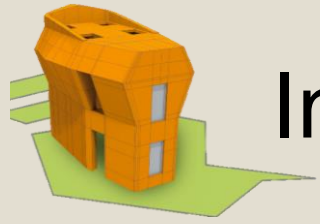


# Towards automated 3D reconstruction of the human body from biplanar X-rays

Laurent Gajny, François Girinon, Matteo Bovio,  
Claudio Vergari, Wafa Skalli

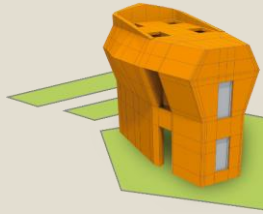
*Journées du GTMG, July 2020*



# Institut de Biomécanique Humaine Georges Charpak

# LBM

Founded in 1979

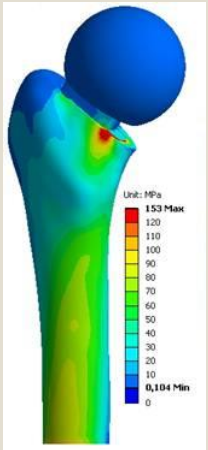


INSTITUT de  
BIOMÉCANIQUE HUMAINE  
GEORGES CHARPAK

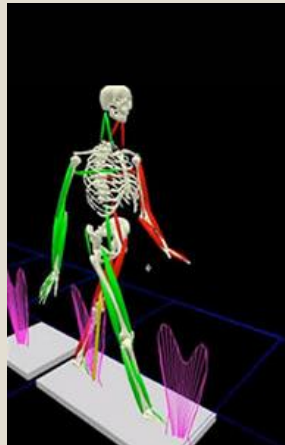
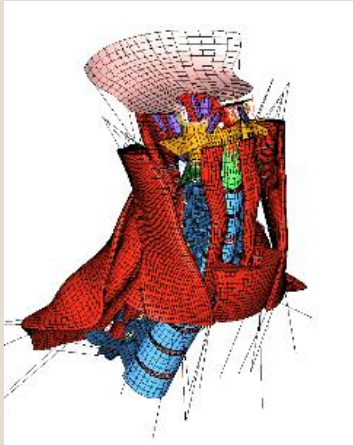
Since 2013

## Our aim :

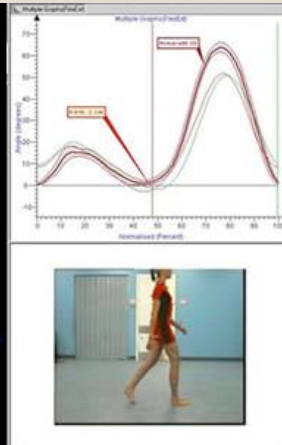
Study and model the musculoskeletal and neuromuscular systems.



Personalized 3D modeling and mechanical properties



Personalized neuromuscular control



*Validated models*

*against*



*real life*



# Biplanar radiographs : the true story



**G. Kalifa**  
Radiologist

*Low-dose  
radiographs*



**G. Charpak**  
Physicist



**J. Dubousset**  
Surgeon

*Medical Imaging  
analysis*



**W. Skalli**  
Biomechanist

*Stereo-  
radiography*



**J. De Guise**  
Biomedical Engineer

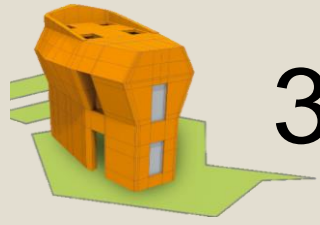


**The EOS System:  
How does it work?**

First systems in hospitals in 2008.

Now in 51 countries.

Around 350 machines worldwide.

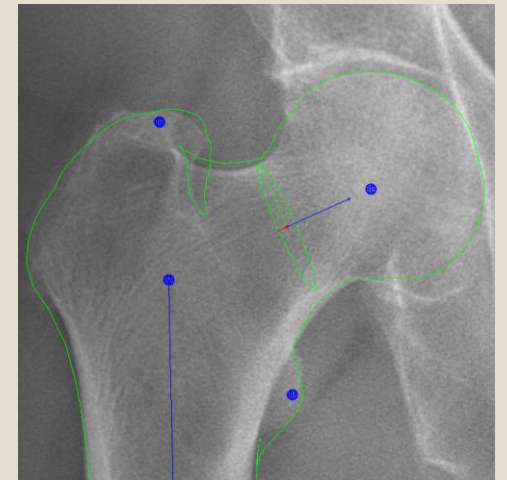
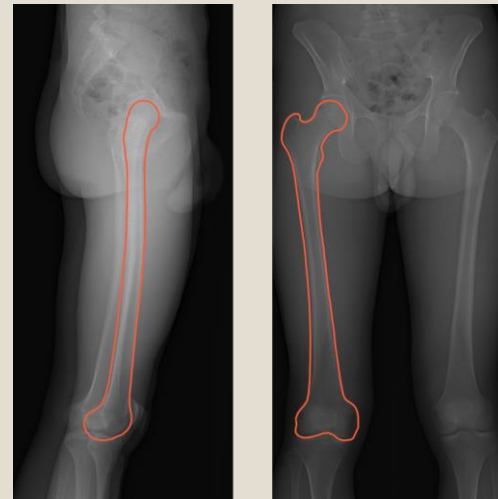
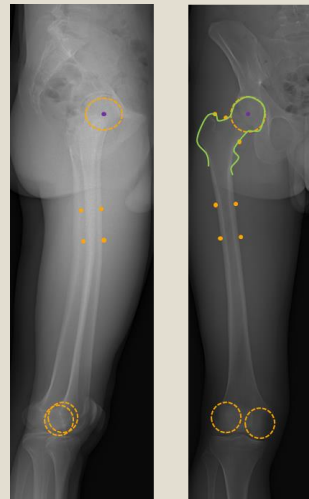
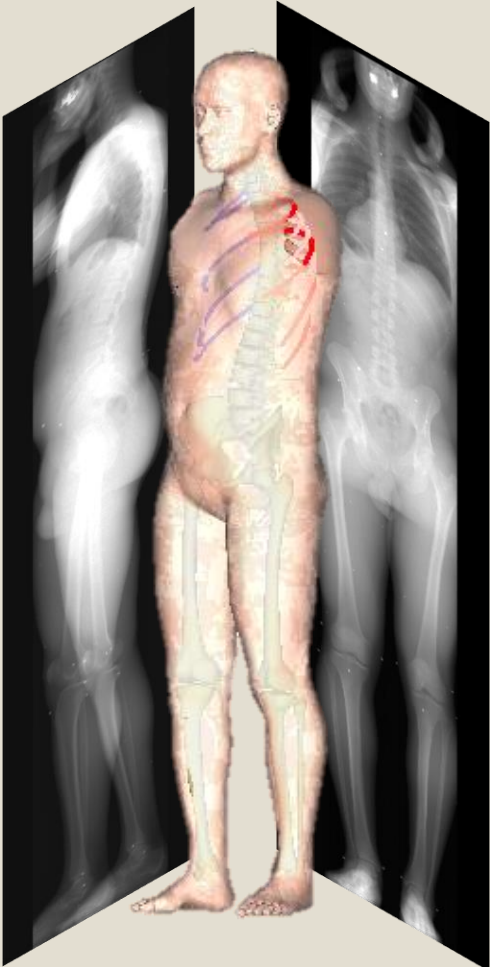
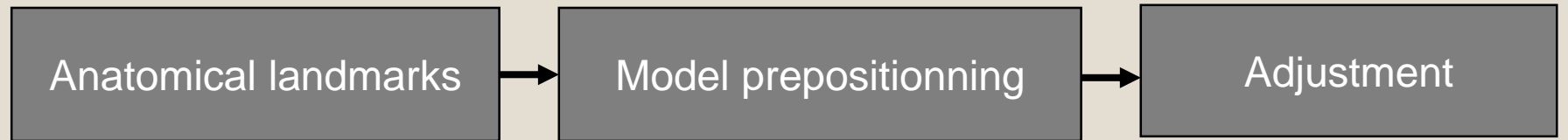


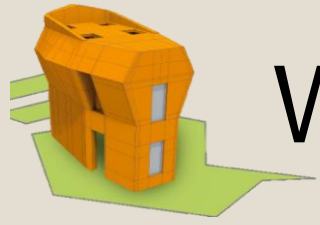
# 3D reconstruction from biplanar X-rays

Reproducible reconstruction methods. Some are available in clinical routine :

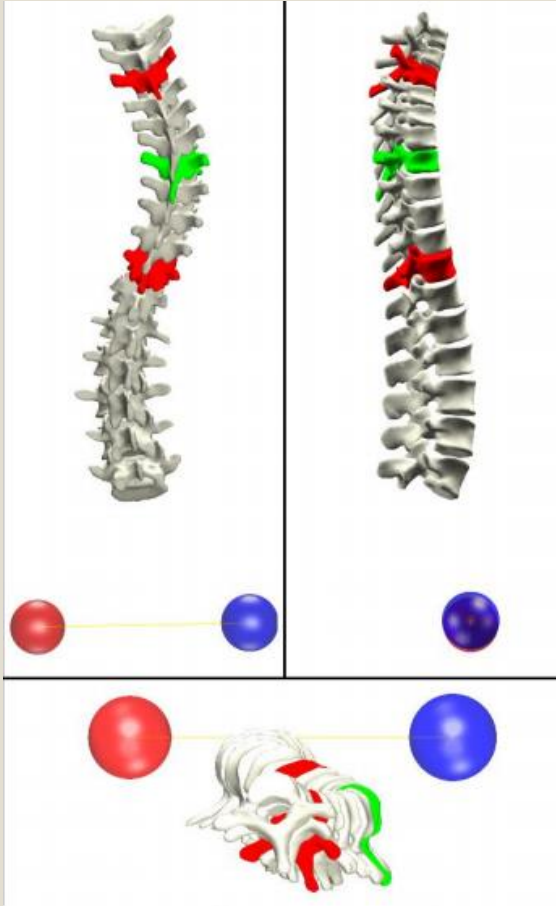
Spine : Humbert et al., 2009

Lower limb : Chaibi et al, 2012; Quijano et al., 2013

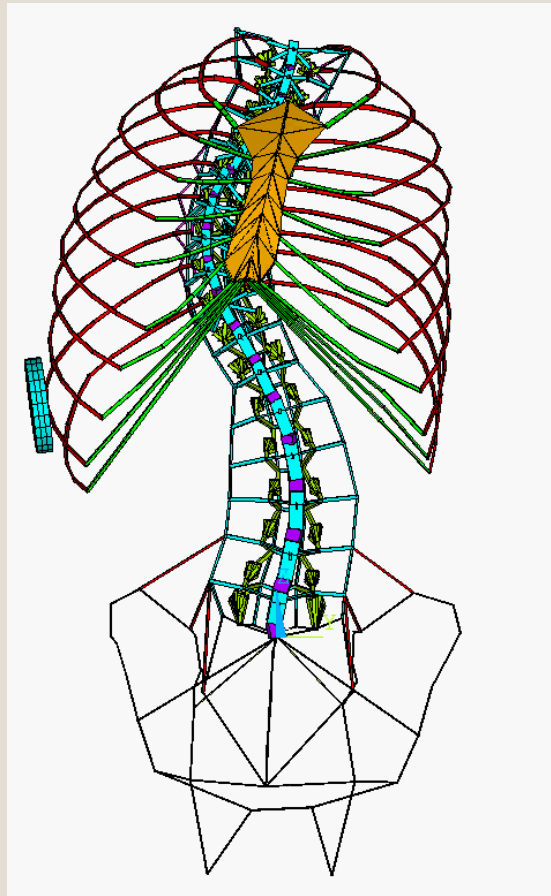




# Wafa Skalli : « 3D, so what ? »



**3D analysis**  
(Skalli et al., 2016)



**3D simulation**  
(Vergari et al., 2016)

3D modeling is a tool.  
Not the end of our work !

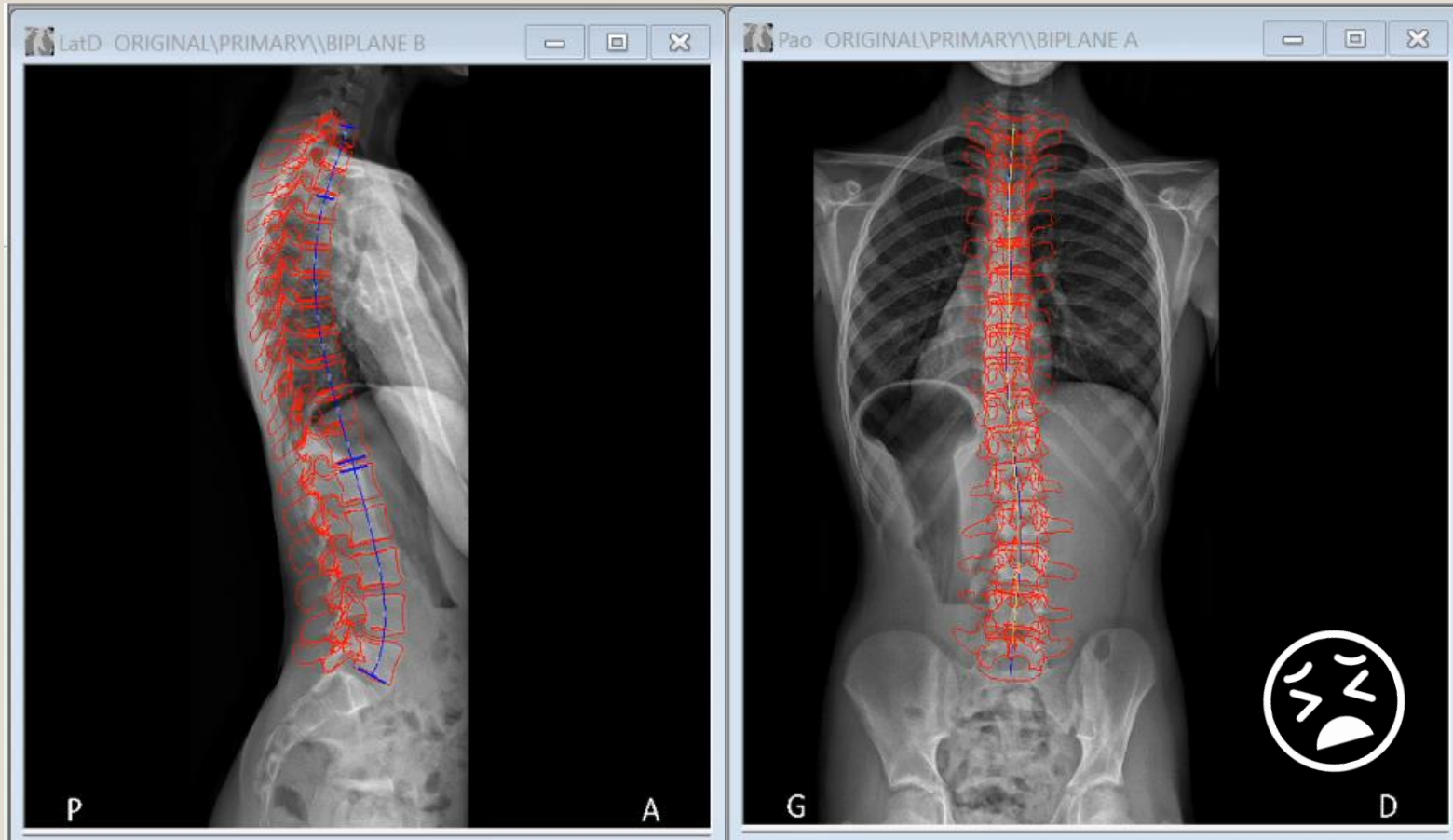
*... but most of the time, the end of mine 😊*

3D parameters (postural or morphological) helps assessing quantitatively a pathology (analysis, predictive tools)

3D simulations can help planifying treatments.



# A great story but ???



## Internal survey, 2015

13 qualified operators responded.

**3400 recons. per year !**

**1500h per year !**

**My aim :**  
Make these methods as automated as possible !



# Outline

1

The common scheme

2

New methods

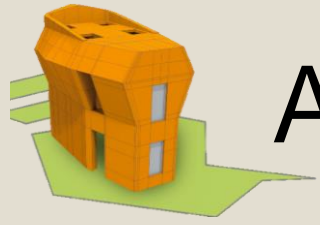
3

What's next ?

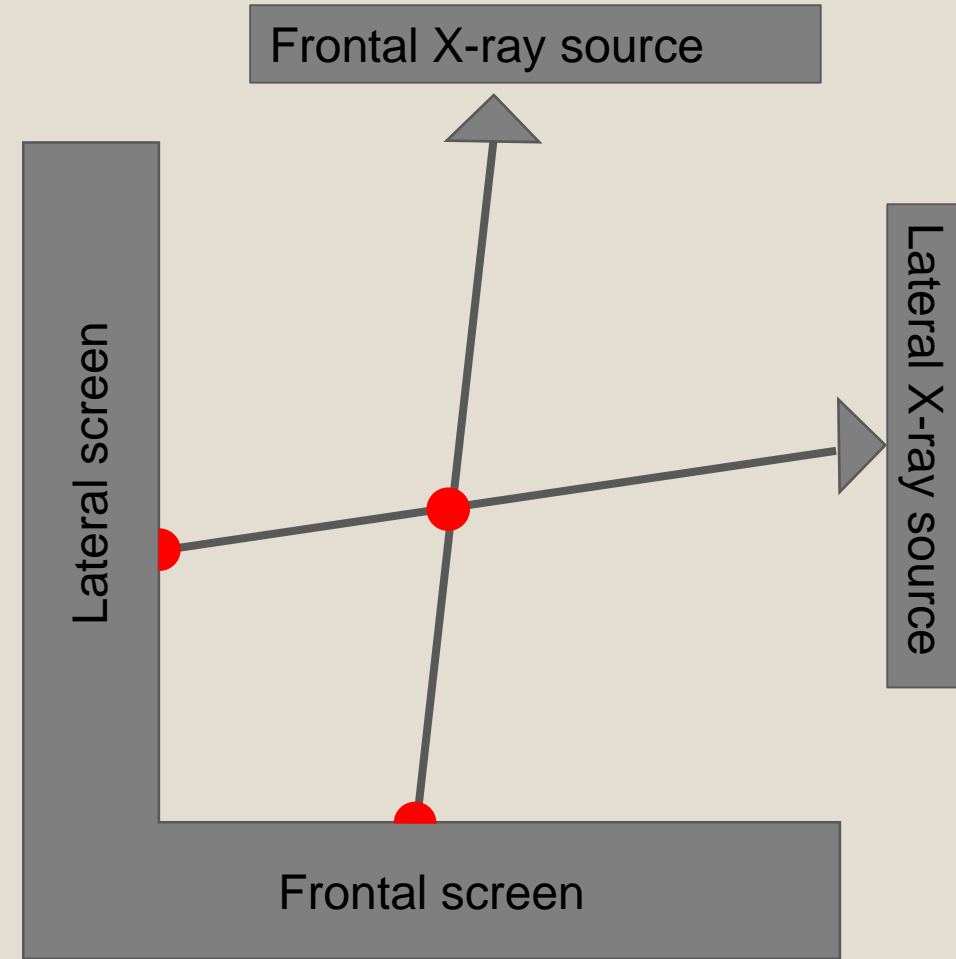
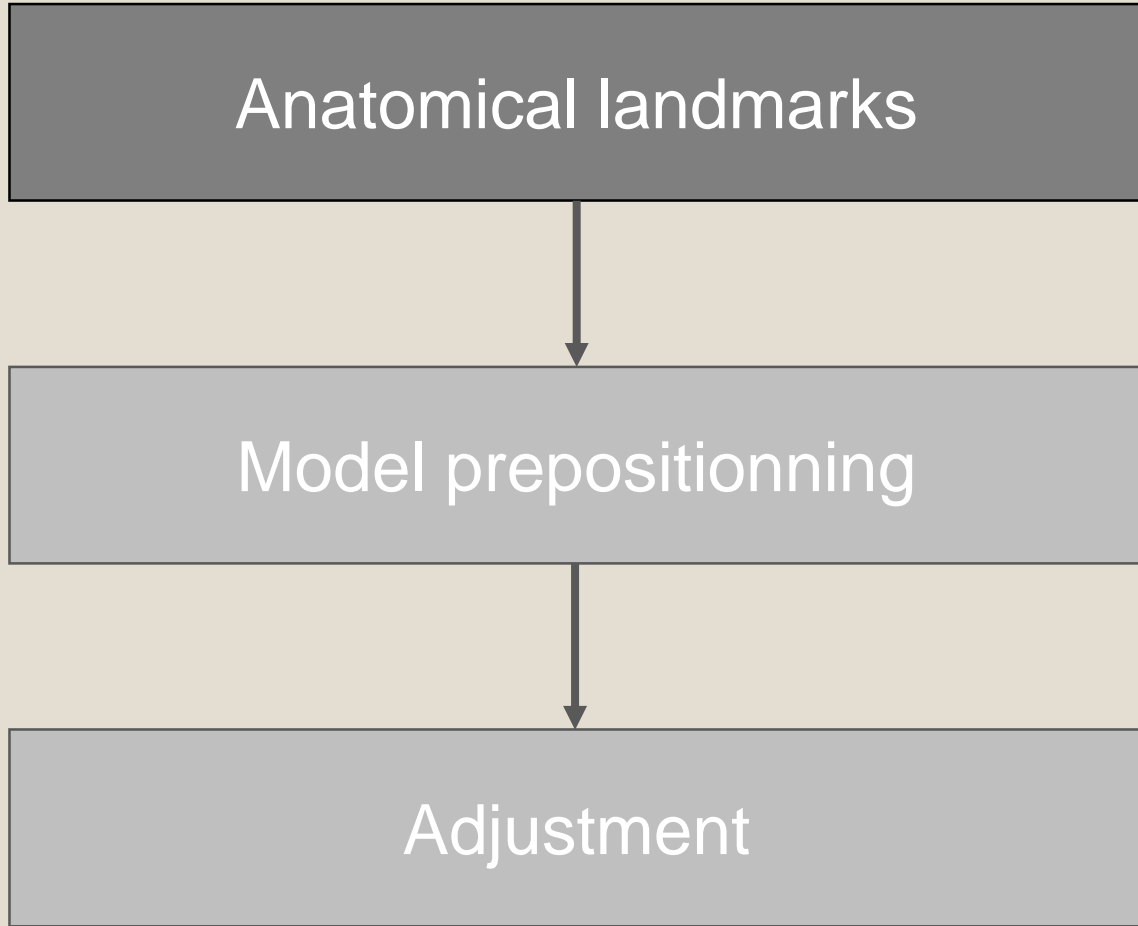
# The common scheme

*Toward automated 3D reconstruction of the human body from biplanar X-rays*

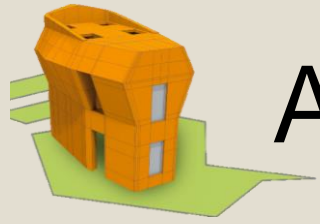




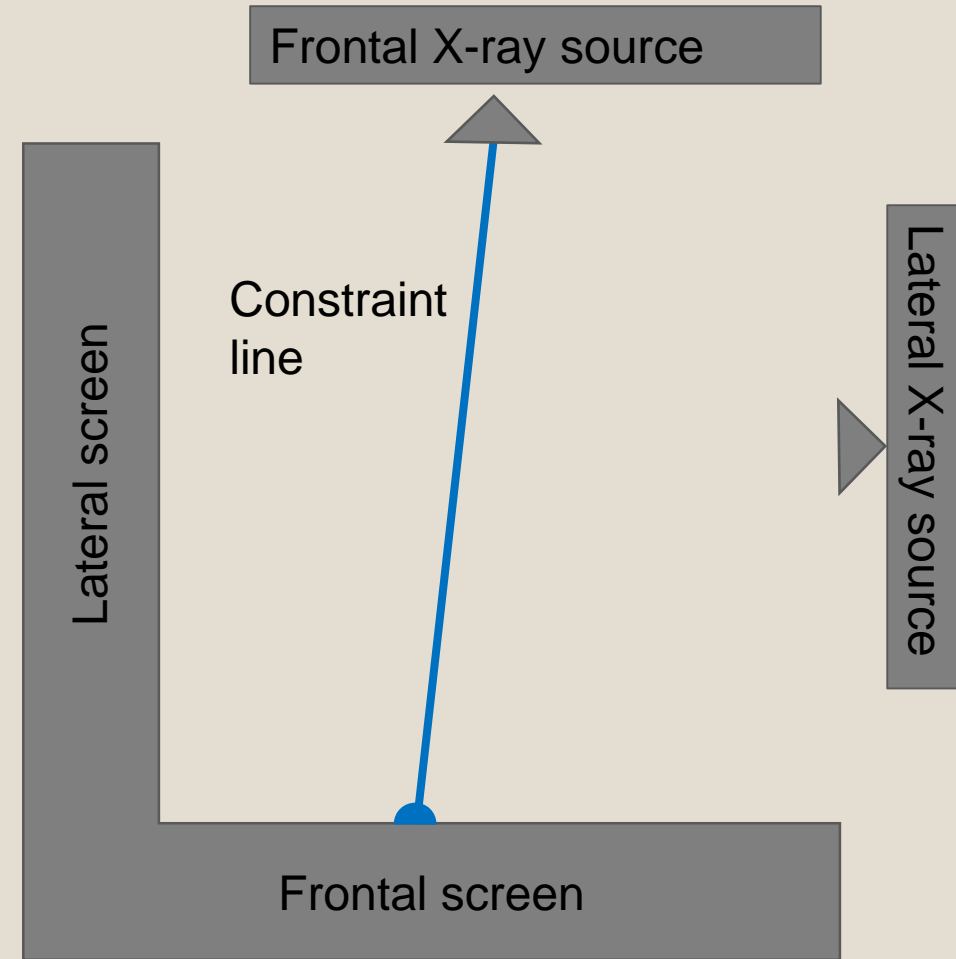
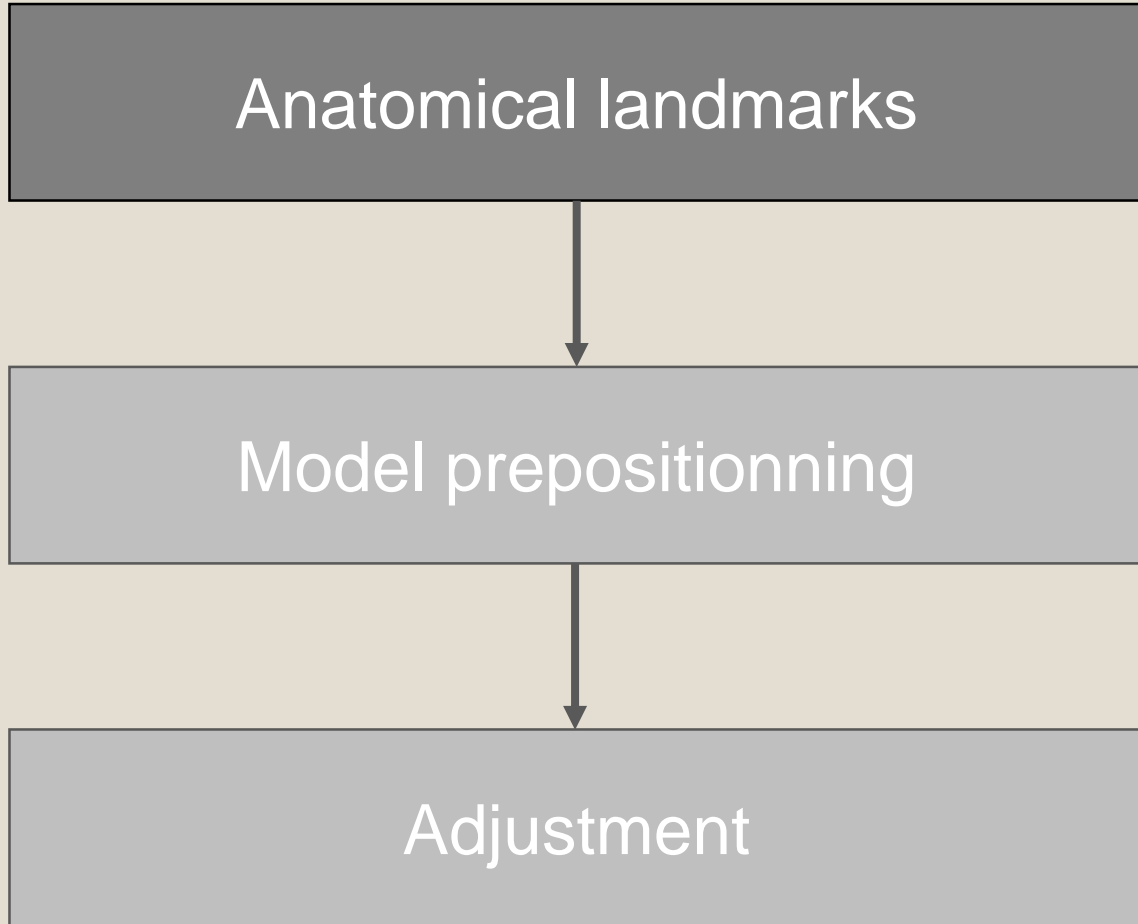
# A common workflow



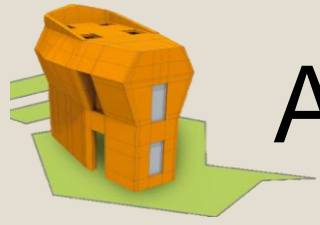
● Stereo-corresponding point (SCP)



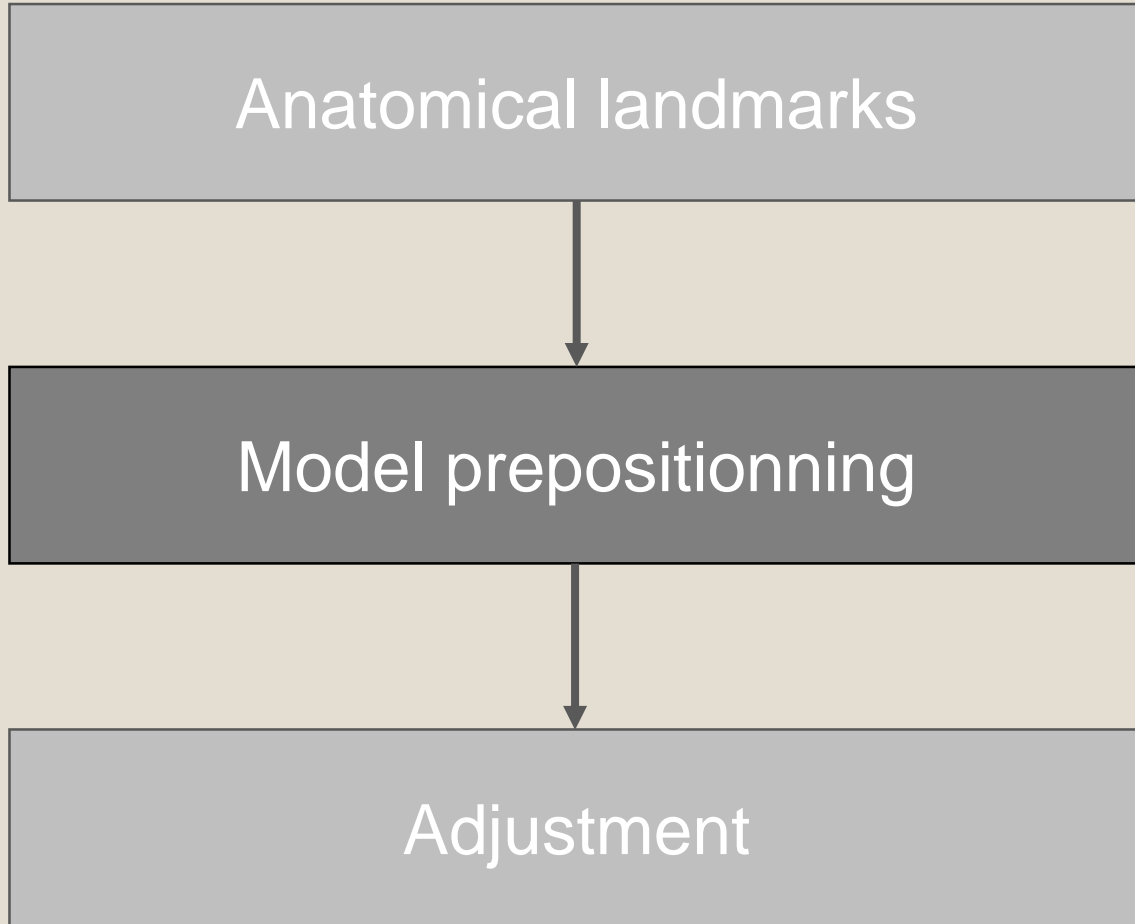
# A common workflow



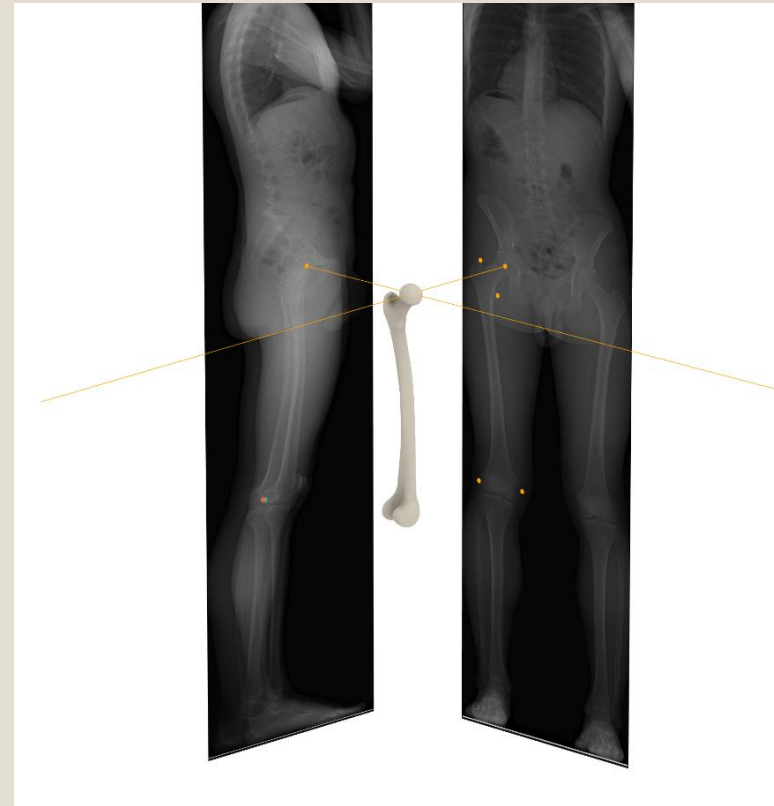
● Non-stereo-corresponding point (NSCP)

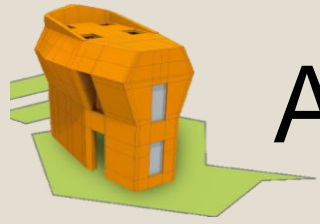


# A common workflow

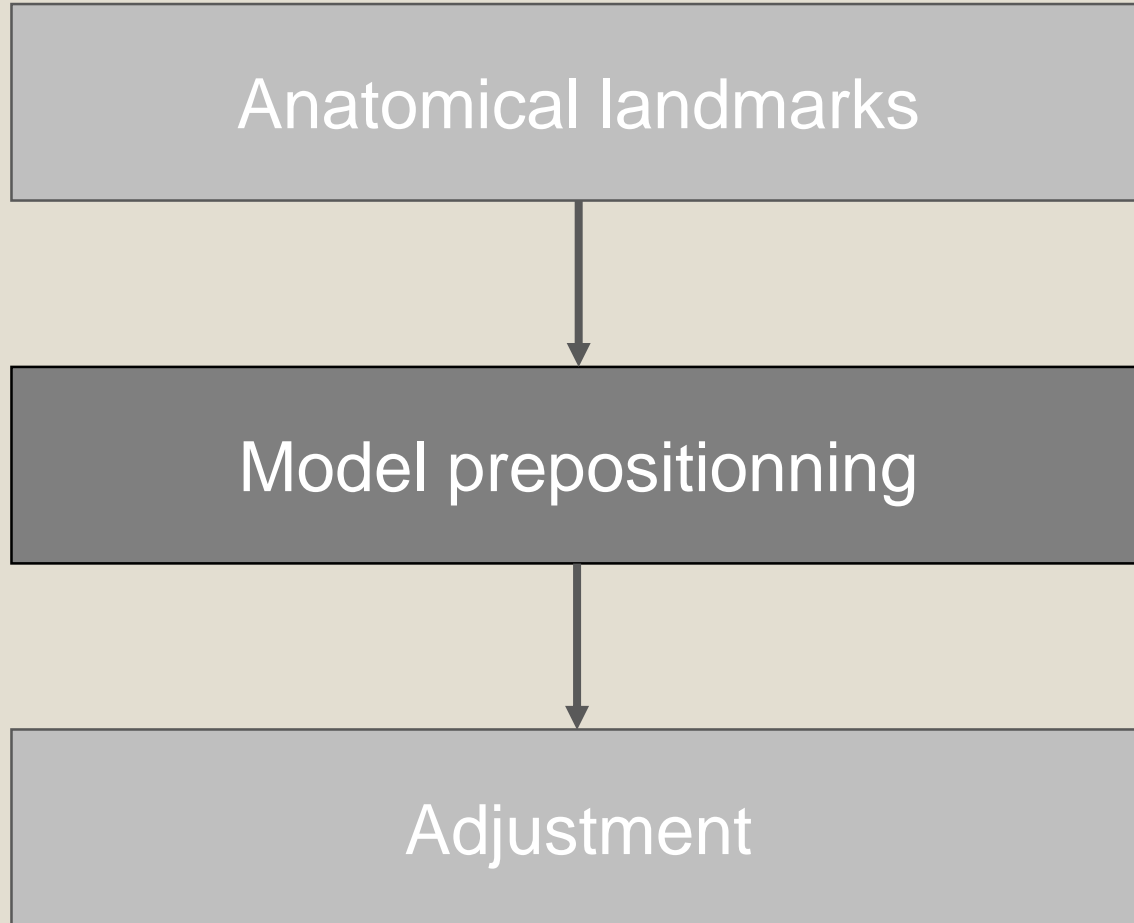


Deformation of a generic template or a statistical shape model to fit the annotated **SCP** data.

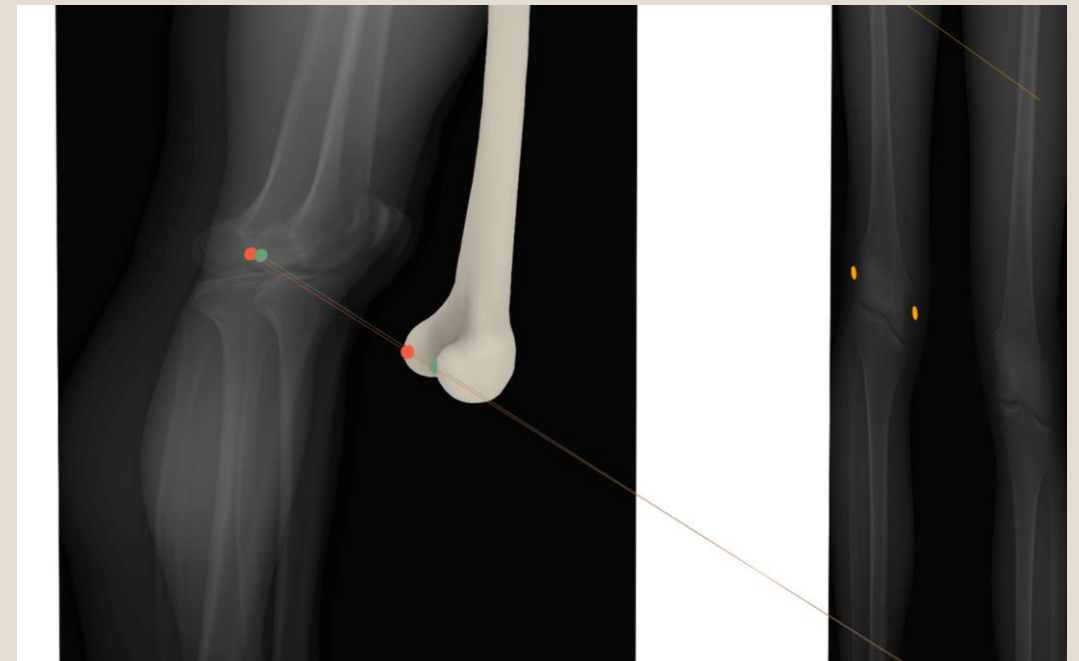




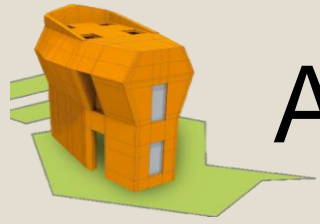
# A common workflow



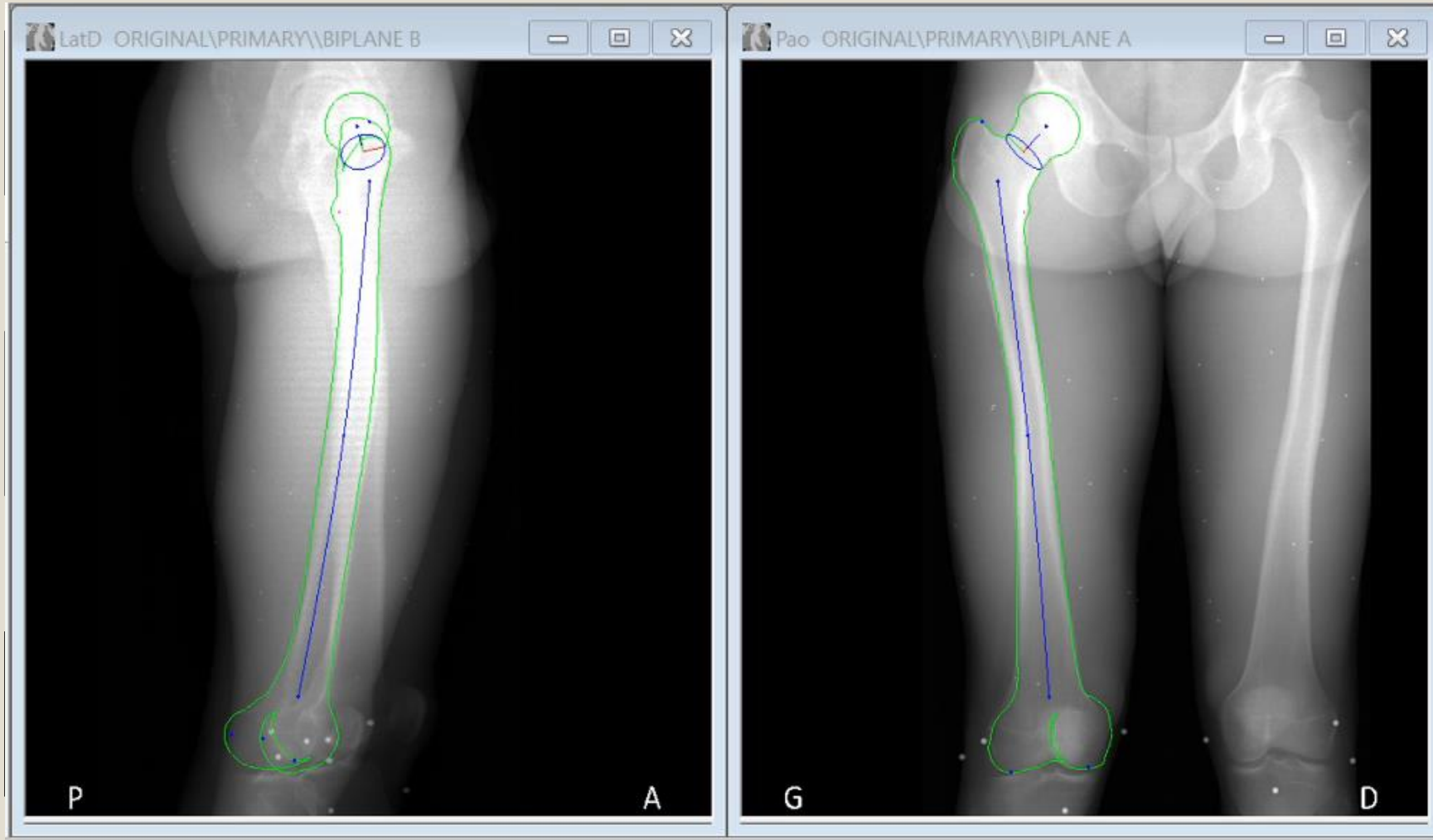
Deformation of a generic template or a statistical shape model to fit the annotated **NSCP** data.



**Typical methods** : Moving Least Squares (Cuno et al., 2007); Posterior Shape Model (Albrecht et al., 2013).



# A common workflow



Fine **manual** deformation of a parametric model (**Moving Least Squares**)

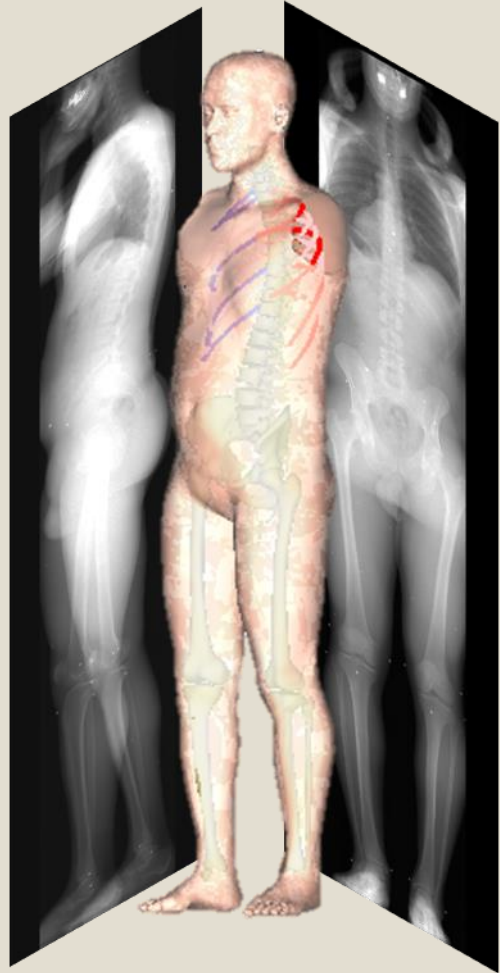
**Manual** contour matching possible using **kriging interpolation/thin plate splines**.

# New methods

*Toward automated 3D reconstruction of the human body from biplanar X-rays*



# Operator time. How far along are we?



2015

Spine : 10 min  
Rib cage : 10 min  
Pelvis : 10 min  
Lower limbs : 10min  
Body shape : 20 min

2020

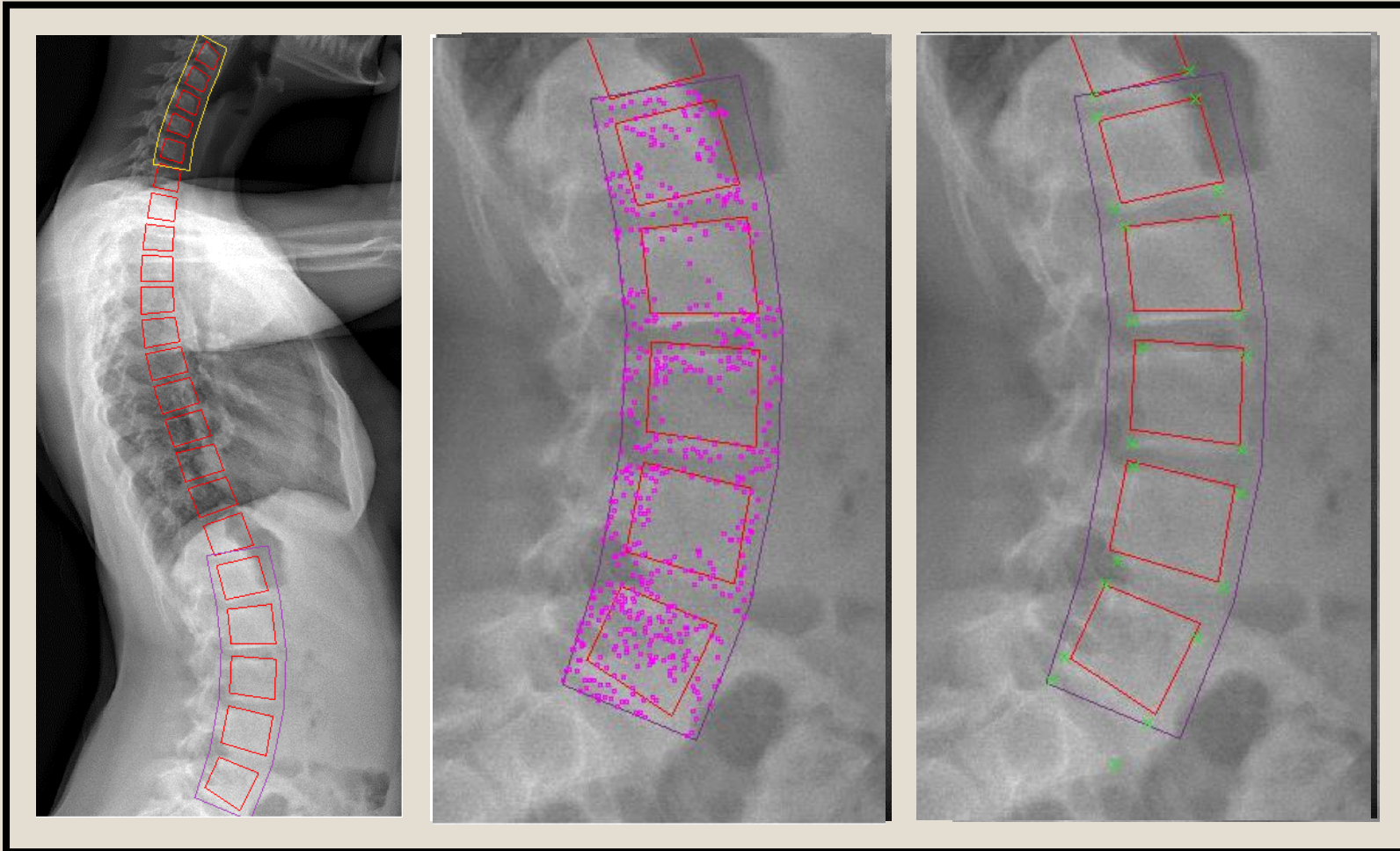
Spine : 4 min  
Rib cage : 10 min  
Pelvis : 2 min  
Lower limb : 5min  
Body shape : 10 min

The main source of improvement ?

Computer vision



# A first example : landmark detection



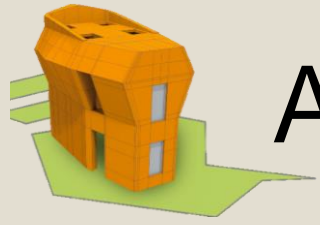
**Shahin Ebrahimi**  
PhD IBHGC, 2017

PostDoc à York  
Univ., Toronto

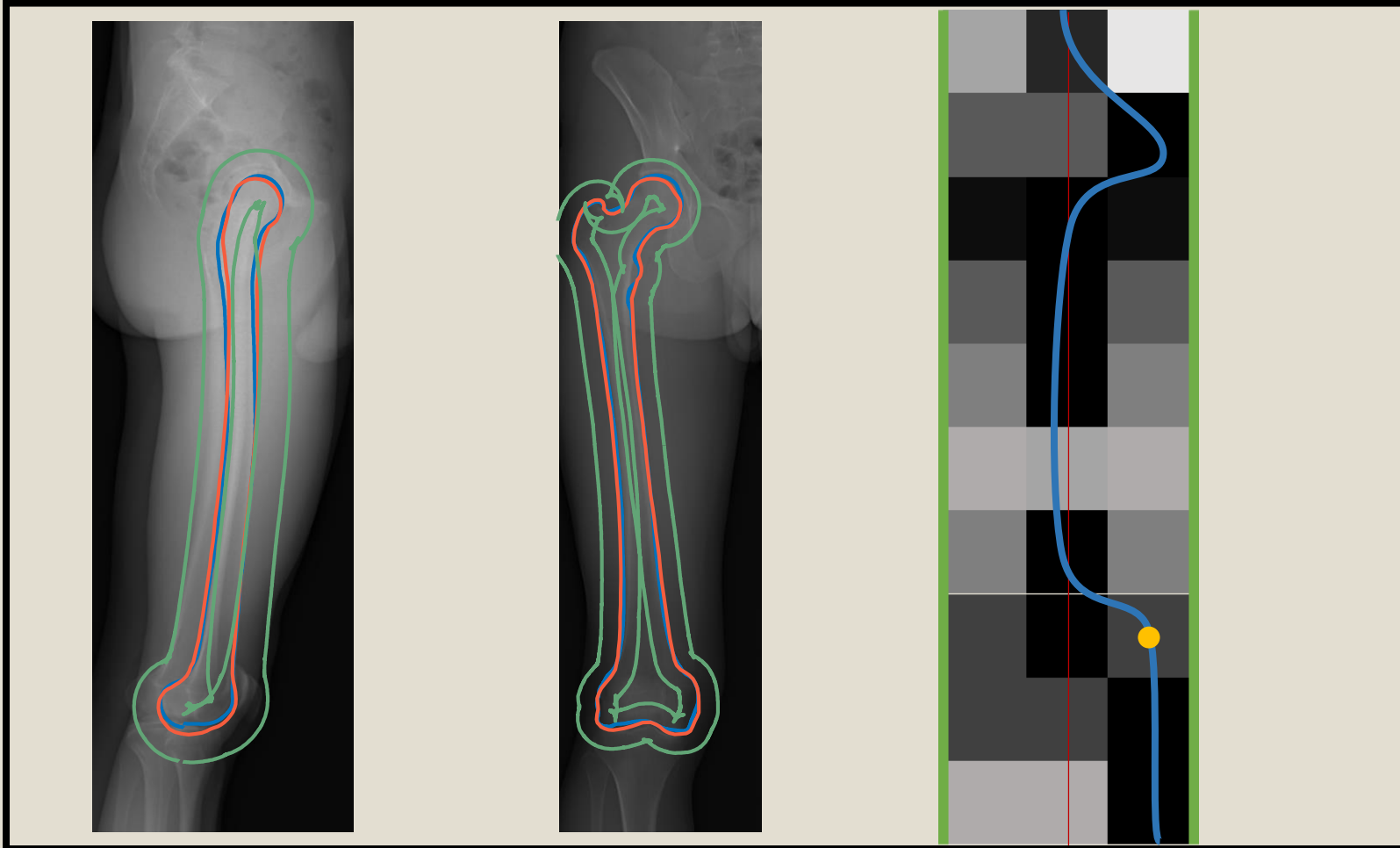
1. **ROI and candidate extraction** from initial solution
2. **Visual descriptors computation** (image gradient, grey scale distribution, corner descriptors)
3. **Classification** using Random Forest.

Shahin Ebrahimi, Laurent Gajny, Wafa Skalli & Elsa Angelini (2019) Vertebral corners detection on sagittal X-rays based on shape modelling, random forest classifiers and dedicated visual features, *Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization*, 7:2, 132-144





# A second example : contour matching



**François Girinon**  
PhD IBHGC, 2018

R&D Engineer  
IMACTIS Grenoble

An iterative shortest-path algorithm based on 3 costmaps :

1. **Oriented gradient** Chav et al., 2015
2. **Statistical cost** based on a built-in Statistical Shape Model.
3. **Manual annotation costmap**

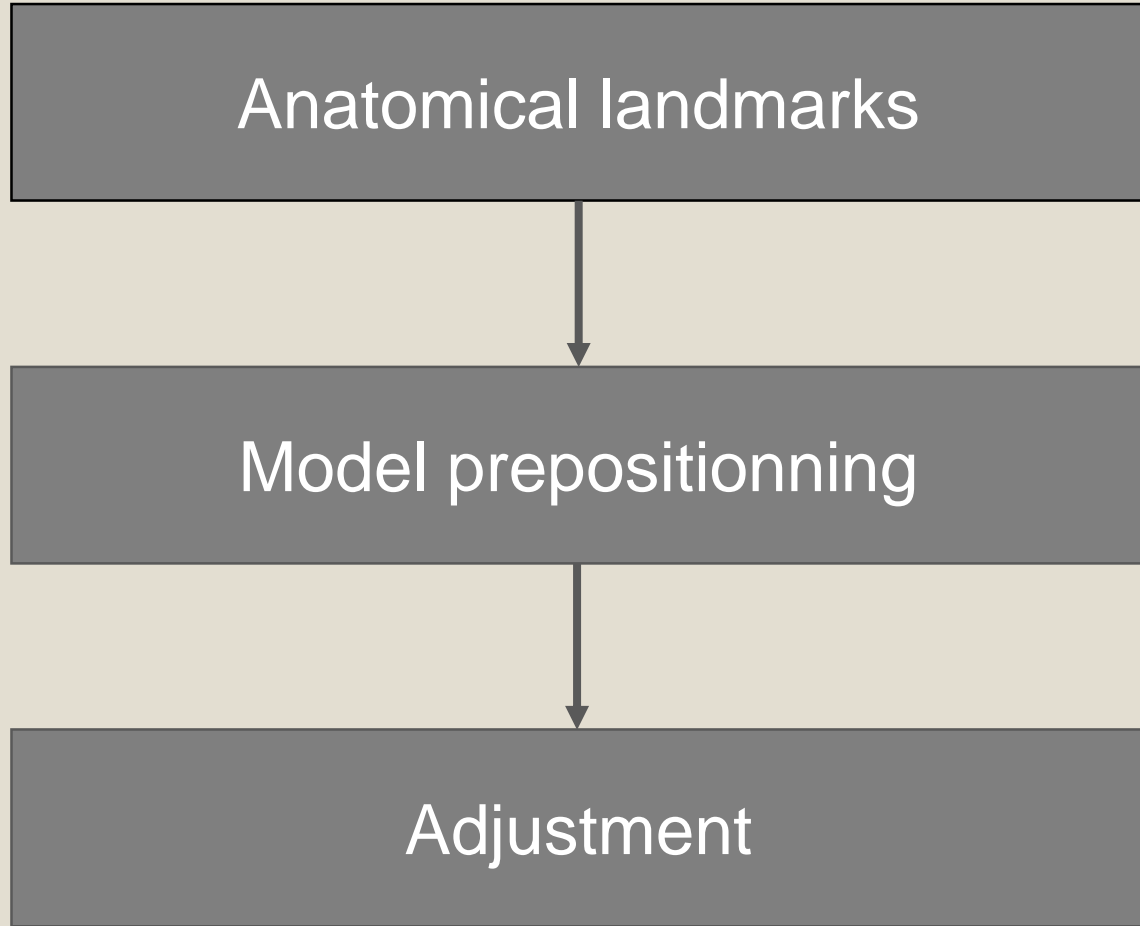
François Girinon, Laurent Gajny, Shahin Ebrahimi, Louis Dagneaux, Philippe Rouch & Wafa Skalli (2020) Quasi-automated reconstruction of the femur from bi-planar X-rays, *Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization*.

# What's next ?

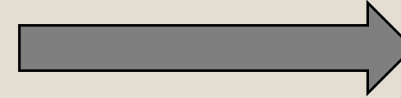
*Toward automated 3D reconstruction of the human body from biplanar X-rays*



# Our next objective : fully automated methods



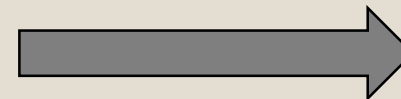
Now !

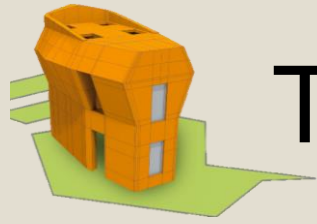


**DEEP LEARNING !**



From 2015 to 2020





# Towards massive data ? The spinal midline

**Database** : 138 patients. Radiographs and reconstructions.



3D model from new method

3D vertebral body



projection



Reference segmentation



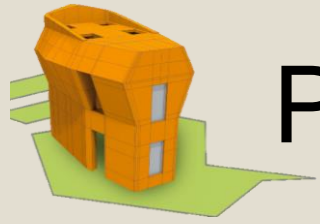
**Zixin Yang**  
MSc. BME Paris, 2019

PhD Student,  
Rochester Institute of  
Technology (USA)

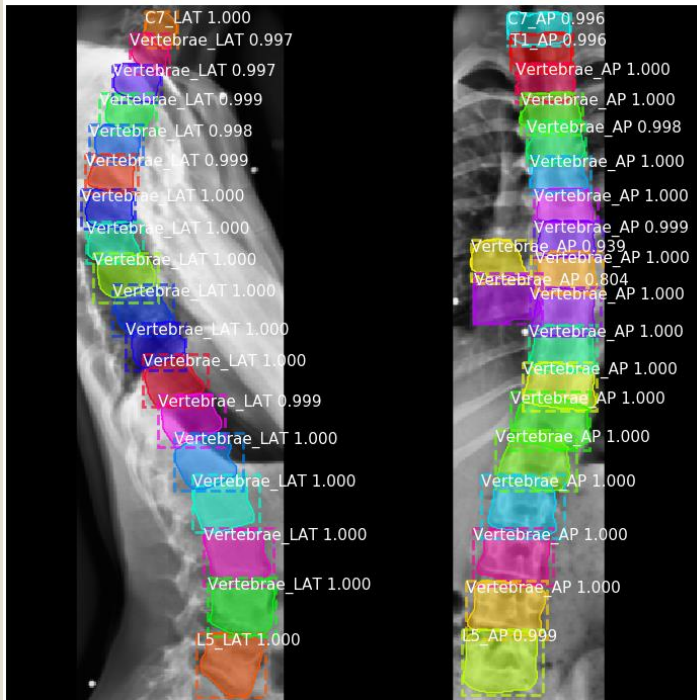
**His aim was :**

Segment the spine and extract  
**the spinal midline :**

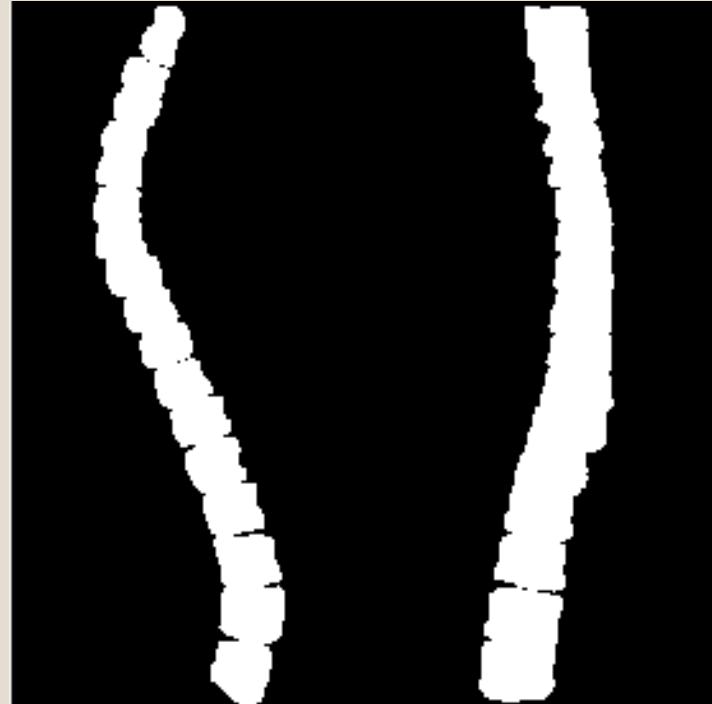
A key-element for  
prepositionning the 3D model !



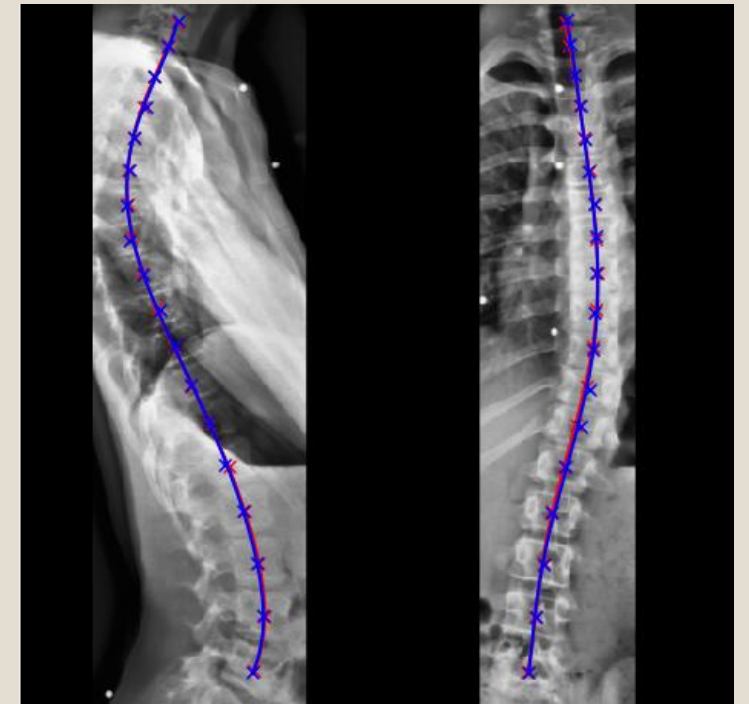
# Pipeline of the method



Segmentation using  
Mask R-CNN



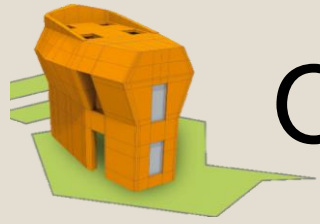
Binary mask after  
post-processing



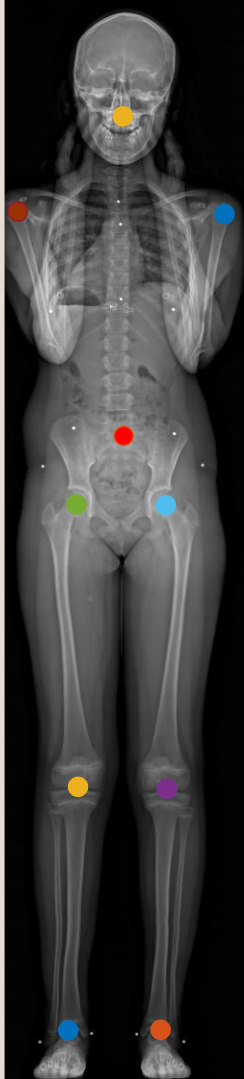
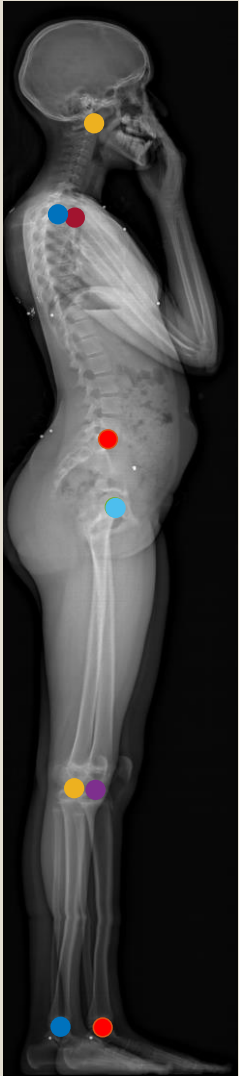
Skeletization

**Mean RMSE (lateral) : 1mm**  
**Mean RMSE (frontal) : 2mm**

Zixin Yang, Wafa Skalli, Claudio Vergari, Elsa Angelini, Laurent Gajny. Automated spinal midline delineation on biplanar X-rays using Mask R-CNN. In: Tavares J., Natal Jorge R. (eds) VipIMAGE 2019. VipIMAGE 2019. Lecture Notes in Computational Vision and Biomechanics, vol 34. Springer, Cham.



# Our next move



**Matteo Bovio**

PhD student, 2020

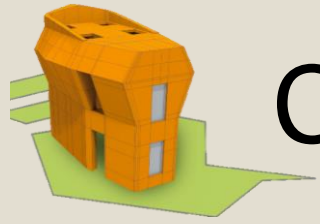
Full-body approach

## Why ?

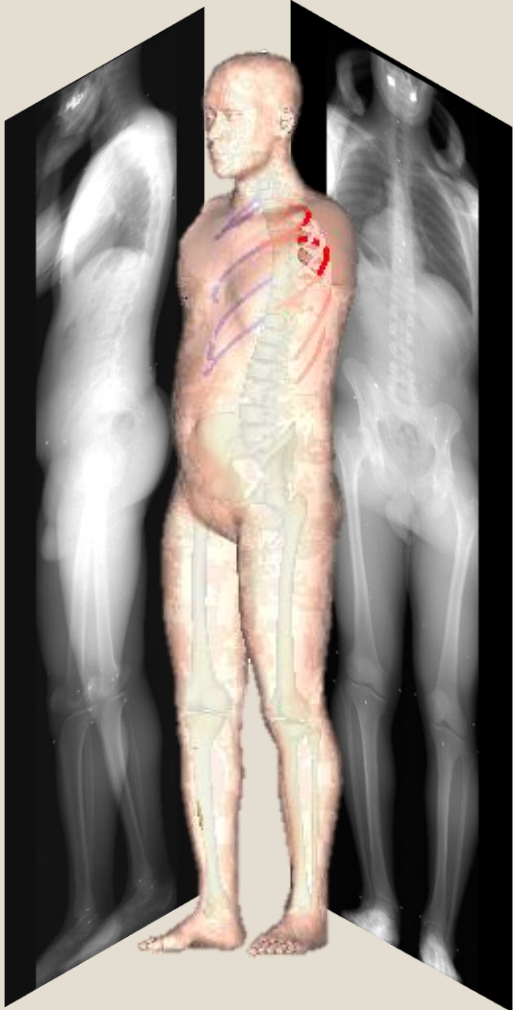
Postural pathologies usually affects the full body.

Separated methods lead to interpenetration.

Cumulated reconstruction time is still important.



# Concluding remarks



Stereoreconstruction of anatomic structures from a couple of X-rays is feasible.

More, it is done and validated !

Many improvements for automation.  
But It still requires a bit of manual intervention.  
A hindrance to large-scale clinical deployment !

Computer vision, in particular deep learning, will solve this soon.



# Thank you for your attention !

Special thanks to the BiomecAM chair program sponsors :



@BiomecaENSAM