Accuracy test of a miniaturized thermal infrared camera to be carried on board UAVs.

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Highlights: The purpose of this study was to evaluate the performance of a miniaturized thermal camera compared with a self-cooled thermal camera. A Blackbody was used as reference and the observed parameters were stability and noise of the sensors. Results revealed that, after pre-heating, both cameras showed similar precision and accuracy. Miniaturized thermal cameras are light enough to be carried onboard UAV platforms.

***Key words:** Thermal camera – Stability – Calibration – Blackbody*

Introduction

Remotely sensed thermal imagery can be used in a number of applications, i.e. assessing drought stress of field crops [1-4] or field phenotyping [5] among other purposes. Unmanned Aerial Vehicles (UAVs) platforms can be used in a short revisiting time, and they have been successfully employed in multi-temporal studies over fruit tree orchards [6].Miniaturized thermal cameras have recently appeared on the market and they are light enough to be carried onboard the UAVs.

A cooled thermal camera has an imaging sensor that is integrated with a self-cooling system, which lowers the sensor temperature to cryogenic temperatures. This reduction in sensor temperature is necessary to reduce thermally-induced noise to a level below that of the signal from the scene being imaged. To reduce weight and volume, miniaturized thermal cameras do not have this self-cooling system and, therefore, it is necessary to calculate the magnitude of signal noise. The aim of this paper was to measure the accuracy and performance of a miniaturized thermal camera (Thermoteknix Miricle 307K) compared with a self-cooled thermal camera (Flir Thermacam B20 HSV). All the measures were taken under controlled laboratory conditions, temperature (20°C ±2°C) and a Blackbody (Portable Infrared Calibrator Fluke 9133) was used as temperature reference. The observed parameters were the stability of the temperature data and noise of the signal.

Materials and methods

The Blackbody Fluke Portable Infrared Calibrator Model 9133 (emissivity 0.95, accuracy ±0.4°C stability ±0.1°C and target size 57mm diameter) was used as temperature reference. It was pre-heated for 30 minutes before every test (30 minutes is the pre-heating time recommended by the manufacturer).

The camera object of the study was the Thermoteknix Miricle 307K and the reference camera was the FLIR Thermacam B20 HSV. Both cameras were placed in front of the Blackbody (thermal reference source) at a given distance of 15cm for the Miricle and 30cm for the Thermacam (Figure 1). Moreover, they were pre-set to a video frequency of 25 frames per second, and the shutter was set to occur every 4 seconds. Shutters are used in thermal cameras to act as a reference for periodic detector calibrations in order to provide a more accurate image of the thermal scene the camera is capturing. Both combined events, pre-heating and shutter, contribute to obtain stable and precise temperatures.

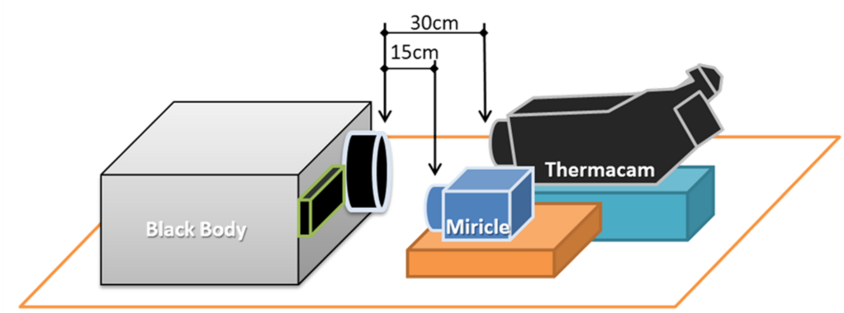

Figure 1: Schematic representation of the experiment. The Blackbody was placed on the left side and the two cameras facing him on the right.

Camera accuracy in the interval -10ºC to 100ºC.

Both cameras were pre-heated for a period of 30 minutes and only video-frames after the shutter event were taken into account. At every selected temperature value, the Blackbody was stabilized for 30 minutes before taking any image sample. Thereafter, 10 video-frame samples were acquired at each reference temperature.

The experiment consisted on placing both cameras in front of the Blackbody (Figure 1), which was set at a range of temperatures between -10ºC to 100ºC (at 10ºC intervals). At every selected temperature value, video frames were taken and their average AOI (central Area Of Interest of 60*60 pixels) temperature values were calculated. Standard deviation values were also calculated for signal noise assessment.

Camera accuracy over time at a given temperature.

Miricle camera was tested while Blackbody temperature was set to a fixed value of 20ºC. Average AOI temperature values were extracted from video-frames during the time period from 0s (internal camera temperature equal to the temperature of the environment) to1800s (pre-heating period defined by camera manufacturer). Furthermore, the standard deviation values were also calculated for signal noise assessment. Camera accuracy was tested by taking one image every 20 seconds (just after shutter events). Data stability during inter-shutter events was also tested by taking images series between two correlative shutter events (4s length) at 6 given moments of the study (300s, 600s, 900s, 1200s, 1500s and 1800s).

Results and Discussion

Figure 2 shows the relationship between thermal camera data (10 samples taken for each temperature interval) and Blackbody temperature. The correlation coefficient calculated between Blackbody and Thermacam camera was high (R^2 equal to 1, Figure 2a), which denoted a strong correlation and, consequently, the Thermacam camera has a good accuracy in temperature acquisition. There was also a strong correlation (R^2 equal to 0.9999) between Blackbody and Miricle Camera (Figure 2b). Furthermore, cameras presented similar regression coefficients.

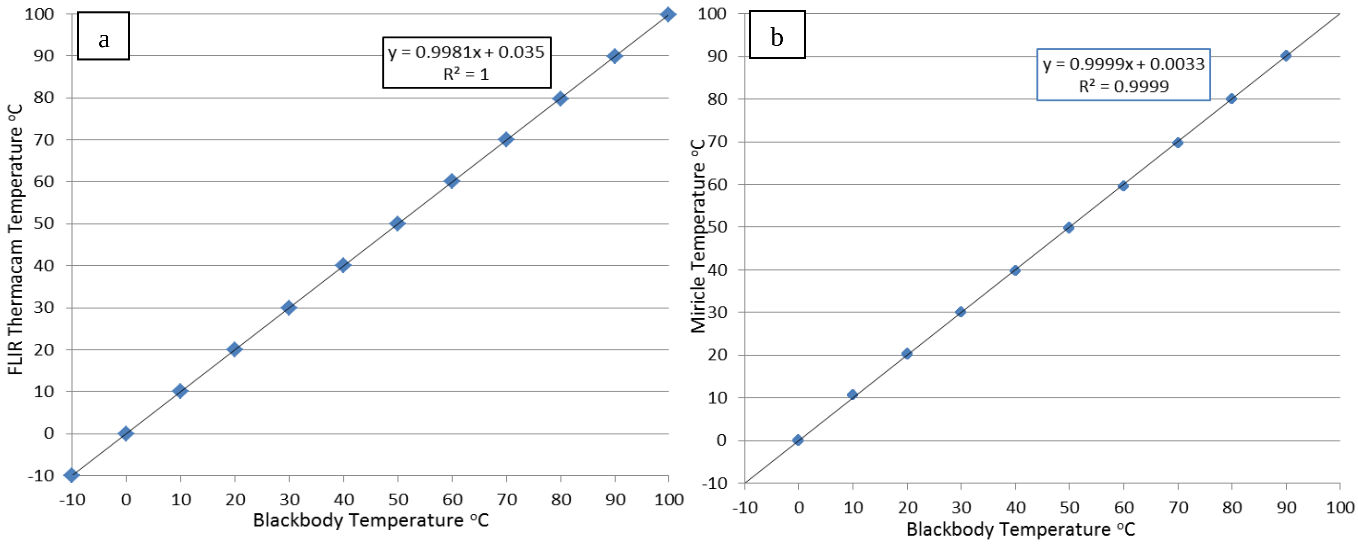

Figure 2: Relationship between Blackbody temperature values and, a) the average temperature data obtained by the FLIR, and b) the average digital values obtained by the Miricle camera.

The evolution of data stability (standard deviation) in the range of -10ºC to 100ºC is shown in Figure 3. The standard deviation values were found in the interval 0.12ºC to 0.35ºC which is under the Blackbody accuracy (±0.4°C), and the lowest values were in the range 30ºC to 50ºC, while the highest values were founded at -10ºC.

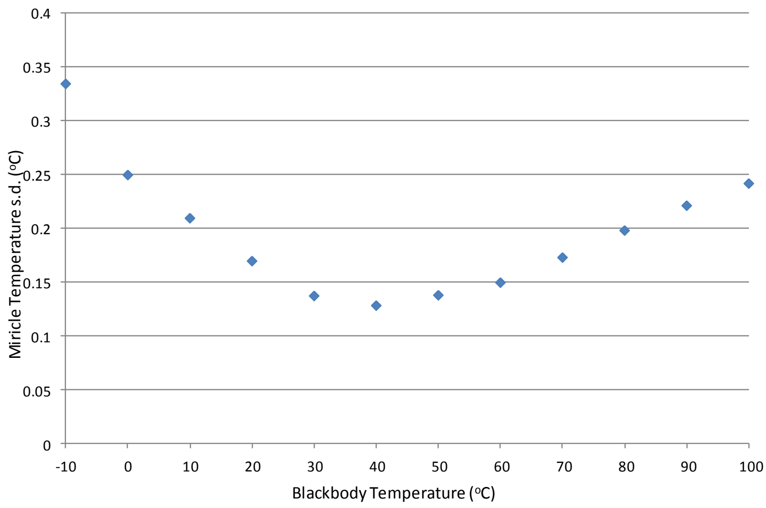

Figure 3: Evolution of standard deviation values in the boundary of temperatures studied. 10 samples taken in every temperature considered.

This study was carried out under temperature controlled conditions and, once pre-heated, thermal camera internal temperature did not suffered strong variations. According to past experience, there were found temperature variations during UAV take-off procedure, and this effect can be a new source of data instability. This effect should be taken into account in future field studies, to be carried out in real flight conditions.

With regard to the stability of the camera after shutter events and during the pre-heating period (Figure 4), there seems to be a pattern of behaviour, repeated approximately every 7 minutes. This pattern consists of an overestimation of the temperature measured, which is corrected gradually, followed by abrupt return to a new temperature overestimation. The temperature ranges of each pattern are reduced as the camera temperature increments. Temperature tends to 20ºC (blackbody temperature), but data stabilization does not become full at the end of the series (1800 seconds).

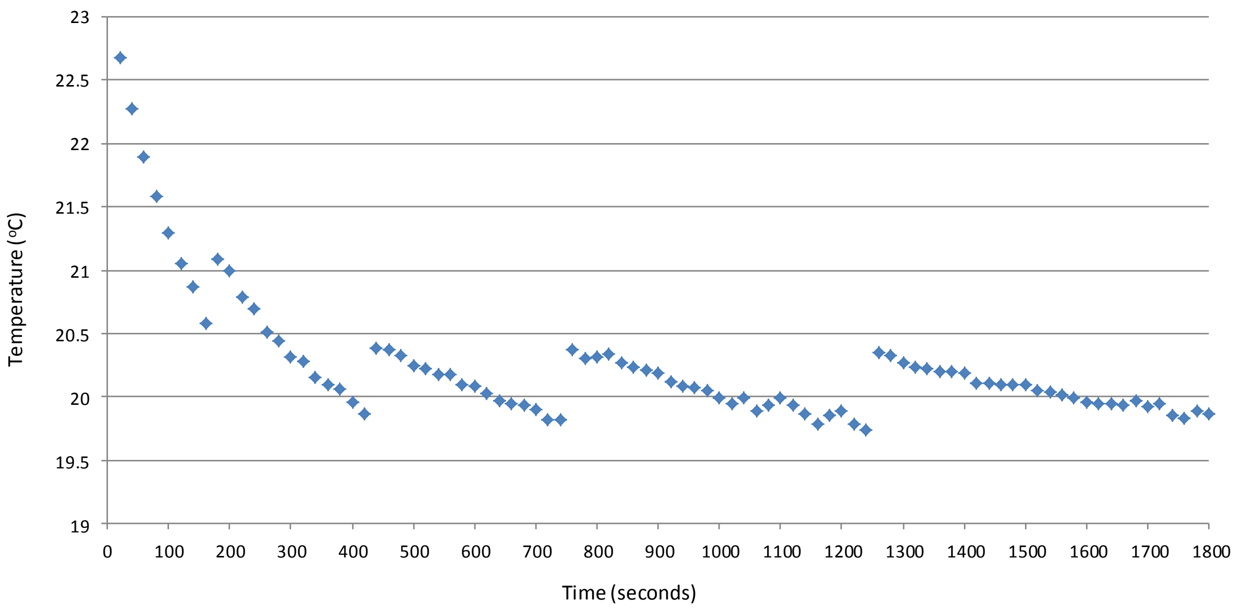

Figure 4: Temperature data after shutter during a period of 1800s in intervals of 20s for the Miricle camera. Blackbody set to 20^{o}C.

Regarding the intra-shutter stability (Figure 5), there were not appreciated great temperature differences between consecutive shutter events. Therefore, the shutter (auto-calibration) does not generate a substantial improvement in data acquisition. On the other hand, there are some differences with the moment considered, especially at 300 seconds. This was in accordance with Figure 4.

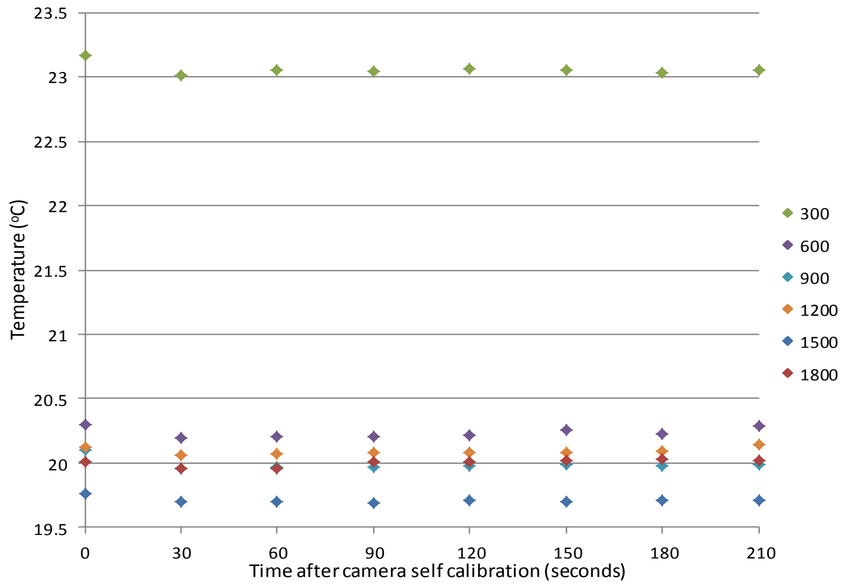

Figure 5: Image standard deviations inter shutter events (set to occur every 4s) at 6 given moments after camera switch on, for the Miricle. Blackbody set to 20^{o}C.

Conclusion

In the temperature range studied, the miniaturized Miricle camera was at least as accurate as the reference Thermacam, and it also showed a high stability in the data acquisition after pre-heating. Besides, to obtain good quality data, it is advisable to pre-heat the Miricle camera for a period longer than 1800 seconds.

It is possible to carry out studies with uncooled miniaturized thermal cameras such as the Miricle 307K on board UAVs, due to their sufficient accuracy. To validate results, it is recommended to study the camera stability under field conditions.

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