Calibration Chart Shooting Guide For the Adobe Lens Profile Creator

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Adobe Systems Inc

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Introduction:

This set of guidelines is designed to provide users of the *Adobe Lens Profile Creator* application with a procedure for shooting a set of calibration chart images with the camera and lens combination of their choice, which is then used by the application to create a profile for customized lens corrections. Please refer to the companion document titled ***"Adobe Lens Profile Creator User Guide"*** on the usage of the application itself.

By following the intended procedure, one may capture a set of chart images that are both compatible for use with the *Adobe Lens Profile Creator* application, and optimal for representing the optical characteristics of the user's camera and lens.

The procedure involves three basic steps:

1. Printing the calibration chart.
2. Setting up the shooting environment for the chart.
3. Capturing a set of chart images for the user's chosen camera and lens.

These guidelines are written for the amateur photographer who is familiar with the basics of shooting with digital SLR cameras. The user should be aware of how to operate their camera in manual shooting mode and how to operate their camera's menu to make adjustments to all available camera settings (ISO, white balance, file format, etc.). One may find it useful to keep their camera's operation manual nearby for reference while running through the shooting procedure.

The *Adobe Lens Profile Creator* application is able to create a lens correction profile for any type of camera, including point-and-shoot cameras and camera phones. While the basic procedure guidelines are written with an SLR camera in mind, notes and appendices are provided for addressing concerns with special types of cameras, lenses, and other advanced shooting method considerations for photographers who wish to further optimize their shooting.

Terminology:

Adobe Lens Profile Creator: The Adobe application used to generate Lens Correction Profiles (LCP files).

Lens Correction Profile (LCP): A file that contains information for Adobe applications on how to apply lens corrections to a specific camera body and lens combination.

Adobe Camera Calibration Chart: A checkerboard chart that is photographed by the user to create a set of images to be analyzed in the *Adobe Lens Profile Creator* application.

Shooting Iteration: A single "set" of images of the printed calibration chart, shot with the user's desired camera/lens combination. An iteration (set) of images should have constant camera settings throughout and be of a single camera body and lens model. The lens should be set to a single aperture, focal length, and relative focus distance (focus should remain about the same from shot to shot) for a single iteration. A typical iteration consists of nine images in the set. Different iterations may be shot and profiled for the same camera/lens combination while using a different aperture, focal length, or focus distance for each respective shooting iteration.

SLR Camera: Single Lens Reflex camera; any camera body that supports interchangeable lenses and the ability to see through the lens itself when looking through the camera's viewfinder.

In-Camera Processing: Adjustments that are made to an image before it is written to the memory card of the camera as an output file. Examples include Sharpening, Contrast, and Color enhancements that can be found in the menus of many digital cameras.

Image Frame: The frame of the entire image, as seen through the live-view display or the viewfinder. *Note: The frame is often slightly cropped in either of these viewing modes, depending on the camera model used. Use the image preview of the camera to confirm the complete image frame.*

Focal Length: [non-technical definition] The "zoom" value of a zoom lens, or a fixed value for a lens, which indicates how close or far-away the subject or scene will appear when viewed through the viewfinder/display of a digital camera.

Focus Distance: The actual distance of the camera from the subject being photographed. In technical terms, it is the distance of the subject to the sensor/film plane.

Zoom Lens: A lens with a range of focal lengths, typically adjusted by rotating a ring on the lens.

Fixed Lens: A lens with a fixed (single) focal length.

Rectilinear Lens: A lens that generates a “normal” looking image, matching closely to the perspective of the human eye; a non-fisheye lens.

Fisheye Lens: A lens that generates a distorted image, bending light differently from a rectilinear lens, to encompass a very short, wide-angle focal length. The corners of an image will appear distorted and “squeezed-in” on a fisheye.

Circular Fisheye Lens: A special type of fisheye lens that creates a circular image, which covers only part of the whole image frame.

Calibration Setup Description:

One key design goal of the *Adobe Lens Profile Creator* is to allow professional photographers to create distortion profiles for their own lens without special photographic studio setup.

In a traditional studio calibration setup, several different calibration charts are required for each type of lens aberrations. For example, for the geometric distortions, a checkerboard or grid chart (straight lines or points) is typically used. The camera is mounted on a work bench to make sure that its sensor plane is properly aligned with the calibration chart. In the case of vignette aberration, a white board illuminated with a uniform light source is required. The characterization program would then analyze the data and estimate the lens aberration model parameters. The use of this type of strictly controlled studio setup limits its adoption by most photographers. It becomes even more challenging if one tries to characterize a fisheye or a wide angle lens where it is almost impractical to cover the whole field of view using a single calibration chart.

Adobe Lens Profile Creator employs the state-of-the-art multi-view image geometry algorithm to estimate the geometric distortion, lateral chromatic aberration and vignette model parameters in a simple setup. By analyzing multiple images of a single checkerboard chart from several different vantage points, *Adobe Lens Profile Creator* is able to recover the full lens aberration model parameters automatically. This new approach significantly simplifies the lens characterization workflow and makes it more accessible to majority of professional photographers who want to produce a complete lens profile for their lens.

Procedures:

Printing the Calibration Chart

1. Select a chart from the collection of checkerboard calibration chart PDF files that are included with the *Adobe Lens Profile Creator* application. Choosing a proper chart will depend on many factors. The rule of thumb is to select the largest chart that you could readily print, and pick one with the smallest squares that the *Adobe Lens Profile Creator* can still reliably detect the checkers for the planned shooting distances.
   a. Calibration charts vary based on the size of the square and the number of squares in the chart. A chart with more squares will provide more data points for the application, while a chart with larger squares will be easier for the application to detect.
   b. It's recommended that when shooting the printed chart with a camera, the chart should take up 1/2 to 1/4 of the image frame of the camera. Consider how close or far away you will need to move your camera to the chart when thinking of where to shoot. Make sure you have enough room for moving the camera away from the chart, and consider the chart's size in regards to this.
   c. Consider the dimensions of the individual checkers when selecting a chart to print and shoot with. For the final image set produced by shooting the chart with a camera, the recommended screen pixel dimension (height or width) for the smallest checker is 20 pixels. *Note: checkers may become distorted by the camera angle in regards to the chart, or by distortion from the lens itself (as in fisheye lens distortion). Hence, the smallest checker may have a height dimension that is different from its width dimension. The larger of these dimensions should be at least 20 pixels.*
   d. If desired, select multiple charts for printing and use a different-sized chart as appropriate for different cameras, lenses, and focal lengths.
   e. Always use a single chart for a given shooting iteration (i.e. for a given camera body, lens, and focal length, shoot only one chart for the set of images. If the body and lens stay the same but you shoot another set under a different focal length, as with a zoom lens, a different chart may be used to accommodate the focal length).
2. If none of the checkerboard PDF files fits your need, you can create your own custom checkerboard, possibly by modifying one of the existing PDF files. Note that you can fully edit these PDF files in products such as the Adobe Illustrator.
3. Print the selected chart or charts on a white, non-glossy paper medium. *Note: Adobe's in-house calibration charts were printed by FedEx/Kinko's on a white, matte sheet and then mounted on a foam or PVC board (for added support with larger charts). The board was then framed inside of a picture frame (making sure the picture frame glass was placed behind the chart to*

avoid unnecessary reflections). Three sizes of charts were printed: 18" x 24", 24" x 36", and 36" x 48". The first two were commonly used for rectilinear lenses. The latter was mostly used for wide-angle and fisheye lenses.

4. Check to make sure the print is completely in register (make sure no color fringing appears around the checker squares) and check to make sure no ink bleeding occurs (check squares should appear sharp and crisp. If they appear soft, check your print settings and reprint the chart accordingly).

Shooting Setup

1. Place or mount the chart on a steady surface, such as a wall or easel.
2. Choose two lights, ideally of the same model, illuminant type (tungsten, fluorescent, etc.), color temperature, lighting strength, and age.
   Note: While a two-light setup is recommended, you may try using additional lights or you may find it more convenient to use ambient lighting or natural daylight. The goal is to achieve constant and approximate lighting uniformity across the chart. The more uniform the lighting that is across the chart, the less variation there is in the vignette model parameter estimation in the generated lens correction profile.
3. Set each light facing towards the chart at opposing 45-degree angles (see Figure 1). The lights should measure an equal distance from the center of the chart to each light source.

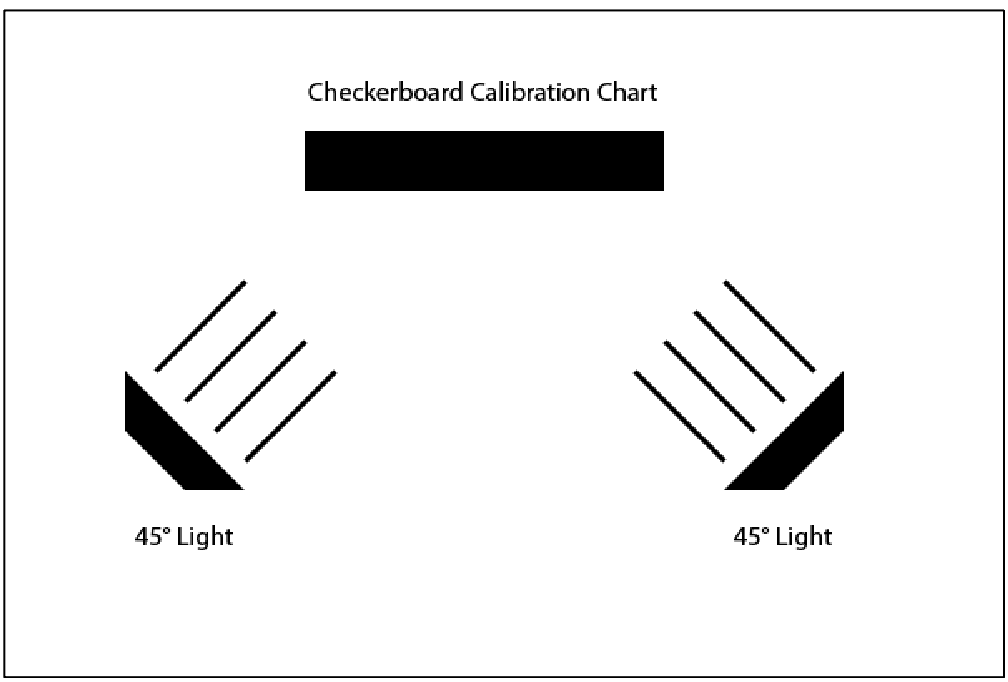

Figure 1: Top-view Lighting Setup for the Calibration Chart

4. Check the visual uniformity of the chart. Keep the lighting setup constant and of approximate uniformity.
5. Make sure the calibration chart is clean and free of dust or specks, particularly those that lie around the edges of the squares, in between black-to-white transitions.
6. Try to avoid clutter in the background of the chart. A uniform background that is darker than the white patches of the chart is recommended. While not entirely necessary, a more uniform background will help the application detect the calibration chart in the captured images. It is ok for light sources to partially be in the background when shooting with extremely wide-angle rectilinear or fisheye lenses.

Capturing the Calibration Chart Image Set

Planning the Required Image Sets

The amount and the type of lens distortions are direct functions of the camera settings, such as the focal length, the focus distance and the aperture. Therefore, to fully characterize the optical properties of a lens, one needs to create a lens profile for each of the many exemplary camera settings. To create one lens profile for one camera settings, one needs to shoot a multiple of calibration chart images (called one image set). Adobe® Lens Profile Creator is able to batch process all the image sets and append each of the generated lens profile (called the sub-profile) into a single lens profile LCP file.

If your lens is an APS-C type of lens, choose an APS-C type of camera to match it when shooting the calibration chart; else choose a full frame camera body.

We recommend the following guidelines when shooting the image sets to create a basic lens profile:

1. For wide angle/fisheye zoom lenses, shoot at the nominal focal length positions as marked on the ring of the lens with a fixed f/11 aperture.
2. For telephoto zoom lenses, shoot at the minimum, maximum and medium focal lengths positions with a fixed f/11 aperture.
3. For prime lenses, shoot at (1 × minimum focus distance) and (5 × minimum focus distance) focus distance positions with a fixed f/11 aperture.

As a step-up for advanced users, we recommend the following guidelines when shooting the image sets to create a more complete lens profile:

4. For wide angle/fisheye zoom lenses, shoot (6 focal length positions) × (3 focus distance positions) × (4 aperture positions) = 72 image sets.
5. For telephoto zoom lenses, shoot (3 focal length positions) × (3 focus distance positions) × (4 aperture positions) = 36 image sets.
6. For prime lenses, shoot (1 focal length position) × (3 focus distance positions) × (4 aperture positions) = 12 image sets.

The focal length positions will include minimum focal length, maximum focal length, and focal lengths in between which are marked/indicated in some way on the ring of the lens. The focus distance positions will include (1 × minimum focus distance), (2 × minimum focus distance) and (5 × minimum focus distance). You may vary based on your shooting setup space limitations. And the aperture positions will include the maximum aperture (the smallest f-number) up to f/8 for fast lenses (i.e. lenses that support f/2 or faster) and up to f/11 for slower lenses. The aperture positions will follow the 1-stop increments.

Prepping the Camera Body

1. Check the firmware version of your camera body and update if appropriate, or shoot with whatever firmware version you plan to use for your shooting workflow.
2. Zero out in-camera processing settings (sharpening, color, contrast, etc.). Default processing settings are typically not set to zero for all parameters; it's best to manually confirm within the camera menu that all settings are at zero and neutral.
3. Set the image file-type to match your shooting workflow. Uncompressed RAW is recommended for photographers who typically work with RAW-files. Highest-quality JPEG is recommended for non-RAW workflow users (see Appendix B, and C for non-RAW file shooting considerations).
4. Set the shooting mode of the camera to "manual" for keeping the exposure constant throughout the shooting iteration.
5. Set your camera to a constant ISO (too much noise could have an effect on the results of the calibration; consider using an ISO around 400 or less, based on your exposure needs). Do not use an automatic ISO setting (see Appendix B for special case cameras where ISO cannot be controlled by the user).
6. Set the white-balance to Auto, or the desired preset appropriate for your shooting environment. White balance, unless extremely inaccurate, should have a minimum effect on LCP quality. You may also customize white balance if you wish to.
7. Set the color profile to the profile you prefer to shoot with and keep them constant in the whole shooting session. Adobe RGB and sRGB are typically available on most camera bodies.
8. Keep the camera's orientation (i.e. "landscape" vs. "portrait") constant for a single shooting iteration.
9. Turn off any date/time imprint features.
10. Turn off any in-camera processing that may be switched off ("creative effects", image correction, vignette/exposure compensation, noise reduction, etc.). See Appendix A: Shooting Theory for further details.
11. Enable histogram and highlight-clipping indication, if available, in the image preview mode of the camera. Use this as an aid to determine if the white of the chart is being clipped due to the exposure level.
12. Set the camera to single-shot image capture.

13. Set the camera to the desired focus mode. A single-point focus may be easiest for keeping the chart in focus from shot to shot.
14. Insert a compatible memory card into the camera.

Prepping the Lens

1. Properly attach the lens to the camera body.
2. Set the lens to the preferred focus mode (auto vs. manual focus). If using auto-focus, set the camera to single-shot focus (as opposed to a continuous focus mode offered on some cameras for focusing moving subjects).
3. Adjust the lens to the desired focal length. Be careful not to accidentally adjust focal length by bumping or moving the focal length ring during shooting. This can alter the focal length metadata produced by the camera.
4. If shooting a zoom lens, adjust the lens to a single focal length for the shooting iteration. When using the application, you may run the application for multiple shooting iterations for a single camera/lens combination, and append the data from additional shooting iterations to the same LCP. Shooting a separate iteration for the minimum, maximum, and middle focal lengths of a zoom lens is recommended.
5. If using a lens with an aperture ring on a camera body that makes aperture adjustments through the camera body, adjust the aperture ring to the proper default position to enable in-camera aperture adjustment. For camera body-controlled aperture adjustments, the aperture ring of the lens is often set to the maximum aperture.

Prepping the Tripod

Note: Using a tripod is recommended for shooting environments that require slower shutter speeds. Combined with live-view, a tripod-mounted camera is also much easier to adjust for making tightly-frame chart shots (see framing procedure below).

1. Adjust the tripod to the appropriate height.
2. Properly mount the camera to the tripod.

Capturing the Chart Images

1. Distance the camera so that the chart fits within the image frame. The entire checkerboard pattern must fit within the image frame and be completely unclipped. It is recommended that the chart take up approximately 1/2 to 1/4 of the area of the entire image frame of the camera when shooting. *Note: This recommendation is based on Adobe's in-house calibration shooting. For your own shooting setup, keep in mind that the goal is to capture a set of images where the checkerboard coverage fills the entire image frame when adding up different areas of coverage from shot to shot.*
2. Be careful not to place the camera so close to the chart that it blocks part of the light falling on the chart itself.

3. Keep this focus distance consistent for a given shooting iteration.
4. Adjust the aperture and shutter speed so to achieve the best exposure possible. Take a test shot and preview the histogram of the image to make certain that an optimum exposure is achieved while not clipping (over-exposing) the highlights of any of the white squares of the chart.
   Note: When choosing an aperture, an aperture of f/8 or f/11 is recommended for most SLR camera/lens combinations. You may wish to use a lower f-number if you typically shoot at a wider aperture and would like to have stronger vignette correction for your LCP file.
5. Once the proper exposure is found, keep the manual exposure settings (aperture and shutter speed) constant throughout the shooting iteration.
6. Choose the number of images to capture for a shooting iteration.
   a. A minimum of three chart images is required for creating an LCP.
   b. Choose a number of images so that, given the area of the chart in regards to the image frame, the chart will cover as many different areas of the image frame as possible.
   c. Nine images are recommended for a single iteration (frame the chart in the center, top, bottom, two sides, and four corners of the image frame for each respective shot, for a total of nine images).

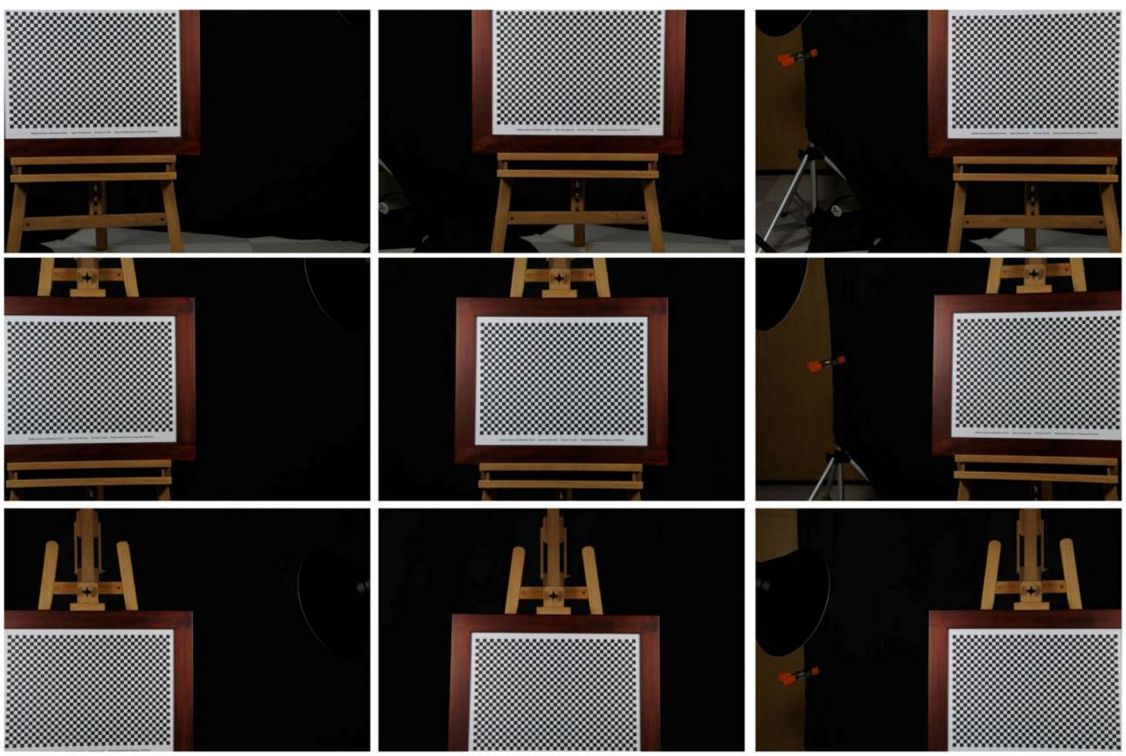

Figure 2: Image Set for the 70mm Focal Length of an 18-200mm Zoom Lens

7. Frame, focus, and capture the chart shots.

a. With the exception of the center-framed chart shot, frame each shot so that the given boundary of the chart runs as close to the edge of the image frame as possible, but make sure that none of the checkers become clipped outside of the frame. Here is one typical framing sequence:
    i. First shoot centered straight on.
    ii. Tilt the camera up, thereby effectively framing the chart at the bottom-center of the image.
    iii. Tilt camera down, thereby effectively framing the chart at the top-center of the image.
    iv. Move camera a bit to the left (so that when turning to the right to face the chart, it is about 10 to 30 degrees). Take a series of shots similar to the first three, above, except that the chart is framed at the center-left, top-left, and bottom-left areas of the image.
    v. Move camera to the right, and do the same for the center-right, top-right, and bottom-right areas of the image.

b. When framing the chart at the edges of the image frame, leave a small amount of visible white between the checkers and the edge of the frame.

c. Lens aberrations are more prominent at the image corners and edges. Try to frame the chart in the view such that checkerboard grids can sample more points along the image corners and edges. It would also help to get better results if one captures more images with the checkerboard framed around the image corners and edges.

d. Using live-view and a tripod is recommended for achieving the tightest framing possible.

e. When framing the chart in different areas of the image frame, use a combination of physically moving and tilting the camera to achieve an optimal balance for LCP generation.
    i. Only moving the camera to frame, so that image plane stays perfectly parallel to the chart, can have an adverse affect on LCP calibration data.
    ii. Only tilting the chart may cause depth-of-field issues, where part of the chart may go too far out of focus due to the large angle of the chart in regards to the image plane. This can also have an adverse affect on LCP calibration data.

f. Re-focus the chart for every new image, if necessary.

g. Once satisfied with the framing and focus, capture each respective image.

h. Use the image preview and preview-zoom options on the camera to check on the framing of the chart and confirm that no checker squares are clipped.

8. You now have a set of chart images ready to be loaded into the application for generating a lens correction profile!

Conclusion

After printing out a calibration chart, setting up the shooting environment, and capturing a set of chart images with a given camera/lens combination, you are now ready to make a customized lens correction profile using the *Adobe Lens Profile Creator* application!

If you would like to learn more, please see Appendix A for advanced information on shooting theory, and Appendix B for special case scenarios with different cameras and lenses.

Appendix A: Shooting Theory

The *Adobe Lens Profile Creator* application works by modeling and predicting the optical behavior of a photographic system (optics + image sensor + image processing). It then uses that model to apply appropriate corrections to geometric distortion, lateral chromatic aberration, and vignetting. The data for these customized corrections is stored in the Lens Correction Profile (LCP) generated by the application.

The application generates a model for optical behavior by drawing on data points from the images of a checkerboard chart shot with the photographic system. It only draws information from the checkerboard part of the images. Since the application is attempting to characterize optical behavior by drawing on a set of finalized images, care must be taken to provide the most representative images possible for a given system.

Optics

The optical characteristics of the photographic system have the largest effect on the quality of the LCP. The optical characteristics that can be controlled by the user are:

- Aperture
- Focal Length
- Focus Distance

These three factors will physically change the way light is passing into the system.

Aperture

Aperture mainly affects the results of vignette correction. If one profiles with a set of images shot at the maximum aperture (the lowest f-number, a.k.a. wide-open), more light falloff will be introduced into the system, and therefore images will have a stronger vignette than if the aperture were adjusted to a higher f-number. For a given camera/lens combination, a profile generated with one aperture may over or under-correct the vignette of images shot with the same camera/lens at a different aperture. When considering the aperture to use with a shooting iteration, it's best to consider your own workflow. Ideally one would generate a different profile iteration for each aperture they would like to correct for.

Focal Length

Focal length has a large effect on geometric distortion, chromatic aberration, and vignette. It fundamentally changes the way light passes into the photographic system by changing the distance relationship of the elements within the lens. Profiling for each focal length you plan to shoot with will provide optimum correction results. For zoom lenses, it is recommended to at least create separate profile iterations for the minimum, maximum, and middle focal lengths.

Focus Distance

Focus distance also changes the distance relationship of elements inside the lens, since changing the focus (to accommodate different subject distances) will move the lens elements. This change has a smaller effect on geometric distortion and chromatic aberration when compared to changing the focal length. Changing focus can still have a large effect on vignette, however.   Focus-related distortions tend to be greater at closer focus distances. For deciding the focus distance to use, it may be ideal to shoot separate iterations for infinity and closer focus distances respectively.

Keep in mind the size of the chart when framing for different focus distances. It may be ideal to shoot more than nine images to cover the entire image frame area when shooting at further distances. A chart with larger chart squares will improve the chances of proper grid detection within the application when using images shot from longer distances. The minimum recommended dimension of a chart square (height or length) inside of an image is 20 pixels.

Image Sensor

The photographer has less to consider in regards to the image sensor when controlling the photographic system. The ISO is the only control to consider, since it controls the gain being applied to the original image signal, giving the perceived quality of changing the sensitivity of the sensor. ISO should not have a strong effect on the quality of the LCP, but shooting at extremely high ISO levels could introduce enough noise to confuse grid detection in the application, or confuse the modeling of the optical behavior itself. If you typically shoot at ISO's higher than 400 (for digital SLR cameras) it may be best to profile at the chosen ISO that you use. If you shoot at ISO's around 400 or less, using any ISO in this range to meet your exposure needs should work fine.

Image Processing

Image processing is the last step in producing a final image from your camera, and has the greatest potential to distort the original optical information that the *Adobe Lens Profile Creator* application seeks to characterize. File format, noise reduction, and in-camera lens corrections should be considered when deciding what settings to use for shooting a calibration chart.

File Format

Photographers that shoot with a RAW file format often have little or nothing to consider in regards to image processing. The goal of the RAW workflow is to give the photographer as much control as possible over original captured image data.

Non-RAW file formats, such as JPEG, can still be used to generate LCP files, but since more in-camera image processing is introduced into this workflow, there is more to consider in regards to camera settings. Image processing changes the original image data that passes through the lens and is captured by the sensor. Since the application functions by characterizing the behavior of this original data, it's best to leave it as untouched as possible when shooting chart images for profile generation.

Due to certain forms of image processing differences between RAW and non-RAW workflows, which cannot be controlled by the user, it is still recommended that you shoot in the file format that follows your own shooting workflow.

Noise Reduction

Most forms of in-camera noise reduction seek to preserve original image information as much as possible, while only removing image information that is not a part of the original subject being captured (i.e. noise from high ISO's, hot pixels, etc.).

In-camera noise reduction should have little effect on the quality of the LCP. Still, since any processing will have some small effect on original image data (and possibly introduce randomness between shots when implemented) it's recommended that you turn off whatever noise reduction settings you can for your camera body.

In-Camera Lens Correction

Some cameras, when shooting in a non-RAW file format, will automatically make certain lens corrections to the image, namely chromatic aberration corrections and vignette correction.

Chromatic aberration corrections are often applied without any option for the user to turn off the correction. Depending on the camera used, some of these corrections may be applied on a shot-to-shot basis, where some images will be corrected for chromatic aberration while others will not be corrected. Vignette correction is more often available to switch on or off. One can avoid these corrections by shooting with a RAW file format. If using a non-RAW file format, consider comparing the results of a RAW versus non-RAW scene by shooting in a RAW+JPEG format mode. You can compare the same scene shot with two different formats to see if corrections appear in the non-RAW file.

If using non-RAW images for calibration, the best results from the *Adobe Lens Profile Creator* application will come from images that have not already been corrected with in-camera lens corrections. Consider ways to avoid these corrections, such as converting RAW images to your desired non-RAW format, before running non-RAW images through the application.

Conclusion

The *Adobe Lens Profile Creator* application is a *characterization* application. It is designed to model (characterize) the optical behavior of your chosen photographic system. Since it draws this model from a set of final output images, the model will ultimately represent the optical data as modified by the full photographic system.

Reducing as much randomness as possible between the optical input and the processed image output will provide you with the best possible profile. It is impossible, however, to eliminate all randomness in any photographic system. Less precise systems, like point-and shoot cameras and camera phones, may still be characterized (see Appendix B).

Experiment with the possibilities and variations that will allow you to make the best corrections possible for the quality of your images!

Appendix B: Special Camera/Lens Scenarios

Certain cameras and lenses require shooting procedures that differ from the general procedure outlined in the main body of these instructions.

Fisheye Lens

A fisheye lens is a lens that bends light differently from a rectilinear lens to give it a wider field of view. The distorted appearance of a fisheye lens is the result of barrel distortion.

A fisheye lens is shot in the exact same manner as a rectilinear lens. One should keep in mind when framing the chart in the corners of the image frame that the distortion of the fisheye makes it impossible to push the checker pattern into the farthest edge of the corner while keeping the entire chart inside of the image frame. Below is an example of a properly shot set of images from a fisheye lens.

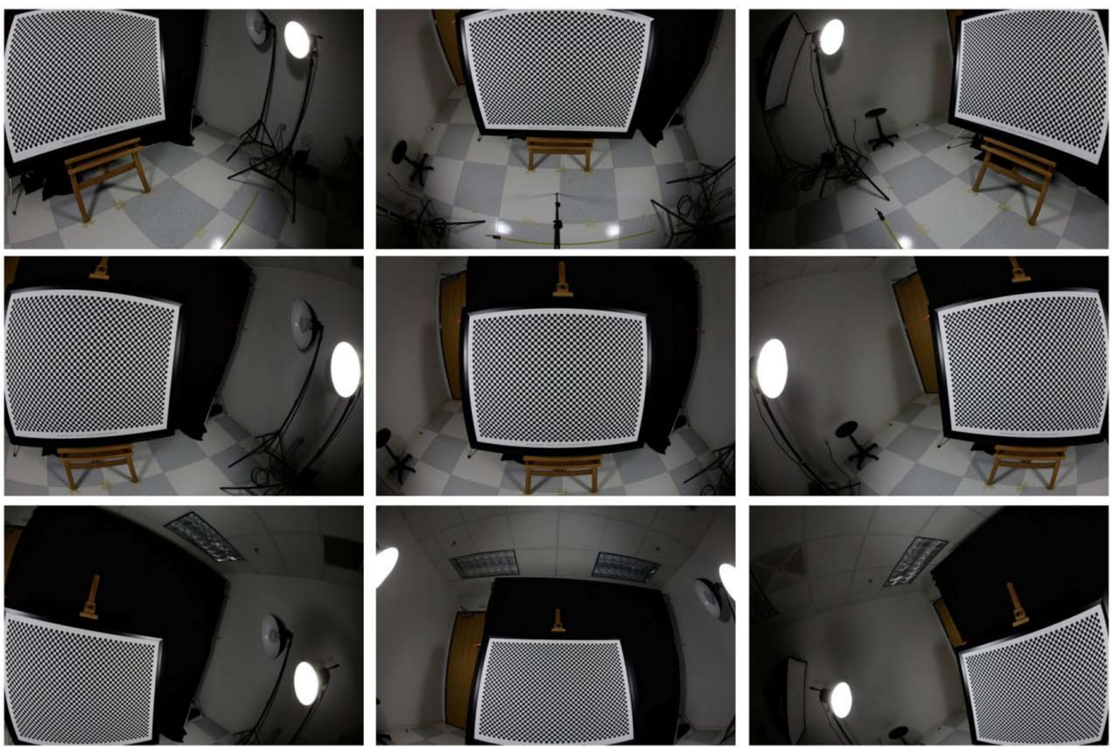

Figure 3: Image Set for a 15mm Fisheye Lens

Keep in mind the recommended 20-pixel minimum pixel dimension for the smallest-sized checker square within a captured chart image. It is best to select a chart with larger physical checkers when shooting with a fisheye lens, since the high level of distortion, particularly at the periphery, will shrink and squeeze the dimensions of checkers near the edges of the image frame.

Circular Fisheye Lens

A circular fisheye lens is a lens that distorts the image (bends incoming light) into a nearly perfect circle. The circular image only covers the center part of a camera's image frame.

The circular fisheye lens is shot in the same manner as the main shooting procedure, with the exception of framing the chart inside of the image.

It is normally best to frame with a combination of moving the camera (up-down, sideways) combined with tilting the camera (angling the camera in regards to the chart plane). For a circular fisheye lens, however, the best framing may be achieved by simply positioning the camera to face the center of the chart, as in a center-framed shot, and then angling/tilting the camera up, down, and side-to-side to frame the remaining shots (with no need to physically move the camera from its center position).

Keep the edge checkers from hugging the circular frame too tightly. The extreme distortion of the lens squeezes the edge checkers of the chart so much that they may become too small for the application to detect if they are too close to the edge of the circular frame. In regards to detecting the chart in the application, one should also consider the physical size of the checkers in the chart, and the camera's distance to the chart, when framing for the circular fisheye.

Since there is no way to frame the chart in the "corners" of the circular image, it is best to rotate the camera slightly to shoot the chart in a diagonal-style position. The diagonal of the chart in the image frame, however, should always be less than 45° from your chosen orientation (landscape or portrait).

Point-and-Shoot Camera

A point-and-shoot camera is a compact camera with a built-in lens. As the name implies, it is designed to be a fully automatic shooting experience for the user. Follow these guidelines if the settings mentioned here are available for the user to control on the camera.

The point-and-shoot camera is shot in the same manner as the main shooting procedure, with the exception of image processing and exposure control.

Image Processing

Check to see if your camera can shoot in a RAW file format. If available, selecting the RAW file format often automatically turns off any available, user-controlled image processing settings that could affect the quality of the LCP.

Whether shooting in a non-RAW or RAW file format, however, it is best to become familiar with the available user-controlled image processing settings before shooting calibration chart images with the camera.

See Appendix A: Shooting Theory (Image Processing) for more information concerning image processing while shooting calibration chart images.

Exposure Control

If available, set your camera's exposure to manual shooting mode. If manual is not available, but aperture-priority is, set the camera to aperture priority to achieve a constant aperture throughout a shooting iteration.

Point-and-shoot camera ISO's, and how they affect the level of noise reduction, can vary greatly in behavior when compared to similar digital SLR ISO's. It is recommended that you shoot with a constant ISO, if available, and set the ISO to whatever you typically shoot with.

See Appendix A: Shooting Theory (Image Sensor) for more detail concerning ISO while shooting a calibration chart.

Camera Phone

The term "camera phone" refers to a camera that is built into (and controlled through) a cell phone.

Most camera phones are fully automatic, with even less control than most point-and-shoot cameras. Camera phones also contain the highest level of in-camera image processing when compared to point-and-shoot cameras or digital SLR cameras, meaning that the optical data is heavily modified before it reaches the *Adobe Lens Profile Creator* application. Camera phones are also more likely to contain lens correction adjustments already inside of their image processing pipelines.

Follow the same guidelines mentioned above for point-and-shoot cameras if any of these controls happen to be available through the menu of the camera phone.

Appendix C: Frequently Asked Questions

Q: *Why shoot nine images, filling up the frame at different angles per shot, when I can shoot one image with the chart filling up the entire frame at once?*

A: Adobe® Lens Profile Creator employs the state-of-the-art multi-view image geometry algorithm to estimate all the camera model parameters, such as the principal point (image center), focal length, and distortion parameters. It requires a minimum of three images of the checkerboard. We recommend shooting nine images instead of the minimum three because it would permit the use of a smaller checkerboard to sample data points closer to the edges of the image frame where the lens aberration are typically more pronounced, and provide fallback images if for some reason the Adobe® Lens Profile Creator fails to process all the images successfully. In general, additional images will improve the robustness and the accuracy of the camera model parameter estimates.
The multi-view image calibration setup utilized by the Adobe® Lens Profile Creator also eliminates the need of an expensive and controlled studio setup, making the technology more accessible to ordinary photographers. In this new setup, the camera and the calibration chart no longer need to be meticulously aligned, or the chart to be uniformly illuminated. There is no need to have a single chart to fill the entire field-of-view of the camera, which is difficult to do for wide-angle or fisheye lenses.

Q: *Should more than nine images be shot when using a wide angle or fisheye lens that requires a greater number of images to overlap the entire image frame?*

A: Choose a number of images to shoot so that, when grouped together, the chart images cover every part of the image frame. For wide-angle or fisheye lenses or for cases where you're shooting a chart further away that takes up less of the image frame per shot, it's recommended to shoot more than nine images.

Q: *Does the chart plane have to be completely parallel to the plane of the image sensor in the camera for all the chart images?*

A: No. Adobe® Lens Profile Creator actually expects camera orientation and location with respect to the chart changes from one image view to the next. It is recommended that one of the nine images is a frontal and approximately in-the-center shot of the chart, but in no way it has to be precisely controlled.

Q: *Can I just keep the camera in one position and move the chart instead?*

A: It's recommended that users move the camera instead of the chart so that the lighting remains constant on the chart, which will provide better vignette correction results when processed. When shooting the chart at very close distances, make sure that the camera/tripod setup does not block any lighting during shooting.

Q: *Do I have to have a perfectly even lighting setup?*

A: No. As long as the lighting setup is consistent between all shots, the Adobe® Lens Profile Creator can detect the pattern of chart lighting from the multiple shots and calculate the relative light falloff that occurs. An optimum exposure (one that does not clip any of the white highlights of the chart while still capturing the maximum range of possible tonal data) will also aid in generating an optimum vignette correction model. Having said all that, a more evenly illuminated lighting would only help to get a more consistent vignette estimation result.

Q: *What type of paper should I print the chart on?*

A: A matte, or at least semi-matte, heavyweight paper is recommended. Glossy is not recommended since specular highlights (light reflection off the chart) can interfere with grid detection. A heavyweight paper is recommended so that, when mounted, the printed chart will remain completely flat. The flatness of the chart is essential for accurate lens profiling, though the images themselves may have the chart shot at different angles.

Q: *Can I display the chart image on a flat-screen LCD TV monitor instead of printing it?*

A: This is a feasible method for shooting chart images for lens profiling, though the quality and potential caveats have not been tested in-house by Adobe. Some user has taken this route and reported good results with the geometric and vignette corrections. Care must be taken to make sure the chart squares display as perfectly square pixels, and that the display is not overexposed. Also, one needs to specify the correct square print dimension in the user interface of Adobe® Lens Profile Creator.

Q: *Where should I place my LCP file so that I can use it in ACR and the Photoshop Lens Correction plug in?*

A: You can place the lens profiles under a user specific or a shared all user location.
User profiles location:

- Mac OSX: /Users/(User Name)/Library/Application Support/Adobe/CameraRaw/LensProfiles/1.0
- Windows 7 or Vista: C:\User\(User Name)\AppData\Roaming\Adobe\CameraRaw\LensProfiles\1.0
- Windows XP: C:\Documents and Settings\(User Name)\Application Data\Adobe\CameraRaw\LensProfiles\1.0

Shared profiles location:

- Mac OSX: /Library/Application Support/Adobe/CameraRaw/LensProfiles/1.0
- Windows 7 or Vista: C:\ProgramData\Adobe\CameraRaw\LensProfiles\1.0

- Windows XP: C:\Documents and Settings\All Users\Application Data\Adobe\CameraRaw\LensProfiles\1.0

Q: *Do I have to shoot the chart against a blank background?*

A: No. The Adobe® Lens Profile Creator can still detect the chart when it's set in front of a busy background. Take care to avoid including any spectral highlights in the background that could confuse the Adobe® Lens Profile Creator's grid detection (shiny objects or anything particularly bright).

Q: *How can I create and use LCP files with older lenses that have no EXIF metadata, or with lenses that have simpler, less distinguishable metadata so that they can't be told apart from each other?*

A: In the Adobe® Lens Profile Creator, please specify a fully qualified camera and lens names (including make and model) so that a user can uniquely identifying the lens profile in the user interface.

Q: *What are the different colored grid points that show up when I run the Adobe® Lens Profile Creator on my images?*

A: Yellow grid points are the initial corners detected by the Adobe® Lens Profile Creator. The yellow zigzag dashed line shows the correct ordering of the detected corners. Red grid points indicate grid detection failures that it will remove the image from contributing to the computation of the lens profile. Looking at the red dots and finding where these red dots are missing in the checkerboard can give clues to why the failure occurred. Cyan grid points are drawn as overlays on top of the yellow grid points. The yellow point shows the original detected corner, and the cyan point shows the new location of the corner as predicted by the lens profile. The yellow points and the cyan points should be as close to each other as possible. The closer the points, the better fit of the estimated lens model to the actual data.

Q: *My images show red grid points and there is a yellow warning sign next to the image file name listing item after running them through the Adobe® Lens Profile Creator. What does this mean? How can I prevent this?*

A: Red grid points on the image indicate a grid detection failure. The Adobe® Lens Profile Creator will not include images that are determined to have a grid detection failure. The most common causes are that the user specified the incorrect checkerboard info in the Adobe® Lens Profile Creator calibration settings, or the presence of specular highlights on the chart, or the chart not being completely in frame, or chart squares being too small in the captured image. In the first case, check to make sure the checkerboard info in the Adobe® Lens Profile Creator is correctly specified. If the checkerboard info is incorrect, try rerunning the same images after correcting the checkerboard info.

Q: *What is the best methodology for determining the "smallest square" to measure in a group of images?*

A: Measuring the smallest checker square in a group of images is used by the Adobe® Lens Profile Creator to help correctly detect the grid. The measurement does not have to be completely accurate; an approximated value is good enough. Scan through your images to find a checker that appears to be the smallest due to the geometric distortion of the lens or the angle it was shot at, and then use the ruler tool to measure across its smallest dimension (length or width) and input the measured data.

Q: *When measuring the square pixel dimension, should the spread of the square due to chromatic aberration or geometric distortion be included in the measurement?*

A: This measurement is an approximation used by the Adobe® Lens Profile Creator to help correctly detect the grid, and does not have to be 100% accurate. Including or not including the spread from chromatic aberration should be fine, although measuring the smallest square should take into account squares that are smallest due to geometric distortion. These squares should be considered for measuring the smallest square. It's also recommended that no square in the image have a dimension shorter than 20 pixels.

Q: *Can the Adobe® Lens Profile Creator profile APS-C "digital" lenses used on a full-frame body?*

A: Yes. The full frame sensor is able to sample image data that is beyond the scope of the APS-C lenses, which is not a bad thing.

Q: *Can the Adobe® Lens Profile Creator profile full-frame lenses used on an APS-C sensor size camera body, and then apply the generated lens profile for lens correction to an image captured with a full-frame camera using the same lens?*

A: Not recommended, because the camera with the APS-C sized sensor (non full-frame sensor) can only sample a limited range of lens aberration data of the full-frame lenses. Applying the generated lens profile for lens correction to an image captured with a full-frame camera using the same lens amounts to extrapolation of lens aberration data to where it does not have any observation data, which may or may not work well.

Q: *The chromatic aberration correction results from my LCP file are not as good as I had hoped. Is there anything I can do to improve this?*

A: Focus distance also affects the chromatic aberration to a smaller degree. For best result, create a sub profile that matches the focus distance as well. In Adobe Photoshop CS5, the sub profiles of the current selected lens profile can be accessed in by right-clicking on the profile.

Some camera vendors enable (sometimes randomly) in-camera corrections that cannot be turned off. It is recommended to use the DNG images instead of Tiff or Jpeg images to create the profiles.

Q: *What if I only shoot images and profile for the minimum and maximum focal lengths of a zoom lens? Will the Adobe Photoshop CS5 still use the profile and make corrections for images shot in between these focal lengths?*

A: Yes. Adobe Photoshop CS5 will interpolate the lens profiles between the two focal lengths.

Q: *How should I meter and expose the calibration chart?*

A: Spot or center-weighted metering should work fine. The goal is to expose the chart to capture the maximum amount of tonal data possible without clipping the white areas of the chart. It's recommended that you keep objects brighter than the white of the chart out of the background so that you can view the white of the chart as your highlight area when looking at a histogram of your image.

Q: *When should lens correction be applied in my workflow?*

A: It is recommended that the lens correction be applied very early in your photographic workflow, before any additional scaling or cropping is applied to the image. The adoption of the non-destructive Adobe Camera Raw based workflow is highly recommended.

Q: *Can I still create a lens profile if the camera I use incorporates its own in-camera lens corrections that I can't turn off?*

A: If you wish to create lens profile for a camera that uses its own lens corrections, it is recommended that you shoot only raw images to prevent the in-camera lens corrections from being applied. Keep in mind that if you make and use a lens correction profile in this manner, the correction will only work for uncorrected images from the camera.

Q: *I want to profile for different focus distances, but my camera does not record this as EXIF metadata. Can I still profile for different focus distances?*

A: Yes. Adobe® Lens Profile Creator estimates the focus distance for each iteration regardless whether or not the focus distance is recorded in the EXIF metadata or not. If the focus distance is recorded in the EXIF metadata, Adobe Photoshop CS5 will try to automatically select the best sub profile with the closest focus distance match.