Enhanced Image Capture Through Fusion

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ABSTRACT

Image fusion may be used to combine images from different sensors, such as IR and visible cameras, to obtain a single composite with extended information content. Fusion may also be used to combine multiple images from a given sensor to form a composite image in which information of interest is enhanced.

We present a general method for performing image fusion and show that this method is effective for diverse fusion applications. We suggest that fusion may provide a powerful tool for enhanced image capture with broad utility in image processing and computer vision.
The Fusion Task

Changing Parameters
(iris, exposure, focus)

Changing Sensor
(IR, visible)

Changing Illumination

Scene of Interest

Occluding Object
(smoke, foreground object)

Set of Source Images
$I_1, I_2, I_3, I_m$

Set of Fused Images
$F_1, F_n$

FUSION
Image Fusion: Objectives

Combine two or more source images to obtain a single composite with extended information content.

Requirements

- retain all useful information from the source images
- not introduce fusion artifacts into the combined image
- look "natural"
Technical Challenge

Pixel averaging, results in ...

1. Loss of Contrast
Technical Challenge

Pixel averaging, results in ...

2. Double Exposure
Pixel-Based Approach

- each output pixel is computed separately
- based on the corresponding source image pixels
- or neighborhoods of corresponding pixels
Pattern-Selective Approach

- copy a pattern at a time
- select most salient patterns only
Composite Imaging

Signal domain

Broadband Image

Set of Narrowband Images

Fusion

Composite Image
<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Description</th>
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<tbody>
<tr>
<td>1983</td>
<td>Burt</td>
<td>model of human binocular vision</td>
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<td>1984</td>
<td>Adelson</td>
<td>multi-focus</td>
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<td>1990</td>
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<td>noise model</td>
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<td>1992</td>
<td>Tinkler</td>
<td>TI method</td>
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</table>
Laplacian Pyramid Transform

Gaussian

RE
Laplacian

Gaussian
Reconstructed
Gradient Pyramid Framework for Image Fusion

Source Image A
Source Pyramid $D_A$

Source Image B
Source Pyramid $D_B$

Composite Pyramid $D_C$
Composite Image C

Select

$M_{ab}$

$S_A$

$S_B$
Composition Based on
Scaled Relative Gradients

$I_A$

$I_B$

$I_C$
Sealed Gradient Operators

\[ G(x, y) \]

\[ \frac{d}{dx} G \]
Gradient Pyramid Transform
Multi-focus example of gradient pyramid fusion. (a and b) Source images obtained with a camera lens set to focus at different distances. (c) The fused image has an extended depth of field.
Multi-exposure example of gradient pyramid fusion. (a and b) Source images obtained with different camera exposure settings to observe patterns in shaded regions (a) and bright, sun-lit regions (b). (c) The fused image includes detail from both regions. (d) Pyramid samples values are normalized and quantized to just 4 bits to demonstrate that a broad dynamic range scene can be represented by a narrow dynamic range signal without loss of critical detail.
A multi-sensor example of gradient pyramid fusion. (a and b) Source images were obtained from a visible light camera (a) and an infrared camera (b). (c) The fused image includes details from both sources.
Summary

- Enhance image capture by combining observations

- Combine to preserve contrast (max gradient)

- Gradient pyramid framework (multiscale)

- Deliberately limit each observation (narrow band)