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Grid-EYE Application Note on Social distancing

People detection and tracking with ceiling mounted sensors

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Content

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1. SENSOR AND APPLICATION OVERVIEW

Ensuring social distancing behavior of people in a vast number of environments has gained significant importance during the last months: Amongst others, detecting and monitoring the number and location of persons - without any violations of private spheres - will be an essential part of contemporary working place concepts.
Let alone these social distancing requirements, the acquisition of temperature data also can be employed to optimize company premises such as working spaces, meeting rooms, shop floors and many more – not only for occupancy management, but also to control an efficient level of heating, air condition or ventilation.

- Meeting Room occupancy
- "Hot Desking" and workspace management
- Service interval optimization (e.g. toilets)
- Occupancy of hotel rooms and dressing rooms
- Shop floor management

This Application Note examines the field of people monitoring in four steps and evaluates two use cases:

Use Cases:

1) With only one sensor, we will detect - even motionless persons in workplaces and meeting rooms. Due to the nature of the low resolution thermal image, privacy and data security is always ensured.

2) Using multiple sensors within a grid, we will monitor walking persons to retrace peoples' behaviour in a group.

2. APPLICATION NOTE CONTENT

1) The Grid-EYE Sensor
We will give you a short introduction on the sensor and the differences to other technologies. More details on the sensor itself and its technology can be found on
https://industry.panasonic.eu/components/sensors/grid-eye

2) Hardware setup for people tracking
Two sensor versions with different viewing angles are mounted on the ceiling. The area's setup will be explained.

3) Technical sensor notes
We will cover the basic physical and technical application background to be able to understand the sensor output data:

a. Sensor field of view and crosstalk between the pixels
b. Sensor output as a function of object size, distance and material
c. Shadowing and object shape
d. Absolute temperature accuracy, offset and noise

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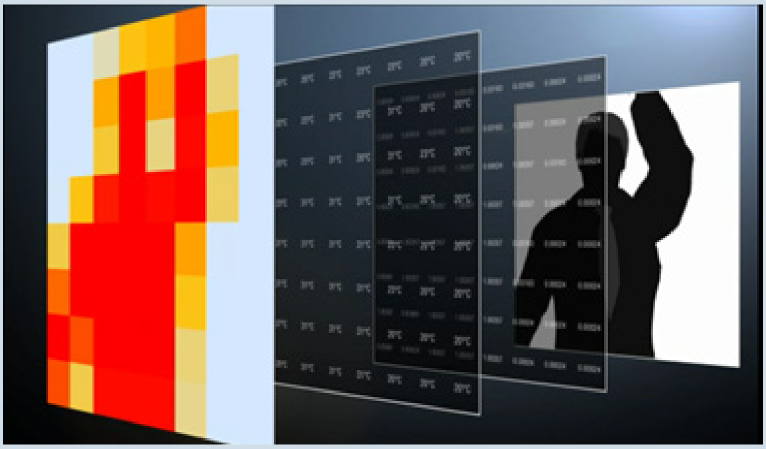
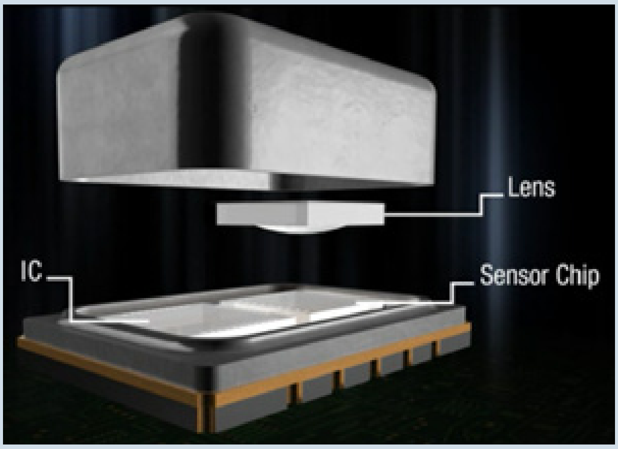
3. THE GRID-EYE SENSOR

Grid-EYE is a high-precision infrared camera and the first ever 64 pixel IR camera in an all-in one compact SMD package, suitable for mass production. Target of this Panasonic patented technology is to drastically decrease the price and the size of thermal imaging cameras so that they can enter consumer and home appliance products. By combining this new sensor technology with Panasonic's "nanopower" Bluetooth Smart modules and software for IR people detection, we are able to achieve a very easy to use product which allows customers to quickly build their own wireless sensor "Internet of Things" applications.





	Moving objects	Motionless objects	Movement direction	Temperature measuring	Respect for Privacy
Pyroelectric	Possible	Impossible	Impossible	Impossible	Possible
Low resolution Thermopile	Possible	Impossible	Impossible	Impossible	Possible
Camera	Possible	Possible	Possible	Impossible	Impossible
Grid-EYE	Possible	Possible	Possible	Possible	Possible

Table 1 Comparison of GridEye Sensor to other technologies

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4. HARDWARE SETUP

For both Applications we will use multiple Grid-EYE Sensors mounted at the ceiling, facing top-down. The sensors are connected to a PC via a Panasonic PAN1740 Bluetooth Module. The raw data is transferred and processed by the PC. The algorithms described in this article could also run by a M0+ microcontroller.

Figure 1 illustrates the possible detection area depending on the used lens. We assume a minimum detection height for humans of approximately 1m from the floor. We recommend the 60° lens for ceiling heights from 3m to 5m. A 90° lens for ceiling heights <= 3m is currently in development. Please contact us for further details.

Lens Types Viewing Angle	35.6°	60°	90°
Status	Mass production	Mass production	Development
Detection Area @ 3m ceiling height	1,7 m²	5.3m²	16m²

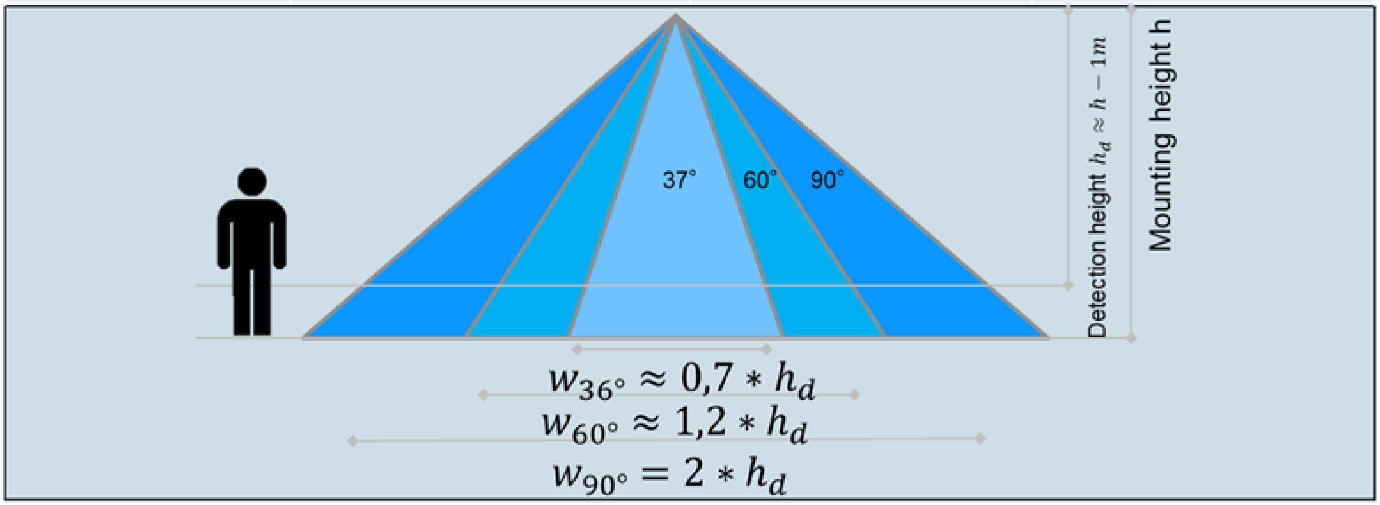

Figure 1 Grid-EYE Human Detection Area depended on the used Lens

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In Figure 2, the essential hardware setup for this Application Note is explained. First tests can be done with one single sensor only. The maximum number of sensor nodes in parallel is only limited by the backend and the used communication protocol.

For this Application Note, we are using ten sensors with a 60° Lens (two parallel, five in series) and three sensors with 90° Lens. Both cover the same area of roughly 40 m².

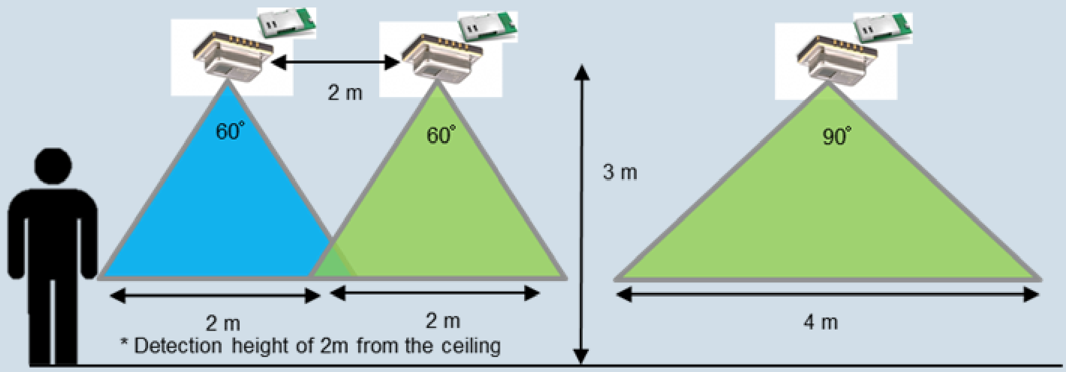

Figure 2: Principle hardware setup for the density monitoring and people tracking. Two different kind of lenses are used: 60° Version (in mass production) and 90° versions (samples available)

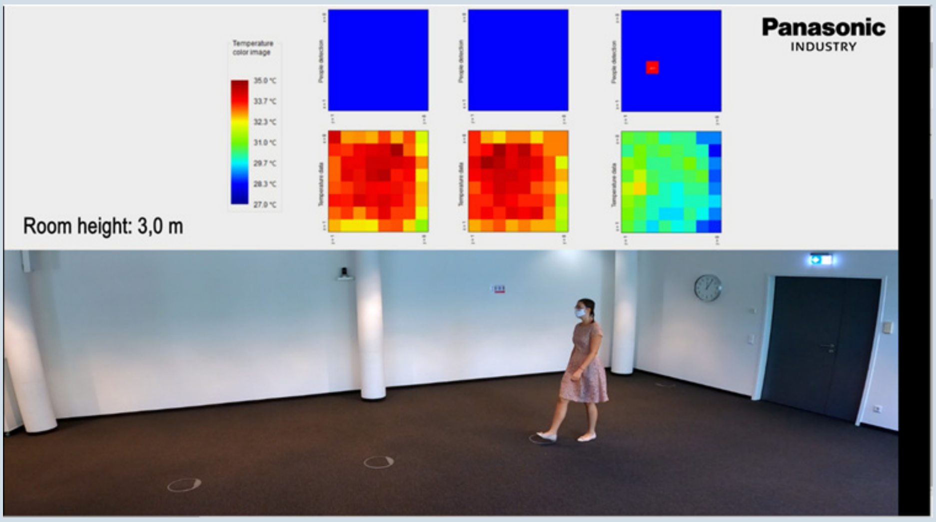

Figure 3: Test setup with three sensors mounted at the ceiling. The red point in the top right picture corresponds to the detected person below.

5. TECHNICAL SENSOR NOTES

Field of view (FoV) and cross-talk

In this paragraph, we will focus on the field of view for the 60° lens. The general findings also apply to all other lenses.

The 60° Grid-Eye sensor features 8 pixels vertically and 8 pixels horizontally which equals an opening angle of typically 7.5° per pixel. This corresponds to the approximated FWHM (Full Width at Half Maximum) value.

As an example, the exact measurements of the horizontal FoV for the Pixels 1-32 are shown in figure 4. Additional measurements can be found in the general application notes on our homepage.

The total opening angle of each pixel depends on its position and is wider than the FWHM value. This optical phenomenon leads to a cross talk between the pixel readouts which can be easily observed by monitoring a small warm object from different distances.

Figure 5 shows the pixel detection area depending on the pixel position. The tolerance of the FoV is typically at +-3 degree based on the full FoV of 60 degrees.

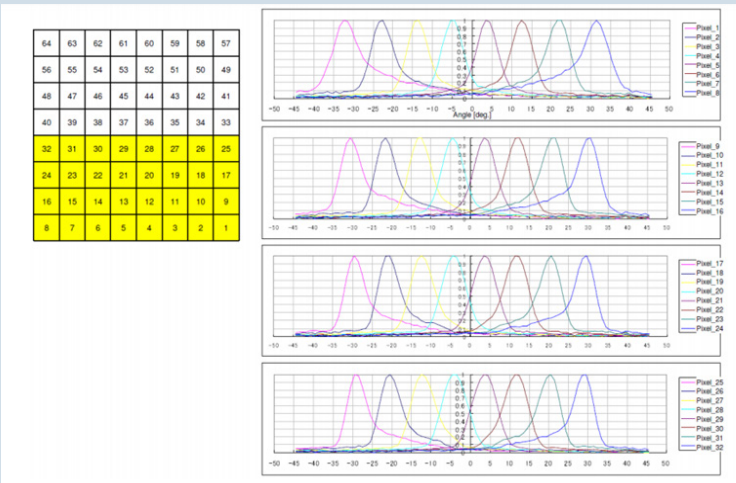

Figure 4: Horizontal Field of View for the Pixels 1 to 32 of the 60° lens.
X-Axis: horizontal FoV in degrees; Y-axis: normalized intensity

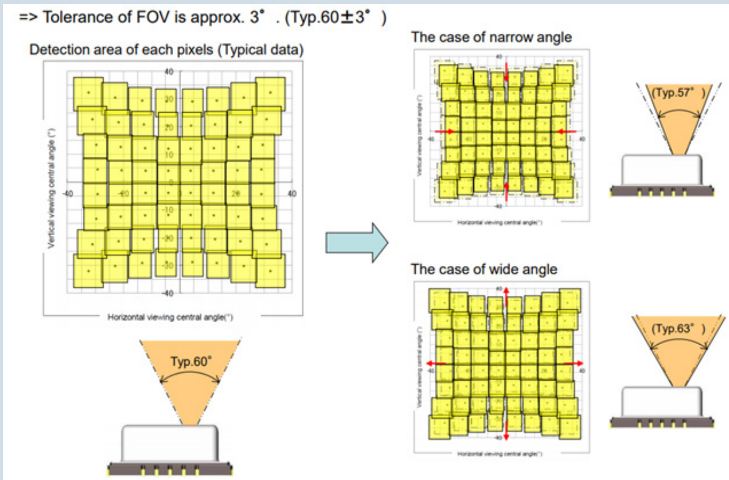

Figure 5: Tolerances of FoV and position of the pixel detection area

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Temperature output as a function of object size, distance and material

The Grid-Eye Sensor features 64 thermopile elements. The elements are integrating every infrared radiation and converting it to a corresponding output signal. The infrared emission of the object depends on its emissivity. The Grid-Eye Sensor is calibrated on the human skin's emissivity of about 0.93 [1].

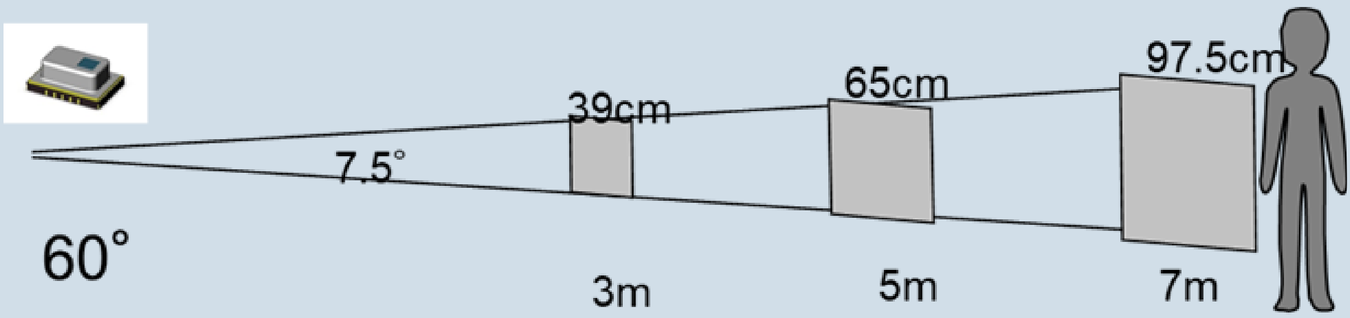

Figure 6: Pixel size depending on distance

Considering an opening angle for one pixel of 7.5 degrees, the pixel size depending on the distance is shown in Figure 6. For the temperature output of the sensor, this leads to two possible detection scenarios:

1) One Grid-Eye pixel is observing only one object with uniformly distributed temperature
2) One Grid-Eye pixel is observing an object which is smaller than the pixel size or has an unevenly distributed temperature

For 1), the sensor output temperature is ideally equal to the object temperature (for details about offset and noise, please see chapter "Sensor offset and noise")

For 2), the sensor output temperature is the size-weighted average of the object and background temperature distribution. For one object in front of a background, the output temperature would be ideally:
"Object temperature" * "Object size in % of the detection area" + "Background Temperature" * "Background size in % of the detection area".

For example:

- Object 1: 30°C, covering 50% of the Pixel
- Background: 20°C, covering 50% of the Pixel
- Sensor output: 30°C *0,5 + 20°C * 0,5 = 25°C

1 For detailed explanations on black body radiation, please see the following:
Robert Siegel, Thermal Radiation Heat Transfer, Fourth Edition, ISBN 1560328398
Emissivity: https://en.wikipedia.org/wiki/Emissivity

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Sensor shadowing and object shape

Figure 7 explains the sensor's output depending on the position of a person below the sensor:

Please note that size and shape of the human person change with its position below the sensor. Person behind each other can be hidden and seen as one block.

For the person detection algorithm, the size of a person and the shape of the silhouette can be used as additional measure next to the temperature difference.

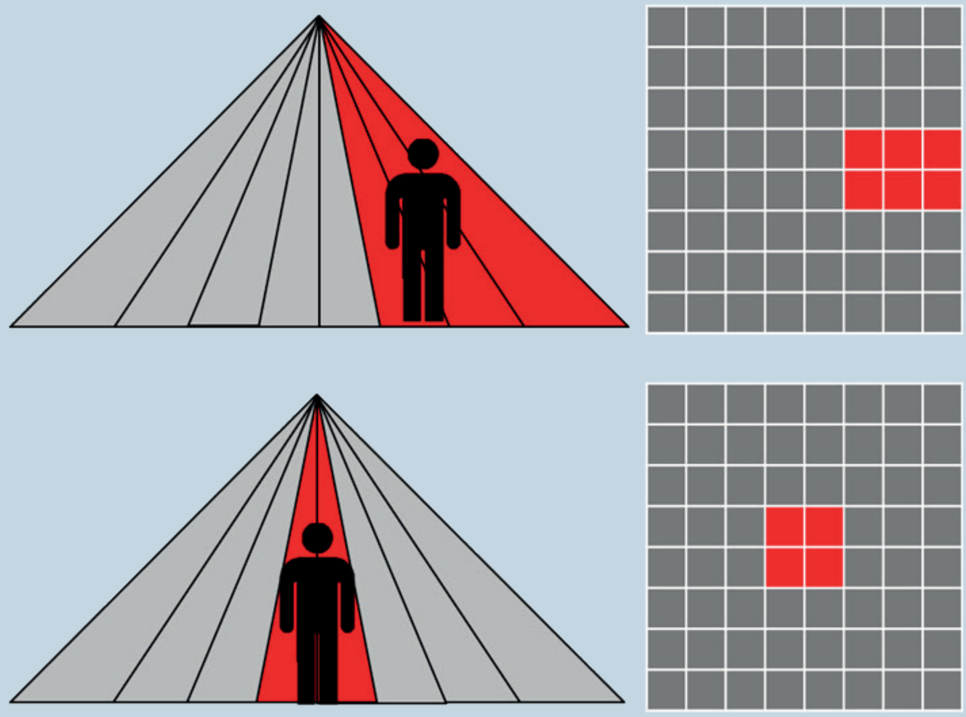

Figure 7: Sensor shadowing and shape of persons

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Absolute temperature accuracy, sensor offset and noise

The Grid-Eye Sensor is factory calibrated on an emissivity coefficient of 0.931, similar to the one of human skin. Considering objects with the same emissivity, the temperature accuracy is depending on:

1) Operating temperature

2) Object temperature

The typical temperature accuracy and sensor noise of the different versions is shown in Table 2. The noise can be reduced by averaging the output signal. The Grid-Eye features a built-in moving average feature with the "1 fps" setting. Please see the datasheet for details.

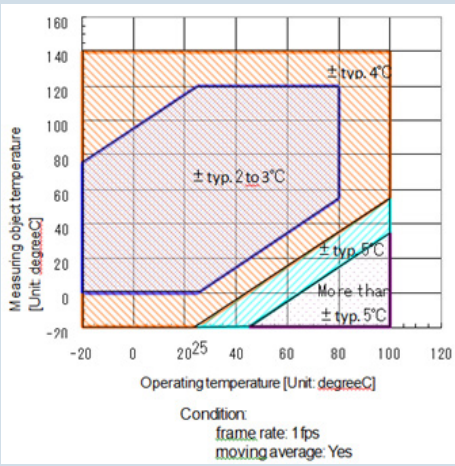

Figure 8 Temperature accuracy of the Grid-EYE sensor, depending of Object and Operating temperature – after factory calibration (AMG88x3)

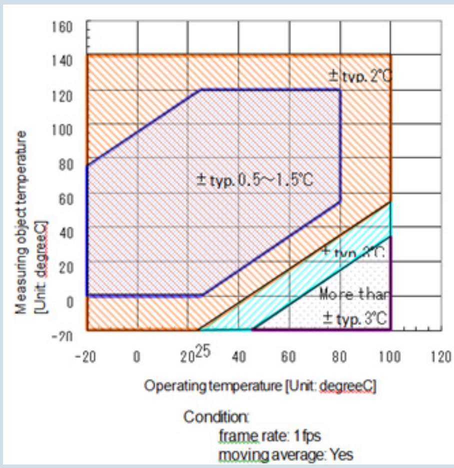

Figure 9 Temperature accuracy of the Grid- EYE depending of Object and Operating temperature - after customer offset reset (AMG88x3)

Figure 8 shows the relation between the two factors for the high-gain version (AMG88x3)

The temperature accuracy of the sensor in the application can additionally be influenced by:

1) Tensions after reflow soldering process
2) External heat sources close to the sensor which lead to a uneven temperature distribution across the sensor chip (e.g. microcontrollers, power supply)

		High Gain AMG88x3	Low Gain AMG88x4
Temperature Accuracy		Typ. ±2.5 °C	Typ. ±3 °C
NETD (Noise Equivalent Temperature Difference)	1 fps setting	Typ. 0.05K	
	10 fps setting	Typ. 0.16K	

Table 2: Temperature Accuracy and Noise

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6. PEOPLE TRACKING

Panasonic is evaluating an accurate people counting and tracking software. The TRACK-ME demo algorithm is available under SLA and free of charge on our Homepage.
Please contact us if you are interested in 90° angle lens and improved software at grideye@eu.panasonic.com.

The TRACK-ME algorithm is divided in three levels. The source codes of level 1 and 2 are freely available, level 3 can be accessed via SLA.

- Level 1: Driver and sensor setup
- Level 2: Image processing and people detection
- Level 3: People tracking

The algorithm divides the scene in a foreground picture with detected humans and a background picture by using an initial movement as trigger. These pictures are updated regularly with every frame, which allows us to distinguish between humans and stationary warm objects like heaters or monitors.

- Background:

Initially after startup, a "Background reset" is performed: The sensor temperature output is averaged for each pixel and stored as background temperature. This background is updated regularly with the actual measured temperatures, subtracting the detected humans in the foreground.

- Foreground:

An initial movement of a heat source is used as trigger to detect a person. The shape and size of the heat-source can be used to verify the detection. The person is labeled and tracked, even when standing still for a longer time.
Multiple persons in one pixel can be distinguished by the history – one person can only "disappear" by leaving the detection area.

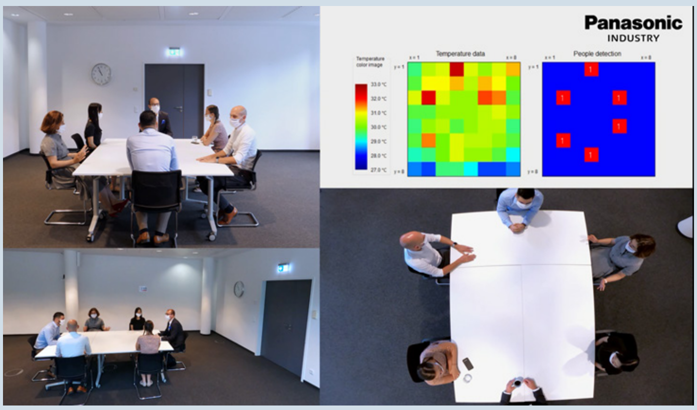

Figure 10: Track-ME Meeting Room demo

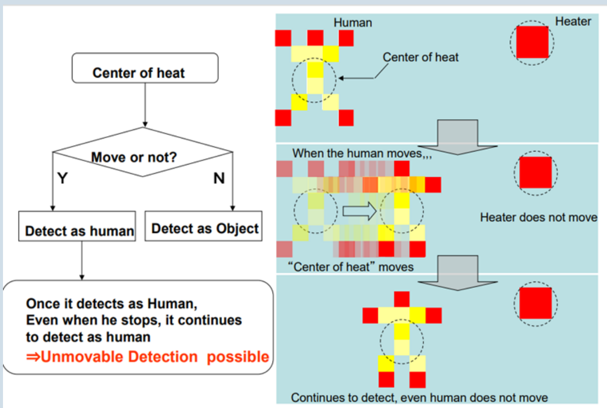

Figure 11: TRACK-ME algorithm - basic human detection scheme

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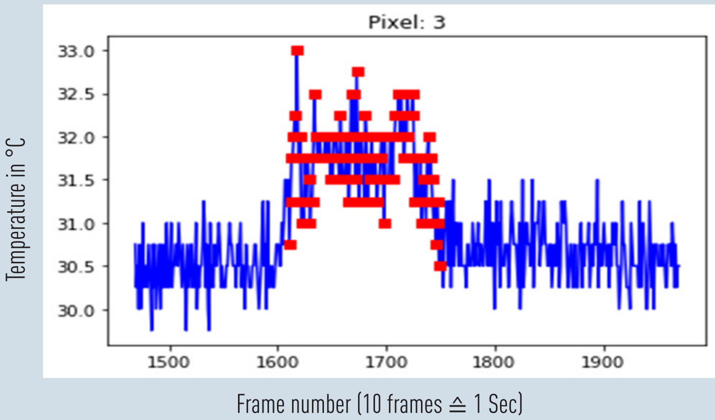

Figure 12: Raw-temperature in blue and detected humans in red for one pixel.
X-axis shows the time in 1/10 sec steps, the y axis the raw temperature in degC

As practical example, a real meeting room scene with 4 and 6 participants has been measured and the data have been analyzed successively.

Figure 12 shows the raw temperature output for one pixel in blue and the detected humans in red. The x-axis represents the time in 1/10 sec. steps, the y-axis the temperature in °C.

In Figure 13, the output of all 64 pixels of the meeting room scene is shown with (right) and without (left) scene overlay. The position of the persons can be observed by the red dots in the charts. A clear positioning and counting of the persons around the table can be observed.

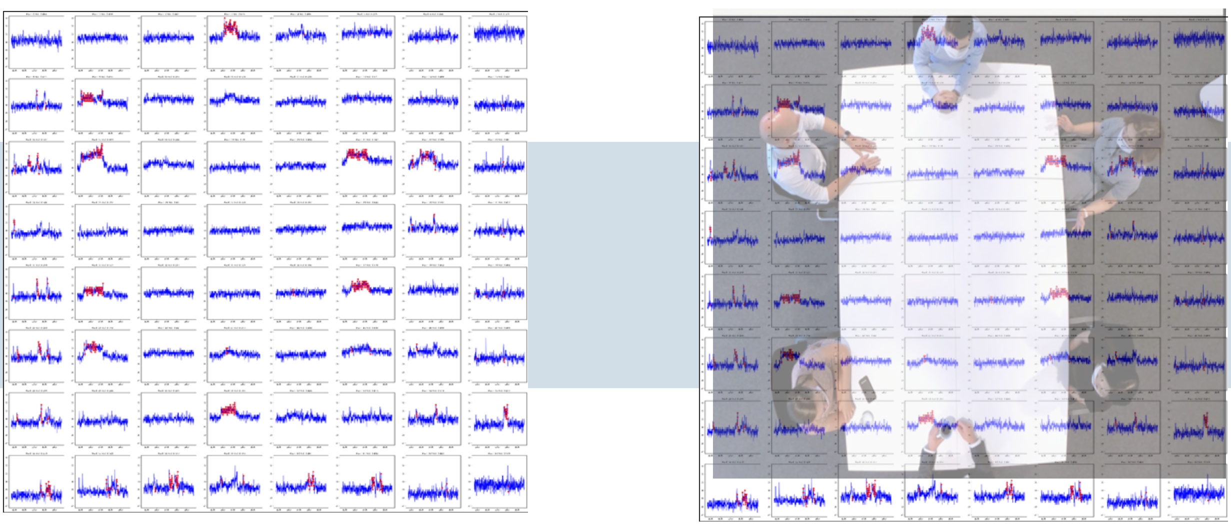

Figure 13: Meeting room with 6 persons, measurement data for all 64 pixels.
x-axis shows the time in 1/10 sec steps, the y-axis the raw temperature in °C

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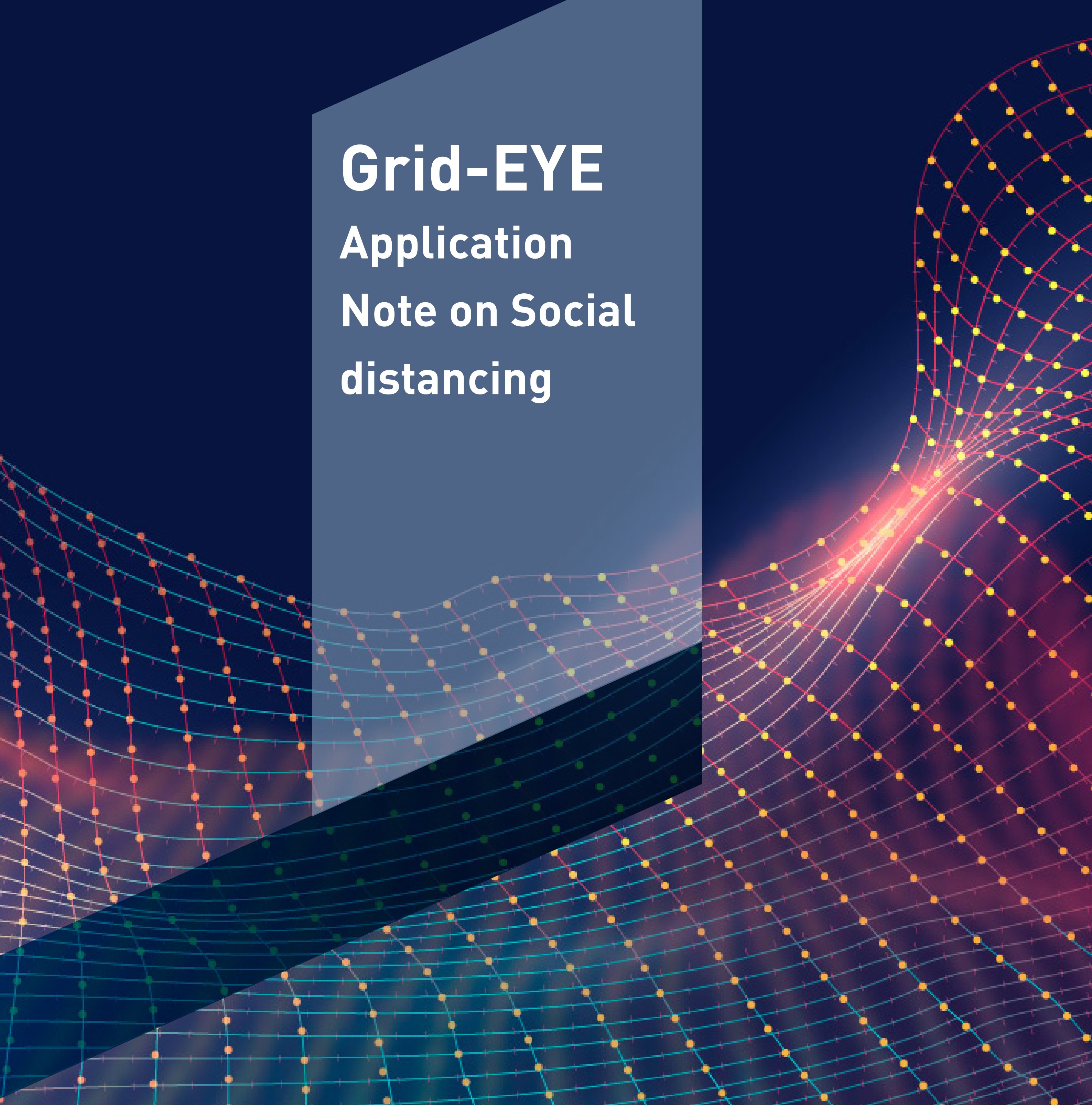
Another typical example is to detect walking persons in a corridor or an open space. Figure 14 shows the raw temperature output in blue and the detected humans in red for one row of 8 pixels of a 90° Grid-Eye Sensor. During a time of approximately 3 seconds, one person is passing the detection area of 4m. The temperature readout frequency of the sensor is set to 10 Hz. A short delay between the temperature raise and the detected person can be seen. This behavior of the TRACK-ME algorithm is explained:

1) As mentioned above, temperature averaging and the background reset are needed to differentiate persons from warm objects. This step takes several frames.

2) Track-ME is not only monitoring one pixel, but also the neighbor pixels to find the center of heat. A step from one pixel to another depends on the total picture.

Figure 14: Walking person, Measurement data for one row of 8 Pixels. X-axis shows the time in 1/10 sec steps, the y-axis the raw temperature in degC. The red dots in the chart is showing a detected person.

[1] Robert Siegel, Thermal Radiation Heat Transfer, Fourth Edition, ISBN 1560328398
[2] https://en.wikipedia.org/wiki/Emissivity



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Panasonic Industry Europe GmbH is part of the global Panasonic Group and provides automotive and industrial products and services in Europe. As a partner for the industrial sector, Panasonic researches, develops, manufactures and supplies technologies that support the slogan "A Better Life, A Better World". Looking back on over 100 years of engineering know-how in electronics, Panasonic is the right supplier when it comes to engineering expertise combined with solutions competence. The company's portfolio covers key electronic components, devices and modules up to complete solutions and production equipment for manufacturing lines across a broad range of industries. Panasonic Industry Europe is part of the global company Panasonic Automotive and Industrial Systems, which generates over one third of Panasonic's overall revenue. More: http://industry.panasonic.eu