Problem Solving Assignment 1

CS6240 Multimedia Analysis

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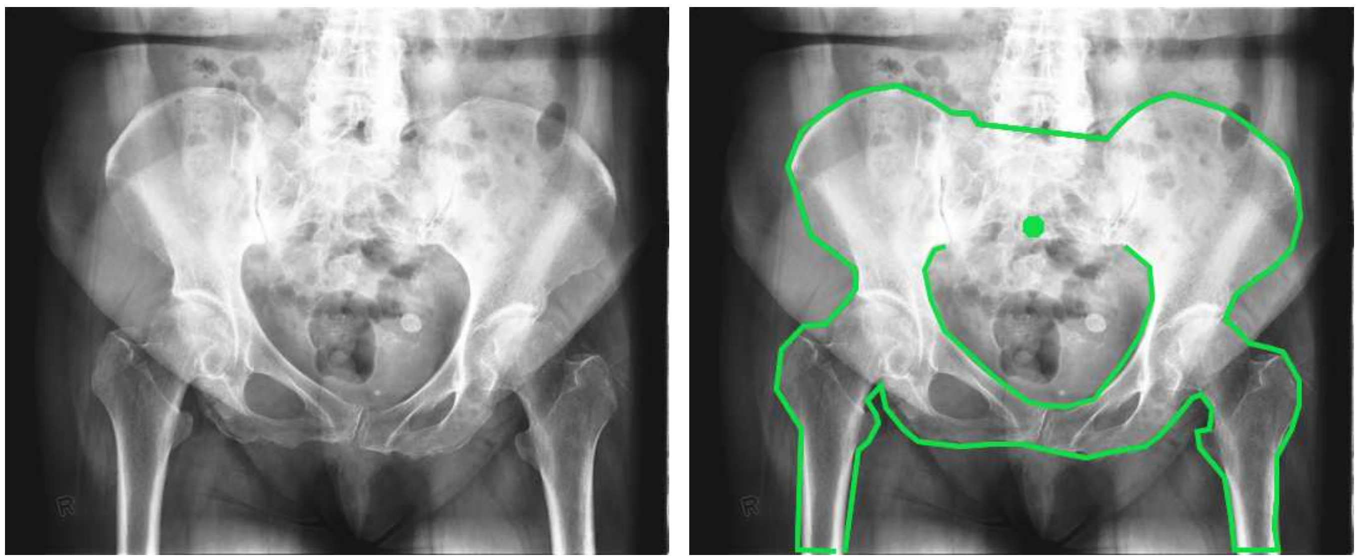
Introduction

The task: Extract the contour of the pelvis bone in an x-ray image.



Assumptions:

- The pelvis bones in different images look similar, but can vary in shape
- The pose of the patients is similar

Introduction

Difficulties:

- Other body tissues and other bones can overlap with the pelvis and create extraneous features in the image and sometimes obscure the pelvis
- High degree of noise in x-ray images (more difficult than CT)

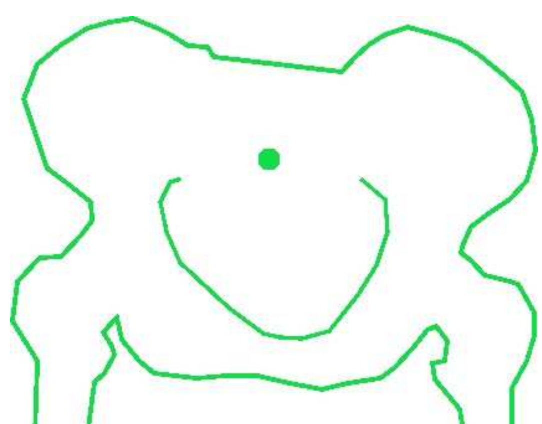
Use ***atlas-based segmentation*** method with global and local transformation.

Atlas-based Segmentation

- Use prior anatomical knowledge
- Use a template model, called the atlas
- Place atlas near to the desired objects
- Peform the atlas to fit the object

In our case:

- Single contour image of the pelvis and femur bones
- Can be obtained from a reference x-ray image using expert knowledge



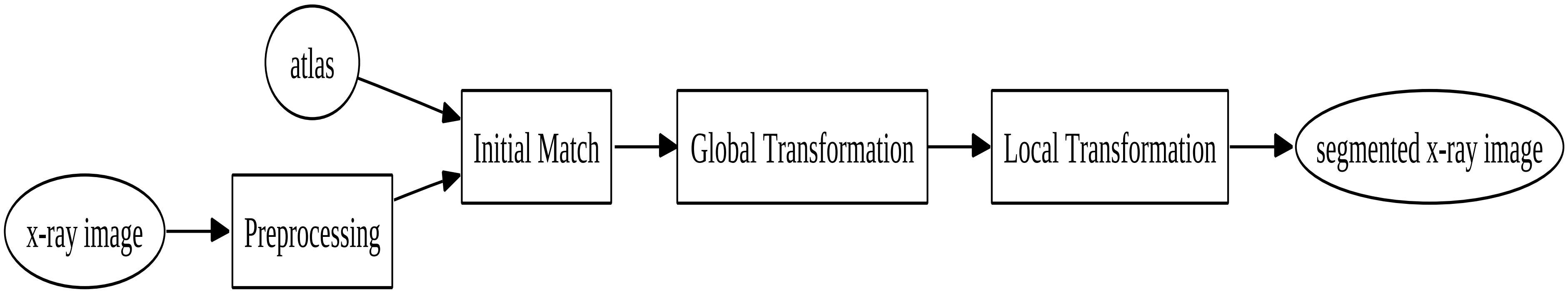
Atlas-based Segmentation

Why use an atlas of the pelvis *and* and femur bone?
Why not only the pelvis?

Observation: While the position of th pelvis is often difficult to find the position of the other objects, i.e. the femurs at the bottom of the image, are easy to find.

Use other objects in the image to find an initial position for the atlas

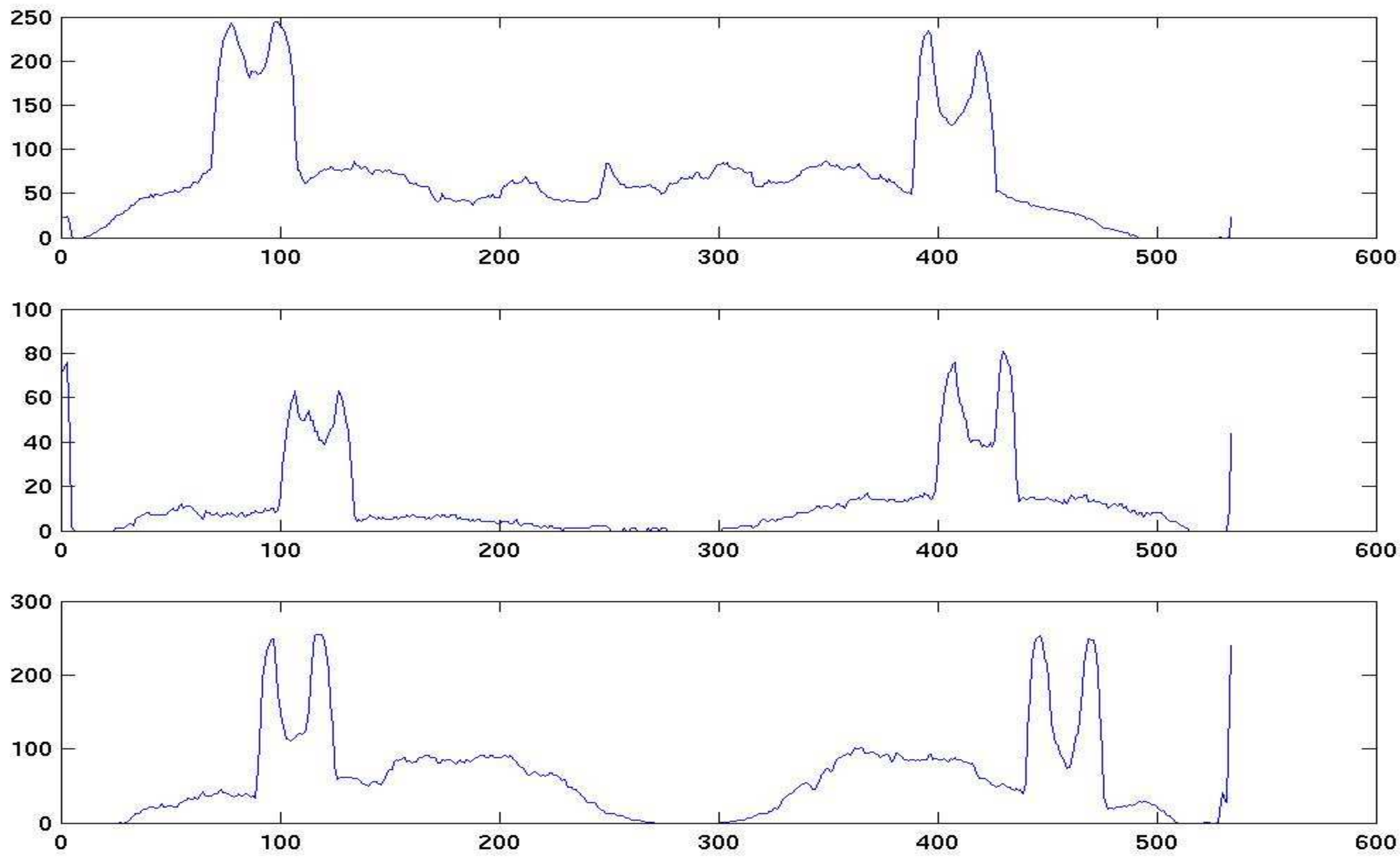
Algorithm - Overview



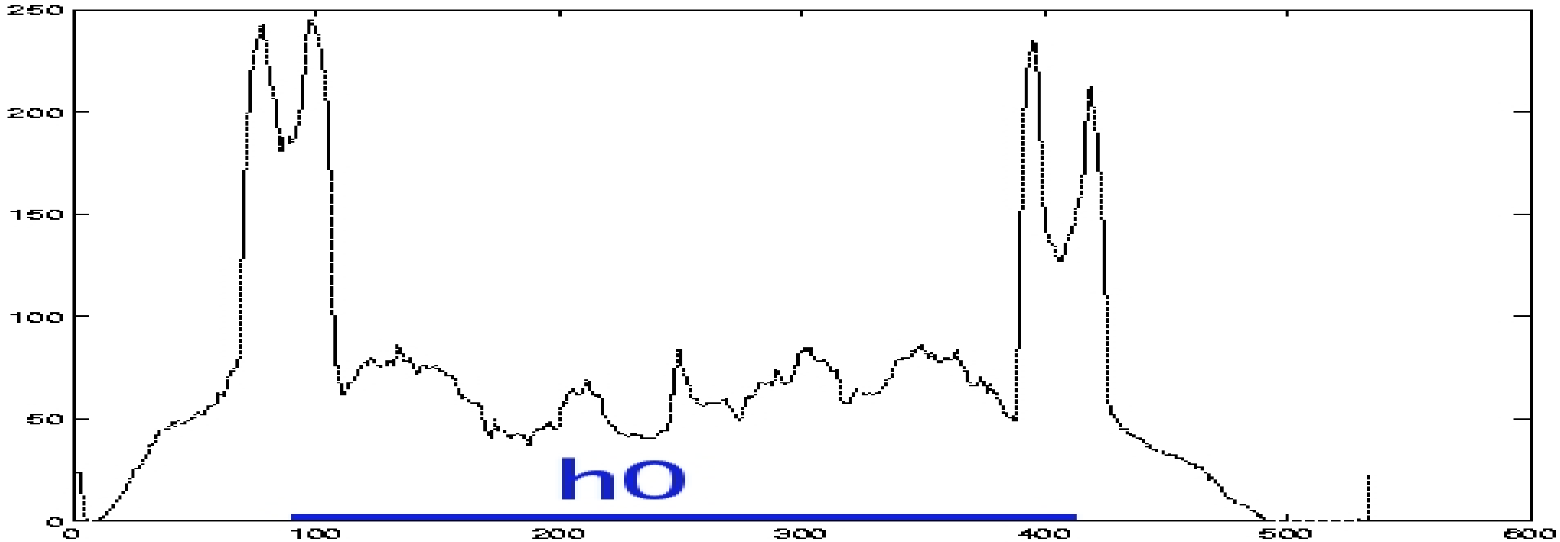
1. Preprocessing: intensity histogram normalization
2. Initial Match: find initial postion of the atlas
3. Global Transformation:
   (a) find point correspondence
   (b) register atlas with image through affine transformation
4. Local Transformation: use active contours to deform the atlas to fit the pelvis

Algorithm - Initial Match

Observation: the femur bones at the bottom have high intensity values:



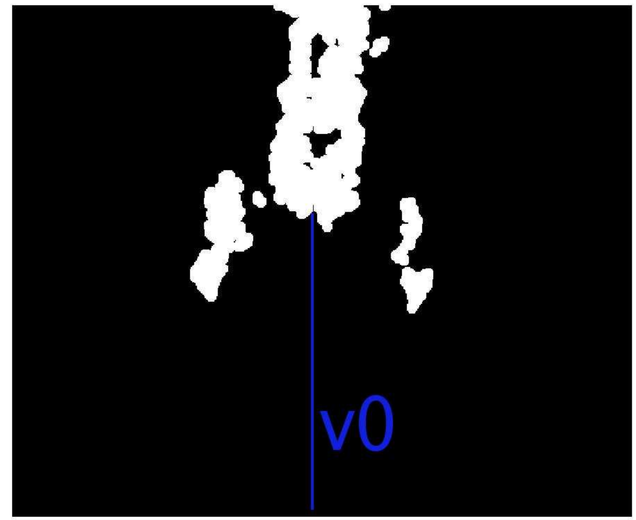
Algorithm - Initial Match



Measure distance between peaks in the last line of the image. We assume that the distance between a patient's legs is proportional to his size.

This gives us a scaling factor for the atlas.

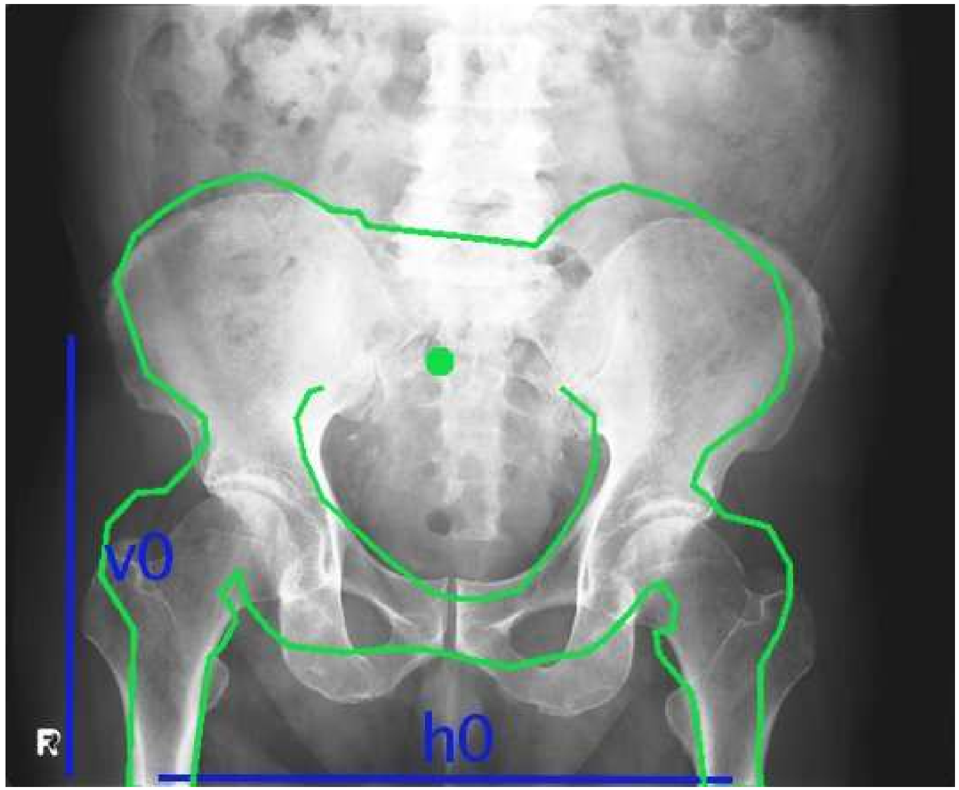
Algorithm - Initial Match



Observation: the spine is a region of very high intensity.

- binarize the image with a high threshhold (e.g. 0.9)
- use morphological opening to remove noise points
- draw a line from the middle of the legs upwards until we hit a white region

Algorith - Initial Match



- use this point as the lower end of the spine
- We place the atlas to a initial position according to the scaling factor h_0 and the y-position v_0

Algorithm - Global Transformation

Use Iterative Closest Point Algorithm to find point correspondence.

Use affine transformation to register atlas to image.

Problem: The number of non-contour points in the image is much higher than the number of pelvis contour points.

Use Sobel edge detector to extract edges. The edges are not connected, but the amount of noise and false edges is relatively low.

Algorithm - Global Transformation

Iterative Closest Point

When the atlas and the image are registered, the points on the contour of the pelvis should be close to the contour of the atlas.

Make an educated guess for the point correspondence. Let f be the closest point function:

$$f(p_i) = p'_i$$

Where p'_i is the closest point to p_i in the image:

$$\|p_i - p'_i\| = \min_{p'_j} \|p_i - p'_j\|$$

Algorithm - Global Transformation

Iterative Closest Point Algorithm

Repeat for t = 0 to max

Find $f(p_i(t))$ for each $p_i(t)$ in the atlas.

Compute affine transformation $A(t)$ that minimizes

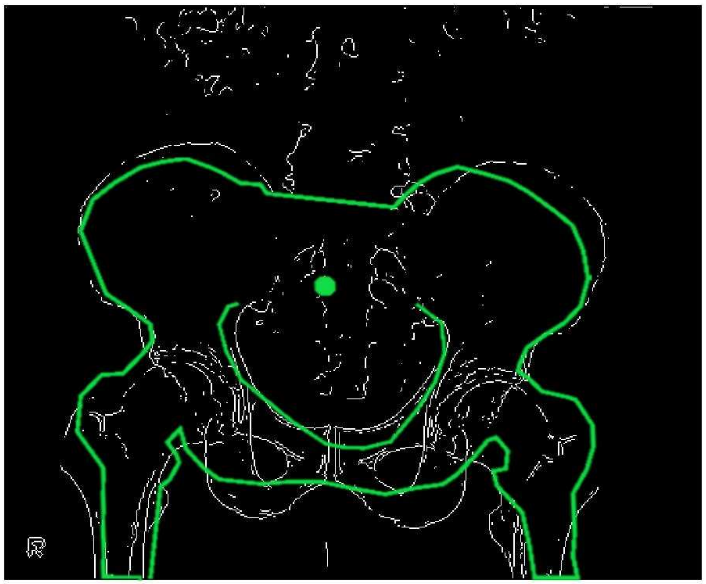
$$E(t) = \sum_{p_i(t)} [A(t)p_i(t) - f(p_i(t))]^2$$

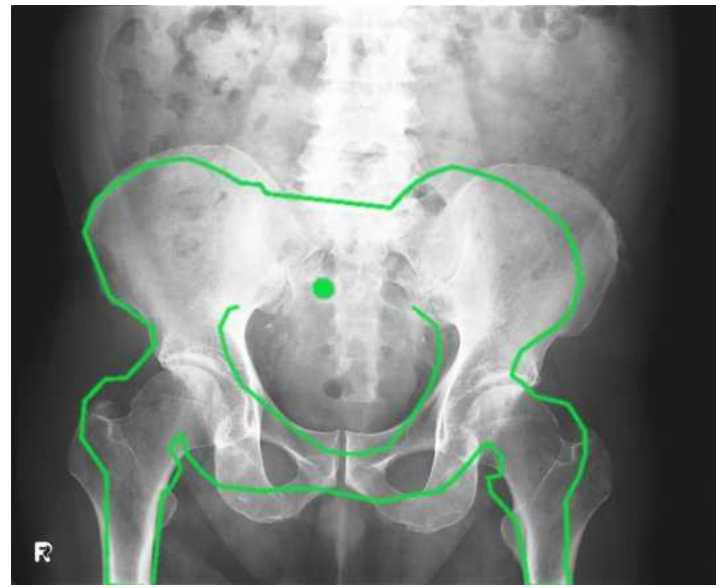
Apply the transformation to all points in the atlas:

$$p_i(t+1) = A(t)p_i(t)$$

until $E(t)$ or $E(t) - E(t-1)$ is small enough.

Algorithm - Global Transformation





The global transformation gives a good starting point for local transformation.

Algorithm - Local Transformation

We use the active contour (snake) algorithm to deform the atlas and match it to the pelvis bone in the image.

The snake is represented by a parametric contour

$$v(s) = (x(s), y(s)), 0 \leq s \leq 1$$

- Does not work with the edge detected image
- Remove the femur bone from the atlas
- Use gradient vector force
- Snake can easily be attracted by noise in the image
- Introduce external force to contrain the snake

Algorithm - Local Transformation

The *internal energy* E_i is defined as:

$$E_i(v(s)) = \frac{1}{2}(\alpha\|v'(s)\|^2 + \beta\|v''(s)\|^2)$$

It represents the degree of the stretching and bending of the snake.

The snake is attracted by edges in the image. These feature are represented by the *image energy* E.

The *external energy* is used to contrain the snake. The snake can be constrained by constraining it's curvature.

Algorithm - Local Transformation

The curvature of the snake is proportional to the second derivative of the contour point.

The external energy is a spring force that represents the difference between the actual curvature and the curvature in a model

$$E_x(v(s)) = k\|v''(s) - \omega(s)\|^2$$

Iteratively deform the snake so that the *total energy* E_T is minimized.

$$E_T = \int_0^1 [E_i(v(s)) + E(v(s)) + E_x(v(s))]ds$$

Summary

- Presented a method for extracting the prelvis bone from an x-ray iamge
- Find initial atlas position by locating the spine and the femur bones
- Apply ICP and affine transformation
- Apply snake with aditional contrains to deform the snake

Reference

- Ying Chen, Xianhe Ee, Wee Kheng Leow and Tet Sen Howe, Automatic Extraction of Femur Contours from Hip X-ray Images
- Ding, Leow, Wang, Segmentation of 3D CT Volume Images Using a Single 2D Atlas
- Besl, McKay, A Method for Registration of 3-D Shapes
- Xu and Prince, Gradient vector flow: A new external force for snakes
- Kass, Witkin, Terzopoulos, Snakes: active contour models

The End

Thank you for your attention!

Any Questions?