Computer-aided Approach to Evaluation of Burn Wounds

Wojciech Tylman, Marcin Janicki, Andrzej Napieralski, and Wojciech Kuzański

Abstract—**A novel method to employ PC-based solutions in evaluation of burn wounds is presented. The proposed approach utilises a computer program, guiding the physican through the procedure and allowing to process infrared and visible light images of the burn wound. Ability to interact with selected models of commercially available thermovision cameras is provided.**

Index Terms—**thermography, medical imaging, medical diagnosis, DICOM**

I. INTRODUCTION

TEMPERATURE measurement is one of the approaches used commonly in medical diagnosis. However, single-point measurements provide only very limited amount of data. Approaches where the detailed temperature map of an area can be obtained are investigated in order to obtain more precise information about the patient and the disease. One field where such approach may be used is the analysis of burn wounds. It is believed that the severity of the wound may be determined by analysis of the temperature of the tissue. Such evaluation could be particularly useful when the correct classification of the wound suggests the choice of the optimal treatment procedure.

Determining temperature map of an area (as opposed to spot measurements) can pose significant problems. In the case of burn wounds contact methods might be impossible to use, as they would cause pain and could also lead to infection. The solution is to use contact-less measurements, among which thermovision methods require special attention.

The remainder of this paper is organised as follows: Section II presents basics of thermovision measurements and Section III deals with the specific requirements of burn wounds measurements. Section IV introduces the proposed software solution, while Section V outlines future research directions and provides closing remarks.

II. THERMOVISION MEASUREMENTS

A. Basis of thermovision

Thermovision – also referred to as (infrared) thermography – performs contactless temperature measurements by recording electromagnetic radiation in the infrared range (usually corresponding to the 7-14 μm wavelengths). Such measurements are possible because every real object which temperature is higher than absolute zero (-273.15°C) emits electromagnetic radiation. The radiation from a black body (i.e. idealised perfect emitter) can be expressed as a function of the body temperature and the wavelength using Planck's law [1]

$$I(v, T) = \frac{2hv^3}{c^2} \frac{1}{\frac{e^{hv}}{kT} - 1} , \qquad (1)$$

where I is the radiation, v is frequency, T is absolute temperature, h is Planck's constant, c is the speed of light, and k is Boltzmann's constant. Because of this phenomenon it is possible to determine temperature of the black body by measuring its radiation in selected wave band. The usefulness of infrared imaging in temperature measurements is amplified by the relationship between the black body temperature and the wavelength at which peak emission occurs. This relationship is described by Wien's displacement law [2]

$$\lambda_{max} = \frac{b}{T} , \qquad (2)$$

where: λ_{max} is the peak wavelength, T is absolute temperature , and b is a constant of proportionality. From this law it can be easily calculated that for temperatures between -65°C and 140°C the peak lies in the aforementioned infrared range of 7-14 μm wavelength, therefore making the typical infrared detector perfectly suited for temperature measurements. The theoretical discussion presented above makes some important assumptions. First of all, a black body object is discussed. As such bodies do not exist in reality, a grey body model has to be used, which introduces an additional coefficient, called *emissivity*, which accounts for reduced radiation from the real-life body. In order to obtain precise measurements of absolute temperature of the object this coefficient has to be determined.

Further analysis shows that even the grey body approach is only an approximation, as it still assumes that the emissivity does not depend on temperature, wavelength or observation angle. For high precision measurements these factors have to be also taken into account.

B. Infrared camera construction

The construction of infrared cameras, or more precisely – infrared sensors that lie in the heart of such cameras – has seen rapid development in recent years. First commercially available infrared cameras employed a single sensor, capable

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of spot measurements. When measurements of area were required, a sophisticated mechano-optical device had to be employed that scanned the desired area, directing the radiation coming from various point to the single sensor. Such approach had many drawbacks: quick changes of area temperatures could not be captured and the whole device was bulky and fragile.

Another problem with early infrared sensors was the necessity of cooling them to low temperatures, often using liquid nitrogen which boils at -196°C. This made the operation extremely cumbersome and expensive.

Next step in the development of infrared sensors was construction of a linear array of detectors, which simplified scanning devices and allowed capturing faster changing temperatures. Finally, matrix detectors have been constructed, capturing *at once* temperatures of the whole area. This dramatically simplified construction of camera and made it possible to construct handheld devices.

Nevertheless, cooling of the sensors was still required. This could be achieved, for example, by miniature helium-filled Stirling engines. Recent development led to construction of *microbolometers*, which operate at room temperature. For some time the measurement accuracy of such sensors was not good enough for precise measurements of temperatures, but latest solutions managed to improve significantly.

C. Cameras used

The presented approach is designed to operate with thermographic cameras produced by FLIR. Specifically, FLIR ThermaCam P660 is used during development phase. This camera uses microbolometer sensor with spatial resolution of 640 columns and 480 rows and thermal resolution of 0.03°C. In addition to recording thermal images, the camera is also capable of recording visible light images, thanks to integrated CCD module. The camera is a hand-held device and may transfer images using digital interfaces (FireWire, Ethernet) or flash memory cards (SD standard). Another camera that can be interfaced with the system is FLIR (Inframetrics) ThermaCam SC 1000, based on a Stirling engine cooled sensor with spatial resolution of 256 rows and 256 columns and thermal resolution of 0.07°C. This camera can transfer images using flash memory cards in CompactFlash standard.

Both cameras are property of the Department of Microelectronics and Computer Science at the Technical University of Łódź.

III. BURN WOUND MEASUREMENTS AND ANALYSIS

A. Precision

The main aim of using thermography in burn wound diagnosis is to determine optimal treatment for different areas of the wound. In particular, early discrimination between areas that will heal without surgical intervention and the areas where the tissue is destroyed and has to be surgically removed is of great importance. It is argued that these areas can be discriminated by temperature measurements; in other words, temperatures of the destroyed tissue will be different from these of the tissue able to heal. It is to be expected that the

measurement will have to be very precise, as the temperature differences (based on which the decision has to be made) may be very small. The precise nature of measurements leads to the following requirements for the proposed solution:

- high precision measurement equipment
- correct measurement procedure – in particular ensuring that the measured area is normal to the axis of the camera and the angle of view is small, which means that for all points of the measured area the radiation received by the sensor will be emitted in direction close to normal
- software processing path ensuring no loss of data precision

B. Visible light analysis

As outlined in previous section, the measurements should lead to discovery of burn areas that require surgical intervention. These areas should be clearly marked, in a way that enable the surgeon to remove all of the destroyed tissue and only the destroyed tissue. The thermal image is not suitable for such task, as it a) has insufficient spatial resolution, and b) is presented in false colours which do not correspond to visible light colours perceived by humans. This asks the following features:

- for every analysed thermal image a visible light image of the same area, but with greater spatial resolution, has to be recorded
- results of the analysis of the thermal image have to be transferred and presented in the visible light image
- both images have to be precisely aligned, so that the areas marked in the visible light images match these discovered in the thermal image.

C. Integration with medical procedures and infrastructure

The proposed solution is to be used in a hospital environment. As a result, it has to adhere to certain standards, in particular connected with storage and retrieval of medical imagery. The solution should not only allow storing the images and their analyses so that they are protected from loss and abuse, but should do this in a way that allows other medical applications to access and process these records. The following needs have to be addressed:

- images and analysis results should be stored in an appropriately protected database
- the record should be easily identifiable as pertaining to particular patients and measurement dates
- the format for stored images should adhere to the DICOM [5] medical standard.

IV. BURNDIAG – A PC SOLUTION FOR ANALYSIS OF BURN WOUNDS

The requirements outlined in previous section guide the development of *BurnDiag* – a software solution to be used on a PC workstation by doctors dealing with burn wounds. The solution should provide easy to use custom tools, best suited to the task of diagnosis, designed and arranged in the way to make the diagnosis quick and error-free.

A. User interface

The software employs Graphical User Interface (GUI) for ease of use. The main window of the application contains two tabs, dividing application functionality into textual description and image processing parts.

1) Textual description

Textual description tab (Fig. 1) allows the physician to enter patient data (name, surname, etc.), as well as details of the examined wound. Separate fields are provided for burn location, its depth classification, description, dressing details and bacteriologic examination description. The examination date, as well as burn accident date can be entered as well.

The choice of information presented in this tab has been guided by the needs of the physician and aim to provide a complete description of the wound and examination. Because the program is intended to work with a database, these fields correspond to entries in a database table. The database can also be queried by other programs, thus creating a way to exchange data between the discussed solution and other programs.
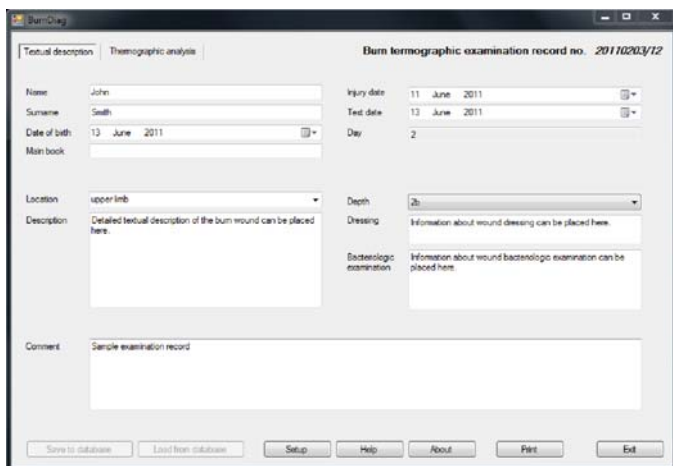

Figure 1. Textual description tab of the BurnDiag PC software.

2) Image processing

The fundamental functionality of the application is exposed through the image processing tab (Fig. 2). This tab is built around two images, the first one displaying the infrared image (Fig. 3), the second one displaying (optional) visible light image. The size of both images is the same, so that after the visible light image is transformed to match the area presented in the infrared one, the physician can easily compare appearance of wound features in infrared and visible spectrum. Furthermore, the mouse cursor is duplicated in the visible light image window, so that when the user points to a feature in the infrared image, the corresponding point is indicated in the visible light image. The temperature under the cursor is displayed continuously.

The user of the software can attach many pairs of images to one examination. As the software at any given time displays only one pair, a selector (spin box) is provided in order to change the currently displayed pair.

As already mentioned, thermographic image is presented in false colors. The choice of the palette applied to the image is important, as it affects ease of analysis of the image. To some extent, it is also a matter of personal preferences and habit of the physician. For these reasons the software allows to choose among a number of false color palettes. New palettes can also be easily added through a text configuration file. The software supports two formats for palette description: the first is based on the palette description format used in the current FLIR software, the second one on the format used in past Inframetrics software. Because of such approach, the user is also able to import her/his palettes used in other tools. The current palette is displayed next to the infrared image, together with edit boxes provided for setting the minimum and maximum temperature presented in the image.
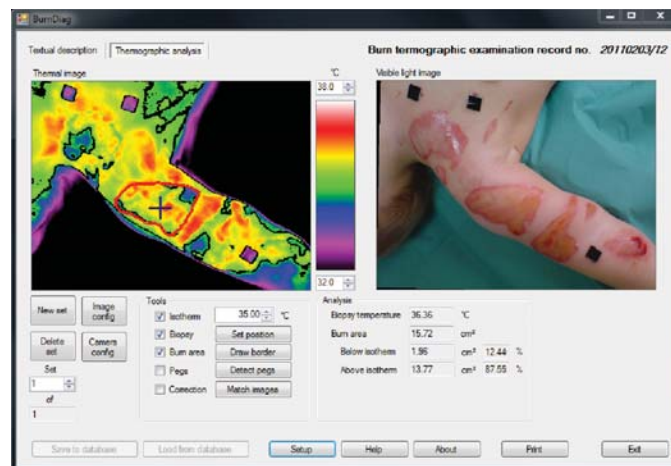

Figure 2. Image processing tab of the BurnDiag PC software. Both infrared and visible light images are shown.

In order to determine which parts of the wound require surgical intervention, two steps have to be performed: the first step is selecting the area of the image that corresponds to the wound. This is done by the physician by drawing a closed path around the wound. The path is drawn in a free-hand mode, functionality allowing corrections of the already drawn path are currently being implemented. Once the wound area is selected, further analysis applies only to this area.
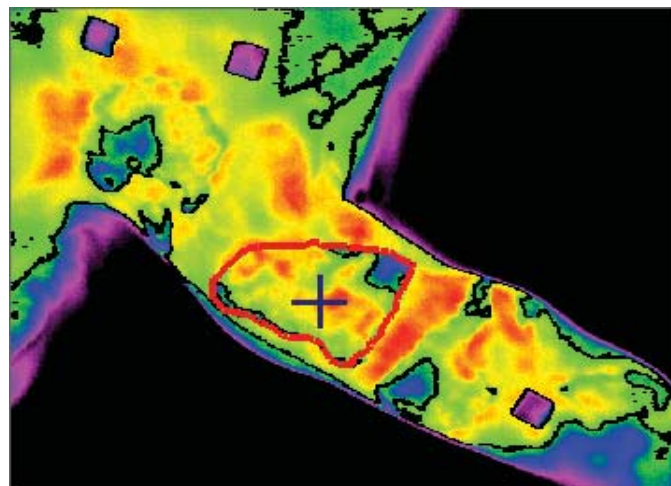

Figure 3. Infrared image as presented by the BurnDiag PC software. Area (red line), biopsy (blue cross) and isotherm (black line) tools are used.

The second step is dividing the wound area into the parts requiring surgical intervention and the parts that will heal without such intervention. This is performed by the software on the basis of a temperature threshold set by the physician. The threshold is used to find (and draw) an isotherm corresponding to the chosen threshold. Once the isotherm is found, it is also used to express these parts in terms of percentage of the whole burn area. The results are displayed under images.

As the thermal analysis may be accompanied by biopsy, the software also allows marking the point from which the tissue is removed and recording the temperature at this point.

In order to further facilitate the analysis, more features are currently being added to the software. One of the most important is the ability to align the infrared and visible images in case when they are taken from significantly different positions (e.g., not with the dedicated camera capable of recording both types of images, but with two different devices). This procedure employs special markers (or pegs) that are placed on the analysed object (e.g., patient's body). Such pegs are visible in Figs. 2 and 3, in this case they are small black squares of plastics. The task of the algorithm is to locate these pegs in both infrared and visible light images and to transform the visible light image so that the coordinates of the pegs in this image precisely match the coordinates of the corresponding pegs in the infrared image. Use of three non-collinear pegs allows to compute coefficients a_0-a_2 and b_0-b_2 of the affine transform, which translates pixel coordinates x, y into u, v (3). Such transform can map a parallelogram onto a square [6] and should be sufficient, provided the images were taken from similar positions.

$$u = a_0 + a_1 x + a_2 y$$
$$v = b_0 + b_1 x + b_2 y$$
(3)

The chief difficulty lies in detection of the pegs in the infrared image, as this image has (relatively) low resolution; furthermore, the contrast between pegs and the environment mainly depends on the temperature difference between them. Using pegs that have been slightly cooled before being placed on the object may improve the reliability of the algorithm.

Because it is expected that the algorithm will not be capable of finding the pegs in every image (and also in order to provide means for aligning pictures without pegs), the software also allows to manually indicate the points used for image aligning. The results of the procedure performed using such approach are presented in Figs. 4-6 and Figs. 7-9. Each of the triple contain the infrared image, the original visible light image and the corrected visible light image. As can be seen, good results are obtained not only in the situation where the original images differ slightly (Figs. 4-6), but also in situations when they differ significantly (Figs. 7-9).

Another feature is automatic calculation of a coefficient that allows expressing the areas in term of area units (cm^2 being the unit of choice), not only in term of percentage of the whole wound. This is done by placing a marker of known area near the wound and detecting the pixels corresponding with this marker in the image taken (for this purpose the aforementioned pegs can also be used).

B. Connection to the camera

The software employs two separate approaches to camera connection. For newer cameras, such as FLIR ThermaCam P660, connection is provided by ActiveX component of FLIR SDK library. This flexible component allows direct connection with a number of different cameras, using a digital interface. It may also be used in an off-line mode, where the images are read from files. This second mode of operation is especially useful, as it means that the procedure of image capture and image analysis can be separated.

For older cameras, such as FLIR ThermaCam SC 1000, only the off-line mode is available. As the FLIR ActiveX component does not support such cameras, separate procedures for reading FLIR custom TIFF format have been developed.

It should be notes that in both cases the files cannot be read using standard image processing libraries. This is due to the fact that both the FLIR JPG and Inframetrics TIFF are in fact extensions of the respective graphics formats: they contain many additional fields used by the loading procedure to compute the temperatures of every pixel.

C. Connection with the database

The description of interface with database, as well as application of DICOM format to the analysed images, will be presented in a separate paper.

D. Algorithms and programming platform

The algorithms used in the application are derived from well-known algorithms used in image processing [7]. However, care must be taken when applying such algorithms to infrared images, as not all procedures will give meaningful results. For example, interpolation procedures used to scale images cannot be applied to the resulting false colour images, as the colour resulting from interpolation between two points may not match the colour obtained by applying the palette to the temperature obtained from interpolation between the same points. For these reasons, most operations are performed on the underlying matrix of temperatures (floating point, single precision) obtained from the camera, and only after that converted to the image.

The application has been written in C# and is targeted at Microsoft operating systems: Windows Vista or later.

V. CONCLUSIONS AND FUTURE RESEARCH

This paper presented a computer-aided approach to burn wounds evaluation. BurnDiag, a PC program performing analysis of the gathered infrared and visible light images has been described. The proposed approach promises fast, contact-less evaluation of burns, guiding the surgeon as to which parts of the wound will heal by themselves and which require surgical intervention. The described program exposes custom tools which allow performing all steps required for analysis: from reading proprietary file formats, through analysis of thermal images, to transferring the results into a visible light image that will guide the surgeon.

The presented solution is still being developed; in particular automatic calculation of areas and automatic matching infrared and visible light images is investigated. Once complete, the usefulness of the solution will be tested in hospital environment.
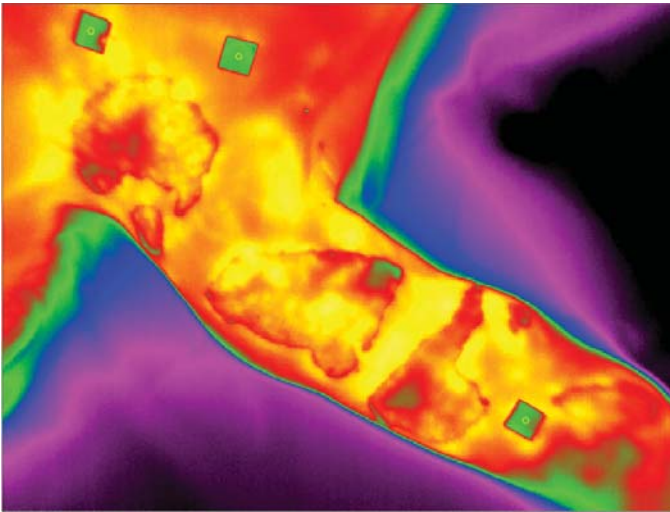
Figure 4. Thermographic image of a wound.
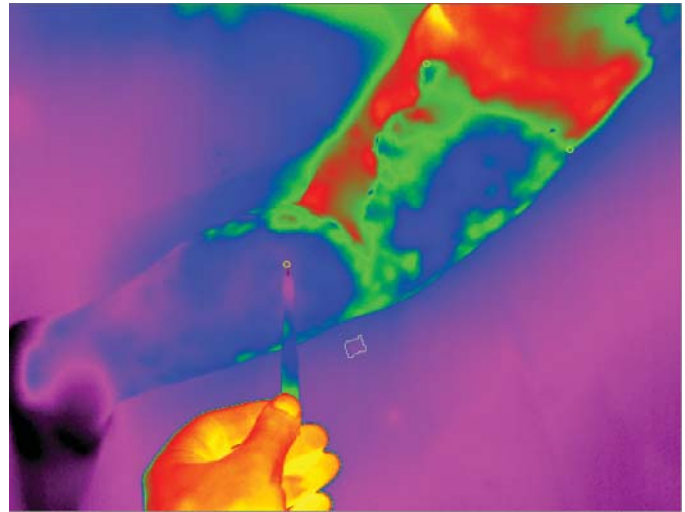Compare with visible light images in Figs. 5 and 6

Figure 7. Thermographic image of a wound.
Compare with visible light images in Figs. 8 and 9

Figure 5. Uncorrected visible light image of the wound shown in Fig. 4.
Case of small difference between the thermographic and visible light image

Figure 8. Uncorrected visible light image of the wound shown in Fig. 7.
Case of large difference between the thermographic and visible light image

Figure 6. Corrected copy of the visible light image shown in Fig. 5

Figure 9. Corrected copy of the visible light image shown in Fig. 7

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