Supplementary material

(1) Objective quality fusion measure Q_w (Piella and Heijmans, 2003; Wang et al., 2004; Petrovic, 2007; Piella, 2009; Fang et al., 2013)

Given u_n:n=1,...,M multi-source input images, and u_0 output fused image, the objective quality fusion measure Q_w is defined as

$$Q_w = \sum_{n=1}^{M} \sum_{w \in W} I_n(w) Q_0(u_n, u \mid w),$$

where $I_n(w) = \lambda \times s(u_n \mid w) \times \max(s(u_n \mid w))$ is the local weight indicating the relative importance of input image u_n in window w, W is the family of all windows, λ is the normalization parameter and $s(u_n \mid w)$ is the local relevance (for example entropy and contrast) of image u_n within the window w.

$Q_0(u_n, u \mid w) = \frac{2\overline{u_n u} + C_1}{\overline{u_n^2} + \overline{u^2} + C_1} \times \frac{2\sigma u_n \sigma_u + C_2}{\sigma_{u_n}^2 + \sigma_u^2 + C_2} \times \frac{\sigma_{u_n,u} + C_3}{\sigma u_n \sigma_u + C_3}$ is the local similarity of fused image u and original image u_n given by the structural similarity index, where $\bar{u}$ is the mean of u; and σ_u^2 and $\sigma_{u_n,u}$ are the variance of u and covariance of u_n, u, respectively. The larger the value of Q_w, the better the fused result.

(2) Objective image fusion performance measure Q^f (Xydeas and Petrovic, 2000; Fang et al., 2013)

The normalized weighted objective image fusion performance measure reflects the quality and precision of perceptually important information obtained from the fusion of input images. The original measure is a criterion of two-image fusion performance. We now extend this measure to a multiple image fusion task, which is given by

$$Q^f = \frac{\sum_{n=1}^{N} \int_{\Omega} Q^{u_n,u}(x) \omega^{u_n}(x) \mathrm{d}x}{\sum_{n=1}^{N} \int_{\Omega} \omega^{u_n}(x) \mathrm{d}x},$$

where $\omega^{u_n}(x)$ is a weight and $Q^{u_n,u}(x) \in [0, 1]$ is an edge information preservation value. $Q^{u_n,u}(x) = 0$ denotes the complete loss of edge information, and $Q^{u_n,u}(x) = 1$ indicates fusion from u_n to u without any waste of information. For $0 \le Q^f \le 1$, a closer value of Q^f to 1 indicates more accurate fusion.

(3) VIFF

VIFF is an objective index for measuring the visual information of images defined as (Han et al., 2013)

$$\mathrm{VIFF}(I_1, \cdots, I_n, I_F) = \sum_k p_k \times \mathrm{VIFF}_k(I_1, \cdots, I_n, I_F),$$

where p_k is a weighting coefficient,

$$\mathrm{VIFF}_k(I_1, \cdots, I_n, I_F) = \frac{\sum_b \mathrm{FVID}_{k,b}(I_1, \cdots, I_n, I_F)}{\sum_b \mathrm{FVIND}_{k,b}(I_1, \cdots, I_n, I_F)}.$$

$\mathrm{FVID}_{k,b}$ represents the fusion visual information with distortion extracted from the source images $\mathrm{FVIND}_{k,b}$ refers to the fusion visual information without distortion and b and k represent the b^{th} block and k^{th} sub-band of an image, respectively. A larger VIFF suggests an improved-high quality image.

(4) AG

The AG is sensitive to subtle details of the image and can be used to define the contrast and clarity of an image. Average gradient is calculated as (see Liu et al., 2006)

$$\mathrm{AG} = \frac{1}{|\Omega|} \int_\Omega \sqrt{\left(\frac{\partial u}{\partial x_1}\right)^2 + \left(\frac{\partial u}{\partial x_2}\right)^2}.$$

Generally, a greater AG indicates a better fusion result.

(5) Entropy (E)

E is an index for measuring image information. The definition of E can be shown as (Huang and Zhao, 2006)

$$\mathrm{E} = -\sum_{i=0}^{L-1} p_i \log_2(p_i),$$

where p_i is the probability of the i^{th} grey in the image, and L is the grey level. Large entropy means rich detail information and a better result.

(6) Mutual Information (MI)

MI (Qu et al., 2002; Piella, 2009; Gao et al., 2013) is a measurement of the fused image and each input, which is defined as

$$\mathrm{MI}(u_m, u) = \frac{\sum_{n=1}^{N} M(u_n; u)}{\sum_{n=1}^{N} H(u_n)},$$

where H denotes the entropy, and $M(u_n;u)$ is the mutual information between u_n and u. Generally, greater MI results in a clearer image.

(7) Spatial Frequency (SF)

SF represents the activity of image in the space domain, which is defined as (Maruthi and Sankarasubramanian, 2007; Gao et al., 2013)

$$\mathrm{SF} = \sqrt{\mathrm{RF}^2 + \mathrm{CF}^2} \ ,$$

where $\mathrm{RF} = \sqrt{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[u(i,j) - u(i,j-1)\right]^2}$ and

$\mathrm{CF} = \sqrt{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[u(i,j) - u(i-1,j)\right]^2}$. A large spatial frequency means a better definition.

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