Thermal Temperature Monitoring

Accurate, Safe, and Effective Measurement

Dahua Technology USA Inc.

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Introduction

Every December 31st is both a time for reflection on another year gone by and a look into the future for the promise of a new year. The year 2020 was to be especially promising because it was the start of a new decade. The millennium was no longer a teenager; it graduated into adulthood. But as we all know, becoming an adult bears adult-size responsibilities and challenges, and none more dire than a virus that not only took over headlines, but also took over the world in the nascent months of 2020. The COVID-19 pandemic has affected millions of people around the globe, bucking social norms, workplace rules, and basic everyday life. Healthcare workers find themselves at war: they no longer just go to work; they are now on the "front lines," engaged in battles with an invisible foe. The pandemic brought unprecedented challenges and decisions that require nimble and unique solutions. One such solution employs thermal camera technology for continuous and non-invasive measurement of external human temperature, without personal contact.

Disclaimer

The Dahua Thermal Temperature Monitoring Solution is not FDA-cleared or approved. The Solution should not be solely or primarily used to diagnose or exclude a diagnosis of COVID-19 or any other disease. Elevated body temperature should be confirmed with secondary evaluation methods (for example, an NCIT or clinical grade contact thermometer). The Dahua solution, when properly installed and configured displays the highest temperature measured from an individual's face. This temperature may include the temperature of the region adjacent to the Medial canthus of the eye, the part of the eye that includes the tear duct. This solution can measure this part of the eye if: A) the application scenario is conducive to allow the camera to capture this part of the eye and B) the eye is not obscured by glasses, a mask, or other obstruction. A temperature measurement from the region adjacent to the Medial canthus more closely correlates to an individual's internal body temperature than a temperature measured from an individual's skin.

Users, through their experience with the solution in the particular environment of use, should determine the significance of any fever or elevated temperature based on the external body telethermographic temperature measurement. Visible thermal patterns are only intended for locating the points from which to extract the thermal measurement. No matter where the thermal camera measures an individual's temperature, keep in mind that certain individuals with elevated skin temperature (EST) may have an elevated body temperature (EBT). In turn, certain individuals with EBT may have a fever, and a subset may have contracted the COVID-19 virus.

Thermal Temperature Monitoring Solution

A thermal temperature monitoring solution typically encompasses a hybrid thermal camera that combines a Vanadium Oxide (VOx) sensor with a visible-light sensor. Most thermal cameras measure temperature to an accuracy within 1.8° F (1.0° C) of actual, adequate for industrial or typical surveillance applications, but monitoring human temperature requires a higher level of accuracy. Comprehensive solutions, like the solution that Dahua offers, that are the most accurate include a blackbody calibration device that maintains a customizable constant temperature as a reference point for the thermal camera. In addition, a network video recorder (NVR) may be included to provide storage for video and temperature data as well as face detection technology.

Thermal Camera

A thermal camera uses a thermal imager, essentially a heat sensor, to detect small differences in temperature. These cameras collect the infrared radiation from objects in the scene and create an electronic image based on information about the temperature differences.

A special lens focuses the infrared light emitted by all of the objects in view, and in turn, is scanned by a phased array of infrared-detector elements. The detector elements create a detailed temperature pattern called a thermogram in about one-thirtieth of a second. The camera obtains this information from several thousand points in the field of view of the detector array.

A circuit board with a dedicated chip then translates the thermogram into electronic impulses, and sends the impulses to a signal-processing unit. The signal-processing unit sends the information to the display, where it appears as various colors, each color based on the intensity of the infrared emission. The combination of all the impulses from all of the elements creates the image.

While all thermal imaging cameras contain an infrared sensor to detect infrared wavelengths, many also incorporate a visible-light CMOS sensor that creates a normal color image to superimpose over the infrared image, providing more context and detail to the infrared image.

Blackbody

A blackbody is a physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence. It not only absorbs radiation, but can also *emit* radiation. The name "blackbody" refers to the function of the device to absorb radiation in all frequencies, not just specific ones.

Because of these characteristics, a blackbody device is a desirable calibration source for thermal imaging based temperature measurement systems. The blackbody functions as a calibration tool, and becomes a target object with a precisely known and controlled temperature. This precision is the basis for accurate calibration of infrared pyrometers, increasing the accuracy of thermal imaging equipment. A blackbody at a constant temperature emits electromagnetic radiation called blackbody radiation. This constant temperature is important in external human temperature measurement where accuracy to ± 0.54° F (0.3° C) is advised by many international standards organizations.

Deploying a thermal imaging system for human temperature measurement poses several challenges: Consider the following issues when purchasing a thermal camera system for human temperature measurement, especially the accuracy of the system and the calibration process.

- Thermal Drift Compensation

  Even a calibrated thermal camera with thermometry (temperature measurement function) experiences temperature drift when the environment temperature changes. Unless the measurement location is of a constant temperature, and the thermal camera is calibrated to that environment, the system cannot be expected to produce temperature measurements at the published specification.

- Temperature Accuracy

  Most thermometry-capable cameras are accurate to ± 1.0° F (1.8° C) or less. For many user-defined human temperature detection thresholds, this level of accuracy is less than desirable.

  It is because of these characteristics that the blackbody device is preferred within a human temperature measurement application. Many blackbody devices are designed for use with thermometry-capable cameras deployed in industrial applications, and measure extremely high or low temperatures. These applications typically do not require the accuracy range suitable for human temperature measurement. Human temperature measurement requires a higher-end blackbody device to deliver an accuracy range suitable for fever detection.

The chart below show tests performed comparing several temperature measurement devices. The test was performed in a controlled environment during a four-hour test span over typical indoor temperature ranges. From the chart, you can see where the thermal camera with blackbody closely matches the oral thermometer readings from ambient temperatures ranging from 66.0° F to 81.0° F (18.9° C to 27.2° C). The thermal camera measurements without blackbody shows a distinct trend of increased temperature readings with increasing ambient temperature. Without the blackbody device, the thermal camera-only solution is accurate only for use at a narrow ambient temperature range, at which it was calibrated.

°F	°C	Thermal Camera Only	Thermal Camera + Blackbody	Oral Thermometer	Temporal (Forehead) Thermometer	Laser Thermometer (Aimed at Chin)	Ambient Temperature from Meter
66	19	98.9° F	98.0° F	97.8° F	96.6° F	93.4° F	66.6° F
68	20	99.1° F	98.6° F	99.0° F	98.5° F	99.1° F	67.6° F
71	22	99.1° F	98.1° F	98.0° F	97.9° F	98.0° F	69.4° F
72	22	99.2° F	97.9° F	97.4° F	98.3° F	95.8° F	70.0° F
74	23	101.5° F	98.5° F	98.6° F	97.3° F	97.3° F	74.3° F
75	24	100.9° F	98.4° F	98.4° F	97.6° F	97.3° F	75.2° F
77	25	101.2° F	98.4° F	98.6° F	98.1° F	96.2° F	76.8° F
79	26	100.7° F	98.4° F	98.1° F	98.3° F	95.8° F	78.3° F
81	27	101.4° F	98.5° F	98.5° F	98.1° F	96.6° F	80.2° F

It is important to consider that the temporal and laser thermometers require contact or close proximity to obtain measurements. The oral thermometer is invasive, and presents great risk of cross-contamination. Those techniques can only measure one person at a time, requiring a few seconds minimum for each one. The Dahua thermal camera with blackbody provides the desired accuracy AND speed, up to 30 people at a time across a wide range of indoor ambient temperatures.

- Human Body Temperature

  It is important to understand that human bodies register different temperatures depending on several factors. In North America, we take it for granted that 98.6° F (37.0° C) is normal body temperature. Technically, however, 98.6° F (37.0° C) is the mean average temperature taken with a calibrated oral thermometer. Generally, the correlation of temperature between methods are as follows[2]:

  - The average normal oral temperature is 98.6° F (37.0° C).
  - A rectal temperature is 0.5° F to 1.0° F (0.3° C to 0.6° C) higher than an oral temperature.
  - An ear (tympanic) temperature is 0.5° F to 1.0° F (0.3° C to 0.6° C) higher than an oral temperature.
  - An armpit (axillary) temperature is usually 0.5° F to 1.0° F (0.3° C to 0.6° C) lower than an oral temperature.
  - A forehead (temporal) scanner is usually 0.5° F to 1.0° F (0.3° C to 0.6° C) lower than an oral temperature.

  Note that the ASTM standard[3] for allowable errors of clinical thermometers is:

  - 0.18° F (0.1° C) in the temperature range of 98.6° F to 102.2° F (37.0° C to 39.0° C)
  - 0.36° F (0.2 °C) in the temperature range of 96.8° F to 98.6° F (36.0° C to 37.0° C) and 102.2° F to 105.8° F (39.0° C to 41.0 °C).
  - The allowable error of clinical thermometers was within a band of ±0.54° F (±0.3° C) in the range below 98.6° F (36° C).

  Since these systems read the external temperature, it likely will be less than the measured oral temperature of the individual. Consider this as you set the temperature threshold for alarm conditions.

What to Set the Detection Temperature to?

This number is user-configurable and users can use these guidelines to set the detection temperature. According to the CDC[4], the definition of a fever is a temperature of 100.4° F (38.0° C) or higher[3]. You might want to set the alarm threshold of the thermometry system up to 0.5° F (0.3° C) lower than that, but that is entirely up to application, it is recommended that you consult a medical authority for advisement. Regardless of what temperature is measured, you should always send people with detected high temperatures to a secondary screening with a clinical-grade thermometer.

Face Detection NVR

A recommended component for the solution is an NVR with face detection capability. Dahua NVR's with face detection can detect a face in a digital image using any ONVIF camera stream, in addition to Dahua Face Detection cameras. Additionally, the face detection process can be applied to the visible image sensor stream of the hybrid thermal camera.

Face Detection and Accuracy

A core requirement of any thermal system is to deliver accurate measurements. In many applications, however, it is not practical to interrupt the flow of people and have them stop at a predetermined spot in order for the system to take a reading. This is a common limitation of handheld thermographic systems, which impede the flow of visitors. One way to increase efficiency is to use face detection as a filter, allowing only temperature measurement of detected faces and nothing else.

This capability has several benefits. For one, it can allow for simultaneous readings, as the system only has to focus on faces for measurement. Second, it helps minimize measurement of non-human heat sources, like a cup of coffee. A system with enough processing power can detect and measure up to thirty faces in the same camera view.

Deployment Layout Planning

Planning the layout of the system prior to deployment is important. First, identify the expected outside temperature versus the temperature inside. If the outside temperature is different than indoors, then that affects ideal location of where the camera should be located (in relation to the entrance) and will affect the accuracy of measurements. This is because the thermal system measures external skin temperature: if the outside temperature is 60.0° F (15.5° C) and the interior ambient temperature is 70.0° F (21.1° C), then external skin temperatures will read lower than actual.

Mitigation Techniques with Large Temperature Differentials

In that case, you need to delay visitors before they reach the thermal measurement area. One way is to create a diversion channel shown in the figure below. Visitors will queue up similar to an airport security checkpoint, where their wait time will be long enough for external human temperatures to regulate after their exposure to the outside temperature. Length of the wait time should depend on the temperature differential and must be tested comparing temperature measurements between the thermal system and use of a clinical-grade thermometer.

Minimizing Environmental Effects

Avoid positioning the camera within view of any bright light sources, including glass doors or windows that show the outside. In addition, avoid having any heat sources in view of the camera, like heating vents, coffee makers and the like. The thermal camera does require initial setup where you define the target measurement area, in which case you may be able to draw the area to exclude such sources.

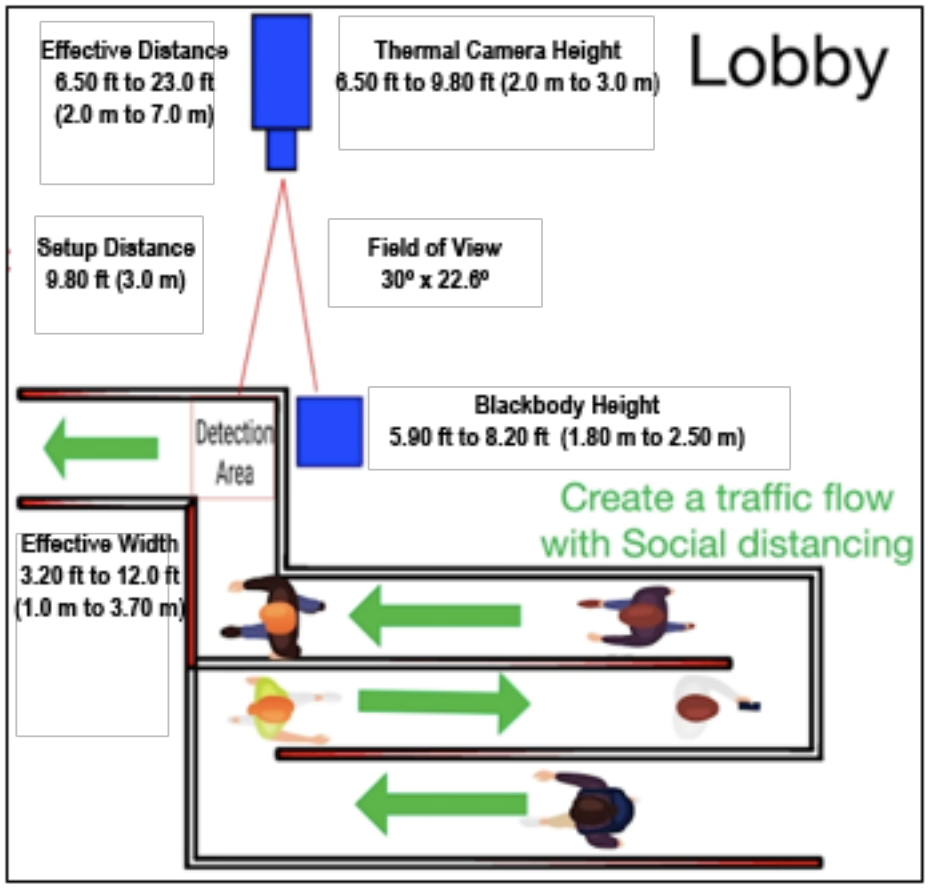

Figure 1: Illustration showing optimal placement of components

- Set multiple lanes when designing the traffic flow pattern. The forehead temperature measurement is more accurate the longer a person is indoors.
- Measure the temperature away from the ventilation at the door.

Calibration

The Dahua thermal camera with human temperature measurement option has a feature in the web UI for ambient temperature setting. Use a third-party thermometer to detect the actual ambient temperature on site and input that number if it is different from the default value. If the readings are still incorrect, adjust the "Human Temperature correction" value in the camera's Web User Interface, detailed in the setup instructions.

The blackbody module requires twenty minutes of pre-heating before operation or configuration. The target temperature is displayed on the rear of the unit. The proper working temperature of the blackbody device is 95° F (35 ℃). If the temperature is not 95° F (35 ℃), manually adjust it to 95° F (35 ℃).

Applications

Due to the precise visibility enabled by detecting heat, industries have used thermal cameras for decades, predominantly by law enforcement and the military. In the wake of the 2020 coronavirus pandemic, the technology saw an uptick in demand as a way to detect people with an elevated temperature in a fast, effective, and safe (contact-free) way. Dahua designed their Thermal Temperature Monitoring Solution for rapid and temporary deployments for a variety of verticals such as hospitals, medical centers, education, industrial business, warehouses, casinos, hospitality, and banking.

Featuring high accuracy, high efficiency, strong adaptability and easy deployment, the Thermal Temperature Monitoring Solution performs preliminary and rapid screening for multiple people at a time. When an alarm is triggered for an abnormal temperature, the person can then be assessed with standard medical temperature measuring equipment to re-check their temperature.

For example, Wynn Resorts used thermal cameras to detect temperatures of guests. Many airports had passengers undergo thermal screening prior to boarding the aircraft and after arrival. Retailers such as Walmart took the temperatures of associates when they first reported to work, and the Atlanta Journal reported a local grocery chain requiring customer temperature checks.

Hospitals

In times of pandemic, many hospitals implement manual fever checks at the entrance; however, this puts staff at unnecessary risk of exposure. With administrators and staff already overwhelmed from high patient intake, many have deployed an automated thermal temperature measuring solution for a safer environment.

Hospital Entrance / ER Entrance

Hospitals pose many security challenges due to 24/7 public access, high-tension work environments, various entry/exit points, and narcotics storage. It is important to deploy video surveillance at all entry points to ensure not only visibility as to who is coming and going, but to deter crime. Due to possible glare from the constantly opening and closing doors, and sun reflection from nearby windows, a camera with Wide Dynamic Range (WDR) is recommended. Dahua's hybrid thermal temperature monitoring camera offers a visible lens with WDR for surveillance and a thermal lens for detecting a person's temperature. By combining thermal imaging with analytics, healthcare facilities can program the system to notify staff automatically if it detects a person within a defined temperature range.

An often-overlooked advantage of hybrid thermal cameras is that they can provide surveillance and thermal detection without compromising a person's identity. This not only respects patient privacy, but also complies with HIPPA regulations. Additionally, a privacy mask can be used on the thermal image so that just the temperature is visible.

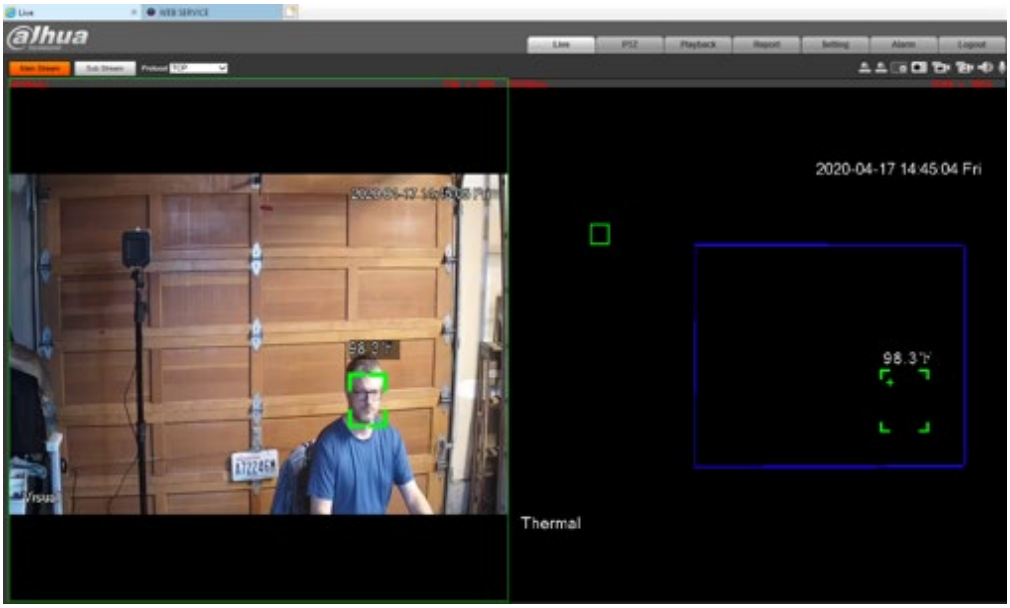

Figure 2 Left side represents the visual lens of the hybrid thermal camera with the temperature reading and the right side represents the thermal lens with a privacy protection mask.

Additionally, on March 17, 2020, the U.S. Equal Employment Opportunity Commission (EEOC) issued an update to its guidance indicating that employers may implement temperature-screening measures in response to the COVID-19 pandemic. The EEOC noted, "Because the CDC [Centers for Disease Control and Prevention] and state/local health authorities have acknowledged community spread of COVID-19 and issued attendant precautions, employers may measure employees' body temperature."

Figure 3 Thermal imaging in use at the entrance to a hospital in Spain.
Photo Credit: David Benito/Getty Images

Warehouses

Many warehousing and logistic centers are considered essential businesses, with employees continuing to work during stay-at-home initiatives. The temperature monitoring solution can provide a time-efficient way to assess potential high temperatures of large groups of people without personal contact. This type of solution is ideal for deploying at employee entrances to mitigate risk of a potential sick worker from entering the building. The solution can also be deployed throughout the facility in the event that someone develops a fever during the workday.

According to CNET.com[5], warehouses such as the e-tail giant Amazon used the technology to streamline temperature checks. The use of thermal temperature cameras allows businesses to contain the virus' spread without shutting down the warehouse operations that are essential to its business. Amazon implemented daily temperature checks in some of their operations locations as an additional preventative measure to support the health and safety of their employees.

Education

Schools have a high population density, with a large number of students and teachers. The temperature monitoring solution can provide a time-efficient way to assess potential high temperatures of large groups of people without personal contact. With schools closed during a pandemic and the curriculum disrupted, having a temperature measurement solution in place lets elementary schools, colleges and universities alleviate anxieties once they reopen. If a second wave comes or another outbreak occurs, the tools will be in place to help flatten the curve of another pandemic.

The technology effectively limits close contact and contributes to combating the virus by lowering the risk of cross-infection caused by contact. It also saves manpower and material resources, while guaranteeing efficient and discreet preliminary screening of all staff, students, and visitors. It can also screen up to 30 people per second, so it is suitable for areas with high traffic such as universities, campuses, and dormitories.

Retail

Retailers can utilize the thermal temperature monitoring solution by deploying it at store entrances to alert staff if customer or employee temperature readings exceed the user-defined threshold. As a result, retailers can limit access to the store to only individuals who are below the threshold. Additionally, employees will feel confident that their workplace has implemented a safe environment and customers will feel safer shopping.

Banking

A number of commercial banks have taken the precautionary measure of installing thermal devices to check the temperatures of not only employees but customers too.

Although many businesses post signs asking for sick customers and employees to refrain from entering the premises, the reality is that some people will ignore it. However, with the thermal temperature solution, the camera will automatically detect and send an alert so the proper responder can react.

Casinos and Restaurants

The gaming and hospitality industry will also benefit from the deployment of thermal temperature monitoring devices at entrances / exits and throughout the facility. For a person with an elevated temperature, a visual alert is sent so that security personnel has a visual image of the person's identity and can re-check their temperature.

Figure 4: Sample alert of a person with an elevated skin temperature

Conclusion

The COVID-19 pandemic has affected the life and livelihood of millions of people, not discriminating who is infected and who can recover. Viable measurement of human temperature is one method to help in the fight to stop the spread of the virus. The Dahua Thermal Temperature Monitoring Solution is an accurate, safe, and effective tool that once installed and implemented can detect elevated external temperature in environments such as airports, hospitals, and clinics.

Dahua Thermal Temperature Monitoring System Components

Click here to navigate to the Dahua Thermal Temperature Monitoring Solution Web page or click links below for detailed information about each component.

Required Components (sold separately)

- **DH-TPC-BF5421-T** Thermal Hybrid Network Camera
- **JQ-D70Z** Blackbody
- **DHI-NVR5216-16P-I** 16-channel NVR

Recommended Accessories (sold separately)

- **VCT-999** Tripod (x2)
- **RQW026-00** Mounting Bracket for camera and blackbody (x2)
- **DHL43-F600** Full HD Monitor

Endnotes

(1) https://en.wikipedia.org/wiki/Black_body
(2) https://wa.kaiserpermanente.org/kbase/topic.jhtml?docId=tw9223
(3) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3257961/
(4) https://www.cdc.gov/coronavirus/2019-ncov/downloads/COVID-19_CAREKit_ENG.pdf
(5) https://www.cnet.com/news/amazon-using-thermal-cameras-for-covid-19-temperature-checks/

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