3D Reconstruction From Bi-Planar X-Rays

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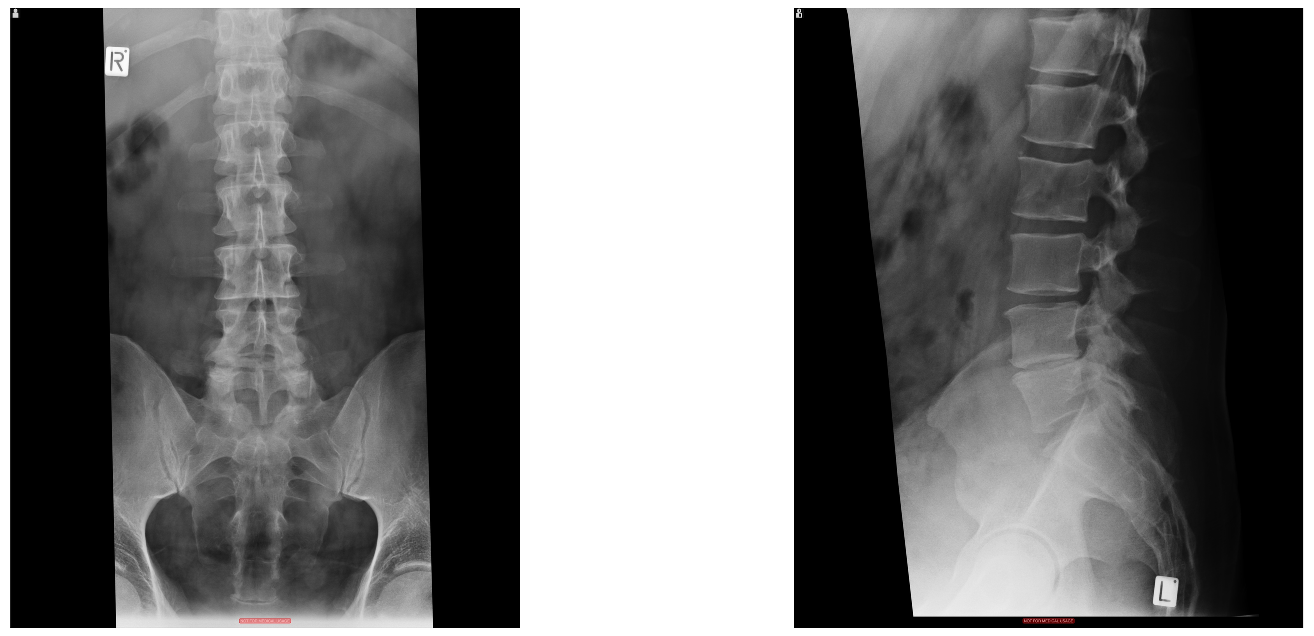
Problem Statement

Can we reconstruct the 3D bone structure in vivo from just two x-rays?



(a) Anterio-Posterior x-ray of human spine (b) Latero-Lateral x-ray of human spine

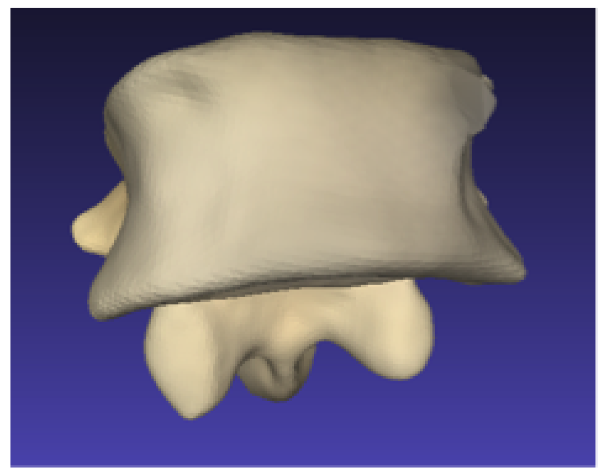
Figure: Examples of data used to reconstruct the 3D human spine

- The reconstruction is an ill-posed problem
- Use of prior knowledge through 3D models of human vertebrae
- Vertebrae are difficult and complicated, but mostly smooth shapes
- Calculate the 3D variations of the data set and directions of variations
- Generate new models to fit to new data
- Find the best fit to new data x-rays

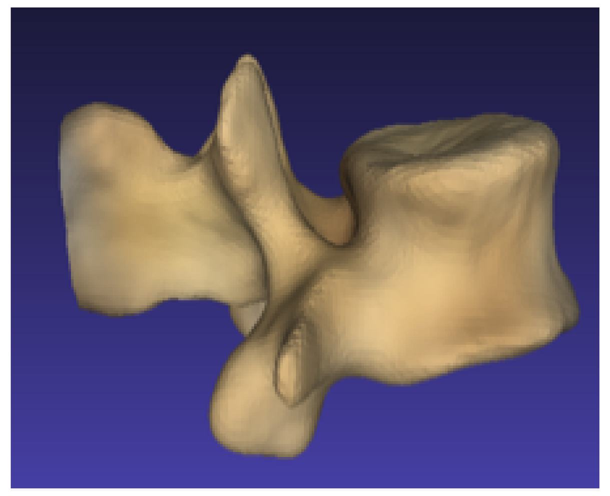
3D Models Of Human Vertebrae

How to extract 3D point clouds from images of real world?

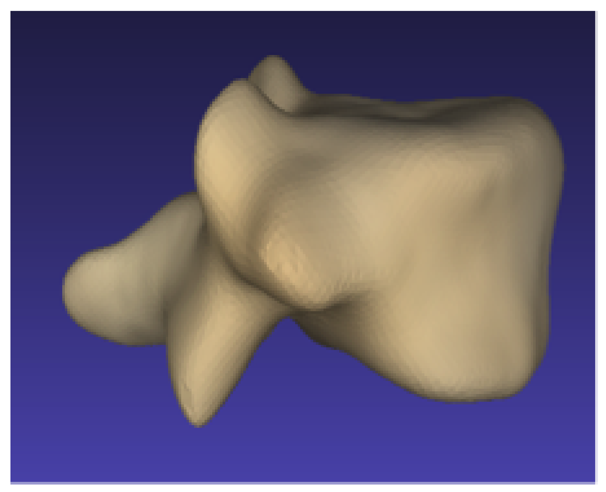
- Use 87 models accessed through the W. D. Trotter Anatomy Museum at the Department of Anatomy, Otago School of Medical Sciences, University of Otago, New Zealand.
- Take on average 280 images around the vertebrae
- Segment the images to remove the non-vertebrae parts in images
- Use an image-based technique to reconstruct 3D models (3D point clouds of vertebrae)



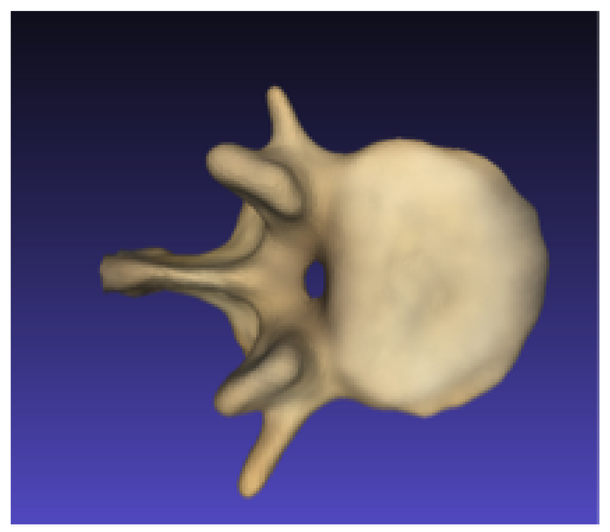
(a) Anterior View



(b) Lateral View



(c) Lateral View



(d) Superior View

Figure: Different views on different 3D models reconstructed

Statistical Shape Models

Using well known methods of morphological studies we could extract different variations and directions.

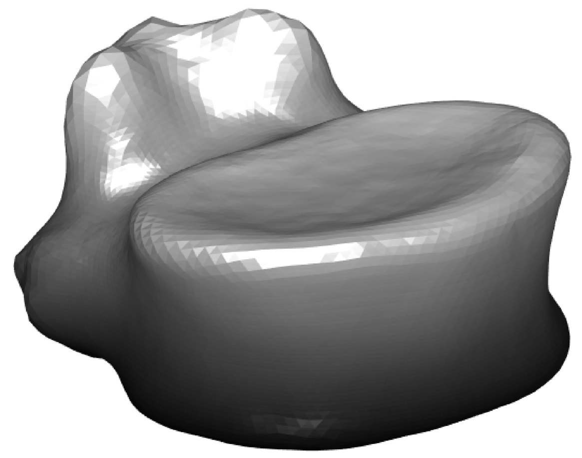
- In 3D, each vertebra represented with n landmarks $(x_i, y_i, z_i) \in \mathbb{R}^3$ in cartesian coordinates
- $s = (x_1, y_1, z_1, ..., x_n, y_n, z_n)^T \in \mathbb{R}^{3n}$
- Using N shapes, mean shape $\bar{s}$ is defined as follows:

$$\bar{s} = \frac{1}{N}\sum_{i=1}^{N} s_i \quad (1)$$

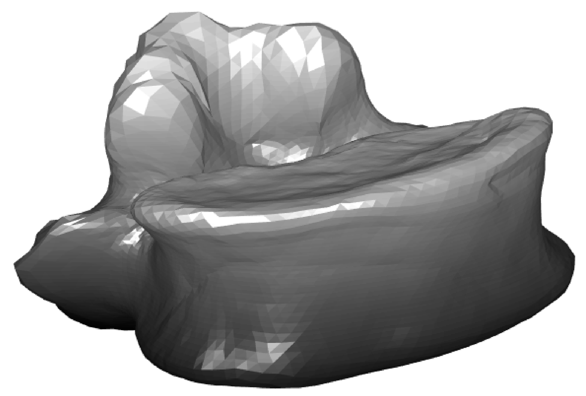
and the covariance matrix as follows:

$$C = \frac{1}{N}\sum_{i=1}^{N}(s_i - \bar{s})(s_i - \bar{s})^T \quad (2)$$

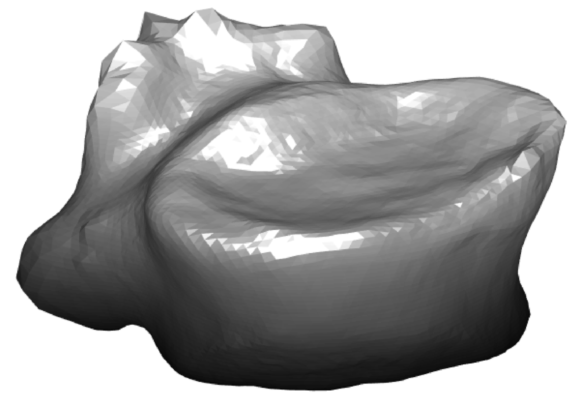
- PCA on C covariance matrix
- new shape $= \phi b + \bar{s}$ where: ϕ represents the orthogonal basis of principal modes and b are the associated weights taken in general between $-3SD$ and $+3SD$



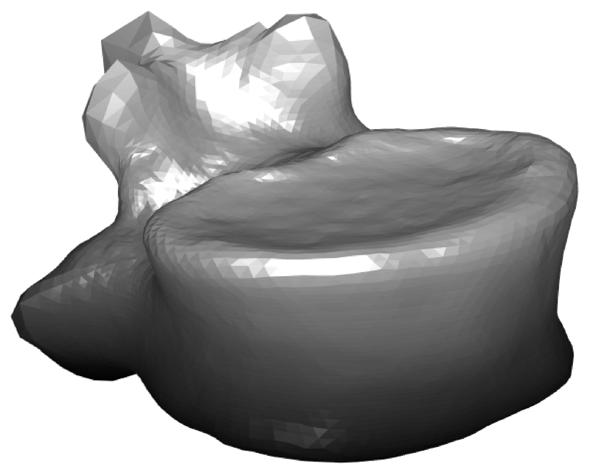
(a) Mean shape of L3 vertebra



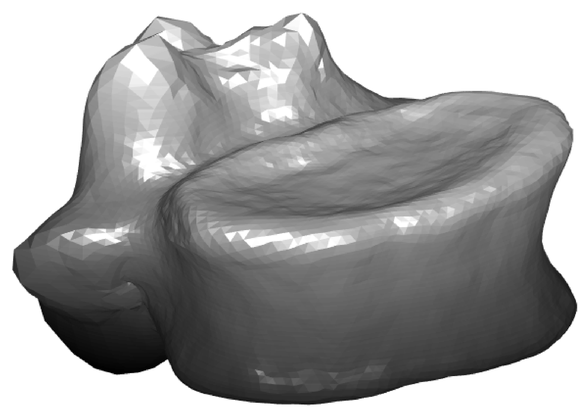
(b) Shape generated by mean -2SD of first principal component



(c) Shape generated by mean +2SD of first principal component



(d) Shape generated by mean +2SD of second principal component



(e) Shape generated by mean +2SD of second principal component

Figure: First and Second Principal Component effects on L3 vertebra

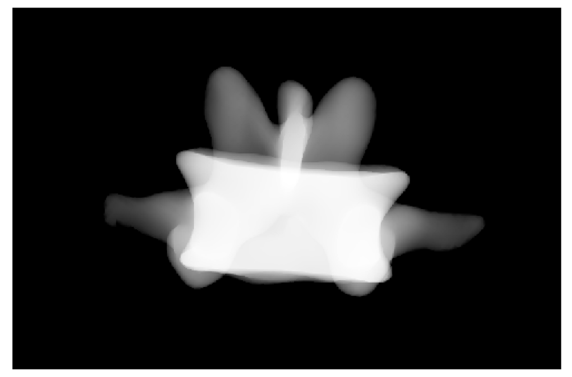
Conclusions, Open Problems, etc.

- Compare results to those provided by a CT scan or/and MRI
- Construct statistical shape model for the whole spine
- Model the soft tissues to have better pseudo x-rays

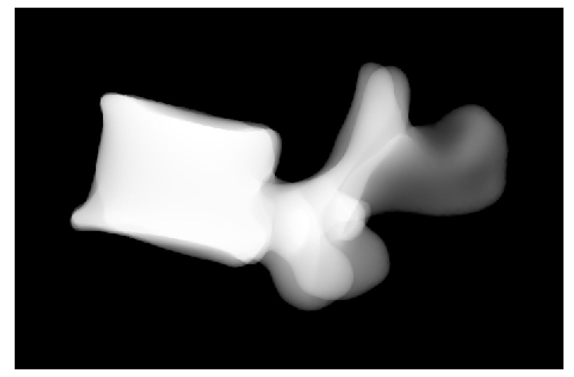
Fitting Prior Knowledge To New X-Rays

To find the best model and location which fits best to the new x-rays we use gradient descent methods.

- Start at mean shape
- Generate pseudo x-ray
- Do a comparison with real x-ray (using a defined error metric)
- Descend along shape and relative position of x-rays planes.



(a) Anterio-Posterior pseudo x-ray of human vertebra



(b) Latero-Lateral pseudo x-ray of human vertebra

Figure: Examples of pseudo x-rays in two views according to a position of vertebra relative to the source of light and the shape variations

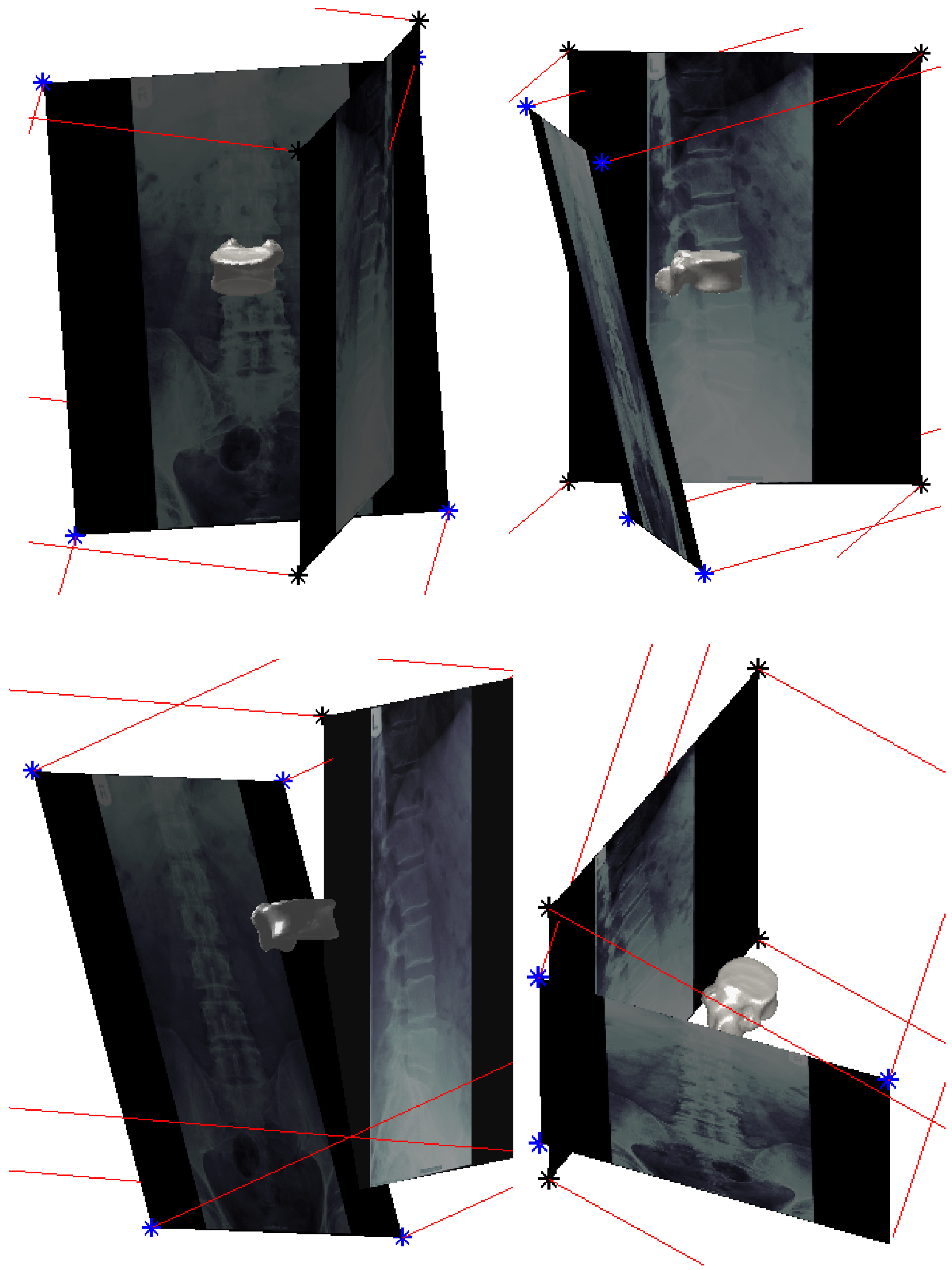


Figure: Different views of 3D reconstruction from bi-planar x-rays

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