

## Abstract

We propose a multi-atlas fusion framework to automatically segment the human pelvic structure from 45 or 135-degree oblique X-ray radiographic images. Unlike most atlas-based approach, this method combines a data set of a priori segmented X-ray images of the human pelvis (or multi-atlas) to generate an adaptive superpixel map in order to take efficiently into account both the imaging pose variability along with the inter-patient (bone) shape non-linear variability.

In addition, we propose a new label propagation or fusion step based on the variation of information criterion for integrating the multi-atlas information into the final consensus segmentation. We thoroughly evaluated the method on 30 manually segmented 45 or 135 degree oblique X-ray radiographic images data set by performing a leave-one-out study. Compared to the manual gold standard segmentations, the accuracy of our automatic segmentation approach is 85%.

## Introduction

X-Ray segmentation of bone structures in the pelvic region is both intrinsically and extrinsically difficult.

- Noise in X-Ray images has a number of origins
- Bone regions in X-Ray images often overlap with soft tissues and other bones.
- Neighbouring tissues inside human body may have similar X-Ray absorption rates.
- The boundaries of the organs may be ambiguous
- There is sometimes no clear edge between two neighbouring bone structures.
- The bone structures density variability, the inter-patient shape variability and the imaging pose variability.

To simplify and guide an automatic segmentation task, a priori anatomical information is essential and may be provided in defining and using a multi-atlas, i.e., a set of training segmented images (possibly with the set of their associated X-ray images).

We propose a segmentation approach based on the multi-atlas. The multi-atlas allows us to generate an adaptive superpixel map which is then exploited to efficiently take into account the non linear target-specific deformations and to comprise all the non-linear variability of the multi-atlas population.

## Method

### Data set and multi-atlas creation

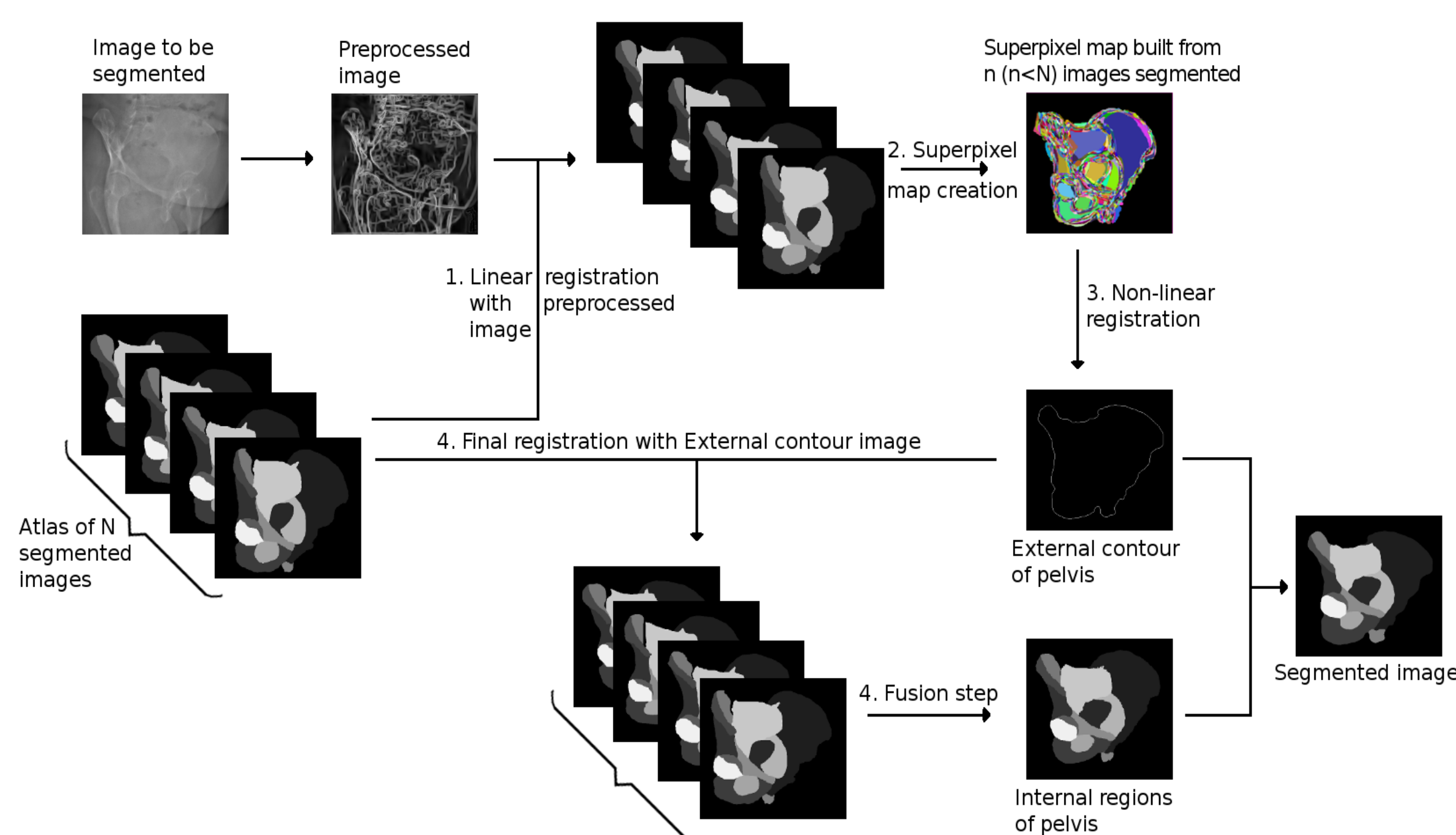
Anonymised 45 and 135 degree oblique X-ray radiographic images of the full pelvic bone from 31 patients without pelvic deformity were manually segmented into 14 different regions of interest (ROIs) by experts well trained in pelvic anatomy and medical image segmentation.

### X-ray image pre-processing

All the acquired X-Ray images to be segmented are firstly pre-processed with a histogram equalization technique and a DCT-based denoising step [1] to enhance the contour of the different bones of the human pelvis region. These contour cues will be then exploited in the contour-based registration step explained in the following section

### Proposed Multi-Atlas Fusion Procedure

1. Linear Registration and Multi-Atlas Selection Step
2. Superpixel Map Creation [2]
3. Non-Linear Registration From the Superpixel Map
4. Final Selection & Variation of Information based Fusion Step [3]



## Conclusion

A new multi-atlas based segmentation method is presented. Unlike most atlas-based approach, the proposed method includes the following contributions.

1. The multi-atlas data set allows us to generate an adaptive superpixel map which comprises all the non-linear variability of the multi-atlas population and allows us to take into account the non linear target-specific deformations of our multi-atlas based segmentation approach.
2. The similarity measure used in our registration step is used in an atlas selection strategy both for the registration step and for the label propagation fusion step, which is herein performed in the variation of information sense.
3. Our approach allows us to consider only the most informative and reliable visual cues in a X-Ray image of the pelvic region (i.e. the external bone contour and the internal region labels of the pelvis).

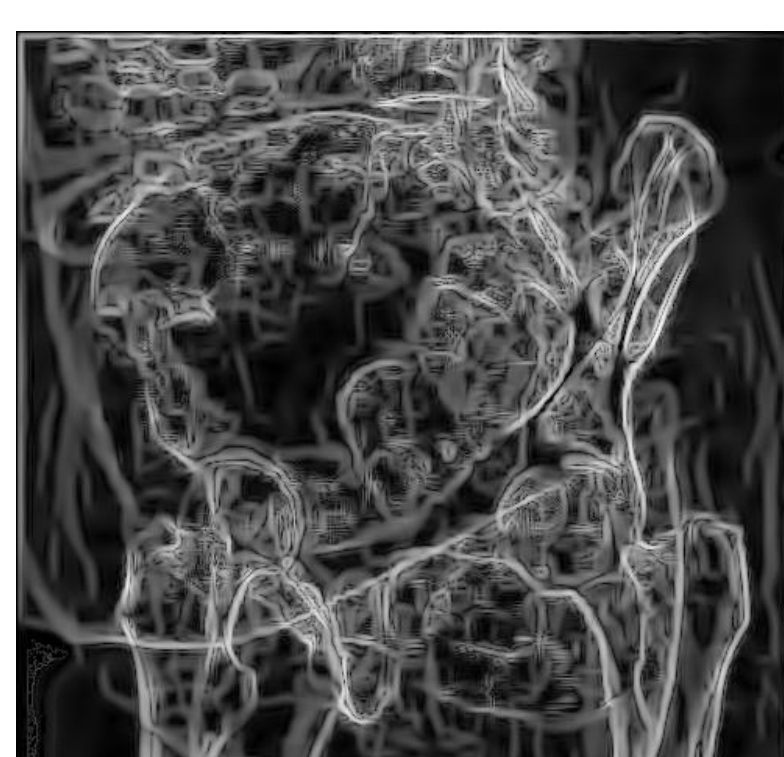
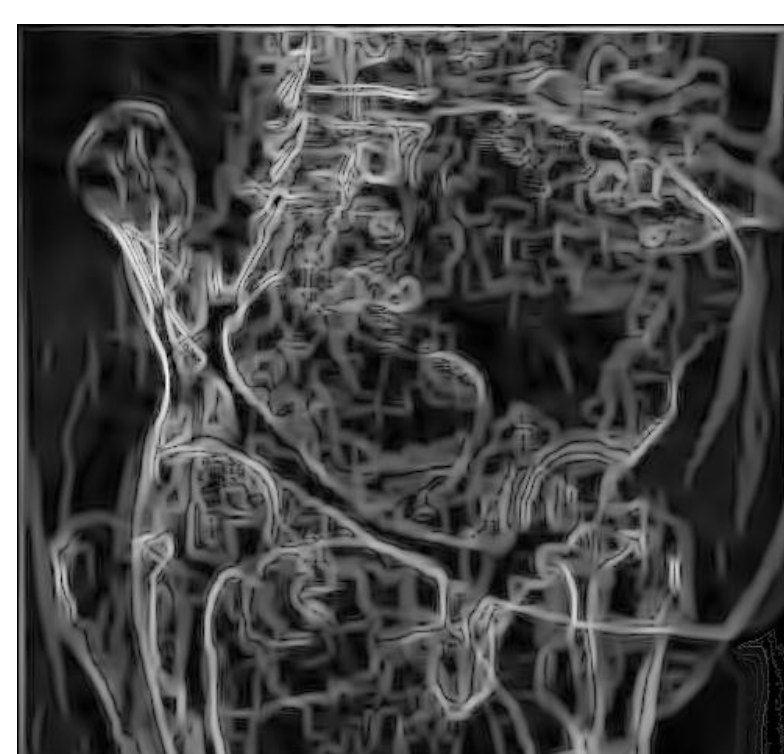
## References

1. G. Yu and G. Sapiro, "DCT image denoising: a simple and effective image denoising algorithm," Image Processing On Line, vol. 1, 2011.
2. X. Ren and J. Malik, "Learning a classification model for segmentation," in 9<sup>th</sup> IEEE International Conference on Computer Vision, October 2003, vol. 1, pp. 10–17.
3. M. Mignotte, "A label field fusion model with a variation of information estimator for image segmentation," Information Fusion, vol. 20, pp. 7–20, 2014.

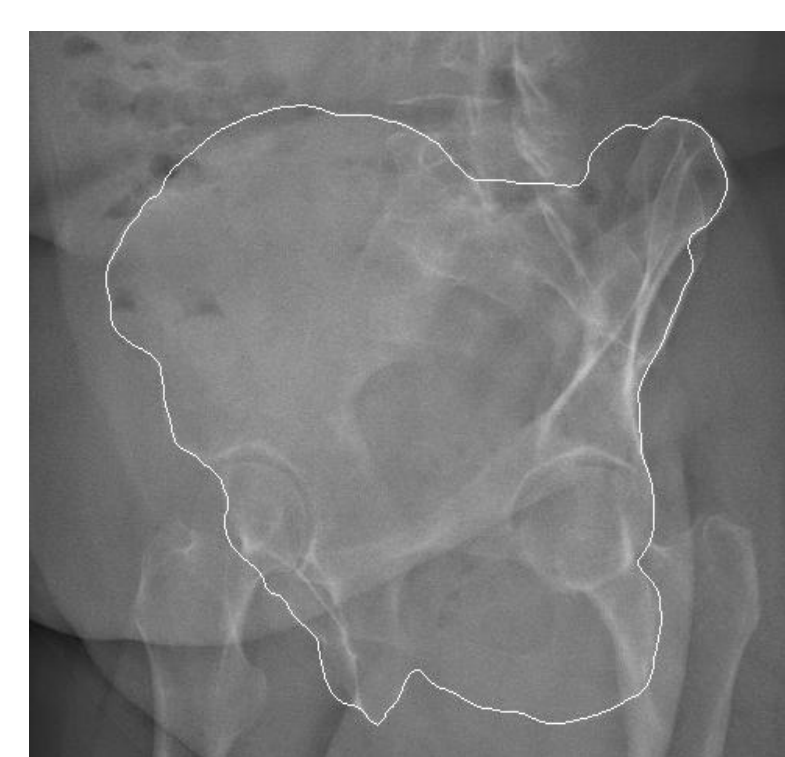
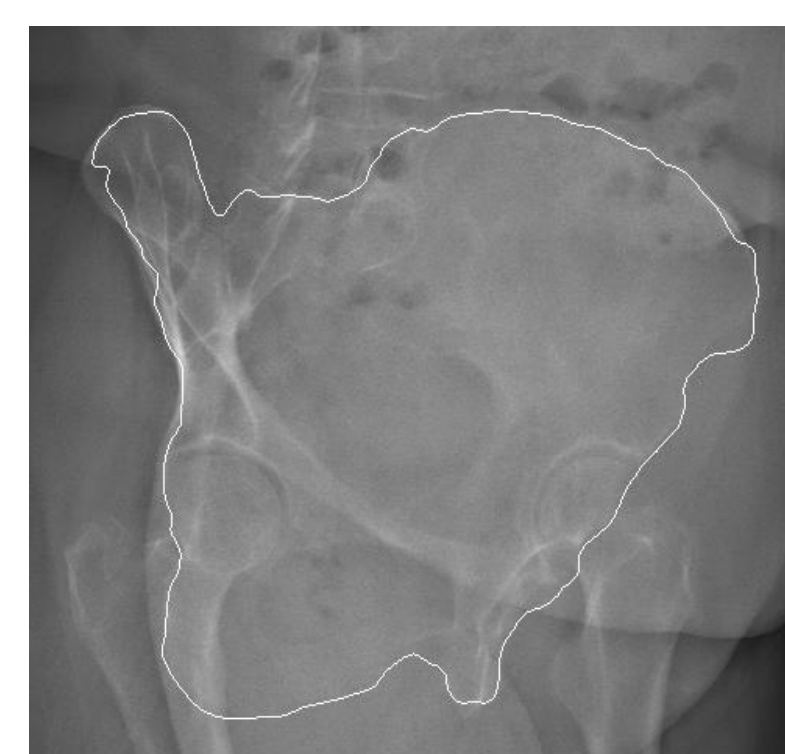
## Experimental Results



Original oblique X-ray radiographic images before the pre-processing step



Original oblique X-ray radiographic images after the pre-processing step



External pelvis contours on the corresponding oblique X-ray radiographic images



Fusion image estimates after the VOI-based propagation step