FlexISP: A Flexible Camera Image Processing Framework

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CAMERA IMAGE PROCESSING
IMAGE PROCESSING PIPELINE

- Demosaic
- Bad Pixel Correction
- Black Level
- Exposure / Focus Adjustment
- Lens Correction
- Metering
- Tone Mapping
- Image Enhancing
- Denoise
IMAGE PROCESSING PIPELINE

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Exposure / Focus Adjustment
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Exposure / Focus Adjustment

Bad Pixel Correction → Black Level

Denoise → Demosaic

Lens Correction → Metering

Image Enhancing → Tone Mapping
IMAGE PROCESSING PIPELINE

- Demosaic
- Bad Pixel Correction
- Black Level
- Denoise
- Lens Correction
- Metering
- Image Enhancing
- Tone Mapping

Exposure / Focus Adjustment

Error markers indicate potential issues or problems in the processing pipeline.
IMAGE PROCESSING PIPELINE

- Demosaic
- Denoise
- Bad Pixel Correction
- Black Level
- Image Enhancing
- Tone Mapping
- Exposure / Focus Adjustment
NOVEL FEATURES

<table>
<thead>
<tr>
<th>Long Exposure</th>
<th>Short Exposure</th>
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NOVEL FEATURES

Single Exposure

Interleaved Exposure
NOVEL FEATURES
Refocusing

Depth
OBJECTIVES

NO PIPELINE

FLEXIBILITY

PERFORMANCE
IMAGE FORMATION
z = DBx
$z = A x$
LINEAR SYSTEM

\[ \text{argmin}_x |z - Ax|_2^2 \]
\[
\text{argmin}_x |z - Ax|^2_2
\]

errors w.r.t. observation
LINEAR SYSTEM

\[ \arg\min_x |z - Ax|^2 \]

errors w.r.t. observation
argmin_x |z - Ax|^2 + \lambda(x)
TOTAL VARIATION
(Rudin et al. ‘92)

$$TV = \sum \| \nabla X \|_1$$
CROSS-CHANNEL
(Heide et al. ‘13)

\[
\frac{\nabla X_r}{X_r} \approx \frac{\nabla X_g}{X_g}, \quad \frac{\nabla X_r}{X_r} \approx \frac{\nabla X_b}{X_b}, \quad \frac{\nabla X_b}{X_b} \approx \frac{\nabla X_g}{X_g}
\]
COLLABORATIVE DENOISING
COLLABORATIVE DENOISING
LINEAR SYSTEM

\[
\arg \min_x |z - Ax|^2 + \lambda(x)
\]

- Total variation
- Cross-channel
- Collaborative denoising
IMPORTANCE OF PRIORS
MORE ON PRIORS...

- TV [Rudin et al. ‘92]
- EPLL [Zoran and Weiss ‘11]
- Curvelets [Candès and Donoho ‘99]
MORE ON PRIORS…

- BM3D
- NLM
- Patchwise NLM
- Sliding DCT
- Averaging

PSNR [dB]

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<th>Bayer image</th>
<th>Interlaced HDR</th>
<th>Burst image stack</th>
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<tr>
<td>BM3D</td>
<td>35.98</td>
<td>44.3</td>
<td>32.02</td>
</tr>
<tr>
<td>NLM</td>
<td>34.1</td>
<td>41.92</td>
<td>31.39</td>
</tr>
<tr>
<td>Patchwise NLM</td>
<td>34.91</td>
<td>44.2</td>
<td>32.01</td>
</tr>
<tr>
<td>Sliding DCT</td>
<td>35.17</td>
<td>40.0</td>
<td>31.34</td>
</tr>
<tr>
<td>Averaging</td>
<td>32.35</td>
<td>43.93</td>
<td>31.49</td>
</tr>
</tbody>
</table>
\[ \text{argmin}_x |z - (Ax)^2| + \lambda(x) \]

(Mostly) Convex Optimization

Primal-Dual
CONVERGENCE

Graph showing the logarithm of the Mean Squared Error (MSE) over iteration count.

- Log(MSE) on the y-axis
- Iteration count on the x-axis
- The graph shows a rapid decrease in MSE followed by a plateau.

RESULTS
CAMERA SYSTEMS

Bayer

Burst

iHDR
CAMERA SYSTEMS

Bayer

Burst

iHDR
First Frame (29.86 dB)
BM3D (36.16 dB)
VBM3D (37.81 dB)
CAMERA SYSTEMS

Bayer

Burst

iHDR
CAMERA SYSTEMS

Bayer

Burst

iHDR
CAMERA SYSTEMS

Bayer

Burst

iHDR
PERFORMANCE

GTX Titan

- Demosaic (5MP): 2.13 seconds
- iHDR (13MP): 7.45 seconds
- Image burst (0.4MPx16): 0.82 seconds
PERFORMANCE

**Tegra K1**

- **Demosaic (5MP)**: 40.5 seconds
- **iHDR (13MP)**: 174.4 seconds
- **Image burst (0.4MPx16)**: 16.7 seconds
MORE ON PRIORS...

The bar chart compares the PSNR [dB] for different image types and processing methods. The image types include Bayer image, Interlaced HDR, and Burst image stack. The methods compared are BM3D, NLM, Patchwise NLM, Sliding DCT, and Averaging. The PSNR values are as follows:

- **Bayer image**:
  - BM3D: 35.98 dB
  - NLM: 34.61 dB
  - Patchwise NLM: 34.91 dB
  - Sliding DCT: 35.17 dB
  - Averaging: 32.35 dB

- **Interlaced HDR**:
  - BM3D: 44.3 dB
  - NLM: 43.97 dB
  - Patchwise NLM: 44.2 dB
  - Sliding DCT: 40 dB
  - Averaging: 43.93 dB

- **Burst image stack**:
  - BM3D: 32.02 dB
  - NLM: 31.39 dB
  - Patchwise NLM: 32.01 dB
  - Sliding DCT: 31.34 dB
  - Averaging: 31.94 dB

The chart shows that BM3D generally achieves the highest PSNR across all image types and methods, followed by NLM and Patchwise NLM.
PERFORMANCE (BM3D)

Tegra K1

- Demosaic (5MP): 40.5 seconds
- iHDR (13MP): 174.4 seconds
- Image burst (0.4MPx16): 16.7 seconds
PERFORMANCE (AVERAGING NLM)

- Demosaic (5MP): 6.7 seconds
- iHDR (13MP): 33.2 seconds
- Image burst (0.4MPx16): 6.6 seconds

TIME IN SECONDS
CONCLUSION
+ others such as:
dehconvolution, super-resolution, JPEG compression and de-blocking.
THANK YOU!

JOIN THE CONVERSATION
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