Smart Temperature Measurement

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Contents

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1 Introduction

A thermal imaging camera is a device which detects infrared radiation emitted by targeted objects. It calculates the corresponding relationship between radiation energy and temperature and shows the surface temperature of the target through different gray values.

Thermal imaging cameras need to calculate the infrared radiation intensity of a target object while eliminating factors that could possibly interfere with providing a reliable temperature reading, such as the surface temperature of hot objects around the target. Thus, to achieve accurate temperature measurement, various testing strategies are implemented depending on target and temperature scenario.

2 Functions Overview

2.1 Spot Temperature Measurement

Spot temperature measurement supports the display of temperature values anywhere in the preview image, as shown in Figure 2.1.

Figure 2.1: Spot Temperature Measurement

2.2 Rule Temperature Measurement

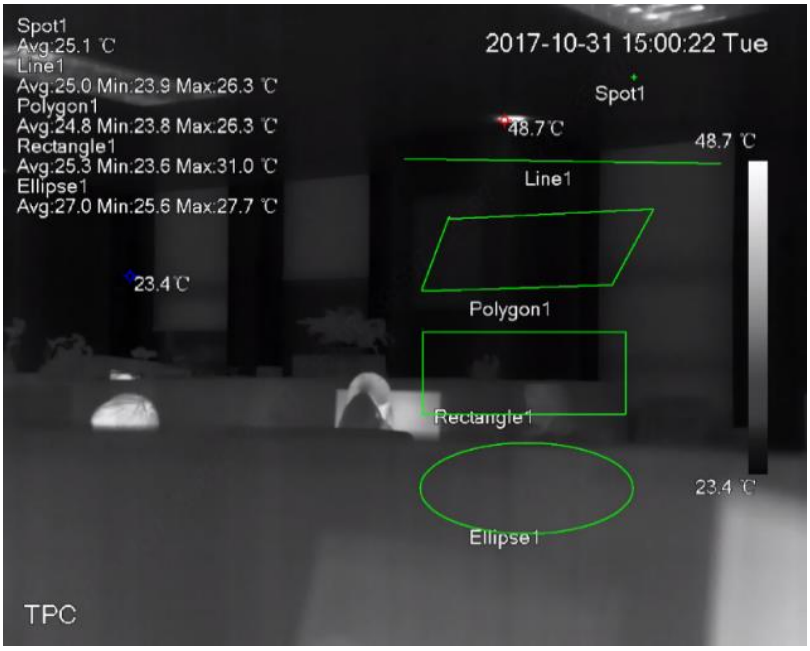

Figure 2.2: Rule Temperature Measurement

Rule temperature measurement provides several modes, such as spot, line, polygon, rectangle, and ellipse mode. It calculates the gray value of all pixels on or within the rule line and displays the average, minimum, and maximum calculated values.

2.3 Temperature Differential Measurement

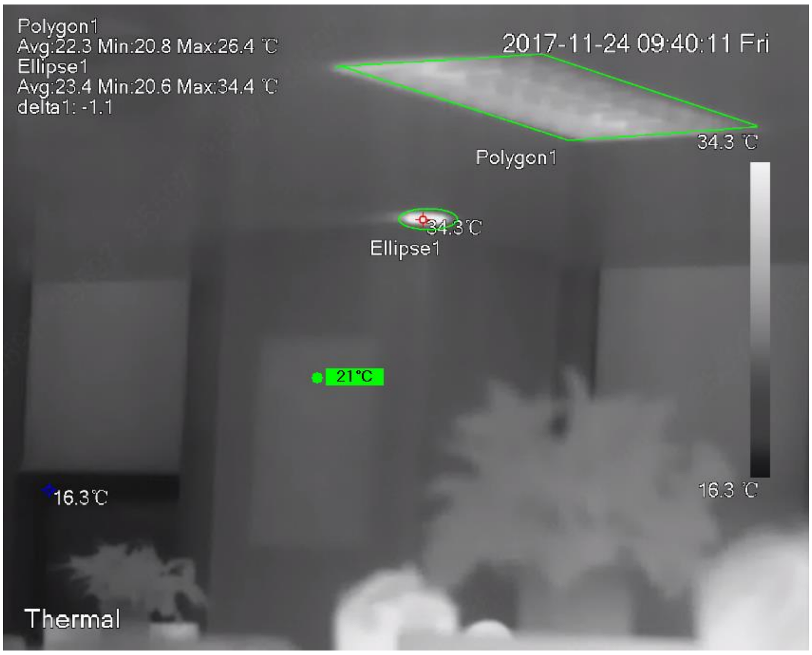

Figure 2.3: Temperature Differential Measurement

Temperature differential measurement compares the temperature of selected spot, line, or area and displays the results on the preview interface.

2.4 Isothermal Palettes

Isothermal imaging makes it possible to configure highlighted temperature-spans in the image. This makes it easier to interpret what takes place in the scene. Unlike traditional color palettes, temperature can be set. The palettes are fixed, but it is possible to adjust the temperatures for the different color ranges, so that a critical temperature will stand out.

Isothermal settings are used to configure the colors in the image that visually highlight temperature differences. There are two palette types that can be applied to the image, and the vertical bar indicates which palette type that is active:

1. Color Palette (default): All the colors in the applied palette are used to color the image but no colors correspond in any way to specific temperatures in the image. The vertical bar shows the selected palette.

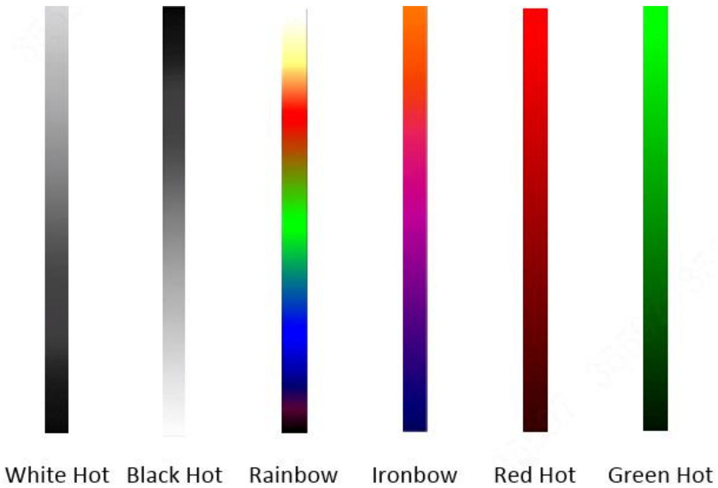

Figure 2.4: Example color palettes in thermal cameras.

2. Isothermal Palette (isothermal enabled): Isothermal palettes make it possible to isolate predefined colors to selectable temperature levels. The vertical bar shows the selected isothermal palette and the entered temperature levels.

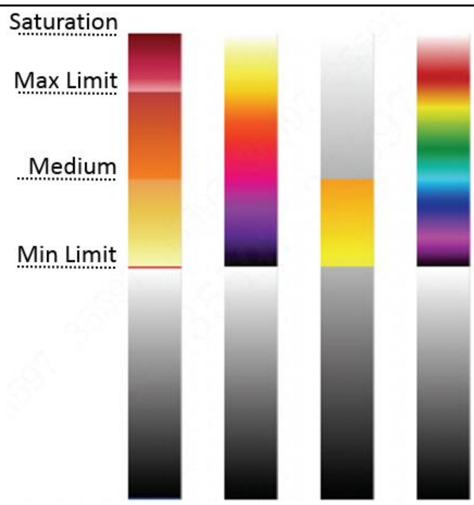

Figure 2.5: Example isothermal palettes in thermal cameras.

Isothermal palettes are used only to highlight specific temperatures as a visual aid for an operator. If, for example, the lower limit is set at a temperature that is critical for a certain object, all temperatures above it will stand out. In the event of a temperature alarm, the operator will rapidly be able to see whether the alarm is false, since the isothermal image will show whether it was the critical object or something else that triggered the alarm.

Figure 2.6: When using isothermal palette, it is possible to highlight the temperature span and easily identify if a surface reaches a defined temperature.

3 Accuracy

Thermal imaging cameras can be used to measure infrared energy emitted from objects and convert it into a visible image. According to the functional relationship of the radiation and the surface temperature of an object, the device can calculate the specific temperature value and display it. However, the radiation does not only depend on the temperature, but also on the emissivity of the object. The surrounding environment also emits radiation, especially high temperature objects at close range, which will be reflected by the surface of the target. The emitted radiation of the object and the reflected radiation are also affected by atmospheric absorption. Therefore, to measure temperature precisely, it's necessary to consider the effect of different radiant sources.

3.1 Target Emissivity

Target Emissivity is the ability of a target to absorb and emit radiant thermal energy from its surface. Different objects have a different molecular structure and arrangement, so the radiant energy they emit is different at the same temperature. For example, superficial emissivity of a piece of 50 ℃ cast iron is 0.81, whereas emissivity of water at 50 ℃ is 0.96. Different emissivity settings are required when measuring different objects. The emissivity of common materials can be seen in the table < Common Material Emissivity >.

For a measured object with unknown emissivity, you can get the actual temperature by using a contact method. Then, use the thermal imaging camera to measure the temperature, and configure the emissivity until the temperature value is same as that one measured through contact. At this point, the setting value is the emissivity of the target.

3.2 Target Reflection

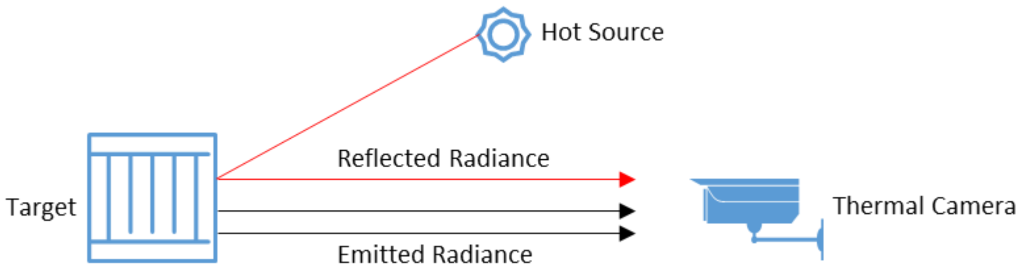

Figure 3.1: Target reflection temperature

Radiant energy of surrounding objects can be reflected off the target surface and transferred to the thermal camera, affecting temperature measurements. For example, when you test the windshield of a car, the temperature measured is often lower than the actual temperature of the windshield. This occurs due to the smooth surface of the glass reflecting cold air into the thermal camera's view. In particular, when the target emissivity is below 0.9 and the target's temperature is lower than the surrounding objects, it is very important to avoid interference from hot sources. You can place a baffle or coat high emissivity materials on the surface of the target to make the result as accurate as possible, as shown in Figure 3.2.

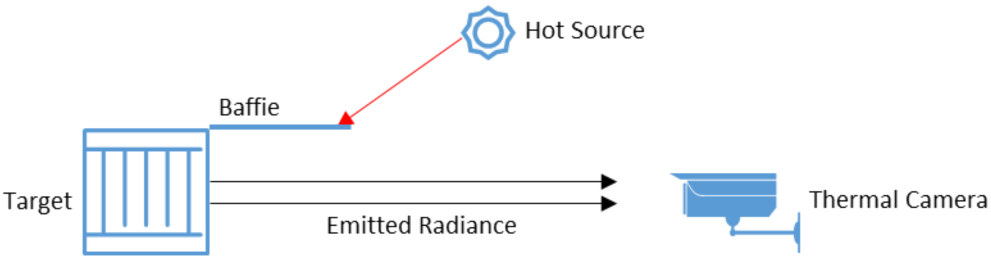

Figure 3.2: Target reflection temperature with baffle

3.3 Target Size and Distance

In most temperature measurement applications, some targets only occupy 1 or 2 pixels. Due to optical diffraction and aberration, the target's radiant energy can't be transferred to the 1 or 2 pixels completely, which leads to misinterpreted measurement results. It is necessary the size of a target is at least 10x10 pixels. Based on this, you can get the maximum distance for accurate temperature measurement of different-size objects with different lenses, as shown in Table 3.1.

Resolution/Lens	Target Dimensions (meters)		
	1	0.3	0.1
336*256			
9mm	36	10.8	3.6
13mm	52	15.6	5.2
19mm	76	22.8	7.6
25mm	100	30	10
35mm	140	42	14
50mm	200	60	20
60mm	240	72	24
100mm	400	120	40
640*512			
9mm	52.9	15.9	5.3
13mm	76.5	22.9	7.6
19mm	111.8	33.5	11.2
25mm	147.1	44.1	14.7
35mm	205.9	61.8	20.6
50mm	294.1	88.2	29.4
60mm	352.9	105.9	35.3
100mm	588.2	176.5	58.8

Table 3.1: Range to target in meters

3.4 Atmospheric Transmission

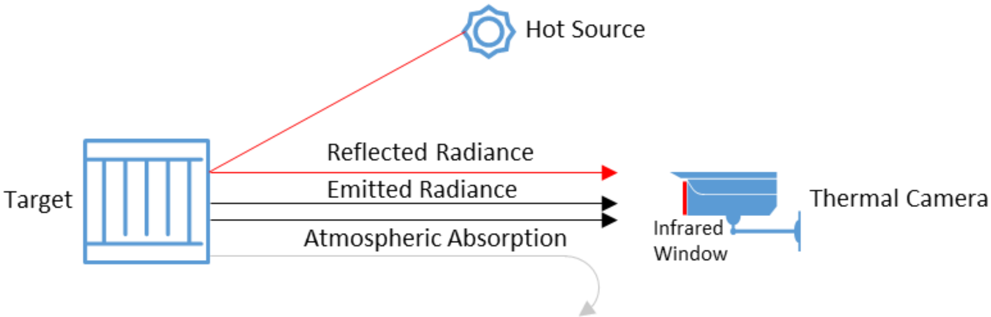

Figure 3.3: Atmosphere transmission temperature

Radiant energy can be transferred to the device through 'air passage'. Hence, atmospheric transmission is a factor that must be considered when making precise temperature measurements in different air environments. In cold and dry air at a distance of 10m, the energy transmission coefficient can reach up to 100%. But in a high temperature and high humidity environment, water vapor absorbs a lot of energy, which means the system must account for transmission losses and a lower coefficient.

Tables 3.2, 3.3, and 3.4 describe the influence of different distances, temperatures, and humidity levels on radiation energy. The atmospheric conditions each table cover 90% of usage scenarios. Each table assumes a fixed air temperature and displays the transmission coefficient as a result of humidity over range for that temperature.

Range (meters)	RH=5%	RH=25%	RH=50%	RH=100%
1	1	1	0.99	0.99
3	1	1	0.99	0.99
10	0.99	0.99	0.98	0.97
30	0.99	0.97	0.97	0.95
100	0.99	0.95	0.94	0.91
300	0.95	0.92	0.89	0.83
500	0.94	0.9	0.85	0.77
1000mm	0.92	0.86	0.79	0.63
2250mm	0.87	0.79	0.66	0.4
3000mm	0.86	0.77	0.60	0.4
5500mm	0.81	0.67	0.41	0.4
10000mm	0.74	0.56	0.40	0.4

Table 3.2: Atmosphere transmission coefficient in different conditions (atmosphere temperature=20℃)

Range (meters)	RH=5%	RH=25%	RH=50%	RH=100%
1	1	0.99	0.99	0.99
3	0.99	0.99	0.99	0.98
10	0.99	0.98	0.98	0.96
30	0.98	0.97	0.96	0.94

100	0.97	0.94	0.92	0.87
300	0.95	0.90	0.84	0.74
500	0.93	0.86	0.79	0.63
1000mm	0.90	0.80	0.67	0.40
2250mm	0.86	0.69	0.42	0.40
3000mm	0.84	0.64	0.40	0.40
5500mm	0.79	0.48	0.40	0.40
10000mm	0.72	0.40	0.40	0.40

Table 3.3 Atmosphere transmission coefficient in different conditions (atmosphere temperature=30℃)

Range (meters)	RH=5%	RH=25%	RH=50%	RH=100%
1	1	0.99	0.99	0.99
3	0.99	0.99	0.98	0.98
10	0.99	0.98	0.97	0.96
30	0.98	0.96	0.94	0.93
100	0.96	0.92	0.88	0.85
300	0.94	0.86	0.77	0.68
500	0.92	0.81	0.68	0.53
1000mm	0.89	0.71	0.47	0.40
2250mm	0.83	0.51	0.40	0.40
3000mm	0.81	0.41	0.40	0.40
5500mm	0.75	0.40	0.40	0.40
10000mm	0.68	0.40	0.40	0.40

Table 3.4 Atmosphere transmission coefficient in different conditions (atmosphere temperature=40℃)

3.5 Infrared Window

In some cases, a window is placed at the front of the thermal camera for extra protection, such as anti-explosion, anti-corrosion, etc. Normally, the window's transmittance is around 90%, inducing an approximately 10% deviation in measurement accuracy due to interference from the shell internal temperature. For example, if the window temperature is 30℃, but shell internal temperature is 35℃, the result will be 50.4℃, higher than the actual temperature. The reflected energy is underestimated, it is not 10% emitted from the 30℃ shell internal air, but 10% from the 35℃. If the window temperature is 0℃, the result will be 52.9℃.

To get an accurate temperature measurement, you need to know the transmittance and temperature of the window, and enter the corresponding parameters into the device. The device can correct results according to the existing conditions.

Atm. Trans. = 1, Window Transmission = 0.9, Window Reflected T = 35 C, e = 0.95, Background Temp = 23 C		
Window Reflected Temperature(Entered)	**Measurement**	**Error**
19	51.5	1.5

23	51.1	1.1
27	50.7	0.7
31	50.4	0.4
35	50	0
39	49.5	-0.5
43	49.1	-0.9
47	48.6	-1.4

Table 3.3: Infrared window with different GUI temperature for measurement accuracy (target temperature 50℃)

4 Summary

Combined with the above factors, a precise temperature measurement should include:

1. **Confirming the target emissivity**. If it is greater than 0.95, that is to say, the reflectivity is very low, you will easily get the exact temperature because it is not sensitive to a wide range of background temperatures. If it is lower than 0.90, to enhance it, you need to spray a material with high emissivity or paste black electrical rubberized tape onto the surface of the target.
2. **Excluding external temperature interference as much as possible**. When the emissivity reaches or is less than 0.9, radiant energy surrounding the object will be reflected by the surface of the target and transfer into the thermal camera, which affects the measurement. The lower the emissivity and temperature, the greater the influence on the results.
3. **Keeping appropriate distance**. Ensure the target occupies enough pixels in the image (⩾10x10).
4. **Consider energy transmission losses**. Especially in high temperature and humidity environments, the atmospheric transmission coefficient is obviously reduced, and the test distance should be no more than 10m.
5. **Entering the correct window transmittance and temperature**. Enhance transmittance and keep the shell internal temperature stable and low. The target emissivity should be as high as possible, especially in scenarios where the temperature of the target is lower than the environment temperature or the internal temperature of the shell.

5 Reference Documentation

< Common Material Emissivity >

About Dahua Technology

Zhejiang Dahua Technology Co., Ltd. Is a leading solution provider in the global video surveillance industry. In 2016, Dahua was ranked 4th in the "Security Top 50" by a&s international.

Dahua is committed to providing the highest quality product with the latest technologies to enable our end users to perform their business successfully. The company has more than 6,000 R&D engineers and technical staff working on cutting-edge technologies in camera lens, image sensor, video encoding & transmission, embedded processor, graphic processing, video analytics, software reliability, network security, and other technologies.