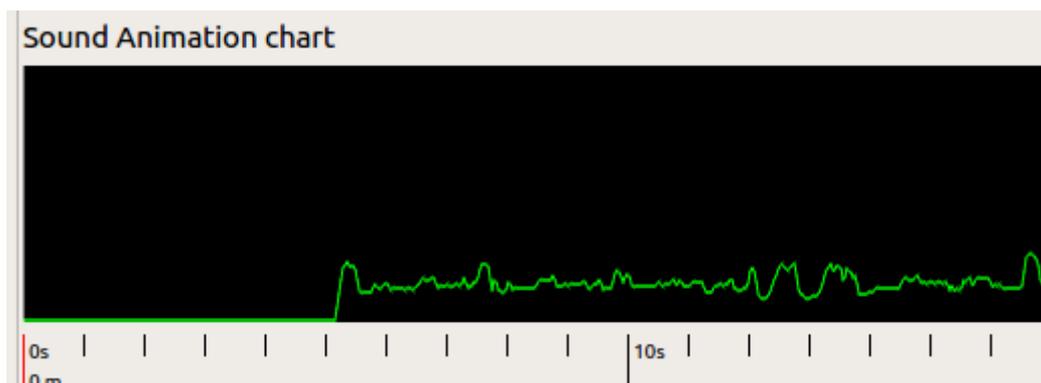
The main point is not to limit the Pitch by having a small band width that does not cover the full spectrum of the fundamental notes used in the audio track.

In Pitch mode the Sound Animation chart rises from silent to high pitch.

In this image the *sound* varies from about 0.2 up to almost 1.0 (maximum *sound*). Therefore the *sound* will have a wide effect on the parameter animation.



In this image the *sound* is fairly constant at around 0.2, so it will have a narrow effect on the animation.



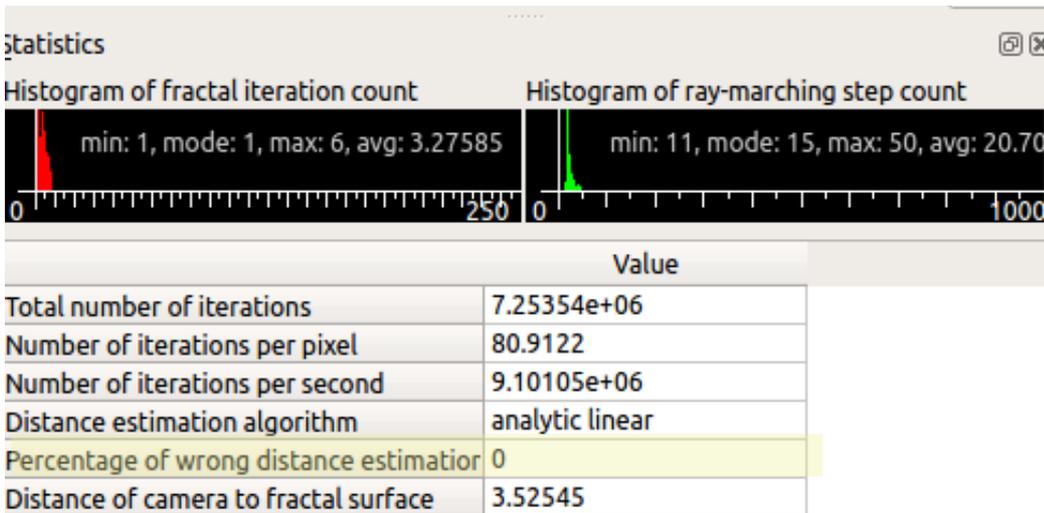


8.5. Testing the parameter

Close the Audio Selection UI and go the Menger_Mod1 fractal tab and test the parameter through a range of values.

If a parameter belongs to a fractal formula, you may notice that the ray marching step multiplier needs to be adjusted to produce a good image throughout the animation range.

As a guide for adjusting the ray marching step multiplier, open View - Show statistics, and monitor Percentage of wrong distance estimations.



Now I decide on the appropriate

size of the addition factor to use for animating the parameter.

I have paraVal “offset y” set at a constant value of 0.0, and I test an addition factor of 3.0. The *sound* will increase the soundVal in the range of 0.0 to 3.0 maximum. However for the effect I want, I am be using Negative influence mode, which will subtract the soundVal from paraVal instead of adding it, therefore the possible range to be tested is 0.0 to -3.0.

The audio file I used only creates *sound* between 0.0 and about 0.2, so the offset values I will be testing are the actual range between 0 and -0.6, i.e. $0.0 = 0.0 * -3.0 \text{ max}$, $-0.6 = 0.2 * -3.0 \text{ max}$.

Note: *There are two types of parameters in this program. The first type can have negative values entered, the second type cannot. It is important when animating a parameter of the second type, that the functions and settings used, do not result in a negative number.*

View the Sound Animation chart to see the what values you are likely to get from *sound* at different parts of the instruments music.

Remember to set the parameter back to the original value when you have finished testing.



8.6. Using Amplitude

Example: Animate the color of the fractal on every beat of the kick drum.

Add material 1 parameter “Palette_offset” to the Keyframe animation table.

Open Anim By Sound, load audio file and Enable Animation by sound.

Adjust Frequency of interest and bandwidth.

Enable “Binary filter” and adjust the threshold so that all the beats are shown in the Sound Animation chart.

Here I am creating an event (at every kick drum beat), that lasts for a minimum duration of 7 extra frames (7/30 seconds). The event is using Addition factor * sound and is triggered every time the sound amplitude increases above the threshold (0.400) and will last for 7/30 seconds.

Events that last less than “say” 7 frames are difficult to observe at 30 fps.

