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Hikvision
Wide Dynamic Range

Dynamic Range / WDR Imaging
Tone Mapping / Digital Wide Dynamic Range
Hikvision WDR Technique

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1. INTRODUCTION

In many practical surveillance applications, the intensity of illumination with a scene can vary excessively. Images taken by standard cameras always seem to have an overexposed foreground or too dark a background due to the limitation of a camera sensor's sensitivity. Over the course of a day, the situation can change with different areas of the scene being over or underexposed. What is required in this situation is a Wide Dynamic Range (WDR) camera.

2. DYNAMIC RANGE

The imaging luminance of a monitored object is mainly dependent on the intensity of illumination radiating or reflecting from the object that is captured by the sensor. The unit of measure for illumination intensity is the lux unit. For a non-light source object being monitored, the reflection intensity is also affected by its surrounding illumination, reflecting ratio, and other factors.

In a real situation, the illumination of di erent areas may di er greatly even in the same surveillance scene. For example, on a bright sunny day, the surrounding illumination in the outdoor area can reach 100,000 lux, while the illumination at the desk indoors is approximately 1000 lux, and the shadowed area below the desk is as low as 10 lux. Assuming that all these areas have similar reflection capability, the reflection ratio of the indoor shadowed area to the indoor normal lighting area to the outdoor area is 1:100:10,000.

If we want to preserve at least five grey scales in the dark area so as to distinguish between objects with different reflectivity, the capability required to acquire the image information of the three parts mentioned above is 10,000/0.2 = 50,000 times, corresponding to a dynamic range of 16 bits (94 db); however, most common image sensors can't reach this value. The dynamic range of the current common CMOS sensor is around 12 bits, or 72 db. When a CMOS sensor is used in such a scene, the image details either in the bright or dark areas will get lost.

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Figure 1 *Image is overexposed or underexposed in wide dynamic range scene*

2.1 WDR IMAGING

Various approaches have been tried to extend the dynamic range of the image sensor, and currently Multiple Exposure and the Per-Pixel Exposure are generally used to control the exposure intensity.

The idea of Multiple Exposure is to get two or more exposures with different time durations on one scene and to accumulate enough data to create a single image. On the other hand, Per-Pixel Exposure can get the same imaging result by setting different sensitivity levels for the neighboring pixels on the sensor. In a dynamic range scene of 94 db as mentioned above, the multiple exposure technique uses the 12-bit (72 db) image sensor to make a first exposure with an exposure time of 1/50 s, which enables the camera sensor to acquire enough details in the darker area, yet the image in the brighter area is overexposed; then the sensor makes a second exposure of 1/800 s to weaken the exposure intensity on the brighter area to 1/16 while the image in the darker area is underexposed. The resulting image contains the subsequent image superimposed over the original, achieving a dynamic range of 16 bits (96 db), which is 16 times that of a 12-bit (72 db) image with a single exposure. Per-Pixel Exposure aims to reach the same resulting image by designing the sensitivity of the high sensitivity pixels to 16 times of that of the low sensitivity pixels.
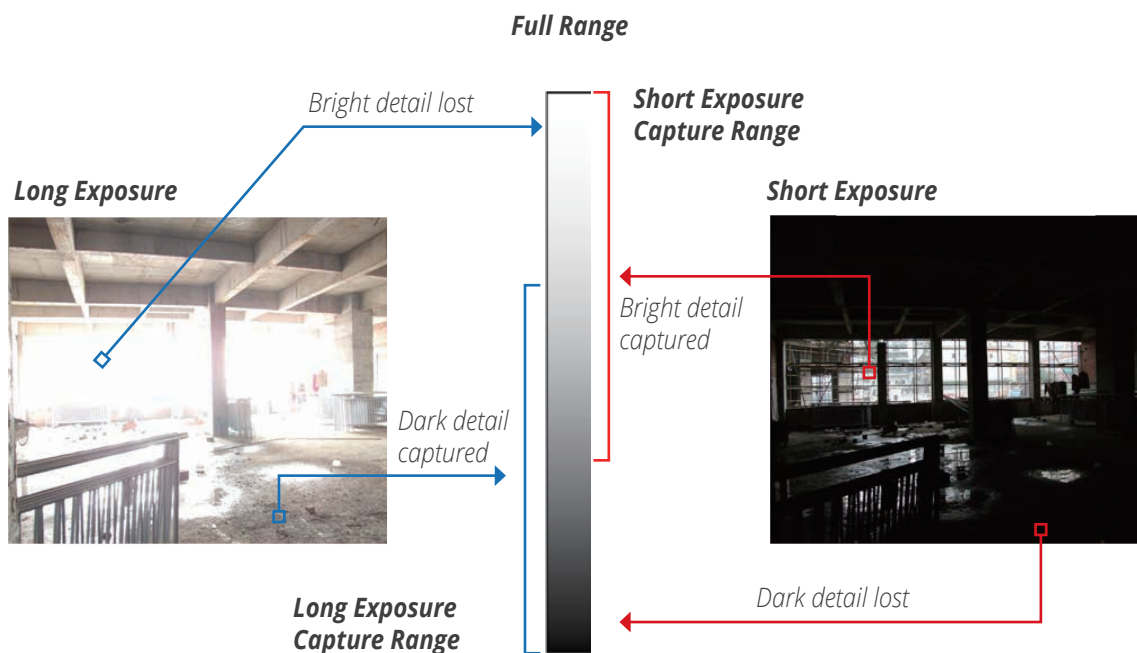
Full Range

Bright detail lost

**Short Exposure
Capture Range**

Long Exposure

Short Exposure

*Bright detail
captured*

*Dark detail
captured*

Dark detail lost

**Long Exposure
Capture Range**

Figure 2 *Extend dynamic range by multiple exposure*

However, although the dynamic range of the imaging sensitivity can be e ectively increased by multiple exposure and per-pixel exposure, they are not perfect. The multiple exposure method will cause some ghosting at the edges of a moving object due to tiny di erences existing in each exposure, and the per-pixel exposure may directly reduce the resolution of the image.

2.2 TONE MAPPING

As display devices, such as LCD monitors, computers and projectors, all have a limited dynamic range that is inadequate to reproduce the full range of light intensities present in natural scenes, tone mapping can be applied to represent the whole dynamic range while retaining realistic color and contrast.

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Tone mapping can be divided into two main types: global and local tone mapping. The method of global tone mapping is similar to the gamma curve in photography since every pixel in the image is mapped in the same way by referring to a non-linear look-up table. When the rate of curve decreases in the gamma table, which is frequently used for dynamic mapping, the output range will be reduced if the input data is large.
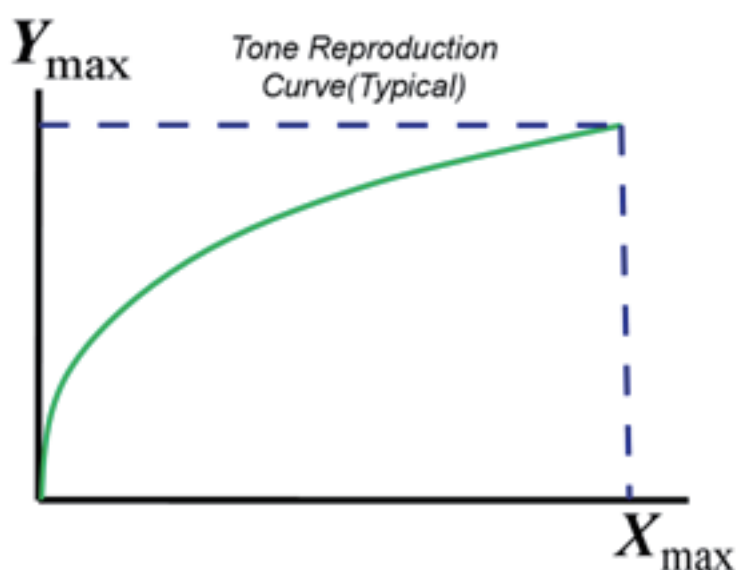

Figure 3 *Global Tone Mapping*

The technique of global tone mapping is simple and fast since every pixel in the image with the same brightness will be mapped in the same way, however, it can cause insufficient contrast or a loss of contrast in brighter areas, etc.

Local tone mapping can change the brightness in each pixel according to features extracted from the surrounding parameters of the image. Pixels located in di erent parts in the image are mapped to different results even though they have the same brightness, and such a method can provide sharp contrast and more details in the resulting image.

2.3 DIGITAL WIDE DYNAMIC RANGE

According to the above background information, the wide dynamic range technique must contain at least two stages: wide dynamic range imaging and tone mapping. For cameras, the real application of wide dynamic range imaging must be supported by the professional image sensor. Currently another technique, which is generally referred to as digital wide dynamic range (digital WDR), is adopted using local tone mapping instead of wide dynamic imaging to provide the image enhancement.

The digital WDR function cannot really extend the dynamic range of the camera, but simply enhances the details in the darker or brighter areas in the image by local tone mapping and optimizing visible contrast.

2.3 HIKVISION WDR TECHNIQUE

Based on the principles of local tone mapping, the Hikvision WDR Technique mainly features Luminance-adaptive Tone Mapping (LATM) and the Space-variant Contrast Enhancement (SVCE).

The LATM technique is an approach of global tone mapping, which can re-map the pixel brightness according to the brightness and contrast of the surrounding scene, aiming to enhance the brightness in darker areas and simultaneously restrain the overexposure in brighter areas. With the LATM-mapped curve, the original WDR values can be re-mapped to compress the dynamic range, and the darker areas in the image can be e ectively brightened by adjusting the greyscale distribution.
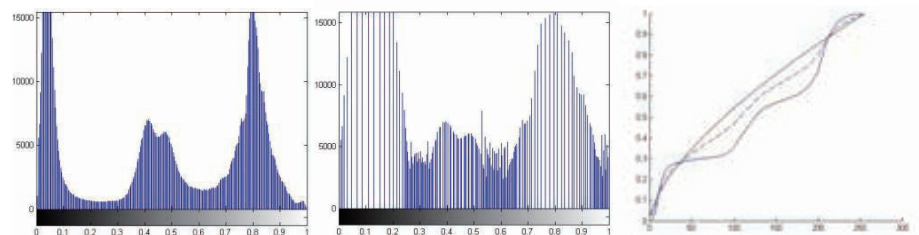

Figure 4 *LATM Mapping*

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By simulating the local characteristics of the human vision system, the SVCE technique is able to enhance the local contrast of the image and reproduce the image details in the dynamic range compression (DRC) function, making image details more realistic and transparent with better contrast.
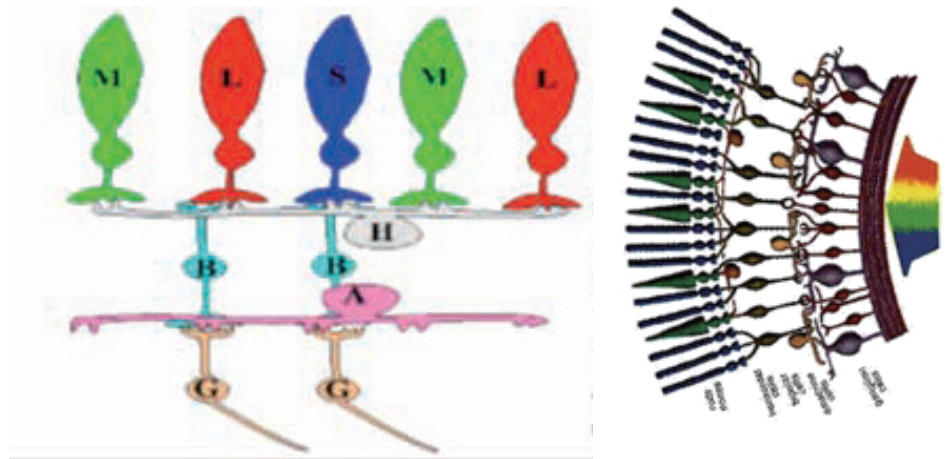

Figure 5 *Simulation Effect of Hikvision WDR Technique*

Hikvision's WDR technology makes full use of the full dynamic range of the sensor itself and is compatible with the complete wide range of sensor output data bits, from 12- to 20-bit. When the sensor outputs high bit data, the WDR algorithm has a better DRC effect and it can remap the high bit data to standard 12-bit data and output vivid wide dynamic images. Because a human's vision system is more sensitive to dark areas, when the sensor outputs standard bit wide data, WDR simulates the characteristics of a human eye and takes full advantage of the dynamic range of the data itself to ensure an optimal wide dynamic effect.
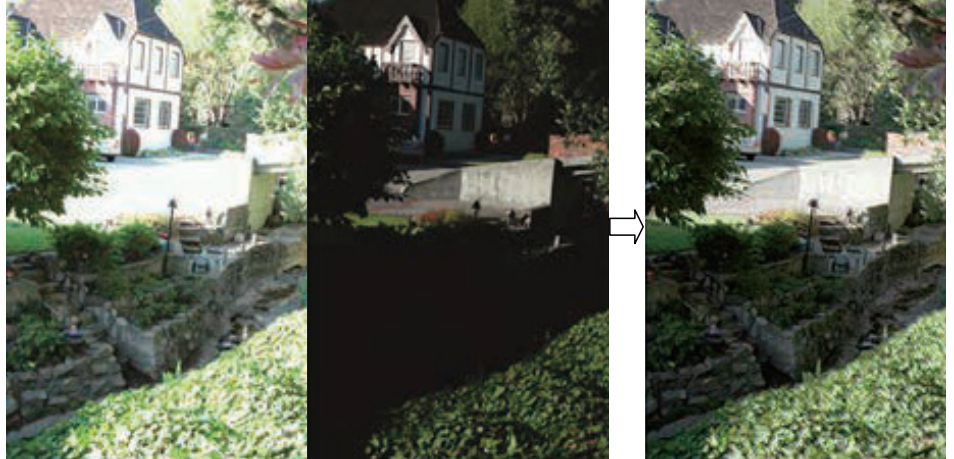
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Figure 6 *Simulation Effect of Hikvision WDR Technique*

Hikvision's WDR technology is applied automatically, just as the human eye can compensate for ever-changing scenes. With other WDR cameras, the WDR feature, which is either on or off, often produces unnatural colors and other issues, especially at night. With Hikvision's automatic WDR, these issues are avoided, with the resulting dynamic range, just the way a human sees it.

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