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A Survey on HDR Images and Image Fusioning Techniques

BABA FAKRUDDIN ALI B H
COMPUTER SCIENCE, VTU BELGUM
India

KAREEMUNNISA
ELECRONICS,VTU BELGUM
India

SURESHA D
COMPUTER SCIENCE,VTU BELGUM
India

Abstract— High Dynamic Range (HDR) image capture and display has become an important engineering topic. The discipline of reproducing scenes with a high range of luminance's has a five -century history that includes painting, photography, electronic imaging and image processing. HDR images are superior to conventional images. There are two fundamental scientific issues that control HDR image capture and reproduction. The first is the range of information that can be measured using different techniques. The second is the range of image information that can be utilized by humans. Optical veiling glare severely limits the range of luminance that can be captured and seen. It is the improved quantization of digital data and the preservation of the scene's spatial information that causes the improvement in quality in HDR reproductions. The objective of Image fusion is to combine the information of the number of images of the same scene from different sensors or the images with focus on different objects. The result of image fusion is an image which is more informative and better quality. This Image fusion is finding its application in all spheres of life. In this paper an introductory approach to some of the image fusion methods has been taken.

Keywords— HDR, FUSIONING, LUMINANCE,

I. INTRODUCTION

HDR images are the reproduction of scenes with a high range of luminance. More specifically, these scenes have a greater range of luminance than reflected or emitted from the reproduction media. This definition includes a great many scenes, because print and emissive display minima are controlled by their ambient surface reflections. Even if the display does not emit light at a pixel, the room light reflected from the surface of the display is that pixels minimal luminance.

By fusioning several distinct exposure we can create HDR images. The term fusion in general means, an approach to extract information that is in several domains. The image fusion (IF) process is to integrate multisensory or multi-view or multifocus information into a new image that contains better quality features and is more informative of all the individual input information. The term quality, and its meaning and measurement depend on the particular application. Image fusion is called Pan sharpening used to integrate the geometric details of the high resolution (Panchromatic) images and color of the low resolution or multispectral (MS) images. The resultant image contains high resolution multispectral image. Panchromatic image is broad visual wavelength range which is rendered in black and white. Multispectral image is that is obtained in different spectral band. Image fusion finds its application in various fields such as satellite imaging, medical sciences, military applications digital cameras multi-focus imaging etc.

II. HISTORY OF HDR IMAGING

Leonardo da Vinci is credited with the introduction of the painting of light and dark.in the year 1478. With the growth of photography in the mid 19th century HDR scenes presented a severe problem for films available at that time. Multiple exposure techniques for rendering HDR scenes go back to the earliest days of negative–positive photography. H.P. Robinson's (1858) composite print "Fading Away" was made using five differently exposed negatives.

Later in the year 1870's and 1880's Hurter and Driffield established the field of photographic sensitometry. They measured the sensitivity function of silver halide films. In 1939 Ansel Adams first described the zone system for photographic exposure, development and printing. It described three sets of procedures: first, for measuring scene radiances; second, for controlling negative exposure to capture the entire scene range, and third, spatial control of exposure to render the high-range negative into the low-range print.

In 1961, Charles Wyckoff developed a multilayered color film with different ASA panchromatic sensitivities (speeds) in each set of color forming layers. The film was used to photograph the detonation of nuclear explosions. The bottom, yellow color separation, layer had ASA=2 and the top, cyan layer ASA = 600. This made a single exposure pseudo color film able to measure dynamic range of 8 log units.

In 1978, A. Adams describes a pre-exposure technique that adds low-level uniform exposure to a negative to increase the total exposure of darkest area above response threshold. The intentional addition of fog increases visual discrimination between blacks in the negative and the print. Although adding fog may seem counterintuitive, it dramatically improves image rendition by providing spatial details. This technique decreases the actual dynamic range to increase the Apparent range. The hardware became commercially available in the early 1970's for the display of digital satellite and medical images. The efficient image processing began with the Frankle and McCann's using I^2S image processing hardware with multi resolution software. In 1984 & 85 McCann described HDR image capture using low-slope film, a graphic-arts scanner and digital image processing in Siggraph courses. These results agreed with those of Jones and Condit. Typical sun and shade images had a range of roughly 3.0 log units. New in this study was the effect of changes in spectral composition of illumination. Tungsten light, without shadows showed a 3.0 log unit range because the long wave light was significantly greater than the short–wave light. Conversely, in skylight the short-wave light was significantly greater than long-wave light. Both showed a 3.0 log unit range, but this was due to spectral shifts in illumination composition, not due to sun and shade.

In 1985 Ochi et al of Sony patented a multiple exposure CCD system using one imaging lens, a beam splitter, and two CCD image regions. An object of the invention was to "produce a still image of excellent quality and which prevents deterioration of the image quality which results from smearing and blooming."

In 1987, Alston et al of Polaroid patented an electronic imaging camera for substantially expanded dynamic exposure range by combining two successive exposures with different durations. In 1993, S. Mann of MIT investigated a series of different digital image fusion techniques. One of these techniques was to merge different exposures to capture a wider dynamic range.

In 1996 an advent of consumer digital cameras produced a new demand for HDR imaging to improve the light response of digital camera sensors, which had a much smaller dynamic range than film. Steve Mann developed and patented the global-HDR method for producing digital images having extended dynamic range at the MIT Media Laboratory.

Mann's method involved a two-step procedure: (1) generate one floating point image array by global-only image operations (operations that affect all pixels identically, without regard to their local neighbourhoods); and then (2) convert this image array using local neighbourhood processing (tone-remapping, etc.), into an HDR image.

The image array generated by the first step of Mann's process is called a light space image, light space picture, or radiance map. Another benefit of global-HDR imaging is that it provides access to the intermediate light or radiance map, which has been used for computer vision, and other image processing operations.

In 1997, Debevec and Malik used multiple exposures and least-square fits to solve for the camera response function and the luminance of each pixel in the scene. Although some people have described its use of multiple exposures as revolutionary,

In 2005 Photoshop CS2 introduced the Merge to HDR function, 32 bit floating point image support for HDR images, and HDR tone mapping for conversion of HDR images to LDR.

III. IMAGE FUSION

Image fusion is the process of combining information from two or more images of a scene into a single composite image that is more informative and is more suitable for visual perception or computer processing. The objective in image fusion is to reduce uncertainty and minimize redundancy in the output while maximizing relevant information particular to an application or task. Given the same set of input images, different fused images may be created depending on the specific application and what is considered relevant information. There are several benefits in using image fusion: wider spatial and temporal coverage, decreased uncertainty, improved reliability, and increased robustness of system performance.

Often a single sensor cannot produce a complete representation of a scene. Visible images provide spectral and spatial details, and if a target has the same color and spatial characteristics as its background, it cannot be distinguished from the background. If visible images are fused with thermal images, a target that is warmer or colder than its background can be easily identified, even when its color and spatial details are similar to those of its background. Fused images can provide information that sometimes cannot be observed in the individual input images. Successful image fusion significantly reduces the amount of data to be viewed or processed without significantly reducing the amount of relevant information.

IV. HISTORYOF IMAGE FUSIONING

Image fusion is a branch of data fusion where data appear in the form of arrays of numbers representing brightness, color, temperature, distance, and other scene properties. Such data can be two-dimensional (still images), three-dimensional (volumetric images or video sequences in the form of spatial-temporal volumes), or of higher dimensions. Early work in image fusion can be traced back to the mid-eighties. Burt was one of the first to report the use of Laplacian pyramid techniques in binocular image fusion. Burt and Adelson later introduced a new approach to image fusion based on hierarchical image decomposition. At about the same time, Adelson disclosed the use of a Laplacian technique in construction of an image with an extended depth of field from a set of images taken with a fixed camera but with different focal lengths. Later Toet and Toet et al used different pyramid schemes in image fusion. These techniques were mainly applied to fuse visible and IR images for surveillance purposes.

Use of the discrete wavelet transform (DWT) in image fusion was almost simultaneously proposed by Li et al. and Chipman et al. At about the same time Koren et al. described a steerable dyadic wavelet transform for image fusion. Also around the same time Waxman and colleagues developed a computational image fusion methodology based on biological models of color vision and used opponent processing to fuse visible and infrared images. The need to combine visual and range data in robot navigation and to merge images captured at different locations and modalities for target localization and tracking in defense applications prompted further research in image fusion. Many other fusion techniques have been developed during the last decade. Today, image fusion algorithms are used as effective tools in medical, remote sensing, industrial, surveillance, and defense applications that require the use of multiple images of a scene.

For recent surveys of image fusion theory and applications, readers are referred to a paper by Smith and Heather and a collection of papers edited by Blum and Liu. Another excellent source that follows the evolution of image fusion systems and algorithms over the last several years is the special sessions on Image Fusion and Exploitation organized by Allen Waxman et al. at the Information Fusion Conferences (2000–2004). The list of papers cited in this introduction is by no means exhaustive but it hopefully provides a flavor of some of the major developments in the field with a focus on recent advances and challenges.

IV. METHODS OF IMAGE FUSIONING

Image fusion methods can be broadly classified into spatial domain and transform domain fusion Brovey method, Principal Component analysis (PCA) IHS (intensity hue saturation) and High pass filtering methods fall in the spatial domain fusion techniques.
Spatial image fusion work by combining the pixel values of the two or more images. The simplest is averaging the pixel values of the input images wavelet transform and laplacian transform come in the transform domain. In the transform domain method the multi scale decomposition of the images is done and the composite image is constructed by using the fusion rule. Then inverse multi scale transform is applied to achieve the fused image.

V.1 BROVEY TRANSFORM

The Brovey Transform was developed to visually increase contrast in the low and high ends of an images histogram (i.e., to provide contrast in shadows, water, and high reflectance areas such as urban features). Consequently, the Brovey Transform should not be used if preserving the original scene radiometry is important. However, it is good for producing RGB images with a higher degree of contrast in the low and high ends of the image histogram and for producing "visually appealing" images. Since the Brovey Transform is intended to produce RGB images, only three bands at a time should be merged from the input multispectral scene The Brovey transform is based on the mathematical combination of the multispectral images and high resolution Pan image. Each multispectral image is normalized based on the other spectral bands and multiplied by the Pan image to add the spatial information to the output image. The following equation shows the mathematical algorithm for the Brovey method.

$$F_i = \frac{M_i}{I_{j=1}^{N}{}_{M_{j+c}}} \# P$$

Where
F_i is the fused image band
M_i is the multispectral band
P is the panchromatic band

V.2 IHS TRANSFORM

The IHS technique is one of the most commonly used fusion techniques for sharpening of the images. It has become a standard procedure in image analysis for color enhancement, feature enhancement, improvement of spatial resolution and the fusion of disparate data sets. In the IHS space, spectral information is mostly reflected on the hue and the saturation. From the visual system, one can conclude that the intensity change has little effect on the spectral information and is easy to deal with. For the fusion of the high-resolution and multispectral remote sensing images, the goal is ensuring the spectral information and adding the detail information of high spatial resolution, therefore, the fusion is even more adequate for treatment in IHS space. The commonly used RGB (XS3, XS2, XS1) colour space is not suitable for a merging process, as the correlation of the image channels is not clearly emphasized. The IHS system offers the advantage that the separate channels outline certain colour properties, namely intensity (I), hue (H), and saturation (S). This specific colour space is often chosen because the visual cognitive system of human beings tends to treat the three components as roughly orthogonal perceptual axes.

V.3 PRINCIPAL COMPONENT ANALYSIS

Principal component analysis (PCA) has been called one of the most valuable results from applied linear algebra. PCA is used abundantly in all forms of analysis - from neuroscience
to computer graphics - because it is a simple, non-parametric method of extracting relevant information from confusing data sets. With minimal additional effort PCA provides a roadmap
for how to reduce a complex data set to a lower dimension to reveal the sometimes hidden, simplified dynamics that often underlie it. The principal component transform is a statistical technique which is used to transform the multivariate dataset of correlated variables into a dataset of uncorrelated linear combinations of the original variables. For images, it creates an uncorrelated feature space which can be used for further analysis instead of the original multispectral feature space. The PC is applied to the multispectral bands. The PC analysis transform converts inter correlated MS bands into a new set of uncorrelated components. The first component also resembles a PAN image. It is, therefore, replaced by a high-resolution PAN for the fusion. The PAN image is fused into the low-resolution MS bands by performing a reverse PCA transform .The panchromatic image is histogram matched to the first principal component (sometimes to the

second). It then replaces the selected component and an inverse PC transform takes the fused dataset back into the original multispectral feature space The advantage of the PC fusion is that the number of bands is not restricted (such as for the original IHS or Brovey fusions). It is, however, a statistical procedure which means that it is sensitive to the area to be sharpened. The fusion results may vary depending on the selected image subsets.

V.4 HIGH PASS FILTERING

For the high pass filtering (HPF) fusion, first the ratio of the spatial resolution of the panchromatic and the multispectral image is calculated. A high pass convolution filter kernel is created and used to filter the high resolution input data with the size of the kernel based on the ratio. The HPF image is added to each multispectral band. Before the summation, the HPF image is weighted relative to the global standard deviation of the multispectral bands with the weight factors are again calculated from the ratio. As a final step, linear stretch is applied to the new multispectral image to match the mean and standard deviation values of the original input multi
spectral image . It shows acceptable results also for multisensoral and multi temporal data. Sometimes the edges are emphasized too much.

V.5 LAPLACIAN PYRAMID

The Laplacian Pyramid implements a "pattern selective" approach to image fusion, so that the composite image is constructed not a pixel at a time, but a feature at a time. The basic idea is to perform pyramid decomposition on each source image, and then integrate all these decompositions to form a composite representation, and finally reconstruct the fused image by performing an inverse pyramid transform.

The first step is to construct a pyramid for each source image The fusion is then im plemented for each level of the pyramid using feature selection decision. There are two modes of the combination averaging and the selection. In the selection process the most salient component pattern from the source image are copied while less salient patterns are discarded. In the averaging case source patterns are averaged reducing the noise. Selection is used where the source images are distinctly different and the averaging is used where the source images are similar.

The laplacian pyramid has the following steps 1) images size checking.2) construction of pyramid level n 3) pyramid level fusion 4) final level analysis 5) reconstruction of fused image.

VI. THE MULTIPLE EXPOSURES FUSIONING TECHNIQUE

High dynamic range images may be captured from real scenes or rendered by computer graphics techniques. The most common approach to obtain an HDR image is to take multiple images of the same scene with different exposure times, and combine them into a single HDR image. The multiple exposures technique is based on the observation that taking multiple images with different exposures, each pixel will be properly exposed in at least one image. There- fore, an HDR image is obtained by appropriately combining the LDR images.

The fusion of a set of LDR images in to an HDR image can be achieved in different methods which can be classified into two main approaches: fusion in the radiance domain and fusion in the image domain.

VI.1 FUSION IN THE RADIANCE DOMAIN

This HDR image generation method consists of three steps,

First, The camera response function is recovered to bring the pixel brightness values into the radiance domain. This function models the effect of nonlinearities introduced in the image acquisition process. Since the camera response function is not always provided by manufacturers, different methods are proposed for its estimation from a sequence of differently exposed images,

Second, All radiance maps are combined into an HDR image encoded specially to store the pixel values that span the entire tonal range of the scene.

Third, a tone mapping operator is used to make the HDR image display- able on common low dynamic range monitors,

let {Lk}k=1…N be a set of N images with exposure Δt_k Given the camera response function f(), the HDR image is computed as the weighted average of pixels values across exposures using the following equation:

$$R_{uv} = \frac{\sum_{K=1}^{N} W(Z_{uv}^{k})f^{-1(Z_{uv}^{k})}/\Delta t_k}{\sum_{K-1}^{N} W(Z_{uv}^{k})}$$

Where R is the combined radiance map, Z_{uv}^{k} is the pixel value at location(u, v) in exposure Lk and $W(Z_{uv}^{k})$ is the weight of that pixel,The weighting function W( ) is designed to reduce the influence of unreliable pixels such as saturated ones.

In order to display the obtained HDR image on a low dynamic range monitor, a tone mapping operator is applied. Tone mapping techniques can be classified into global and local methods. Global methods specify one mapping curve that applies equally to all pixels, while local methods provide a space-varying mapping curve that takes into account the local content of the image.

VI.2FUSION IN THE IMAGE DOMAIN

They directly produce a tone mapped- like HDR image. However, methods that fuse the images in the radiance domain produce a true HDR radiance map in the combination step which contains the whole dynamic range of the captured scene. This radiance map can later be used for different processing or display applications.

This is the other methods combine multiple exposures directly without the knowledge of the camera response function These methods combine LDR images by preserving only the best parts of each exposure. The final HDR image is obtained as a weighted average of pixel values across exposures

$$I_{uv}^{c} = \sum_{K=1}^{N} W(Z_{uv}^{k})Z_{uv}^{k}$$

Where I^{c} is composite image

The choice of the weighting function is crucial to get good and accurate results. combine multiple exposures using contrast, saturation and well- exposedness as parameters for weighting functions. They also use a Laplacian pyramid blending framework to avoid artifacts in the composite image

The two different HDR image generation processes are depicted in Fig. 1. The performance of the methods that combine images in the radiance domain highly relies on an accurate estimation of the camera response function, which is sensitive to image noise and misalignment. Moreover, these methods require tone mapping operators for HDR images reproduction. Methods that combine exposures in the image domain are more efficient since they avoid the estimation of the camera response function and do not require tone mapping.

VII. APPLICATIONS OF IMAGE FUSIONING

All imaging applications that require analysis of two or more images of a scene can benefit from image fusion. Reducing redundancy and emphasizing relevant information can not only improve machine processing of images, it can also facilitate visual examination and interpretation of images. Image fusion has been used as an effective tool in medicine. fused multimodality medical images to improve diagnosis and treatment planning. Image fusion has been used in defense applications for situation awareness surveillance target tracking, intelligence gathering and person authentication. Image fusion has also been extensively used in remote sensing in interpretation and classification of aerial and satellite images

VIII. CONCLUSION

This paper describes the five-century history of HDR imaging. Glare is the scene- and camera- dependent scattered light falling on image sensors. First, glare limits the range of luminances that can be accurately measured by a camera, despite multiple exposure techniques. HDR image capture cannot accurately record the luminances in scenes beyond the glare limit. Second, magnitude estimate between white and black do not correlate with luminance: they depend on physical glare and physiological contrast. The improvement in HDR images, compared to conventional photography, does not correlate with accurate luminance capture and display. The improvement in HDR images is due to better digital quantization and the preservation of relative spatial information.

Depending upon the type of the application and the requirement of the user that one might have desire to obtain the visually beautiful image someone else may require the more details of the colors for getting more detailed accurate results about the image The Brovey method provides nice images which present sharp details but close examination indicated that the dark areas became darker, and the white one whiter than the original images. The PCA method provides better enhanced fused images and has better fused image without much change in the spectral and spatial information of the original image.

Methods that combine exposures in the image domain are time-efficient as they avoid the camera response function estimation and tone mapping. On the other hand, methods that combine exposures in the radiance domain give a true HDR radiance map which might be useful for later processing or display applications.

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AUTHORS PROFILES

Mr. Baba Fakruddin Ali B H received his B.E degree in Electronics and communication engineering from Islamiah Institute of Technology, Bangalore in 2011. Currently he is perusing M.Tech degree in Computer Science and Engineering at Canara Engineering College, Mangalore. His areas of interest are Image processing, embedded system. He has published 2 international journal and 1 national conference paper.

Ms. Kareemunisa S received her B.E degree in Electronics and communication engineering from Islamiah Institute of Technology, Bangalore in 2011. Currently she is perusing M.Tech degree in Electronics Engineering at HKBK Engineering College, Bangalore. Her areas of interest are Image processing, embedded system, RTOS, , She has published 2 international journal and 1 national conference paper.

Mr. Suresha D, Asst Professor, is a Faculty of Canara engineering college, Mangalore at visvesvaraya Technological University Belgum, Karnataka. Prof. Suresha D obtained his B.E (computer science and engineering) from Kuvempu University, Jnanasahyadri, Shankaragatta and M.Tech (computer network engineering) from visvesvaraya Technological University Belgum, Karnataka. his research area include image processing, information and network security and Adhoc Networks. He has published 9 international journal and 2 national conference paper

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