Retinex Image Processing: Improved Fidelity To Direct Visual Observation

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Abstract

Recorded color images differ from direct human viewing by the lack of dynamic range compression and color constancy. Research is summarized which develops the center/surround retinex concept originated by Edwin Land through a singlescale design to a multiscale design with color restoration (MSRCR). The MSRCR synthesizes dynamic range compression, color constancy, and color rendition and, thereby, approaches fidelity to direct observation.

Introduction

A comparison of the recorded color image and the "view through the viewfinder" are strikingly different (Figure 1) for most everyday scenes due to the presence of shadows. Color and detail in shadows are far more clear in the direct view than in recorded images. We have developed Land's concept of a center/surround retinex[1] to the level of singlescale retinex (SSR) design for which there is a tradeoff between dynamic range compression and tonal rendition that is governed by the choice of the surround space constant. Comparison of processed images to direct scene viewing established that no value of an intermediate space constant could simultaneously provide sufficient dynamic range compression and good tonal rendition. The singlescale retinex provided a building block for the construction of a multiscale retinex which does couple acceptable dynamic range compression with good tonal rendition. Color constancy is excellent for all forms of the retinex but color rendition was elusive as a result of the gray world assumption implicit to the retinex computation. A color restoration was developed and applied after the multiscale retinex in order to overcome this color loss but with a modest dilution in color constancy.

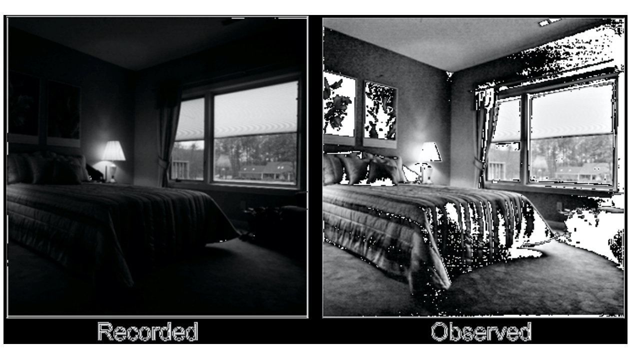

Figure 1. The discrepancy between recorded images and direct observation. Human vision strongly compresses visual information across wide-ranging illumination conditions within a scene.

Methods and Results

Here we briefly highlight results that are described comprehensively elsewhere.[2-5] The design of the singlescale retinex (SSR) consists of: 1) the choice of a surround function; 2) the placement of the log function; and 3) final signal processing prior to display/print. Of the three mathematical functions[1,6,7] previously used for a retinex surround, we found the best visual performance with the Gaussian compared to either the exponential form or the inverse square form originally used by Land. Unlike previous studies, we find that the placement of the log function is quite important in both mathematical and visual terms. We show that its placement after the surround formation is preferable to placement prior to surround formation. Processing after the basic spatial retinex operation was found to be a "canonical" gainoffset applied uniformally to all color bands rather than an auto gainoffset[6] calculated across the full three band data. These elements lead to a SSR defined as:

$$R_i(x, y) = \log\ I_i(x, y) - \log\ [F(x, y) * I_i(x, y)] \quad (1)$$

where Ii(x,y) is the image distribution in the ith color band, * denotes convolution, and F(x,y) is a Gaussian surround function. This is followed by the constant gain-offset applied across all color bands which, thus far, has proven to be universally constant or "canonical" for all images tested. This characteristic provides for general purpose and automatic application of the method and for simple construction of a multiscale retinex as:

$$R_{m,i}(x, y) = \sum_{k=1}^{n} c_k\, R_{k,i}(x, y) \quad (2)$$

for the kth surround space constant. The design of the multiscale retinex was found to require a minimum of three scales for image frame sizes of about 512 × 512 pixels. A comparison of direct viewing of scenes to scene photometry established that dynamic range compression for human vision is typically 5:1 or so for outdoor scenes with shadows and easily achieves 500:1 for mixed interior/exterior scenes. From this it is evident that everyday scenes often exceed the 255:1 (8bit) dynamic range of most color imaging systems and that wide dynamic range color imaging, together with the retinex, or other compressive processing, is essential if recorded color images are to approach the quality of observation. The use of test scenes together with a battery of diverse digital images revealed that the violations of the gray world assumption implicit to the retinex were a common occurrence both zonally and globally in images. The degree of impact on color rendition ranges from slight desaturation of color to rather severe graying for the extreme cases of "monochromatic" scenes. Therefore a color restoration that could be universally applied was developed because scene content is not predictable. Thus the MSRCR is given by:

$$R_{m',i}(x, y) = R_{m,i}(x, y) * I_{i'}(x, y) \qquad (3)$$

where the color restoration, I'i (x,y), is:

$$R_{m',i}(x, y) = R_{m,i}(x, y) * I_{i'}(x, y) \qquad (4)$$

The current form of the MSRCR does compare favorably with direct viewing by synthesizing dynamic range compression and color constancy with color and tonal rendition.

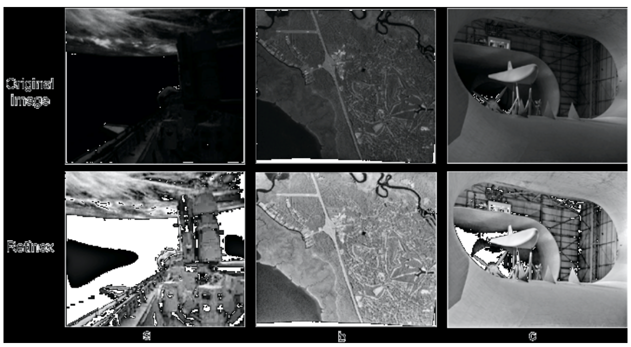

Figure 2. Enhancement of aerospace images using the MSRCR: a) Shuttle operations, b) remote sensing, and c) aeronautical research documentation.

Applications

We isolate two applications of the MSRCR to illustrate a wider range of applications aerospace image enhancements and digital photoprocessing. The MSRCR can be used to advantage in both space operations and remote sensing (Figure 2). For the former, the often dramatic lighting variations present in space operations can be ameliorated and better visual information achieved. For remote sensing, the MSRCR brings out the visual information present in large shadow zones and large zones of low reflectance, such as water areas. An example of an enhancement for improved documentation of aeronautical research is also shown. The automatic correction of low exposure images is evident and is useful for digital photoprocessing.

The MSRCR can be used as a "digital darkroom," allowing burning and dodging of areas that would have been extremely labor intensive if not impossible using traditional darkroom techniques. Although there are software packages that allow the selective lightening and darkening of specific areas of digitized images, in the cases below, it would be impractical because of the degree of detail required in the selection of these areas and the different changes required for each selection.

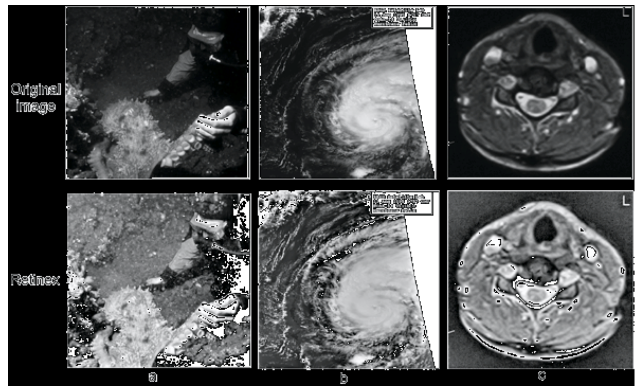

Figure 3. The MSRCR as a digital photo-processing method: graceful automatic "burning and dodging": a) Underwater image from traditional film camera; b) image from satellite data; c) digitized image from nuclear magnetic resonance (NMR) film.

References

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