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Investigating the Accuracy of Temperature Measurement Devices for Measuring Human Body Temperature

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Abstract: Accurately measuring human body temperature is vital for diagnosing and monitoring medical conditions. However, commonly used temperature measurement devices often lack precision. This project focuses on assessing the accuracy of three devices which are the clinical thermometer, FLIR T640 infrared camera, and ACISION HTC7200 thermal camera. The study explores infrared thermography as a potential alternative for measuring body temperature. The main objective is to determine if infrared cameras can replace the clinical thermometer effectively. An experiment was conducted using the three devices to measure patient temperatures. The collected data was analyzed, graphically represented, and categorized by age groups to assess the impact of inaccurate measurements. Statistical methods such as mean, median, variance, and standard deviation were employed to evaluate device accuracy. The clinical thermometer had the lowest standard deviation value (0.5044), indicating its superior accuracy compared to the other devices. The study emphasizes the potential negative consequences of inaccurate temperature measurements on patient outcomes. By addressing these challenges and investigating temperature measurement device accuracy, this project aims to enhance medical diagnostics and improve patient care.

Keywords: Device Accuracy, Infrared Thermography, Standard Deviation

1. Introduction

This research project focuses on comparing temperature measurement devices to assess their accuracy in measuring fever patients' temperature at Klinik 14 Jam during night hours. The primary methods employed are infrared thermography, thermal imaging, and temperature scanning. The project aims to accurately identify high fever patients using infrared imaging to prevent complications. Temperature measurement devices in the medical field can provide inaccurate readings due to various factors. Thermal cameras offer a faster and non-contact measurement process compared to forehead temporal thermometers [1]. This study evaluates the reliability of thermal imaging cameras in

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measuring body temperature, providing a cost-effective and non-invasive approach to fever detection. The objectives include assessing the precision of temperature measurement devices, examining temperature patterns across age groups, and calculating statistical parameters of patients' temperatures. The study aims to enhance medical knowledge, improve fever detection, and provide valuable insights into temperature measurement devices effectiveness.

2. Methodology

In the methodology section of this thesis, the focus will be on 3 specific subtopics. Firstly, the experimental set-up and activities will be thoroughly discussed, highlighting the procedures and arrangements implemented during the experiment. Secondly, factors to be considered during the experiment will be addressed, examining the various variables and parameters taken into account to ensure reliable and accurate results. Lastly, the necessary tools and equipment's required to conduct the experiment will be described, emphasizing their role in facilitating the research process.

2.1 Experimental set-up and activities

For accurate temperature measurements, it is recommended to prepare the FLIR T640 infrared camera by turning it on 20 minutes prior to data collection. This allows the camera's sensors to stabilize, leading to more reliable results [2]. Mounting the camera on a tripod positioned 2 meters away from the subject ensures clear and precise images. Fully charged batteries and spares should be available for uninterrupted operation. Configuring the FLIR T640 involves specific settings such as emissivity, reflected temperature, and subject distance. Adjusting humidity and atmospheric temperature based on DATA LOGGER GM1365 values optimizes the camera's performance. Similar parameters should be used for the ACISION HTC7200 thermal camera to ensure reliable comparisons. Forehead temporal/clinical thermometers offer a convenient and non-invasive method for collecting temperature data from patients. The DATA LOGGER GM1365 helps detect environmental conditions' impact on temperature fluctuations. Proper documentation including patient information, ambient temperature, relative humidity, picture number, and temperature values is essential for traceability and analysis. To ensure meaningful conclusions and reliable analysis, it is important to reach the target of collecting temperature readings from 81 patients. The FLIR T640 camera's captured images can be evaluated and simulated using FLIR tools software on a laptop, allowing for in-depth analysis and visualization. Creating a plotted graph comparing temperature accuracy from different devices provides a clear understanding of their performance.

2.2 Consideration factors during experiment

Environmental factors

i) Size of room

Size of the room should provide ample space for both the patient and the evaluation tools, as well as maintain consistent room temperature. For example, in this case study, a spacious room is required to position the tripod with an IR camera at a distance of approximately 1 to 2 meters from the patients.

ii) Ambient temperature

Ambient temperature plays a crucial role, as it affects the accuracy of thermal imaging. It is recommended to maintain a temperature range between 18 to 25 degrees Celsius to prevent patient shivering or excessive sweating [3].

iii) Relative humidity

Controlling relative humidity is important to avoid patient discomfort. Uncontrolled humidity levels can impact the infrared thermography evaluation, as steam particles in the air can emit infrared emissions, and it can also affect patient temperature.

Technical factors

i) Validity

Validity is crucial as it determines the accuracy and connection of the measurement to the real world. Infrared thermography's validity lies in estimating subject temperature through captured infrared radiation. The skin infrared thermometers possess a good validity in which the value of validity r = 0.92 [4]. Hence, good validity is important for a better and accurate result.

ii) Protocol

Standardized protocols play a key role in enhancing infrared thermography (IRT) and minimizing technical issues [5]. The distance between the subject and the infrared camera is emphasized, with various studies considering the measured region and camera's optical properties.

iii) ROI selection

The region of interest (ROI) in this experiment is the forehead. The temperature of the forehead will be used to determine if the person is having fever or not. Computer simulation and segmentation have been employed in various diagnosis applications to enhance the ROI selection [6].

2.3 Experimental tools and equipments

FLIR T640 infrared camera

- The infrared camera measures the temperature up to 2000°C
- Has the highest infrared resolution in its class where the thermal images are sharp with 307,200 pixels (640 x 480) for the best long-range detection, photography, and temperature measurements.

Tripod

- Adjustable tripod with an approximate length of 185cm.
- Used to mount the FLIR T640 infrared camera on it.

ACISION HTC7200 thermal camera

- The sensor has high sensitivity with 160 x 120 resolution.
- Has an in-built rechargeable battery and has laser function to focus on the long-distance thermography target.

Clinical thermometer

- Has the ability to measure a temperature range of -20°C to 55°C.
- The maximum allowable error is ±0.3°C.
- Purpose is to measure temperature of the patients.

DATA LOGGER GM1365

- This device is used to record and store the ambient temperature and relative humidity data.
- This data logger has a temperature measuring range of -30°C to 80°C and relative humidity range of 0 to 100% RH.

3. Results and Discussion

3.1 Analysis using FLIR Tools Software

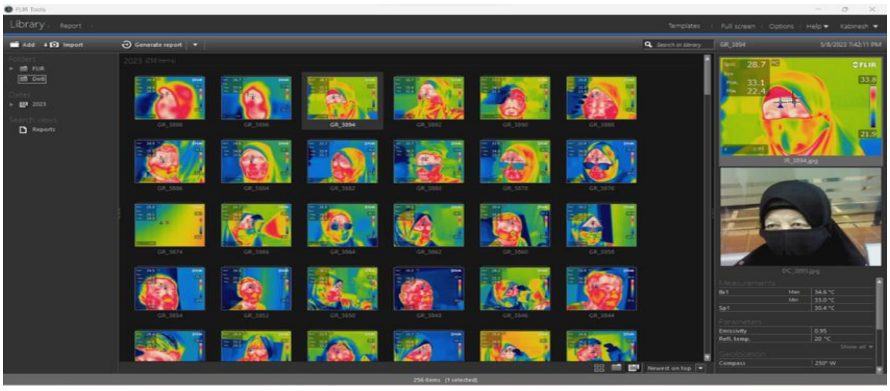

Figure 1: FLIR Tool library files

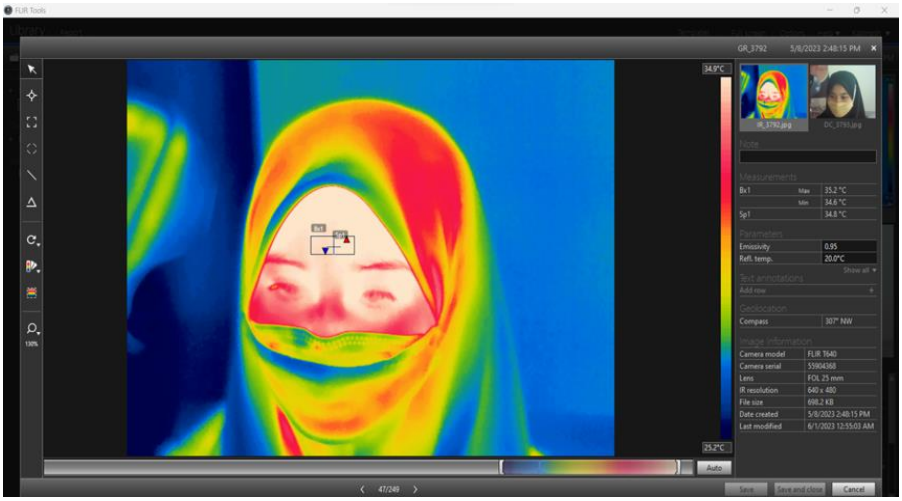

Figure 2: Temperature analysis in FLIR Tools

The box and spot measurement tool are placed in the region of interest which is the forehead. This method is performed in FLIR tool software. SP1 is the desired temperature, and the data can be obtained from the right-hand side under measurements. Other values such as minimum and maximum temperature value, emissivity, and reflected temperature can also be adjusted to suit the study's needs. The temperature of the person shown below is 34.8°C.

Figure 3: FLIR Tools report

3.2 Experimental results and discussions

Table 1: Parameters for FLIR and ACISION infrared camera

	Relative humidity (%)	Ambient temperature (°C)	Emissivity	Reflected temperature (°C)	Object distance (m)
DAY 1	54	24	0.95	20	2
DAY 2	55	24.4	0.95	20	2
DAY 3	54.5	24.2	0.95	20	2
DAY 4	54	24	0.95	20	2
DAY 5	54	24	0.95	20	2

Representation of data in graphical form

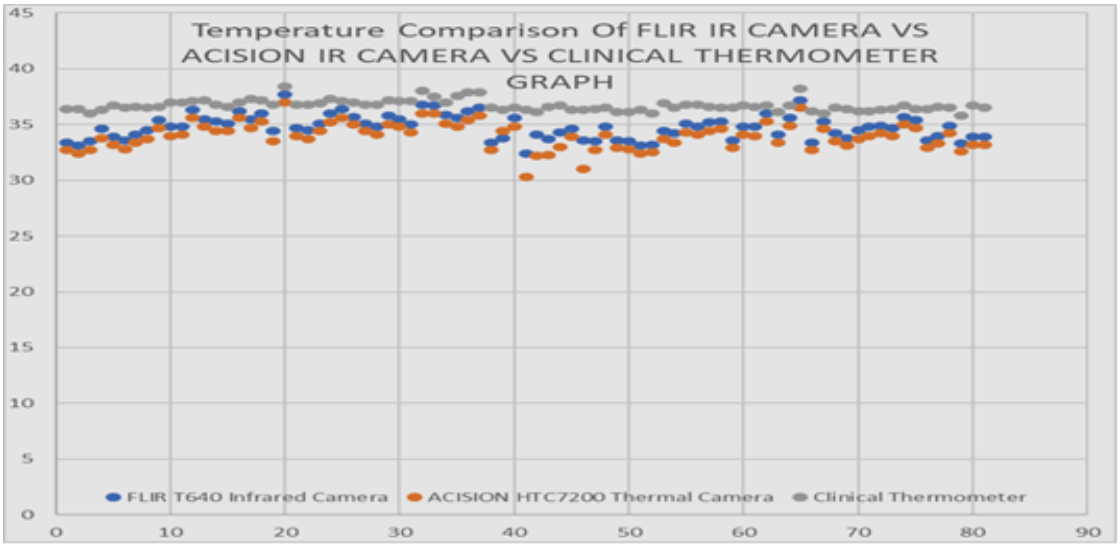

Figure 4: Scatter plot graph

Based on the scatter plot graph, it is clear that the clinical thermometer is significantly more precise and accurate compared to the FLIR T640 Infrared Camera and ACISION HTC7200 Thermal Camera. The clinical thermometer recorded temperatures within the normal human body temperature range, accurately identifying fever in 12 out of 81 patients whose temperatures exceeded 37.2°C. In contrast, both the FLIR and ACISION cameras provided lower temperature readings than the actual body temperature, with the FLIR camera being slightly more accurate than the ACISION camera. The graph also revealed that the fever threshold measured by the FLIR camera was 35.5°C, while the ACISION camera measured it as 34.7°C. Any temperature above these respective thresholds with the corresponding camera indicates fever. Two out-of-range data values for the ACISION camera can be considered insignificant errors. Therefore, although infrared cameras have their applications, such as detecting temperature anomalies in larger areas or non-contact measurements, they may not match the accuracy and precision of a clinical thermometer for measuring body temperature specifically.

3.3 Experimental results and discussions

In the conducted analysis, the participants are classified into 3 distinct age categories such as children, adult, and elderly. This categorization was employed to facilitate a comprehensive examination and comparison of the data across different age groups. Based on the experimental data, there are 28 children's, 40 adults, and 13 elderlies from a total of 81 samples obtained. The selection of these categories is justified based on several relevant factors such as medical relevance, potential differences in immune response and mechanical engineering perspective which is physiological differences.

a) Medical relevance

Age-related variations in body temperature

- Body temperature regulation varies across different age groups due to factors such as variations in metabolic rates, hormonal changes, and immune responses. Infants and elderly individuals, for instance, may have different baseline temperatures compared to adults.

b) Potential Differences in Immune Response

- Different age groups exhibit variations in immune response capabilities. Children may have developing immune systems, while the elderly may have compromised immune function. Accurate temperature measurement becomes crucial in assessing febrile responses and identifying potential infections or illnesses. Evaluating device accuracy within each age category allows for better understanding and addressing potential challenges related to immune responses.

c) Mechanical engineering perspective

Physiological differences

- Different age groups may exhibit variations in skin properties, such as thickness, moisture content, and emissivity, which can impact the accuracy of temperature measurements. For example, infants may have thinner skin layers compared to adults, potentially affecting the heat transfer dynamics.

3.4 Visual representation of sample using color palettes

In infrared thermography, different color palettes are used to represent different temperature ranges, allowing for easier interpretation of the thermal data. Color palettes in infrared thermography are used to map the measured temperatures onto a visible image. They assign specific colors to different temperature ranges, providing a visual representation of the temperature distribution across the object or scene being observed. The choice of color palette can greatly affect how the temperature data is interpreted and understood.

Figure 5: Color palette 'Above'

The "above" color palette is particularly useful when identifying and analyzing regions of elevated temperature or hotspots. By using this palette, it is possible to identify areas that have temperatures above a certain threshold, allowing for efficient detection of fever. Based on the image obtained from the above palette, it is evident that the forehead is the hotspot region exhibiting the highest temperature.

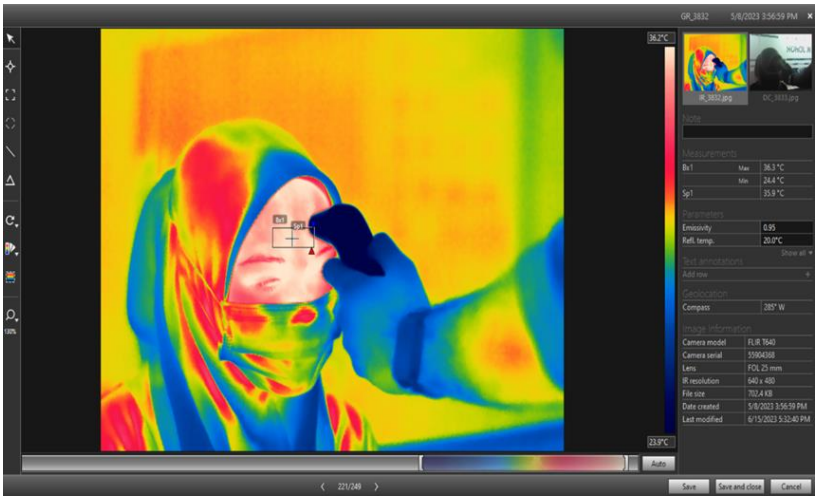

Figure 6: Color palette 'Rainbow'

The rainbow palette uses a full spectrum of colors, ranging from purple to red, to represent different temperature values. It provides good contrast and is useful for identifying fine temperature variations.

3.5 Application of engineering statistics method

Table 2: Mean temperature value of devices

	FLIR	ACISION	Clinical Thermometer
TOTAL	2816.6	2752.9	2973.6
MEAN	34.8	34	36.7

Since the clinical thermometer provides a mean temperature closer to the established normal body temperature of 36.7°C, healthcare professionals may consider temperatures measured with this device as a more reliable indicator of potential illness or abnormality. If an individual's temperature deviates significantly from 36.7°C, either higher or lower, it may be an indication for healthcare professionals to assess the individual's health condition more closely.

Table 3: Median value of devices

	FLIR	ACISION	Clinical Thermometer
TOTAL	2816.6	2752.9	2973.6
MEAN	34.8	34	36.7
MEDIAN	34.8	34	36.6

The median temperature helps diagnose and monitor patients. Healthcare providers can determine if a patient's temperature is within the expected range, which can indicate infection, inflammation, or other conditions. However, temperatures measured by FLIR and ACISION equipment differ greatly from normal body temperature, making them ineffective for identifying inflammation or medical conditions. To reliably detect inflammation, a clinical thermometer is recommended as it closely matches normal body temperature. It detects significant deviations in median temperature, indicating the presence of inflammation or other conditions.

Table 4 : Variance and standard deviation of devices

	Variance	Standard deviation
FLIR	1.122	1.059
ACISION	1.374	1.172
Clinical Thermometer	0.2544	0.5044

Variance and standard deviation are important measures for clinical decision making as they indicate the variability of temperature measurements within a population. The clinical thermometer shows lower variability, with a smaller standard deviation and variance compared to both the FLIR and ACISION devices. The FLIR camera exhibits higher variability than the clinical thermometer, although it is better than the ACISION camera in terms of standard deviation. However, the ACISION camera has the highest level of variability, making it the least accurate device for measuring human temperature. These measures help healthcare professionals assess the risk and determine the need for further diagnostic tests based on temperature variability.

4. Conclusion

The project concluded by recommending the use of a clinical thermometer as the preferred temperature measurement device for human body temperature. Comparative analysis revealed that the clinical thermometer demonstrated higher accuracy compared to FLIR and ACISION infrared cameras. The clinical thermometer, in particular, has the lowest standard deviation value, indicating higher precision in producing precise temperature results.

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