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Faculty of Engineering
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BM3122 - Medical Imaging

Thermal Imaging Systems

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Abstract

Thermal imaging systems have gained significant growth in medical applications, enabling non-invasive and real-time temperature monitoring of human tissues. This report delves into the principles of operation, diverse applications, and quality assurance measures associated with thermal imaging systems in the medical field.

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1. Introduction

Thermal imaging systems, also known as infrared cameras or thermographic cameras, have found extensive use in various fields, including medicine. These systems enable visualization and measurement of surface temperatures by capturing the infrared radiation emitted by objects. In medical applications, they offer a non-invasive approach to assess physiological conditions, monitor patients, and assist in surgical procedures.

Fig 1 – Process of Thermal Imaging

2. Principle of Operation

Thermal imaging systems are engineered to detect and visualize temperature differences between objects and their backgrounds, translating these differences into visible images. This technology is rooted in the perception of infrared (IR) radiation emitted by objects due to their temperature. The operation of thermal imaging systems can be summarized as follows:

2.1 Detection of Temperature Differences

Thermal imaging relies on the fact that all objects emit IR radiation based on their temperature. Every object with a temperature above absolute zero emits infrared radiation. The intensity of this radiation is proportional to the object's temperature, following Planck's radiation law.

Objects in the field of view emit IR radiation that varies according to their thermal state, creating a temperature distribution map. The contrast between an object's IR radiation intensity and the background's IR radiation intensity determines the resolvability and clarity of the resulting thermal image.

2.2 Sensor and Wavelength Range

Thermal imaging systems operate in the infrared spectrum, capturing IR radiation emitted by objects. Unlike night vision systems, which often operate in the visible or near-infrared spectrum, thermal imagers detect longer wavelength IR radiation. The two primary wavelength ranges are the medium wave infrared (MWIR) range of 3-5.55 µm and the long wave infrared (LWIR) range of 8-14 µm. These ranges are chosen because they coincide with the peak emission of thermal radiation for objects in the temperature range of -50°C to +50°C.

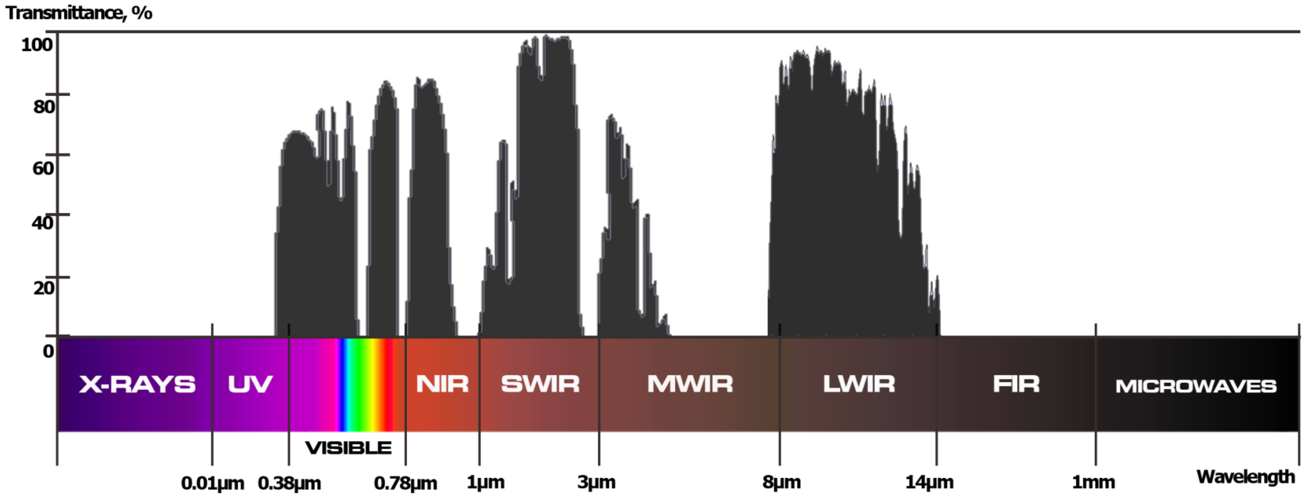


Fig 2 – Electromagnetic Spectrum

2.3 Microbolometer Array and Temperature Measurement

At the core of every thermal imager is a microbolometer array, also known as a thermal sensor. Each pixel of this array can precisely measure the temperature of the corresponding area in the observed scene. The microbolometer array captures the incoming IR radiation and translates it into electrical signals, allowing for the creation of temperature distribution maps.

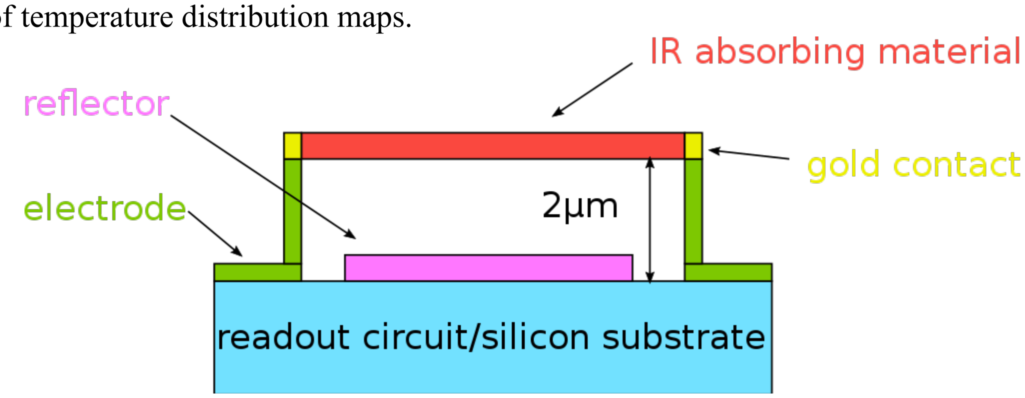


Fig 3 – Cross-sectional view of microbolometer

2.4 Image Processing and Visualization

The detected temperature information is processed by a microprocessor and other electronic components. This processing involves converting the temperature differences into a visual representation. This representation is displayed to the observer through an eyepiece or directly on a screen.

3. Applications in Medical Field

Thermal imaging displays many applications in the medical field due to its ability to capture and visualize temperature differences in various parts of the body. The following are the most common applications of Thermography.

Fever Screening and Infection Control

Thermal imaging systems are widely used for fever screening in high-traffic areas like airports and hospitals. They can quickly identify individuals with elevated body temperatures, potentially indicating fever or infection. These systems have proven crucial during disease outbreaks for early detection and containment as in COVID-19 pandemic.

Fig 4 – Quarantine officer monitoring a thermal scanner on passengers from an arrival flight at airport

Breast Health

Thermal imaging has gained significant attention for its role in breast health assessment. It serves as a powerful supplementary tool for the early detection of breast cancer, benign tumors, mastitis, and fibrocystic breast disease. By comparing the temperature differences between the breast under examination and the normal breast, abnormal heat signatures indicative of tumor metabolism can be detected. The increased vascularity associated with cancerous tumors also generates additional heat, enhancing the thermal signature.

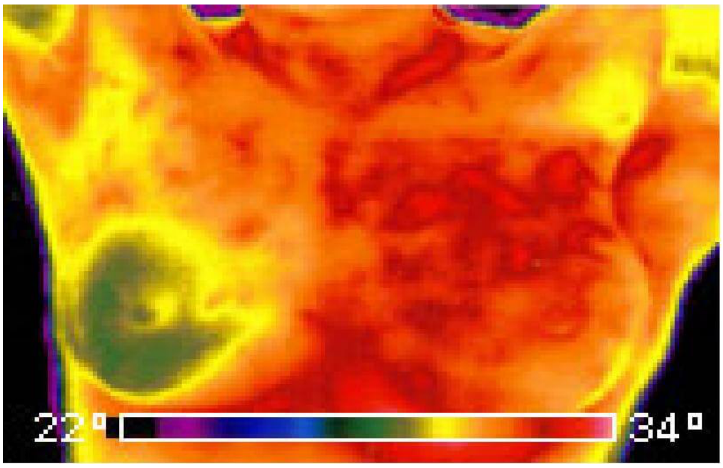


Fig 5 – Thermal Imaging for Breast pathologies

Vascular Imaging

Thermal imaging aids in assessing blood flow through the vessels of the neck and head, for the detection and differentiation of various vascular conditions such as Extra-Cranial Vessel Diseases. Due to the thin tissue covering the blood vessels in these areas, thermal imaging can visualize changes in blood flow and detect potential vascular diseases that could lead to stroke.

Also, it can be used in dental health for identifying temperature changes related to dental decay and toxic materials.

Additionally, it used for diagnosing circulatory disorders, and monitoring wound healing. Peripheral vascular diseases, deep vein thrombosis, and diabetic foot complications can also be evaluated using thermal imaging.

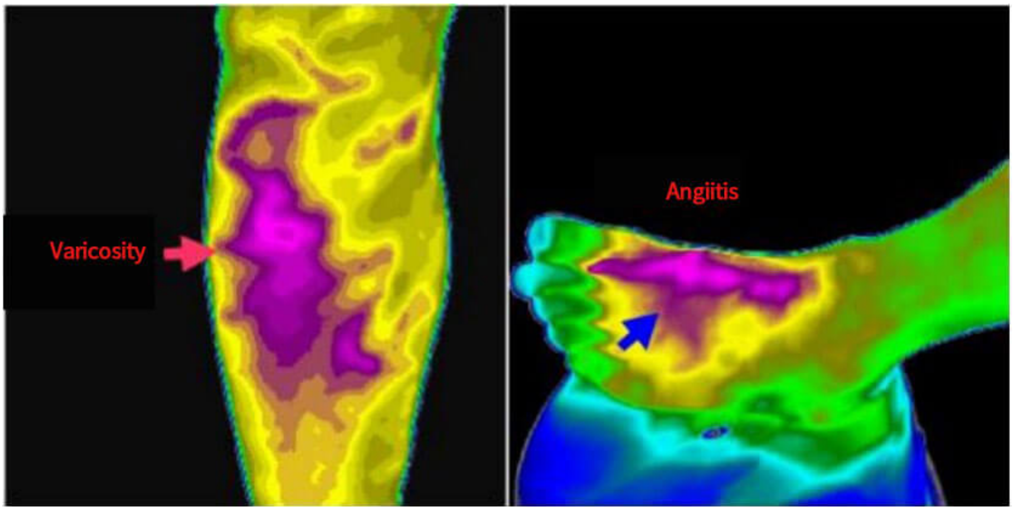


Fig 6 – Diagnosis of Peripheral Vascular Diseases

Neuro-Musculo-Skeletal Diseases

Thermal imaging is being used in diagnosing and analyzing a spectrum of back, neck, and extremity disorders. The technology's ability to detect increased heat signatures resulting from muscle strain or injury makes it a valuable tool for chiropractors, neurologists, and orthopedists. By assessing the thermal map in specific muscle areas, practitioners can pinpoint trigger points and diagnose conditions such as fibromyalgia.

Moreover, thermal imaging helps in understanding altered gait or weight-bearing mechanics, potentially revealing underlying spinal or foot conditions. Nerve damage, often caused by conditions like disc herniation and spinal nerve root compression, presents as cool areas of hypothermia on thermal images, contributing to accurate diagnosis of the disease.

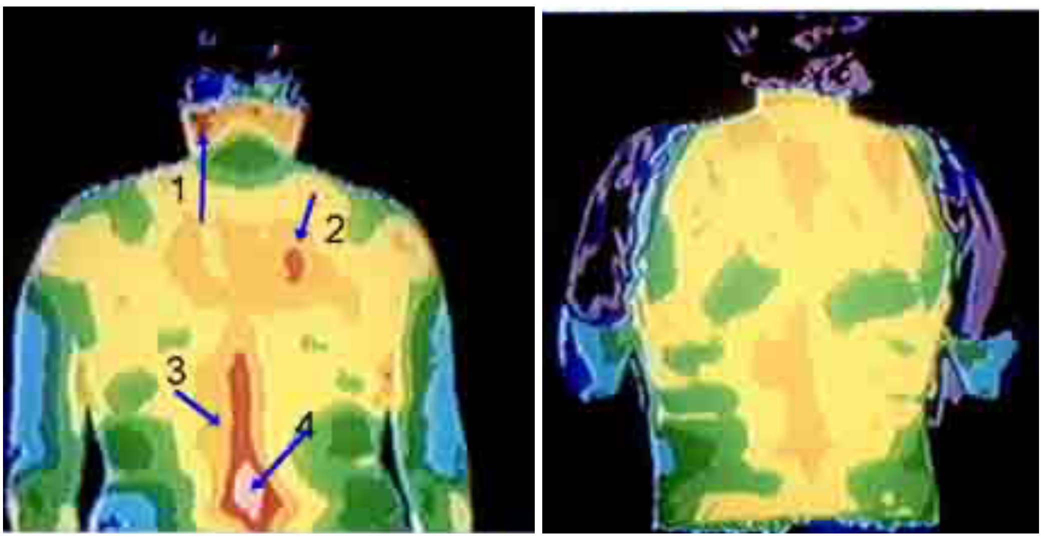


Fig 7 – Images of Pre and Post thermograms of a patient suffering from diagnosed fibromyalgia

Other Medical Applications

Respiratory Dysfunctions: Thermal imaging is applied for monitoring asthma, allergies, bronchitis, and respiratory infections. It played a role during the SARS epidemic and remains useful in detecting abnormalities in lung and respiratory function.

Digestive Disorders: In cases of gastrointestinal pathology, such as appendicitis, irritable bowel syndrome (IBS), colitis, and ulcers, thermal imaging aids in the diagnostic process by identifying abnormal heat patterns.

Urinary Diseases: Thermal imaging offers a non-invasive method to monitor urinary tract infections, kidney pathology, and other urinary-related disorders.

Reproductive Disorders: The technology finds applications in gynecological evaluations, offering insights into uterine, prostate, polycystic ovary, and endometriosis conditions.

Endocrine Disorders: The technology aids in evaluating hormonal changes, identifying thyroid disorders like hyperthyroidism and hypothyroidism, and contributing to diabetes management.

Surgical Assistance: Thermal imaging assists surgeons in pre- and post-operative procedures, helping to locate tumors, identify surgical areas, and monitor post-surgical healing.

Skin Problems: The technology contributes to diagnosing skin tumors, skin cancers, and monitoring wound healing progress.

4. Standardization and Quality Assurance in Clinical Thermal Imaging

To ensure the reliability and consistency of clinical thermal imaging procedures, it is crucial to establish standardized protocols and quality assurance measures across various aspects of the process.

5.1 Preparation of the Patient

Patient preparation is a fundamental step in obtaining consistent and accurate thermal images. Guidelines should be provided to patients regarding factors that could influence the imaging results. This includes advising patients about refraining from smoking, certain exercises, drug use, and cosmetics on the day of examination. Additionally, maintaining a controlled environment with stable temperature and humidity is crucial as well.

5.2 Standardization of the Thermal Imaging System

Medical thermal imaging involves different systems with components like detectors and lenses. Ensuring the accuracy and stability of temperature measurements is vital. Often, these systems take longer to stabilize than indicated by manufacturers. Additionally, variations in measurements between different systems require cross calibration for uniformity. Collaborating with calibration experts, such as the National Physical Laboratory, facilitates the creation of portable standards for consistent measurements. Employing substantial camera stands also ensures consistent camera positioning, contributing to reliable outcomes.

5.3 Image Capture Protocols

Standardizing image capture protocols minimizes variability arising from camera angles and distances. Establishing a set of standard views is crucial. These views define the camera's position and angle to ensure consistency. Software-generated capture masks facilitate consistent imaging by ensuring that the target fills the frame based on anatomical landmarks. The distance between the subject and camera is adjusted to match the thermogram closely to the mask outline, ensuring consistency across different body sizes.

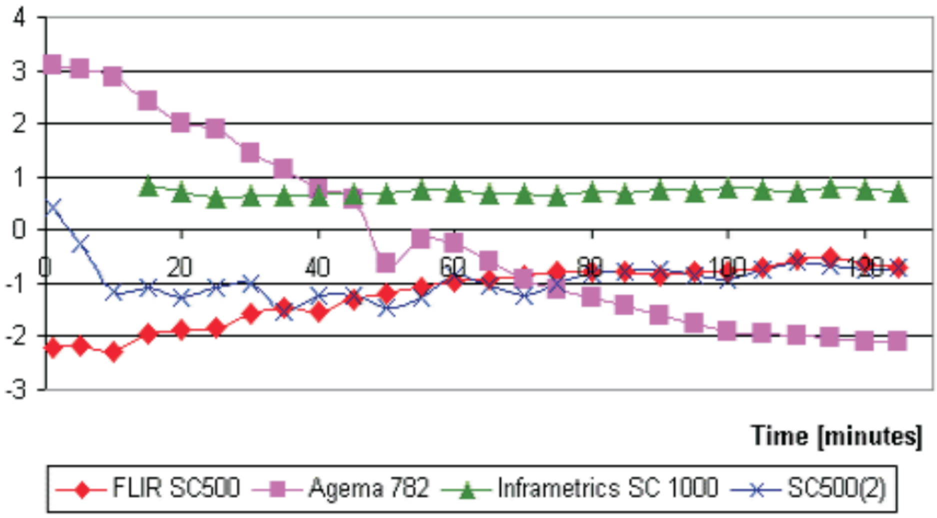


Fig 8 – Shows variable offset in four calibrated IR cameras and camera mount

5.4 Image Analysis Protocols

Standardized image analysis protocols are essential to enable consistent interpretation of thermal images. Regions of interest (ROIs) for temperature analysis are defined based on anatomical landmarks. The use of these landmarks ensures accurate placement of ROIs, and minor adjustments can be made if needed. This approach improves reproducibility in temperature analysis and minimizes subjective variability.

Standard View	LEFT ARM (dorsal view)
Upper	wrist
Lower	below the axillar fold
Other	arm 90° abducted and elbow 90° bent, the outline of the of the deltoidmuscle is within the image
Image	
IMAGE ANALYSIS	
Standard View	LEFT ARM Number of ROIs 3
Description ROI 1	Shape: circle Outline of the circle is adjacent to the cubital fold and the lower edges of the elbow.
ROI 2	Shape: trapezoid Upper left corner: cubital fold. Upper right corner: insertion of the deltoid muscle. Lower right corner: axillary fold. Lower left corner: tip of elbow.
ROI 3	Shape: trapezoid Upper left corner: ulnar end of the wrist. Upper right corner: radial end of the wrist. Lower right corner: cubital fold Lower left corner: tip of the elbow.
Image	

Fig 9 – Anatomical description of the field of view for image capture of the fore arm

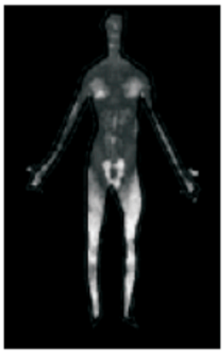
Standard View	TOTAL BODY (anterior view)
Upper limit	the most cranial point of the head
Lower limit	soles of the feet
Other detail	arms and legs slightly abducted, palms point forwards, head is a vertical position, not rotated or tilted to the side
Image IMAGE ANALYSIS	
Standard View	TOTAL BODY (anterior) Number of ROIs 1
Description	Shape: polygon, following the outline of the body
Image	

Fig 10 – Anatomical description of the field of view for image capture of the whole body according to the new protocol and the region of interest for image analysis of the anterior surface

5.5 Reporting, Archive, and Storage of Images

Implementing standardized reporting, archiving, and storage practices ensures comprehensive record keeping and easy retrieval of patient images for comparison over time. Structured reporting templates should include essential patient information, imaging system details, and findings. Software tools can facilitate the organization of patient data and images, ensuring data security.

5.6 Education and Training

Proper education and training of clinical users are essential for ensuring consistent and accurate thermal imaging procedures. Physicians and technicians should receive comprehensive training on standardized protocols, image capture, analysis, and reporting. The development of educational materials, training courses, conferences, and journals dedicated to thermal imaging in medicine, supports continuous learning and improvement within the field.

Reference

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6. Ring, E.F.J. & Ammer, Kurt & B.Wiecek, & P.Plassmann, & Jones, Carl & Jung, Anna & Murawski, Piotr. (2007). Quality assurance for thermal imaging systems in medicine. Thermology International. 17. 103-106.