IMAGE FUSION THROUGH LINEAR EMBEDDINGS

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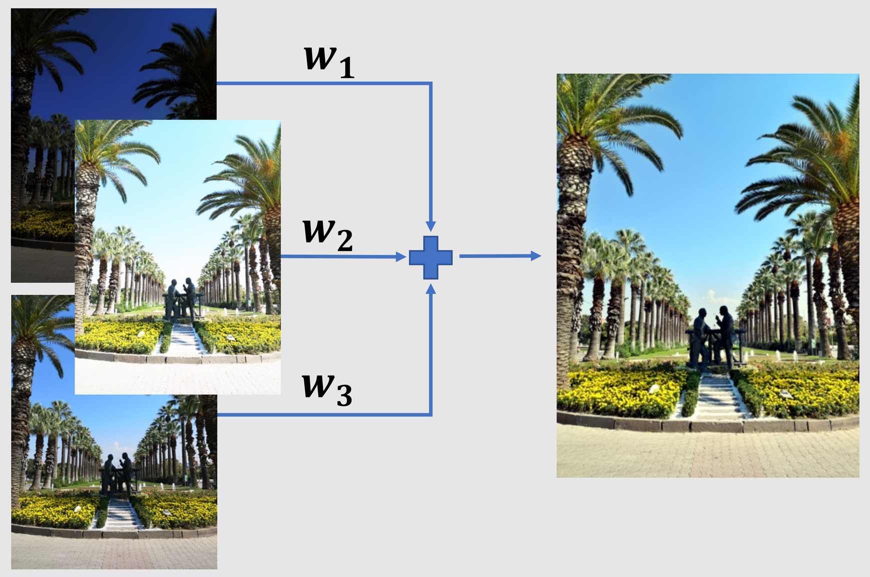
Problem-Context Definition

- Fuse images to create more informative content
- Severely over-exposed images result in faulty weight maps
- New framework for weight map characterization
- A method for MEF and its extension to visible-infrared image fusion

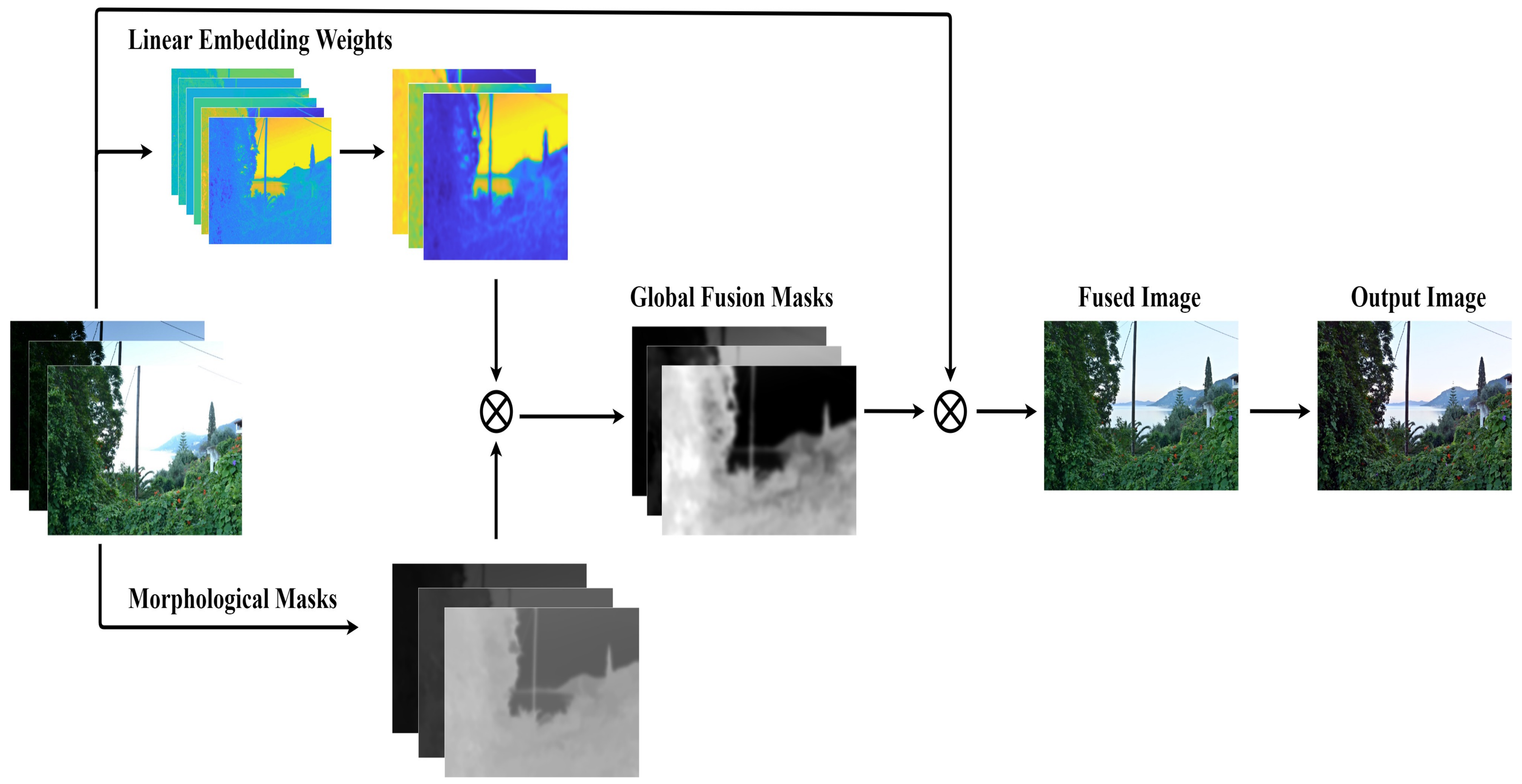
Proposed Multi-Exposure Image Fusion Algorithm

- Creating HDR-like content from stack of LDR images



w_i : weight maps for each input image

- Preserving
  - Fine details
  - Vivid colors
- By taking advantage of
  - Image Fusion
  - Linear Embeddings
  - Morphological Masking



Contributions

A novel and effective image fusion framework:

- Weight map characterization via linear embeddings (LE)
- Map refinement via adaptive morphological operation
- First study benefiting from LE for weight extraction in image fusion

Determination of exposures

- Obtain PDFs to form feature vectors
- Apply k-means clustering method to group all exposures (k = 3)
- Apply sliding window technique to each set to obtain 3 exposures

Adaptive morphological masking

- Natural texture
- Remove small blemishes without damaging overall structures

# of darkest pixel intensity $\mathcal{U}$ < # of brightest pixel intensity $\mathcal{O}$, $r^* = 20$
# of darkest pixel intensity $\mathcal{U}$ > # of brightest pixel intensity $\mathcal{O}$, $r^* = 11$

✓ Opening-by-reconstruction operation → Closing-by-reconstuction

Fusion

➢ **Global Fusion Masks**

$\mathbf{G}_1 = \mathbf{M}_1 \otimes \mathbf{E}_3$ $\mathbf{G}_2 = \mathbf{M}_2 \otimes \mathbf{E}_2$ $\mathbf{G}_3 = \mathbf{M}_3 \otimes \mathbf{E}_1$

✓ Top 1% & Bottom 1% pixel values of $\mathbf{G}_2$ stretch to obtain a more balanced $\mathcal{N}$

$$\mathbf{F} = \mathrm{U} \otimes \mathbf{G}_1 + \mathrm{N} \otimes \mathbf{G}_2 + \mathrm{O} \otimes \mathbf{G}_3$$

✓ Top 1% & Bottom 1% pixel values of $\mathbf{G}_2$ saturated to obtain a more balanced $\mathcal{N}$

Weight maps via linear embeddings

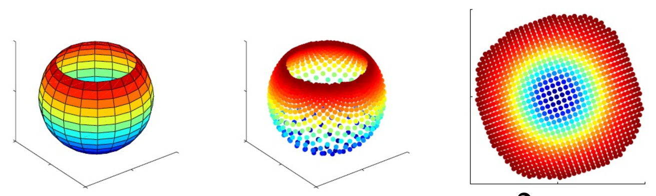
$$\{\mathbf{W}_i^1, \mathbf{W}_i^2\} = \arg\min_{\{w_1,w_2\}} \left\| \boldsymbol{o}_i - [\boldsymbol{u}_i \;\; \boldsymbol{n}_i] \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} \right\|_2^2 \quad s.t \;\; w_1 + w_2 = 1$$

$$\{\mathbf{W}_i^3, \mathbf{W}_i^4\} = \arg\min_{\{w_3,w_4\}} \left\| \boldsymbol{u}_i - [\boldsymbol{n}_i \;\; \boldsymbol{o}_i] \begin{bmatrix} w_3 \\ w_4 \end{bmatrix} \right\|_2^2 \quad s.t \;\; w_3 + w_4 = 1$$

$$\{\mathbf{W}_i^5, \mathbf{W}_i^6\} = \arg\min_{\{w_5,w_6\}} \left\| \boldsymbol{n}_i - [\boldsymbol{u}_i \;\; \boldsymbol{o}_i] \begin{bmatrix} w_5 \\ w_6 \end{bmatrix} \right\|_2^2 \quad s.t \;\; w_5 + w_6 = 1$$

$\boldsymbol{o}_i, \boldsymbol{n}_i, \boldsymbol{u}_i$ are kernel of Over, Normal, Under Exposed images, respectively

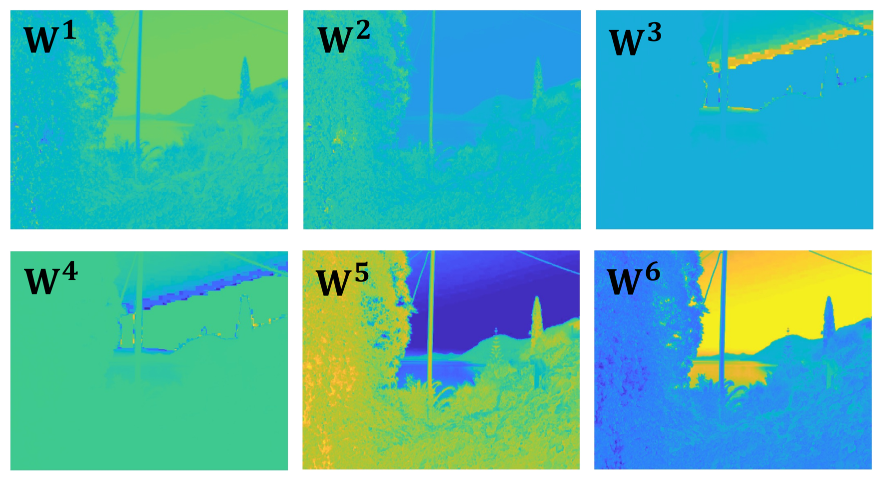
$\mathbf{W}_{1,2}^j$ are optimal weights



Inspired from LLE[2]

Main Idea

- Preserve
  - Intrinsic geometric characteristics of the manifold
- ➢ Sparsity constraint
  - ➢ Only neighbors of the patch are of interest
- ➢ Sum-to-one constraint
  - ➢ Enforces invariance to rotations, rescalings, translations

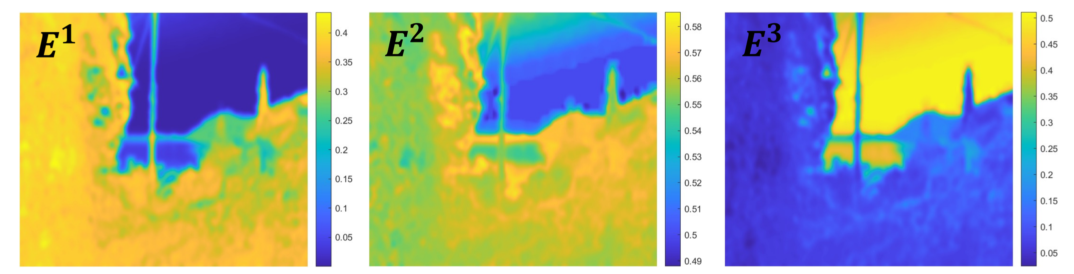


To obtain LE weights

$\mathbf{E}_1' = (|\mathbf{W}_1| + |\mathbf{W}_5|) * \mathcal{G}$, $\mathbf{E}_2' = (|\mathbf{W}_2| + |\mathbf{W}_3|) * \mathcal{G}$, $\mathbf{E}_3' = (|\mathbf{W}_4| + |\mathbf{W}_6|) * \mathcal{G}$

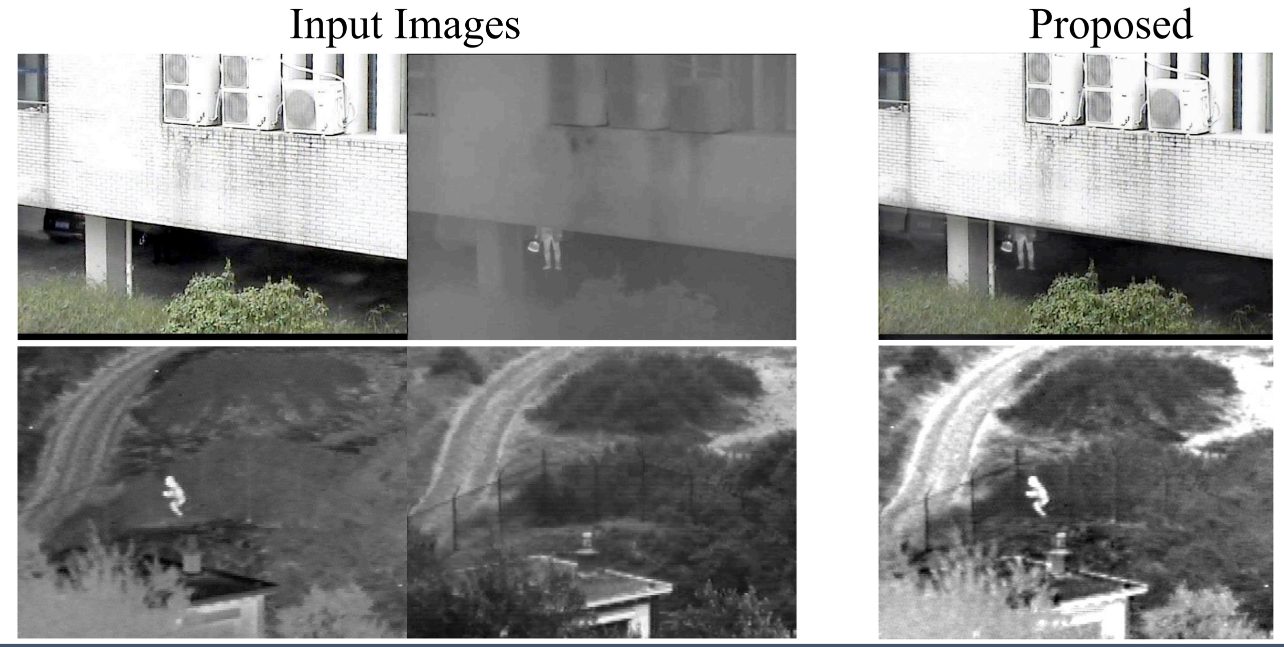
$\mathbf{E}_k = \mathbf{E}'_k \oslash (\mathbf{E}_1' + \mathbf{E}_2' + \mathbf{E}_3')$, $k = 1,2,3$

$\mathcal{G}$ Gaussian Filter
$*$ Convolution operation
$\oslash$ Element-wise division



Results for Multi-Exposure Image Fusion

Application for Visible-Infrared Image Fusion*



* Not optimized yet

1) O.Ulucan , D.Karakaya and M.Turkan. (2021) Multi-exposure image fusion based on linear embeddings and watershed masking. *Signal Processing* , Vol. 178, No. 107791
2) Roweis, S. T. and Saul, L. K. (2000) *Nonlinear dimensionality reduction by locally linear embedding*, Science, Vol. 290(5500), pp. 2323–2326.

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