Vignette and Exposure Calibration and Compensation

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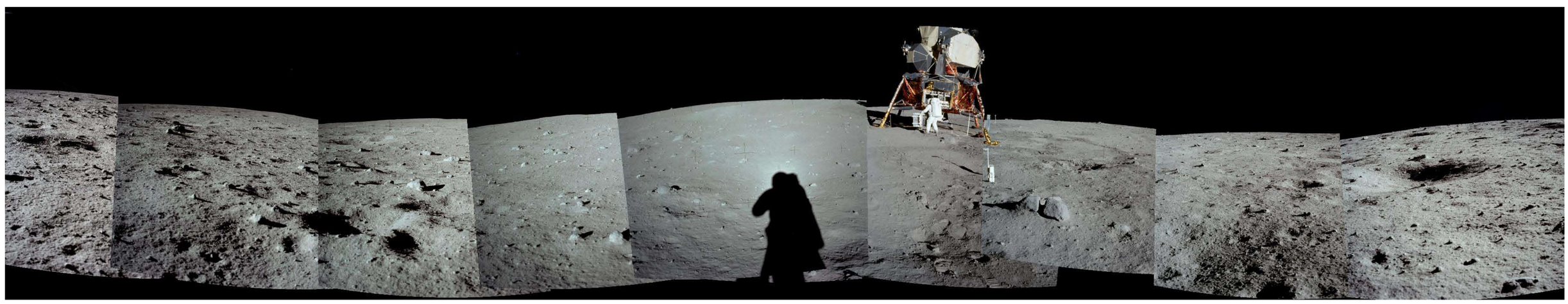
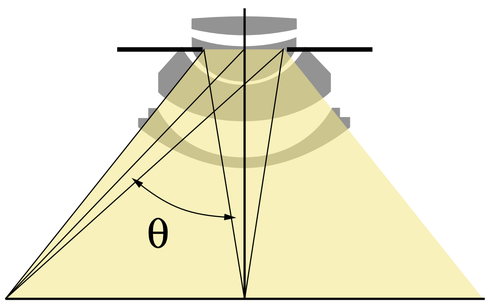
Problem Statement: Given a sequence of aligned images, such as those used to compose panoramas, recover the response curve, varying exposures, and vignetting. Correct for the effects of variable exposure and vignetting in the given images.

Panoramic photograph sequence from Apollo 11, aligned using AutoStitch and composited without blending:



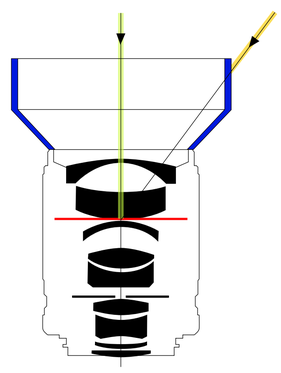
After compensation for spatiotemporal exposure variation -- vignetting and exposure duration -- and Photomontage blending:

Sources of Vignetting



Natural Vignetting: $\cos^4(\theta)$

Optical Vignetting: occlusion after aperture



Mechanical Vignetting: occlusion before aperture

Model and Approach

$$P_{\mathbf{x},i} = R_\beta(t_i L_\mathbf{x} M_\alpha(r_{\mathbf{x},i}))$$

$\mathbf{x}$	indexes over scene points
i	indexes over images
$P_{\mathbf{x},i}$	color of point $\mathbf{x}$ as seen in image i
R_β	response curve parameterized by β
t_i	exposure of image i
$L_\mathbf{x}$	radiance toward camera of point $\mathbf{x}$
M_α	vignette curve parameterized by α
$r_{\mathbf{x},i}$	distance of point $\mathbf{x}$ from center of image i

Givens: $P_{\mathbf{x},i}$ $r_{\mathbf{x},i}$
Unknowns: $\alpha, \beta, L_\mathbf{x}, t_i$

Reconstruction error minimized using nonlinear optimization: alternating Nelder-Mead downhill simplex

Recovery Ambiguities

Exposure and scene radiance can only be recovered up to a scale ambiguity.

An additional exponential ambiguity exists for unknown response:

$$\begin{aligned} R'(E) &= R(E^{1/\gamma}) \\ t' &= t^\gamma \\ L' &= L^\gamma \\ M' &= M^\gamma \\ R'(t'L'M') &= R(tLM) \end{aligned}$$

It can be shown that these are the only ambiguities for general scenes. (Degenerate scenes have additional ambiguities.)

Compensation and Blending

Source images, aligned and composited without blending:

Photomontage blending [Agrawala et al. 2004]:

Exposure and vignette compensation only:

Compensation and blending: