Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

Overlay of thermal and visual medical images using skin detection and image registration

Gerald Schaefer, Roger Tait and Shao Ying Zhu

Abstract— **Thermography captures the temperature distribution of the human skin and is employed in various medical applications. Often it is useful to cross-reference the resulting thermograms with visual images of the patient, either to see which part of the anatomy is affected by a certain disease or to judge the efficacy of the treatment. An attractive approach to provide this information is to overlay the two image types and show a composite image to the clinician. Producing such an overlay however is a non-trivial task due to differences in image capturing conditions of the two modalities. In this paper we introduce an approach that produces accurate overlays of thermal and visual medical images. First unnecessary background information of the visual part are removed by an image segmentation step based on skin detection. The thermal image is then aligned through an intensity based image registration technique. Experimental results based on an set of visual-thermal image pairs demonstrate the effectiveness of the proposed approach.**
Keywords: infrared imaging, thermal imaging, thermography, image registration, skin detection

I. INTRODUCTION

Advances in camera technologies and reduced equipment costs have lead to an increased interest in the application of infrared imaging in the medical fields [3]. Medical infrared imaging uses a camera with sensitivities in the infrared to provide a picture of the temperature distribution of the human body or parts thereof. It is a non-invasive, radiation-free technique that can also be used in combination with anatomical investigations based on x-rays and three-dimensional scanning techniques such as CT and MRI and often reveals problems when the anatomy is otherwise normal. It is well known that the radiance from human skin is an exponential function of the surface temperature which in turn is influenced by the level of blood perfusion in the skin. Thermal imaging is hence well suited to pick up changes in blood perfusion which might occur due to inflammation, angiogenesis or other causes. Asymmetrical temperature distributions as well as the presence of hot and cold spots are known to be strong indicators of an underlying dysfunction [8]. Computerised image processing and pattern recognition techniques have been used in acquiring and evaluating medical thermal images [5], [9] and proved to be important tools for clinical diagnostics.

Often visual and infrared images of the patient are taken to relate inflamed skin areas to the human anatomy which is useful for medial diagnosis as well as for assessing the efficacy of any treatment. Currently this process requires great expertise and is subject to the individual clinician's ability to mentally map the two distinctly different images. Therefore an overlay of the two image types resulting in a composite image which makes it possible to cross-reference regions with unusual temperature distributions to the human anatomy will provide a useful tool for improved medical diagnosis. In this paper we introduce an approach for automatically generating such overlay images.

In an earlier work [7] we have covered a first approach to the automatic alignment of visual and thermal medical images based on image registration. However, that method required the visual image be segmented into foreground (i.e. the patient) and background which was typically performed manually with an image processing toolkit and took considerable time to do. In this paper that first step is completely removed. Based on a skin detection model, areas corresponding to skin regions and hence to the patient are automatically identified and serve as the basis of the segmentation step. Once the images are segmented (the infrared image usually does not require any pre-processing as the background in lab setting is typically much cooler compared to body temperature) the two images need to be aligned geometrically, a task that is non-trivial due to differences in capturing conditions (perspective, sensor size, captured region, etc.) of the two modalities. An intensity-based image registration which transforms one of the images based on translation, rotation and scaling operations is employed to perform the alignment. The resulting images are then visually placed on top of each other to form a composite image that can be presented to the clinician. Based on a set of thermal and visual image pairs the usefulness of the presented approach is demonstrated.

The rest of the paper is organised as follows: The next section explains the segmentation procedure based on skin detection that is applied to the visual image. The image registration step is detailed in Section III while Section IV describes how the composite image is generated. Section V provides some experimental results and Section VI concludes the paper.

II. SKIN DETECTION BASED SEGMENTATION

As the overlay is achieved through application of an intensity based image registration algorithm as will be explained in the next section and as the background of thermal images taken in a temperature controlled lab is typically in stark contrast to the patient's body heat the same contrast must

G. Schaefer and R. Tait are with the School of Computing and Informatics, Nottingham Trent University, Nottingham, United Kingdom, `Gerald.Schaefer@ntu.ac.uk`, `Roger.Tait@students.ntu.ac.uk`

S.Y. Zhu is with Applied Computing, University of Derby, Derby, United Kingdom, `S.Y.Zhu@derby.ac.uk`

be achieved for the visual image. That is, the background needs to be separated from the foreground (i.e. the patient). In our approach we make use of the fact that thermal imaging picks up the skin temperature and hence employ a skin detection technique on the visual image. We adopt, with some variations, a computationally simple method introduced in [1] which is based on the fact that the hues of human skin occupy only a small region in colour space. The algorithm which operates on the visual (RGB) image proceeds in the following steps:

Step 1: The R, G, and B values at each pixel are transformed into a log-opponent colour representation by

$$\begin{pmatrix} I \\ R_g \\ B_y \end{pmatrix} = \begin{pmatrix} L(G) \\ L(R) - L(G) \\ L(B) - \frac{L(G)-L(R)}{2} \end{pmatrix} \quad (1)$$

with

$$L(C) = 105 \log_{10}(C + 1 + n) \qquad C = \{R, G, B\} \quad (2)$$

where n represents some random noise (in the range $(0; 1)$) to prevent banding artefacts in dark regions.

Step 2: A measure of texture amplitude T is then derived from the intensity channel by building a difference image of the original image and a median filtered version of it. The resulting texture channel is then again median filtered as are the chromaticity components (at a finer scale compared to the texture channel).

Step 3: Next, hue H and saturation S are calculated as

$$H = \tan^{-1}\left(\frac{R_g}{B_y}\right)$$
$$S = \sqrt{R_g^2 + B_y^2} \quad (3)$$

Step 4: Pixels that fall within a certain hue-saturation range and do not exceed a texture threshold are identified. In particular, all pixels that fall within

$$\{T < 5 \text{ and } 110 < H < 155 \text{ and } 5 < S < 60\}$$

or

$$\{T < 5 \text{ and } 130 < H < 170 \text{ and } 30 < S < 130\}$$

are marked as skin pixels.

Step 5: Using morphological operations holes are filled and edges smoothed to provide the final output of the skin detector.

III. IMAGE REGISTRATION

Using the detector described above regions in the visual image are identified that correspond to skin colours and hence to the patient. Non-skin areas are removed by setting their pixel values to 0 (black). In the thermal images patients are usually well separated from the background in controlled lab conditions so little pre-processing need to be applied. If necessary, an adaptive thresholding algorithm can be applied to improve the separation of patient and non-patient areas.

Once both image types have been prepared, an image registration process is initiated. Registration is a method used to geometrically align two images taken from different sensors, viewpoints or instances in time [10]. In the medical field, registration is often used to monitor growth, verify the effects of treatment and make comparisons of patient data with anatomically normal subjects [4]. In the application presented here we employ registration to align two images of different modalities: visual and thermal.

In registration algorithms a reference (fixed) and a sensed (moving) image are often aligned through a combination of scaling, translation and rotation, i.e. through an affine transform which is also the type of transform that we employ in our approach. Registration techniques can typically be classified as either intensity or landmark-based. Both techniques have advantages and disadvantages in their own unique approach. The main difficulty of landmark-based algorithms is the need to identify a set of corresponding control points in both images based upon which the best matching transform is sought. Landmarks can be found either manually or automatically. While manual selection of control points can be fairly time consuming and requires user interaction, automatic identification of landmarks constitutes a challenging problem and often requires a priori knowledge of the image features involved.

As we are interested in a fully automatic method that should be applicable on a wide range of different images (different patients, poses, etc.) we adopted an intensity-based approach to registering the two images. In intensity-based techniques all image information is utilised and the best alignment is derived as that which optimises a pre-defined similarity metric between the registered images. The steps involved are transform optimisation, image re-sampling and similarity computation which are applied in an iterative manner until the process has converged. We employ a gradient-decent optimiser, B-spline interpolation for the re-sampling and a mutual information measure as similarity metric; more details on the registration procedure can be found in [7]. If required, the workload can also be distributed through a parallel processing approach [7].

IV. OVERLAY GENERATION

Once an appropriate transform has been found and image registration performed (typically the visual image is selected as reference and the thermal one as sensed image), a composite image is created. This is simply performed by computing a weighted sum of the respective pixel values of the original visual image and the thresholded thermogram. Equal weights will generate an average of the two images whereas different weight factors will put more emphasis on one of the two modalities.

V. EXPERIMENTAL RESULTS

We have used a set of thermal-visual image pairs to evaluate our proposed method. Two examples are provided in Figures 1 and 2 each of which shows the original visual image, the thermogram, the visual image segmented based on

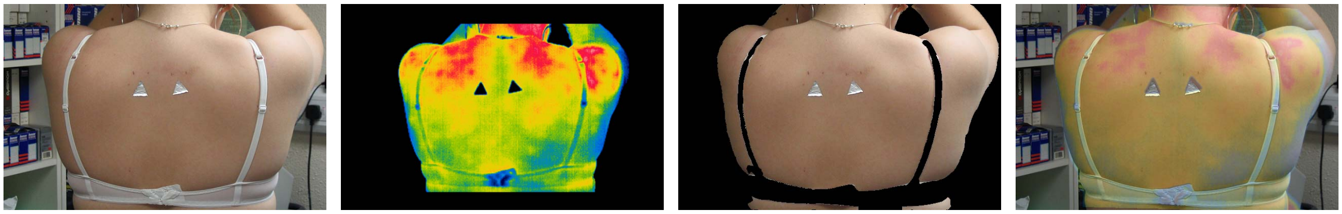

Fig. 1. Example 1 of thermal-visual overlay: Original visual image, thermogram, segmented visual image, composite image (from left to right).

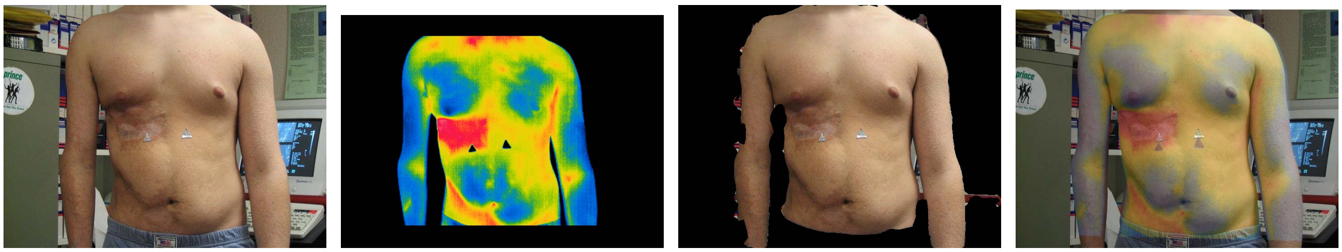

Fig. 2. Example 2 of thermal-visual overlay: Original visual image, thermogram, segmented visual image, composite image (from left to right).

the output of the skin detection step, and the final, overlaid image. In both cases, the final image was weighted as 80% visual and 20% thermal. As can be seen, in both cases an accurate overlay of the two image types is achieved.

The generated images are currently being used in the assessment of morphea (localised scleroderma) patients [2], [6]. In Figure 2 the warmer area of the chest overlay indicates the distribution of a morphea lesion.

VI. CONCLUSIONS

We have presented a fully automatic approach to the generation of composite thermal-visual images for medical diagnosis. Based on a visual image and a thermogram of the same patient an overlay of the two is created that allows to relate local thermal phenomena to the human anatomy. The visual image first undergoes a skin detection stage which identifies those areas that correspond to the patient and discards the remainder. An intensity-based image registration algorithm is then employed to align the thus segmented image with the thermogram, after which a weighted overlay of the two images is generated. A set of visual-thermal image pairs have been used to demonstrate the usefulness of the proposed approach.

ACKNOWLEDGEMENTS

This work was supported by the Nuffield Foundation under grant number NAL/00734/G.

REFERENCES

[1] M.M. Fleck, D.A. Forsyth, and C. Bregler. Finding naked people. In *4th European Conference on Computer Vision*, pages II:593–602, 1996.

[2] K. Howell, M. Visentin, A. Lavorato, C.D. Jones, G. Martini, R.E. Smith, C.P. Denton, F. Zulian, C.M. Black, J.I. Harper, and P. Woo. Thermography, photography, laser doppler flowmetry and 20 mhz b-scan ultrasound for the assessment of localised scleroderma activity: A pilot protocol. *Thermology International*, 14(4):144–145, 2004. abstract.

[3] B.F. Jones. A reappraisal of infrared thermal image analysis for medicine. *IEEE Trans. Medical Imaging*, 17(6):1019–1027, 1998.

[4] J.B.A. Maintz and A. Viergever. A survey of medical image registration. *Medical Image Analysis*, 2:1–36, 1998.

[5] P. Plassmann and E.F.J. Ring. An open system for the acquisition and evaluation of medical thermological images. *European Journal of Thermology*, 7:216–220, October 1997.

[6] G. Schaefer, R.J. Tait, K. Howell, and A.A. Hopgood. Automated overlay of visual and thermal images for the assessment of morphea patients. *Thermology International*, 15(4):157, 2005. abstract.

[7] R.J. Tait, G. Schaefer, K. Howell, A.A. Hopgood, P. Woo, and J. Harper. Automated overlay of visual and thermal medical images. In *Int. Biosignal Conference*, 2006.

[8] S. Uematsu. Symmetry of skin temperature comparing one side of the body to the other. *Thermology*, 1(1):4–7, 1985.

[9] B. Wiecek, S. Zwolenik, A. Jung, and J. Zuber. Advanced thermal, visual and radiological image processing for clinical diagnostics. In *21st IEEE Int. Conference on Engineering in Medicine and Biology*, 1999.

[10] J. Zitova, B. anf Flusser. Image registration methods: a survey. *Image and Vision Computing*, 21:977–1000, 2003.