Different Exposure Images of the Same Scene Based on Matlab

Xun Zhang¹, Ying Pan² and Ying Liu³

¹Changjiang institute of survey, planning, design and research, Wuhan, Hubei 430081, China
²Zhixing college of Hubei University, Wuhan, Hubei 430081, China
³Key Laboratory of Metallurgical Equipment and Control Technology of Ministry of Education, Wuhan University of Science and Technology, Wuhan, Hubei 430081, China

*Corresponding author e-mail: zhangxun@cjwsjy.com.cn

Abstract. During the shooting process of the camera, the problem of overexposure or underexposure often occurs, leading to the loss of important information in the picture. In response to this problem, this article first restores the camera's light response curve by taking multiple images with different exposures for the same static scene, combining the principle of least squares and the B-spline function fitting method, and obtaining the pixel values and exposure in the image the mapping relationship between them, and then fuse the scene photo images of different exposures into a high dynamic range image. Secondly, the synthesized high dynamic range image is deal with by Matlab program, and the exposure time is 8s, 1/2s, 1/30s, and 1/500s to reconstruct the image. Finally, experimental results show that the effects of the synthesized high dynamic range image and reconstructed exposure image are significant.

Keywords: Image synthesis, Matlab, Exposure

1. Introduction
Due to the continuous advance of digital image technology, high-definition lifelike images are more and more popular. According to different objects, it has different meanings. In the field of digital photography and imaging, dynamic range refers to the percentage of the maximum and minimum brightness in a digital image, and its brightness unit is Canberra / square meter. In actual reality, the illumination has a very wide dynamic range, as shown in Table 1.

Table 1 Brightness values under different lighting conditions in the actual scene

| Scenes          | Light value \( \text{cd} / \text{m}^2 \) |
|-----------------|----------------------------------------|
| Starlight       | \( 10^{-3} \)                            |
| moonlight       | \( 10^{-1} \)                            |
| Indoor lighting | \( 10^2 \)                              |
| Outdoor sunny   | \( 10^5 \)                              |
| sunshine        | \( 10^8 \)                              |

At present, the application fields of HDR images are very wide. It can be widely used in movie stunts, simulation of the human visual system, satellite remote sensing images and many other fields [1]. In this paper, multiple images taken by a digital camera under distinct exposure times in identica
scene are combined with the least squares principle and the B-spline function fitting method to generate smoother light response curves, and then synthesize high dynamic range synthesis image\cite{2}. In order to solve the problem of overexposure or underexposure of the camera during the shooting process, this paper uses Matlab program to reconstruct the exposure of the image to improve the brightness of the image so that the details of the bright and dark areas of the image.

2. Matlab Overview

2.1. Application of Matlab in image processing
As shown in Figure 1, Matlab has five major applications in image processing.

![Application of Matlab in image processing](image)

**Figure 1** Matlab application in image processing

2.2. Examples
Image edge processing is easy to identify the image contour. The following is a specific application example of Matlab in image edge detection research. For instance, using gradient operator and LoG operator to detect edges, the running result is shown in Figure 2:

![Original image](image)

**Figure 2** Edge extraction

3. High dynamic range image
A high dynamic range image is an image type that can represent large-scale changes in brightness in an actual scene. The pixel values in the image are proportional to the actual brightness values of corresponding points in the scene.

3.1. High dynamic range image signal processing flow
The image processing flow is shown in Figure 3.
3.2. High dynamic range image format
The high dynamic range image obtained through the synthesis algorithm has too much data and cannot be encoded in the criterion 24-bit RGB (sRGB) form. It needs to be processed in a specific format. Common HDR image formats include HDR format, TIFF format, and Open EXR format [3] [4], as shown in Table 2.

| HDR Image format | Encoding | Pixel level (bit) | Dynamic Range |
|------------------|----------|------------------|---------------|
| HDR              | RGBE     | 32               | 10^{76}       |
| TIFF             | LogLuv24 | 24               | 10^{4.8}      |
| EXR              | HalfRGB  | 48               | 10^{10.7}     |

4. Multiple Exposure Image Fusion

4.1. Restore the corresponding curve of the imaging system
The illumination respond profile of imaging system is the key to synthesize high dynamic range image [5]. This article uses several images with different exposure times for the same scene to fit the light response curve.

4.2. Restore light response curve
The illumination response curve of the imaging system is the relationship curve between the camera exposure amount H and the image pixel-value V (if the image is colored, R, G, B, and 3 colors are processed separately).

4.2.1 Synthesis principle
Take M different exposure photos for the same scene at fixed points, and take the sampling points corresponding to the N groups of positions from these images. Suppose there is a functional relationship between V and H: (the V mean a discrete, and the v represents a corresponding continuous variable)

\[ V_y = f(H_y) \]  4-1

Among them, \( f \) is a non-linear function; \( i \) is an index of a pixel position, and \( j \) is an index of a different image.

As shown in Figure 4, the ordinate V indicate the pixel value, and the abscissa lnH represents the logarithmic value of the exposure amount. It is assumed that the illuminance at each point is unit 1. The symbols of the same shape in the figure represent the same set of points in different images. Each set of sampling points corresponds to a characteristic curve. By shifting these N (= 4) curves left and
right, they are stitched together smoothly, and the synthesized light response curve shows obvious non-linear characteristics in light and dark areas.

![Figure 4 Process of fitting light response curve](image)

4.2.2 Implementation method
The above process of fitting the response curve can be achieved by solving the statically indeterminate equation \[6\]. By negating the function (1) and taking the logarithm, we get:

\[ F(V_j) = \ln E_j + \ln \Delta t_j \quad 4-2 \]

Among \( \Delta t \) indicate the shutter time, and \( E \) indicate the illuminance.

So as to make the sampling point satisfy equation 4-2 with the least square error, the solution of equation 4-2 can be transformed into the solution of objective function equation 4-3:

\[ \sum_{i=1}^{N} \sum_{j=1}^{M} \left[ F(V_j) - \ln E_i - \ln \Delta t_j \right]^2 = 0 \quad 4-3 \]

So as to reduce the influence of non-linear factors at both ends of the curve, weights can be introduced in equation 4-3 to make the fitted curve smoother and a smoothing term can be introduced:

\[ F'(v) \approx F(v-1) - 2F(v) + F(v+1) \quad 4-4 \]

Then there are:

\[ \sum_{i=1}^{N} \sum_{j=1}^{M} \left[ w(V_j) \left[ F(V_j) - \ln E_i - \ln \Delta t_j \right] \right]^2 + \eta \sum_{V=1}^{256} \left[ w(V) F''(V) \right]^2 = 0 \quad 4-5 \]

Among them, \( \eta \) is a smoothing coefficient, and \( w \) is a weight.

In equation 4-5, \( \Delta t_j \) and \( w(V) \) are known, \( F(V_j) \) and \( \ln E_i \) are unknown, and \( F(V_j) \) is the mapping between \( V \) and \( H \) (or \( E \)). For \( N \) sets of sampling points, there are \( N \times M \) equations. In addition, this paper takes \( F(128) = 0 \). Then these \( N \times M + 1 \) equations constitute a solution system for 256 \( F(V_j) \) and \( N \ln E_i \). Matlab. In order to make this system super statically determinable (at least statically determinate), it is required that \( N \times M + 1 \geq 256 + N \), that is the number of sampling points \( N \geq 255 \) (M-1).

4.3. Reconstructed image exposure
Figure 5 shows 8 digital photos in the same scene. The exposure time is 15s、4s、1s、1/4s、1/15s、1 / 60s、1 / 250s、1 / 1000s. In this paper, Matlab program is used to synthesize HDR images of photos with different exposures in the following scene. The synthesized high dynamic image is shown in Figure 6. The Matlab program is accustomed to further reconstruct the synthesized HDR image into four pictures with exposure times of 8s、1/2s、1/30s and 1/500s respectively to display the details.
of the HDR image at different exposure times in order to further observe the image. The reconstructed image is shown in Figure 7.

Figure 5 Digital photos of different exposure times in the same scene

Figure 6 Composite HDR image

Figure 7 Reconstructed image after exposure

5. Conclusion
Based on Matlab, this paper researches and analyzes images with different exposures in the same scene. This paper theoretically analyzes the capture method and signal processing flow of high dynamic range images. Combining the principle of least squares and B-spline function fitting method to restore the camera's light response curve, the mapping relationship between the pixel values and the exposure in the image was obtained. The experimental results show that the light response curve of the restored imaging system studied in this paper. The method of synthesizing high dynamic range images is reasonable and feasible. The high dynamic range images synthesized from different exposure times in the same scene are good. The reconstruction of image exposure through Matlab is feasible and good results are obtained.
References

[1] Song L M, Wang H Q, Chen C, Ye S Q and Gu W K 2009 Tone Mapping for High Dynamic Range Image using a Probabilistic Model J. Journal of Software 20 734–743

[2] Zhu E H 2017 Research on Single Exposure HDR Image Generation Technology D. Southwest University of Science and Technology

[3] Maronna R, Martin D and Yohai V 2006 Robust Statistics: Theory and Methods J.Chichester: John Wile & Sons, Ltd 87–114

[4] Li Y Y 2016 Research on Image Dynamic Range Stretching Method D. Chang'an University

[5]Debevec P E and Malik J 1997 Recovering High Dynamic Range Radiance Maps from Photographs C. Computer Graphics Proceedings, ACM SIGGRAPH Los Angeles 369-378.

[6] Yang K H, Ji J, Guo J J and Yu W S 2009 High Dynamic Range Image and Level Mapping Operator J. Journal of Automation 35 113-122