Enhancing contrast in IR images

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A novel approach to improving the visibility of IR images preserves both global contrast and detailed information by incorporating a simple, popular image-processing technique.

Infrared imaging, which provides visual information not detectable by the human eye, is widely used in both military and, increasingly, commercial applications, such as surveillance and personal hand-held cameras, and night-vision systems in vehicles. Unlike images captured by CCD/CMOS sensors, however, long-wave IR images are typically low-contrast: the IR sensor cannot clearly differentiate the object from the background when both have similar emissivity. As a result, getting better IR images requires contrast enhancement.

Methods proposed for improving performance are generally based either on so-called histogram equalization or on human visual systems. The histogram technique has the advantage of low computational complexity but can produce unwanted artifacts such as over-enhancement and reduction or loss of image detail. Human visual system–based methods, on the other hand, make use of attributes such as contrast sensitivity and luminance masking. They do a good job of enhancing local contrast but distort the global contrast of the original image.

One way of generating visually pleasing images while preserving global contrast is to employ ‘contrast stretching,’ which expands the original range of pixel values. Among many stretching methods, the simplest, called linear stretching, involves normalizing the pixel value range from the minimum to the maximum of the dynamic range of the image. However, this approach fails when images contain small areas with very high or very low levels of gray (see Figure 1). Here, we describe a novel contrast enhancement scheme that simultaneously preserves global contrast and the detailed information of the original image.

As a first approach to the problem, we adopted a mean-based stretching method that selects the range using the mean and standard deviation of the pixel values in the input image. However, results of experiments showed that mean-based stretching leads to a loss of detail in high- or low-luminance areas: see Figure 2, lower left panel, and Figure 3(b). We then decided to combine mean-based stretching with gradient domain processing (GDP), a recently developed and very popular method of manipulating the gradient and pixel values of an image. Figure 2 shows a schematic diagram of our approach. First, we obtain the stretched image by applying mean-based stretching, and then we use the gradient of the original image to calculate the target gradient. Finally, we use GDP to reconstruct the enhanced image by combining the stretched image and the target gradient.

In GDP, the enhanced image can be obtained by solving an optimization problem. More specifically, both the stretched image and the target gradient are used to formulate an energy function.

Continued on next page
Figure 3. (a) Original image. Results of (b) mean-based stretching and methods based on (c) perception,\(^5\) (d) histogram equalization, and (e) the human visual system.\(^6\) (f) Our approach, combining mean-based stretching and GDP.

By minimizing the energy function using a numerical technique, we obtain the final image. In our simulation, we tested 20 IR images with various scenes. Figure 3 shows results associated with an outdoor scene.

A comparison between our method and conventional algorithms shows that our technique not only effectively improves visual quality but also preserves global contrast and image details (see Figure 3). Note that the perception-based contrast enhancement fails to control the brightness, whereas the human visual system-based method distorts the global contrast. The resultant image obtained by the local histogram-based method looks unnatural. Experimental results indicate that the proposed scheme effectively improves visual quality while preserving global contrast and detail. In addition, our algorithm requires less processing time than conventional approaches (about 23ms for 320 × 240 images, which is 4–50 times faster than conventional algorithms, apart from mean-based stretching).

In summary, we have described a new contrast enhancement scheme for IR image processing using detail-preserving stretching. Our method is posed as a minimization problem that maintains both gradient and global contrast. Because the technique offers faster computing speed over conventional alternatives, it has potential for use in real-time processing applications such as hand-held cameras, surveillance systems, and driver-assist systems in vehicles.

Currently, our algorithm assumes that the image is not corrupted by noise or that the amount is negligible. Since noise is a common feature of real-world applications, however, our next step will be to enhance IR images characterized by high levels of noise.

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References