http://dx.doi.org/10.21611/qirt.2014.089

A Template Based Method for Normalizing Thermal Images of the Human Body

by R. Vardasca*, **, J. Gabriel*, C. D. Jones**, P. Plassmann** and E. F. J. Ring**

* LABIOMEP, IDMEC-Polo FEUP, Faculty of Engineering, University of Porto, Porto, Portugal, *ricardo.vardasca@fe.up.pt, jgabriel@fe.up.pt*
** Medical Imaging Research Unit, Faculty of Computing, Engineering and Science, University of South Wales, Wales, United Kingdom*, ricardo.vardasca@southwales.ac.uk, carl.jones@southwales.ac.uk, peter.plassmann@southwales.ac.uk, francis.ring@southwales.ac.uk*

Abstract

The medical thermal images provide information about human body physiology. The images are analysed using regions of interest (ROI), which in human body are characterized of having a complex shape, differing slightly within subjects. Those differences such as size and position over time between different examinations affect an accurate analysis. A standardised method is needed to address comparison or average of several images. The proposed method is based in a geometrical template using triangles and barycentric coordinates. Despite an accuracy of 98% within the studied images, further research is needed in the automatic discovery of control points of the ROIs.

1. Introduction

Since 1956 infrared imaging is used in medicine, it consists in an imaging method of capturing human body skin surface thermal radiation providing real-time physiologic information about peripheral microcirculation and autonomous nervous system [1,2]. In order to improve the validity of standard examinations, capture protocols have been proposed [2,3,4] for subject, lab and equipment preparation as in the manner of conducting the exam. A set of 24 anatomical ROI were proposed enforcing their repeatability and data consistency, improving the screening method [4,5].

Because even having a similar shape, the different human body ROIs differs according to the subject, especially in size, and when performing an examination of consecutive images, it is difficult to keep the subject remain still at the same position during the capture. Thus the images need to be standardised to allow an accelerated and accurate analysis.

Several studies were conducted in thermal medical images to assess the effect of image enhancement [6], object outlining [7] and interpolation methods [8] for image segmentation and registration. From them it was concluded that the most suitable method of image enhancement was the homomorphic filter to aid the objects boundaries discovery through the template or probabilistic based methods [7], any other kind of application of noise removal techniques should be avoided [6]. However the same study concluded that none of the outlining methods was by itself enough to delineate automatically the ROIs, thus an extra post-processing was needed. The most adequate interpolation method to be used in reconstruction of medical thermal images is the Nearest Neighbour [8], which by the nature of the images, affects less the original measurements.

The literature existing methods for reconstructing an image from another based in a template (warping) [9] are: triangulation (fast), field-based points (based in vectors, needs a modified weighting function and may provoke ghosts and singularities at crossovers), free-form deformation (high degree of polynomials and control points in a grid that can be very complex to implement) and multi-pass spline (uses a mesh of control points, being very efficient but has a laborious specifications and the splines cannot cross).

The aim of this study is to present and demonstrate a new method of standardising ROIs of regional views of medical thermal images through using geometrical templates delimitated by control points, operating the pixels translation with a computationally simple warping transformation, with high accuracy and repeatability.

2. Methodology

The thermal images of the regional views of the human body were captured according to the Glamorgan protocol [3] by FLIR A40 thermal camera, which has a resolution of 320x240 pixels, accuracy of ± 2°C and bias of 0.1°C, the room temperature was of 22ºC and all subjects had been exposed to a 15 minutes acclimatization before examination. After capture, the images were stored on a database with aid of the CTHERM (thermal image capture and analysis software package)[10].

The triangle is the simplest shape that can be represented in image processing. Triangular based interpolation has the advantage of preserving the geometry of the lines that are combined [11], having a similar effect to the Nearest Neighbour method. The developed geometrical models based in triangulation and are presented in the Fig. 1.

Barycentric coordinates were revealed in 1827, by a German Mathematician August Möbius, it consists on for each inner point of a polygon with a certain number of vertices it will have correspondence to other inner point of a polygon with the same number of vertices [12], being its barycentric coordinates the distance from the point to the

http://dx.doi.org/10.21611/qirt.2014.089

vertices and its sum equal to 1 (Fig. 2). The normalized barycentric coordinates have as properties: linearity, positivity and follow the Lagrange property [13]. They can be applied to linear interpolation of data. This approach uses barycentric coordinates to make the correspondence between pixels of the original and resultant image of the transformation. Barycentric coordinates are coordinates based on the weights (distance) from the vertices of a triangle.

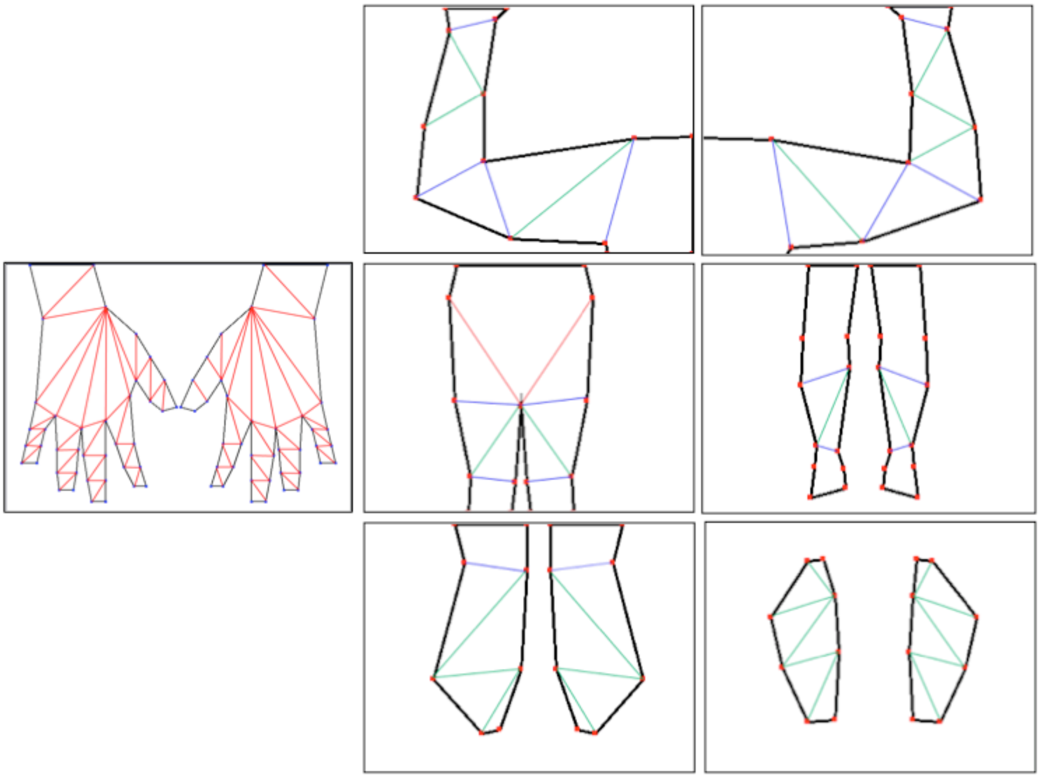
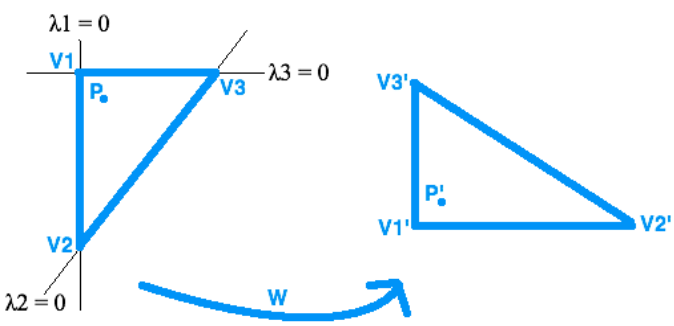


Fig. 1. *The geometrical human body ROIs models using triangulation.*

An application was developed in C# programming language to load thermal images and showing an overlay anatomical model of the local view with correspondent adjustable anatomical control points (Fig. 3). Those points can be adjusted to the object on the scene and when the user selects the warping option, the transformation operation starts. It creates concurrently the regions of each ROI and the triangles that constitute the base of the control point's positions. It is a fix number of control points based models that can be dynamically adjusted. The resultant models are static and well defined. There is maintained the correspondence of the control points through and array of Cartesian coordinates. Per each source region based on its pixels, a range of statistical values (mean, maximum, minimum, standard deviation, skewness and kurtosis) are calculated and later saved on a CSV (comma separated values) file.



$$P = \lambda1 V1 + \lambda2 V2 + \lambda3 V3 \qquad P' = \lambda1 V1' + \lambda2 V2' + \lambda3 V3'$$

$$\lambda1 + \lambda2 + \lambda3 = 1$$

Fig. 2. *Point correspondence between source and destination triangles using barycentric coordinates.*

http://dx.doi.org/10.21611/qirt.2014.089

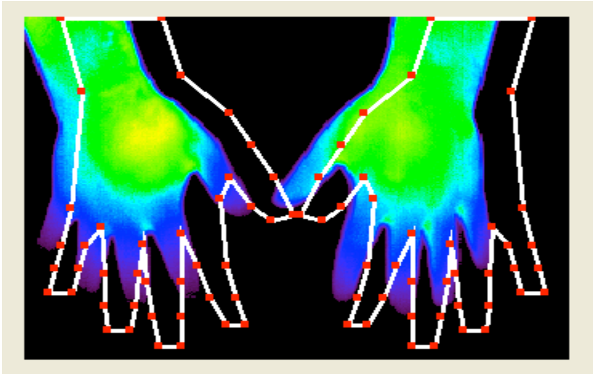


Fig. 3. *Adjustable control points overlaying the thermal image ROI.*

The creation of the warped image starts with reverse transformation calculation per each pixel of each target triangle, a Barycentric coordinate of that pixel is calculated according to the system shown on Fig. 4. A Cartesian coordinate is required from the equivalent source triangle given a previously obtained Barycentric coordinate, the value of the pixel of that cartesian coordinate on the original image is copied to the resultant current pixel image, that original was completely formed by black pixels. The correspondence of the triangles is maintained through an array of triangles with their vertices coordinates. Fig. 5 shows a representation of the algorithm fluxogram.

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{pmatrix} x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \\ 1 & 1 & 1 \end{pmatrix} \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix}$$

Fig. 4. *Barycentric coordinates correspondence system with cartesian coordinates.*

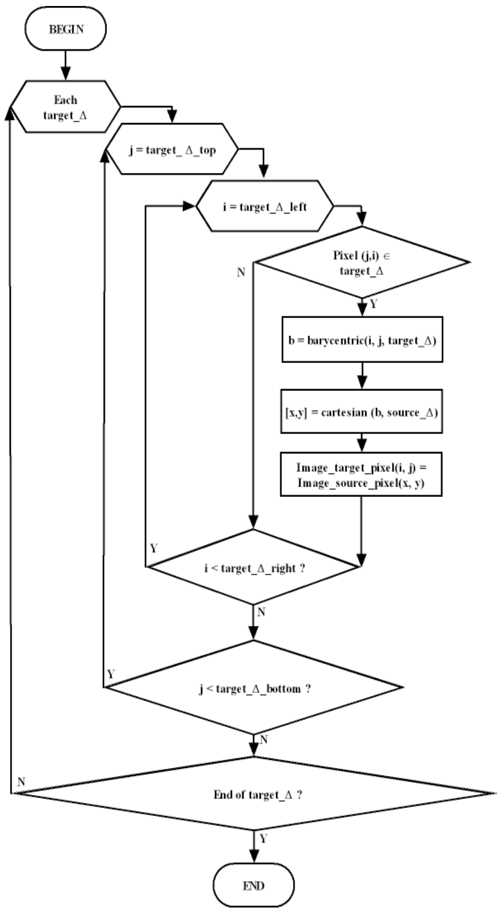


Fig. 5. *Warping algorithm fluxogram.*

http://dx.doi.org/10.21611/qirt.2014.089

2. Results

From a total of 980 processed images, when measured back with CTHERM, a maximum of 2% difference of mean temperature and standard deviation was obtained comparing with the correspondent original recorded non-standardised image. For a better understanding, an example of a converted image is presented on Fig. 6. The statistical significance of the correspondence on the obtained values when performed a standard t-test for means comparison was $p < 0.01$ after verifying a normal distribution through the K-S test. An example of non-standardized images and standardized images in shown on Fig. 7, where it can be visualised the importance of standardising images to a template shape in order to compare them and perform accurate analysis.

The time to process a standardised image, after adjusting the control points, was 1.72 ± 0.5 seconds. A statistical test of ICC using SPSS was performed in the two groups of 980 images before and after standardization in two runs of manual designed ROIs for non-standardised images and two runs of standardized images using the approach presented in this study. The values are shown on table 1.

According to the obtained values from the statistical analysis, it can be concluded that the standardized ROIs data is more reliable and consistent than the non-standardized, enhancing repeatability. For assessing the program operator error, 12 different users used the developed application, and an error inferior to 1% was obtained, with statistical evidence of user results independence (chi-square test, p<0.01).

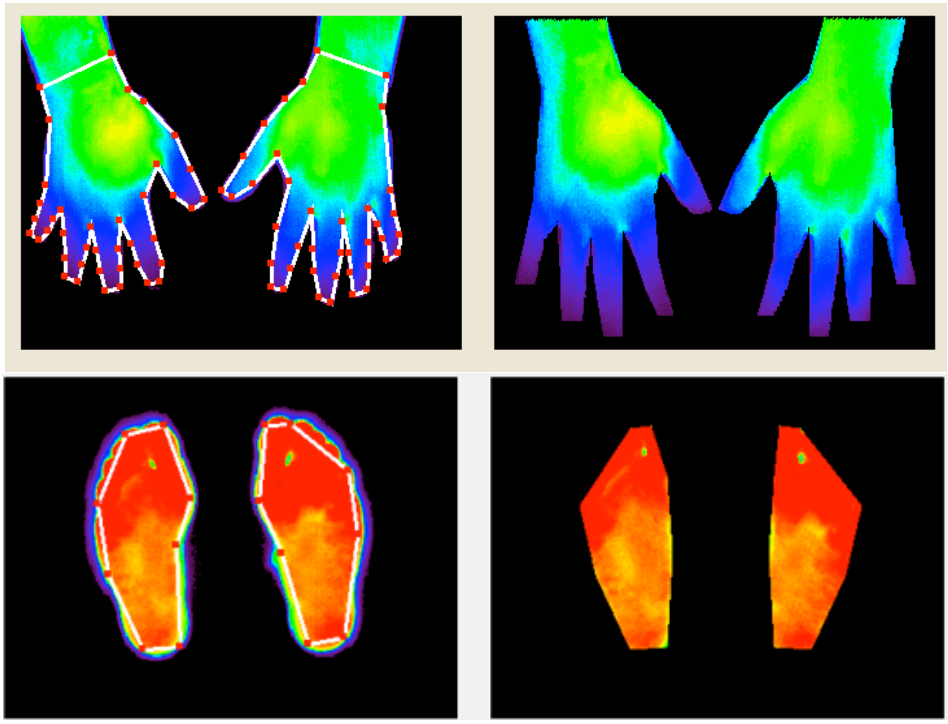


Fig. 6. *Resultant image of barycentric triangulation warping (top: dorsal hands, bottom: dorsal feet).*

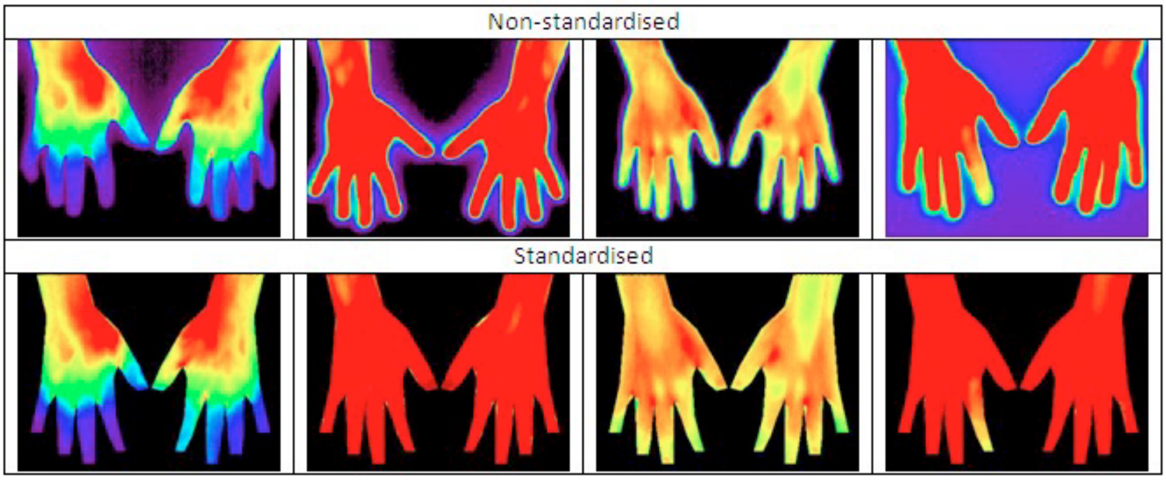


Fig. 7. - *Comparison between non-standardized and standardized thermal images of the dorsal hands.*

http://dx.doi.org/10.21611/qirt.2014.089

Table 1. The data consistency and reliability statistical analysis results before and after standardization.

ROI	Type	Reliability coefficient alpha	Interclass Correlation Coefficient	95% c.i. of ICC
Hands	Before Standardization	0.97	0.94	0.91 to 0.96
	After Standardization	0.99	0.98	0.93 to 0.99
Arm (right anterior)	Before Standardization	0.94	0.91	0.88 to 0.95
	After Standardization	0.97	0.94	0.91 to 0.96
Arm (left anterior)	Before Standardization	0.94	0.91	0.88 to 0.94
	After Standardization	0.95	0.94	0.92 to 0.95
Thighs	Before Standardization	0.95	0.92	0.89 to 0.94
	After Standardization	0.97	0.96	0.93 to 0.98
Lower legs	Before Standardization	0.91	0.90	0.87 to 0.92
	After Standardization	0.95	0.92	0.89 to 0.95
Dorsal feet	Before Standardization	0.93	0.92	0.90 to 0.94
	After Standardization	0.96	0.94	0.91 to 0.96
Planar feet	Before Standardization	0.96	0.93	0.91 to 0.95
	After Standardization	0.99	0.97	0.95 to 0.98

3. Discussion

The current approach using templates of ROIs warp models when compared with the usage of other warp methods [8] produces equivalent results, presenting minimal processing time and complexity. This approach is valid for models that are similar to the masks used to position the subject, the camera distance from the target and for scaling transformations that do not exceed 10%, according to the obtained results. When these conditions are not verified, the error will increase exponentially, therefore decreasing the applicability of the method.

This method is suitable for all regional views of the human body and can be used to other medical imaging modalities as well. The outcomes are of great importance for projects involving reference databases [4] and to have layers of different modalities of the same anatomical area. The negative aspect of this approach is that the time consuming in adjusting the overlay control points to the correct location, which as to be performed manually. The described solution or similar may be included in future developments of medical thermal imaging analysis software packages enhancing the standardisation of the analysis.

4. Conclusion

The proposed method is fast, computationally cheap and accurate, allowing careful analysis and repeatability of all ROIs of regional views of the human body. Comparison and averaging of images is possible after standardizing the images. An initial guess or automatic discovery of the anatomical control points that delimit the ROIs models using intelligent methods of contour following is suggested as further investigation for improving this proposal.

This approach enables the standardization of medical thermal images from different ROIs of the human body, which when stored in a database in a large number can become an important medical reference for either healthy and pathological situations, allowing image operations such as comparison, averaging or subtraction.

ACKNOWLEDGMENT

This research is sponsored by FEDER funds through the program COMPETE - Programa Operacional Factores de Competitividade and by national funds through FCT-Fundação para a Ciência e a Tecnologia, under the Project "AAL4ALL - Padrão de Cuidados Primários para Serviços de AAL" (FCOMP-01-0124-FEDER-13852) co-financed by FEDER, Programa Operacional Factores de Competitividade.

REFERENCES

[1] Ring E.F.J., Ammer K., "Infrared thermal imaging in medicine". Physiological measurement, vol. 33.3, pp. R33, 2012.

[2] Vardasca R., Simoes R., "Current Issues in Medical Thermography", in Topics in Medical Image Processing and Computational Vision, Tavares J. M. R. S. and Jorge R. M. N. (Eds.), Springer Netherlands, pp. 223–237, 2013.

[3] Schwartz R.G., "Guidelines for Neuromusculoskeletal Thermography". Thermology International, vol. 16, pp 5-9, 2006.

[4] Ammer K., "Standard Procedures for Recording and Evaluation of Thermal Images of the Human Body: The Glamorgan Protocol". Thermology International, vol. 18, pp. 125-144, 2008.

http://dx.doi.org/10.21611/qirt.2014.089

[5] Ring E.F.J., Ammer K., Wiecek B., Plassmann P., “Technical challenges for the construction of a medical IR digital image database”. Proc. SPIE, Detectors and Associated Signal Processing II, Chatard J.P. and Dennis P.N.J. (Eds.), vol. 5964, pp. 191-198, 2005.

[6] Vardasca R., Bajwa U., “Impact of Noise Removal Techniques on Measurement in Medical Thermal Images”. Thermology International, vol. 18, pp. 153, 2008.

[7] Bajwa U., Vardasca R., Ring E.F.J., Plassmann P., “Comparison of boundary detection techniques to improve image analysis in medical thermography”. The Imaging Science Journal, vol. 58, pp. 12-19, 2010.

[8] Vardasca R., “Template Based Alignment and Interpolation Methods Comparison of Regions of Interest in Thermal Images”. In proceedings of the 3rd Research Student Workshop, Faculty of Advanced Technology, University of Glamorgan (UK), pp. 21-24, 2008.

[9] Gomes J., Darsa L., Costa B. and Velho L. “Warping and Morphing of Graphical Objects”. Morgan Kaufmann, San Francisco, California, 1999.

[10] Plassmann P. Murawski P., “CTHERM for standardized thermography, Thermology International”, vol. 13, pp. 79, 2003.

[11] Rase W.D., “Volume-preserving interpolation of a smooth surface from polygon-related data”. Journal of Geographic Systems, vol. 3, pp. 199-213, 2001.

[12] Hormann K., “Barycentric coordinates for arbitrary polygons in the plane”. Technical Report, Clausthal University of Technology, Clausthal-Zellerfeld, Lower Saxony (Germany), 2004.

[13] Meyer M., Barr A., Lee H., Desbrun M., “Generalized barycentric coordinates on irregular polygons”. Journal of graphics tools, vol. 7, pp. 13-22, 2002.