The Half-quadratic Splitting (HQS) Method for Shadow Removal

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Motivation

- **Shadows**
- caused by uneven illumination, can degrade image quality by reducing visibility and introducing unwanted artifacts.
- make it more difficult to implement image segmentation, object recognition and other basic tasks for computer vision.
- **Goal**

Develop a solution for shadow removal using the thought of inverse problem.

$$b = A(x) + \eta$$

Method

- **Idea:** ***Think of shadow as Gaussian noise in the Y (luminance) channel***

Problem Formation

$$\boldsymbol{b} = \boldsymbol{x} + \boldsymbol{\eta}$$
$$\boldsymbol{x}_i \sim \mathcal{N}(\boldsymbol{x}_i, 0), \boldsymbol{\eta}_i \sim \mathcal{N}(\mu, \sigma^2)\ (\mu < 0)$$
$$\boldsymbol{b}_i \sim \mathcal{N}(\boldsymbol{x}_i + \mu, \sigma^2)$$

$\mu = \mu_{sh} - \mu_{nonsh}$
$\sigma \leftarrow \mu, y_{shadow}$

MAP Solution

$$\boldsymbol{x}_{MAP} = arg\ min_{\boldsymbol{x}} -\log(p(\boldsymbol{x}|\boldsymbol{b}, \mu, \sigma))$$
$$= arg\ min_{\boldsymbol{x}} \frac{1}{2\sigma^2}\|\boldsymbol{b} - \boldsymbol{x} - \boldsymbol{\mu}\|_2^2 + \psi(\boldsymbol{x})$$

TV prior

HQS With TV

$$L_\rho(\boldsymbol{x}, \boldsymbol{z}) = f(\boldsymbol{x}) + g(\boldsymbol{z}) + \frac{\rho}{2}\|\boldsymbol{D}\boldsymbol{x} - \boldsymbol{z}\|_2^2$$
$$\boldsymbol{x} \leftarrow (\rho \boldsymbol{D}^T\boldsymbol{D} + \boldsymbol{I})^{-1}(-\boldsymbol{\mu} + \boldsymbol{b} + \rho \boldsymbol{D}^T\boldsymbol{z})$$
$$\boldsymbol{z} \leftarrow \textit{element-wise soft thresholding op}$$

$\Longrightarrow$ *Adjust* $\begin{cases} \kappa \\ \lambda \\ \rho \end{cases}$ *for shadow removal*

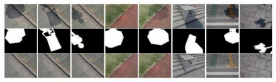
***Note**

- ***b, x, η*:** pixels in the shadow area
- ***Solving the inverse problem*:**
- Use the whole image as input
- Update the luminance for the shadow area
- Shadow-free area stay the same
- (Above applied to ***b, x, z, v***)

rgb2ycbcr → Solve in Y → ycbcr2rgb → evaluate

Dataset

- **ISTD-The Image Shadow Triplets dataset**



Related Work

- HQS for Deconvolution
- Shadow Detection and Removal Based on YCbCr

References

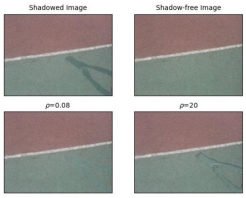
[1] Image Deconvolution with the Half-quadratic Splitting Method, Lecture 10 and notes.
[2] Deb, K., & Suny, A. H. (2014). Shadow detection and removal based on YCbCr color space. SmartCR, 4(1), 23-33.
[3] Shor, Y., & Lischinski, D. (2008, April). The shadow meets the mask: Pyramid-based shadow removal. In Computer Graphics Forum (Vol. 27, No. 2, pp. 577-586). Oxford, UK: Blackwell Publishing Ltd.

Experimental Results

- **Qualitative**
- shadow image
- shadow-free image (HQS)

- **Quantitative (ρ)**

	0.08	0.1	0.12	1	5	10	20
PSNR	**33.317**	33.312	33.306	32.627	31.340	30.871	30.533
SSIM	**0.9510**	0.9509	0.9507	0.9406	0.9290	0.9266	0.9254
RMSE	**0.0215**	0.0215	0.0216	0.0233	0.0271	0.0286	0.0297



Discussion

- We developed a solution to remove shadow in an image using the HQS method.
- **Pros:** simple framework, efficient, acceptable result
- **Cons:** poor performance with dark shadow(hard/Umbra), params tuning required for each image
- **Future work**
- ➢ automatic shadow detection
- ➢ removal method for dark shadow
- ➢ Improve performance by adjusting chroma channels