

# Lens analysis tool

## Overview

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The lens analysis utility is the primary tool V-Ray supplies for creating, previewing, and editing of V-Ray lens files (\*.vrlens), and contains a camera distortion analyzer, and a tool for correcting/distorting images. The VRLens files can be used in Houdini, 3ds Max, Maya etc. to provide realistic (measured) camera distortion (as opposed to the simple quadratic and cubic modes). The VRLens format also supports zoom lenses, and the distortion parameters are linked to the focal length of the V-Ray Physical Camera. So, as the camera is zoomed in and out, the distortion parameters are automatically varied. This provides for a very realistic level of camera distortion simulation.

## Location

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Currently, on all operational systems the **lens\_analyzer.exe** is located in V-Ray's folder (where the V-Ray files are extracted) > **appsdk > bin**.

## Workflow for Generating VRLens files

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There are two ways to generate .VRLens files. One is using a set of calibration images obtained by photographing a calibration chart with the camera we want to measure. The other one is using photographs and manual analysis.

V-Ray lens files are created with the lens analysis utility from a set of calibration images photographed with the camera we want to measure. They may also be created from arbitrary photographs using manual analysis. The general workflow to produce a .VRLens file for a particular camera (or a particular lens, if the lenses are interchangeable) is like this:

1. The utility creates a calibration chart file by selecting **Analysis Print Test Chart...** The utility outputs a PostScript (PS) formatted file. PS is a standard printer format, which can be easily converted to PDF via the ps2pdf utility (where applicable) or through an online service, <http://www.ps2pdf.com/>
2. The calibration chart is printed on a sheet of paper, which is later photographed with the camera to be analyzed;
3. The image files from the camera are downloaded to a computer, where they are processed with the lens analysis utility: first, the photos are added (with the **Add photos...** button) to the lens profile and then analyzed (by clicking **Analyze...**);
4. The analyzed lens profile is saved (by selecting **Profile Save Profile**) to disk.

Alternatively, you can use arbitrary photographs and manual analysis to obtain the lens profile:

1. Use the **Add photos...** button to add the images that you want to analyze;
2. Click on the **Analyze manually** button;
3. You will get a window with the selected image, where you can draw lines along the edges in the photo that should be straightened out. Using the **Select** mode, click and drag along a few vertical and horizontal edges in the photo. The utility will try to follow the edge. Use the **Eraser** mode to erase parts of the edge that may be wrongly followed. Use **Ctrl+Z** to undo operations.
4. After you are done, click on the **Analyze** button.
5. Save the lens profile from **Profile Save Profile**.

The .VRLens file is ready to be used with the V-Ray physical camera in 3ds Max, Maya, etc;

## Workflow for Generating UV Gradient Distortion Maps

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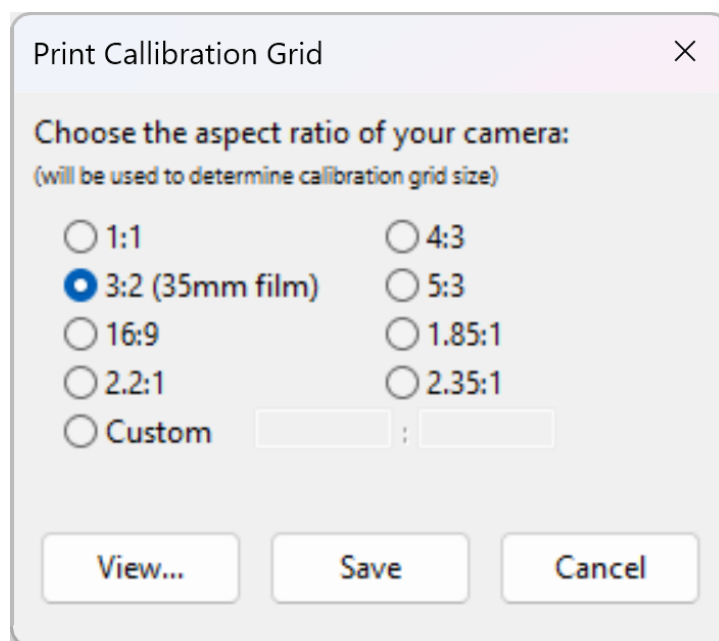
If instead of a .VRLens file, you need to generate a UV gradient distortion map, the workflow is as follows:

1. Analyze a number of images, either using the chart method or using any photographs with manual analysis, as described above;
2. Go to **Correction Correct/Distort images...**
3. Add files (e.g., one of the original photos) using the **Add photos...** button;
4. Specify an output folder for the distortion map in the **Output directory** field.
5. Go to the **Options** tab and turn on the **Generate only distortion map** option;
6. Click on the **Preview** button to check what image will be generated;
7. Choose a suitable output format for the image (full floating-point OpenEXR file is preferred);
8. Click the **Process** button.

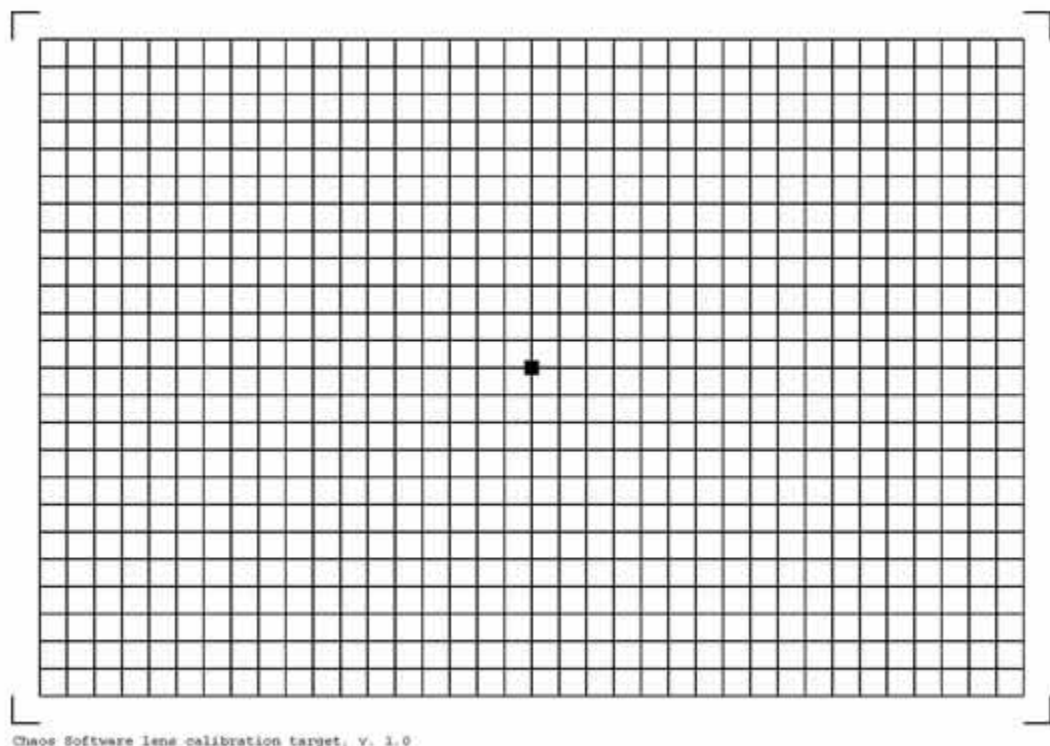
The resulting UV distortion gradient map can be used in Nuke, in the 3ds Max physical camera, and in the V-Ray physical camera when the distortion type is **Texture**.

## Printing a Calibration Chart

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From **Analysis Print Test Chart...**, you should choose the aspect ratio of the camera (the image sensor or that of the film gate). Using the correct ratio is beneficial for the accuracy of the method. Pressing the **View...** button opens the generated PS file in your default PostScript viewer (under Windows, you may need to install one – for example, the freeware GSview). You may also choose **Save** and convert the resulting PostScript file to PDF via the online service <http://www.ps2pdf.com/>. Both ways work. The chart then needs to be printed on a sheet of clean white paper (size is not important; A4/Letter is OK). The grid lines need to be straight and free from defects (e.g., gaps, scratches, and other irregularities). The illustration below shows an example calibration chart.



## Photographing the Calibration Chart

The printed chart should be placed on a flat surface (wall, whiteboard) and pinned/taped/glued so that it is tense and without any bumps. The camera should be placed directly in front of the chart, so the photograph contains the whole grid and just a bit of margin around it. Ideally, the four L-shaped corners should correspond to the corners of the photograph, but it doesn't hurt if they don't – it is fine as long as the whole grid is present and it doesn't come too close (e.g., a few pixels) of the image edges. The image center should be the black dot in the middle of the grid (the software is picky about that – only 1.5 boxes of offset is enough to have your image rejected). Pay great attention to the placement of the camera; it should be directly in front of the chart and should point in a direction precisely perpendicular to the sheet. Even a small offset will introduce a perspective distortion, which greatly reduces the accuracy of the analysis (and therefore, the software is extremely picky about this). Other things you should pay attention to:

Enough illumination should be provided to ensure fast shutter speeds when using suitable ISO settings (to eliminate the possibility of motion blur or excessive noise levels).

Correct focusing. Fuzzy images might be hard to analyze.

Image resolution: 2 megapixels is sufficient. The utility gladly accepts larger images, but they don't provide better accuracy.

No RAW files – the utility only accepts the range of image formats supported by V-Ray – this excludes all RAW image formats. JPEG is sufficient for the purposes of the analysis.

## Prime vs. Zoom Lenses

For a prime lens (i.e., a lens with a fixed focal length), you only need one photograph of the calibration chart (but you are encouraged to take more shots as outlined in the **hints**; see next paragraph). For a zoom lens, you need several photographs at various zoom levels to build a complete profile of the lens (V-Ray will interpolate the distortion parameters during rendering, so a few photos are sufficient). This means you have to re-adjust the zooming of the lens and the camera position several times and make a photograph at each focal length. These calibration photos should cover the entire lens range. The amount of calibration photos required for an accurate profile is somewhat variable and depends on the lens type and your needs. A simple rule that you might find useful is to consider the zoom factor of the lens and use the same amount (rounded to integer) of calibration focal lengths. E.g. to profile a 28-135mm lens, which has a zoom factor of around 5 ( $135/28 \approx 4.82 \approx 5$ ), you need 5 photos spaced evenly in the 28-135 range. On more wide-angle lenses, where the distortion is usually more prominent in the wide end of the zoom range (and the parameters there change faster), it makes more sense to concentrate more photos on the wide end. E.g. to cover an 18-55 lens, an example calibration progression could be 18mm, 24mm, 30mm, 40mm, and 55mm.

In our tests at Chaos Software, creating lens profiles proved to be a tedious job, so you may find these **hints** useful:

Most important of all, it is strongly recommended to use a tripod during the photography. It eliminates many factors that may ruin your images to the point they get rejected by the lens analysis utility.

Take a few photos at each focal length for redundancy reasons. The utility will later assign a score to each photo, so you can easily choose which images to keep or discard.

The utility may reject a photo for various reasons, but the most common is because of existing perspective distortion. It means the camera wasn't directly in front of the center of the calibration chart during the shot. You must redo the photography in that case.

Remember that the viewfinders of cameras do not usually cover 100% of the real image but crop out some of it. Thus, if you target 100% coverage in the viewfinder, you may later find out that you've left a margin around the grid that is needlessly large. You need to experiment to find the best shooting conditions.

If your viewfinder has a "central" focusing point or mark, keep in mind that it may not coincide with the true image center. You can derive the correcting offset you need to apply through some experimentation.

Avoid using direct (non-bounced) flash. It tends to overexpose some parts of the image, so some grid lines may be washed out to full white.

If you really need to get some images accepted, you can tune the error thresholds using **Analysis Error Thresholds...** This is a last-resort solution; don't use it if possible.

## Analyzing the Calibration Photos

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The photos from the camera are transferred to the PC and processed with our lens analyzer tool. First, you should click on the **Add Photos...** button and import the calibration photos (for a zoom lens, the software may ask you to provide the focal lengths of the photographs if it can't fetch them from image metadata. In this case, you need to supply the correct focal length for each photo; otherwise, the profile will be incomplete). Then, click on the **Analyze...** button. As the images are processed, the utility prints out a statistic for each file: whether the analysis is successful or not, the error message if it fails, and a quality rating (like "perfect", "very good", etc.) based on the following performance criteria:

**Inter-central distance:** The distance between the true image center and the central bud of the grid in the photo. Less than 70% of cell size is considered OK.

**Perspective distortion:** Measures how much the grid outline differs from an ideal rectangle. More than 2% of deformation is deemed unacceptable.

**Central angle:** A measure of the angle between orthogonal lines near the grid center. If they are off by more than 0.5° from a straight angle, the image is rejected.

**Grid misalignment :** The rotation of the grid with respect to the image. Anything below 10° is OK.

If the utility rejects a photograph for a reason other than those four criteria, it may be helpful to turn on the detection-stage preview from **Analysis Show Detection Details** and retry analysis. The preview may give you a hint as to why the detection finds the image difficult. After the analysis phase, the table describing the profile is populated with the detected distortion parameters of all successfully analyzed photos.

**Note:** if you followed the advice to take several redundant photos for each focal length, you can now either trim the profile manually by removing the inferior photos, as judged by the analyzer or by using the automated merging tool accessible from **Analysis Consolidate Profile**. **Consolidate profile** does not just remove the redundant photos – it averages the parameters of any calibration photos with the same focal length, so it is theoretically optimal. In either case, the final profile must have only a single set of parameters per each focal length. The table contains the following fields:

**Calibration photo:** The path to the analyzed image file. It exists for your convenience only. The profile works fine if the file no longer exists (or if the profile is transferred to another machine –it does not matter that it lacks the photo files)

**Focal length:** This is the focal length of the photograph. Depending on the type of lens, this parameter may be important or not:

**Prime lenses:** Since a prime lens would ultimately have only one table entry, it is not important what the focal length field holds (it may even be empty). The profile will work anyway.

**Zoom lenses:** It is important to have a focal length per each set of distortion parameters (i.e., each entry in the table). Here you need to adopt a consistent "focal length framework", because there are several incompatible choices:

35mm-equivalent focal length framework, whereas any real (optical) focal length is converted to the equivalent focal length in 35mm film. E.g., on a Canon APS-C sensor body (where the image sensor diagonal is 1.6 times smaller than the 35-mm system's diagonal), the crop factor is 1.6x, and a 50mm lens mounted on an APS-C body behaves as an 80mm lens on a full-frame body utilizing 35mm film ( $80 = 50 \times 1.6$ ). This framework works well with the V-Ray physical camera, as it also mimics a 35mm camera.

Actual (optical) focal length framework, where the crop factor multiplication is not done. All recorded focal lengths correspond to direct lens settings. In this mode, it may be beneficial to alter the physical camera defaults to reflect the exact properties of your camera (e.g., to be able to get the same field of view, etc.) The lens utility prefers the first system and tries to calculate the 35mm-equivalent focal length of your photographs from EXIF metadata, contained in the images (JPEG and TIFF files only). If this data is not present, but information about the optical focal length is available instead, the lens utility will use the latter after issuing a warning about that.

**K0:** This parameter controls image scaling. Should be very close to 1 in most cases.

**K1:** Represents the first-order symmetric (radial) distortion coefficient and is the primary indicator of the type of distortion (it will also be the most variable parameter throughout the zoom range). It is typically around 0, with positive values indicating barrel distortion and negative indicating pincushion distortion.

**K2:** Some very wide-angle lenses have such distortion characteristics near the edges of the frame that are impossible to capture using the first-order coefficient alone and thus require a second-order coefficient. K2 is also symmetric. On most moderate lenses, this parameter would be very close to 0.

**Squeeze (Sqz):** This parameter captures the asymmetrical features of the lens due to the image being stretched in an X or Y direction. It should be around 1 in most cases.

**x (Lx):** Captures the asymmetrical distortion along the X direction. Usually 0.

**y (Ly):** Same as x, but along the Y direction.

Note: The primary determining parameter is K1. All other parameters will be close to their default ("no-distortion") values, but since the photographed grid can never be analyzed with absolute precision, some "noise" is expected to exist in the parameters. Further, when both K1 and K2 are nearly zero, the other parameters lose their significance and may fluctuate widely. In short, do not pay great attention if the parameters are not quite at their expected values –this doesn't mean there is a flaw in your lenses.

## Analyzing a Photo Manually

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The lens analyzer can also analyze an arbitrary photo by detecting the bending of lines that should be straight. These are usually the edges of buildings, borders of rectangular panels, windows, or other objects that are straight in the real world. Any rectilinear perspective transformation should keep the lines straight in the 2D picture as well. However, the lens distortion makes them slightly curved. The procedure to manually analyze such photographs consists of selecting a few of those lines, with the software taking care of tracing the exact line/edge contours in the picture and figuring out the necessary distortion parameters which would make these lines "straight".

Two tools are used for the manual analysis: a selector tool and an eraser tool. To choose the select tool, the user has to click on the selector button, which is positioned in the top left corner of the window, or press 's'. For the eraser tool, the eraser button is used or the 'e' key.

To analyze the picture, the user has to use the selector tool to select the lines from the image that should be straight. To do so, the user has to press the left mouse button over some point of the line, drag the mouse over another point, and then release the button. While doing this black line with two circles at each end is shown over the image. The first end of the line is over the first detected point over the line that the user is currently selecting. The second end is under the mouse cursor. When the left mouse button is released, the line becomes green, and the second end is positioned over the selected line too. If the program detects the line successfully, red circles over the points of the line are drawn. If the user doesn't like the result, he can delete the selection by pressing the right mouse button over the dragged line and selecting delete from the context menu. When he presses the right mouse button, the line that will be deleted, if the user clicks delete, will change its color to cyan. If the user doesn't like some of the detected points, he can use the eraser tool to delete them. When the eraser tool is used yellow circle is drawn under the cursor. When the user presses the left mouse button, the points under the circle are deleted. The size of the eraser can be changed using the scroll or the '-' (for decreasing) '=' (for increasing) buttons. When enough edges are selected, the **Analyze** button is used for calculating the result. If there are no selected edges and the user presses Analyze, the program shows an error and doesn't close the dialog. Suppose there are not at least two perpendicular edges, and the user presses Analyze. In that case, the program shows a warning that the results from the analysis may not be accurate, and if the user wants, he can select more edges. Technically, two vertical and two horizontal edges are required for reliable results, and the closer to the edges of the image they are, the better.

In the manual analysis dialog, the user can use undo/redo commands. To do this, the standard key combinations **Ctrl+Z**(undo) and **Ctrl+Y**(redo) are used.

### Tips for good results from the manual analysis:

1. Select more edges. There's no limit to the number of edges you select. If they aren't enough, there is a chance that the results from the analysis will be incorrect.
2. Select more edges where the distortion is more pronounced.
3. Select perpendicular edges. Due to the nature of the lens distortions, it is crucial for the analysis to have information from edges that are perpendicular to each other.
4. When you select an edge, the point that you press the mouse button down shouldn't be a cross point of two edges.
5. If the edge that you want to select is very distorted, draw a line at the least distorted part of the edge.

## Modifying Lens Profile Data

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In the lens analysis utility:

You may change a focal length data (or enter one) by double-clicking on the respective cell in the table

You may change the distortion parameters by double-clicking on any parameter cell. If the image calibration file is present in your system, you will have a detailed preview of the “destination”, a straight grid of points (represented by small blue circles), and the detected grid intersection points after the correction (represented by small red crosses). The objective is to tune the parameters in such a way that the red crosses coincide with the blue circles. You can zoom the preview by holding the right mouse button in the preview area and moving the mouse up or down. You can pan by holding the left mouse button and moving the mouse. The parameters are present at the bottom of the dialog, and you can change them by typing their values directly or by clicking on the arrows associated with each parameter (the values will be incremented or decremented based on the “tuning precision” setting). **Note:** if the calibration photo is unavailable, a simpler dialog with no preview will appear.

## Test Correction Utility

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You can see an example of how an “un-distorted” image will look by selecting one of the calibration images (click on its name) and selecting **Correction Test correction**. This corrects the calibration photo using the detected distortion parameters. You can switch between the corrected and original files for comparison.

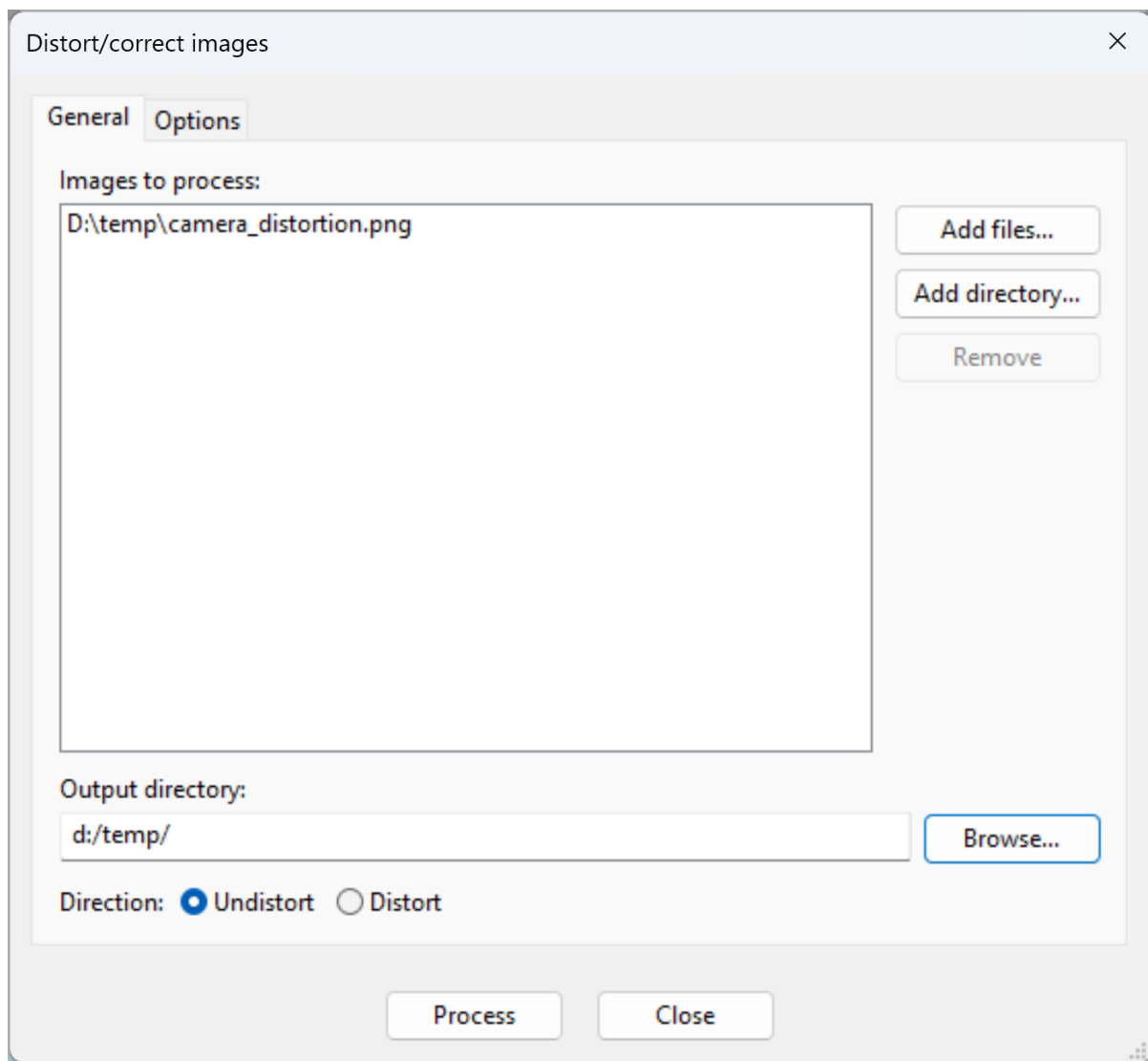
## Arbitrary Image Correction/Distortion Utility

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You may correct or distort an array of arbitrary image files using **Correction Correct/Distort images....** Thus, a “perfect” image (e.g., from a render with no distortion whatsoever) can be distorted to match the characteristics of a measured camera or an image sequence shot by a real camera can be corrected. Hence, it matches the quality of a theoretical “perfect” camera.

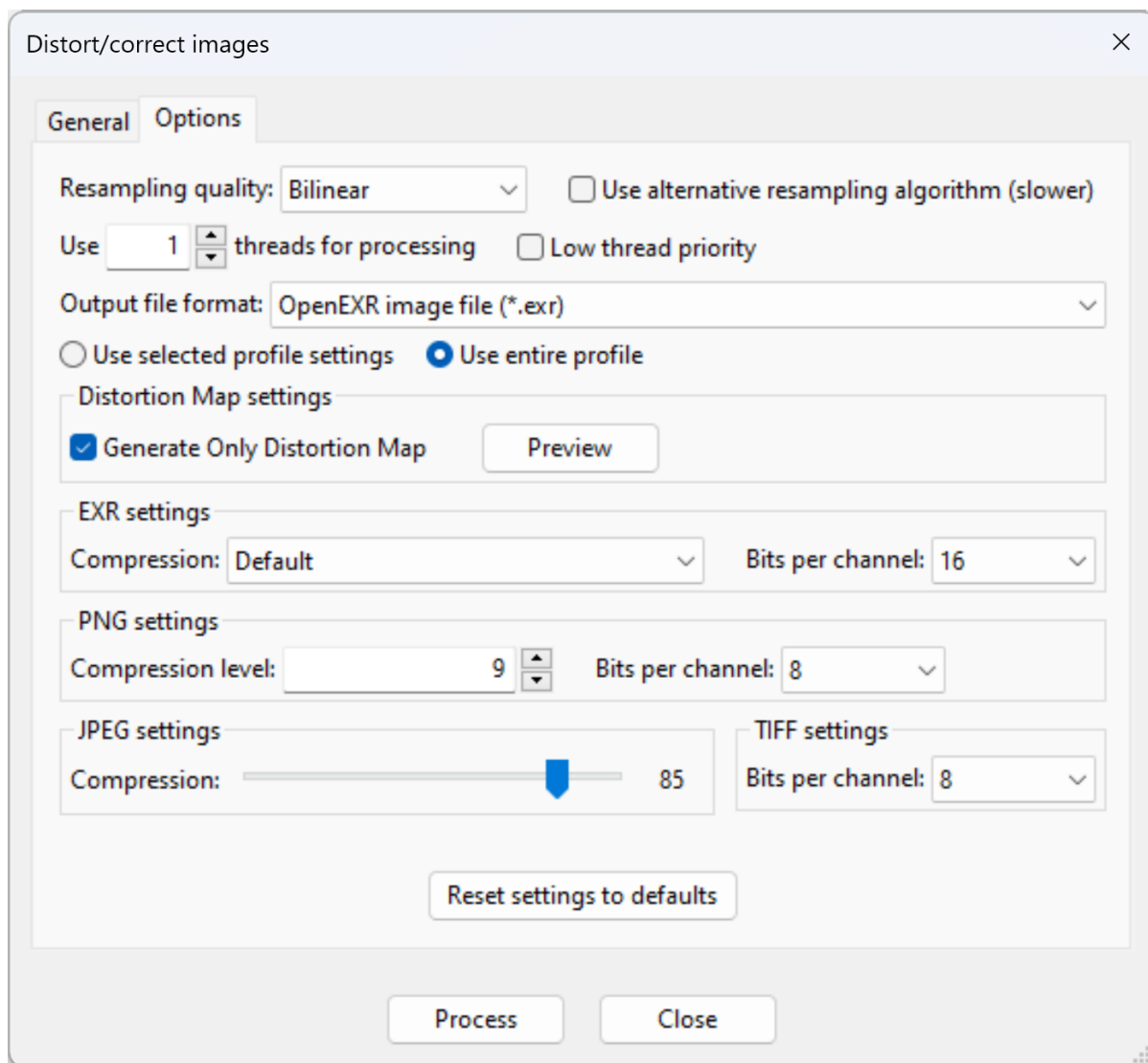
This utility uses the complete lens profile, so, for zoom lenses, it calculates the needed distortion parameters per image in a manner similar to the way it is done in the V-Ray Physical camera during rendering. As a consequence of this, you need the focal lengths of each image that is going to be corrected or distorted; otherwise, the parameters cannot be correctly interpolated. The utility would try to infer this from EXIF metadata; when that fails, it presents you with several choices, see below.

### General



Here, you select the images to be processed. Use **Add file...** to add individual files, or **Add directory...** for a whole directory, possibly including the full directory hierarchy below the selected one. Please note that the hierarchy is not preserved in the output directory in that case. The output directory indicates where the processed files are to be stored, and you can select the direction of the process here. When you're all set up, click **Process**.

## Options



Here, you can tweak various parameters regarding the process.

**Resampling quality** – Specifies the image resampling function - choices are Nearest neighbor, Bilinear, or Area, which are quality/speed tradeoffs. Bilinear is fast and adequate for most purposes, so it is the default.

**Use alternative resampling algorithm (slower)** – This is only meaningful when using Nearest neighbor or Bilinear resampling, and the processing direction is Undistort. Because of the mathematics involved in the distortion/undistortion formulas, it is much faster to transform an image in the “distort” direction. However, the “undistort” direction can still be achieved using the same internal machinery but with inverting the image transfer function. This approach uses somewhat more memory and, in some extreme cases, could introduce image artifacts. This option should be mostly left unchecked; if the image quality is unacceptable, you may try to turn this option on and see if the quality improves.

**Use XXX threads for processing** – The image process is naturally multi-threaded and will use all the processing power available in the system. Here, you can tweak the number of working threads. **Note:** the amount of memory required for processing is proportional to the number of threads. With a lot of threads and when working with large images, your system may end up consuming all the memory available, and some of the images will not be processed as a result. The situation can be alleviated by lowering the number of threads.

**Low thread priority** – When enabled, uses below-normal worker thread priority, giving more CPU time to other running tasks.

**Output file format** – Specifies the output image format. By default, it is the same as the format of the source images.

**Generate only distortion map** – When enabled, instead of performing the distortion on the input images, this option allows the export of a red/green gradient distortion map that can be used in Nuke, the 3ds Max physical camera, or the V-Ray physical camera.

**EXR settings, PNG settings, JPEG settings, TIFF settings** – Controls various parameters used when writing the corresponding image types.



## Correcting/Distorting Using a Prime Lens Profile

With a profile of a prime lens, all images will be processed with the same set of distortion parameters, so no further complications can arise.

A zoom lens profile, but with distortion parameters from a single calibration photo.

If you have several entries in the table (e.g., the profile of a zoom lens), click on the entry you want to use for correction/distortion. Then, at the **Options** tab of the Correct/Distort utility, another item will appear: **Use selected profile** settings and **Use entire profile**. If you select the former, then your images will be processed using the specified parameters only. As this situation is otherwise identical to the "Prime lens" scenario, no complications can arise either.

## A Full Zoom Lens Profile

This is the most complex situation, where you have a full zoom lens profile, having different distortion parameters at various focal lengths, and you want to process an array of images, which can also have various focal lengths. So, before starting the actual image processing, the utility will first try to read the EXIF metadata from all input images. If some of the images don't have EXIF, or the focal length information isn't written in there, the utility will give you the following choices:

Don't process (skip): this option will skip any files that don't have focal length info.

Use specific parameters: use only a specific entry of the zoom lens profile (this is the same as the previous scenario) and essentially assume that all input images are of that specific focal length

Assume the focal length is: this is similar to the previous option but allows you to specify any focal length; it is not confined to the focal lengths present in the profile

Specify focal lengths from the file: supply a text file that lists the assumed focal length of each input file. That text file needs to be in the following format:

```
"Image_0001.exr" 35.6
```

```
"Image_0002.exr" 36.2
```

```
"Image_0003.exr" 38.0
```

...i.e.

```
"«file name»" «focal length»
```

with one file per line.

## Correction/Distortion Utility Limitations

The correction utility cannot preserve directory hierarchies; the output files are written "flat" in the output directory.

Only the color and alpha channels are supported. Image files containing a number of channels embedded in them (e.g., holding separate V-Ray Render Elements) will not be supported fully, and channels other than RGB and Alpha will be discarded.

Reading of .PSD and .VRIMG (V-Ray Image File) is supported, but writing is currently not.