

Toward the Detection of Overlapping Body Parts in Infrared Images

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INTRODUCTION

Diseases such as arthritis cause inflammation of the tissues around the joints. Typically, patient consultation relies on the doctor's qualitative physical assessment to determine disease progression and treatment effectiveness. Although Magnetic Resonance Imaging (MRI) could provide useful diagnostic images to monitor disease progression, cost and long waiting lists limit its use. Infrared (IR) cameras can produce images of temperature distributions on the human body, which can then be used as indicators of pain [1] [2] that could be used as an alternative for early quantitative diagnosis of arthritis.

However, for such a system to be effective, automatic segmentation of the medical IR images into regions of interest (ROI) is desirable. Unfortunately, overlapping body parts can obscure key features or parts of the contours associated with the ROIs, preventing automatic segmentation. The work presented here describes a system, which can automatically detect overlapping limbs in diverse medical images. The algorithm reliably tags images where overlap occurs in order to prevent erroneous medical interpretation.

Although textbooks have already been written describing segmentation of visual images [3], the low resolution and contrast typically associated with IR images makes these former algorithms unsuited to IR segmentation. However, the following four papers are concerned with medical imaging applications [4][5][6][7].

Herry et al. [4] segmented approximately 1000 IR images of hands and upper forearms using Canny edge detection [8]. Unwanted edges were removed according to their eccentricity, proximity to the edge of the image and length of edges.

Selvarasu et al. [5] segmented IR images of legs using a region growing algorithm where the seed pixel had the median value of the ROI. A difference threshold was used to determine whether adjacent pixels belonged to the ROI.

Yoon et al. [6] segmented IR images of forearms using a temperature threshold to obtain a binary image. They used a thinning algorithm to reduce the hand and forearm to a skeleton. A vertical line profile was used to locate the position of the wrist (at the valley point), which allowed separate segmentation of the forearm from the hand.

Ng et al. [7] segmented IR images of breasts using the Roberts cross-gradient operator to find a preliminary ROI. A combination of contrast stretching and median filtering was used to enhance the gradient image.

However, these algorithms were only tested on one subpart of the human anatomy. The aim of the work undertaken here is to achieve a general solution to detection of overlapping body parts in any region of the body.

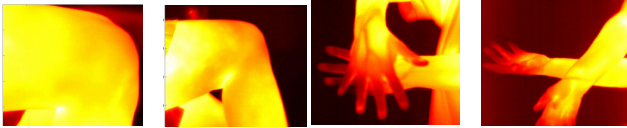
In addition to the medical imaging field, there has been research into IR segmentation for a wide range of applications. For example, multiresolution approaches have been used for military and surveillance applications e.g. [10][11][12]. Therefore, the work presented below also gives some consideration to multiresolution techniques applied to the overlapping body problem.

Section I describes a system which addresses the overlapping body problem. Section II provides experimental results. Section III compares some of the techniques considered and section IV discusses future work.

I. OVERLAPPING BODY SYSTEM

Detection

Four different images of overlapping limbs were used during the system development and subsequent experiments. These images can be seen in figure 1 below.



(a) Knees (b) Legs (c) Hands (d) Arms

Fig. 1 Images used in the system development and during experiments

The diagram in Fig. 2 shows the initial framework developed to detect overlapping body parts. The labels A to I in Fig. 2 correspond to the images in Fig. 3, which illustrates the outputs of the system using the IR image of 'legs' as an example. As can be seen, first of all, the image has a temperature threshold applied to it (A). The next stage involves finding the binary image by applying Otsu's thresholding method to the temperature thresholded image. Median filtering of the resulting binary image is carried out using a 3x3 matrix (B). The perimeter of the binary image is then found and dilated with a disk structuring element of size six (C). At the same time, Canny edge detection is used to find the edges in the IR image (D). The edges that fall outside the binary image ROI are discarded (E). Bridging is carried out between the remaining edges (F). The edges then undergo a morphological closing operation using a line structuring element of length 15 pixels that is oriented in the same direction as the edge being closed. The perimeter is formed from the outer edge of the binary image. Only edges that touch the perimeter of the binary image are kept, all others being discarded as not being associated with the overlapped region (G). Using a region growing algorithm, the ROIs are filled (H). The two regions that appear in this example indicate overlapping body parts. The perimeters of each ROI are found in order to allow an accurate way of observing the overlapped parts of the image (I).

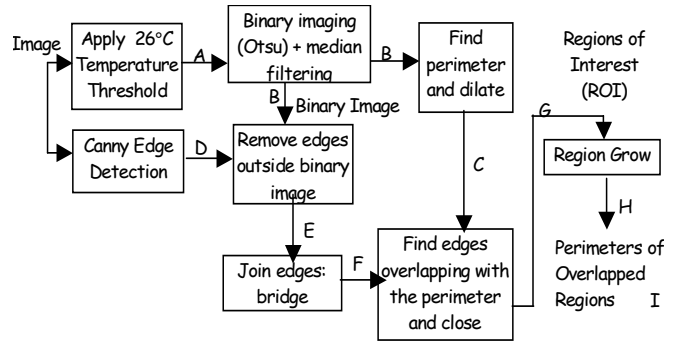


Fig. 2 System used to detect overlapping body parts

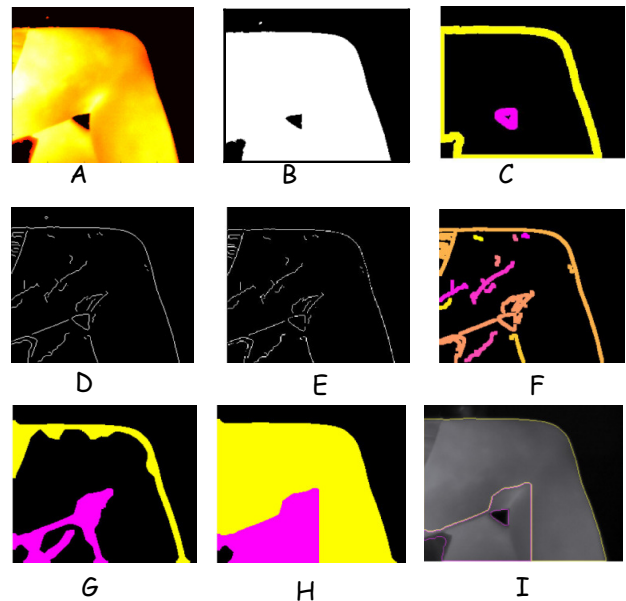


Fig. 3 Outputs from each part of the system in Fig. 2

Classification

A separate hand/arm detector was developed to supplement the system, as shown in Fig. 4. Firstly, the vertical profile is obtained by summing the binary values in each row of the binary image (B in Fig. 2) and the horizontal profile involves summing the binary values in each column in the binary image. The profiles are then smoothed by low pass filtering. By taking the first-order derivatives of the smoothed profiles, it is experimentally observed that the zero-crossing count is significantly higher for overlapped hands or arms, as compared with legs or knees. Therefore, if the zero-crossing count is found to be ≥ 6 in both the horizontal and vertical directions, the image is considered to include either overlapping hands or arms.

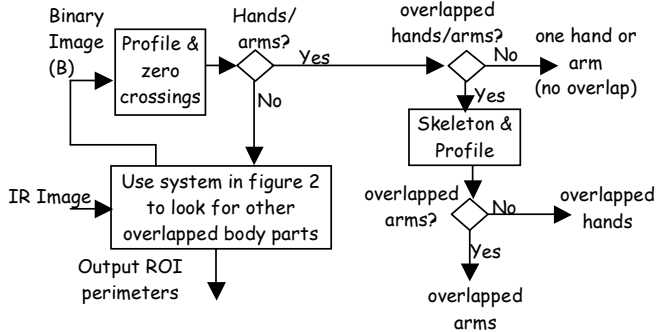
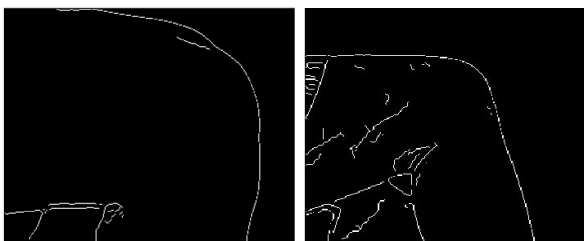


Fig. 4 Overlapping body part detector system with hand/arm detector

Once overlapping hands/arms are detected, it is possible to determine if they are overlapped hands or arms and where the overlap occurs in the image with more precision. The skeleton of the image is obtained by using a thinning algorithm. If the skeleton contains two pairs of branches which are connected by a single line, the area where the skeleton has reduced to a single line must represent the overlapped arm region. This is because the arms only fuse together in the image in the region of overlap. However, if there is no single line in the skeleton, then only the hands are overlapping, not the arms.

II. RESULTS

The Canny edge detection gave the results shown in Fig. 5 after the edges outside the binary image ROI have been removed (cf. E in Fig. 2). As can be seen, the overlapping edges of the body parts can clearly be observed in both Canny edge results.



(a) Knees (b) Legs

Fig. 5 Canny edge detection results

The edges remaining, after elimination of those that did not touch the dilated perimeter of the binary image ROIs, are shown in Fig. 6, where the different shades represent separate edges. These are the edges of interest with respect to overlapping body identification.

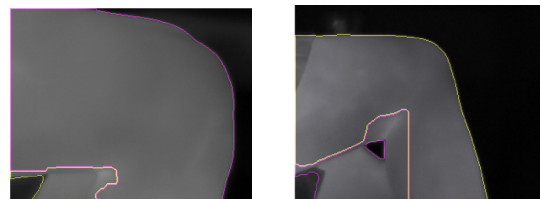
These edges have already been subjected to the morphological operations of bridging and closing.



(a) Knees (b) Legs

Fig. 6 Edges of interest

The knees and legs results in Fig. 7a and b show different edges for regions where body parts are overlapping. The perimeters of the overlapping region grown areas are shown in Fig. 7 for the knees and legs images.



(a) Knees (b) Legs

Fig. 7 Overlapping regions' perimeters

The results for the hand/arm detector on the arms image (Fig. 1d) can be seen in Fig. 8. This skeleton was obtained with a temperature threshold of 24°C.

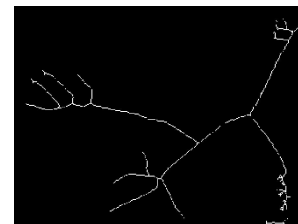


Fig. 8 Skeleton of crossed "arms" image

III. COMPARISON OF TECHNIQUES

This section discusses other techniques that were applied to the overlapping body problem.

The JSEG algorithm [13] has been applied very successfully to perform unsupervised segmentation of colour texture regions in optical images. Figure 9 shows the results of applying JSEG to the knees image.

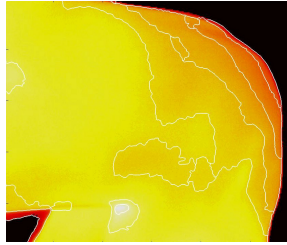


Fig. 9 JSEG applied to the knees image

Whilst the segmentation has done a good job of segmenting ROIs with different temperature distributions, it has failed to segment the overlapped body area. The reason for this is that the temperatures of the adjacent overlapped leg regions are almost identical.

The works of [10][11][12] suggest that multiresolution processing could be an effective approach to apply to the overlapping body problem. Therefore, figure 10 gives an example, where the wavelet Le Gall (5,3) has been applied to the legs image to one level of decomposition. The detailed coefficients have been inverse transformed to give the image shown in figure 10. The figure shows that there are key edges missing from the image (compare with the labeled edges of figure 5(b)).

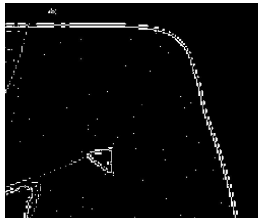


Fig. 10 Inverse detailed coefficients of the wavelet transform

IV. CONCLUSIONS

IR image segmentation is a necessary step to achieve an automatic IR diagnostic system for inflammatory diseases, such as arthritis. Overlapping body parts can cover parts of the contours associated with ROIs, thus causing problems during the segmentation process and later on with medical interpretation. This paper has described a system, which successfully detects different overlapping body parts in four IR images with superimposed arms, legs, hands and knees. Future work will: carry out experiments on a larger number of images, with a wider range of body poses, in order to test the robustness of the system.

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