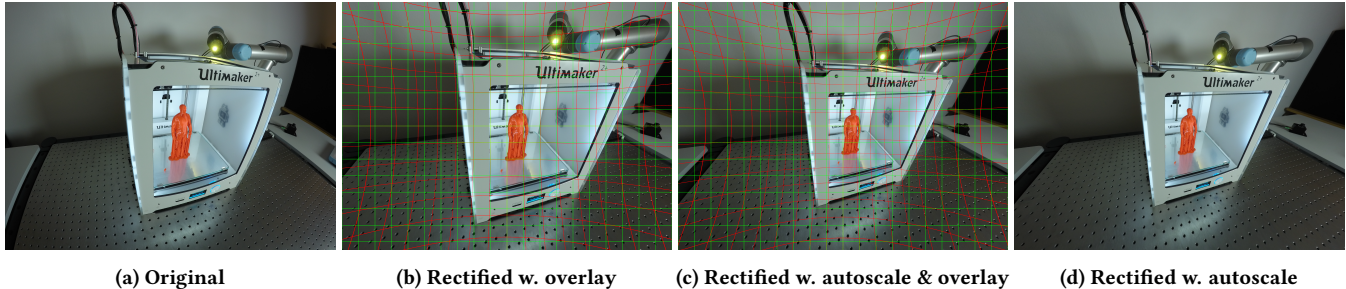# Photon Rectify: Undistort any footage on the timeline

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(a) Original   (b) Rectified w. overlay   (c) Rectified w. autoscale & overlay   (d) Rectified w. autoscale

Figure 1: Rectification of GoPro content from "4:3 wide"-mode. 1a: Original output of GoPro camera, suffering from a large amount of barrel distortion. 1b: Rectified footage using Photon Rectify. Green and red lines outline the deformation field. Notice that a lot of the image is cropped away. 1c: automatic scaling of the content is enabled and a considerable amount of pixels is regained. 1d: Result without overlay.

CCS CONCEPTS

•**Computing methodologies → Image processing;** *Video summarization;*

KEYWORDS

lens distortion, rectification, scaling, real-time, video-processing

INTRODUCTION

Action cameras have allowed footage from previously unseen points of view, drones allow for innovative aerial shots, which a few years ago, were either impossible or required a helicopter, and finally DSLR video and lens adaptors have made *any* lens available for video production. These advances provide especially low-budget movie productions with completely new flexibility and potential.

Due to multiple factors such as: size-limitations, cost, and the desire for a wide field of view, footage might suffer from noticeable lens distortions (fig. 1a). To mitigate distortion, and to mimic, and possibly blend, with the output of way more expensive high-end optics, proper lens correction must be carried out. Photon Rectify aids movie productions in doing so by enabling fast and accurate lens-correction right on the timeline in the industry standard video editing tools, Adobe After Effects and Adobe Premiere.

Although accurate and reliable camera calibration is a fairly solved problem in academia [Zhang 1999], with tools readily available to researchers through e.g. the OpenCV library [Bradski and Kaehler 2008], the technology has been poorly transferred to the industry and in particular video production. While Adobe Photoshop provides tools and presets for rectification of photos acquired through *some* cameras and lenses, only primitive deformation tools are available for timeline video editing. Photon Rectify brings accurate camera calibration and such rectification to video editing following the computer vision de facto standard [Bradski and Kaehler 2008; Zhang 1999]. Correction is done either using predefined parameters (fig. 1b) or through custom calibrations. Any combination of camera and lens can easily be calibrated using Photon Rectify's build-in calibration tool. The tool makes it easy to create sharable presets for an *endless* amount of sensor/lens combinations. Moving beyond standard image calibration, Photon Rectify also allows for automatic scaling of content (fig. 1c & 1d). This ensuring that there are no missing pixels in the output, while maximizing the valid coverage of the sensor. The scaling is built directly into the resampling pipeline and manually controllable, which avoids double interpolation as a result of later scaling. Finally, to accommodate artistic needs, the plugin provides a linear blending control that allows smooth transitions between distorted and undistorted footage.

METHOD

Rectification and calibration. Given an image center, (c_x, c_y), and a camera focal length, f, in pixels units, a pixel coordinate (x, y) may be represented in normalized, centered coordinates and have a (squared) radial distance by:

$$\hat{x} = \frac{x - c_x}{f}, \qquad \hat{y} = \frac{y - c_y}{f}, \qquad r^2 = \hat{x}^2 + \hat{y}^2 \qquad (1)$$

Iterating over the output image, $(\hat{x}_{\mathsf{out}}, \hat{y}_{\mathsf{out}})$, undistortion can be achieved by sampling in the input image $(x_{\mathsf{sample}}, y_{\mathsf{sample}})$ according to the lens distortion as shown in fig. 2. We only correct for
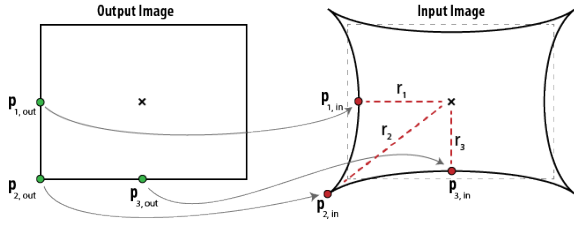
Figure 2: Sampling in the input image according to image distortion. An optimum scaling of sampling can be found such that no pixels outside the input image are looked up.

radial distortion as follows:

$$\hat{x}_{\mathsf{sample}} = \hat{x}_{\mathsf{out}} \cdot dist_{\mathsf{radial}} \qquad (2)$$
$$\hat{y}_{\mathsf{sample}} = \hat{y}_{\mathsf{out}} \cdot dist_{\mathsf{radial}}$$

Where $dist_{\mathsf{radial}}$ is a 6th order polynomial, which describes the radial distortion:

$$dist_{\mathsf{radial}} = 1 + K_1 r^2 + K_2 r^4 + K_3 r^6 \qquad (3)$$

Determining the calibration parameters, (f, K_1, K_2, K_3), can easily be done using checkerboard-based calibration [Bradski and Kaehler 2008; Zhang 1999]. Photon Rectify includes a simple tool for custom calibration of any camera. Not only does it allow for rectification in post production, it also allows for camera calibration in the post production, which is handy, when your production footage turns out to have undesirable distortion. As many video cameras have a wide variety of output resolutions and crops, we use the sensor normalized focal length: $f_{normalized} = f_{pixel}/w_{pixel}$, where w_{pixel} is the width of the sensor in pixels. This allows the same calibration to be used for footage with identical sensor coverage at different resolutions; such as 1080p and 4k which is a common option. Many sensors also have different crops for different modes such as: Photo 4:3, Video 16:9, Cinematic 21:9, as well as sensor crop zoom. As an example fig. 3 shows the 5 crops for a GoPro 3+/4/5 camera. As a convenience for the advanced user with technical insight to his or her camera, the calibration tool in Photon Rectify allows input of crop-sizes, and then automatically generates the corresponding parameters in one go for all crops. This allows the user to only capture footage in one format (preferably the full chip format), rather than for all possible capture modes. The resulting calibration is easily transferable and community sharable as an individual camera parameter preset file.

Autoscaling the sampling. Depending on the type of radial distortion, content may either bulge outwards (barrel), bend inwards (pin cushion), or a combination of both (mustache). As a consequence, pixels may be lost or empty regions may occur, if proper scaling of the footage is not applied. In fig. 2 we highlight three key points, $(\mathbf{p}_{1,out}, \mathbf{p}_{2,out}, \mathbf{p}_{3,out})$, placed on the edge of the output footage. Optimal scaling achieves two goals: it makes all pixels valid, while also minimizing the loss of pixels outside the sampling. The optimum is found, when at least one of the keypoints is sampled exactly on the edge of the input image, $\mathbf{p}_{k,out} = \mathbf{p}_{k,in}$, while the rest are either sampled on the edge or inside. Let us introduce a scaling term, s, to the centered, normalized coordinates and (squared) radial distance:

$$\hat{x}_s = \hat{x} \cdot s \qquad \hat{y}_s = \hat{y} \cdot s \qquad r_s^2 = r^2 \cdot s^2 \qquad (4)$$
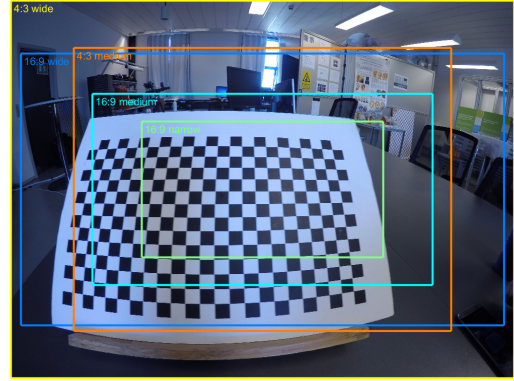
Figure 3: Different crops applied to the GoPro CCD sensor, effectively resulting in different distortions for every mode.

The radial distortion then becomes:

$$dist_{\mathsf{radial,scaled}} = 1 + K_1 r^2 s^2 + K_2 r^4 s^4 + K_3 r^6 s^6 \qquad (5)$$

Given the condition for optimal scaling above, we wish to find the value s such that:

$$\hat{x}_{\mathsf{out}} = \hat{x}_{\mathsf{sample},s}$$
$$\hat{x}_{\mathsf{out}} = \hat{x}_{\mathsf{out}} \cdot s \cdot dist_{\mathsf{radial,scaled}}$$
$$0 = s \cdot dist_{\mathsf{radial,scaled}} - 1 \qquad (6)$$

Since the $dist_{\mathsf{radial,scaled}}$ is differentiable for s, eq. 6 can be solved for s using Newton's approximation method. Few iterations are usually needed for this to converge. The value s is found for the three keypoints, and the smallest scaling is chosen (smaller s equals more zoom). While autoscaling keeps the most valid pixels, the plugin also allows for disabling or manually setting the scaling. The latter is important, when scaling is needed, as it avoids interpolating twice in first undistorting and then scaling.

Correction blending. As a final feature Photon Rectify allows users to smoothly turn the correction on or off. Note that the radial distortion polynomial in eq. 5 can easily be modified with a blending coefficient, $\alpha \in [0, 1]$:

$$dist_{\mathsf{radial,scaled}} = 1 + \alpha(K_1 r^2 s^2 + K_2 r^4 s^4 + K_3 r^6 s^6) \qquad (7)$$

Footage taken with a very wide angle might appear a bit *sharp*, when totally rectified, while leaving some distortion might *soften* it a bit. It also accommodates artistic needs.

CONCLUSION

To summarize, we here present a plugin that provides accessible image rectification of any video content. With this, artists can now choose to apply rectification directly on the post production timeline, adding new flexibility. Photon Rectify bridges another gap between computer vision and video production.

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