AUTOMATIC EXTRACTION OF THE 3D SYMMETRY LINE OF BACK SURFACE: APPLICATION ON SCOLIOTIC ADOLESCENTS

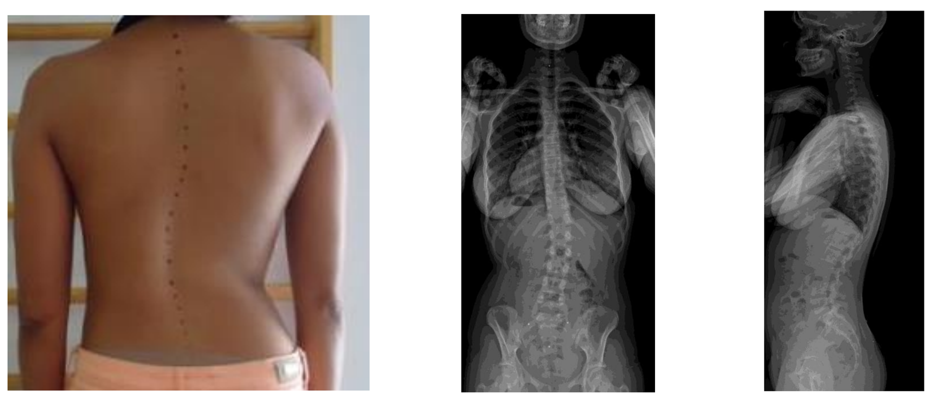
Marion Morand[1,2], Olivier Comas[1], Christophe Fiorio[2], Gérard Subsol[2]

1. DMS Imaging, Nîmes, France
2. Research team ICAR, LIRMM, CNRS - University of Montpellier, France

mmorand@dms-imaging.com

SCOLIOSIS

- Permanent and progressive deformation of the spine
- Detection by clinical examination of the 3D back shape
- Definitive diagnosis by full spine radiographs



3D ACQUISITION SYSTEM

- X-ray dose is a major public health concern, especially with children
- Noninvasive optical systems give a 3D mesh of the back surface
- Define 3D parameters to quantify back surface deformation

BIOMOD system (DMS Imaging)

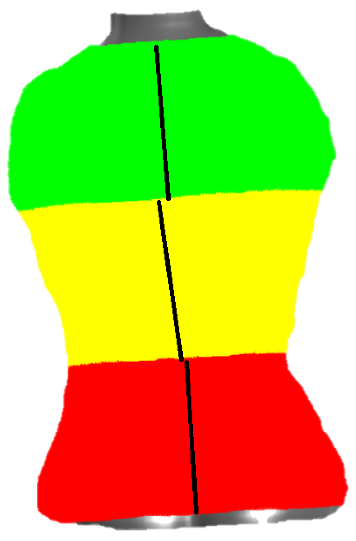
SYMMETRY LINE OF THE BACK

- Estimation of the spinous process line, correlated to the internal spine morphology [1]
- Limits of state-of-the-art methods [2]:
  1) Complex geometry of the back surface (lumbar flat area, large deformations, …)
  2) The spinous process line does not always correspond to the back valley

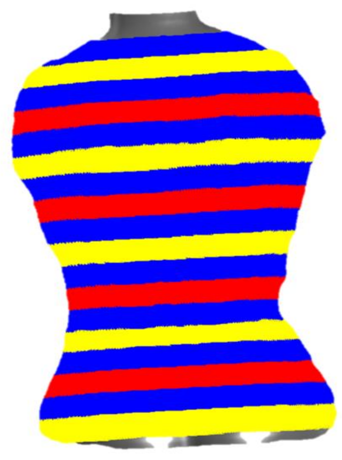
OBJECTIVE: To assess scoliosis, extract automatically the symmetry line

METHOD

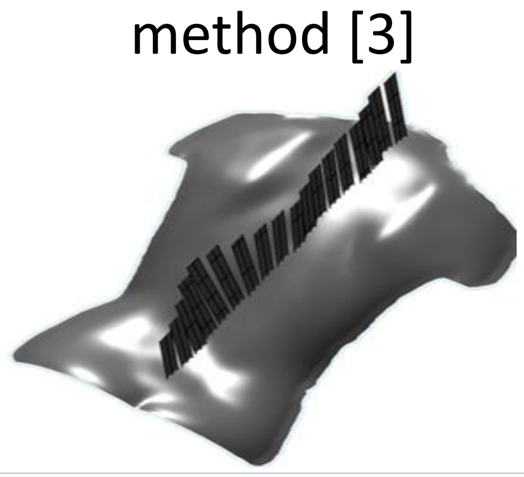
Initialization of the symmetry line by PCA on 3 regions (thoracic sup and inf, lumbar), orthogonally to the direction defined by the prominent vertebra and the intergluteal fold



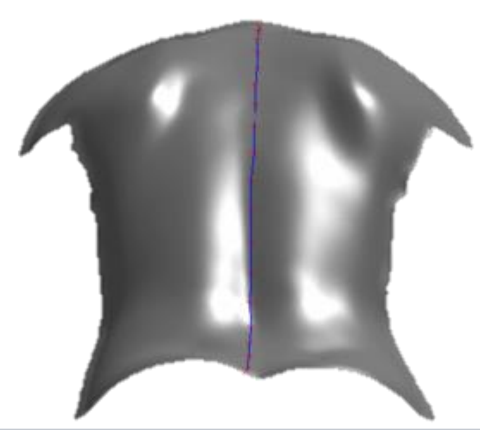
Definition of thick strips, orthogonally to the line



For each strip, compute automatically a symmetry plane by a robust ICP-based method [3]



Creation of the 3D symmetry line by intersection of the symmetry planes and the back surface



RESULTS

- Acquisition of the 3D back surface of 112 patients, affected by scoliosis, in standing position
- Reference line is manually determined by landmarks placed by clinician on spinous processes
- Comparison symmetry line / reference line by Mean Deviation Error, RMSD along the anterio-posterior axis and the right-left axis
- Analysis of the influence of the scoliosis severity (Cobb angle) and the BMI:

	Number of patients	Number of patients/Cobb range			Number of patients/BMI range		
	112	22 / [5° – 15°]	68 / [15° – 25°]	22 / [25° – 54°]	42 / [14 – 17]	58 / [17 – 19]	19 / [19 – 22]
$RMSD_{lat}$ (mm)	4.82 ± 1.81	4.54 ± 1.90	4.89 ± 1.97	4.91 ± 1.08	4.88 ± 1.71	4.84 ± 1.95	4.45 ± 1.36
$RMSD_{depth}$ (mm)	0.69 ± 0.34	0.58 ± 0.33	0.71 ± 0.34	0.73 ± 0.34	0.72 ± 0.34	0.67 ± 0.33	0.74 ± 0.36
MDE (mm)	5.8 ± 2.28	5.57 ± 2.43	5.89 ± 2.44	5.84 ± 1.47	5.91 ± 2.28	5.77 ± 2.37	5.59 ± 1.77

- ➢ Results in the same accuracy range as the state-of-art methods
- ➢ Robust with respect to pathology and morphology variation
- ➢ Promising method to overcome the limitation of existing methods

FUTURE WORK

- Validate the method with 3D spinous process line reconstructed from frontal and sagittal full-spine X-rays
- Extend the method to patients in lateral bending posture
- Study correlation between local symmetry planes and vertebral rotation

[1] Drerup, B. (2014). Rasterstereographic measurement of scoliotic deformity. Scoliosis, 9:22.

[2] Cappetti, N. and Naddeo, A. (2017). A survey of methods to detect and represent the human symmetry line from 3D scanned human back. Advances on Mechanics, Design Engineering and Manufacturing, Springer, 797–808.

[3] 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 Conf. on Computer Vision and Pattern Recognition, Anchorage, USA.

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