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HIGH DYNAMIC RANGE IMAGE PROCESSING TECHNOLOGY

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Abstract. High dynamic range images can be used to capture real environments through digital equipment, and images with high dynamic range are synthesized through specific algorithms in the obtained image information. In the process of image capture, due to the performance of digital equipment, there will be noise in the captured image, which will affect the quality of the image during synthesis. It is necessary to reduce the noise in the image and then synthesize a high dynamic range image. Due to the low dynamic range of traditional display devices, high dynamic range images cannot be directly displayed on traditional devices, and the high dynamic range images are mapped to the dynamic range of the display for display by a method of color scale mapping. Therefore, this paper mainly studies the methods of high dynamic range image synthesis and color scale mapping.

Keywords: high dynamic range image synthesis, multi-exposure image, linear transformation, color scale mapping.

Introduction

The synthesis and display process of high dynamic images involves the principle of camera grayscale image generation and the theory of color scale mapping. This paper briefly analyzes the process of the camera to generate grayscale images and the high dynamic range image synthesis algorithm, and finally introduces the basic theory of color scale mapping.

Digital Image Imaging Process

The imaging process of a digital image can be summarized as that the light passes through the aperture, the shutter, the image sensor, the ADC conversion, and the camera's own color scale mapping curve to generate a displayable grayscale image. In this process, aperture and shutter can be equivalent to a linear response function. Subsequent processing steps: image sensor, ADC conversion, and color scale mapping curve can be equivalent to a camera response function with nonlinear function characteristics.

The most important thing in the synthesis of high dynamic range images is to obtain the nonlinear response function, which describes the brightness values corresponding to different gray scales, so as to restore the original high dynamic dynamic range through the input gray scale image. Among the many solving methods, an effective solution for calibrating the camera response function is to obtain a set of multi-exposure images by shooting the same scene under different exposure time intervals, and then process the grayscale data of each exposure image. Finally, a luminance image that restores the dynamic range in the original scene is synthesized. The core idea of this method is to obtain brightness information of pixels with higher brightness in grayscale images with low exposure, and obtain brightness information of pixels with low brightness in grayscale images with higher exposure. The brightness information is integrated, and the camera response function is fitted according to the properties of the nonlinear response function.

Synthesis of High Dynamic Range Images

The real image in the natural environment has a large dynamic range. From noon to late night, the dynamic range is about 109, while the display device image range of the image is only 102, which is far away. Therefore, the high dynamic range image cannot be completely saved and displayed. In the process of digital image processing, the brightness level is usually divided by 8 bits, and the maximum level range displayed is 0~255. Synthesizing high dynamic range images can not only increase people's perception of real natural scenes and improve the description of image details, but also has very important research significance for subsequent processing processes such as image segmentation and edge detection [1–2].

Usually, images are acquired by converting photon signals into image pixel information through the CCD (charged couple device) sensor in the camera [3]. Developers develop the latest CCD components to improve the dynamic range of image sensor components. Mitsunaga proposed to design an image sensor to change the exposure by changing the spatial position, and then, by placing an optical mask in front of the photosensitive array of the image sensor, because the transmittance of the incident light corresponding to each position is different, the image array Different exposures can be obtained at different positions, and finally the image sensor will form a frame of high dynamic range image. Others have proposed similar design schemes. For example, Tublin proposed to design a camera that uses the principle of the photosensitive unit of the camera to first detect the difference in incident light between adjacent pixels, then quantify the size of the incident light, and finally make the camera generate a high dynamic range image [3]. The above two design ideas are basically to improve and design the lighting of the camera image sensor, and the ultimate goal is to improve the adaptability of the camera to the dynamic range, but this will increase the development cost of the camera to a certain extent The effect of a large dynamic range is not very good, and the cost of the hardware itself is relatively high, which limits the further development and application of the camera, resulting in the development of a high dynamic camera that cannot be widely used by mass consumers.

The basic principle of the software synthesis algorithm is to use ordinary camera equipment to obtain image sequences under different exposure conditions in the same scene for the same scene, and then use various algorithms to synthesize a high dynamic range algorithm. The details in the image are composited into one image to expect greater dynamic range. The software algorithm has a certain effect on images in static scenes, but if the object is displaced during the image sequence synthesis process, it will cause ghosting, that is, object ghosting may occur. This will result in poor quality of the generated high dynamic image, and even affect the visual effect.

According to the above, the key to synthesizing high dynamic range images is to find the nonlinear response function g, that is, to find the brightness values corresponding to different gray scales, so as to restore the dynamic range of the input image. An effective way to calibrate the camera response function is to capture a set of multi-exposure images by shooting the same scene under a set of different exposure time conditions, and then extract, organize, and analyze the grayscale data of each exposure image to synthesize A luminance image that represents the light distribution of the original scene. The core idea of this method is to extract the brightness information of pixels with higher brightness in the grayscale image with lower exposure, and extract the brightness information of pixels with lower brightness from the grayscale image with higher exposure. The brightness information is integrated, and the camera response function is fitted according to the properties of the nonlinear response function. Debevec's algorithm and Mitsunaga's algorithm are representative of the methods for finding the fitted nonlinear response function.

Color Scale Mapping

Level mapping is a general term for a method that "converts" a high dynamic range image into a viewable image. The purpose is to solve a common problem that plagues people when viewing high dynamic range images, that is, CRT, LCD, printers and other images. The displayed dynamic range is limited.

In image transformation, how to maintain image details, colors, and other important information for expressing the original scene requires a large contrast attenuation to transform the scene brightness to a displayable range. Tone mapping is essentially to solve this kind of problem. Tone mapping is a computer graphics technique for approximating high dynamic range images on limited dynamic range media [4]. CRT, LCD monitors or printouts, projectors, etc. all have limited dynamic range. Tone mapping is inherently expressive and its goals vary from application to application. Different occasions have different requirements for images. In some occasions, some require high-quality images, some require more details in the image, and some require the maximization of image contrast. In practical applications, the integrity of the display device in the display brightness range may not be complete, but people require that the real scene and the display image match.

The values of all pixels in the HDR image are directly related to the measured luminosity values of the actual environment, and the stored pixel values are linear. This property is called scene correlation. The color space of the current LDR image is for a specific output device, and their output is related. The data displayed in this way is low dynamic range data, which meets the range of the output device, but there will be recorded scenes that do not correspond to the color space. Therefore, the color values contained in the LDR image are limited, and the information describing the real scene can be as close as possible to the original data of the scene. HDR images can only be displayed on high dynamic range devices. A specific method is required to map the pixel values of high dynamic range images to the color space of the device. This mapping method is called tone mapping. The general model of color scale mapping is shown in Figure 1.

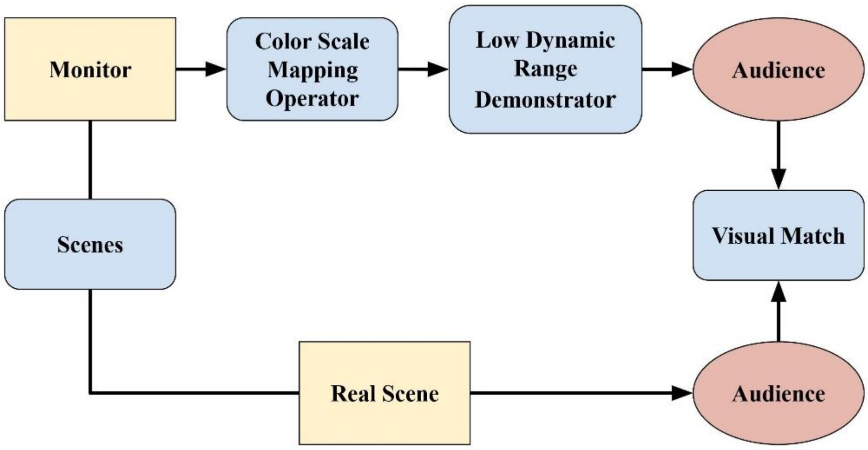

Figure 1. General model for color scale mapping

The tone mapping algorithm has been diversified in recent years. The tone mapping filter is its typical representative, $L = Y / Y + 1$, the filter is the radianc value, and the mapping of Y in the [0, ∞] domain, to the range [0, 10] show the output. Algorithms based on the gradient domain are more complex. This type of algorithm is concerned with maintaining contrast without considering the mapping of brightness. The contrast or the brightness ratio of different brightness regions is the most attractive source of inspiration for this type of method. This tone mapping preserves better contrast detail and typically produces very sharp images, but this tone mapping results in a flattened overall image contrast. The most typical examples of tone mapping methods are: high dynamic range image perception framework and gradient domain high dynamic range compression. The implementation method of high dynamic range image tone mapping is an idea obtained from anchoring theory of lightness perception. Lightness constancy and its spectacular failures in the human visual system can be fully understood in this theory. The central theory of this tone mapping method is to map high dynamic range images into illuminated uniform structures or regions and to compute local luminance values. Merge according to the luminance ratio of all unused areas, so as to calculate the pure luminance value of the image. The key is to correspond the constant brightness value to the brightness of the brightness positioning lighting, or which brightness value is perceived as white in the scene. This kind of tone mapping retains the natural color of high dynamic images, because its implementation method does not affect the local contrast. The tone mapping algorithm can be roughly divided into two categories according to the spatial correlation: local tone algorithm (spatial correlation) and Global tone algorithm (space independent). Because most tone mapping algorithms are designed for the visual reproduction of tone levels of grayscale high dynamic range images, they do not take the brightness range of the image into account [4]. After compression, the color gamut of the image is compressed at the same time. Will cause the image color to shift visually. The research on the tone mapping algorithm in the field of image processing is a hot spot. The tone mapping algorithm can map the brightness range of the real world scene to the range that the output device can output. The characteristics of the human visual system and the compressed luminance range are also considered while preserving the perceptual quality of the image. So far we have not been able to create an objective quality criterion from quantitative data. All tone mapping algorithms will lose information in the process of compressing the brightness range, such as contrast, brightness, image details, etc., and this information are only retained in the image in a targeted manner.

Conclusion

This paper mainly introduces the relevant theoretical basis of high dynamic range processing technology, and provides theoretical background knowledge for future algorithms. First, the digital image imaging process is introduced, and the response process of digital equipment is explained; secondly, the theory of high dynamic range image synthesis is introduced, and the synthesis method of high dynamic range images is explained in two ways: software and hardware. Finally, the color scale mapping of high dynamic range images is introduced, and the global color scale mapping algorithm and the local color scale mapping algorithm are briefly introduced.

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