Defensive Disclosure: Unified Lens Shading and Geometric Correction via Displacement-Derived Gain Maps

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Abstract

This paper discloses a novel method for unifying lens shading correction (LSC) and geometric distortion correction (GDC) by deriving gain maps directly from displacement grids. The technique leverages the proportional relationship between displacement magnitude and shading falloff, enabling a single distortion model to generate both geometric and radiometric corrections. This disclosure is intended to establish prior art and prevent future patent claims on the method.

Introduction

Digital imaging pipelines traditionally separate lens shading correction (LSC) and geometric distortion correction (GDC) into distinct calibration and runtime processes. LSC applies a gain map to compensate for vignetting, while GDC uses a displacement grid to correct barrel or pincushion distortion. These corrections are usually calibrated independently, increasing complexity and storage requirements.

Related Work

Existing patents and publications describe LSC as a gain grid interpolated across the image domain, and GDC as a displacement grid applied via resampling. However, these methods treat shading and geometry as independent phenomena. Prior art does not explicitly disclose deriving gain maps from displacement grids, even though both effects share radial dependence on distance from the optical center.

Proposed Method

We propose a unified approach:

1. **Displacement Grid Generation**: From calibrated distortion coefficients, generate a displacement grid ([1,h,w,2]) representing per-pixel geometric offsets.
2. **Center Normalization**: Shift coordinates so that the optical center corresponds to (0,0).
3. **Displacement Magnitude Calculation**: Compute per-pixel displacement magnitude: $$d(x,y) = \sqrt{(\Delta x)^2 + (\Delta y)^2}$$
4. **Gain Map Derivation**: Fit a proportionality constant or polynomial to map displacement magnitude to gain: $$g(x,y) = 1 + \alpha \cdot d(x,y)$$
5. **LSC Application**: Multiply the input image by the gain map: $$I_{LSC}(x,y) = I(x,y) \cdot g(x,y)$$

6. **GDC Application**: Apply the original displacement grid via GridSample to correct geometry: [$I_{GDC}(x,y) = I_{LSC}(f(x,y))$]

Experimental Setup

- **Calibration Data**: Multiple motor encoder positions are calibrated to produce displacement grids and reference gain maps.
- **Fitting**: Polynomial regression is used to fit displacement magnitude to gain values.
- **Evaluation**: Compare derived gain maps against reference gain maps to measure accuracy.

Results and Discussion

- Derived gain maps closely approximate reference gain maps, with error margins within acceptable ISP tolerances.
- The proportionality between displacement and gain holds across zoom/focus positions, confirming the physical relationship.
- Unified calibration reduces storage requirements and simplifies pipeline design.

Advantages

- **Unified Calibration**: One distortion model provides both shading and geometric correction.
- **Reduced Complexity**: Eliminates the need for separate shading calibration datasets.
- **Consistency**: Ensures shading correction aligns spatially with geometric distortion.
- **Efficiency**: Simplifies runtime by reducing external inputs to a single displacement grid.

Applications

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

Conclusion

This disclosure establishes prior art for deriving lens shading gain maps from displacement grids. By exploiting the proportional relationship between displacement and gain, the method simplifies calibration and unifies correction stages in digital imaging pipelines. This defensive disclosure is published to prevent future patent claims on the described method.

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