A Preprocessing Framework for Low-Cost Retinal Fundus Images

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Background and Purpose

A low-cost fundus camera provides a **cheap and mobile** solution to capture images of the human eye background. The images suffer from **poor illumination conditions** and **low signal-to-noise ratios (SNR)**.

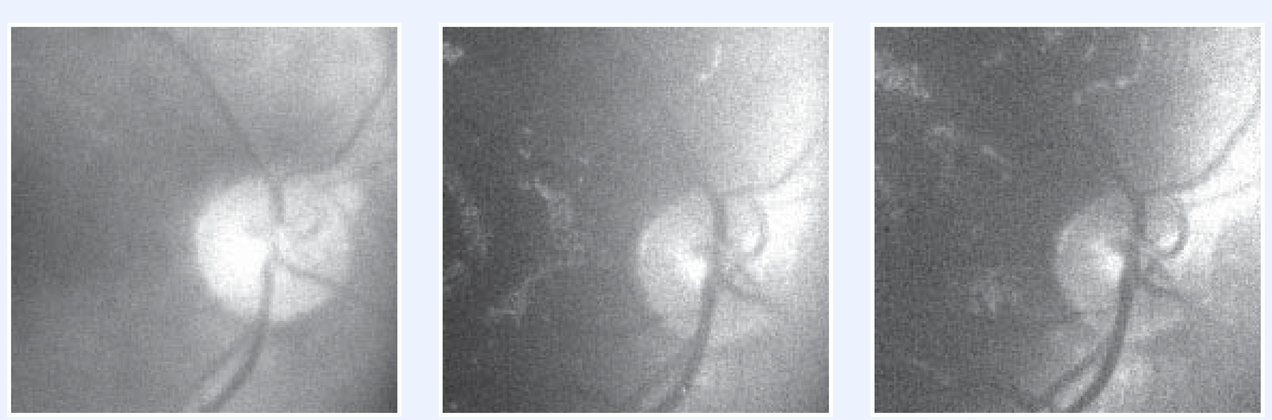
We propose a **preprocessing framework for quality improvement** of fundus images captured by a low-cost camera prototype.

Method: Image Acquisition

We use an **industrial CCD camera** to capture uncompressed sequences of fundus images (for further details on hardware see also poster #3106, session D1235):

- Frame rate (per color channel): 2 fps
- Field of view: 68°
- Spatial resolution of full images: 1280 × 960 pixels

Color images are acquired by **sequential acquisition of three frames** representing the RGB color channels via illumination by **three different LEDs** (Figure 1).



(a) Red (b) Green (c) Blue

Figure 1: The color channels from a region of interest showing the optic nerve head.

For each color channel an image sequence consisting of 18 frames were acquired from a healthy subject using our camera prototype. The evaluation was done for a region of interest showing the optic nerve head.

Method: Image Processing Pipeline

Our framework is designed as a pipeline to obtain **one image of improved quality** from a sequence of raw input frames. The proposed pipeline consists of two stages for processing of single frames and image sequences for each color channel (Figure 2).

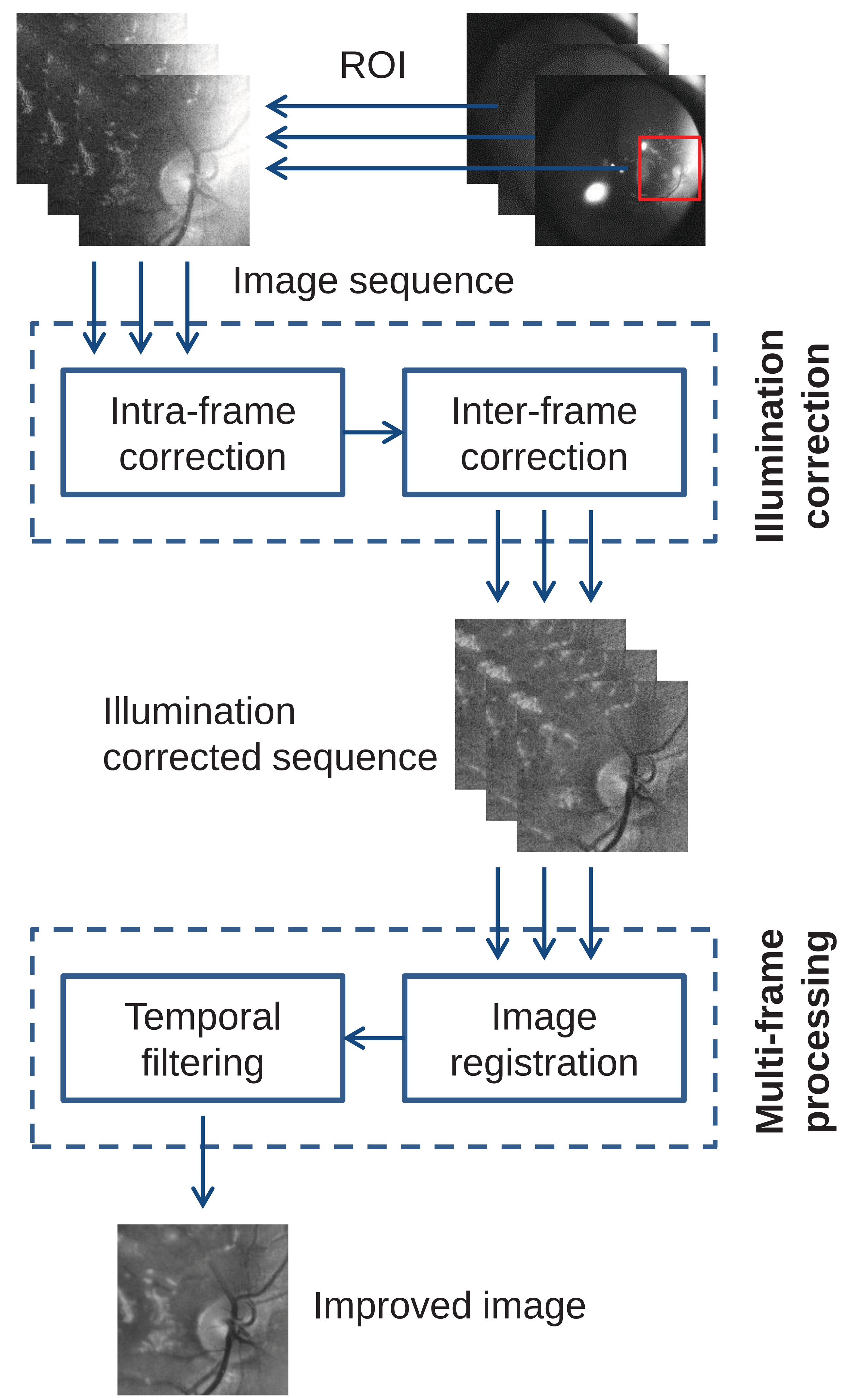


Figure 2: The proposed processing pipeline for a single color channel.

Illumination correction:
Illumination artifacts are removed for each single frame in two steps as done e. g. for MRI [1].

- **Intra-frame correction** using parametric surface models (e. g. B-splines)
  → Correction of inhomogeneous illumination per frame
- **Inter-frame correction** using histogram matching to the median histogram of all frames
  → Equalization of intensity distributions per sequence

Multi-frame processing:
The image sequence is fused into one single improved image.

- **Image registration** [2] is used to align all frames
  → Compensate motion caused by human eye movements during image acquisition
- **Temporal filtering** using adaptive frame averaging [3] is performed
  → Obtain single denoised image with increased SNR

RGB composition:
Color information is recovered by composing the preprocessed single color channels.

→ Image registration aligns single color channels to each other

Method: Image Quality Assessment

Image improvement for an image $\mathbf{I}$ is assessed using two SNR measures (in dB unit) [4, 5]

$$\mathrm{SNR}_1 = 20\log_{10}\left(\frac{\mu_h}{\sigma_h}\right) \qquad \mathrm{SNR}_2 = 10\log_{10}\left(\frac{\max\left(\mathbf{I}^2\right)}{\sigma_h^2}\right)$$

where μ_h and σ_h is the mean and standard deviation in a homogeneous image region respectively.

→ **Measurement of denoising performance**

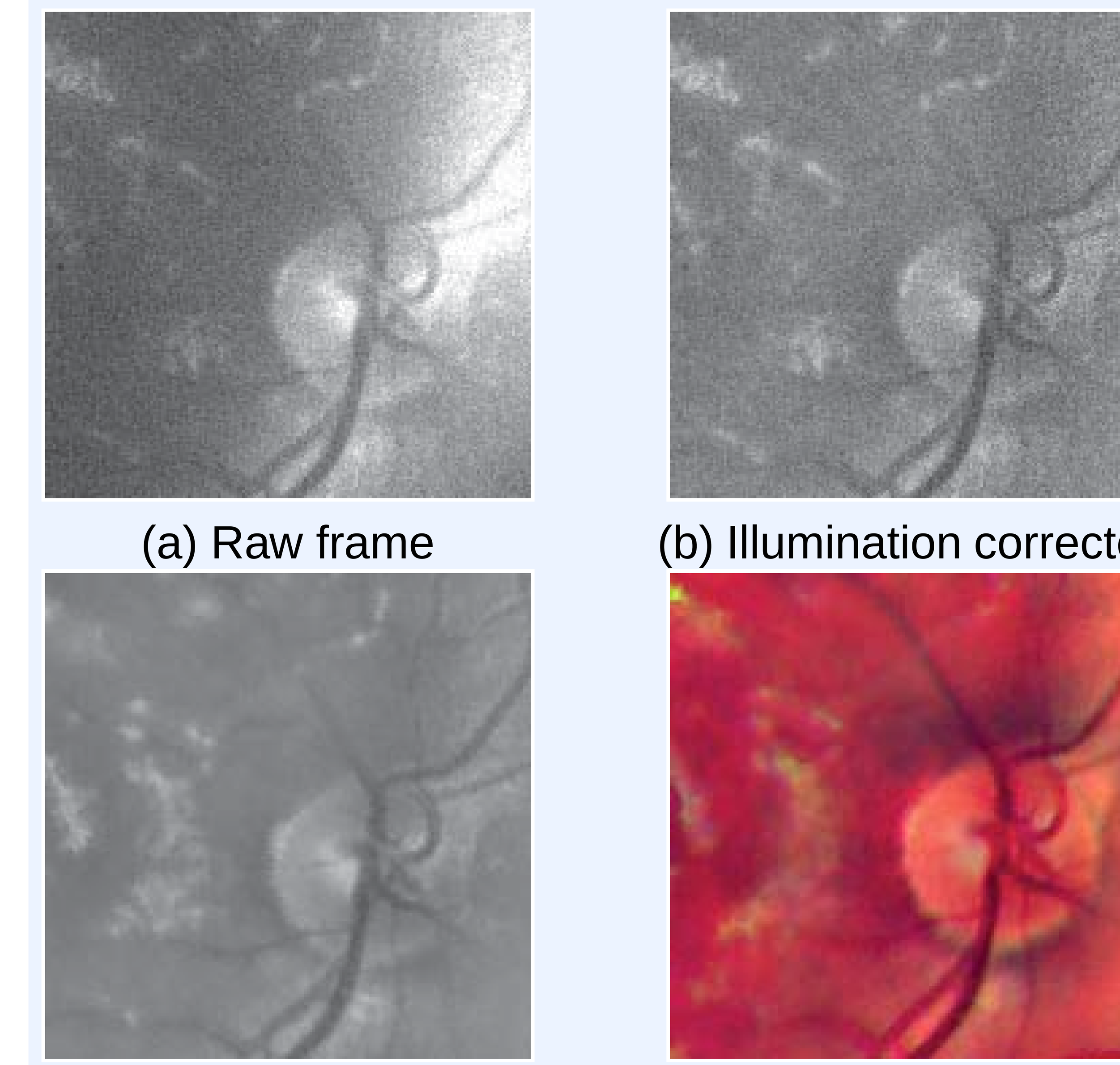
The median $\mathrm{SNR}_{1,2}^{\mathrm{raw}}$ of a raw image sequence is compared to the increased $\mathrm{SNR}_{1,2}^{\mathrm{inc}}$ after processing.

Results

Qualitative results for the blue color channel are shown in Figure 3. Our pipeline reduced **illumination artifacts and image noise**. **Structural details (e. g. blood vessels, optic disk boundary) were preserved**.

The estimated SNRs (in dB) for sequences corresponding to the different color channels were determined:

Channel	$\mathrm{SNR}_1^{\mathrm{raw}}$	$\mathrm{SNR}_1^{\mathrm{inc}}$	$\mathrm{SNR}_2^{\mathrm{raw}}$	$\mathrm{SNR}_2^{\mathrm{inc}}$
Red	24.66	28.92	28.02	35.58
Green	23.87	27.58	26.97	35.69
Blue	19.78	29.29	27.51	40.66



(a) Raw frame (b) Illumination corrected (c) Denoised image (d) RGB image

Figure 3: Results for a region of interest showing the optic nerve head.

Conclusion and Outlook

The proposed framework enables **quality improvement of low-cost fundus images**. Illumination correction and denoising are initial steps for further processing stages. In our future work we will extend denoising to **super-resolution** to increase the spatial resolution.

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Commercial Relationship

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