Fast Near Infrared Fusion-Based Adaptive Enhancement of Visible Images

By

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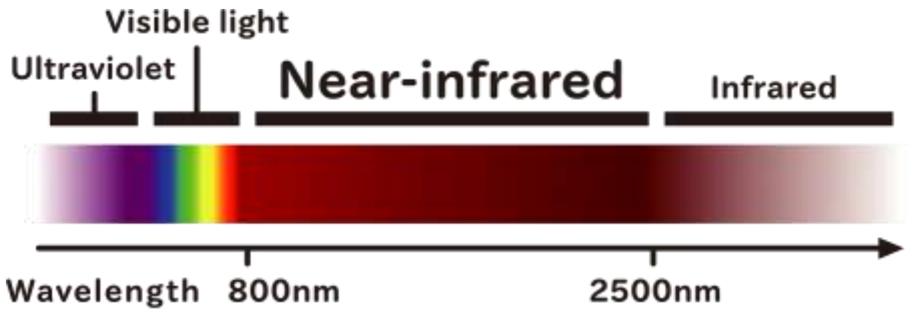
Outline

- Introduction
- Previous Visible & Near-Infrared Fusion Approaches
- Proposed Fast Adaptive Fusion Approach
- Complexity analysis
- Experimental Results
- Conclusion

Visible (VS) Band

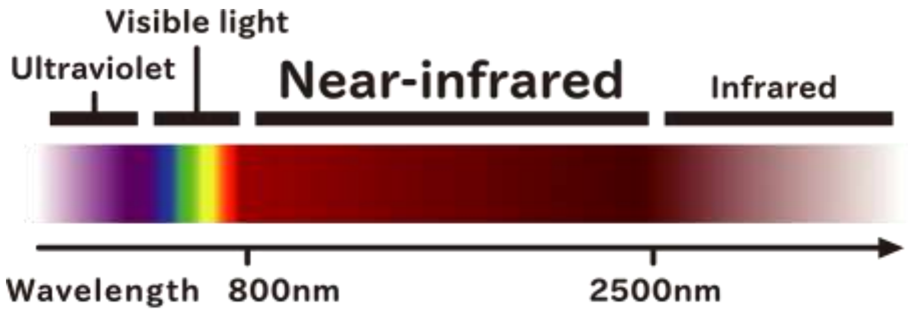


- Captures λ ∈ [400, 700] nm
- Suffer from degradation
  - Haze, mist, fog, overwhelming/poor lighting

(VS)

(NIR)

Near Infra-red (NIR) Band



- Captures λ ∈ [650, 1650] nm
- Properties:
  + Propagate well in challenging imaging conditions
  – Material dependent, so some details about objects made from the same material may be lost.

(VS)

(NIR)

Why VS & NIR Fusion?

- VS and NIR can capture complementary spectral radiations

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- VS and NIR can capture complementary spectral radiations
- Fusion exploits the complementary details provided by VS and NIR images in order to
  - Enhance VS image
  - Image de-hazing

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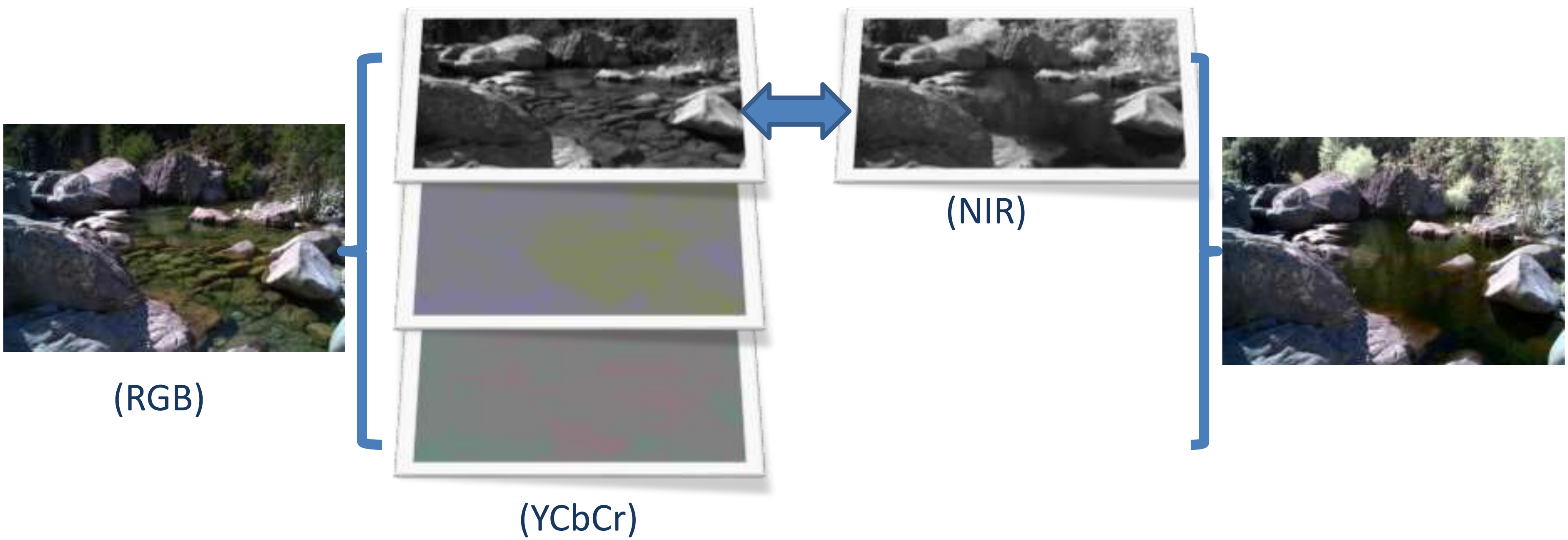
Previous VS-NIR Fusion Approaches (1)

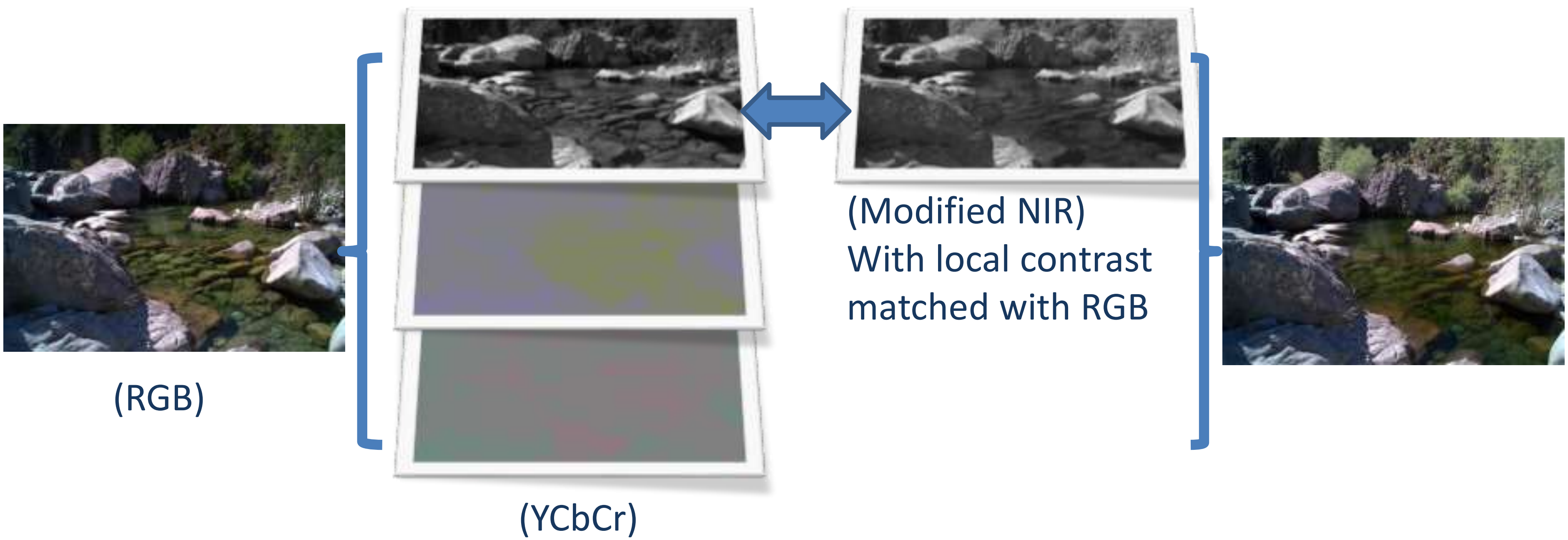
1st approach: replace either a color plane or the luminance plane of the VS image with the NIR one [1]



Drawback: VS image degraded when NIR image suffers from details loss in some areas.

Previous VS-NIR Fusion Approaches (2)

2st approach: alter the pixel values of NIR to match the luminance plane of the VS image while preserving the local contrast of the NIR image[2].



Better result but VS image still degraded when NIR image suffers from details loss in some areas.

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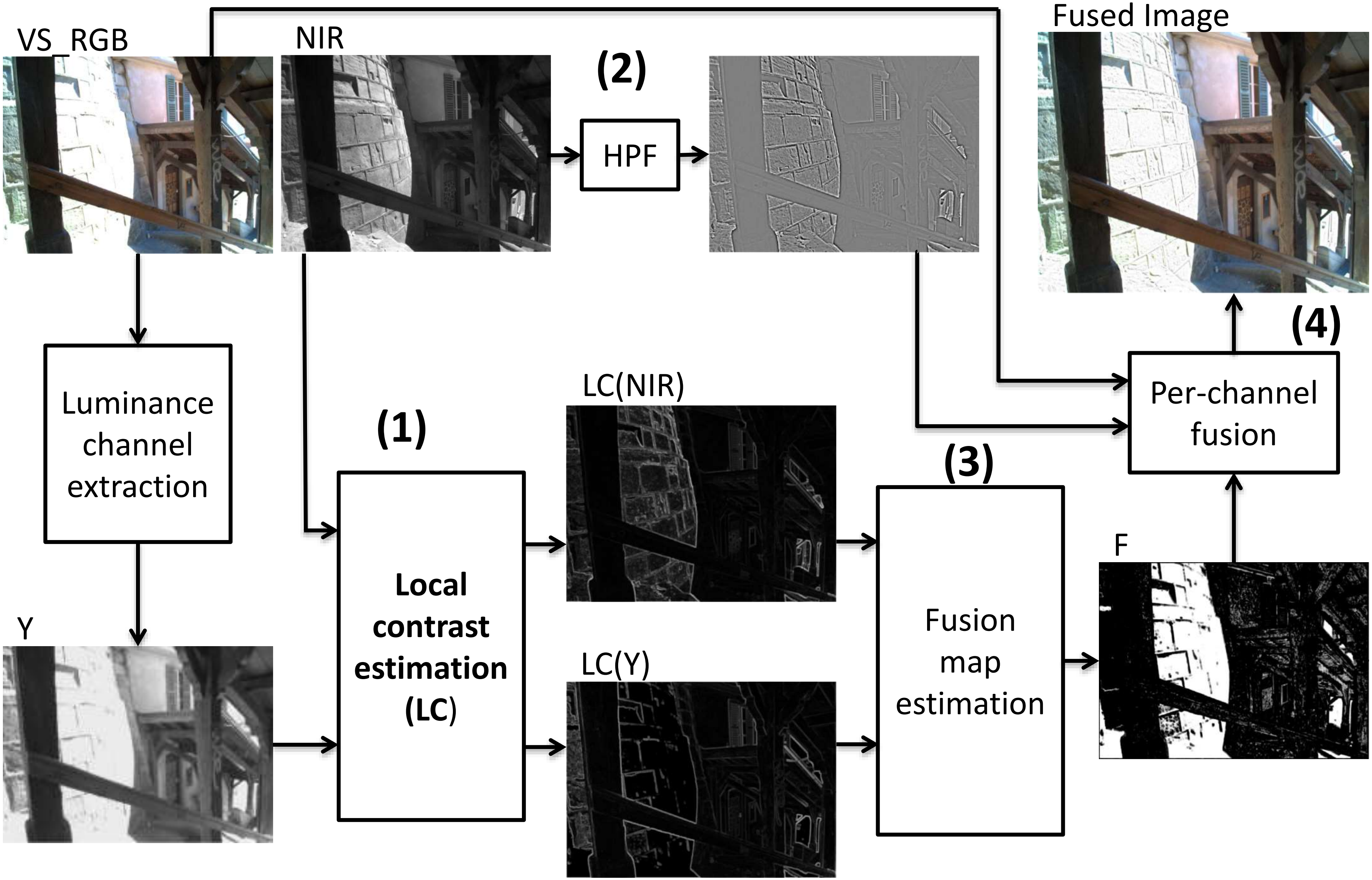
Proposed Fast VS-NIR Fusion Approach

- We propose a fast VS-NIR fusion approach to achieve better VS image enhancement.
- Key features
  - Spatial details which are only **apparent** in NIR and **lost** in VS should be incorporated into the fused image.
  - The **spectral contents (colors**) of VS should be **preserved** after fusion.

Block Diagram

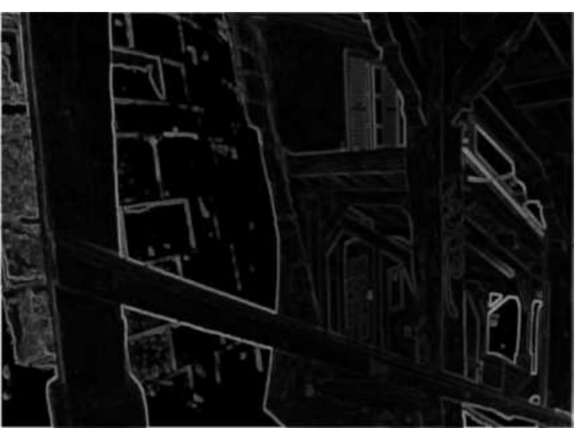


(1) Local Contrast Estimation

- Inspired by [3], our local contrast is defined as

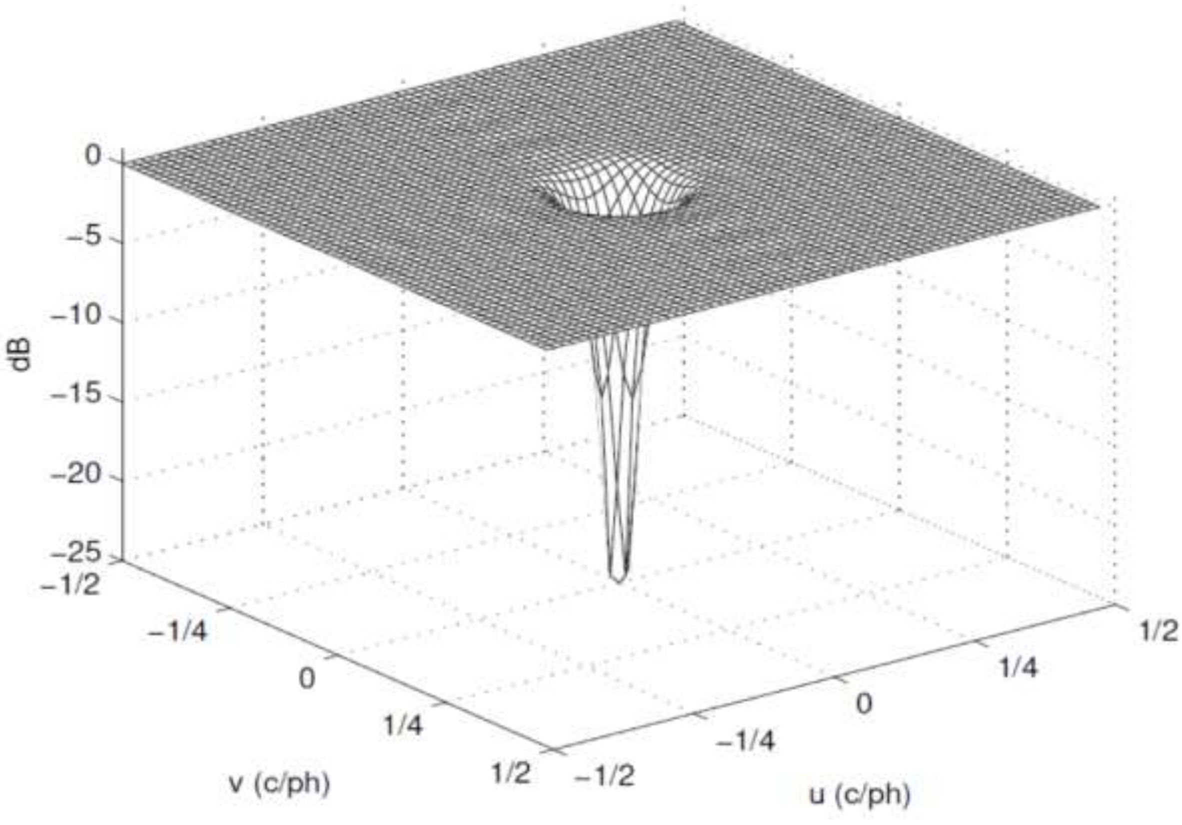
$$LC\left(I\left(\mathbf{x}\right)\right) = \alpha\left(\max_{\mathbf{x}'\in\mathcal{N}\left(\mathbf{x}\right)} I\left(\mathbf{x}'\right) - \min_{\mathbf{x}'\in\mathcal{N}\left(\mathbf{x}\right)} I\left(\mathbf{x}'\right)\right) +$$

$$\left(1-\alpha\right)\left(\max_{\mathbf{x}'\in\mathcal{N}\left(\mathbf{x}\right)} \left\|\nabla I\left(\mathbf{x}\right)\right\|\right),$$

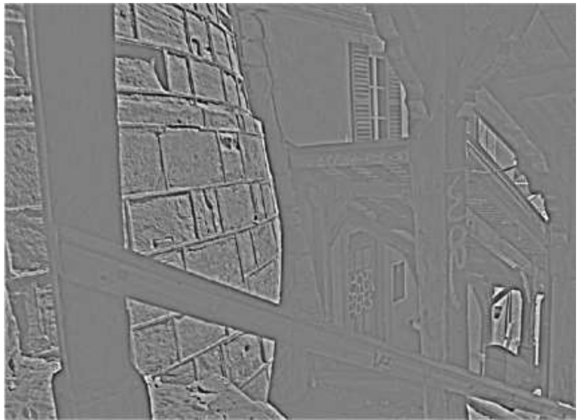


(2) Spatial details exctraction from NIR

- High pass filter is designed to extract the higher frequency contents (spatial details) of NIR



HPF



(3) Fusion Map Estimation

- Fusion map determines the regions that suffer from missing spatial details in VS compared to NIR

$$F(\mathbf{x}) = \frac{\max\left(0, LC\left(I^{\mathrm{NIR}}(\mathbf{x})\right) - LC\left(Y^{\mathrm{RGB}}(\mathbf{x})\right)\right)}{LC\left(I^{\mathrm{NIR}}(\mathbf{x})\right)}$$

(4) VS-NIR Fusion

- Given
  - Estimated fusion map

(4) VS-NIR Fusion

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(4) VS-NIR Fusion

- Given
  - Estimated fusion map
  - Extracted spatial details from NIR
- Fused image is generated as

$$J^{\mathrm{RGB}}(\mathbf{x}) = I^{\mathrm{RGB}}(\mathbf{x}) + F(\mathbf{x})\left(g * I^{\mathrm{NIR}}\right)(\mathbf{x})$$

J^{RGB}

I^{RGB}

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Complexity Analysis

- Proposed algorithm is non iterative and has low computational complexity

Operation	Add/sub (A)	Mult/div (M)	Comparison (C)
Local contrast estimation	9	10	$3S^2$
Fusion map estimation	1	1	1
Fused image generation	k^2+3	k^2+1	0

$$\mathbb{C}(n) = n\left(\mathrm{A}\left(k^2+13\right)+\mathrm{M}\left(k^2+12\right)+\mathrm{C}\left(3S^2+1\right)\right)$$
$$= \mathbb{O}(n).$$

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Dataset [1]

- 477 pairs of VS-NIR images organized into 9 categories.
- The images were captured using a modified SLR camera by using an IR-block or IR-pass filter in front of the camera's lens.
- Example

Methods Under Comparison

- We compare the proposed approach with
  - Luminance plane replacement approach [1]
  - Contrast-preserving mapping approach [2]
- Approaches are compared visually. Images shown next are
  - VS
  - NIR
  - Fused image using [1]
  - Fused image using [2]
  - Fusion map
  - Fused image using proposed approach

Example 1

(VS)

(NIR)

Fused image using [1]

Fused image using [2]

Fusion map

Fused image using prposed approach

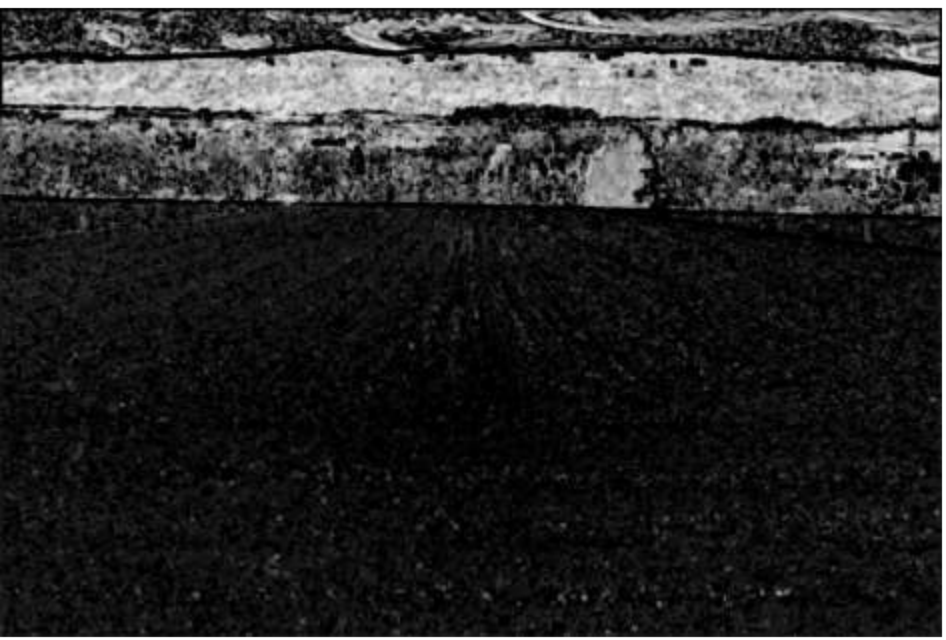
Example 2

(VS)

(NIR)

Fused image using [1]

Fused image using [2]



Fusion map

Fused image using prposed approach

Example 3

(VS)

(NIR)

Fused image using [1]

Fused image using [2]

Fusion map

Fused image using prposed approach

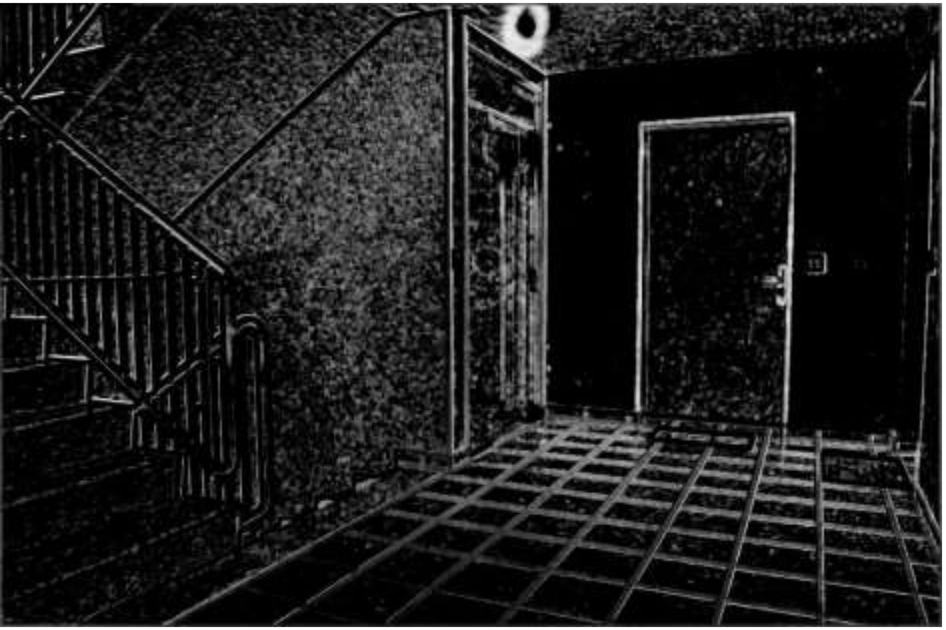
Example 4

(VS)

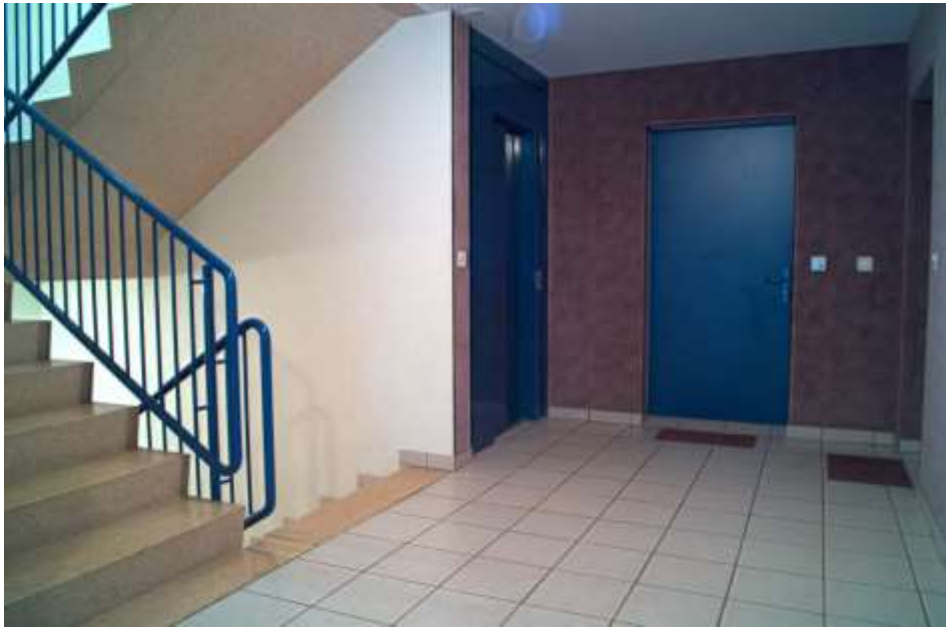
(NIR)

Fused image using [1]

Fused image using [2]



Fusion map



Fused image using prposed approach

Conclusion

- We propose a fast, non-iterative VS-NIR fusion approach to achieve adaptive VS enhancement
- Key advantages
  - Adaptively prevents unnecessary boosting of spatial details
    - Only **spatial details apparent** in NIR and **lost** in VS are incorporated into the fused image.
  - **Preserve spectral contents (colors**) of VS after fusion.
  - **Fast** and **low computational complexity**
    - Perform fusion of 682×1024 image pair in 0.7 sec.
    - Suitable for embeded hardware implementation

References

[1] C. Fredembach and S. Süsstrunk, “Colouring the near-infrared,” *Color and Imaging Conference*, vol. 2008, no. 1, pp. 176 182, 2008.

[2] C. H. Son, X. P. Zhang, and K. Lee, “Near-infrared coloring via a contrast-preserving mapping model,” in *IEEE Global Conf. on Signal and Information Proc. (GlobalSIP),* Dec 2015, pp. 677– 681.