Human Pose Recovery and Behavior Analysis group

Posture Analysis and Range of Movement Estimation using Depth Maps

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Motivation

- **80% of the world population** is affected of **back pain** during his life.
- Many current practices to analyze back problems are expensive, subjective, and invasive.
- A **novel tool** for posture and range of movement estimation based on the analysis of 3D information from depth maps:
  - Reeducating to prevent MSDs.
  - Tracking the patient's evolution in rehab.

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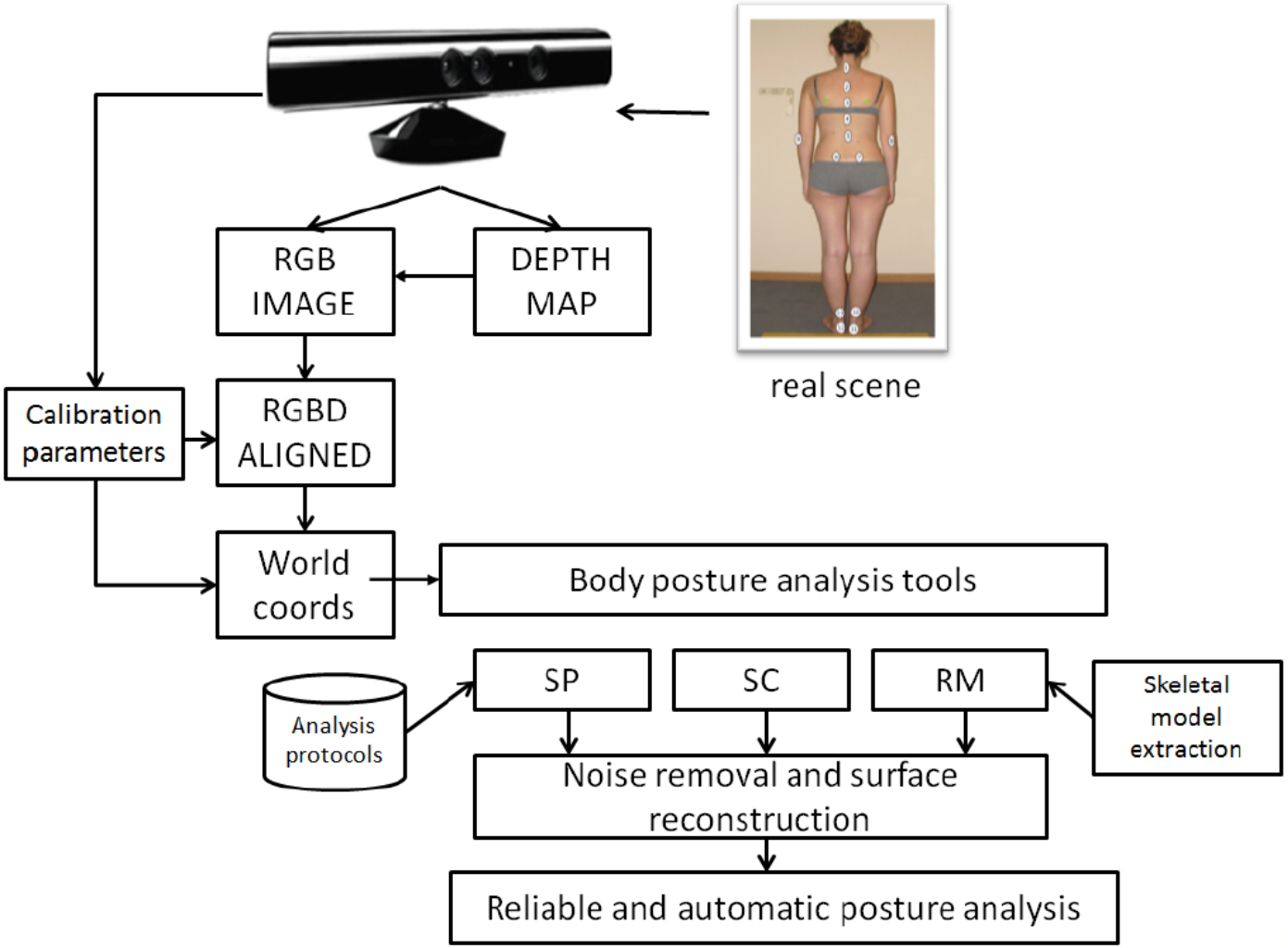

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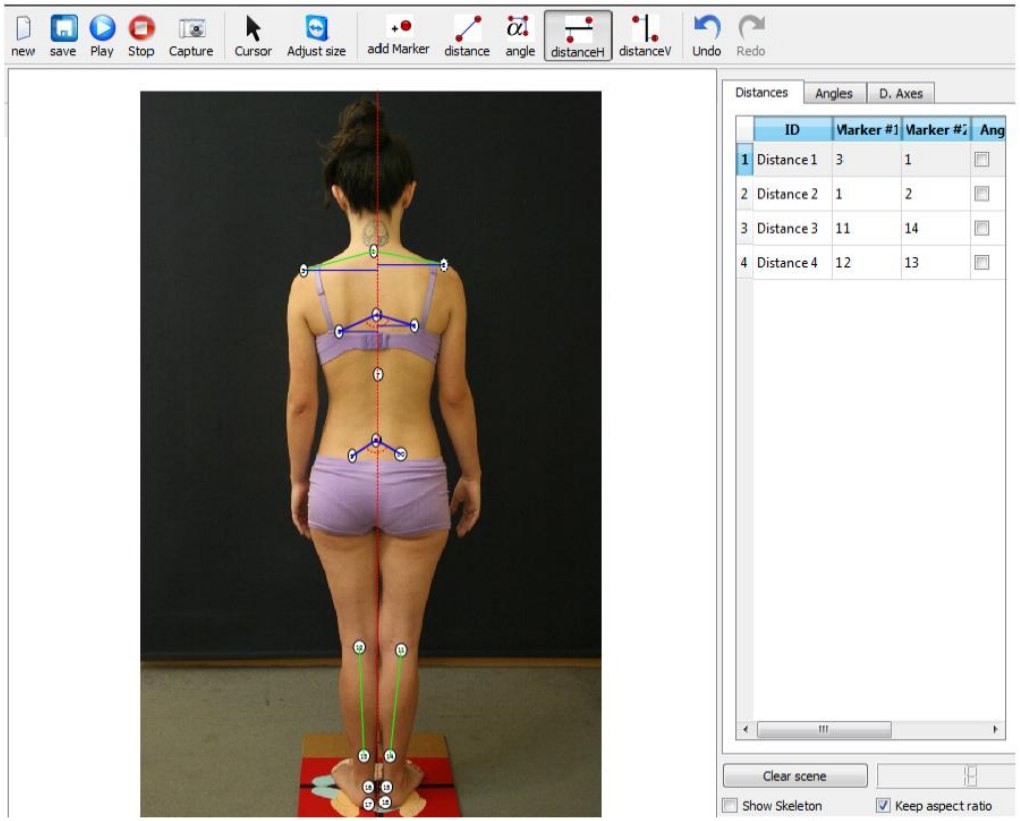
- **keypoints** are manually set from RGB data displayed in the screen.
- The relations (three-dimensional measurements) are established among the **keypoints** defined by the user.
- We define a **protocol** as a set of keypoints and the relations among them.
- Given a new set of points, we could **apply a predefined protocol** or perform a **free analysis**.



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SP analysis : Matching protocol

- Sum of least squares minimization.

$$\text{argmin}_{C'} \sum_{i=1}^{N} \|C'_i - T_i\|^2$$

- Soft pre-alignment using *Iterative Closest Point* (ICP).

$$E(\mathcal{R}, \mathcal{T}) = \sum_{i=1}^{N} \sum_{j=1}^{N} w_{i,j} \|T_i - \mathcal{R}(C_j) - \mathcal{T}\|^2$$

- Correspondence relaxation based on adjacency matrix *A*.

$$A(i,j) = \begin{cases} 1 & \text{if} \quad M(i,j) < \theta_M \\ 0, & \text{otherwise.} \end{cases}$$

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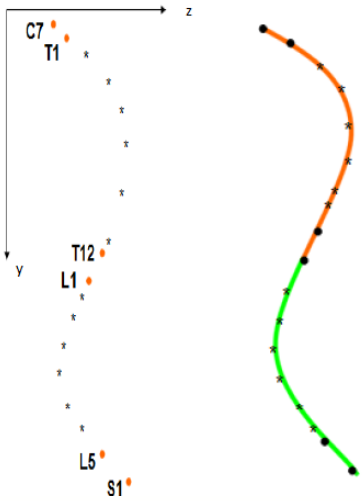
(A)

(B)



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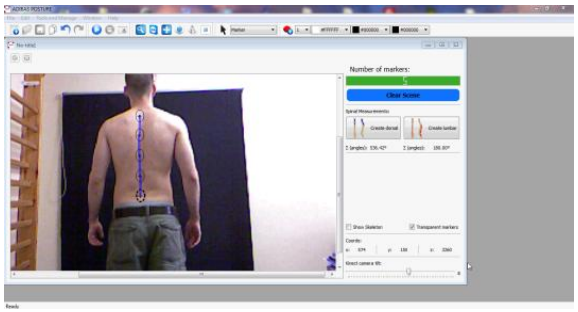

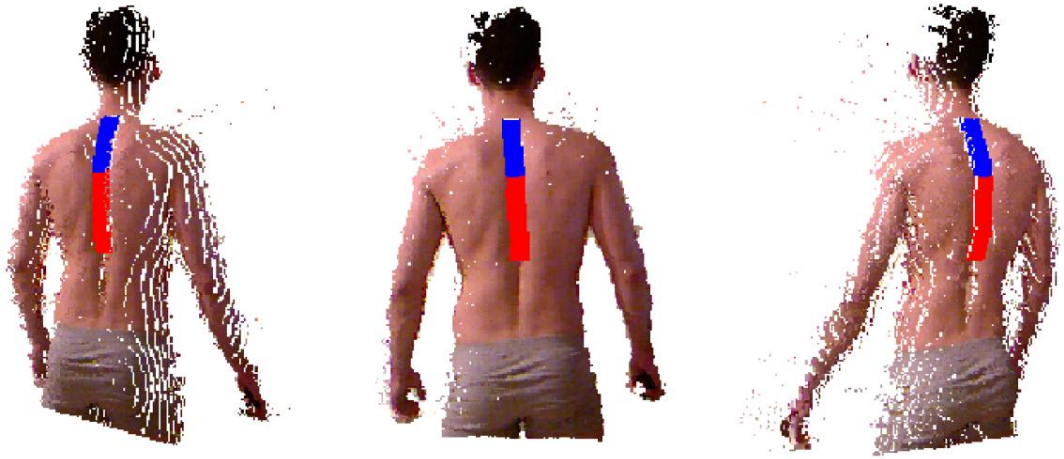

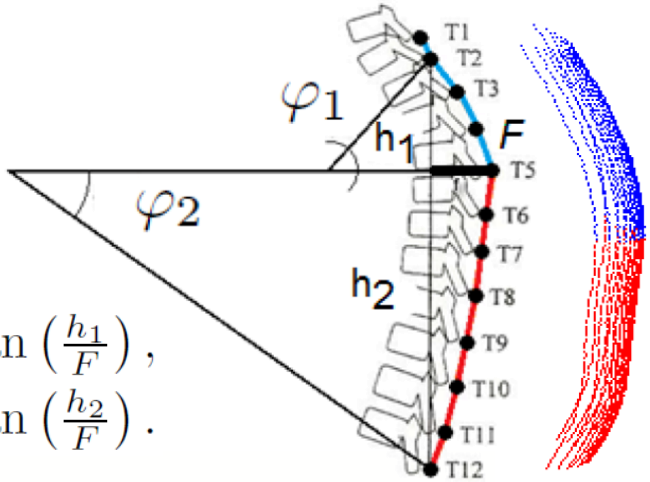

$$\varphi_1 = 180 - 2 \cdot \arctan\left(\frac{h_1}{F}\right),$$
$$\varphi_2 = 180 - 2 \cdot \arctan\left(\frac{h_2}{F}\right).$$

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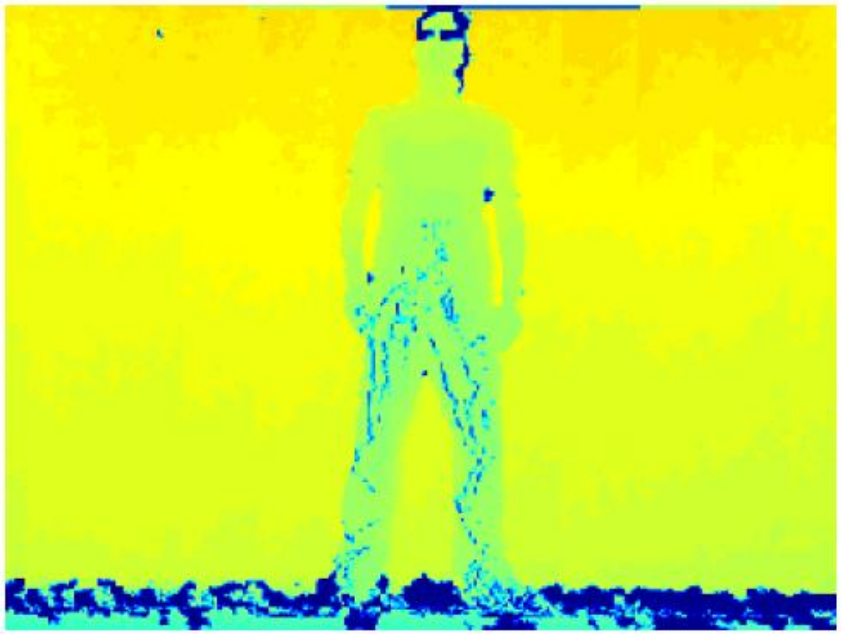
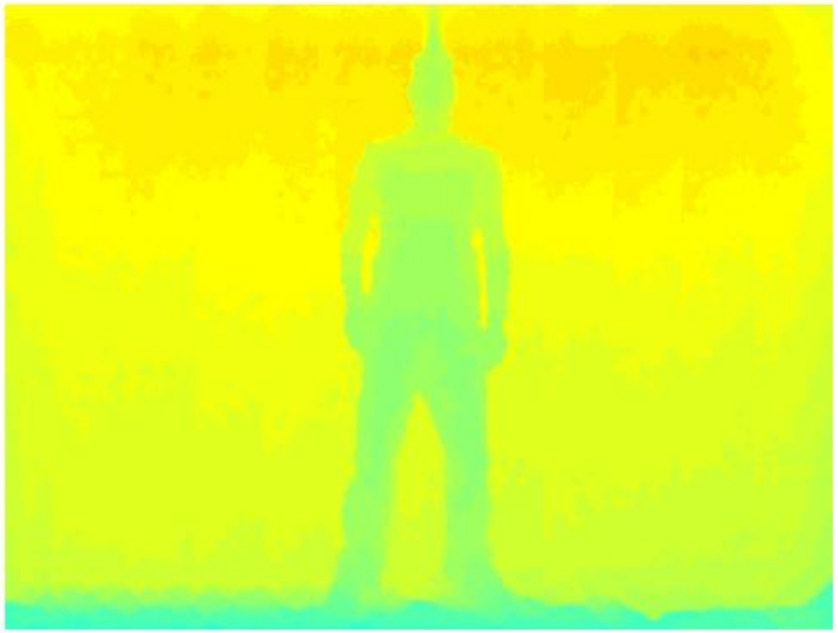
- **Noisy depth** maps
  - Statistical noise removal.
  - Filling Holes (Inpaint Naive Strokes*).





M. Bertalmio, A. L. Bertozzi, G. Sapiro, ”Navier-Stokes, Fluid Dynamics, and Image and Video Inpainting”, Proceedings of the International Conference on Computer Vision and Pattern Recognition , IEEE, Dec. 2001, Kauai, HI, volume I, pp. I-355-I362

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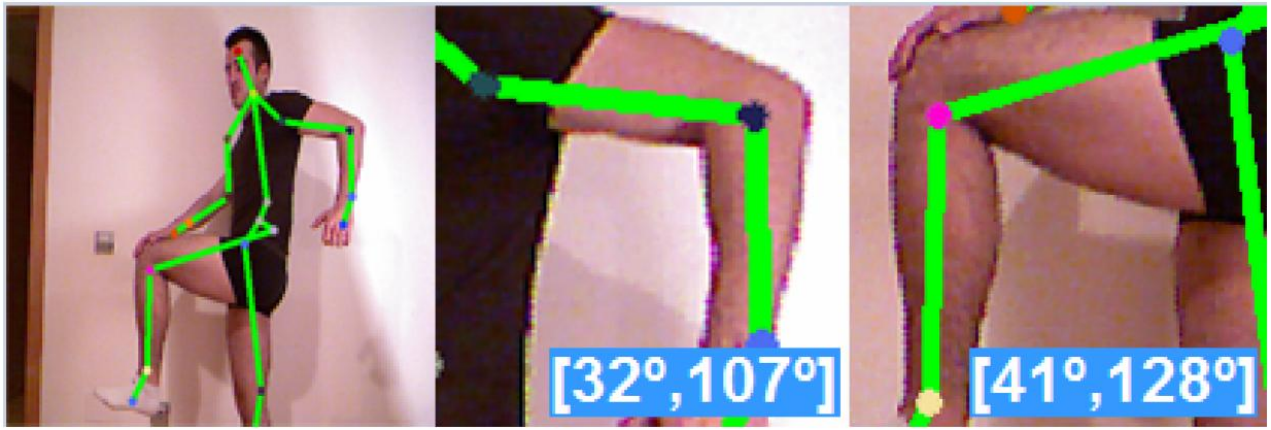
- ***Random Forest*** limbs pixel-level labeling.

$$f_\theta(D, \mathbf{x}) = \mathbf{D}_{\left(\mathbf{x}+\frac{\mathbf{u}}{\mathbf{D_x}}\right)} - \mathbf{D}_{\left(\mathbf{x}+\frac{\mathbf{v}}{\mathbf{D_x}}\right)},$$

$$P\left(l_i|D, \mathbf{x}\right) = \frac{1}{\tau}\sum_{j=1}^{\tau} P_j\left(l_i|D, \mathbf{x}\right)$$

- **Skeletal model** extraction from the segmented limbs.



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- **Data and settings**
  - **SPA**
    - 500 tests labeled by three different observers (inter-observer correlation > 99% for all planes).
    - A test contains a set of angles and distances, placing twelve infrared led markers on the body of the subject.
    - 20 subjects.
    - Automatic validation of the tests: infrared markers are detected by means of thresholding a HSV infrared-filtered image.
  - **SCA**
    - 10 subjects.
    - Leroux protocol, placing nine markers over the spine.
    - The relationship between lateral anthropometric and radiographic measures was assessed with the mean of the differences.

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Results (III)

- **Validation**
  - **AVV** correspond to the average absolute value
  - ’◦’ corresponds to the degree.
  - **SPA**

Distance subject-device (m)	1,3	1,9	2,2
AAV (◦ movement)	2,2	3,8	5,2
AAV (mm)	0,98	1,42	2,1
AAV (◦ angles)	0,51	1,04	1,24
AAV (%)	0,46	0,77	1,3
Standard Error (%)	1,01	1,18	1,71

Pose and range of movement precision.

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- **Validation**
  - **SP**

Curvature	X-Ray Mean (SD) Range	Flexicurve Mean (SD) Range	Difference Mean (SD) Range	Absolute Difference Mean (SD)	≤ 5° n	5° < x ≤ 10° N	> 10° N
Thoracic	43.7 (11.0) 18° to 71°	42.9 (8.8) 26° to 65°	0.8 (8.1) -16° to 16°	6.5 (4.7)	26	12	9
Lumbar	40.5 (10.1) 22° to 62°	40.0 (7.9) 21° to 59°	0.5 (8.3) -17° to 16°	6.8 (4.6)	23	13	11

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Applications

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Conclusions

- Semi-automatic posture analysis and range of movement estimation using **multi-modal data (rgb + depth).**
- Provides assistance in the **posture reeducation task** to **prevent and treat** MSDs.
- Gaussian noise is removed and depth map is reconstruct as a **preprocessing step**.
- Keypoints defined by the physician are matched using a **novel point-to-point fitting procedure**.
- **High precision** in terms of **distance**, **degree**, and **range of movement** estimation.
- **Clinical specialists** supports its inclusion in the **clinical routine**.

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