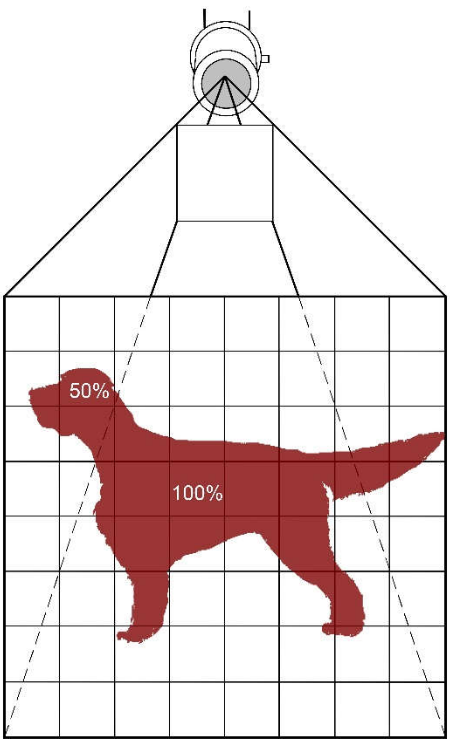
Basic expertise for spatial radiometric measurements

How to obtain the best visual performance for your IR image

An IR camera optics is usually described by the same parameters as optics for the VIS spectrum, the main difference between the two is the material: For IR optics usually Germanium, Silicon, Zinc Sulfide or Chalcogenide is used, since these materials show good transparency in the IR spectrum. The most common are Ge and Si, where Ge shows a better transparency but at the cost of higher price.

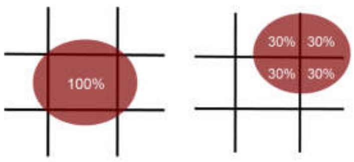
The two main parameters to describe the optic system is the focal length and the f-number. The focal length (f) determines in combination with the dimension of the focal plane area (FPA) the field of view (FOV) of the camera. The f-number (N) is the ratio of the focal length to the diameter of the entrance pupil (D). Since it is defined as N=f/D, the f-number gets smaller the larger the entrance aperture gets. The smaller the f-number, the more radiation can be received by the IR sensitive chip, resulting in a better signal to noise ratio (SNR). Low f-numbers of course require a lens system with larger diameters, resulting in a higher price of the system. Furthermore, the f-number also has an influence on the dynamic range (temperature measurement interval) of the IR camera: The lower the f-number, the more radiation will be detected by the IR sensitive pixel at the same object temperature, resulting in a smaller object temperature measurement range. The object temperature measurement range can be expanded by optical filters, which cut off certain parts of the IR spectrum. This allows good SNRs for lower object temperatures as well as increased measurement range.

The pixel pitch of a chip and the FOV of the optical system are the main parameters that determine the spatial resolution of the measured object. Usually, our standard optics set to infinity, which means that each object will generate a sharp image, if the distance between principal plane of the optics and the object is large enough. If the image of the object (or, more precise, the image of specific features and details of the object) gets smaller than the pixel pitch, the pixel will detect a mixed temperature of the object and the background. For a better explanation refer to the following image:



There are two pixels, where the filling factor of the dog versus the background is shown. For the 100% pixel the camera will detect the temperature of the specific part of the dog, but for the 50% filled pixel, the camera will measure the superposition of the dogs head temperature and the background. In example: If the dogs head temperature is 30°C and the background is 20°C, the camera will detect 25°C.

Therefore it can be seen, that small features of object may not be reliable detected under certain circumstances. This is of course true for every IR camera. Also, movement of an object may change the reading significantly, as shown here:



Position 1 Position 2

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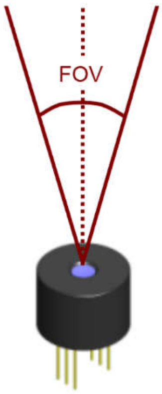
The ray law can coarsely determine the FOV of the camera:



$$FOV = 2 * arctan\left(\frac{P * n}{2 * f}\right)$$

P equals the pixel pitch, n the number of elements in the corresponding direction. This means the FOV can vary in x and y direction, if the number of elements is not equal in both directions. In example: An 80x64 thermopile array has a pixel pitch of 90µm. Combined with a 17mm focal length optics the FOV will result in 24° x 20°.

$$FOV = 2 * arctan\left(\frac{90\text{e-}6 * 80}{2 * 0.017}\right) = 23.9°$$

Note, that this formula does not work well for wide FOV optics, since the aberrations of the system can be not considered.

To determine if an image is large enough for a filling factor of 100% also the ray law can be used: The image size *I* can be easily calculated by I=(O*f)/d, where O is the object size, f the focal length and d the distance of the object. The image size divided by the pixel pitch results in the number of pixels illuminated. In example: A human with a shoulder width of 50 cm is 1.5 meters distant from an HTPA32x31L10. Therefore, f=0.01m, O=0.5m, d=1.5m I=3,33E-3m. With a pixel pitch of 220µm, this result in 15 pixels illuminated.