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Analysis of temperature drift in bolometric thermal imaging cameras

PHD THESIS

ABSTRACT

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The significant popularity rise of thermal cameras use can be observed in recent years. This is an effect of the technological progress in the production of microbolometer detectors Focal Plane Arrays (FPA). What is more, Infrared (IR) cameras available today on the market have larger and larger image resolutions. At the same time, IR FPAs characterize with better parameters. The most significant parameter Noise-Equivalent Temperature Difference (NETD), that describes thermal sensitivity of the camera, reaches the values of 20 mK. Such low NETD was available few years ago only in photon cameras. Nowadays, this high sensitivity of uncooled thermal cameras allows to use them in the applications where recently only expensive cooled cameras were suitable. However, technological advances did not solved the problem of temperature drift which is the main disadvantage of microbolometer detectors. Nowadays, in all constructions of microbolometer, metrological infrared cameras, the temperature drift compensation is performed by using a mechanical shutter. The drift correction is based on a periodic shutter activation during which it is moved between the detector array and the lens [7, 6, 10]. At this moment the observed scene is 'frozen', which leads to the loss of few frames of images sequence. In some applications like scientific research, active thermography, massive fever screening or monitoring the continuous image acquisition is crucial and cannot be interrupted. Therefore, uncooled cameras cannot be used due to the shutter system. There are documented attempts to develop methods for carrying out the correction with limited use of the shutter, or without the shutter. Some of these methods focus only on the non-uniformity correction without considering the temperature measurement [1, 2, 4, 8]. Other methods are not fully tested [3, 5] or require large amount of memory and computation power [9]. In result, there is no shutter-less measurement uncooled infrared camera available on the market today. There are only observation cameras that have shutter-less correction algorithms. None uncooled camera enables an uninterrupted temperature measurement for tens of minutes. The temperature drift of the bolometer detectors is caused by:

- read-out circuit integrated with the IR sensors, which warms up everything inside the case, including the detectors array,
- detector case, which heats unevenly by radiation each detector in the focal plane array,
- all mechanical elements along the optical path between the focal plane array and the lens
- electronic circuits powering the system and processing data along image transmission path, which dissipate power and heat up the camera.

The effect of irradiation by mechanical parts, such as the case and the lens, is particularly visible at the edges of the IR image. Thus, the problem of correcting temperature drift of the detector array is a complex issue and cannot be solved using one-dimensional approach. In order to solve this problem it is necessary to take into account all the factors that cause this undesirable phenomenon. Therefore, the effective signal correction method should take into account:

- temperature of all system components which radiation affects the detector array,
- a multi-dimensional, non-linear estimation of temperature drift correction coefficients.

The aim of the research was to develop a new algorithm of thermal drift correction for the uncooled, metrological infrared camera. The camera with implemented algorithm should allow to update correction coefficients of the detector array in real time, reducing the use of the shutter and scene "freezing". An important aspect of the research was to take into account all of the previously described causes of the thermal drift in static and dynamic conditions. It is especially important to shorten the delay time after turning on until the camera is ready for the reliable temperature measurements.

The idea of the novel thermal drift correction algorithm is the actualization of initially calculated matrix of offset coefficients. These offset coefficients are calculated with the use of the mechanical shutter shortly after powering up the camera. As system initialize and temperature rise, the standard 2-point non-uniformity correction is performed. This allows to overcome the problem of factory dispersion of the detectors characteristics, which correction coefficients (gain and offset) are rather randomly distributed. The thermal drift affects the pixels gray level offset, mainly because of parasitic radiation and self-heating.

It is assumed that the change of signal values depends on two main factors:

- pixel position in the focal plane array as each pixel is illuminated differently with parasitic radiation from the camera elements,
- temperature of the camera's element that generate the radiation power in the direction to the detector.

The thesis presents a concept of the novel signal correction method for the measurement uncooled IR camera. The concept assumes the calculation of thermal drift using nonlinear, multidimensional approximation of the 3 independent drift components: main drift, residual non-uniformity and fixed patter noise. The last one is corrected using linear function with one coefficient for every detector of the FPA. The correction value for first two is calculated for each pixel as a function of the pixel's position on the FPA. The correction polynomial formula is same for the whole matrix. However, the coefficients of the polynomial vary due to the change of the cameras working parameters, its inside and outside (environmental) temperature. These coefficients are calculated in real time by estimator based on artificial neural network which uses data from multiple temperature and radiation sensors that are placed inside the camera.

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