The influence of angles and distance on assessing inner-canthi of the eye skin temperature

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SUMMARY

BACKGROUND: Infrared Thermography (IRT) has been proposed as primary screening method for mass assessment of populations at risk of pandemic condition related to high fever. Similar as other applications of IRT in medicine, distance and angles to target have an influence on the temperature measurements. Those can be partially corrected with extra camera lenses and advanced maths. This research aims to identify the impact of using different distances and angles, using standard camera lenses and standard image analysis software, in the assessment of the inner-canthi of the eye region of interest temperature.

METHODS: Thermal images were captured with a portable IR camera FLIR E60 in an air-conditioned room, equipped with a thermo-hygrometer, a carpet with distance and angle information and a chair.

A total of 14 healthy participants were recruited who signed their informed consent after the procedure was explained to them. Facial image capture was performed in line with the Glamorgan protocol recommendations. Distances were selected from 70 to 200 cm and angles from 0 to 180 degrees' angles at 15 degrees' intervals. The distance of 100 cm and angle of 90 degrees was used as reference for calculating the differences to the other settings.

RESULTS: In all participants, the mean temperature of the inner canthi of the eye varied by 0.1ºC at distances between 80 and 120 cm when compared with the reference, and by 0.4ºC and 0.5ºC at angles of 105 and 75 degrees, respectively.

CONCLUSIONS: To minimise the measurement error, distances between 80 and 120 cm and angles as close as possible to 90 degrees should be used when the inner-canthi of the eye temperature is recorded with conventional lenses and standard image analysis software for fever screening.

KEY WORDS: angle of view, distance camera to object, fever assessment, inner-canthi, infrared thermography

DIE BEDEUTUNG DES BLICKWINKELS UND DER ENTFERNUNG FÜR DIE BESTIMMUNG DER TEMPERATUR DES INNEREN AUGENWINKELS

HINTERGRUND: Im Fall einer drohenden Pandemie von mit hohem Fieber einhergehenden Erkrankungen wurde die Infrarot-Thermografie (IRT) als primäre Screening-Methode für die Massenuntersuchung von Populationen vorgeschlagen. Ähnlich wie viele andere Anwendungen der IRT in der Medizin, beeinflussen der Abstand und der Winkel zum Zielobjekt die Messungen, die teilweise durch den Einsatz von zusätzlichen Kamera-Objektiven und höherer Mathematik korrigiert werden können. Die vorliegende Studie zielt darauf ab, die Auswirkungen unterschiedlicher Abständen und Winkel auf die Temperaturwerte des inneren Augenwinkels bei Verwendung von Standard-Objektiven und Standard-Software zur Bildanalyse zu untersuchen.

METHODE: Die Wärmebilder wurden mit einer tragbaren IR-Kamera FLIR E60 in einem klimatisierten Raum aufgenommen, der mit einem Thermo-Hygrometer, einem Teppich mit Distanz-und Winkelinformationen und einem Stuhl ausgestattet war. Insgesamt wurden 14 gesunde Teilnehmer rekrutiert, die eine Einwilligungserklärung unterzeichneten, nachdem ihnen das Verfahren erklärt worden war. Die Wärmebilder des Gesichts wurden im Einklang mit den Empfehlungen des Glamorgan-Protokolls aufgenommen. Es wurden Abstände von 70 bis 200 cm und Winkel von 0 bis 180 Grad Winkel bei 15 Grad Intervallen ausgewählt. Der Abstand von 100 cm und der Winkel von 90 Grad wurde als Referenz für die Berechnung der Unterschiede zu den anderen Einstellungen verwendet.

ERGEBNISSE: Verglichen mit der Referenz, variierte die mittlere Temperatur des inneren Augenwinkels bei allen Teilnehmern um 0,1 °C bei Abständen zwischen 80 und 120 cm, beziehungsweise um 0,4°C und 0,5 °C bei Winkeln von 105 und 75 Grad.

SCHLUSSFOLGERUNGEN: Um den Messfehler zu minimieren, sollten Abstände zwischen 80 und 120 cm und Winkel so nah wie möglich bei 90 Grad verwendet werden, wenn die Temperatur des inneren Augenwinkels mit herkömmlichen Linsen und Standard-Bildanalysesoftware für Fieber-Untersuchungen aufgezeichnet wird.

SCHLÜSSELWÖRTER: Blickwinkel, Abstand zum Objekt, Fieberbeurteilung, Innerer Augenwinkel, Infrarot- Thermographie

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Introduction

Infrared thermal (IRT) imaging has been used in medical applications since 1956, it is fast, safe, remote and an innocuous modality of recording skin surface temperature. The information obtained is associated with peripheral blood flow, which is influenced by the autonomous nervous system. It has been employed in several clinical applications

as a monitoring method for the vascular, sympathetic, musculo- skeletal and locomotor systems [1-3].

In order to increase the accuracy and repeatability of the method, recommendations were made [3-6] for its standardisation in terms of examination room, recording equipment and subject preparation, before and during the appointment, and manner of conducting the examination. This reduces the variables that may affect the measurement and increases the exchange and understanding.

Fever in clinical terms mean that the human body core temperature has been elevated to a value over 37.5 °C [7]. It is one of the most common medical signs, being responsible of about 30% of healthcare visits by children. Fever occurs in up to 75% of adults who are seriously sick. Prolonged fever can result in tissue destruction owing to the catabolism of body proteins. In severe cases, it can cause death or being an indicator of pandemic condition such as SARS, H1N1, H1N5 or Ebola [8].

The idea of using IRT for fever screening monitoring the face emerged in China about 15 years ago [9], during the SARS outbreak in southeast Asia. In 2004, two technical references for using the imaging technique for fever screening were developed in Asia through Singapore Standards authority SPRING [10,11]. Later, in 2006, the ISO initiated an interest group ISO/TC121/SC3-IEC62D/JWG8, Project Team 9 on Human Body Screening Thermographs. The effort of this task force resulted in two standard documents [12,13], one in the requirements and essential performance, and another that is a technical report on deployment, implementation and operational guidelines of performing the febrile identification.

Despite the existing documentation, which is poor in recommendations for distance and angles to the target, most of airports or high people traffic facilities fail to comply with the existing standards [14], putting cameras at inadequate angles and high distances, reducing the likely hood of identifying subjects at high risk of fever.

Another aspect of discussion is the region of interest [ROI] at the face that should be used for identifying the febrile states, the inner-canthi of the eye was proposed by Wood in 1964 [15].

A comparison was made between the temperature of the inner canthus of the eye obtained from infrared thermography, considered a core temperature estimation method for fever mass screening, and oesophageal temperature [as gold standard] in 10 subjects among four conditions: resting, exercise, recovery and passive heating. The two methods showed differed significantly results during all conditions [mean and their relationship was inconsistent between conditions, indicating that further research is required in the field focused in fever cases [16].

A study using high-sensitivity thermal imaging technology [17] aimed to predict core temperature of human subjects remotely from the face while performing simulated field operations wearing thermal protective garments. It consisted of 6 participants, from which measures of core and skin temperature were taken before, during, and after treadmill exercise in a heated room. A relationship and a strong correlation was found between core temperature and thermal imaging of the central region of the face in all subjects, occurring the best agreement during exercise. Despite the technology showing promise, it requires refinement, through the use of alternative measurement sites.

Another experiment was performed [18] to assess the relationship between core temperature (oral and tympanic) and IRT recordings from the frontal, lateral face (maximums) and forehead temperatures in a controlled laboratory setting with the 1517 participants (215 were considered febrile) standing at 1, 2, 3, 4 and 5 meters from the thermal camera. It was found that the forehead IRT temperature differed substantially from the core temperature, and the maximum lateral temperature should be used. The reading should also be taken at a defined distance from the camera. The recorded temperature with infrared imaging decreased linearly with the increase in distance. The agreement between core and estimated temperature was less accurate in women, elderly people, and those with fever. In order to maximize the sensitivity of infrared detection of fever, a lower cut-off temperature ($\leq$35.5ºC) was recommended.

A research aiming to verify if the temperature obtained with IRT at the inner canthus of the eye was related to brain temperature taken invasively [19], found strong correlations between temperatures of both sites of the inner canthi of the eye and of the brain. It also showed that in patients with a lesion in a side of the brain, the correspondent side had elevated inner canthus of the eye temperature.

A proposal for automatic detection and localization of the face and eyes in thermal images aiming to determine inner canthi of the eye temperature was made [20]. It can handle automatic temperature measurement which was impossible with traditional methods, a good correlation between the axilla temperature and that obtained by the algorithm was found. However, standardization of measurement through IRT is required for proper temperature assessment.

Since at a real situation, the subjects moving is random and the angles of the skin surface and distances change in a dynamic manner, which contributes to the misdetection of the inner canthi area of the eye in infrared images, that can also be affected by any other unwanted objects that have the same temperature. Asking a single person to stand still for 2 seconds to capture a thermal image of the face can be ineffective and this will lead to long queue in public. In order to address this, a combination of physiology-based and optical flow algorithm to extract vascular network from the face was proposed [21]. The thermal camera was provided with colour and audible alarming and when a suspicious individual was detected, the alarm will report to the operator its current location. Although some operational aspects need further research such as individuals wearing spectacles, masks and hats, their distance and angle to the camera.

Two recent experiments [22, 23] aiming to validate the inner canthus of the eye temperature obtained with a thermal camera as a non-invasive alternative measurement to the intestinal core temperature [through gastrointestinal telemetry pill or rectal assessment] during rest, exercise and post-exercise conditions, observed poor agreement between the values obtained and therefore, the inner canthus of the eye did not demonstrate to be a valid substitute measurement to invasive core temperature assessments in sports and exercise science settings, which is similar to other 'surface' measures.

A recent study, performed by Ring et al. [24-26], has employed the ISO standards with the inner canthi ROI and successfully identified paediatric febrile subjects with IRT.

Despite all this controversy present in the literature about the application of the inner canthi of the eye ROI in temperature assessments with IRT imaging, the improvement of its implementation requires attention.

It is aim of this research to identify the impact of using different distances and angles, using standard camera lenses and standard image analysis software, in the assessment of the inner-canthi of the eye ROI mean temperature.

Materials and Methods

The examination took place at an acclimatized room [mean temperature of 22.9±0.3°C, relative humidity of 59.0±2.1%, absence of incident lightning and air flow) at the Faculty of Engineering, University of Porto. For images capture a recently supplied calibrated thermal camera FLIR E60sc [focal plane sensor array of 320x240, NETD of <50mK at 30ºC and measurement traceability of 2% of the overall reading) was used. For verifying the room environmental conditions, a temperature and humidity data logger Testo 175H1 with a digital display and capacity to store the mean temperature and relative humidity was used.

The sample used was composed of 14 healthy participants [described in table 1), which had avoided a heavy meal, coffee, tea, alcohol or had smoked 2 hours before the appointment. They were requested to not engage in any sport or physiotherapy activities in the day of examination and to refrain from using any oil or ointment in the face. To all the procedure was clearly explained and the informed consent signed was obtained. All the participating females were in the luteal menstrual phase.

To facilitate the capture of images in the correct distances and angles, a drawn carpet was used on the room floor [figure 1) and in every case with the camera facing the target a thermal image was taken. Before capture, a period of acclimatization of 10 minutes was applied to every subject to establish a thermal equilibrium with the room conditions. The subject was seated on a bench, remaining still with the face straight, facing the opposing wall at a 90-degree angle, to facilitate a stable position.

For comparisons and according with the internationally image capture recommendations [3, 5, 6) the values recorded at 100 cm distance and 90-degree angle were used as reference for each subject.

The first image taken was the 100 cm at 90-degree angle of the subject standing still seated in a bench and looking straight ahead, followed by the 70 to 200 cm at the same angle, then at the same distance of 100 cm images were taken from the subject from 0 to 180 degree angles, at 15-degree interval. Each subject took in average 15 minutes.

Table 1
Sample characterization.

Gender	N	Age	BMI
All	14	25.1±4.4	22.0±2.8
Males	7	26.7±5.0	23.4±3.3
Females	7	23.6±3.3	20.6±1.2

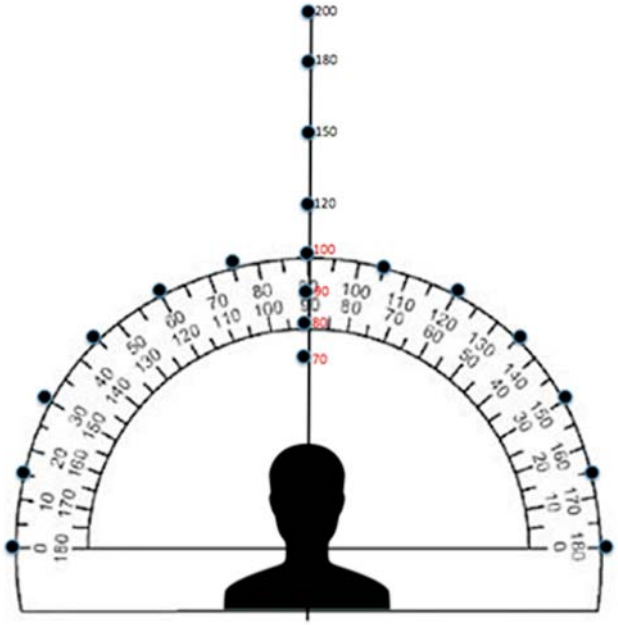

Figure 1
Indication of the capture location in terms of distances and angles.

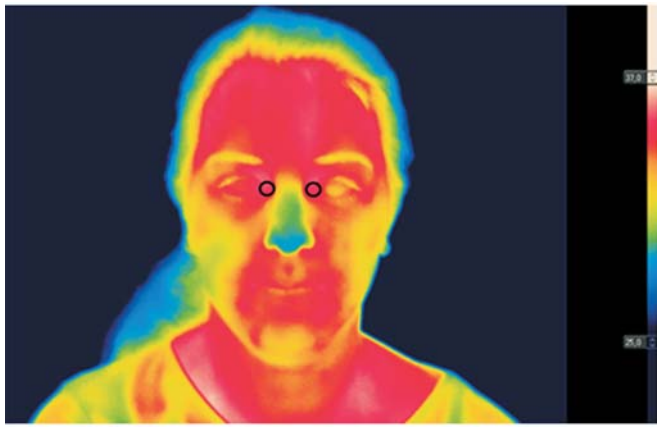

Figure 2
Indication of the ROI used to assess the inner-canthi of the eye temperature.

Table2
Comparison of the results of core body temperature determination.

Group	Inner canthus of eyes thermal imaging
All	35.4±0.5
Females	35.5±0.5
Males	35.2±0.4

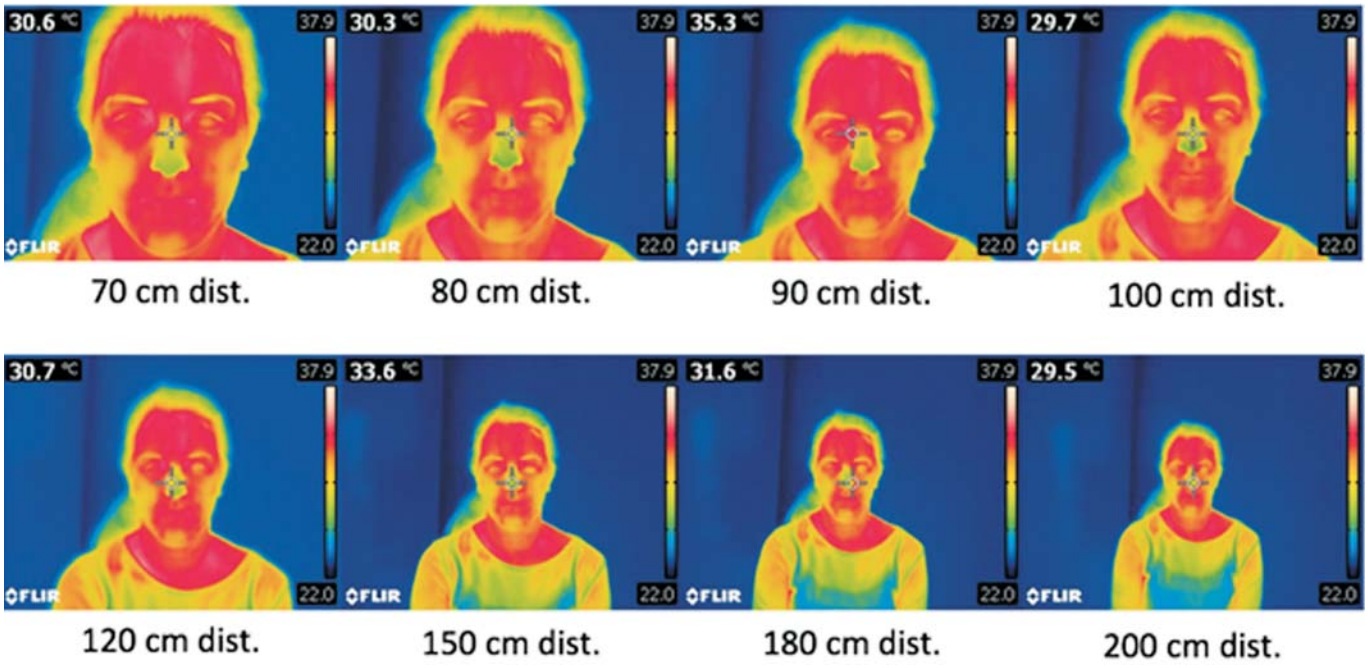

Figure 3
Examples of the images taken at different distances and 90-degree angle.

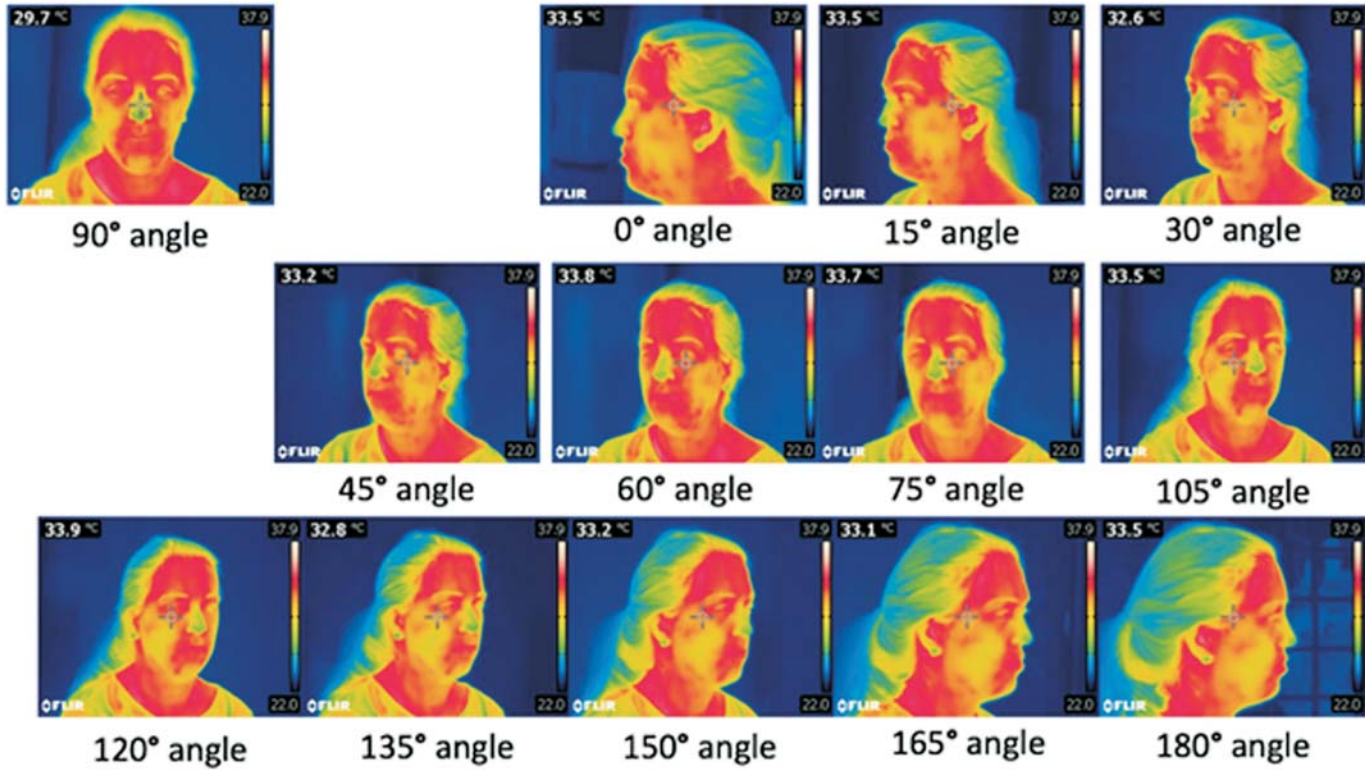

Figure 4
Examples of the images taken at different angles and 100 cm distance.

For analysing the images, the software package FLIR ThermaCAM Researcher Pro 2.10 was used. Regions of interest of 64 pixels were drawn at the area of the inner-canthi of the eye [figure 2) to enforce consistency within all distances. For both eyes in the images taken facing the camera at a 90 degrees' angle. At the area of the left inner canthi in the images facing the camera at the range from 0 to 75 degrees' angles and at the area of the right inner canthi in the images facing the camera at the range comprehended between 105 and 180 degrees' angles.

For statistical analysis, all the variables had their normality tested through the Shapiro-Wilk test and then parametric methods (ANOVA) were used to summarize the data.

Results

The measured values with thermal imaging at the ROI of inner-canthi of the eye, mean of both eyes ROIs, at a distance of 100 cm and 90-degree angle and genders are presented in table 2.

The figure 3 shows the different images taken at the different distances and 90-degree angle and the figure 4 presents the distinct taken images at the angles from 0 to 180 degrees' angles and 100 cm distance.

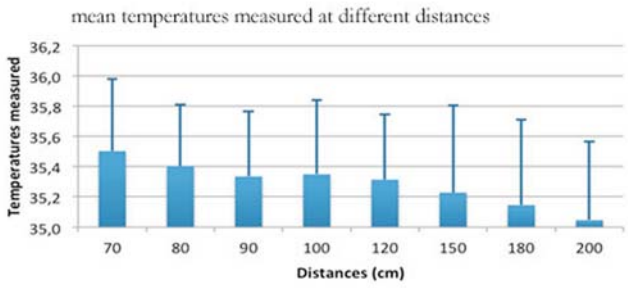

Figure 5
Comparison of mean temperatures (with SD) of the inner- canthi of the eye ROI measured at different distances and at 90-degree angle..

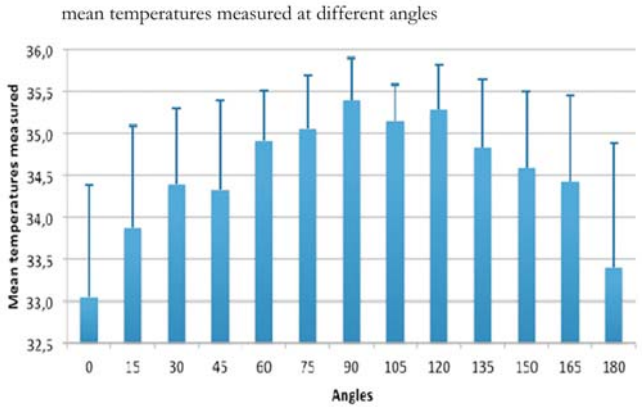

Figure 6
Comparison of mean temperatures (with SD) of the inner-canthi of the eye ROI measured at different angles and at 100 cm distance.

The results obtained in the temperature assessment of the inner-canthi of the eye ROI at different distances and 90-degree angle are provided in figure 5. From it can be observed that in a 20 cm distance difference from the reference (100 cm), below and above, the difference on the mean temperature value suffers a variation of 0.1°C. For other distances, it has higher variations. There was statistical evidence of variation in the results outside the range of 80-120 cm [$p > 0.05$).

The results obtained in the temperature assessment of the inner-canthi of the eye ROI at different angles and 100 cm distance are provided in figure 6. From it can be observed that for the closest assessed angles 75 and 105 degrees' angles, the difference was 0.5ºC and 0.4ºC correspondingly, for other more distant angles there were higher statistical significant variations ($p > 0.05$).

Discussion

This study has followed the IRT imaging guidelines [3-6] and international ISO standards [12-13] for use in medicine and the ROI proposed [15] and used in paediatric fever assessments [24-26]. It is well known that distances can be corrected using different angle lenses, normally the IR cameras come by default with 24-degree angle lenses, for closer views higher angle lenses are required, the opposite happens for distant views. However, having more lenses mean increased cost, that most of researchers and health professional cannot afford. The angles can be corrected through complicated maths and heavy image processing techniques such as warp and morphing, which none of the currently available IRT images software package has these features. These advanced tools have also the disadvantage of generating undesired errors. In this research, it was decided to use generic standard tools, which are available to any IRT user.

Given this, in a lab setup for fever identification, using a threshold value of > 37.5°C [7], the mean temperature of the inner-canthi of the eye ROI can be used remotely, following the existing guidelines [3-6] and international standards [10-14], through IRT, since it uses a distance from the camera to the subject face comprehended between 80 and 120cm and an angle closer to 90-degree.

In another application this research could be useful is in the assessment of thyroid eye disease [27].

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