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Hard Shadows Removal Using An Approximate Illumination Invariant

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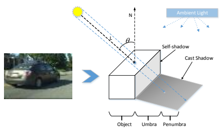
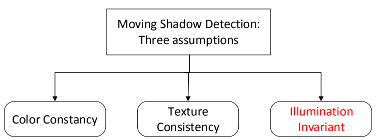
Motivation

Hard shadows removal from foreground masks is a challenging step in change detection. We propose a simple and effective method to address hard shadows.

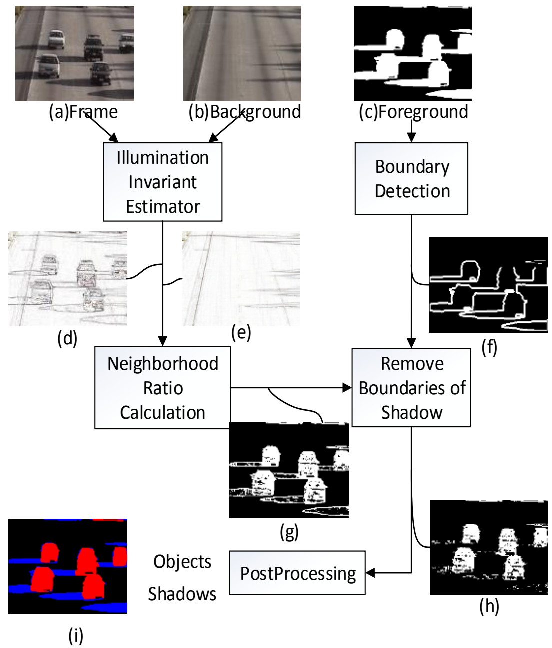


Contribution

Illumination invariant for moving shadow detection. For inside portion, Pixel-wise neighborhood ratio is calculated to remove the most of inside shadow points. For the boundary portion, we take advantage of color constancy to eliminate the edges of hard shadows and obtain relative accurate objects contours.



Flowchart



The Proposed Method

Firstly, the approximate illumination invariants of input frame and background are estimated by the proposed illumination invariant estimator (see (d) and (e)). The neighborhood ratio between the illumination invariants of frame and background is calculated to discriminate object from shadow (see (g)). Then the input foreground is used to detect the outlines of connected regions (see (f)). By color constancy method we discriminate shadows' boundaries from objects' boundaries (see (h)). Finally, post-processing with morphological operation is operated to fit the objects' contours and produces the desired mask (the red) and shadows (the blue).

According to Lambertian reflectance, any pixel of an image obtained from fixed and static scene can be described by a simple luminance model:

$$\mathbf{L}(x) = \mathbf{I}(x)\,\mathbf{R}(x) \Longrightarrow \mathbf{R}(x) = \mathbf{L}(x)/\,\mathbf{I}(x) \quad (1)$$

Lumination component; Illumination component; Reflectance component

$\mathbf{L}(x)$ can be acquired by standard RGB camera while $\mathbf{I}(x)$ cannot be gained directly and should be estimated approximately.

$$I_{max}(x) = \max\{L(t)\},\ I_{min}(x) = \min\{L(t)\},\quad t \in \boldsymbol{W}, \quad (2)$$

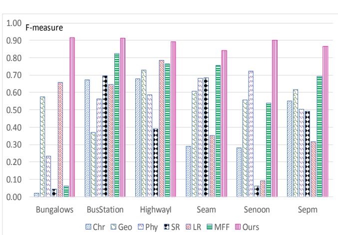
$$\alpha = (I_{max}(x)-I_{min}(x))/I_{max}(x),\ \ I(x) \approx I_{max}(x)\cdot(1-\alpha) + I_{min}(x)\cdot\alpha + \varepsilon \quad (3)$$

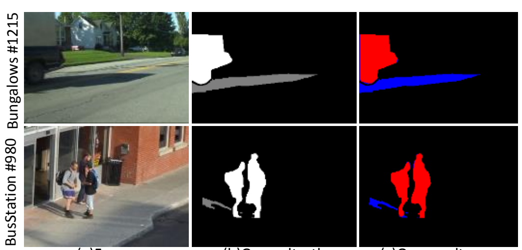
The reflectance component can be computed by $\mathbf{L}(x)$ and $\mathbf{I}(x)$. Compared to the calculation of single pixel, a small neighborhood region (eg, patch) is more robust to light changes. Thus, neighborhood ratio calculation is designed by

$$\Omega(x) = \begin{cases} 1, if\, |I_c(x) - I_b(x)| < \lambda \\ 0, otherwise \end{cases} \qquad shadow = \begin{cases} 1. if\ \left(\sum_{j=1}^{n} \sum_{k\in\{b,g,r\}} \Omega_k(j)\right)/3n > \tau \\ 0, otherwise \end{cases} \quad (4)$$

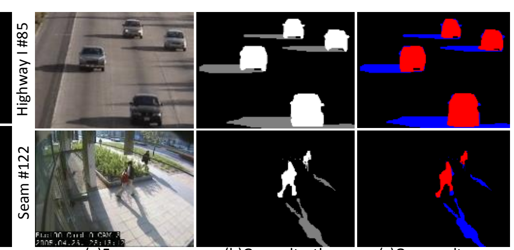
We take advantage of color constancy techniques to detect boundaries according to the size of connected region. The larger the size of connected region is, the wider the boundaries are. Finally, the shadows including umbra and penumbra are detected.

Experimental Results





(a)Frame (b)Groundtruth (c)Our results



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Visual and quantitative results validate the proposed method's effectiveness and robustness. The most important innovation of this paper is the introduction of illumination invariant and estimation by spatial information. Our algorithm has been implemented in C++ and processes 50~60 frames a second for a resolution frame. The algorithm has been tested on a 3.5GHz Xeon machine with memory size of 8G. After optimization, the time consumption can be reduced further. The proposed method is applied to multiple outdoor sequences and has promising results in accuracy and processing speed.

[1] Bingshu Wang, Yuyuan Li, Yong Zhao, and C.L. Philip Chen, "Hard Shadows Removal Using an Approximate Illumination Invariant", In 2018 IEEE International Conference on Acoustics, Speech and Signal Processing.
[2] Bingshu Wang, Yule Yuan, Yong Zhao, and Wenbin Zou. "Adaptive Moving Shadows Detection Using Local Neighboring Information." In Asian Conference on Computer Vision（ACCV）, pp. 521-535. Springer, 2016.