DEEP COLOR CONSTANCY USING TEMPORAL GRADIENT UNDER AC LIGHT SOURCES

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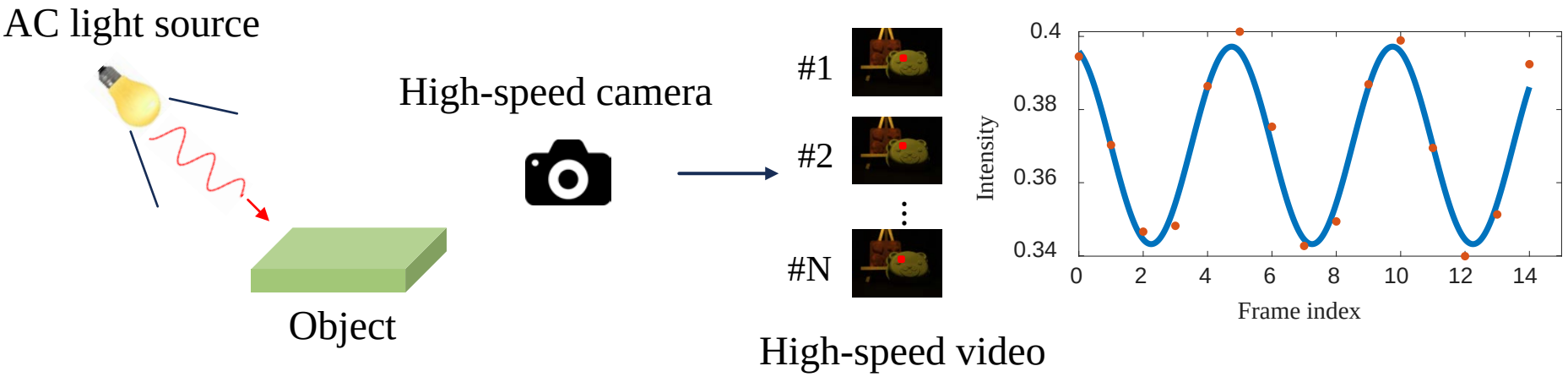
Introduction

- Color constancy
  - Ability to recognize the inherent color of an object which is invariant to illuminant environments
  - Contrary to human visual system, the color of an object in a digital camera is severely affected by illuminant.
  - Color constancy process is necessary for image signal processing pipeline to eliminate the influence of illuminant color.

White-balanced image

Under color illuminant environment

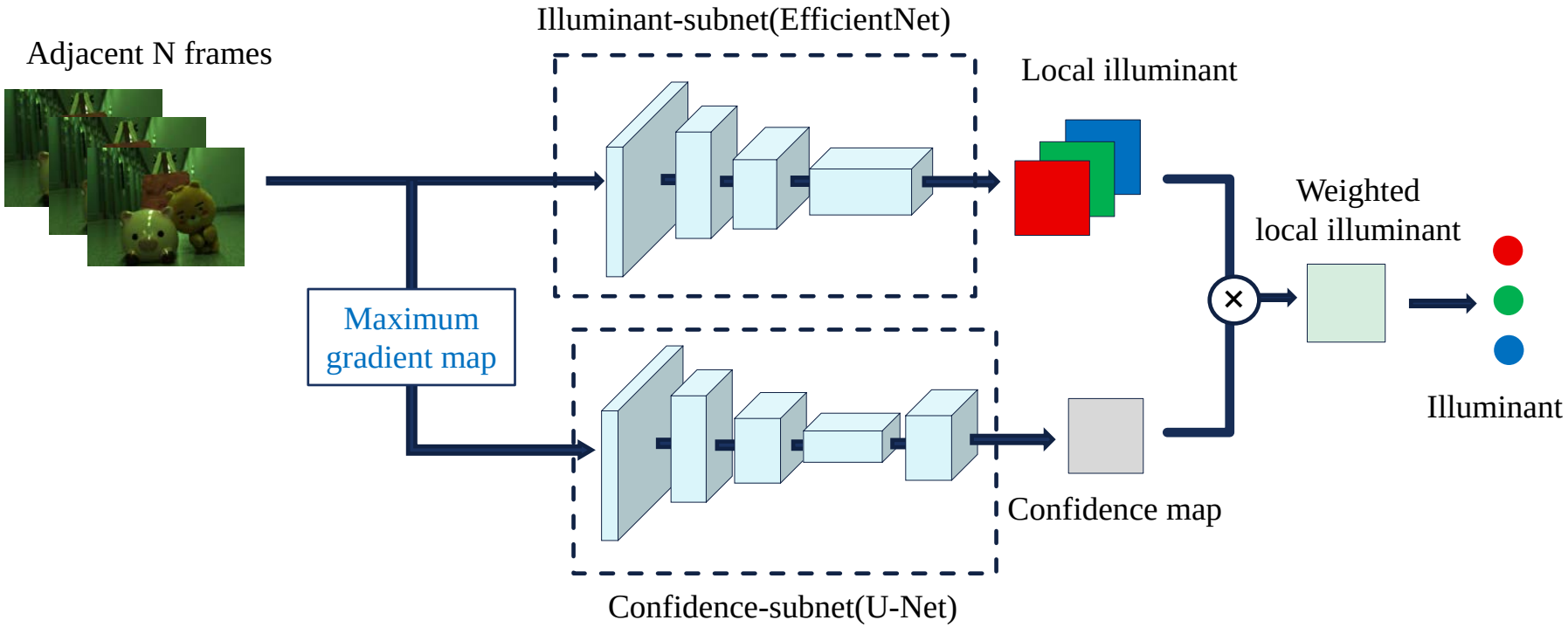
High-speed video and AC light source



- Since the alternative current (AC) power is used for supplier of electric bulbs, the intensities of light sources vary with double the AC standard frequency.
- With high-speed camera whose capturing speed is faster than this fluctuation, the intensity variation can be captured easily [1].
- These variations of intensity provide useful information for illuminant estimation.
- The more scenes are strongly affected by AC-powered illuminant, the more fluctuation is observed through high-speed camera

[1] J.-S. Yoo, and J.-O. Kim, "Dichromatic model based temporal color constancy for ac light sources", *in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 12 329–12 338, 2019.

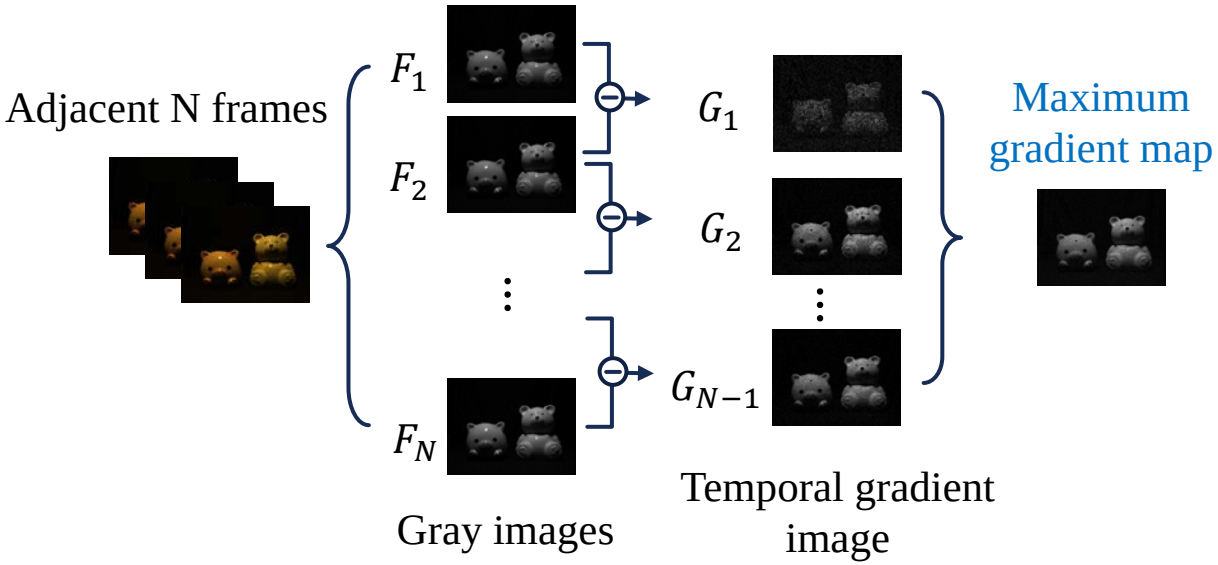
Proposed method



- Multiple frames of high-speed video
- Illuminant-subnet(EfficientNet-B0 [2]) for estimating local illuminants
- Confidence-subnet(U-Net [3]) for estimating confidence map
- Confidence: accuracy of the local illuminant estimated at Illuminant-subnet
- Estimated illuminant: weighted sum of local illuminants
- Loss function: angular error between the estimated illuminant $\hat{\Gamma}$ and ground truth illuminant Γ_g

[2] M. Tan and Q. V.Le, "Efficientnet: Rethinking model scaling for convolutional neural networks", *in Proceedings of the International Conference on Machine Learning*, pp.6105-6114,2019.
[3] O. Ronneberger, P. Fischer, T. Brox, "U-Net: Convolutional networks for biomedical image segmentation", arXiv:1505.04597 [cs.CV],2015.

Maximum gradient map



- Consecutive N frames are converted to gray images, $F_1, \cdots, F_N$
- Temporal gradient image: absolute difference between two adjacent gray frames
- Maximum operation is applied for every pixel
- The maximum gradient map represent the amount of intensity fluctuation
- Stronger illumination leads to larger fluctuation of intensity and temporal gradient
- With this maximum gradient map, we can identify image regions which are significantly affected by the illuminant.

Experimental result

- High-speed dataset
  - Images under various environments and with various objects for general performance
  - Lab setup closed environment: ideal condition of a single light source
  - Public indoor open environment: multiple light sources including sunlight
- Total 225 images
  - 150 images for training
  - 75 images for test

Closed environment

Open environment

Experimental result

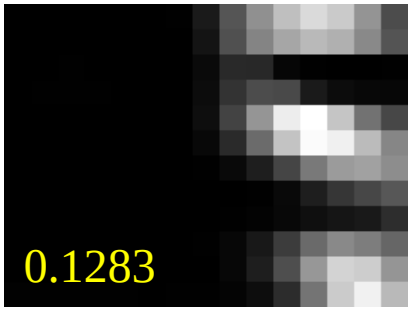
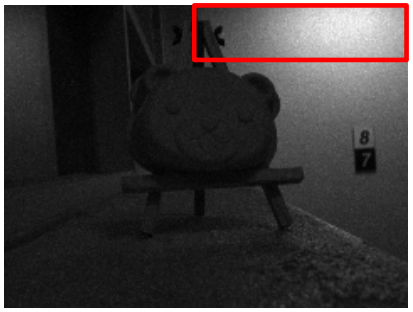
- Optimizer: Adam
- Batch size: 16
- Learning rate: 0.001
- Number of adjacent frames for the input (N): 9
- Loss: angular error

Comparisons with learning based methods

	Bianco et al. [4]	FC4 [5]	Proposed
Average angular error	1.79	2.26	0.95

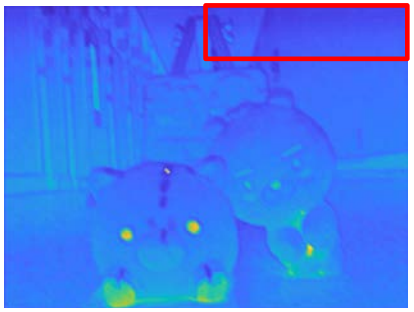
[4] S. Bianco, C. Cusano, and R. Schettini, "Color constancy using CNNs," *in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp.81-89,2015.
[5] Y. Hu, B. Wang, and S. Lin, "FC4: Fully convolutional color constancy with confidence-weighted pooling", *in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp.4085-4094,2017. .

Experimental result

Input	Maximum gradient map	Confidence map	Corrected image
			
			

- Bright region in maximum gradient map: more affected by illuminant, because stronger illumination leads to larger fluctuation
- Regions illuminated a lot by AC light bulbs are learned to be highly confident
- It would be reasonable to assume that the illuminant can be estimated accurately on regions illuminated strongly by AC lights

Experimental result

Input	Grey index map	Confidence map	Corrected image
			
			

- It shows exceptional case that high confidence regions do not match with the intensity of maximum gradient map [6].
- To analyze the reason, the grey index map of the scene is compared with the confidence map.
- The results show that for weakly illuminated images, grey pixels are helpful for illuminant estimation.

[6] K.-F Yang, S.-B Gao, and Y.-J Li, “Efficient Illuminant Estimation for Color Constancy Using Grey Pixels,” CVPR2015, pp.2254-2263,2015.

Conclusion

- We proposed a novel temporal color constancy method via deep learning under AC light sources.
- Sinusoidal variations of AC lights are used for illuminant estimation. The proposed network consists of two subnets for estimating local illuminants and its confidence.
- The confidence of local illuminant estimation is learned from max gradient of intensity variations.
- The proposed method can achieve better performance than state-of-the-art methods.

Thank you