# Automatic DRR Enhancement for Patient Positioning in a Radiotherapy Treatment

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# Outline


1. Introduction
2. Method
   - Mathematical Morphology Operators
   - Automatic enhancement of DRR's
3. Results
4. Conclusions

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## A radiotherapy treatment consists of

- First stage: dosimetry planning
- Second stage: radiation dose

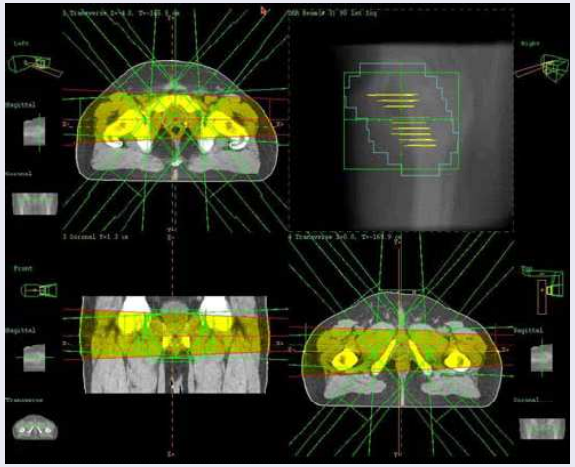
## Hospital Universitario Virgen de la Arrixaca

- Planning stage:
  *Pinnacle Radiation Therapy Planning Computer System* from ADAC Laboratories
- Treatment stage:
  *iView* system from Elekta Digital Linear Accelerator

## Planning stage

- The first stage consists in a dosimetry planning:
  - x-ray volumetric scanning of the patient,
  - fiduciary marks on the skin (external references),
  - delineate the tumour volume and critical organs in CT images.
- Optimal treatment plan: number, size, shape and position of the radiation beams.
- DRR's are synthetically generated from the CT scan.

(a) CT scanner



(b) Planning software

## Treatment stage

- The problem is to place the patient correctly in the accelerator
- The x-ray treatment must precisely match the radiotherapy planned doses
- Compare DRR from planning with portal image obtained in the accelerator
- Move the couch with the patient longitudinally and transversally.

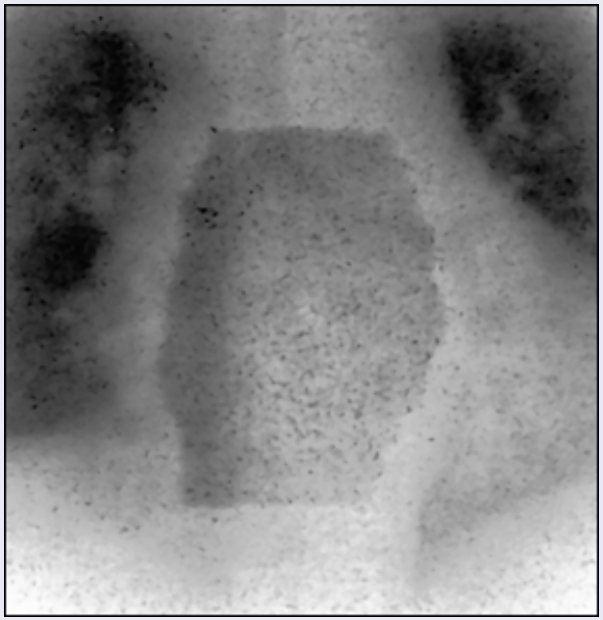
(a) Linear accelerator

(b) Software for manual validation of the positioning

## Treatment stage

- The positioning is verified by comparing the DRR with a portal image acquired in the accelerator
- DRR image and portal image make up reference and location images (reference and template in image registration)

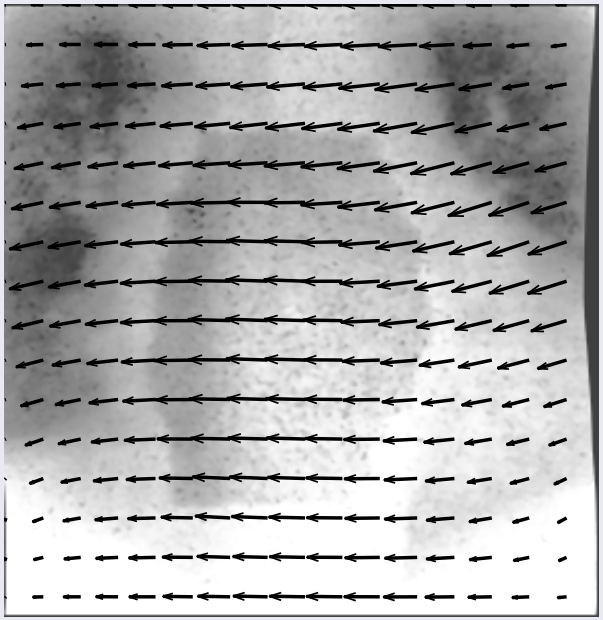
(a) DRR image or reference image



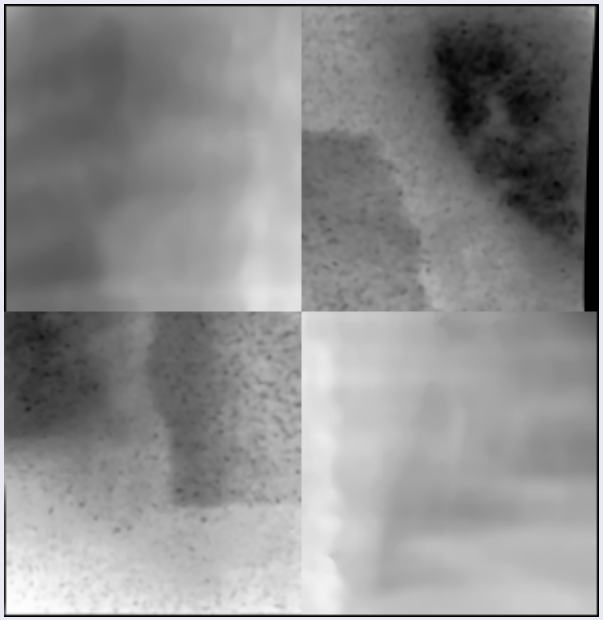
(b) Portal image or localization image

## Treatment stage

- The positioning is verified by comparing the DRR with a portal image acquired in the accelerator
- DRR image and portal image make up reference and location images (reference and objective in image registration)



(a) Estimated displacement vector field



(b) Mosaic from the DRR and the registered portal

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## Dilation and erosion

- The dilation of a gray-scale digital image $f(x, y)$ by a flat structuring element $b$, denoted $f \oplus b$, is defined as

$$(f \oplus b)(x, y) = \max\{f(x - x', y - y') | (x', y') \in D_b\}$$

(a) Original image

(b) Dilated image

## Dilation and erosion

- The gray-scale erosion of $f$ by structuring element $b$, denoted $f \ominus b$, is defined as

$$(f \ominus b)(x, y) = \min\{f(x + x', y + y') | (x', y') \in D_b\}$$

(a) Original image

(b) Eroded image

## Opening and closing

- The opening of image $f$ by structuring element $b$, denoted $f \circ b$, is defined as

$$f \circ b = (f \ominus b) \oplus b$$

i.e. the erosion of $f$ by $b$, followed by the dilation of the result by $b$.

- The closing of $f$ by $b$, denoted $f \bullet b$ is defined as

$$f \bullet b = (f \oplus b) \ominus b$$

i.e. dilation followed by erosion.

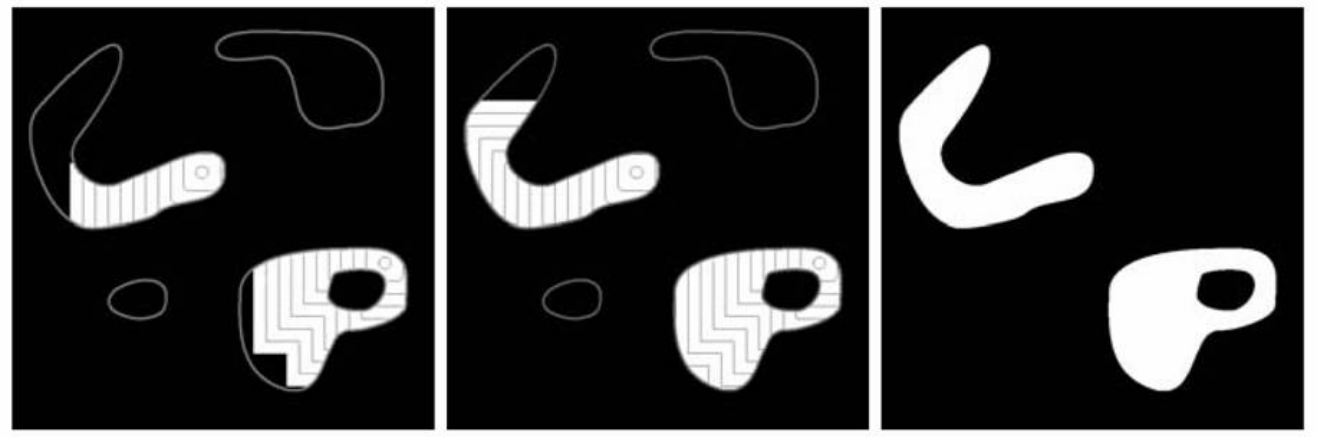
## Reconstruction

- It involves
  - a structuring element $b$,
  - marker image $f$ which is the starting point,
  - mask image $g$ which constrains the transformation ($f$ must be a subset of $g$).

- The reconstruction of $g$ from $f$, $R_g(f)$, is defined by
  1. Initialize $h_1 = f$
  2. Repeat
     $$h_{k+1} = (h_k \oplus b) \cap g$$
     until $h_{k+1} = h_k$.

# Reconstruction

Original image (mask) | Marker image | 100 iterations



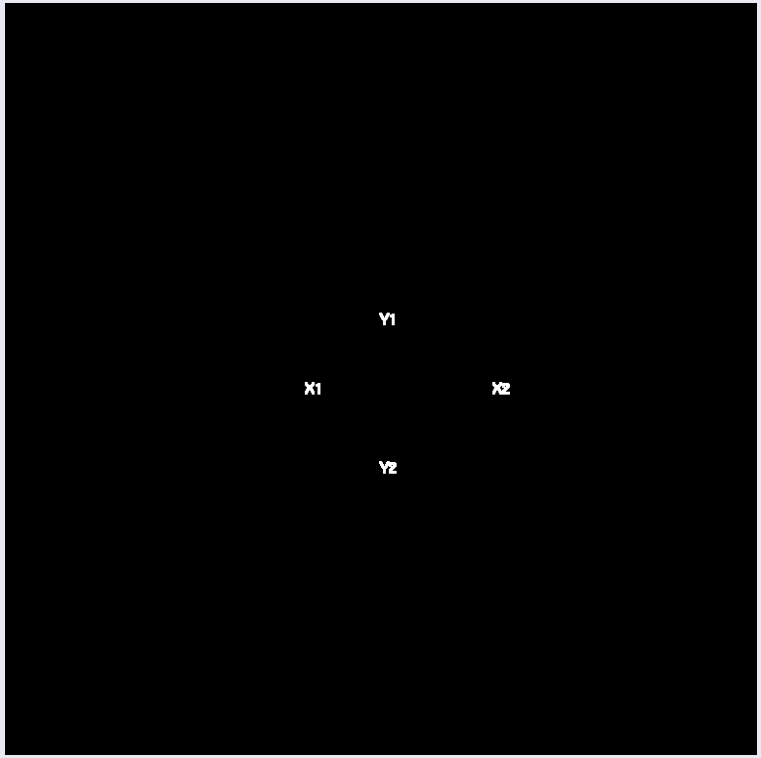
200 iterations | 300 iterations | final result

# Automatic enhancement of DRR's

- *Pinnacle Radiation Therapy Planning Computer System*
- CT dataset unavailable

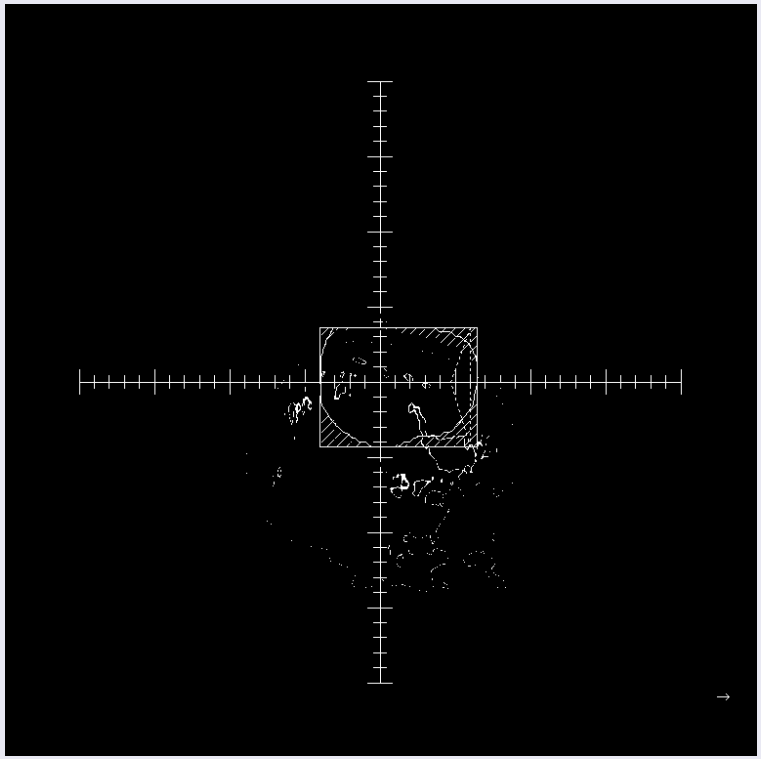
## Step #1

- Characters X,Y,1 and 2 are located by correlation
- Locations are stored in a mask



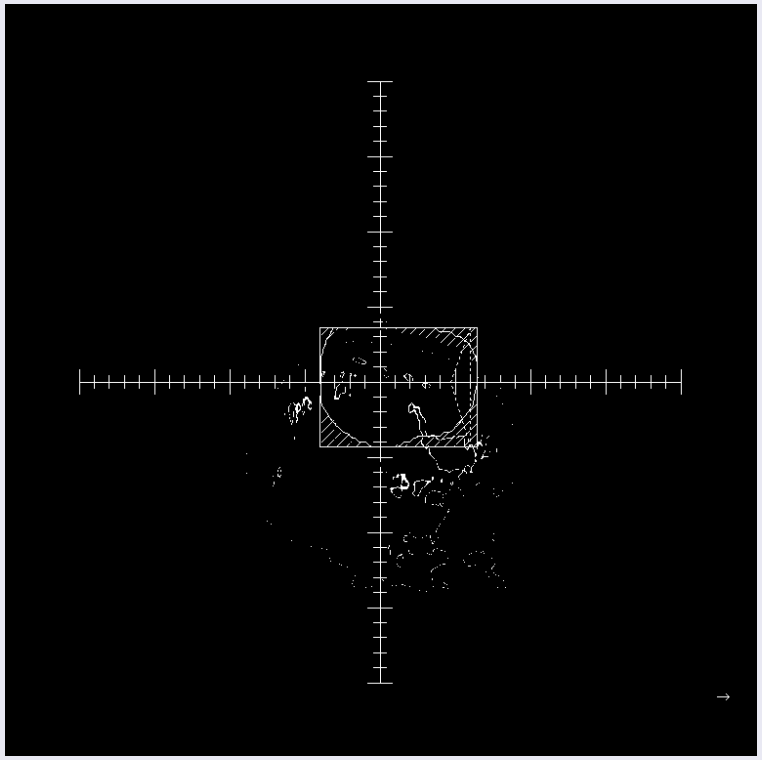
## Step #2

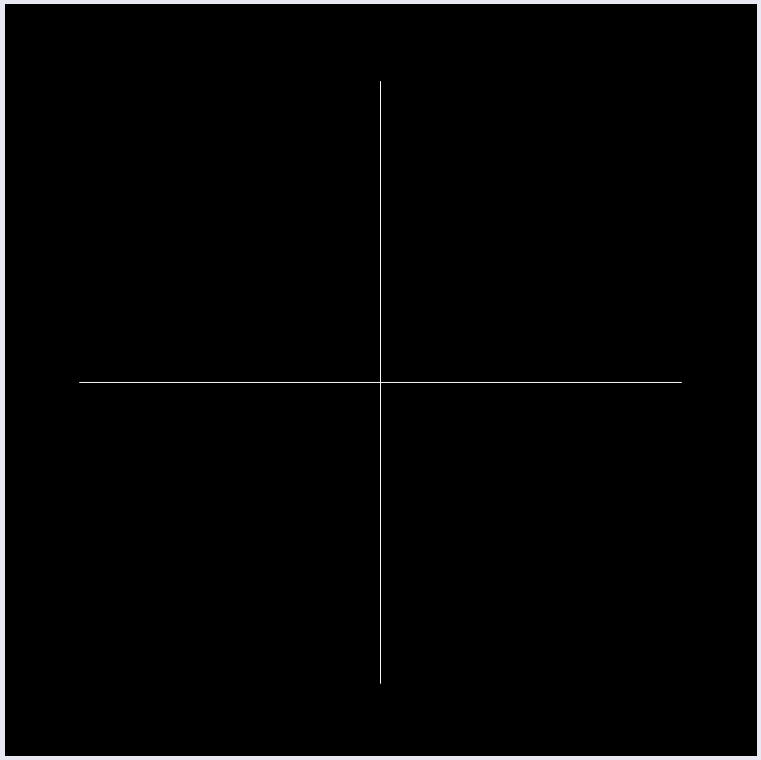
- Gray level of axes is obtained by opening of the DRR
- Estructuring element of size $1 \times 615$



## Step #3

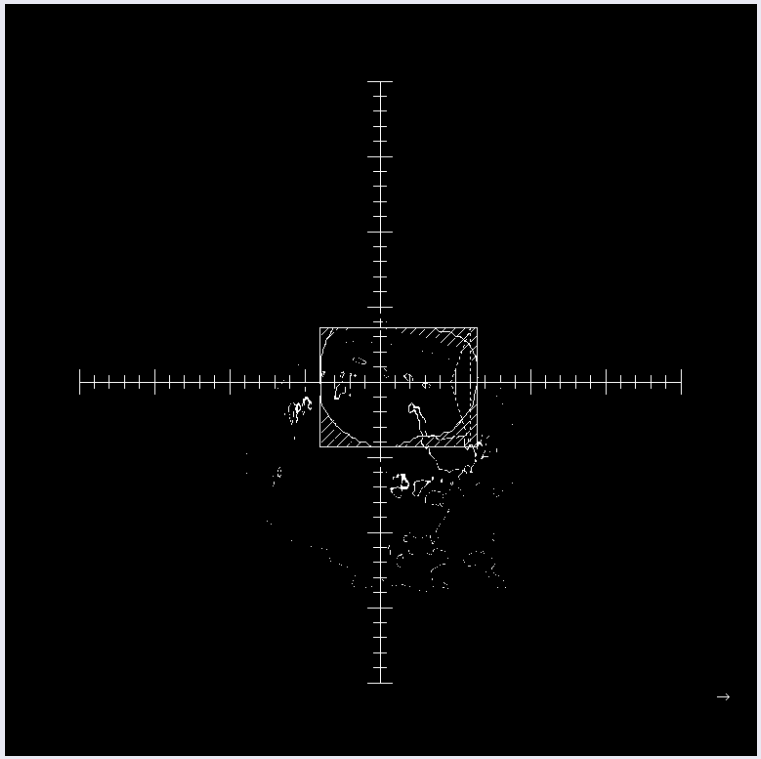
- Vertical and horizontal axes are extracted by opening
- Estructuring elements of size $1 \times 399$ and $399 \times 1$

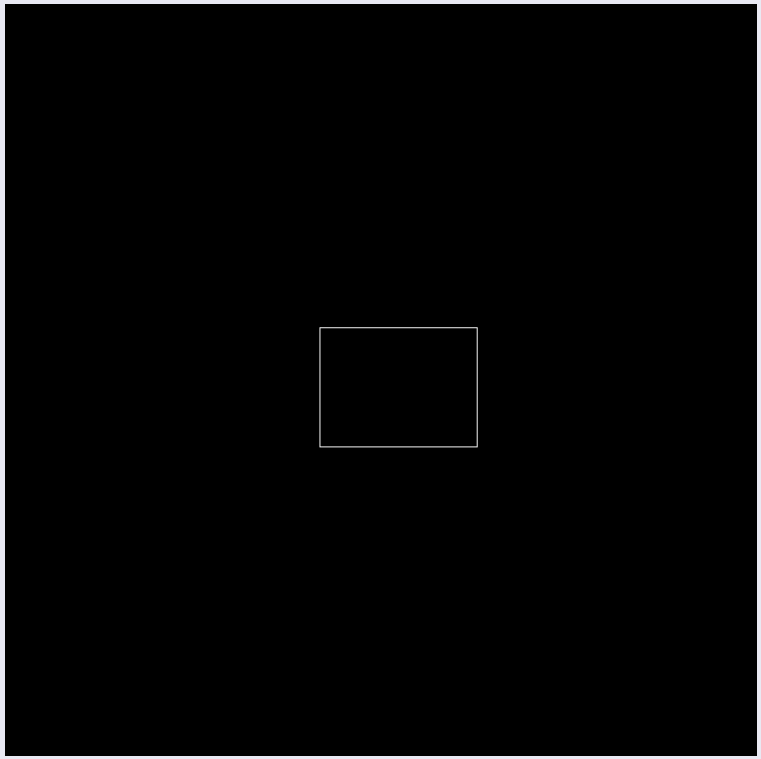




## Step #4

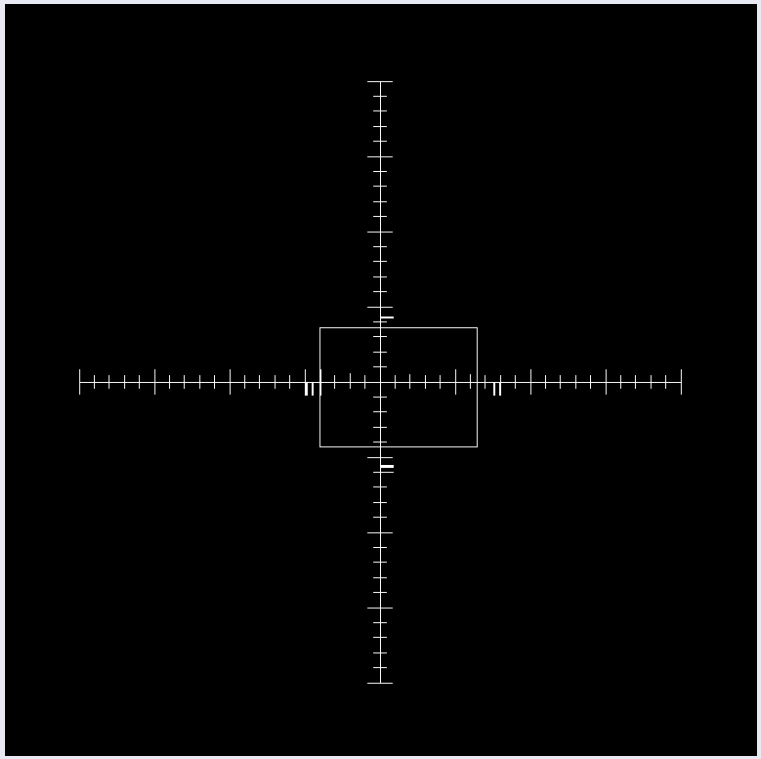
- Box is obtained by subtracting the axes from *imth*
- Maximum of two openings with se $1 \times 51$ and $51 \times 1$





## Step #5

- Axes and box already detected
- Lines are 1pixel width $\rightarrow h_h = \frac{1}{2}[1\ 0\ 1]$ and $h_v = \frac{1}{2}[1\ 0\ 1]^\top$ are used for restoring with linear interpolation

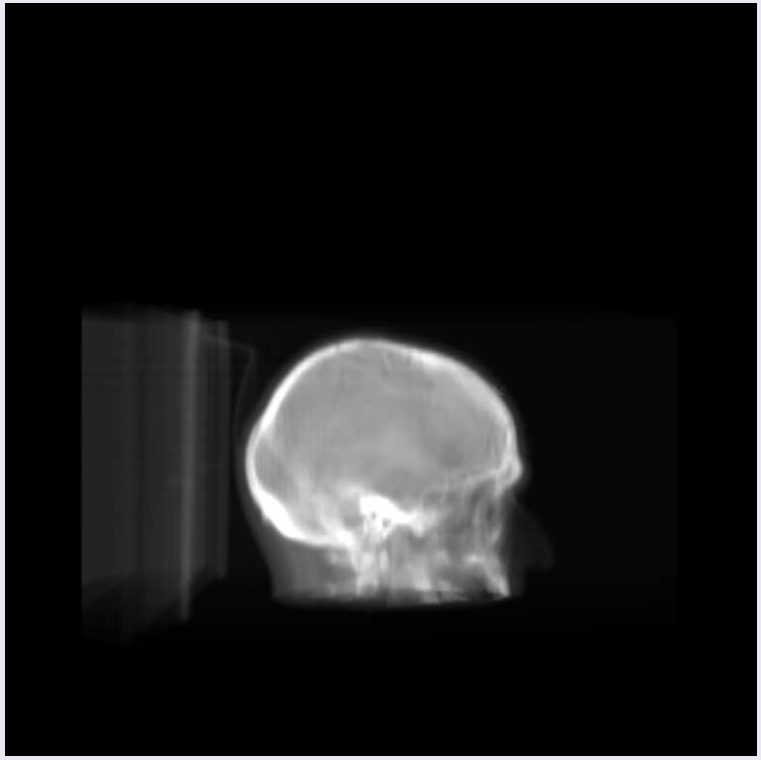


## Step #6

- Text is removed by the erosion with se 7×3 → marker
- Mask is the DRR with axes restored
- Thresholded difference between original and reconstructed DRR → text_mask

## Step #7

- Spatially variant filtering for restoring gray level of pixels covered by text



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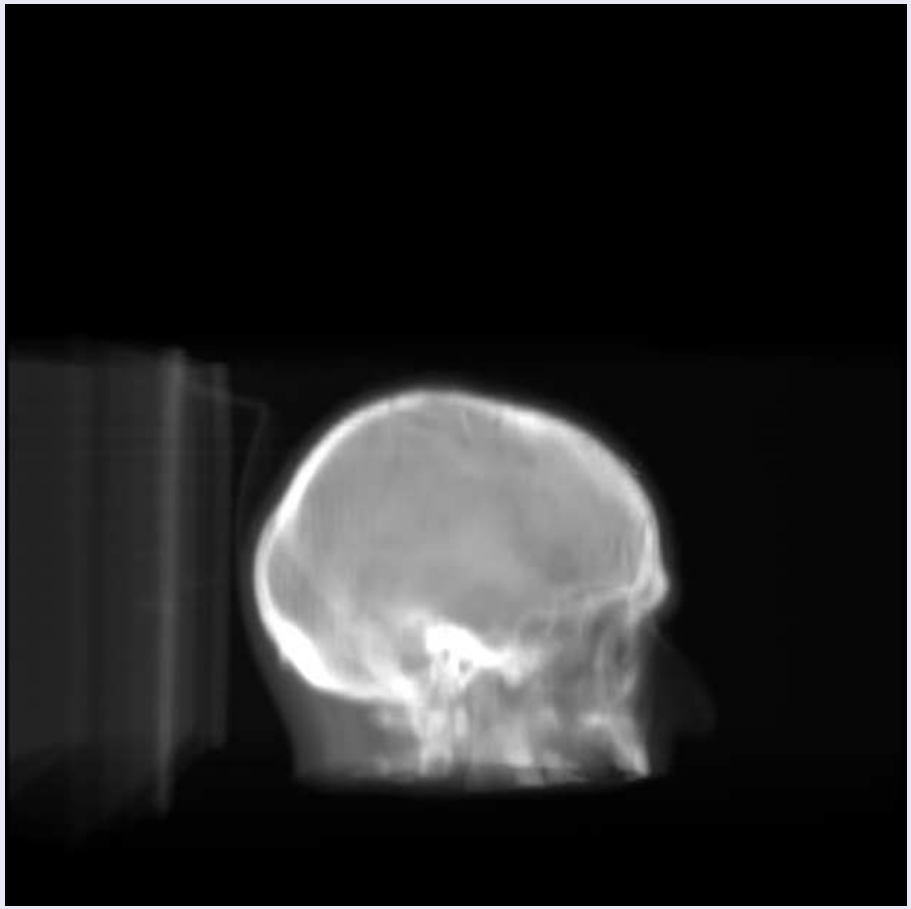
# DRR #1

DRR provided by *Pinnacle*

Enhanced DRR

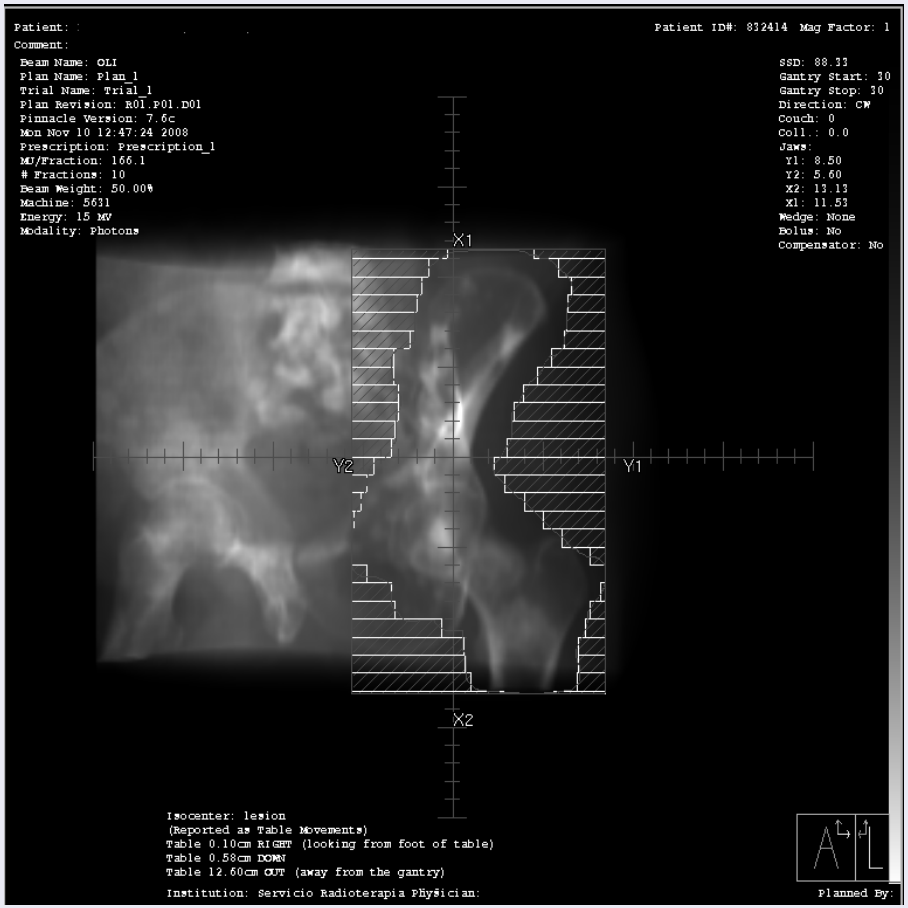
# DRR #2

DRR provided by *Pinnacle*

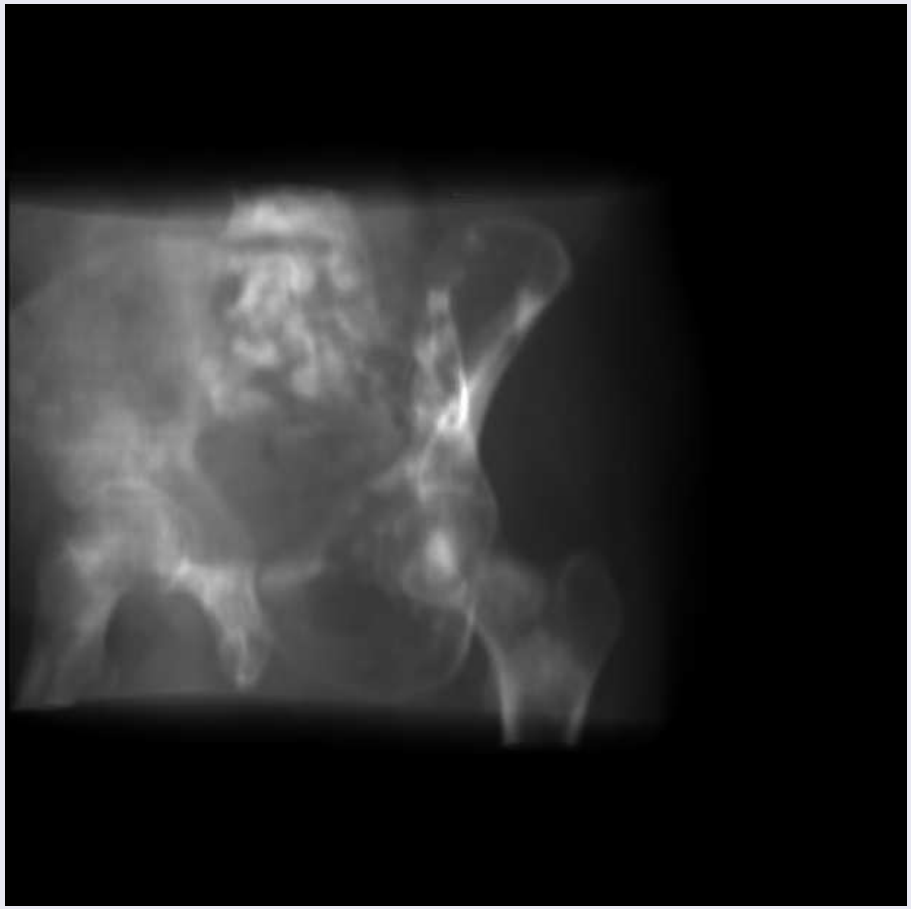


Enhanced DRR

# DRR #3

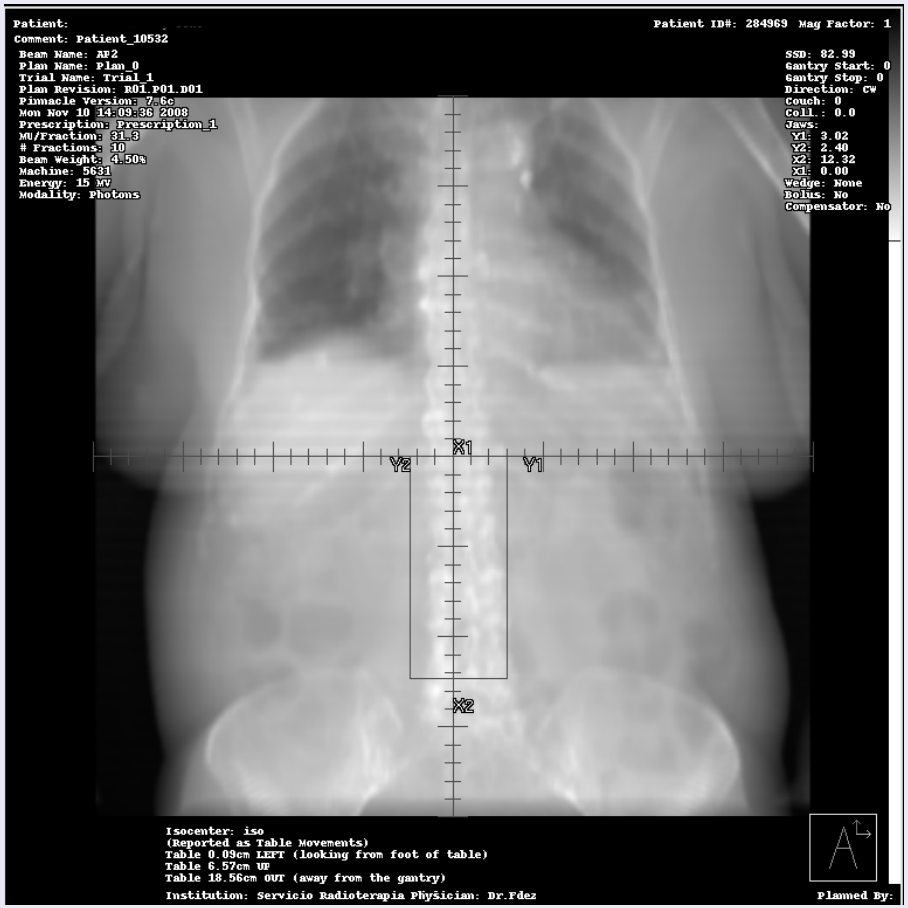



DRR provided by *Pinnacle*



Enhanced DRR

# DRR #4

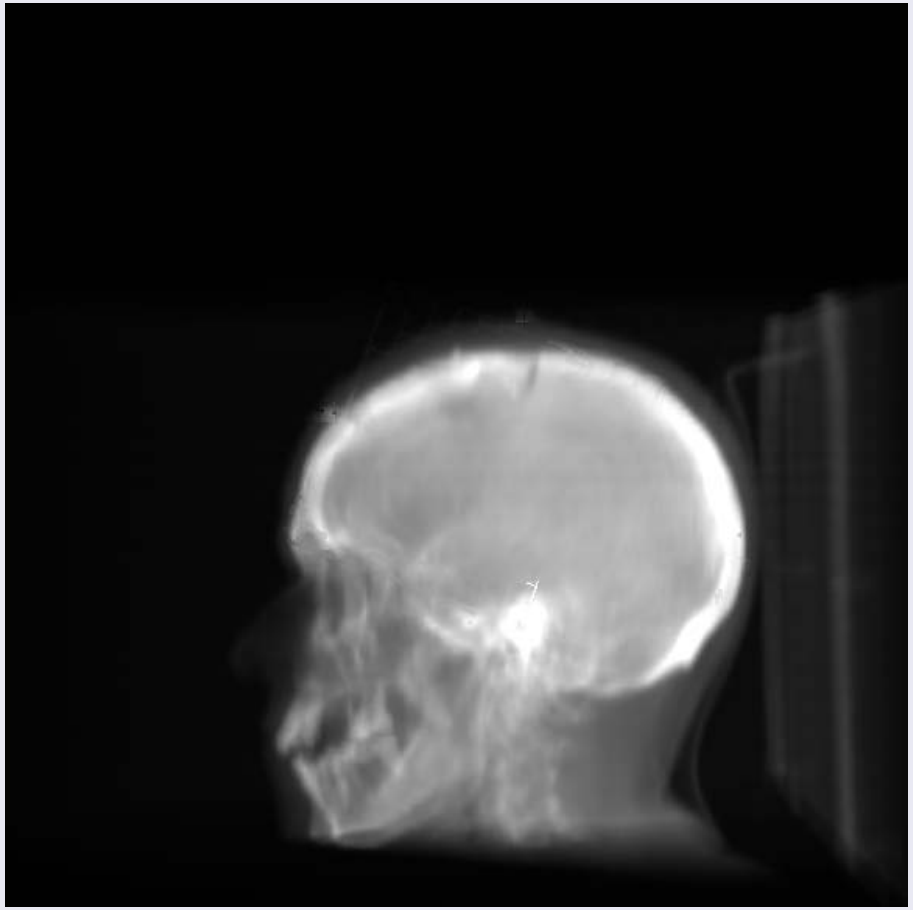



DRR provided by *Pinnacle*

Enhanced DRR

# DRR #5

DRR provided by *Pinnacle*



Enhanced DRR

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- Digitally reconstructed radiographies (DRR's) turn out to be essential in the planning and verification of radiotherapy treatments
- These images are used in radiotherapy planning in order to mark out the area to be radiated.
- At the beginning of each radiation session, several DRR's are compared with portal images which are acquired at the moment.
- By means of image registration tasks, the displacement field between DRR's and portal images is obtained and the correct positioning of the patient is achieved.
- The preprocessing of both kinds of images is mandatory for the correct operation of the image registration algorithm.
- This talk describes the automatic enhancement of DRR's with morphological operators to be integrated in the Hospital Universitario Virgen de la Arrixaca (Murcia, Spain).

Thank you for your attention

Any questions?

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