The Effect of Distortion Correction on Image Quality. 2. Sony FE 24mm F2.8 G Lens on a Sony A7RM3 Camera

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Summary
This paper investigates the correction of barrel distortion in images produced by the Sony FE 24mm F2.8 G lens (SEL24F28G) on a Sony A7RM3 camera (ILCE-7RM3). Distortion correction was done with the lens profile included with Photoshop. Image degradation due to correction was arguably undetectable at 100% magnification, except in the corners and at far edges. Perceived loss of quality at the image margins depends on subject matter: it is more apparent with fine details. These results should not be generalized to other lens – camera combinations, or to other post processing software. Links to full-resolution crops of uncorrected and corrected image pairs are provided in the text. Inspection of these crops reveals that distortion-correction affects all areas of the image, even those that are not obviously distorted in the uncorrected image. That is, distortion correction appears to entail whole-image resampling.

Key words: Barrel distortion, Sony FE 24mm F2.8 G lens, Sony A7RM3 camera, Distortion correction, Image resampling, Photoshop, Adobe Camera Raw, Downsampling.

1. Introduction
Some degree of optical distortion is present in images produced by most lenses. Typically, optical distortion is characterized as “pincushion”, in which straight lines near the edges of the image are bowed inward; or “barrel”, in which the lines near the edges bulge outward; although more complex types of distortion are also possible. With digital images, distortion can be corrected in-camera or in post-processing. Such “software” distortion correction appears to involve whole-image resampling. The relative ease of software distortion correction frees lens designers and manufacturers from the need to correct distortion in “hardware”; in other words, by including additional optical elements in the lenses themselves. The result is that lenses can be smaller, lighter, and less expensive. It is generally unclear, however, how software distortion correction affects other aspects of image quality. This paper examines the effect of distortion correction for a lens that exhibits pronounced barrel distortion. A previous paper examined correction of pincushion distortion.

2. Materials and Methods
2.1. Lens and Camera
The lens was a Sony FE 24mm F2.8 G lens, which was rented from LensRentals.com. The camera was a Sony A7RM3. The lens is compact and light weight, which is not surprising
given its modest maximum aperture. Lens dimensions (without hood) are 7.0 cm (2.75 in) diameter and 4.6 cm (1.82 in) length. The filter size is 49 mm, and the lens weighs 164g (5.8 oz). The listed retail price as of this writing is US$ 600.

Barrel distortion is typical of wide-angle lenses, and this lens is no exception: in fact, distortion is pronounced, as can be seen in comparisons of un-cropped images (Figs. 1 – 3). With this camera - lens combination, distortion correction happens automatically in-camera for JPEGs. (This includes the JPEGs embedded in raw files, and there appears to be no way to disable this behavior.) Furthermore, distortion correction also takes place in “real time”, so that the image in the viewfinder or on the rear monitor is also corrected, regardless of the camera image quality settings. Whether real-time correction is good or bad is likely a matter of personal preference: arguments can be made both ways. However, a casual user will likely have no idea how much distortion this lens produces. In order to see the distortion, it is necessary to shoot raw images, and then to view those images in Camera Raw (or other software) with distortion correction disabled.

2.2. Image Processing

Uncompressed raw (ARW) files were processed in Adobe Camera Raw and Photoshop (in both cases, using the latest versions available in late 2021 and early 2022). Each member of an uncorrected and corrected pair was processed identically, with the obvious exception that the built-in lens profile was used for distortion correction (Optics panel of ACR). The default distortion correction value of “100” was accepted, and vignette correction was set to “0”. No sharpening or noise reduction was applied in Camera Raw. Images of the resolution target were not sharpened at any stage. Images of outdoor scenes were sharpened in Photoshop using my customary procedure. Image processing and evaluation were done on a 2017 iMac with a 27-inch 5K display (approximately 218 ppi).

2.4. Image Viewing

Un-cropped, downsampled images are provided in-line with this text. These can be used to evaluate the degree of distortion and to give landmarks for crops. Critical evaluation of the effects of distortion correction requires uncompressed, full-resolution crops, which cannot be conveniently included with this document. Evaluation images can be downloaded using the provided links. They can viewed in Photoshop or any application that supports uncompressed, layered TIFF files and ProPhotoRGB color space. Each image contains two layers, which superimpose the uncorrected (Not DC) and distortion-corrected (DC) images. Some images have an interposed third layer which shows the effect of 50% distortion correction. The effects of distortion correction can be easily evaluated by toggling layer visibility. These are full resolution crops and can be viewed at any magnification supported by your viewing software.

3. Results

3.1. Image 1 – Resolution Target

Uncorrected and corrected images of a home-made test chart are shown in Fig. 1. The rectilinear nature of the chart makes the pronounced barrel distortion readily apparent. The center of the chart appears to bulge outward toward the camera. Distortion correction seems to “push
Fig. 1. Resolution test chart. Top: uncorrected. Bottom: distortion corrected. At maximum aperture — f/2.8, ISO100. Tripod-mounted.
down” on the center of the chart so that it flattens out. In the process, most of the wall behind the chart, visible in the uncorrected image, is removed. Given that the overall dimensions are the same in both images (7952 x 5304 pixels), it is clear that distortion correction involves addition of synthetic pixels — the pixels lost by removing the wall have been replaced by expanding some portions of the chart, particularly the corners. In addition, the center of the chart is “compressed” in the corrected image, so some pixels are “lost”. In other words, the image is resampled — the precise method being unclear. Strong vignetting occurs in the corners.

This image was made with the lens at maximum aperture (f/2.8). The dimensions of the test chart are 76 x 51cm (30 x 20 in). Thus, the image recorded by the sensor is reduced by a factor of about 20x. Although not visible in Fig. 1, the line pairs on the test chart have associated numbers. These numbers represent the line-pair frequencies as printed on the chart, and can be used to estimate the line-pair frequencies as recorded by the camera sensor. For example, in the center of the image, this lens is able to resolve the line-pairs printed with a resolution of 4.05 lp/mm (see center crop). This corresponds to a resolution on the sensor of about 81 lp/mm (4.05 x 20).

Full-resolution crops of the center, mid top edge, mid right edge, and lower right corner are provided. On a high-ppi display, it may be useful to view these at 200% magnification. For the center and top-edge crops, there is essentially no difference between the uncorrected and corrected images with regard to ability to distinguish line-pairs and to read the smallest text. Microcontrast appears to be just slightly degraded in the corrected images: one effect is that text may seem marginally more crisp in uncorrected images. Also, the MTF values for resolvable line-pairs may be slightly higher in uncorrected images. (Recall that no sharpening has been applied.) Comparison of corrected and uncorrected right-edge and lower-right-corner crops yields similar a conclusion: the corrected image seems just slightly softer when viewed at high magnification, but without apparent loss of text legibility or line-pair discrimination.

Away from the image center, distortion correction increases the size of image details, such as text. Thus some details may be easier to discern in corrected images, particularly when viewed at less than 100% magnification. The opposite is true in the center of the image, where correction makes details smaller.

3.2. Image 2 – Winter Oaks with Leaf Litter

This is a natural subject with considerable fine detail (Fig. 2). Distortion might not be apparent in the uncorrected image: even when viewed reduced and side-by-side, some effort is required to see differences between “before” and “after” images (Fig. 2). Uncorrected and corrected full-resolution crops are provided for the center, right side, mid bottom edge, and lower right corner.

The following assessment is based on viewing the crops at 100% magnification on a high-ppi display. In the center, distortion correction has no apparent adverse effect on image quality; except that the slight size reduction that results from correction makes very small details somewhat harder to see. Away from the center, the story is quite different, particularly far from the center (right edge and lower-right corner). To my eyes, at least, the “stretching” of the image that is entailed by distortion correction smears details. The effect is quite noticeable when “before” and “after” images are layered, and layer visibility can be toggled.
Fig. 2. Winter oaks with leaf litter. Top: uncorrected. Bottom: distortion corrected. 1/400 sec, f/5.6, ISO 100, hand-held.
Fig. 3. Mural. Top: uncorrected. Bottom: distortion corrected. 1/800 sec, f/5.6, ISO 100, hand-held.
The amount of distortion correction in Camera Raw is adjustable. In addition to uncorrected and 100% corrected versions, the crops also include 50% corrected images. The effect is as one would expect: 50% correction gives intermediate results. Lastly, as is generally the case, differences in quality between corrected and uncorrected images become much less apparent when image size is reduced, which is typical for many applications.

3.3. Image 3 – Mural

This is an outdoor mural on the side of a building (Fig. 3). Given the architectural nature of the subject, distortion is readily apparent, and most people would undoubtedly choose to correct the image. Note that in the corrected image, there is some remaining perspective distortion (keystone) because the camera was tilted slightly in order to capture the top of the mural. Full-resolution crops are provided for the center, upper left corner, and right side below the midline. I suggest that correction produces a very slight loss of microcontrast in the center of the image, an effect perhaps related to size compression. Microcontrast might be restored by slightly stronger sharpening. This image differs from that of the oaks in that now there is little in the way of high-contrast fine detail. As a result, distortion correction has less effect on apparent image quality, even in the corners when viewed at high magnification. For example, loss of sharpness is imperceptible in the corrected upper-left-corner crop. The crop from the right edge does show some smearing of fine detail in the corrected image — visible in the texture of the asphalt, for example. Nevertheless, for this image, any loss of detail in the corners and edges is arguably a small price to pay for removing obvious distortion.

4. Conclusion

Although this lens has pronounced distortion, it is not necessarily the case that one will want to apply distortion correction to all images. For some subjects, distortion will not be obvious. If distortion is objectionable, and correction is necessary, several points are worth considering. Distortion increases with the square of the distance from the center. Therefore, it is strongest in the image corners and far edges. For most images, important parts of the subject are not at the margins. Furthermore, distortion correction appears to have no negative effects on sharpness/resolution over most of the image, except perhaps for an almost imperceptible reduction in microcontrast. Therefore, if distortion is obvious and needs to be corrected, any loss of detail or sharpness at the corners or edges may be of little, or no, consequence. Also, if the subject permits, a centered square crop will remove the most distorted parts of an image.

Given that distortion correction seems to involve wholesale image resampling, my feeling is that it should be done on an image-by-image basis, even with this lens. On the other hand, if images are to be downsized, any defects that might be introduced by distortion correction will tend to be obscured. In that case, making correction the default setting might be justified.

Lastly, and as always, there are trade-offs. The Sony FE 24mm F2.8 G, is small, light, and relatively inexpensive. On the A7RM3, autofocus is very fast and accurate. It has useful features such as an aperture ring and an AF/MF switch that encourage quick and easy shooting. In short, it is easy to carry and it is an enjoyable lens to use. Resolution in the image center is excellent, even at maximum aperture. In fact, resolution is still quite good at the farthest edges at f/2.8. One has to get fairly deep into the corners to encounter serious loss of resolution.