Defensive Disclosure: Approximating Lens Shading Gain Maps via Polynomial-Power Method

Abstract

This paper discloses a method for approximating lens shading correction (LSC) gain maps by applying a polynomial function of displacement magnitude and raising it to a power, typically four, to mimic cos^4 law falloff. The approach unifies geometric distortion correction (GDC) and shading correction by leveraging the displacement grid as the basis for both corrections. This disclosure is intended to establish prior art and prevent future patent claims on the method.

Introduction

Lens shading correction (LSC) compensates for vignetting, while geometric distortion correction (GDC) corrects barrel or pincushion distortion. Traditionally, these are calibrated independently. However, displacement magnitude from GDC polynomials correlates with shading falloff. By approximating gain maps as a polynomial of displacement and raising the result to a power, shading correction can be derived directly from geometric distortion models.

Related Work

Existing patents and publications describe LSC as gain grids interpolated across the image domain and GDC as displacement grids derived from distortion polynomials. Prior art does not explicitly disclose approximating gain maps by raising polynomial displacement functions to a power, though cos^4 law falloff is a known optical principle.

Proposed Method

1. **Displacement Polynomial**: Use calibrated distortion polynomial ($r' = r$ ot $(1 + k_1 r^2 + k_2 r^4 + ...)$) to compute displacement magnitude ($d(r) = r' - r$).
2. **Polynomial Gain Approximation**: Define a polynomial gain function: [$g(d) = 1 + a_1 d + a_2 d^2 + a_3 d^3$]
3. **Power Law Adjustment**: Raise the polynomial gain to a power (p), typically 4: [$g'(d) = (g(d))^p$] This mimics cos^4 law falloff and steepens correction near edges.
4. **LSC Application**: Multiply the input image by ($g'(d)$).
5. **GDC Application**: Apply the original displacement grid via GridSample to correct geometry.

Experimental Setup

- **Calibration Data**: Flat-field captures across zoom/focus/aperture states.

- **Fitting**: Polynomial coefficients (a_i) fitted from displacement vs. gain data; exponent (p) chosen empirically or fitted.
- **Evaluation**: Compare derived gain maps against reference gain maps.

Results and Discussion

- Raising polynomial gain to power 4 approximates $\cos^4$ law falloff, producing realistic shading correction.
- Fitted exponents between 2 and 4 yield best matches depending on lens design.
- Derived gain maps closely match reference maps with acceptable error margins.

Advantages

- **Unified Calibration**: One distortion polynomial provides both shading and geometric correction.
- **Physics-Informed**: Power law adjustment aligns with $\cos^4$ law optical falloff.
- **Flexibility**: Exponent (p) can be tuned per lens, channel, or state.

Applications

- Mobile camera ISPs
- Embedded vision systems
- Real-time image correction pipelines
- AR/VR imaging modules

Conclusion

This disclosure establishes prior art for approximating lens shading gain maps via polynomial-power methods. By raising polynomial displacement-based gain functions to a power, shading correction can be unified with geometric distortion correction, simplifying calibration and runtime processing.

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