The Fusion of Exposure Bracketed Pairs

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I. Motivation

Many cameras today offer a setting called "bracketing". With this setting, the camera will take multiple pictures with different exposures in succession and allow the user to pick the "best" one.

Figure 1. short exposure image has sharp details but low brightness, poor colors, and noise.

Figure 2. Long exposure image contains poor details but has no noise and good colors.

The Bertalmío-Levine model[1] performs especially well on exposure bracketed images with nonlinear but low range motion.

Figure 3. Fusion of Figure 1 and Figure 2 using model from (1).

II. Objectives

- Combine long and short exposure images without accenting noise or losing detail.
- Extend exposure bracketing model to video (ie., Propagate the color from one long exposure image to short exposure frames)
- Extend exposure bracketing model to color transfer (ie., Transfer color from one image to a grayscale image)

III. Model

Given an long exposure image I_u and an short exposure image I_o , we want to create an image I that combines the sharp detail of I_u and colors of I_o. This method uses an image functional $E(I)$ with two terms.

A. Gradient Direction Term:

$$E_g(I) := \int_\Omega \left(|\nabla I(x)| - \nabla I(x) \cdot \frac{\nabla I_u(x)}{|\nabla I_u(x)|} \right) \mathrm{d}x$$

The minimizer, I, of $E_g(I)$ has the same normalized gradient direction field as I_u, forcing the edges of the two images to coincide.

B. Color Matching Term:

We want the colors of our fused Image I to match the colors of I_o. However, transferring color globally produces artifacts in the image due to occlusions and motion. By minimizing the following functional, the local histograms of I_o will match that of I.

$$E_h(I) := \frac{2}{WH} \iint w(x,y)|I(x) - \tilde{I}_o(y)|\, dxdy + \frac{1}{WH} \iint w(x,y)|I(x) - I(y)|\, dxdy$$

where W and H are the dimensions of the image domain, $w(x,y)$ is a decreasing function of the distance $\|x\text{-}y\|$, and $\tilde{I}_o$ is a warped version of I_o that has similar geometry to I_u.

C. Total Energy:

After combining the above energy terms, we produce the following functional, $E(I)$, whose minimization will produce the desired fusion result:

$$E(I) = E_g(I) + \lambda E_h(I)$$

where $\lambda > 0$ is a fixed constant.

IV. Results

A. Exposure Bracketed Pairs:

Figure 4. Left, short exposure image.

Figure 5. Right, long exposure image.

Figure 6. Left, fused image using (1) (difficulties with occlusion and large range motion).

Figure 5 reflects the large amounts of occlusion between the two images.

B. Color Transfer:

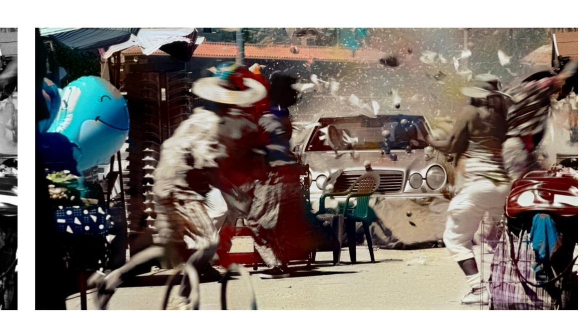
Figure 7. Left, long exposure still image.

Gray Video Frames: *Fusion Results:*

Gray Frame 1

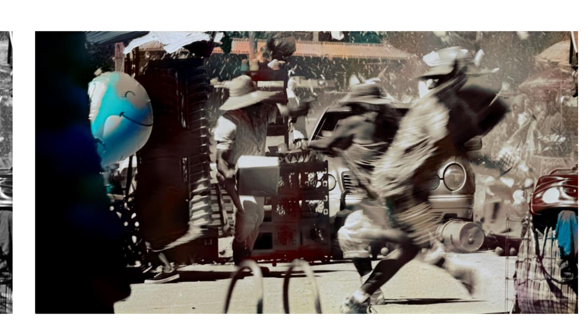
Fused Frame 1

Gray Frame 10



Fused Frame 10

Gray Frame 20



Fused Frame 20

V. Future Work

Nonlinear motion is difficult to deal with. The model in (1) handles this type of motion well in the low range case. However, as motion range increases, problems arise due to occlusions that cause discoloration and blur.

In IV.A, the long exposure image was taken before the short exposure image, giving the impression that the short exposure image captured more movement. As a result, discoloration appears along the window of the bus in Figure 6. It might be possible to avoid this issue in the future by segmenting our image pair; choosing specific regions to use for detail in one image and specific regions to use for color in the other.

Extending the idea of image segmentation further, we could choose specific regions for detail and color over multiple images and then fuse these images together. This idea seems most practical with video and has applications to High Dynamic Range (HDR) imaging.

In IV.B, there are some objects that move a lot over each frame and other objects that remain still. By tracking the amount of motion of different regions between frames, we could treat still objects and moving objects more accurately.

VI. References

1. M. Bertalmío and S. Levine, "Variational approach for the fusion of exposure bracketed pairs," *IEEE Trans. Image Process.*, 22 (2013), pp. 712–723.
2. M. Bertalmío and S. Levine, "Fusion of Bracketing Pictures," *in Visual Media Production, 2009. CVMP'09. Conference for.* IEEE, 2009, pp. 25–34.

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