# Trends in Mobile Medical Thermography

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*Abstract*— **The usage of computational systems in medicine is changing from traditional computers to mobile devices with high performance wireless network connections and high definition touch screen user interface. Medical imaging like other clinical information systems, follow that paradigm. Although Medical thermography is the second oldest modality of medical imaging, it has been disregarded for years. However recent technological improvements and the definition of standard capture protocols raised the interest in its usage in recent years. It is presented in this article the requirements that future medical thermography applications should include to be successful in common clinical practice.**

***Keywords*—Infrared imaging, Medical imaging; Mobile applications; Thermography**

## I. Introduction

Sir William Herschel discovered the infrared radiation in 1800 by passing the sunlight through a prism and holding a thermometer just beyond the red end of the visible spectrum. His son, John Herschel recorded, using alcohol lotion and carbon, the first image of solar radiation, during a day, in 1840 calling it a thermogram. For decades the technology has been used only for military and astronomical purposes. Clinical thermography is a non-contact, non-ionizing method to monitor physiology in real-time, being a window to the peripheral circulation system and to the autonomous nervous system [1].

In 1996, Ray Lawson, a Canadian physician, introduced thermal imaging in medicine, investigating skin surface temperature in breast carcinoma patients [2]. Since then it was widely used in most of the medical fields, having successful clinical applications on: inflammatory arthritis, osteoarthritis, soft tissue rheumatism, enthesopathies, tennis elbow, fibromyalgia, complex regional pain syndrome, peripheral circulation, fever screening, burns, renal dialysis and malignant diseases (location of melanomas and chemotherapy monitoring) [3].

The equipment evolved since it was firstly introduced in clinical applications. The cameras have reduced in size, become more portable, reliable and offering different communication interfaces, wired and wireless. Some decades ago, good definition images were only possible through liquid nitrogen refrigeration, which made the equipment larger and noisy. Uncooled infrared cameras present nowadays image quality closer to cooled cameras than in the past. The sensors have improved considerably over the years, which contributed to an increase in imaging quality. Their size has been reducing and sensitivity increasing, resulting from a technology evolution from one sensor, to a line of sensors and finally to an array of sensors, also called focal plane array [1].

In order to verify if the recording equipment is under adequate conditions, for quality assurance purposes, a battery of simple tests was proposed to verify the following parameters: start-up drift, long-term offset drift, offset variation over observed range, image non-uniformity, thermal 'flooding', spatial resolution and thermal resolution. These tests are recommended and should be performed periodically in order to make sure that the measurements being made are correct [4].

Despite the early interest from the clinical professionals in the modality and equipment limitation, good studies were performed [1]. However in 1977, the Breast Cancer Detection Demonstration Project (BCDDP) report was published about the sensitivity of thermography compared to other methods of breast cancer detection. The results demonstrated that

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thermography appeared in third, after ultrasound and mammography, presenting a sensitivity of only 39% and a specificity of 82% [5]. This study, using limited equipment and not mentioning any protocol to deal with known conditional environment variables (ambient temperature, humidity, air flow and subject acclimatization period) affecting the examination, has discredited thermography in clinical setting for years.

In order to raise interest and prove the feasibility for the usage of thermal imaging in medicine, concerns were outlined to standardize the capture of images [6 - 8]. Guidelines were proposed for the subject preparation before and during appointment and manner of conducting the examination [9, 10]. Minimal requirements and specifications for thermal camera suitable for clinical use were outlined [11] and international standards released defining the usage of thermal cameras for massive fever detection [12] and for the recommended mode of deployment including the testing of the systems and the training of their users [13].

All this recent developments contributed to an important improvement of the technique and acceptance from the clinical professionals, however, work needs to be done for standardizing the analysis of the images is needed.

Ledley introduced the concept of using computers in medicine in 1959 [14]. Computers evolved over time, becoming smaller and powerful, in the late 90's the usage of laptops was very popular, it allowed portability increasing the satisfaction of the users. In early 2000's the concept of mobile computing and its applications emerged [15 - 19], but it clearly got another dimension and changed the environment of workplaces using mobile computing solutions with the appearance of the smartphone iPhone in 2007 and the tablet Apple iPad® in 2010. It changed the paradigm of using information systems. The so-called applications or "apps" replaced the traditional programs and the user interface changed from mouse, keyboard and monitor to a touchscreen. Having network connection, it brought satisfaction to the end users, enforcing portability and productivity.

The aim of this publication is to raise warning in the need of fulfilling the existent gap of having a specific dedicated mobile computing application for medical thermography, which could make a difference in the wide acceptance and common daily usage of the technique in clinical practice.

## II. MEDICAL THERMAL IMAGING SOFTWARE

All infrared camera manufacturers provide proprietary software, which allow camera connection (through Firewire, USB, Ethernet or Gigabit-Ethernet), interaction with camera commands (focus, temperature scale, emissivity value and recording), image recording in a proprietary format and basic analysis tool.

Thermal cameras used in medicine are standard cameras that are also used in industrial and other applications. In consequence the developed proprietary software is also very generic and does not suit the majority of specific clinical applications.

Plassmann and colleagues attempted to define a specific range of tools needed for clinical thermal imaging purposes [20 - 23]. They developed a computational system, CTHERM®, that was able to acquire a thermal image from FLIR A series and AGEMA® thermal cameras. For facilitating the camera and subject positioning the system used overlay shapes of regions of interest of the human body. After the image capture, it was stored in a database with information about the subject and the institution where the image was taken. The software allows drawing regions of interest to analyse thermal properties, showing the histogram, such as: mean, maximum, minimum temperature and standard deviation. It also permitted to use isotherms and cross-section for more accurate analysis. As a built-in medical prognosis tool it had a specific cold stress test to the hands analysis, which was able to calculate the index between the baseline image and the image of after 10, 15 or 20 minutes recovering from the provocation. The CTHERM® has also a reporting tool to export images and information to the Microsoft Word text processor. This software only worked in Microsoft Operating Systems 2000 and XP professional and used a FLIR Thermovision SDK®.

Currently FLIR provides free and licenced software. The FLIR WebViewer® is free and intuitive and easy-to-use online tool to analyze and evaluate infrared images. Images can be uploaded, then execute simple procedures such as

measurements in regions of interest, palettes changing, read out camera properties and save the processed images into the computer. The FLIR Tools are available for Microsoft Windows® and Apple Mac OS X® operating systems, and is a free package that allows: importing of infrared images through a USB cable from the camera or SD card; edit radiometric images to thermal tune level and span, change the palette, or adjust parameters such as emissivity and reflective temperature; add measurement tools such as spots, area boxes, circles, lines, Delta T; add text annotations and edit image descriptions; create professional PDF image sheets and reports; add headers, footers, and logos; create, import, edit and export template, choose a report format; edit MSX images and "Sketch on IR/Visual" images; and display stored compass and GPS information. There is also through a paid licence the FLIR Tools+, which offers: pair and group FLIR thermal images and digital photos independent of when or how the separate images were originally captured; stitch FLIR infrared images regardless of the order they were taken to help to measure and paint the complete thermal picture in one full scene (with a minimum of 30% overlap); record and replay thermal video sequences, create a temporal plot with the recording, and export the sequence to AVI format; and advanced reports with improved speed, allowing to create a Microsoft Word® report 50% faster. The FLIR IR Camera Player® is a free Windows-based remote control and viewer for cameras from FLIR Systems. With it is possible to: record a video stream from the camera; save a frame from the video stream as a snapshot image (*.bmp); perform autofocus, focus far, and focus near; auto adjust the camera image; freeze the camera image; save a camera image in the camera; change colour palette; and add an image description and a text comment to an image. The FLIR QuickReport® is a free Windows based application that allows users to organize and analyse the radiometric images from its infrared cameras and present them in a report in just three easy steps. The FLIR ResearchIR® is a commercial windows-based scientific and professional tool for camera system command and control, high-speed data recording, real-time or playback analysis, and reporting. It allows: sizable image display with selectable colour/grey scale palettes; multiple analysis tools with user defined settings for detailed data examination; to save, locate, or open previously stored images or image sequences; multiple image scaling modes with built in histogram display to simplify manual scaling of the image, view detailed image quantitative data from the image analysis tools; and to plot the desired analysis tool result over a period of time or frame number [24].

The TESTO IRSoft® is a windows-based software package that allows TESTO thermal camera connectivity and basic analysis through regions of interest basic measurement [25].

The Fluke SmartView® Thermal Imaging Analysis and Reporting Software is a windows-based software that provides a suite of tools for viewing, optimizing, annotating, and analyzing thermal images and videos from a Fluke thermal camera. It also generates fully customizable and professional-looking reports [26].

InfraTec's state-of-the art IRBIS 3® software package is a windows-based tool for thermographic image data analysis and for creating reports in Microsoft Word®. It offers basic functionalities such as: support for infrared camera file formats of InfraTec's product range; multi-lingual user interface; visualisation of thermal images with screen/printer-optimized colour palettes; manual and automatic temperature range selection; temperature profiles along any lines and across any measured areas; automatic indication of maximum and minimum temperature mean value; print and export of thermal images or tables of measured values; display of up to 10 coloured isotherms; image improvement through digital filtering; and an integrated Word-based report function [27].

For mobile computing market, the only thermal camera manufacturer that provides software packages for mobile devices is FLIR. They provide the FLIR Tools Mobile App®, which is a free FLIR Wi-Fi App for Apple® and Android™, and Kindle™ Mobile Devices. It works only with FLIR E (E40, E50, and E60) and all models of T series of infrared cameras. It allows users to: import stored images wirelessly; adjust the temperature span and contrast levels; change colour palettes; add temperature measurement tools; play back voice

comments; auto and manually adjust the focus; adjust picture-in-picture, thermal fusion, and IR and visible light image blending; remote control the FLIR infrared camera; support for MSX (Multi-Spectral Dynamic Imaging) images; support for sketch images on both IR and visual with toggling ON/OFF feature; support for same FOV (field of view match); and edit text comments [24].

## III. Discussion

As there are no cameras designed specifically for clinical applications, there is also no specific software for the clinical setting compatible with the various capture equipment available in the market. One important aspect to take into account is to store the images in a DICOM format, which is not defined for medical thermography yet. There is no doubt that there are already thermal image capture devices equipped with wireless network connection that satisfy the minimal requirements for clinical practice [11]. The contemporary mobile devices are also equipped with compatible wireless network connection, efforts are recommended to manufacturers, researchers and health professional to define a common and standard format of images. The FLIR Tools Mobile App, apart from the record format is a good starting point. Allows the camera control and the basic image analysis features. It is worth to add the medical specific features present in the CTHERM software package [23] and some extra features such as pre-processing tools (image enhancing), segmentation features (edge/shape detection/registration), variation analysis (spatial, temporal and frequency) and image normalization for a more accurate analysis and comparison [22].

Undoubtedly, following the standard recommended medical thermal imaging protocols and having in addition a software package for medical devices, being able to be integrated with the thermal cameras and PACS and RIS systems, would attract more health professionals that are not aware of the importance of medical thermography, enforcing its credibility and contributing to become part of the common clinical practice in a portable convenient and satisfactory manner. Having these tools would also facilitate the availability of the modality for applications in surgical units, intensive care units and infectious diseases units.

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