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Multi-atlas based clavicle segmentation in chest image data

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Abstract – This contribution explores the capabilities of the multi-atlas based segmentation technique [1] to delineate clavicle bones in chest radiographs. The segmentation is carried out within 299 images which have been made available in [2] together with the corresponding ground truth for the clavicle bones (see Fig.1 left). The segmentation process is made difficult by the superposition of several anatomical structures, which is inherent in X-Ray data. Strong noise and artefacts caused by pathologies, objects (e.g., necklaces) and the image acquisition technique also contribute to rendering clavicle detection as a challenging task. In addition, the strongest edges are outside the image area relevant for clavicle segmentation (see Fig. 1 original images). In [3], a combination of different approaches (including classification-based methods and statistical appearance models) is applied sequentially. This work examines to what extent a uniform method can be contrived to solve the problem. We propose a three-stage registration method embedded within a multi-atlas approach.

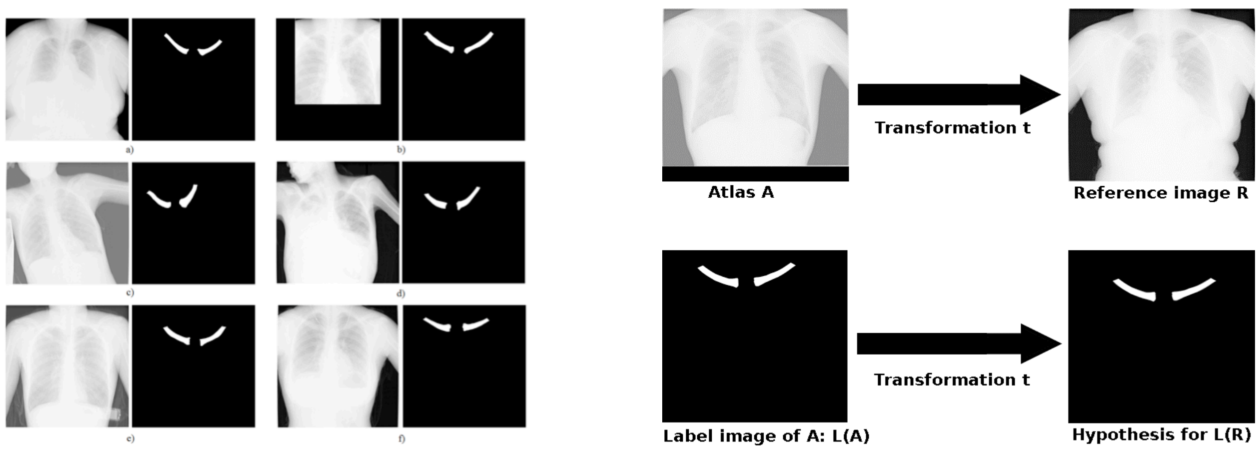

Fig.1: Left: Original images and corresponding ground truth for the clavicle bones. Right: The principle of atlas-based segmentation. After registration of the template image (atlas A) with the reference image R we obtain the transformation t. Subsequently, within the label propagation process, this transformation is applied to the ground truth image L(a), leading to the presumed position of the clavicle bones in the reference image R.

To segment a reference image, the remaining 298 images serve as atlases (template images). For each atlas, three registrations take place with the respective reference image. A schematic registration process [4] is illustrated in Fig.2 (left). A coarse localization of the clavicles is achieved by means of a first affine registration using the full template and the entire reference image. In order to transfer the clavicle ground truth, which has been manually annotated in the atlas, to the reference image, the transformation determined during registration is applied to the label image of the template (label propagation). This process is depicted schematically in Fig.1 (right). In the second stage, an additional affine registration is performed on a smaller region-of-interest (ROI) around the clavicles. The transformed label image of the first registration stage is used to determine the ROI. Finally, in the third stage, demons-based registration [5] also allows local, non-linear deformations. The resulting displacement field transforms the label image computed after the second stage and yields the final segmentation result for the atlas. In this way, a hypothetical segmentation of the clavicle bones is determined for the reference image by means of all atlas datasets. In order to merge the individual atlas segmentations, various label fusion methods were tested. In the unweighted variant, each propagated label is taken into account with the same weight (Fig.2 right). Alternatively, weighted (global or local) voting variants were contrived. The weight is determined for each atlas by means of the mutual information, which has been employed as registration metric.

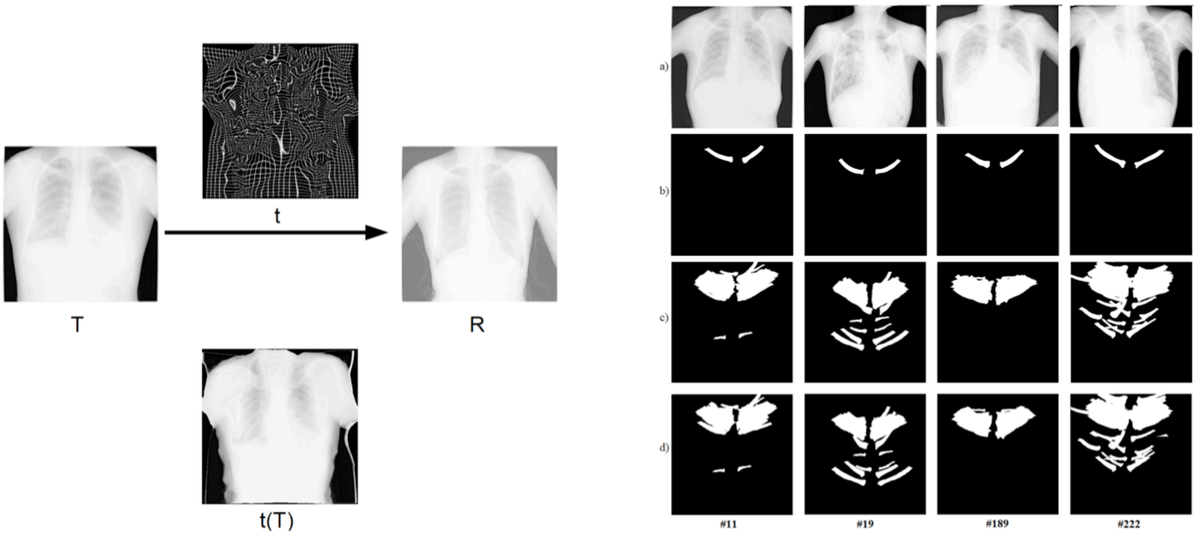

Fig.2: Left: Schematic representation of the registration process. Template image T (atlas) and reference image R are registered using mutual information as metric. The yielded transformation t leads to the transformed template image t(T). Right: Unweighted label propagation of atlas registrations. Original images in top row, corresponding ground truth for the clavicle bones in second row, propagated labels after first affine registration in third row, respectively propagated labels following the second affine registration in bottom row.

The best results were obtained by unweighted voting. Overall, the highest Dice Similarity Coefficient DSC = 0.79 ± 0.12 is yielded using a 35% voting score. In other words, a pixel in the reference image is considered to belong to the clavicle bone, if at least 35% of the 298 propagated atlas labels have voted accordingly. The mean DSC value of 79% demonstrates that the multi-atlas based segmentation technique can be successfully employed towards the localization of clavicle bones in chest X-Ray images. However, a subsequent fine-tuning will be required in order to precisely extract the bone contours.

References

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