New-Generation Camera Environment Adaptability Technical White Paper

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1 Overview

The collection of High-definition (HD) video information by PUs ensures HD video effect. A key component in a video conferencing system is a camera, which collects image signals. The quality of collected image signals will directly affect the image quality of the video conferencing system.

The camera supports a series of operations, such as the image collection, analog/digit (A/D) conversion, and video signal processing. During image collection, various light conditions may affect the image quality. To provide a better video effect, lots of image processing technologies are developed. This document introduces some key technologies, including the 3A, low illumination, wide dynamic range (WDR), and noise deduction.
2 Camera Introduction

2.1 Operating Principle

The camera essentially is an optical-electrical-digital signal conversion and transmission device. Subject emitted or reflected light is focused to the charge coupled device (CCD) or complementary metal-oxide-semiconductor (CMOS) sensor device through the lens. The optical signal is converted into the electrical signal by the sensor device, and then the electrical signal is converted into the digital signal using the A/D conversion technology. Finally, the digital signal is processed by the image signal processing (ISP) processor to output analog or digital signal and is displayed on the display device.

![Operating principle](image)

The camera ISP process can be considered as an image processing pipeline that contains various image processing modules. Each module processes different characteristics of the image, including the defect correction, color enhancement, noise reduction, and contrast and resolution enhancement. The raw data output by the camera image sensor is processed by multiple ISP modules and displayed on the display device as video images.

![ISP](image)
The left image shows the original image output by the camera, and the right image shows the image after being processed by the ISP technology.

2.2 Technical Specifications

2.2.1 Resolution

The camera supports images of the following resolutions:

- 1080p (1920 x 1080): 2.0 megapixels
- SXGA (1280 x 1024): 1.3 megapixels
- 720p (1280 x 720): 0.92 megapixels
- XGA (1024 x 768): 0.8 megapixels
- SVGA (800 x 600): 0.5 megapixels
- VGA (640 x 480): 0.30 megapixels (0.35 megapixels: 648 x 488)
- CIF (352 x 288): 0.1 megapixels
- SIF/QVGA (320 x 240)
- QCIF (176 x 144)
- QSIF/QQVGA (160 x 120)

2.2.2 3A

Auto-exposure (AE): The camera automatically determines the parameters, such as the exposure, aperture control, shutter speed, and gain, using the program according to the light conditions of the shooting scene.

Auto-white balance (AWB): The camera automatically corrects white balance using the program, properly restoring white of images taken under different color temperatures or light conditions and using white as the base color to restore other colors to white.

Auto-focus (AF): The camera automatically focuses on the subject to be shot using the program based on a certain strategy.

2.2.3 Color Bit Depth

The color bit depth reflects the color identification capability and imaging color performance. The color bit depth is the quantization precision for the A/D converter to convert the analog signal to the digital signal, which classifies the signal into multiple levels. A greater color bit depth leads to more color quantity and displays richer image details.

2.3 Technical Specifications That Judge the Camera Quality

2.3.1 Definition

Definition is an important parameter that measures the camera quality. The general test method is shooting the definition template. You can view the black and white stripes of
different resolutions arranged at intervals on the test image on a monitor that has higher resolution than the camera. If the stripes are clearly displayed, the camera has a high resolution. The black and white stripes whose resolution is higher than that of the camera are displayed in gray and cannot be identified.

2.3.2 Color Reproduction

Camera color reproduction is the color compliance between the image shot by the camera and seen by people. Closer color compliance indicates better color reproduction. Camera color reproduction is a factor that affects the color reproduction of the entire video system, which can also be affected by the color reproduction of the display device. In addition, color reproduction is also affected by subjective factors. Different viewers' evaluation about color reproduction is different.

2.3.3 3A Effect

The AE effect is reflected by the camera response speed in the scenario with brightness variations. Under different light conditions, the camera can output images with suitable brightness neither too dark nor too bright. The AWB effect is reflected by the color balance in different color temperatures and color cast situation in special scenarios such as a large area with pure color. The AF effect is reflected by the camera auto-focus accuracy, speed, and focus stability.

2.3.4 Image Noise

Image noise is considered to be various factors that hinder people from obtaining effective information of the image. It is unpredictable theoretically and can only be recognized using the probability statistics. In a camera, the size of the sensor, operating temperature, and light conditions are the main factors affecting the amount of noise. Larger size of the sensor enables unit pixel physical area to receive more photons, which ensures higher signal-to-noise ratio (SNR). Lower operating temperature of the sensor enables the circuit to generate less thermal noise, which ensures better image quality. Better light conditions enable the sensor to receive more light, which reduces image noise. The noise characteristics of the digital image include the space, frequency domain, and time domain. The noise can be modeled based on the characteristics. The common noise models include the Gaussian noise, Rayleigh noise, and salt and pepper noise.

2.3.5 Video Smoothness

Smoothness is measured by the number of image frames collected per second in motion videos. A higher frame rate leads to higher video smoothness.

2.3.6 Viewing Angle

The viewing angle is a parameter to measure the camera shooting range, which is determined by the focal length and the size of the imaging component. A smaller focal length or larger size of the imaging component leads to a larger shooting angle. With the same local length, cameras that have larger viewing angle can shoot a wider range, but lead to a smaller object. When the focal length is zoomed in, the camera viewing angle turns small, but the object is enlarged.

2.3.7 DoF

Scenes in front of and behind the object that the camera focuses on can clearly image. The distance between the nearest and farthest objects that appear acceptably sharp in an image is
called depth of field (DoF). The DoF is affected by the aperture, object distance, and focal length.

When the focal length and object distance are constant, a larger aperture leads to shallower DoF.

When the focal length and aperture are constant, a shorter object distance leads to a shallower DoF.

When the object distance and aperture are constant, a larger focal length leads to a shallower DoF.
3 New-Generation Camera Introduction
4 Main Technologies

4.1 3A Video Processing Technology

4.1.1 AE Technology

AE control is a function that the camera uses to process photographed images in real time and adjust the image sensor and parameters that affect image brightness during processing. This function ensures that the brightness of the image sequence is consistent with the subjective feeling of the human eye and the environmental illumination.

AE control aims to make sure that the brightness rendered by the camera is at the same level as the ambient brightness perceived by the human eye. The following indicators determine the AE control performance:

- **Effect**
  Ideally, the image brightness is suitable for the human eye, the obvious overexposure phenomenon does not exist in the bright region in the image, and the dark region is clear enough to discern details.

- **Stability**
  AE control is stable if the camera can adjust the brightness of images whose content is the same to the same level when the environment changes. If AE control is unstable, the brightness of the original image and the new image captured after the environment changes is different, which leads to unsatisfied experience.

- **Sensitivity**
  When the appearance and disappearance of a bright or dark object (white or black object) causes that a certain area of the captured image changes, AE control adjusts the subjective sensitivity of the image brightness. If AE control is too sensitive, little change of the scene may cause that the image produces significant brightness variation similar to flashing, which does not comply with the human eye cognitive feelings.

- **Convergence time**
  When the scene changes, the AE algorithm needs a period for adjusting the brightness. This period cannot be too long or short. If the period is too long, the image brightness cannot adapt to the new scene. If the period is too short, the image brightness changes suddenly, which affects the user experience. A good AE algorithm adjusts the image brightness to a target value within the convergence time that meets user requirements.

- **Noise**
In a dark scene, AE control enhances the image sensor or ISP gains to improve the image brightness, which increases the image noise. Proper AE control limits the image noise within a reasonable range that will cause little impact on user's viewing. Improper AE control increases the image noise to an extent that will not be accepted by viewers.

Key technologies of AE control include how to obtain the AE control target value and the policy that is used to implement AE control. The key to obtain the AE control target value is how to evaluate the brightness of the shooting scene and then determine the target brightness.

The method of evaluating the shooting scene brightness is known as the metering technology. Current cameras use metering technologies, including the center-weighted average metering, partial metering, spot metering, multi-spot metering, and evaluative metering.

The center-weighted average metering mode applies to objects that are located in the center of the shooting scene. You can select a larger area in the middle of the image to estimate the required brightness of the scene. In most cases, the center-weighted average metering mode is accurate. However, for objects that are not located in the center of the shooting scene or that are located in backlight conditions, this metering mode cannot provide a correct result.

Different from the center-weighted average metering mode, partial metering mode applies to metering of partial areas in the shooting scene. This mode is used when the object has intense brightness contrast with the background and occupies little space in the shooting scene.

If you need accurate exposure of precise small-scale objects, spot metering can be used to avoid the impact caused by complicated light conditions or backlight conditions on the object. Spot metering uses a very small area in the shooting scene as a reference point and obtains the light conditions in this area as the exposure basis. The multi-spot metering is the expansion of the spot metering mode. By metering of multiple small areas in the shooting scene, the brightness of the scene can be estimated to reach the optimal exposure effect. This mode is suitable for shooting objects in backlight conditions.

Evaluative metering is a complicated and intelligent metering mode, and is widely used in cameras. Evaluative metering usually divides the shooting scene into a number of metering areas. Each area has different evaluation weights. The overall exposure value can be calculated by weighting after the independent metering of the areas. This mode can provide better metering effect in most shooting scenes.

The key of the AE control policy is what camera parameters to control and what policy to use to obtain the proper image brightness. The parameters that control the image exposure include the aperture, exposure time, and image gain.

An aperture is a component that controls the light to pass through the lens and go into the image sensor. Letter F is used to indicate the size of the aperture. If the value of F is smaller, the aperture is larger and more light goes into the lens per unit time. The aperture size also affects the DoF of the image. A larger aperture leads to a smaller DoF, and a smaller aperture leads to a larger DoF.

The camera's exposure time can be considered as the electronic shutter speed of the camera. Usually, the time ranges from 1/50 to 1/100000 second. The camera's frame rate output requirements determine the limitation of the exposure time. For example, the camera that supports the 60 fps video output requires the exposure time of up to 1/60 second. Shorter exposure time leads to less light going into the image sensor. Therefore, if the image is darker, the process of shooting a moving object is more fluent.

The image gain refers to the amplification degree of the image brightness, including the analog gain in the analog domain and digital gain in the digital domain. Changing the image gain can increase or decrease the brightness of the image. However, excessive image gain will result in a substantial increase in image noise.
An appropriate AE policy should control the aperture, exposure time, and image gain comprehensively. This ensures that the image brightness have better adaptability for different scenes and brings the viewers a good viewing experience.

Huawei's HD video conferencing camera supports AE control. The scene metering uses the intelligent evaluative metering technology. This technology divides the image into multiple areas. Different areas have different weights based on the probability of shooting object’s appearance. The final brightness of the whole image refers to the exposure weights of different areas.

Apart from the partition weight, the algorithm uses the intelligent analysis for metering data, identifying the backlight scenes and enabling the algorithm to adapt to these special scenes. The exposure brightness is not fixed. It varies depending on the illumination changes of the scene. In the low illumination condition, the exposure brightness of the object is set at a lower level to comply with the human eye's subjective viewing effect, reduce noise, and obtain important details of the object such as face. In the high illumination condition, the exposure brightness of the object is set at a higher level to obtain a brighter and clearer image.

The AE control policy of the Huawei HD video conferencing camera intelligently adjusts the aperture, exposure time, and image gain to ensure better experience in different scenarios. For example, to obtain an optimal image, large DoF, low noise, and high frame rate must be set in high illumination conditions. In low illumination conditions, to increase the brightness and reduce noise, small DoF and low frame rate must be set. The camera software program will automatically use the aperture priority or exposure time first algorithm to match the adjustment policy.

Apart from the control of image brightness, the AE can output the metering results in real time as the input for real-time adjustment of the ISP other functions. For example, the ISP noise reduction module can adjust the noise reduction intensity based on metering results. You are advised to reduce the noise reduction intensity or disable the noise reduction function in high illumination conditions, and improve the noise reduction intensity in low illumination conditions. In backlight conditions, the WDR function automatically starts to increase the brightness of the dark region in the image, which helps the viewer to see the dark region details clearly.

4.1.2 AWB Technology

The color rendering of an object in different illumination conditions is also different, which is determined by the color temperature of the light source. The object reflection spectrum and its true color have a certain deviation. For white objects, the deviation is the most obvious. If a white object is shot by the camera in low color temperature conditions, the image captured is reddish yellow; while in high color temperature conditions, the image captured is bluish. The white balance technology corrects the color of the image captured by the camera in different color temperature conditions, which makes white objects rendered truly white, which meets the requirements of the human eye’s cognitive habits.

White balance processing can be classified into manual white balance and AWB. Manual white balance means that the image of an object in white or gray color captured in the environment of a color temperature is analyzed and the component data of red, green, and blue colors is averaged, which makes the component value similar. The human eye is most sensitive to the green component of the image, which is generally not adjusted. To achieve the white balance of the image, you can change the gain of red and blue components. The advantage of the manual white balance processing is accurate color reproduction effect of white balance. Due to the complication of human intervention, the AWB is used to implement automatic white balance correction of images by the program, which is used by current cameras. The index to judge the AWB processing capability includes the following:
- **Accuracy**
  The AWB effect can be measured by the color reproduction of the white or gray color of the object that is processed by white balance. The poor AWB may lead to obvious color cast of the white or gray object in the scene.

- **Environment adaptability**
  The camera may be used for different color temperature environments. Therefore, the AWB algorithm must have good adaptability to both low color temperature and high color temperature, which helps accurate color reproduction of the white or gray color. The AWB algorithm with poor adaptability may get better effect in light conditions of certain color temperature, while produce obvious color cast in other light conditions.

- **Sensitivity**
  The AWB algorithm cannot be too sensitive to the image content. For scenes with large area of solid color, the AWB algorithm's sensitivity to the image content may lead to image color cast. For example, if a large area of red objects in a scene is processed by white balance, the actual image turns bluish.

As seen from the principle of the AWB, the core technology of the AWB is how to adapt to the light environment of different color temperatures to find red and blue gains. Most traditional AWB algorithms are based on the grayscale world hypothesis. Assume that the change of colors in an image is sufficiently rich, the average color value of the image can cancel a variety of differences in color and the average color of the entire image is gray, which makes the mean of red, green, and blue color components tend to be equal. Therefore, you can obtain the red and blue color gain by calculating the mean of red, green, and blue color components in an image.

The AWB algorithm based on the grayscale world is simple. However, if the color of a scene is not rich, especially when there are objects of a large area of solid color, large deviations appear in this algorithm, which is caused by the fundamental reason that the current image scene does not comply with the grayscale world hypothesis. To overcome the shortcomings of the AWB algorithm based on the grayscale world hypothesis, a lot of algorithms are put forward, which has better adaptability to the scene of a large area of solid color.

Huawei HD video conferencing camera uses the AWB algorithm of improved grayscale world hypothesis and color temperature estimation. The color temperature estimation algorithm is based on a priori knowledge. This algorithm pre-measures the camera response data under the standard light source environment of different color temperatures and obtains the pre-gain in the standard environment. When the AWB function is enabled for the image captured in the current light environment, the data sampling statistics is performed for the image in real time. By comparing the sampling statistics with the pre-measured data, you can estimate the color temperature characteristics under the current light environment and obtain a suitable red and blue color gain. More standard light sources of different color temperatures lead to more accurate data and color temperature estimation and better AWB effect.

The AWB technology of the Huawei HD video conferencing camera features good AWB effect and strong adaptability to different scenes. The camera can accurately restore the image after being processed by the AWB technology in the light environment of different color temperatures. Obvious color cast does not exist in images of large areas of solid color.
4.2 Low Illumination Video Processing Technology

4.2.1 Illumination

Illumination means the extent of the objects in the environment to be illuminated and is represented by the luminous flux accepted by a unit area. The unit of illumination is lux. One lux of illumination is defined as the luminous flux of 1 lumen uniformly distributed per square meter. Lumen is the unit of luminous flux. One lumen (lm) is defined as the luminous flux emitted by a point light source of the luminous intensity of one candela (cd) within a unit solid angle. The following table lists the illumination values in common scenarios.

<table>
<thead>
<tr>
<th>Index</th>
<th>Scenario</th>
<th>Illumination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outdoor at a summer noon with direct sunlight</td>
<td>100,000</td>
</tr>
<tr>
<td>2</td>
<td>Outdoor in a cloudy day without direct sunlight</td>
<td>10,000–1000</td>
</tr>
<tr>
<td>3</td>
<td>Indoor in a clear summer day</td>
<td>500–100</td>
</tr>
<tr>
<td>4</td>
<td>Stairs and corridors without light</td>
<td>8–10</td>
</tr>
<tr>
<td>5</td>
<td>Night of full moon</td>
<td>0.2</td>
</tr>
</tbody>
</table>

To obtain the desired shooting effect, the digital camera requires a shooting environment with certain illumination, which ensures a sufficient amount of light to be imaged to obtain high-quality images. However, it is difficult for most meeting rooms to obtain sufficient illumination to meet the ideal shooting conditions.

For example, it is difficult for a large conference room with a limited number of lamps to obtain high illumination. Due to remodel difficulties, it is difficult to install new lamps in old conference rooms, which cannot improve the conference room illumination.

Moreover, high illumination for a long period of time causes human eye fatigue, which discomforts people. Therefore, the brightness of the lights is artificially reduced in a lot of meeting rooms.

The ordinary camera imaging in low illumination is not ideal. For example, for some cameras, underexposed phenomenon, low brightness, and lack of the ability to display details of the dark region in the image may appear. For other cameras, to maintain the image brightness in low illumination conditions, the overall gain of the image is set high, which leads to obvious image noise.

It can be seen that the camera's low illumination effect has a great impact on the user experience, which is an important indicator to measure the performance of the video conferencing camera.

4.2.2 Factors Affecting the Low Illumination Effect

There are many factors affecting the camera low illumination effect, one of which is the size of the camera sensor and the resolution. Under certain resolution, a larger size of the sensor enables unit pixel physical area to receive more photons, which ensures higher SNR. A large-sized sensor can obtain more light under low illumination conditions for imaging, so the image noise is small.

Currently, most phones or low-end cameras use the 1/6-inch or 1/4-inch image sensor whose price is low and imaging quality in low illumination conditions is poor because of the small
size. Mainstream video conferencing cameras generally use the 1/3-inch image sensor. The sensor with this size can achieve a better balance between image quality and price. High-end cameras use the image sensor of 2/3 inch or larger size. Cameras of this type can get better image quality in low illumination conditions, but the price is more expensive.

**NOTE**
The image SNR and the image definition are both important indicators to measure the image quality level. A larger SNR leads to a cleaner image, on which you hardly see noise interference (known as particles and image blur). A small SNR leads to a heavier image blur in the image. The following are the factors that affect the SNR:

- Power interference
- Interference generated by overheat of electronic components
- Noise generated due to small voltage on the photosensitive element enlarged into 0.7 V video signals
- Noise caused by enhanced amplifier gain in low illumination conditions

Apart from the physical size, the SNR and the dynamic range of the image sensor are also important factors affecting the imaging quality in low illumination conditions.

Under the same physical size, the image sensor with a high SNR has higher photosensitivity, which leads to smaller image noise in low illumination conditions. The bit depth used by the digital signal after the A/D conversion by the image sensor describes the dynamic range of the camera. Common cameras use the digital signal of 10-bit depth. Advanced cameras can use the digital signal of 12-bit depth. With the increase of the bit depth, more image details are captured by the camera, and the image quality is better.

**NOTE**
The image bit depth refers to the number of bits used to store each pixel and is also used to measure the image resolution. The image bit depth determines the number of colors of each pixel in a color image or the gray level of each pixel in a grayscale image. For example, on a monochrome image, if each pixel has 8 bits, the value of the maximum grayscale is $2^8$ (256). If the RGB pixel in a color image is 4, 4, and 2 respectively, the maximum number of colors is $2^{4+4+2}$ (1024). That is, when the pixel depth is 10 bits, the color of each pixel is one of the 1024 colors.

The size of the aperture also affects the image quality in low illumination conditions. An aperture is a component that controls the light to pass through the lens and go into the image sensor. Letter F is used to indicate the size of the aperture. The value of F is the ratio of the focal length to the effective lens diameter. If the value of F is smaller, the aperture is larger and more light goes into the lens per unit time. A camera with a large aperture can obtain more light in low illumination conditions for imaging, so that the image quality is better and less noise exists.

Apart from the image sensor and the lens, the ISP algorithm also plays an important role in improving the image quality in low illumination conditions. A key technology is the noise reduction technology. The image noise in low illumination conditions is much greater than that in the normal illumination. Therefore, how to effectively remove noise on the basis of preserving image details is an important method to improve the quality of the image captured in low illumination conditions.

The ISP algorithm uses two methods to reduce image noise: SNR and TNR. The basic principle of the SNR is using the spatial filtering method to remove the additive noise in the image. The basic principle of the TNR is using the temporal filtering method to remove the dynamic noise in the video. The correlation between adjacent frames of the video image can be effectively utilized to filter the multi-frame image, which effectively eliminates the noise with dynamic changes on the time domain in the video image.

Another key technology of the ISP is the WDR technology. Detail defects exist in the dark region of the image captured in low illumination conditions. The WDR technology enables
the camera to get enough details in the dark region for imaging and improves the image quality.

Due to the high cost for increasing the size of the photosensitive device and the data bit depth, the common method to obtain the WDR image is using different exposure time durations for multiple exposures for the same scene to obtain an image of two or more frames and using the digital image processing technology to synthesize the multi-frame image into a WDR image.

The use of this WDR technology usually requires special photosensitive devices. The dark region of the synthesized WDR image is taken from the original image that has been exposed for a long time. This enables the dark region of the image to have sufficient brightness and displays details in the dark region.

4.2.3 Low Illumination Technology of Huawei HD Cameras

Huawei HD video conferencing camera uses a 1/3-inch 1080p image sensor that has a high SNR and dynamic range and can obtain high-quality images in low illumination conditions. Some high-end video conferencing products, such as the telepresence system, use 2/3-inch image sensors, which makes the noise level of the image captured in low illumination conditions more rational. In addition, Huawei HD video conferencing camera uses the lens with F1.8 or a larger aperture, ensuring sufficient light to be imaged in an image sensor in dark scenes and improving the image quality.

Huawei HD video conferencing camera also uses a special ISP algorithm to improve the image quality in low illumination conditions. To reduce image noise caused by low illumination, the camera's ISP algorithm uses the intelligent noise reduction technology, including the SNR and TNR.

The SNR technology uses different noise reduction strategies for different parts of the image. The clarity of the image is ensured on the basis of a good noise reduction effect. Meanwhile, the SNR technology performs self-adaptive noise reduction according to the image brightness. For dark regions whose noise is large, the noise reduction intensity can be appropriately enhanced to obtain a good noise reduction effect. The SNR technology uses a better spatial filtering algorithm, which makes the processed image clearer.

The TNR technology uses the temporal filtering algorithm for different regions. The trailing phenomenon caused by noise reduction is effectively reduced. The TNR technology uses a better temporal filtering algorithm, which reduces more image noise and makes the processed image more stable. Combined with the AE technology, the intelligent noise reduction technology detects light conditions in the shooting environment in real time and intelligently changes the noise reduction strategy.

Moreover, to solve the problem of inability to display details in the dark region of the image captured in low illumination conditions, Huawei HD cameras also support the WDR technology in various ways.

One is called digital WDR image processing technology, which does not require special photosensitive devices. This technology takes advantage of the dynamic range of the image sensor and adjusts the image gain, GAMMA curve parameter, and noise reduction parameter to enhance the brightness of the dark region in the image and display the details in the dark region clearly. The digital WDR technology supports real-time analysis of the light conditions in the scene and intelligently adjusts the image processing module parameters to reach a predetermined desired effect.

Apart from the digital WDR technology, the photosensitive device used by Huawei HD cameras also supports the WDR technology similar to multiple exposures. The data obtained from multiple exposures is processed by the ISP module to form the final WDR image. Huawei HD camera uses the unique WDR image synthesis algorithm to optimize the
traditional WDR image synthesis algorithm, which reduces image blurring and ghosting and provides better images in low illumination conditions.

4.3 WDR Video Processing Technology

4.3.1 WDR Definition and Application Scenario

The WDR is a technology that enables a camera to shoot images in strong light contrast conditions. When a region of high brightness under the irradiation of strong light sources (such as the sunlight, lamplight, or reflect light) and a region of low brightness caused by shadows or backlight exist in the same image, the bright region is overexposed and becomes white, and the dark region is underexposed and becomes black, seriously affecting the image quality. The camera has limitations in displaying the bright and dark regions in the same scene, which is called dynamic range.

In a broad sense, the dynamic range refers to the change span of a certain changing thing. That is, the dynamic range is the range from the lowest point to the highest point of the change values. The description of this range is generally the difference between the highest point and the lowest point. In terms of the indicator of captured image quality, the dynamic range refers to the adaptability to the light reflection in the shooting scene, that is, the variation range of brightness (contrast) and color temperature (contrast).

The dynamic range of the captured image is the ratio of the maximum brightness value to the minimum brightness value. Due to its own dynamic range limitation, the ordinary CCD or CMOS camera has restrictions in displaying the bright and dark regions in the same scene.

For example, in a video conferencing scene, the camera can shoot indoor objects and scenes outside the window. Brightness outside the window is often much higher than the brightness of indoor objects. The indoor illumination may be only dozens of lux (illumination unit, represented by the luminous flux accepted by a unit area), while the outdoor illumination may exceed 10,000 lux. In this scene, the human eye can see both the indoor and outdoor objects clearly because of the large dynamic range that the human eye can perceive.

However, for the ordinary camera whose dynamic range is limited, the quality of images captured by the camera is poor. If you want to shoot outdoor objects, short exposure time is recommended, but indoor objects will become dark in the image and their details cannot be captured. If you want to shoot indoor objects, long exposure time is recommended, but outdoor objects will be overexposed and their details cannot be captured. Similar scenes include the backlight scene and the scene of shooting luminous objects such as highly reflective objects or fluorescent lamps.

To solve the preceding problems, the WDR technology must be used to enable the camera to obtain enough details in both bright and dark regions and improve the image quality.

4.3.2 Technical Principle

There are two factors affecting the camera dynamic range: one is the exposure time of the camera; the other exists in the A/D conversion process.

- Exposure time
**Figure 4-1** Imaging of different exposure time (left: short exposure time; middle: medium exposure time; right: long exposure time)

The exposure time of the video camera is limited by the frame rate. Uniform exposure time for shooting a frame of image may be too long or too short. The ideal exposure time ensures the optimal SNR for each pixel. Short exposure time applies to the bright region of the image and long exposure time applies to the dark region of the image, which allows each region of the image to get the best quality. The physical size of each pixel of the photosensitive device also affects the dynamic range of the camera. Large physical pixel size can obtain a better SNR, which improves the dynamic range of the image.

- **A/D conversion**
  The bit depth used by the digital signal after the A/D conversion by the image sensor describes the dynamic range of the camera. Common cameras use the digital signal of 10-bit depth. Advanced cameras can use the digital signal of 12-bit depth. With the increase of the bit depth, more image details are captured by the camera, and the image quality is better. In addition, current displays use the display format of 8-bit for each color. Therefore, the question of how to convert the digital signals of the image with high bit depth to 8-bit display digital signals must be considered to obtain the WDR image.

- **Current WDR technology situation**
  Due to the high cost for increasing the size of the photosensitive device and the data bit depth, the common method to obtain the WDR image is using different exposure time durations for multiple exposures for the same scene to obtain an image of two or more frames and using the digital image processing technology to synthesize the multi-frame image into a WDR image. The use of this WDR technology usually requires special photosensitive devices. The dark region and the bright region of the synthesized WDR image are taken from the original image that has been exposed for a long time and a short time respectively. This ensures better details displayed in the dark and bright regions of the image.

  However, this method also has some defects. One major defect is that if fast moving objects exist in a scene, long exposure time may lead to image blur of moving objects. Besides, moving objects of different brightness may cause different motion blurring and ghosting. If the image synthesis algorithm is not ideal, obvious synthetic traces may appear in certain regions. In addition, certain regions of the WDR image may generate significant noise.
4.3.3 WDR Technology of Huawei HD Cameras

Huawei HD cameras support two WDR technologies. One is called digital WDR image processing technology, which does not require special photosensitive devices. This technology takes advantage of the digital signal of the 12-bit depth and adjusts the image gain, GAMMA curve parameter, and noise reduction parameter to improve the WDR effect of the image.

For example, for the over-bright region of the image, the digital WDR technology can reduce the brightness to prevent overexposure. For the over-dark region of the image, the digital WDR technology can improve the brightness and noise reduction intensity to display details in the dark region clearly.

The digital WDR technology supports real-time analysis of the light conditions in the scene and intelligently adjusts the image processing module parameters to reach a predetermined desired effect. The digital WDR technology makes full use of the image processing technique within the original dynamic range of the photosensitive device to obtain a better subjective image effect and avoid image blurring and ghosting defects caused by the WDR technology such as multiple exposures.

The defect of the digital WDR technology lies in that the original dynamic range of the photosensitive device is not expanded. It is difficult to get ideal details in processing the data of the bright region in the image. When the image brightness of the dark region improves, the image noise increases.

Figure 4-3 Comparison between the image not processed by the digital WDR technology (left) and the image processed by the digital WDR technology (right)
Apart from the digital WDR technology, the photosensitive device used by Huawei HD cameras also supports the WDR technology similar to multiple exposures. Exposure can be carried out in different ways under the control of the photosensitive device pixels by the program. The exposure strategy includes multiple exposures for different time durations for the entire frame of image and multiple exposures for different time durations for raw data by pixel. The data obtained from multiple exposures is processed by the ISP module to form the final WDR image. The algorithm of the ISP module is well-designed to ensure the dynamic range without data loss in the entire process.

Huawei HD camera uses the unique WDR image synthesis algorithm to optimize the traditional WDR image synthesis algorithm, which reduces image blurring and ghosting and provides better images in low illumination conditions.

4.4 Intelligent Noise Reduction Technology

4.4.1 ISP Noise Reduction Technology of Common Cameras

For a digital image, the image acquiring and transfer are the major source of noise. The performance of the CCD or CMOS image sensor used by current cameras is affected by a variety of factors, and different levels of noise are generated as a result. For example, when the CMOS image sensor is used to collect videos, the sensor size, operating temperature, and light conditions are the main factors affecting the amount of noise. Larger size of the sensor enables unit pixel physical area to receive more photons, which ensures higher SNR. Lower operating temperature of the sensor enables the circuit to generate less thermal noise, which ensures better image quality. Better light conditions enable the sensor to receive more light, which reduces image noise.

The noise characteristics of the digital image include the space, frequency domain, and time domain. The noise can be modeled based on the characteristics. The common noise models include the Gaussian noise, Rayleigh noise, and salt and pepper noise. The noise reduction technology for digital images is an image recovery process in nature. The noise reduction technology uses the priori noise model to recover image degraded by the noise and enables the processed image to reach the predetermined desired effect.

Figure 4-4 Comparison between the original image and the image degraded by the noise
Currently, the camera application scenarios pose higher requirements for image sensor cost, performance, and environment adaptability. A sophisticated ISP noise reduction technology attracts more attention and becomes one of the key technologies in the camera field by providing high-quality images even when the size of the image sensor is small, the operating temperature is high, and the light conditions are complicated.

### 4.4.2 ISP Noise Reduction Technology of Huawei HD Cameras

Huawei HD cameras use the ISP noise reduction technology, which includes the SNR and TNR.

The basic principle of the SNR is using the spatial filtering method to remove the additive noise in the image. Spatial filtering uses a neighborhood (a small rectangle) to perform predefined actions on image pixels surrounded by the neighborhood. A new pixel is generated after the spatial filtering. The coordinates of the pixel are the coordinates in the center of the neighborhood. Pixel values are the results of the filtering operation. Compared with traditional SNR technology, Huawei intelligent SNR technology uses more advanced strategies that can remove more image noise and obtain clearer images. Huawei SNR technology has the following advantages:

- **Traditional SNR** is executed on the entire image regardless of region difference, which affects the image definition during noise reduction; the intelligent SNR technology uses different noise reduction strategies for different regions of an image, which ensures the image definition during noise reduction. For example, noise reduction is not done or less done for the subject edge to maintain the image definition. For flat areas with less texture, the noise reduction intensity should be increased to obtain the optimal noise reduction effect.

- The intelligent SNR technology carries out noise reduction in the image according to the image brightness. For example, the noise is relatively small in bright regions of the image. Therefore, reducing the noise reduction intensity can reduce the impact on image definition. For dark regions whose noise is large, the noise reduction intensity can be appropriately enhanced to obtain a good noise reduction effect.

- The SNR technology uses a better spatial filtering algorithm, which makes the processed image clearer.

**Figure 4-5** Comparison between the original image and the image processed by the SNR technology
The left image is the original image. The right image is the image processed by the SNR technology.

The basic principle of the TNR is using the temporal filtering method to remove the dynamic noise in the video. Spatial noise reduction is carried out on a single-frame digital image. However, a video is a sequence of consecutive images, providing more reference information than a single image. The correlation between adjacent frames of the video image can be effectively utilized to filter the multi-frame image, which effectively eliminates the noise with dynamic changes on the time domain in the video image. Huawei TNR technology has the following advantages:

- The TNR technology uses the temporal filtering algorithm for different regions. For example, the temporal filtering intensity is reduced for the motion regions of an image to effectively reduce the trailing phenomenon caused by noise reduction, while the intensity is enhanced for the static regions to effectively remove noise.

- A complicated motion detection algorithm is used to detect the motion region in the image. Motion detection has been a great challenge of the TNR. Inaccurate motion detection leads to obvious point or block shaped defects in the image after the noise reduction. Huawei's motion detection algorithm improves the detection accuracy for static and motion regions in the image.

- The TNR technology uses a better temporal filtering algorithm, which reduces more image noise and makes the processed image more stable.

In addition, Huawei's intelligent noise reduction technology combines the AE and WDR technologies to obtain better noise reduction effect in complicated light conditions. The AE and WDR algorithms can detect light conditions in the shooting environment in real time and intelligently changes the noise reduction strategy. For example, in high illumination conditions, the noise reduction intensity can be reduced, or the noise reduction function can be disabled; while in low illumination conditions where the image noise is large, the noise reduction intensity can be enhanced.