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User's Guide

Caustics Generator Pro

Caustics textures in HDR format

April 2020

Caustics Generator Pro

Introduction

Caustics can be described as the light pattern you see at the bottom of a pool on a sunny day. This tool will let you render such caustics light patterns in a high dynamic range image format.

The rendered images can be animated and are tileable in both space and time. This means that they are ideal for use in real-time graphics such as games and simulations, but can also be used for architectural renderings, film rendering or advertisement renderings where water needs to be illustrated.

About the program

The Caustics Generator Pro program is divided into a stand-alone command line based version of the Caustics Generator program and a user interface application for interactive use of the renderer. The user interface program interactively shows how the final image looks given the current parameters. The user can also render full sequences and play it as an animation to see how it actually looks when animated. Besides animation, the preview is also able to show how the rendered image looks when tiled, which is useful for getting a better feeling of how it may look when used in a bigger context.

The Caustics Generator Pro version is intended for professional users that want to have higher dynamic range in their images and for the users that want more powerful tuning of their results. It is also intended for those who want to integrate the program into their own production pipelines or script the generation of caustics images.

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Caustics Generator Pro

Usage

The Caustics Generator Pro program contains both a command line program and a program that provide the user with a graphical user interface. The command line program is executed from a Command Prompt and is given command switches in order to control the various parameters that define the image output.

The command line switches that can be given to the program is listed by supplying a `--help` command switch to the program.

```
> CausticsGeneratorCmd.exe --help
```

This will print the available switches and a brief description of what they do.

```
Usage: CausticsGeneratorCmd [-v] [-w <int>] [-h <int>] [-b <int>] [-a <int>] [-r
<int>] [--bg_red=<double>] [--bg_green=<double>] [--bg_blue=<double>] [-d <double>]
[-i <double>] [-a <double>] [-f <double>] [-t <double>] [-l <int>] [-s <int>] [-e
int] [-o <output>] [--hdr] [--bmp] [--heightmap] [--normalmap] [--help] [--version]
Caustics Generator Pro 5.0
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Options:
-w, --width=<int>          output image width (default is 256)
-h, --height=<int>        output image height (default is 256)
-b, --blur=<int>          motion blur samples (default is 1)
-a, --antialias=<int>     antialias level (default is 1), valid values {1,2,4,8,16}
-r, --resolution=<int>    render resolution (default is 128)
--bg_red=<double>         background color for red channel (default is 0.0)
--bg_green=<double>       background color for green channel (default is 0.0)
--bg_blue=<double>        background color for blue channel (default is 0.0)
-d, --depth=<double>      water depth (default is 1.5)
-i, --intensity=<double>  light intensity (default is 0.05)
-a, -f, --amp_filter=<double> amplitude filter (default is 30.0)
-f, -f, --freq_filter=<double> frequency filter (default is 1.5)
-t, -f, --time_filter=<double> time filter (default is 32.0)
--spectral_samples=<int>  number of color spectrum samples (default is 1)
--refraction_spread=<double> refraction index spread when using spectral sampling
                           (default is 0.08)
--light_angle=<int>       sun light angle from zenith, in degrees (default is 0)
-l, --length=<int>        animation length (default is 32)
-s, --start=<int>         start frame to render (default is 1)
-e, --end=<int>           end frame to render (default is same as animation length)
-o <output>              output file (default is "CausticsRender_%03d")
--hdr                    save output in High Dynamic Range format
--bmp                    save output in BMP file format (default)
--heightmap              save height map for each frame
```

The program must be given at least one switch in order to start generating images as output. All command switches have default values that are used if they are not explicitly set when the program is run.

Caustics Generator Pro

In the simplest form, Caustics Generator Pro can be given the -v switch in order to generate some output images. The program then starts rendering images and saves them to disc. The rendering is aborted by pressing Ctrl-C on the keyboard.

```
> CausticsGeneratorCmd.exe -v
Generating water waves...
Rendering frame: 1/32 (/32) Progress: 0.00%
Rendering frame: 1/32 (/32) Progress: 100.00%
Render Time: 1.51 s
Saving: 'CausticsRender_001.exr'

Generating water waves...
Rendering frame: 2/32 (/32) Progress: 0.00%
Rendering frame: 2/32 (/32) Progress: 100.00%
Render Time: 1.24 s
Saving: 'CausticsRender_002.exr'

Generating water waves...
Rendering frame: 3/32 (/32) Progress: 0.00%
Rendering frame: 3/32 (/32) Progress: 100.00%
Render Time: 1.24 s
Saving: 'CausticsRender_003.exr'

Generating water waves...
Rendering frame: 4/32 (/32) Progress: 0.00%
^C
```

The rendered images are by default saved in the same folder as the program is run from. In the above case it has generated the images CausticsRender_001.exr, CausticsRender_002.exr and CausticsRender_003.exr which are the first three images in an animation that is 32 images long.

When looking at the generated images they will look like below.

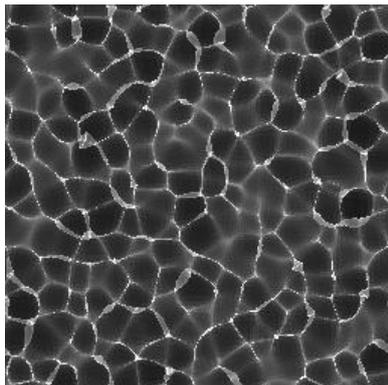


Figure 1 CausticsRender_001.exr

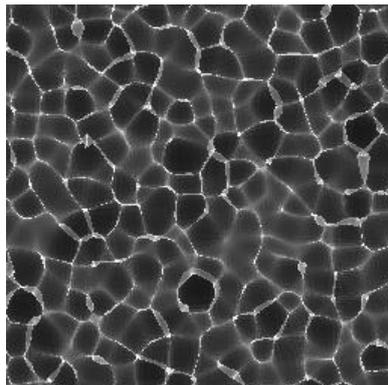


Figure 2 CausticsRender_002.exr

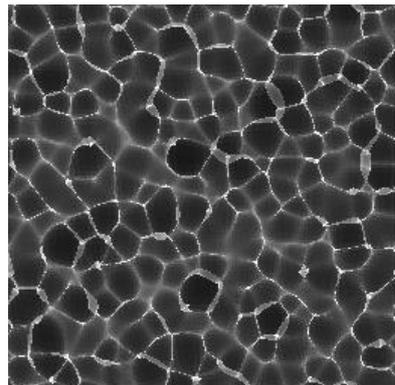


Figure 3 CausticsRender_003.exr

At a first glance, the images may look alike, but they are actually slightly animated. They are actually animated such that when the full 32 images are played in a loop they will seamlessly loop forever. They will not only loop in time, but each image also tile in all directions as seen in Figure 4 where the first image is shown in five copies.

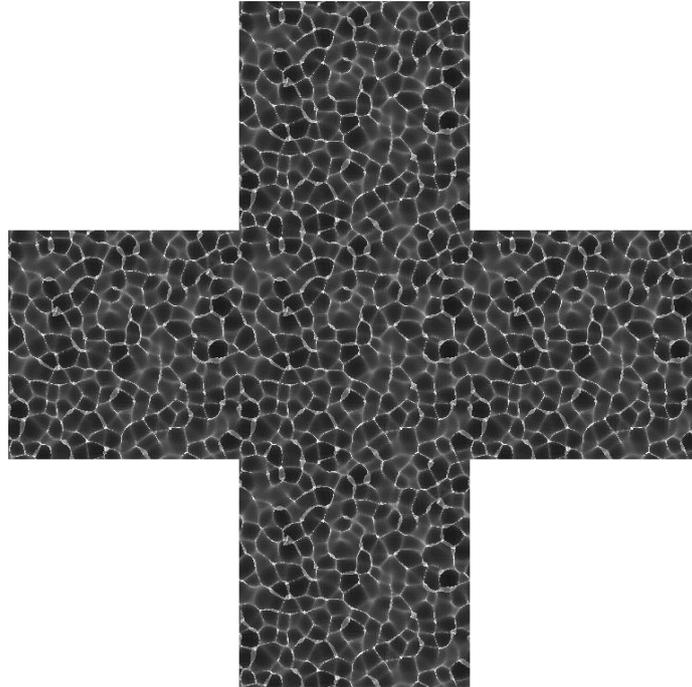


Figure 4 CausticsRender_001.exr in five copies showing that the images tile in space.

Command Line Switches

This chapter gives a brief understanding on how each command line switch affects the output result. Each command line switch comes with two different names, a short name and a long name. There is no difference in using one or the other; it is only a preference of the user which one to use.

-w, --width=<int>

This switch is given an integer number that controls the number of pixels wide that the generated image will have.

Default value is 256.

-h, --height=<int>

This switch is given an integer number that controls the number of pixels high that the generated image will have.

Default value is 256.

-b, --blur=<int>

This switch is given an integer number that controls the number of sub steps to render between each animation step. The sub images are merged together into the final image in order to give a motion blurring effect that smoothes out fast movement in animations. This parameter is mostly useful in animations that are very vivid.

The render time increases linearly with the number of blur samples specified.

Caustics Generator Pro

The default value is 1, which means that no in-between sub images are rendered.

-a, --antialias=<int>

This switch is given an integer number that controls the number of samples per pixel to calculate for each pixel in the image. This is used for removing the sharp jaggedness that otherwise appears when only calculating with one sample per pixel, as shown in the difference between Figure 5 and Figure 6. To produce good quality images, this parameter must be set as high as possible. The rendering time is affected linearly with the number of anti-aliasing samples so a trade-off must be made between rendering time and quality.

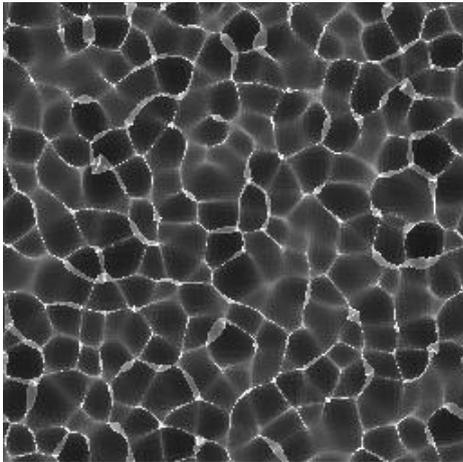


Figure 5 Anti-aliasing set to 1, i.e. no anti-aliasing

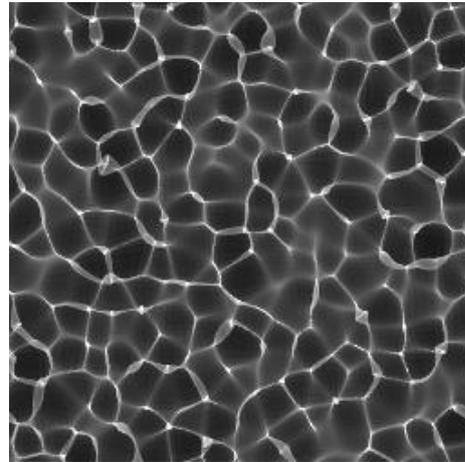


Figure 6 Anti-aliasing set to 16

Valid values for the anti-aliasing parameter are 1, 2, 4, 8 or 16. The default value is 1.

-r, --resolution=<int>

The resolution is used for controlling the smoothness of the surface waves. A low resolution gives less quality of the final rendered image, which is often seen as bad smoothing of the color gradients, while a high resolution gives better quality as seen between Figure 7 and Figure 8.

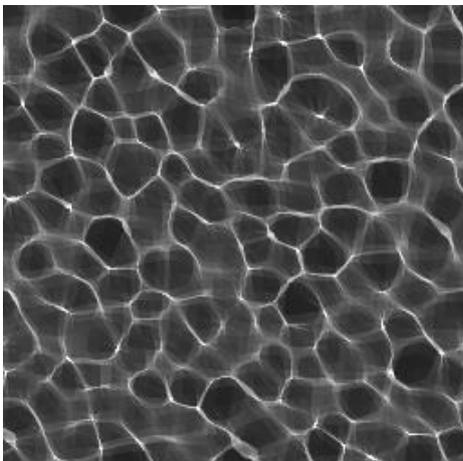


Figure 7 Image rendered with resolution 64 and anti-alias 16

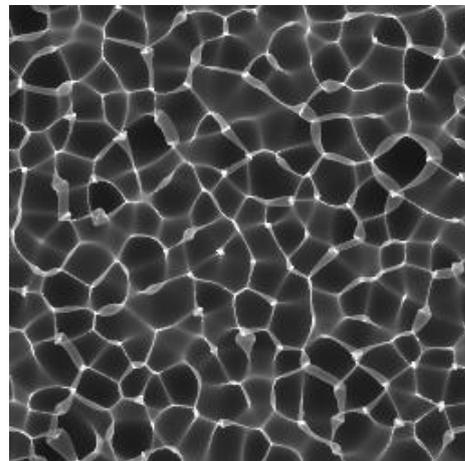


Figure 8 Image rendered with resolution 256 and anti-alias 16

Caustics Generator Pro

The needed resolution is dependent on the image width and height. A good rule of thumb is to have a resolution around half the width or height of the image. A resolution value that is greater than the width or height is generally not needed if the animation is not very vivid.

The default value is 128.

--bg_red=<double>, --bg_green=<double>, --bg_blue=<double>

These options set the color for the red, green and blue channels of the background color that is drawn behind the caustics pattern. A value of 1.0 means full saturation when rendering a BMP image, while in high dynamic images the values may be set to a values greater than 1.0.

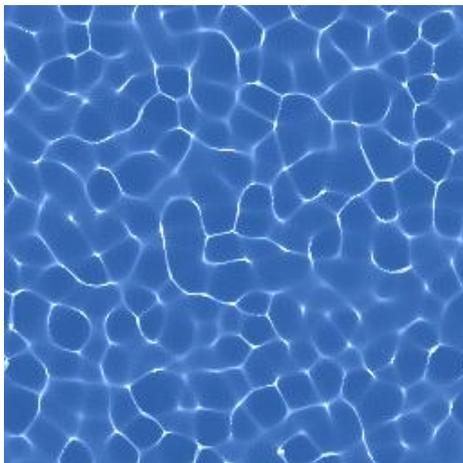


Figure 9 Background color is set to Red=0.17 Green=0.36 Blue=0.65

The default value is 0.0 for all color channels.

-d, --depth=<double>

This switch controls water depth, i.e. the overall distance between the water surface and the bottom on which the caustics pattern is projected. The result produced by changing the depth is intimately coupled with the values given for the amplification, frequency and time filters. Generally, the greater the depth value is the more drawn apart will the caustics patterns be as seen in

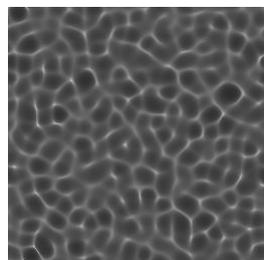


Figure 10 Depth = 0.5

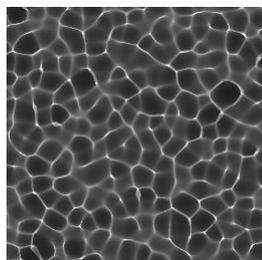


Figure 11 Depth = 1.0

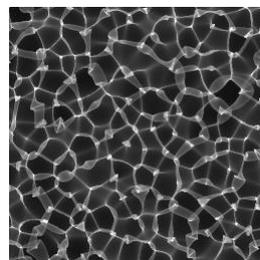


Figure 12 Depth = 2.0

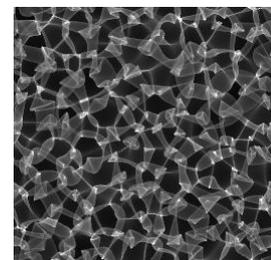


Figure 13 Depth = 3.0

The default value is 1.5.

Caustics Generator Pro

-i, --intensity=<double>

This switch controls the intensity of the light that produces the caustics patterns. The greater the value is the greater intensity the pattern will have. Since the images are rendered in high dynamic range format, the light intensity can be adjusted by post-processing or changing the scale of the pixel values in other applications, but this parameter can be used if the values are not in the desired range in the first place.

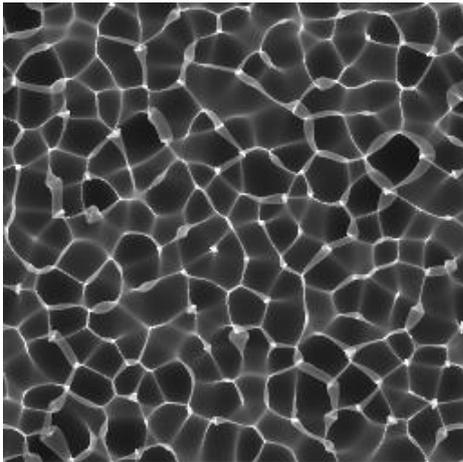


Figure 14 Intensity = 0.05

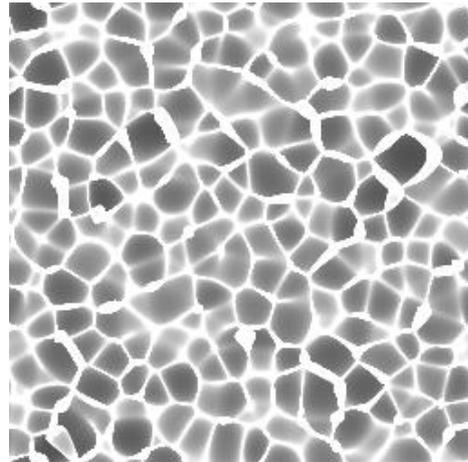


Figure 15 Intensity = 0.5

The default value is 0.05.

-a, -f, --amp_filter=<double>

The amplitude filter switch controls the height of the water waves that are used for generating the caustics pattern. This parameter is intimately coupled with both the depth and the frequency and time filters. This parameter may at first glance look like it is producing the same effect as the depth parameter but the difference is that raising the amplitude instead of the depth gives animations that are more vivid.

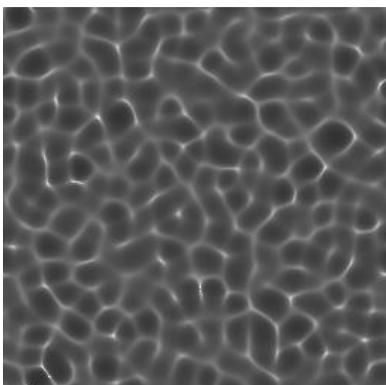


Figure 16 Amplitude = 10

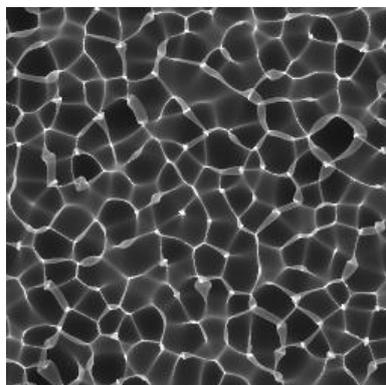


Figure 17 Amplitude = 30

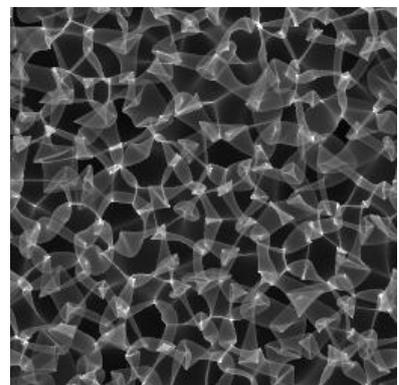


Figure 18 Amplitude = 60

The default value is 30.0.

Caustics Generator Pro

-f, -f, --freq_filter=<double>

The frequency filter switch controls how wide the waves are that generate the caustics pattern. Lowering this value gives more caustic pattern strokes within the image, while raising it will give larger strokes. Notice that lowering the frequency value also affects the appearance of the caustics. This means that the depth or amplitude filter may have to be changed in order to keep the general appearance of the caustics pattern.

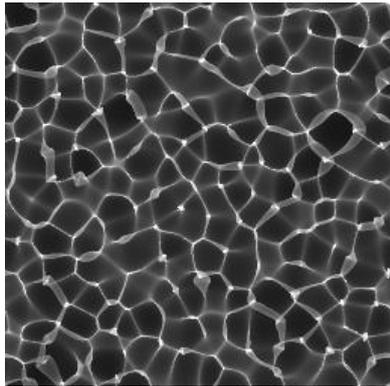


Figure 19 Depth = 1.5 Frequency = 1.5

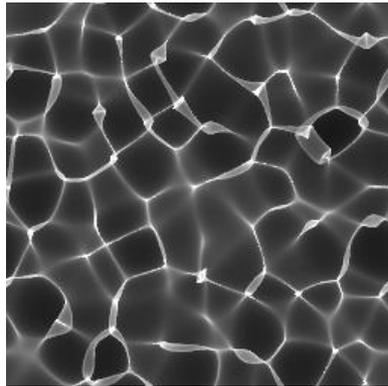


Figure 20 Depth = 6.0 Frequency = 2.5

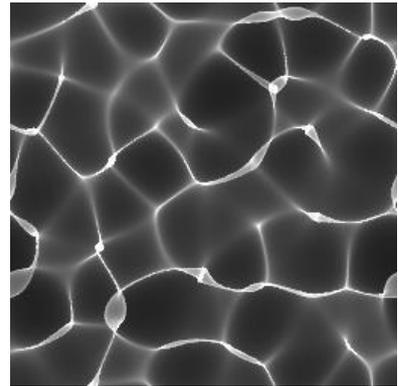


Figure 21 Depth = 15 Frequency = 3.5

The default value is 1.5.

-t, -f, --time_filter=<double>

The time filter switch controls the vividness of the animation. Raising this value gives a more vivid movement of the caustics pattern between frames in the animation. Just as for the rest of the filter parameters, changing this parameter also changes the general appearance of the caustics pattern, which means that the other filter parameters may have to be changed too in order to keep the general appearance.

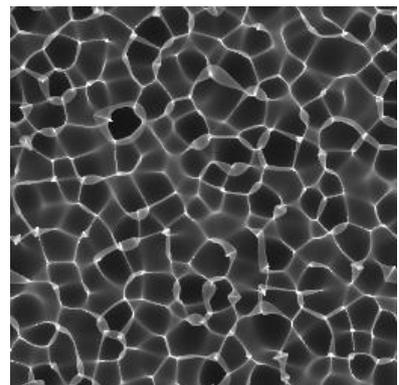
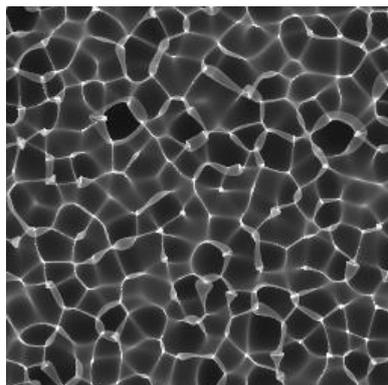
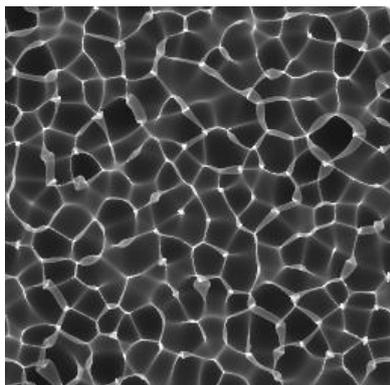


Figure 22 Images from an animation sequence using depth = 1.5, frequency = 1.5, amplitude = 30 and time filter = 32

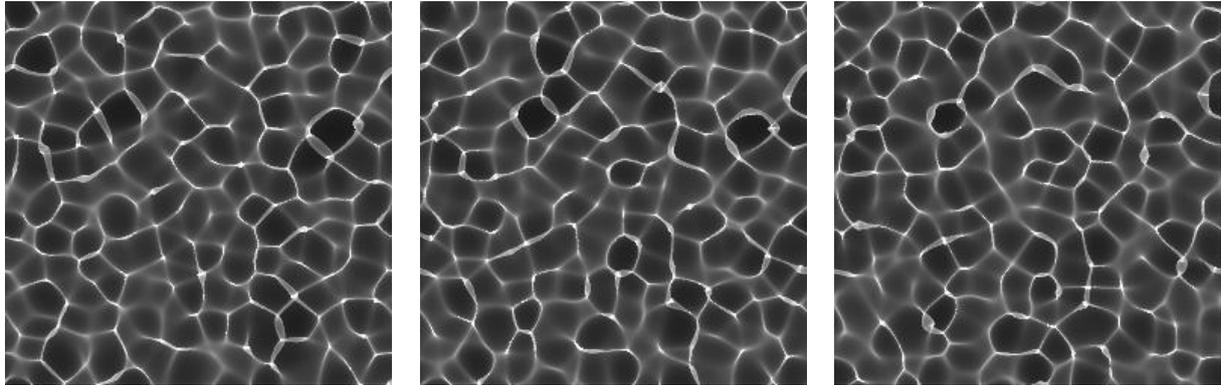


Figure 23 Images from an animation sequence using depth = 4.0, frequency = 3.0, amplitude = 30 and time filter = 55

The default value is 32.0.

--spectral_samples

Light passing between two different medium causes different refraction depending on the wavelength of the light. For a full spectrum light, like the sun, this will cause spectral scattering, or what could be seen as a rainbow coloring effect. This spectral scattering can be simulated by calculating caustics images where the different light wavelengths refract differently.

The spectral_samples option sets how many sample points in the visual spectra that shall be simulated. Higher values mean that it takes more time to simulate but it also produces a higher quality spectral image.

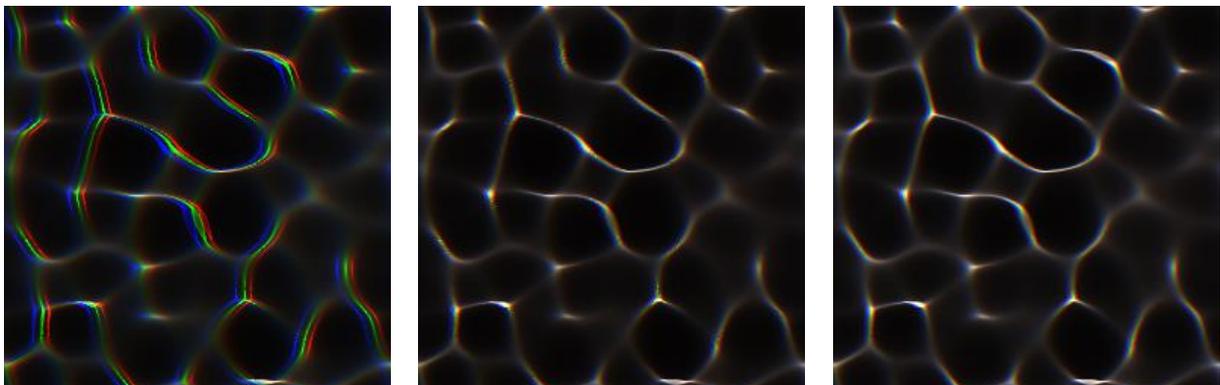


Figure 24 Images showing spectral sampling using three RGB samples to the left, a low setting of 10 samples in the middle and the best quality of 80 samples to the right.

The lowest number of spectral samples is 1, which turns off spectral sampling and the highest value is 80. The default value is 1.

--refraction_spread

For air to water, the refraction index for different light wavelengths is fixed. The simulation in the Caustics Generator can however set an arbitrary refraction index spread in order to exaggerate or lessen the spectral effect. This can be used to achieve better visual pleasure in the images and allows you to achieve the look you are after.

Caustics Generator Pro

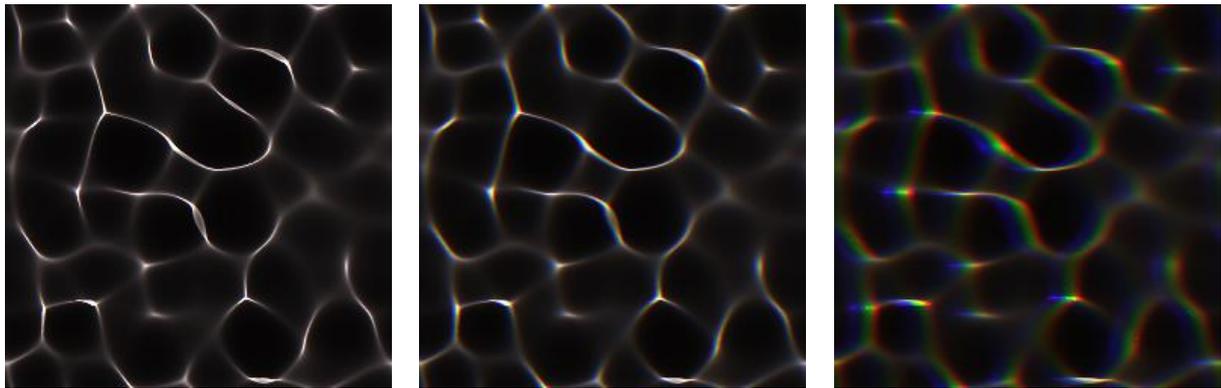


Figure 25 Images showing an increasing amount of spectral refraction spread.

The refraction spread parameter only has a meaning if the spectral samples is turned on.

--light_angle

When the sun is at zenith, the spectral coloring is spreading the same wavelength color equally in all directions when waves are seen from above and thus not causing so much prismatic coloring effect. Giving the light a greater angle from zenith will spread the colors more in the light direction.

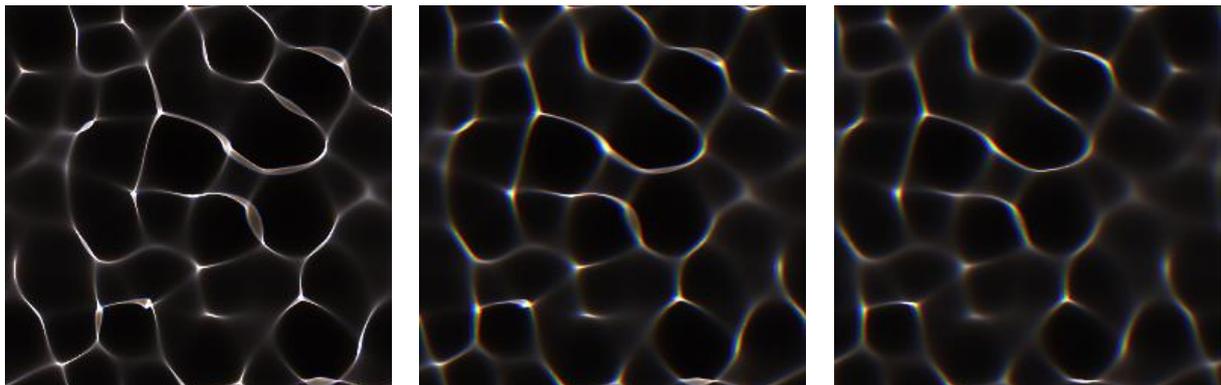


Figure 26 Images showing an increasing light angle when using spectral rendering. The left image shows the light angle 0, i.e. at zenith. The two other images show increasing light angle.

The light angle is only really useful if the spectral samples is turned on. It however affects the pattern even if spectral sampling is not used.

The default value is 0, so you may want to increase it if you turn on spectral sampling.

-l, --length=<int>

This switch controls the total number of animation frames. Since the animations loop in time, this parameter is used to control how many frames that you want before the animation shall loop. This is usually determined by the replay rate at which you will play the animation.

Changing the number of frames alters the appearance of the caustics pattern so it is a good idea to set the animation length as the first step before tweaking the other parameters.

The default value is 32 frames.

Caustics Generator Pro

-s, --start=<int>

This switch tells the renderer at which animation frame to start the rendering.

Default value is 1.

-e, --end=<int>

This switch tells the renderer at which animation frame to stop the rendering.

Default value is to render to the end of the animation, i.e. the same as the animation length.

-o <output>

This switch sets the file name that the generated images will be saved on disc as. The frame number is inserted into the file name by writing a %d somewhere in the file name. The frame number can also be formatted to always have a given number of digits in it by writing a modifier to the %d option. To have three digits which are padded with leading zeroes then specify %03d.

The default file name is “CausticsRender_%03d” which will generate images with file names such as CausticsRender_001.exr, CausticsRender_002.exr, CausticsRender_003.exr etc.

--hdr, --bmp

This switch selects the file format of the output images. You can specify either one of the switches or both if you would like to output both high dynamic range (EXR) as well as bitmap (BMP) images.

The default is to output high dynamic range images if none of the switches are given.

--heightmap

When this switch is used the renderer will output the water surface height data used during the caustics calculations as a gray-scale bitmap image. The height data is scaled to fit within the 0 to 255 color range that can be stored in a BMP image.

The bitmap image has the width and height, in pixels, set by the Resolution parameter.

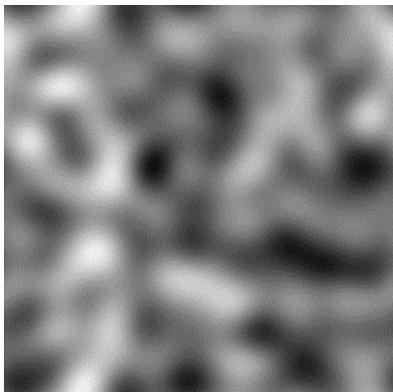


Figure 27 Water surface output as a height map

Caustics Generator Pro

--normalmap

When this switch is used the renderer will output the water surface normal vectors used during the caustics calculations as a colored bitmap image. The R, G and B channels in the bitmap corresponds to the spatial dimension (X, Y and Z) of a pixel's normal in the height surface. The 0 to 255 pixel channel value corresponds to a -1 to 1 value in object space. This means that a RGB value of {128, 128, 255} represents a normal vector of {0, 0, 1}, i.e. a vector pointing straight upwards from the surface in 3D-space.

The bitmap image has the width and height, in pixels, set by the Resolution parameter.

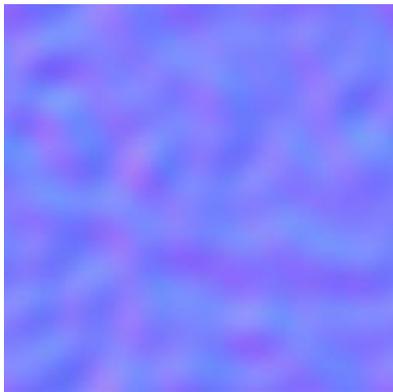


Figure 28 Water surface output as a normal map

-v, --verbose, --debug

This switch tells the program to print verbose output while rendering the images. This is useful for seeing the progress of the rendering. If the verbose option is not turned on, the program will be quiet while working.

--help

This switch tells the program to print the help text instead of rendering any image.

--version

This switch tells the program to print the program version information instead of rendering any image.

Caustics Generator Pro

Choosing the right parameters

With the command line version of Caustics Generator Pro it can be hard to set the parameters in a good way for the program to produce the output you desire. It is therefore recommended to use the graphical user interface version of Caustics Generator first in order to tune the parameters before using the command line version. Caustics Generator has a graphical user interface in which the changes to the parameters can update a live image. This makes it far easier to find a good set of parameters.

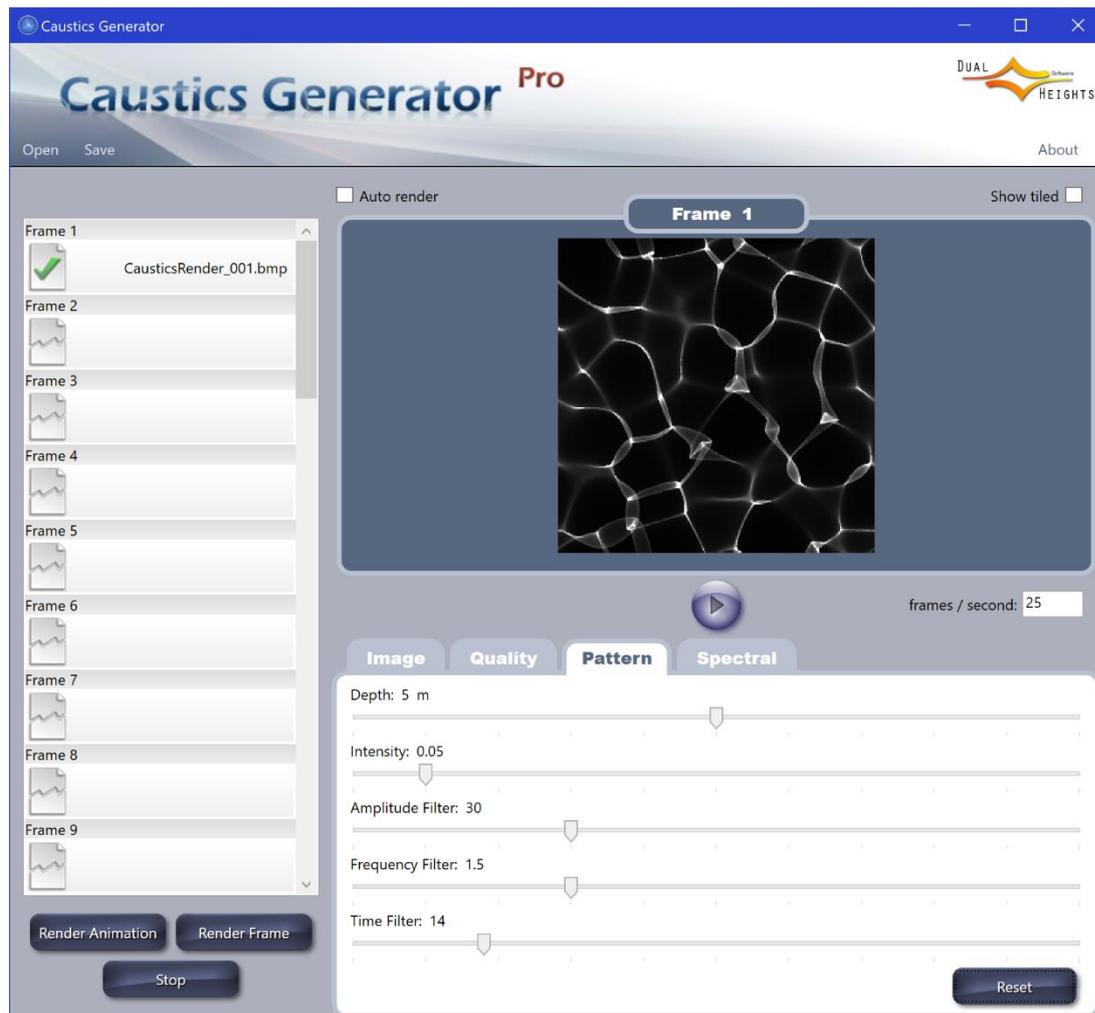


Figure 29 The graphical user interface of the Caustics Generator program

The parameters are divided into categories in the four different tabs called Image, Quality, Pattern and Spectral in the user interface. The parameters used to render the image in Figure 29 are supplied to the command line version of Caustics Generator Pro in the following way:

```
> CausticsGeneratorCmd.exe --bmp --width 256 --height 256 --blur 1 --antialias 16  
--resolution 128 --depth 5 --intensity 0.05 --amp_filter 30 --freq_filter 1.5  
--time_filter 14 --length 32
```