3D inference of the spine from a depthmap of the back

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Summary

Goal

Detection • Quantification of spine deformities in 3D

Research question

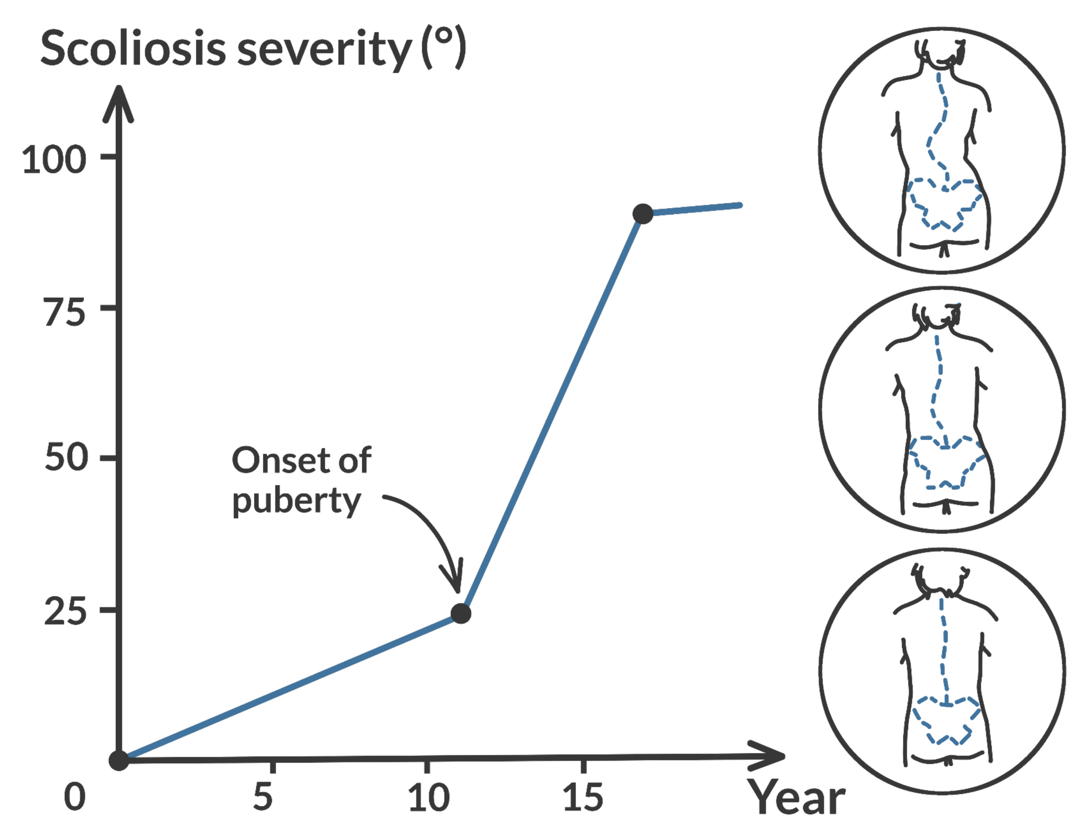
Can we guess scoliosis from a single depthmap ?

Take away message

Depthmaps allow:

- Non-ionizing detection of scoliosis
- Location and quantification of the deformities
- Automatic characterization in 3D

Adolescent Idiopathic Scoliosis



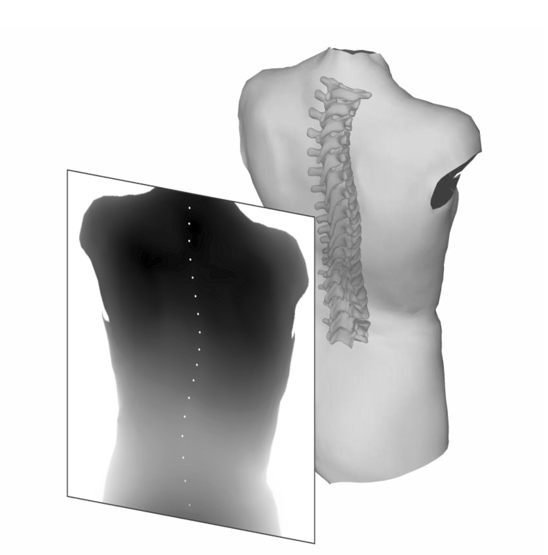
Adaptation from Duval-Beaupere 1984

Dataset

121 subjects (31% with scoliosis) from different sources:

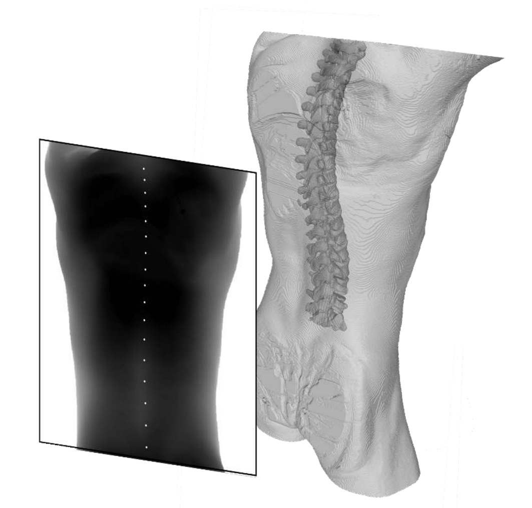
Grenoble Hospital

- 3D avatars using anatomical modeling



NMDID [2]

- Segmentation of CT-Scans



References

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[4] Kokabu et al. An algorithm for using deep learning convolutional neural networks with three dimensional depth sensor imaging in scoliosis detection. *Spine Journal*, 21:980–987, 2021.

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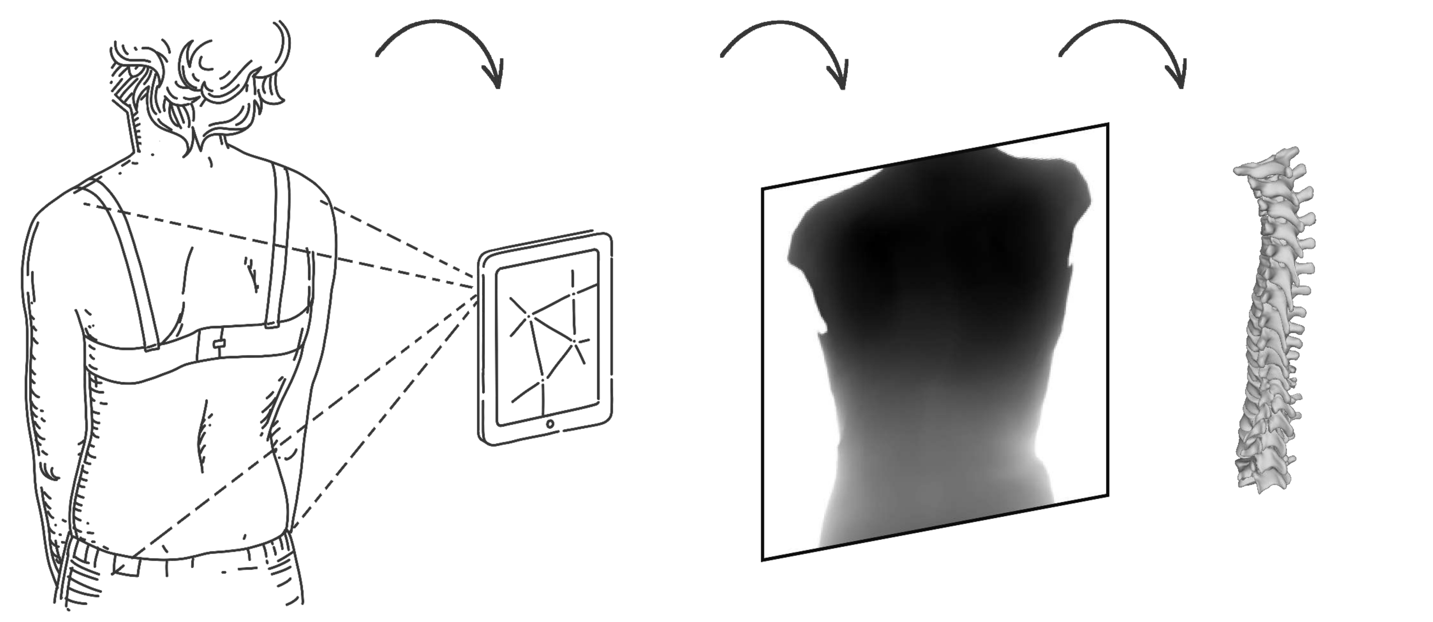
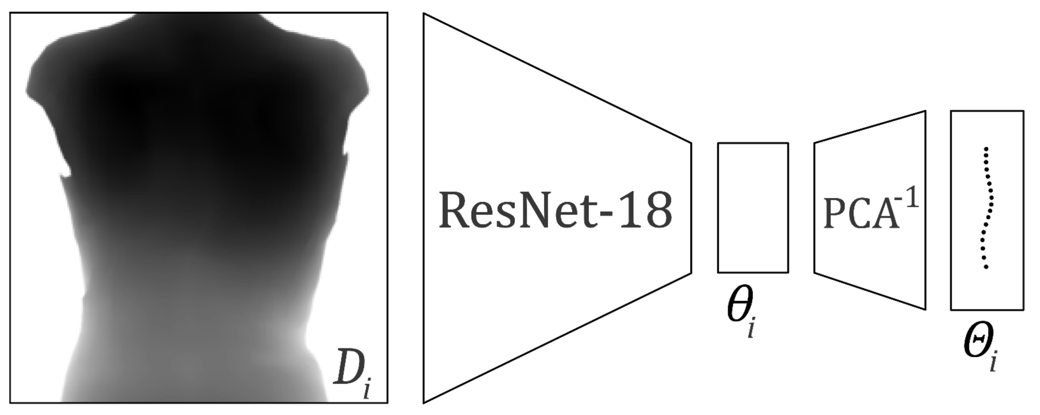
Our approach



Representation

- Skin: Depthmap cropped on ROI
- Spine: 3D vertebra positions (anteroposterior axis relative to T08)
- Curvatures: Cubic B-Splines [1]

Architecture of the regression model

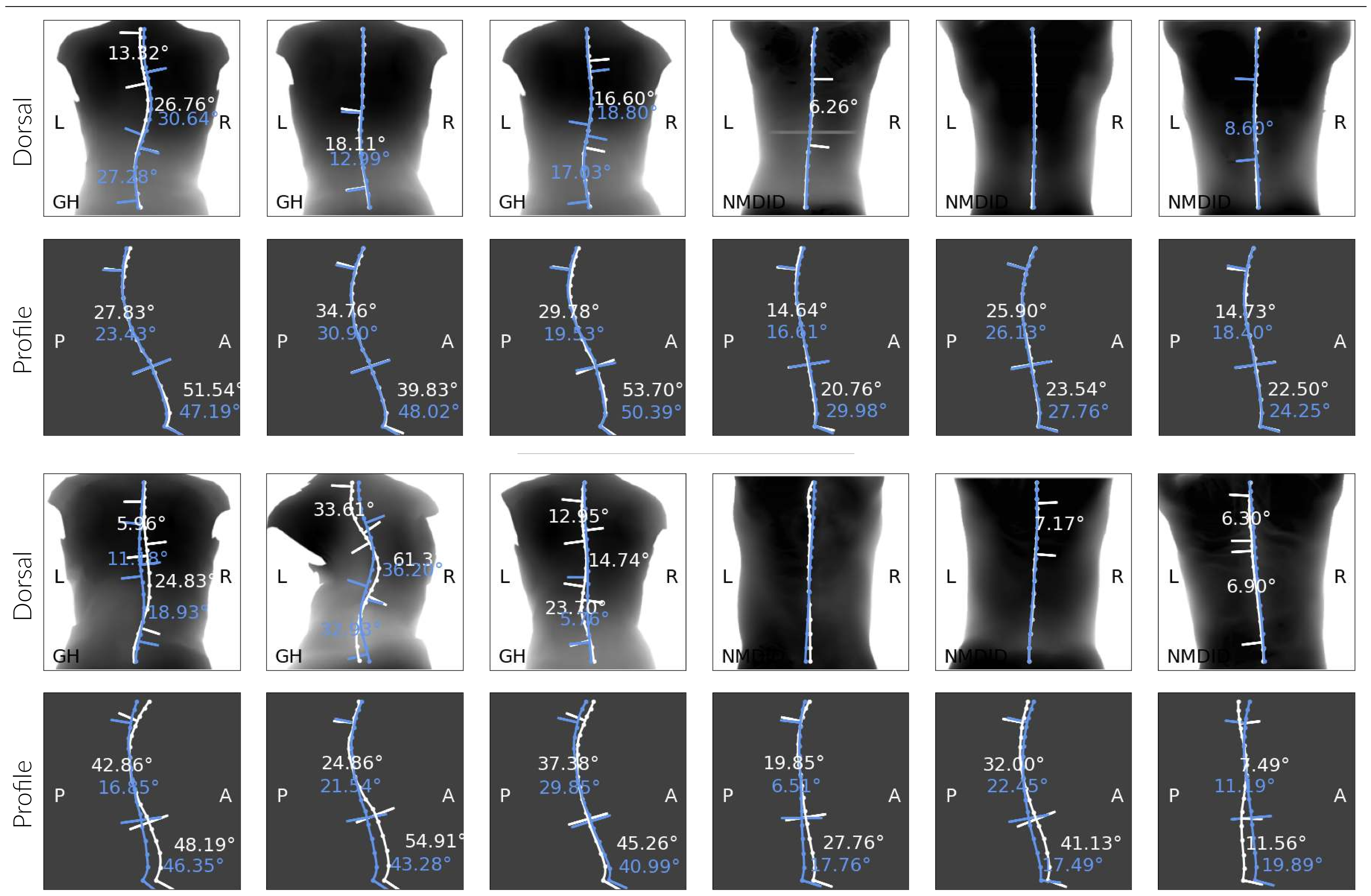


PCA^{-1}	Inv. transformation of the PCA model
MSE	Mean Squared Error
$D_i \in \mathbb{R}^{224\times224}$	Depthmap of subject i
$\theta_i \in \mathbb{R}^{20}$	Reduced spine representation
$\Theta_i \in \mathbb{R}^{3\times17}$	3D coordinates of the vertebrae
$\omega_\theta \in \mathbb{R}$	Weight on the θ predictions
$\omega_\Theta \in \mathbb{R}$	Weight on the Θ predictions

$$Loss = \omega_\theta MSE(\hat{\theta}, \theta) + \omega_\Theta MSE(PCA^{-1}(\hat{\theta}), \Theta)$$

Results

Predictions (blue) vs. Ground-truth (white)



Metrics

Method	Image	Positions (mm)	Angles (°)			Classification		
		3D	Sev	Kyp	Lor	Sens	Spec	AUC
Ours	Depth	7.1 (4.7)	5.5 (6.2)	6.3 (5.4)	8.2 (6.9)	64	99	90
[6]	RGB	×	×	×	×	88	84	95
[5]	Moiré	×	3.4 (2.6)	×	×	NA	NA	NA
[4]	Depth	×	[4.4-4.7]	×	×	99	42	NA

Comparison with state-of-the-art reported values on different datasets. In positions: average distance error (with standard deviation). In curvatures: mean absolute error (with std) of severity, kyphosis and lordosis. In classification: sensitivity, specificity and AUC. NA: Not Available. ×: Not computed.

Classification