A robust method to compute the 3D symmetry line and the torsion of the human back surface: Application to scoliosis

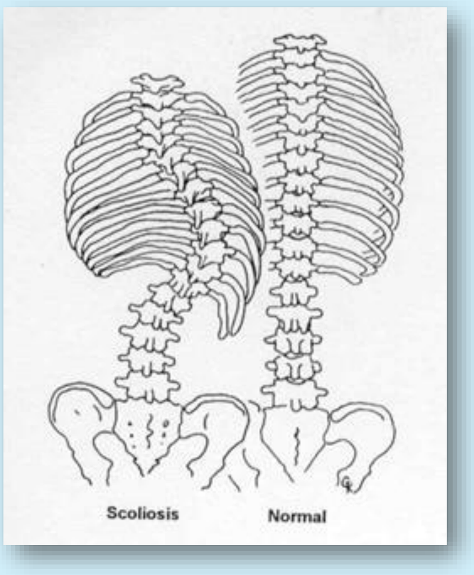
Marion MORAND [1,2], Olivier COMAS [2] , Christophe FIORIO [1] and Gérard SUBSOL [1]

1. Research team ICAR, LIRMM, University of Montpellier / CNRS, France
2. DMS Imaging, Mauguio, France

mmorand@dms-imaging.com

INTRODUCTION

Scoliosis is a lateral deviation of the spine with rotations of vertebra, which provokes trunk asymmetries.



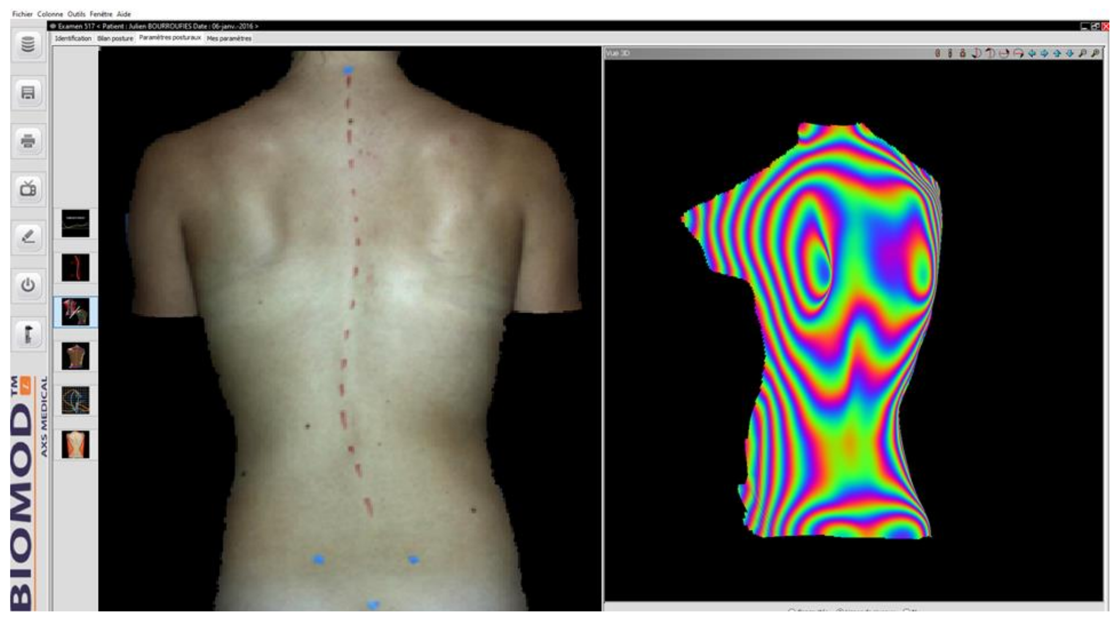
Scoliosis deformation

Spine X-ray (front view)

BIOMOD ACQUISITION SYSTEM

Optical 3D scanners were designed to overcome X-ray hazards. The BIOMOD acquisition system, based on Moiré topography method, provides a 3D point mesh which represents the back surface.

BIOMOD acquisition system



BIOMOD software

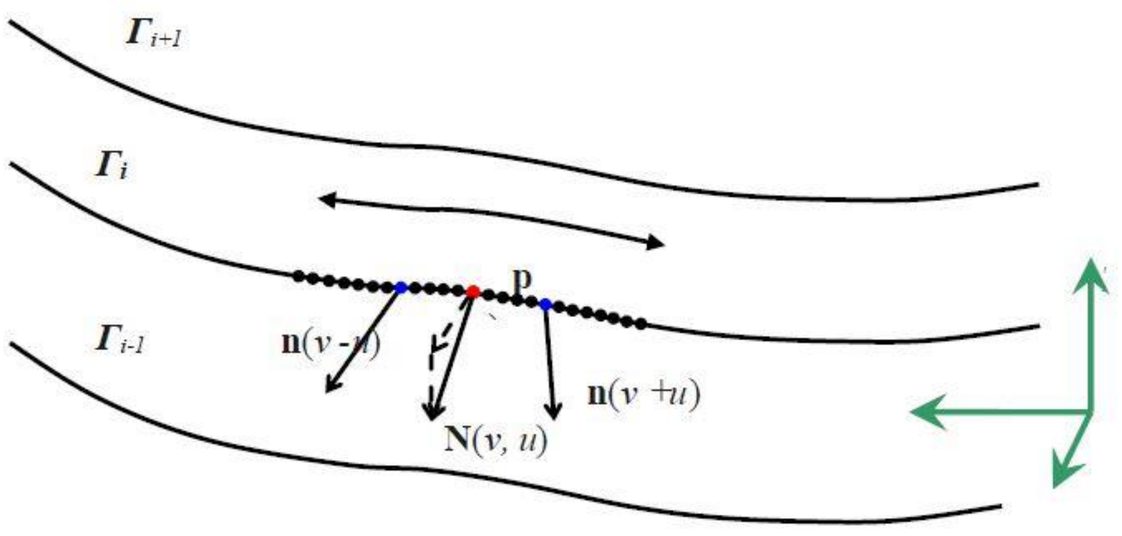
OBJECTIVES In order to emphasise trunk asymmetry, compute automatically the 3D symmetry line and the local torsion of the back surface

REFERENCE METHOD [1]

1. Computation of profile curves by sectioning the back surface by horizontal planes
2. For each profile curve, compute: $N(P(v)) = \underset{\delta\epsilon[-\frac{Lo}{2};\frac{Lo}{2}]}{\text{mean}} \frac{n(v-u)+n(v+u)}{||(v-u)+n(v+u)||}$

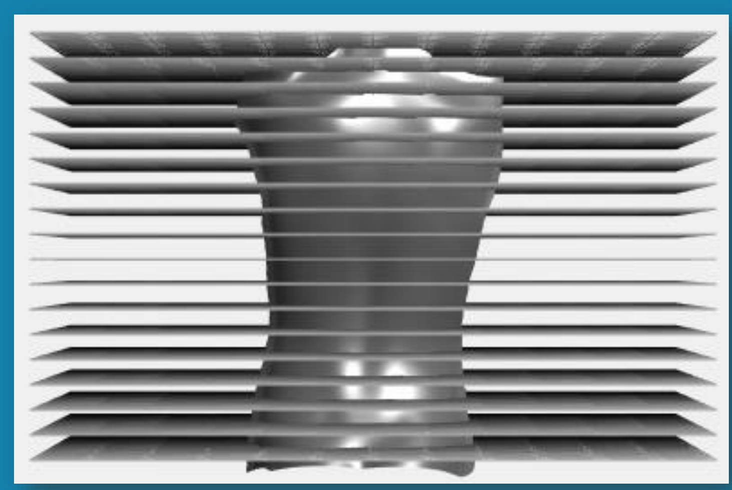
and define the symmetry point Ps by: $N(P) \approx cst \Leftrightarrow Ps = \underset{P}{\text{argmin}} \sqrt{\sigma_{N_x}^2 + \sigma_{N_y}^2}$

3. Estimation of the symmetry line by interpolation of symmetry points



OUR METHOD

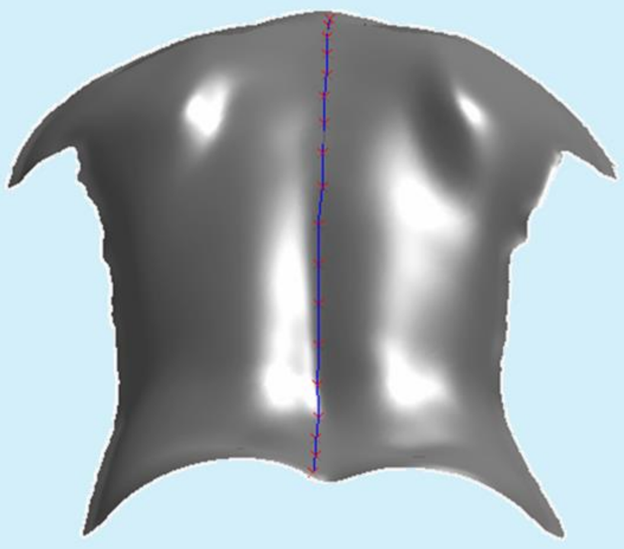
1. Apply a PCA to the back surface mesh and find an approximation of the symmetry plane
2. Define 18 equidistant layers of surface points



3. For each layer, refine the plane by using the ICP-based method [2]
   a. Reflect the points within the layer over the plane
   b. Register the original point cloud with the reflected one
   c. Compute the best symmetry plane by least square minimisation
4. Define the symmetry point at the intersection of the midplane of the layer and the back surface
5. Estimation of the symmetry line by interpolation of symmetry point

EXPERIMENTS

1. 21 patients affected by light scoliosis
2. Acquisitions by the BIOMOD system in standing position
3. Computation of the symmetry line by both methods
4. Comparison of the results (horizontal planes of method 1 correspond to layer midplane of method 2)



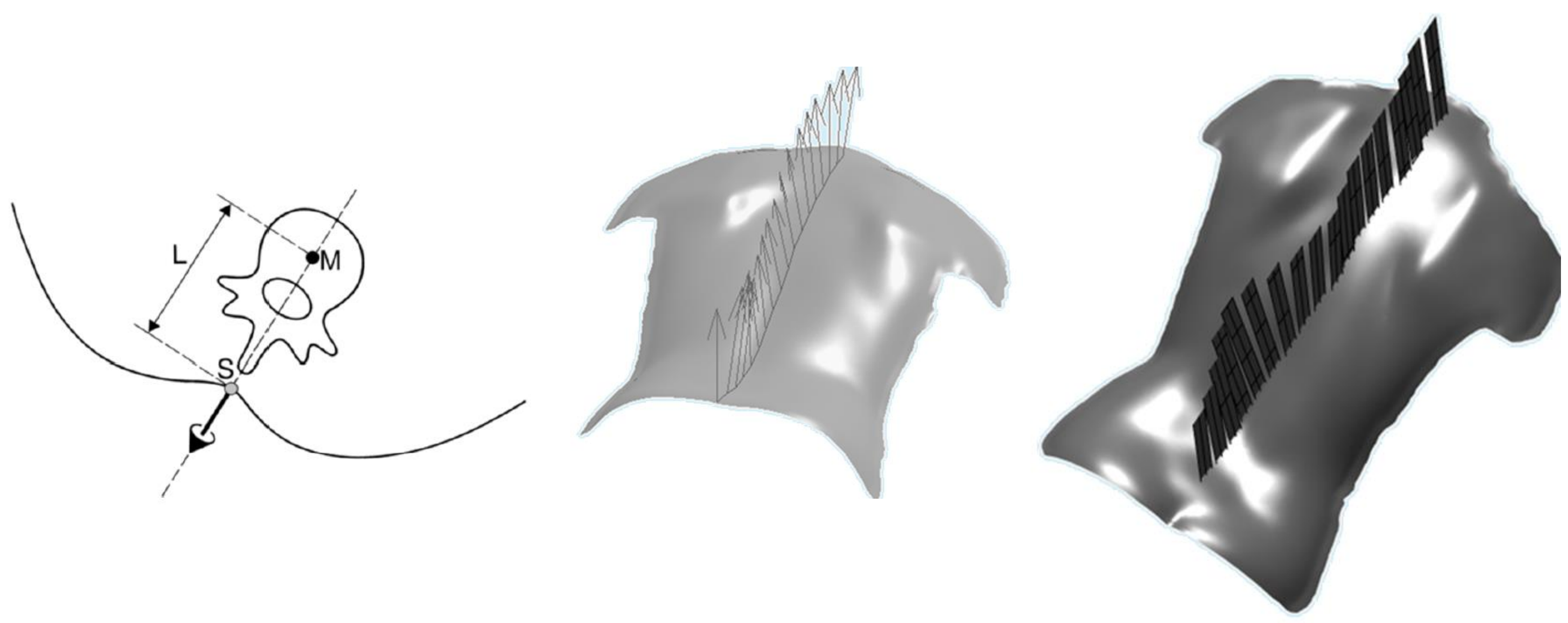
Mean deviation	4.86 mm
Maximum deviation	19.8 mm
Minimum deviation	0.06 mm

Comparison between the blue reference method [1] and our red method

The mean deviation between both methods (4.86 mm) is similar to the mean deviation between the reference method [1] and the manual palpation (5.1 mm).
Maximum deviation occurs when the patient is in shift position.

BACK SURFACE ROTATION

Drerup [3] proposed to compute the direction of the surface normal at the symmetry point and correlated this parameter to the axial vertebral rotation.



Computation of rotations by Drerup [3] (left) and our method (right)

Using a more global approach based on point layers instead of profile curves, we get less-sensitive results to acquisition noise or sampling characteristics.

FUTURE WORK

The preliminary results seem promising and are in the process of validation by comparison with radiographs. We also plan to extend our method to patients in lateral bending or rotation positions.

SURGETICA Strasbourg Nov. 20-22 2017

[1] Di Angelo, L. and Di Stefano, P. and Spezzaneve, A. (2012), Experimental validation of a new method for symmetry line detection. Computer-Aided Design and Applications, 7:1-17.
[2] Combes, B. and Hennessy, R. and Waddington, J. and Roberts, N. and Prima, S. (2008). Automatic symmetry plane estimation of bilateral objects in point clouds. IEEE Conference on Computer Vision and Pattern Recognition, 2008, Anchorage, United States.
[3] Drerup, B. (2014). Rasterstereographic measurement of scoliotic deformity. Scoliosis, 9:22.