Template Based Alignment and Interpolation Methods Comparison of Region of Interest in Thermal Images

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Abstract—**Clinicians often have to compare two or more medical images with each other. Usually it is not the entire image that is important but only particular regions of interest (ROIs). In order to simplify the comparison and to reduce a source of human error a new approach for semi-automatically aligning ROIs is proposed. Using thermal (infrared) images as an example this paper builds on the author's previous work on automatically producing contour outlines of ROIs by applying noise removal and edge detection techniques.**
This study uses the outcome of the previous work to produce an initial and approximate ROI template shape from one of the images. This template shape is displayed as an overlay onto the second image together with control points which the user can manually move into new positions that match the contours of the second image. Using this shift of the control points the second image can then be transformed (morphed) into the same outline shape as the first image.
It is the aim of this work to compare the results of applying three different interpolation methods commonly used for scaling and transforming images. The measures used for comparison are the changes of temperature mean and standard deviation in the ROIs resulting from transformation. Results show that the change in mean temperature is less than 0.5ºC in the worst case and 0.2ºC in the best (Nearest Neighbour algorithm).

Index Terms—**Aligning, Interpolation methods, ROI, Templates, Thermal Images**

I. Introduction

MEDICAL images are one of the most frequently used auxiliary diagnostic modalities and the comparison of images is a routine task for many clinicians. Images are, however, often taken at different angles, sizes or scales which makes a direct comparison difficult and prone to errors. A computerised alignment system could therefore improve the quality of analysis, reduce a cause of human error, save time and contribute to a standardisation of procedures [1].

A proposed solution to accomplish this goal would be a semi-automatic tool with quality assurance combining the most suitable techniques for noise removal, edge detection, anatomical control point determination in an image alignment algorithm together with the best interpolation method.

Infrared medical imaging is an objective screening method for assessing injuries and pathologies states that influence the peripheral temperature of the human body. It is a highly accurate technique, 100% safe and does not involve contact with the patient or radiation [2].

Thermal images are captured following a standard protocol [3,4] that also defines the usage of template shapes or Regions of Interest (ROIs) which are overlayed onto the life video feed from the thermal camera. These overlay outlines help to position the patient in well defined and repeatable positions. In spite of this process patients can never be brought exactly into the correct position and body shapes between patients can also be significantly different. As a result images are hardly ever perfectly aligned.

Image interpolation is a method of constructing new data points (i.e. pixels) in a digital image within the range of a discrete set of known data points (other pixels) by calculating a new point between two existing data points [5]. In this paper three frequently used and well documented interpolation techniques will be tested with respect to the errors they introduce into the altered images. These methods are:

- Nearest Neighbourhood interpolation is a simple method that consists of a new pixel receiving the value of the "brightest" pixel (the one with the highest value), typically in a 2x2 pixel neighbourhood. It is a very fast method but is known to generate errors [6].
- The Bilinear interpolation method calculates the median value, again typically of a 2x2 neighbourhood and assign this median to the new pixel. This algorithm results in a visually smoother image than the previous one [6].
- Bi-cubic interpolation considers a 4x4 neighbourhood with 16 pixels. Due to the size of the neighbourhood these pixels are not all located at the same distance from the one pixel to be interpolated. Consequently closer pixels are given a higher weighting in the calculation of the average value of the new pixel. This method produces noticeably sharper images than the previous two methods. It is widely used as a standard in commercial applications for image editing [6].

In this paper some of the following image processing techniques will be referred to:

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- Median Filtering is a non-linear digital filtering technique, often used to remove noise from images. It is particularly useful to reduce so called 'speckle' noise and 'salt and pepper' noise. In typical applications the filter sorts pixels in an odd sized input window (usually square, i.e. 3x3, 5x5 etc.) by value and then assigns the middle value in the sorted list (e.g. in a 3x3 window with 9 pixels this would be position 5) to the pixel in the middle of the window [7].

- Gaussian blurring is an image filter technique that convolves the image with a Gaussian (or normal) distribution. It is in effect a low pass filter, smoothing the image. It thus reduces image noise but also the amount of detail. It is therefore used mainly as a pre-processor in computer vision algorithms in order to enhance underlying image structures [8] but not directly for producing images for presentation.

- Canny edge detection is a probabilistic method. It aims to identify an 'true' edges by localising edges with little contrast or smooth transitions, thus avoiding the production of false edges. The detector starts by suppressing noise in the image using the first derivative of a Gaussian as a pre-filter. In order to then find edges and their directions it determines the intensity gradient of the currently processed region by suppressing non-maximum gradients and using a hysteresis threshold. It finally uses a differential edge detection technique. The Canny edge detector can be adjusted bt changing parameters such as the size of the Gaussian filter and the low and high hysteresis thresholds for gradient intensity that define an edge [9].

- Thinning is a geometrical transformation of a digital image into another topological equivalent simplified image [10]. Broadly speaking it produces a line of 1 pixel thickness from wider lines or regions.

II. Materials and Methods

This work follows a previous study aimed at determining the most reliable edge detector operator for medical thermal images [11].

From the author's database of thermal images 20 faces imaged in full anterior (frontal) view are used in this study. The facial anterior view is selected here because it is the region of the human anatomy with the highest variations in temperature. This makes facial images 'worst cases' for the tests described in the following sections. Tests and visualisations are coded in the C# programming language under Microsoft Visual Studio .Net 2005 (see Fig. 1). The application reads the CTHERM thermal image file format [12] and converts it into a standard bitmap (BMP). Once opened a new file is initially subjected to a median noise removal filter followed by a Gaussian blur operation to minimise noise. A Canny edge detection operator is then executed over the now noiseless image to discover the face outline. In order to improve the visual appearance of the outline it is subjected to a thinning transformation. This also removes artefacts such a short erroneous edges.

In order to facilitate the transformation of the image into a standard sized image the already mentioned standard image capture overlay template outline is displayed over the original unprocessed image. In a reversal of its original purpose (i.e. moving the patient so that he/she aligns with the template) the template shape is in this case moved to align with the patient's image. This is achieved by calculating the centres of mass for both the template shape and the outline resulting from the filtering process described above. This results in an image showing the thermal image with its outline together with the template outline. The program now has to transform the current shape of the face into the target shape given by the template outline. This is achieved by using a number of control points located along the perimeters of both outlines. These control points are automatically positioned by using the coordinate system produced by the respective two main axes of the outlines (a horizontal and a vertical line with their origins at the centres of mass of the outlines) as a reference. This process works well at smooth sections of the outline but may require user intervention at sharp discontinuities such as the ear lobes.

The scaling or morphing process used in this work is a method that uses the control points in both the template shape and the facial outline shape as anchors. Pixels located exactly at the position of a facial outline are moved to the respective position of the control point in the template. All other pixels are moved proportionally dependent on their relative positions with respect to the control points. Any gaps in between pixels that are produced by this moving process are closed in turn by the three interpolation methods mentioned earlier.

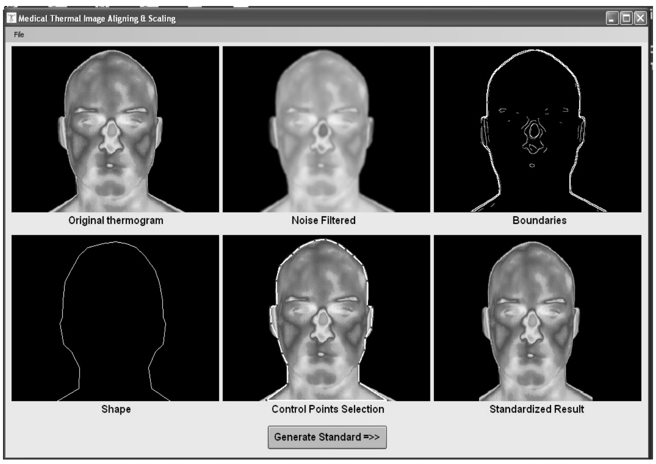

Fig. 1: C# Application to load and process thermal images. From upper left to lower right: source image, filtered image, Canny edge detector, thinning, control points selected, final 'morphed' result.

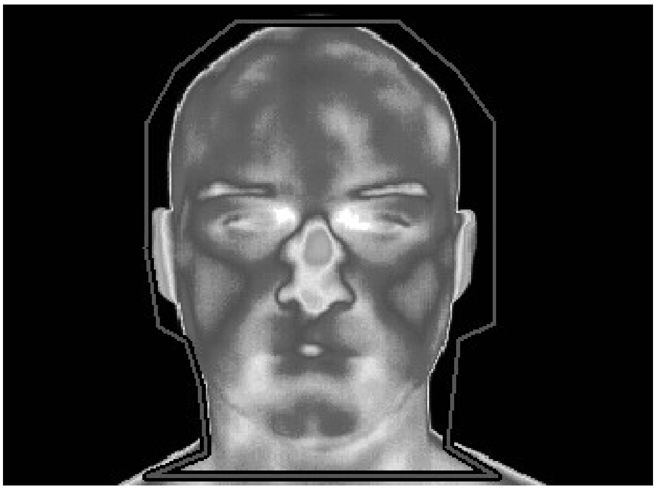

Fig. 2: One of 20 source images together with the region of interest within which mean and standard deviation are calculated.

To assess the performance of the three interpolation methods all result images are imported back into the CTHERM software package [12]. The CTHERM tool for calculating the temperature mean and standard deviation of the faces area is then used as shown in figures 2, 3, 4 ad 5. Visually, the difference between images is hardly noticeable at all but by calculating the difference between the figures obtained from the original image and the three interpolated images the “best” algorithm can be identified.

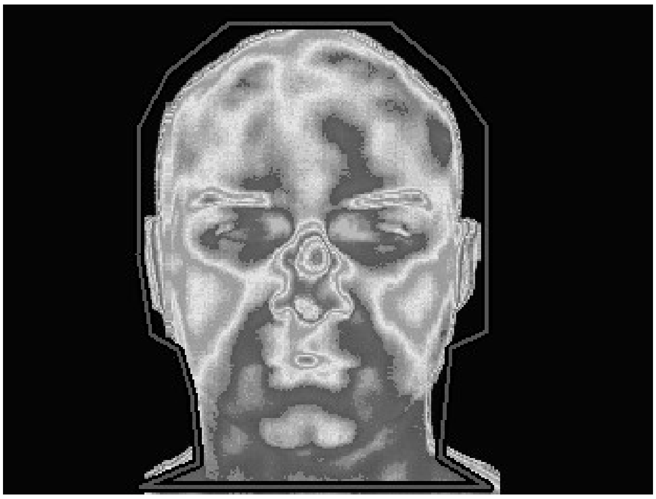

Fig. 3: Result of Nearest Neighbourhood interpolation

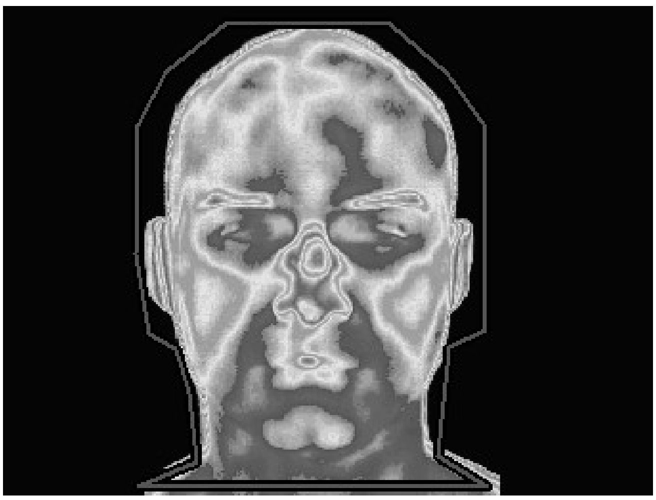

Fig. 4: Result of Bilinear interpolation

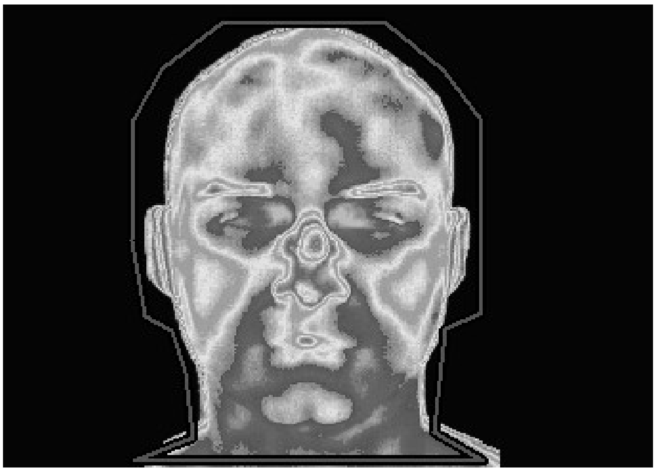

Fig. 5: Result of Bi-cubic interpolation

III. Results

The average of the mean temperature values obtained from measuring on the original 20 images was 30.21 ℃ with the warmest and coldest faces varying by ± 4.28 ℃ receptively. After adding interpolation pixels by the Nearest Neighbourhood algorithm this mean temperature was 30 ℃ ± 3.25 ℃. For Bilinear interpolation the mean was 29.95 ℃, ± 3.28 ℃ and for the Bi-cubic process a mean of 29.72 ℃ ± 3.60 ℃ was found. These results are illustrated in figure 6. The performance of the algorithms with respect to standard deviation are shown in figure 7.

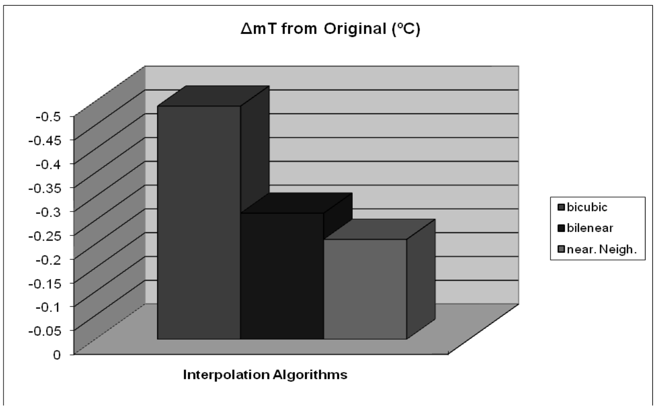

Fig. 6: Difference in mean temperature between the original and the results of interpolation methods

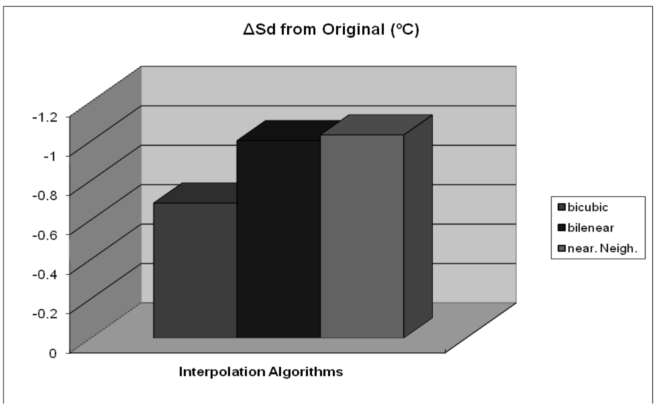

Fig. 7: Difference in standard deviation between the original and the result of interpolation methods

The results of the measurements of the four different types of images of the 20 samples were analysed in the SPSS statistical package software. After running a Student t-test with a 95% confidence interval (approx. two standard deviations) between all pairings of the three interpolation method results it can be concluded that the pairs Bi-cubic / Bilinear and Bi-cubic / Nearest Neighbourhood are not correlated, as they exhibit a significant difference with $p<0.05$. For the Bilinear / Nearest Neighbourhood pairing results are inconclusive with $p>0.05$.

The results of the three methods were also subjected to a Kendal correlation coefficient test which showed as expected a significant correlation of the data sets (assuming that the results are directly related) with $p<0.05$.

The Friedman correlation coefficient test finally demonstrated statistical evidence that the results of the three applications are indeed significantly different ($p>0.05$) and not produced by random factors such as the selection of the source face images.

IV. Discussion

A previous study by the author demonstrated that the use of a median filter in conjunction with with subsequent Gaussian blurring is in the type of images used here superior to homomorphic filters usually recommended for this type of application [11]. An additional advantage of this process is the simplicity of its implementation.

The findings of this study contradict the results of other studies on non-thermal digital images [6, 12], which recommend the use of algorithms based on Bi-cubic interpolation. This is probably caused by the fact that on these other studies the aim was to re-size images whereas in this study the aim is to fill gaps produced by morphing processes.

V. Conclusion

Medical thermal images are based on temperature measurements of the human body's surface. If scaling is needed to facilitate interpretation and comparison between sets of images an interpolation method will be needed that fills any gaps arising from the scaling or morphing process. This process should introduce as little error as possible.

According to the results shown by this study the recommended interpolation method for scaling medical thermal images produced by following the standard capture protocol [3, 4] is that using the Nearest Neighbourhood operation.

VI. Future Work

Subsequent research work will involve a detailed study on image scaling / morphing methods to test if alternative methods to the one used here may produce improved results. The outcome of this work will then enable the author to build a database of 'normals', i.e. a collection of images taken from normal healthy volunteers. These images will all be aligned to the same shape and superimposed on top of each other to produce a benchmark of normal temperature distribution of the human body. Such a benchmark including the normally to be expected deviations from the norm will allow clinicians to identify pathological deviations more easily and reliably.

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