Assignment Report:

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Image Fusion with Guided Filtering

Synopsis:

- Through image fusion, different images of the same scene can be combined into a single fused image.
- A good fusion algorithm takes care of the following:
  - It can preserve most of the useful information of different images.
  - It does not produce artifacts.
  - It is robust to imperfect conditions such as mis-registration and noise.
- The proposed method is based on a two-scale decomposition of an image into a base layer containing large scale variations in intensity, and a detail layer capturing small scale details. A novel guided filtering-based weighted average technique is proposed to make full use of spatial consistency for fusion of the base and detail layers.
- **Guided Filter:**
  The guided filter assumes that the filtering output O is a linear transformation of the guidance image I in a local window ω_k centered at pixel k.
  $O_i = a_k I_i + b_k \quad \forall \quad i \in \omega_k$
  Where ωk is a square window of size (2r+1)×(2r+1) and a_k and b_k are constants in ω_k and can be estimated by minimizing the squared difference between the output image O and the input image P.

$$E(a_k, b_k) = \sum_{i \in \omega_k} \left((a_k I_i + b_k - P_i)^2 + \epsilon a_k^2 \right)$$

a_k and b_k obtained by minimizing the above expression are given as follows:

$$a_k = \frac{\frac{1}{|\omega|}\sum_{i \in \omega_k} I_i P_i - \mu_k \overline{P}_k}{\delta_k + \epsilon}$$
$$b_k = \overline{P}_k - a_k \mu_k$$

The filtering output can be given by

$$O_i = \overline{a}_i I_i + \overline{b}_i$$

Where $\overline{a}_i = \frac{1}{|\omega|}\sum_{k \in \omega_i} a_k,\ \overline{b}_i = \frac{1}{|\omega|}\sum_{k \in \omega_i} b_k$

➢ Image fusion with guided filtering

- Two-Scale Image Decomposition :
  - ➢ The source images are first decomposed into two-scale representations by average filtering. The base layer (B_n) can be obtained by convolving the source images with a simple averaging filter.
  - ➢ The detail layer can be easily obtained by subtracting the base layer from the source image.

$$D_n = I_n - B_n$$

The two-scale decomposition step aims at separating each source image into a base layer containing the large-scale variations in intensity and a detail layer containing the small- scale details.

- Weight Map Construction With Guided Filtering :
  - Laplacian filtering is applied to each source image to obtain the high-pass image H_n.

$$H_n = I_n * L$$

  - Local average of the absolute value of H_n is used to construct the saliency maps S_n.

$$S_n = |H_n| * g_{r_g, \sigma_g}$$

  - The saliency maps are compared to determine the weight maps as follows

$$P_n^k = \begin{cases} 1 \text{ if } S_n^k = \max\left(S_1^k, S_2^k, \ldots, S_N^k\right) \\ 0 \text{ otherwise} \end{cases}$$

  - Guided image filtering is performed on each weight map P_n with the corresponding source image I_n serving as the guidance image to obtain the base and detail weights.

$$W_{nB} = G_{r_1, \varepsilon_1}(P_n, I_n), \quad W_{nD} = G_{r_2, \varepsilon_2}(P_n, I_n)$$

- Two scale image reconstruction
  - Two-scale image reconstruction consists of the following two steps.
  - First, the base and detail layers of different source images are fused together by weighted averaging and then the fused image F is obtained by combining the fused base layer B and the fused detail layer D.

$$\overline{B} = \sum_{n=1}^{N} W_n^B B_n$$

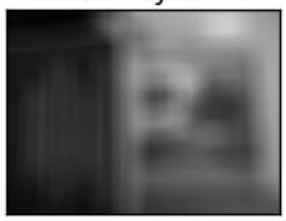
$$\overline{D} = \sum_{n=1}^{N} W_n^D D_n$$

$$F = \overline{B} + \overline{D}$$

Image Fusion Process:

Original Image I1

Base Layer B1



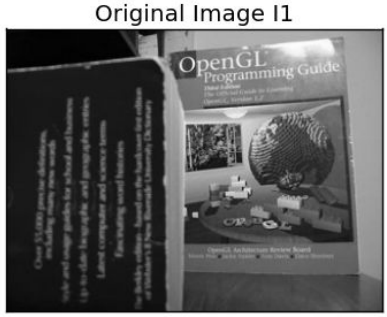
Detail Layer D1

Original Image I2

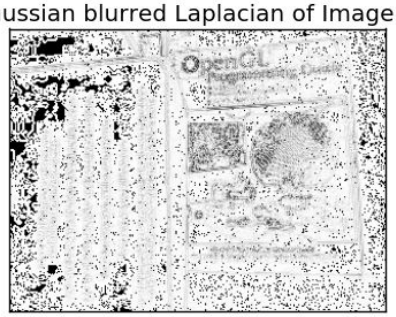
Base Layer B2

Detail Layer D2

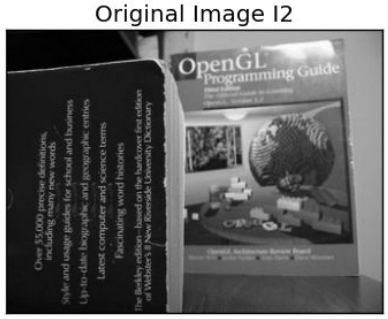
Original Image I1



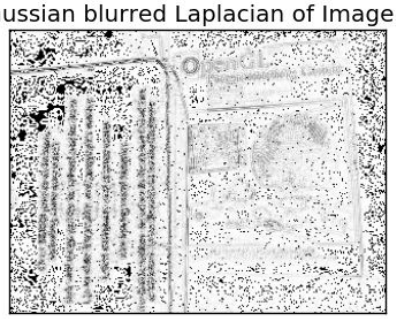
Gaussian blurred Laplacian of Image I1



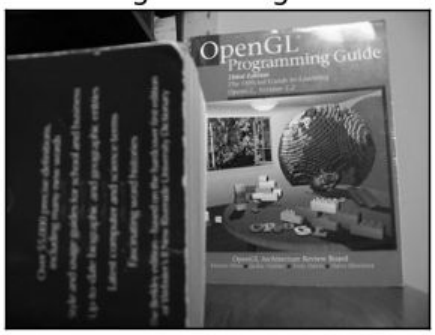
Original Image I2



Gaussian blurred Laplacian of Image I2

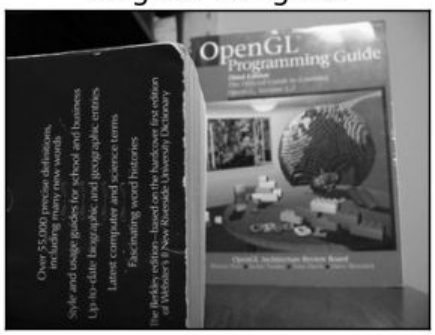


Original Image I1



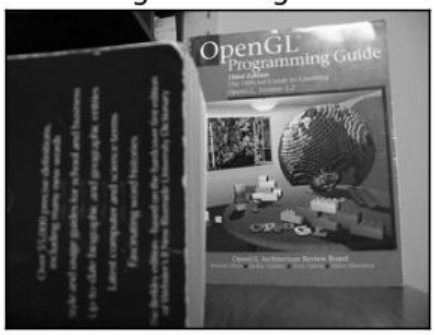
Weight Maps P1

Original Image I2



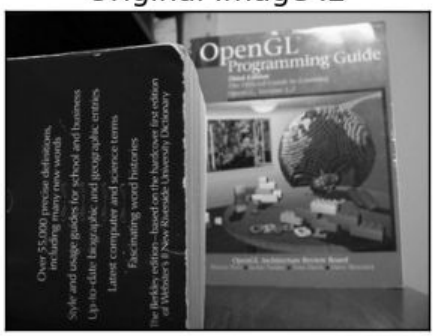
Weight Maps P2

Original Image I1

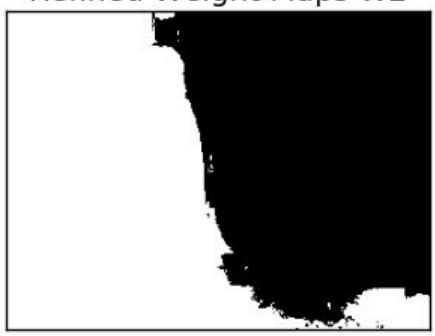


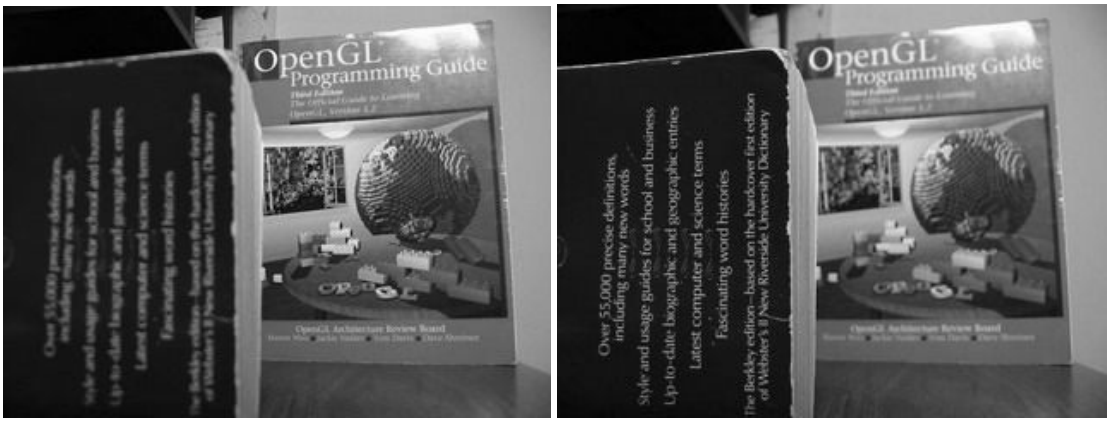
Refined Weight Maps W1

Original Image I2

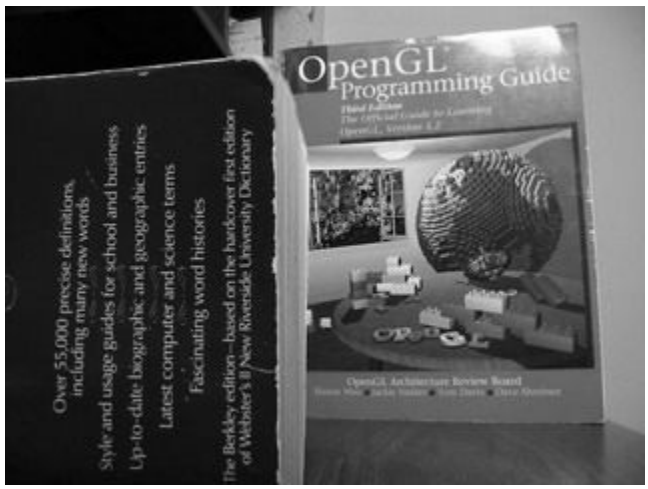


Refined Weight Maps W2





Input Images



Final Fused Image