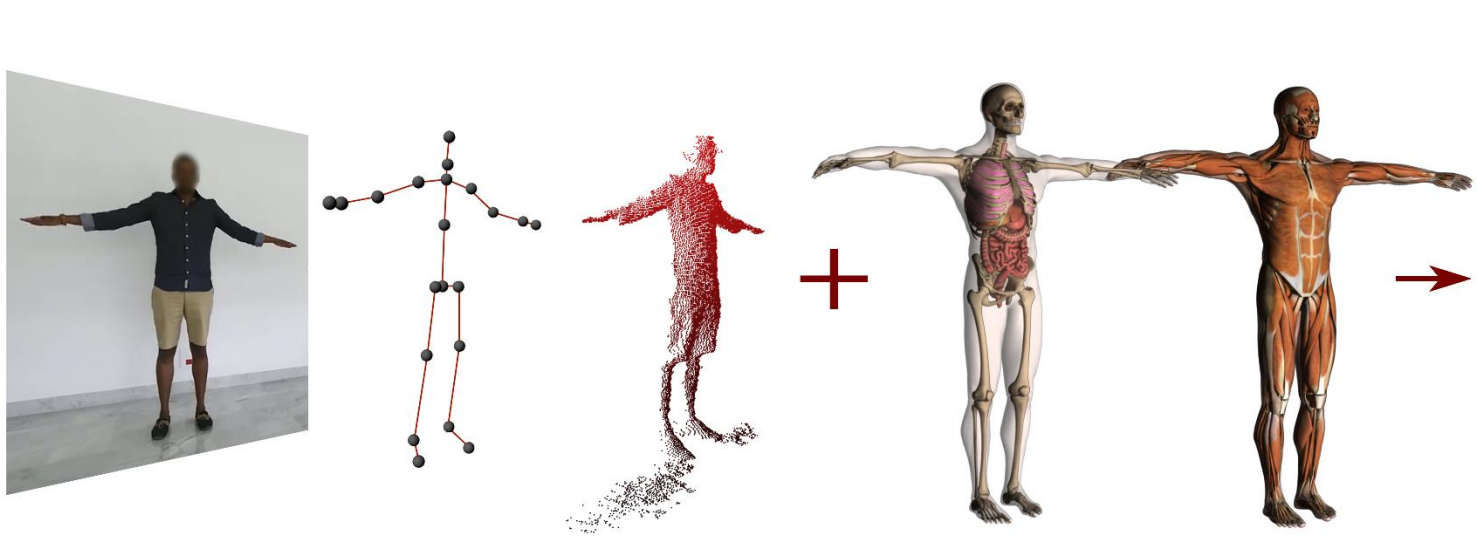
MIG 2016 San Francisco

PERSYVAL-Lab

Armelle Bauer

Anatomical Mirroring: Real-time User-specific Anatomy in Motion Using a Commodity Depth Camera.



Armelle Bauer [2, 3], Ali-Hamadi Dicko [2, 4], François Faure [2, 4], Olivier Palombi [1, 2, 4], Jocelyne Troccaz [3]

[1] LADAF, [2] LJK, [3] TIMC-IMAG, [4] AnatoScope — **INRIA, CNRS, Univ. Grenoble Alpes**

This work has been partially supported by the LabEx PERSYVAL-Lab (ANR-11-LABX-0025-01) funded by the French program Investissement d'avenir.

Overview

Related Work :

- Learning anatomy media
- Using new technologies
- Mirror-like augmented reality (AR)

Our approach :

- The Living Book of Anatomy (LBA)
- User registration Step
- User tracking Step

Conclusion

- Results
- Conclusion and future work

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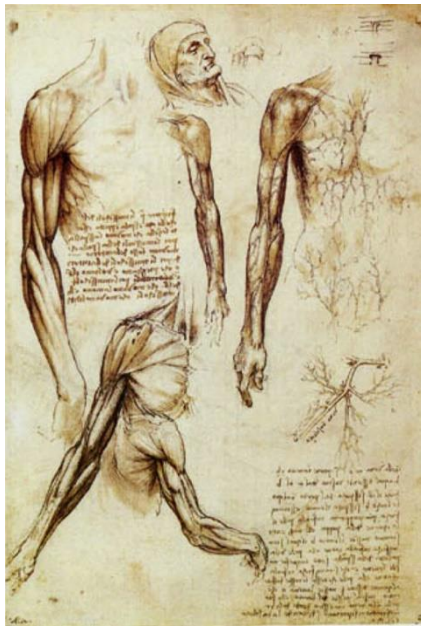
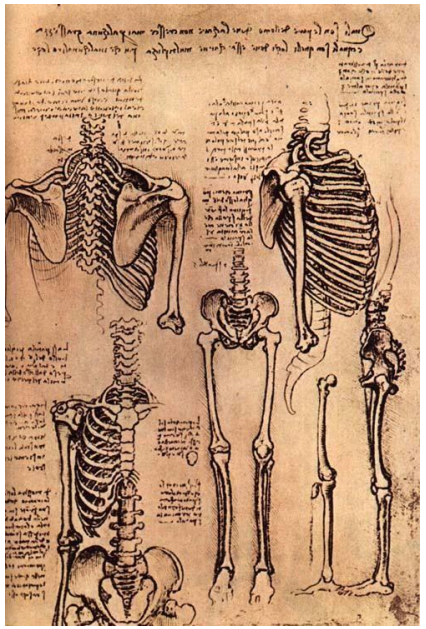
Motivation : Learning Anatomy

Anatomy : static and dynamic structured knowledge

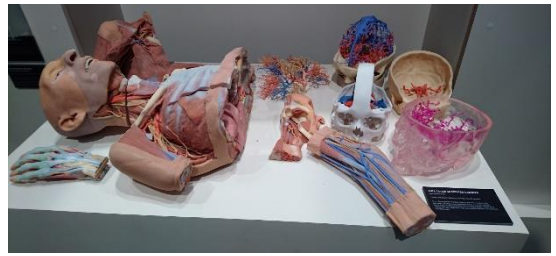
To make the complex task of anatomy learning easier :

cadaver dissections





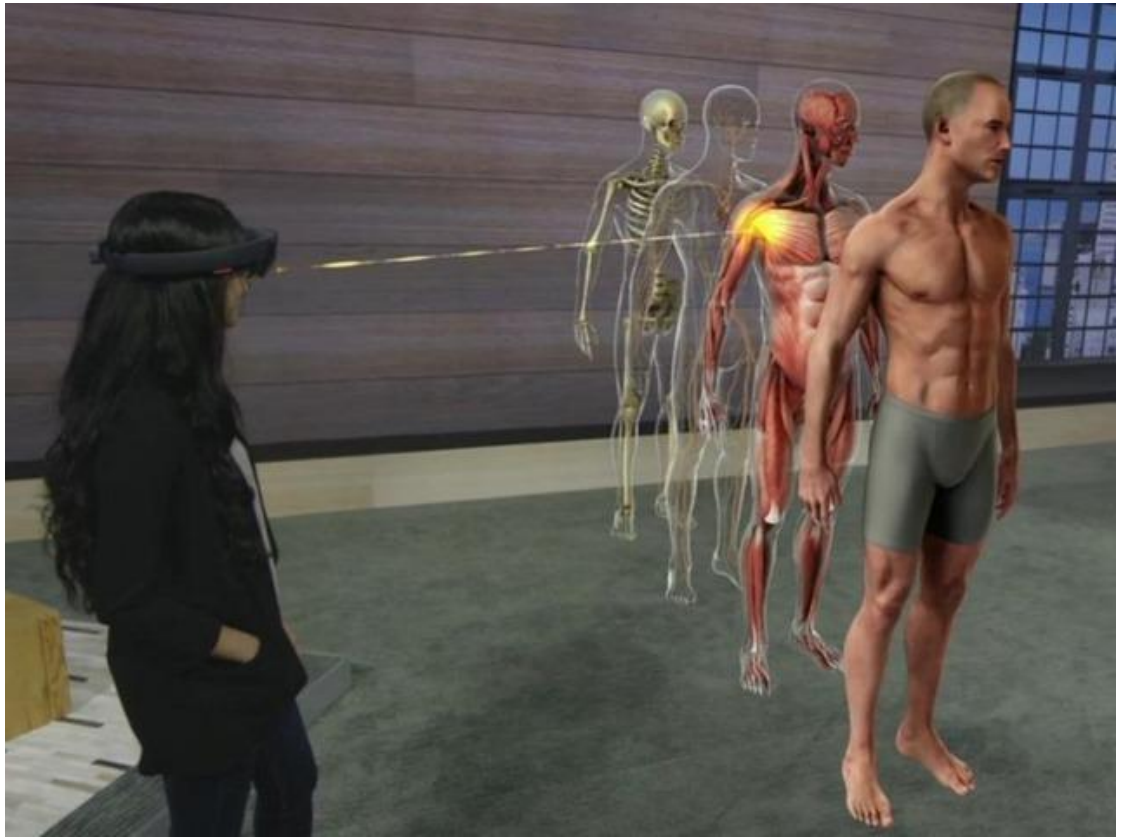
drawings, books



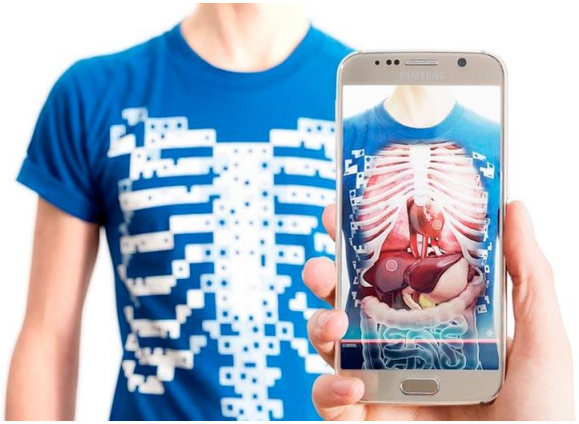
3D models

Learning anatomy for : medicine students, sports students, general education.

Mixed reality to learn anatomy

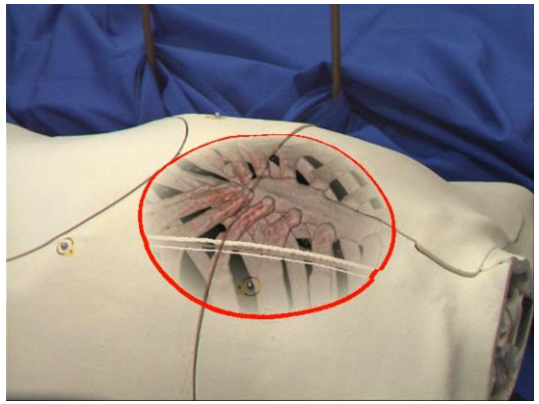


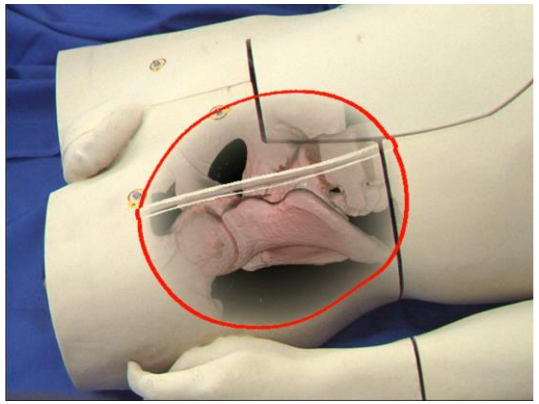
HoloLens [Microsoft]



Virtual-Tee

S.A.G.E. [Anderson& all, 2012]





Visible korean human phantom [Navab 2008]

Visualization and **Interaction** with anatomical content displayed onto the user's color map in **real-time** :

Magic Mirror [Blum et al, 2012]

Digital Mirror [Maître, 2014]

Anatomie Spiegel [Borner et al, 2015]

We improve these works by :

- Displaying a **user-specific anatomy** superimposed onto the user's color map.
- Animating the 3D model in **real-time** by maximizing anatomical plausibility.

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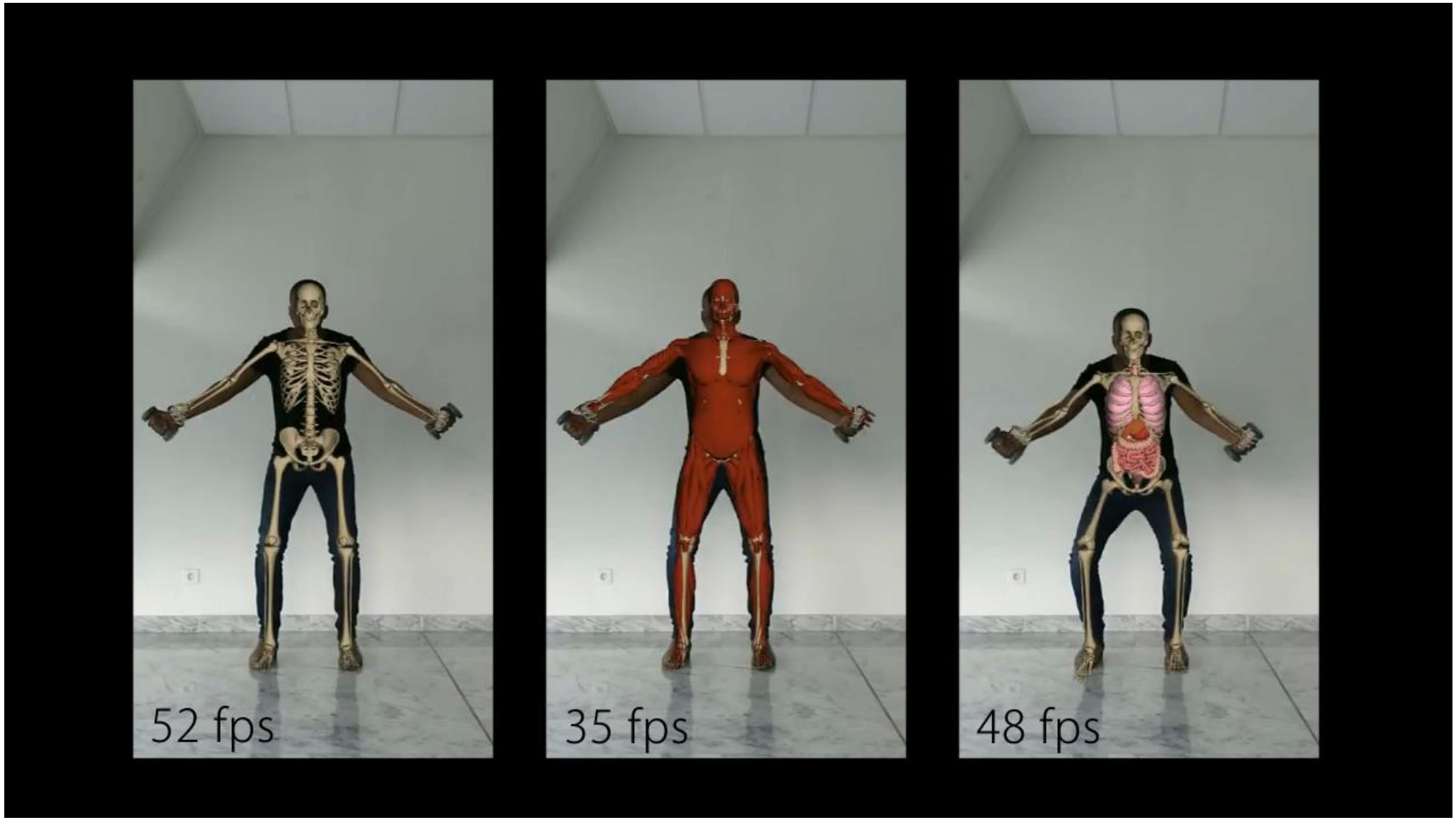
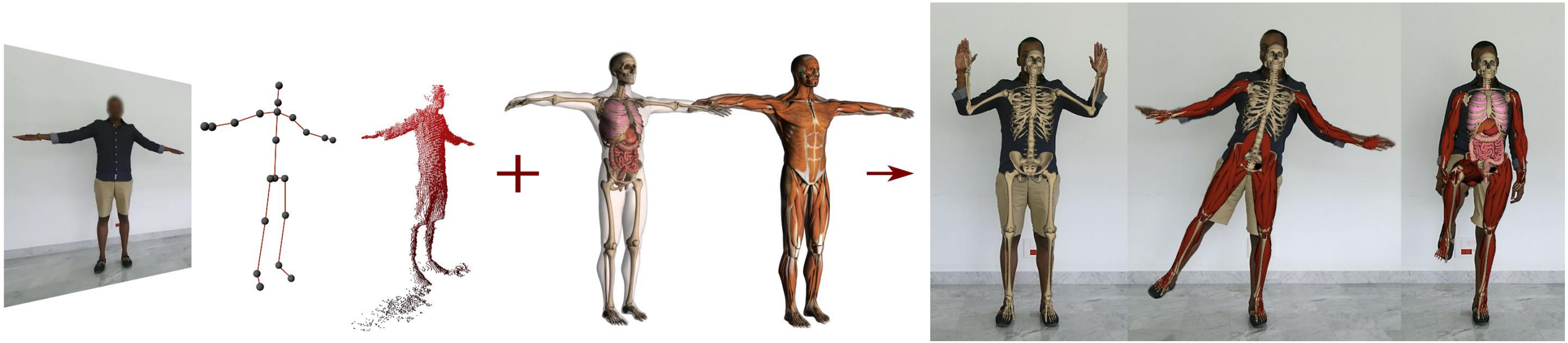
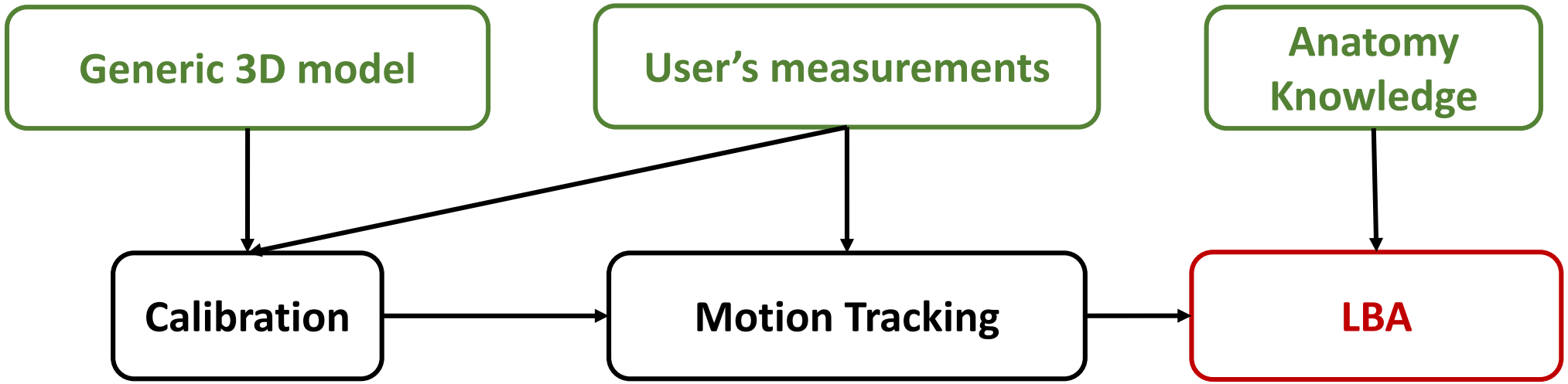
Results of our system

Living Book of Anatomy (LBA)



Pipeline of our system





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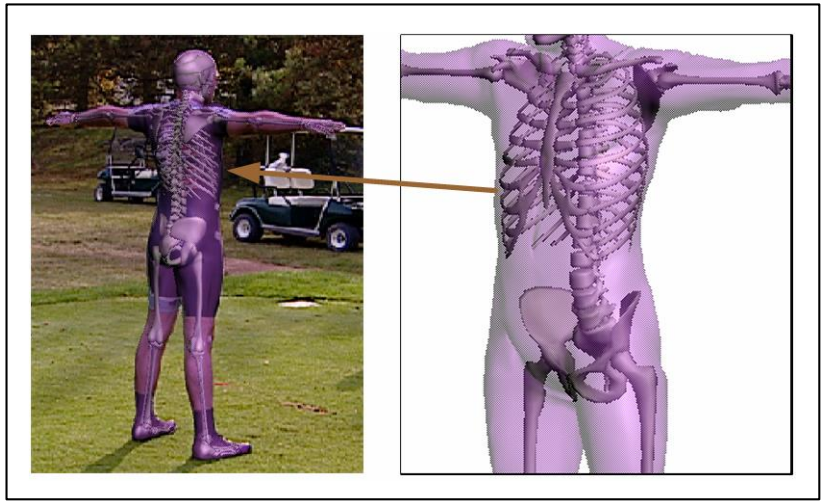
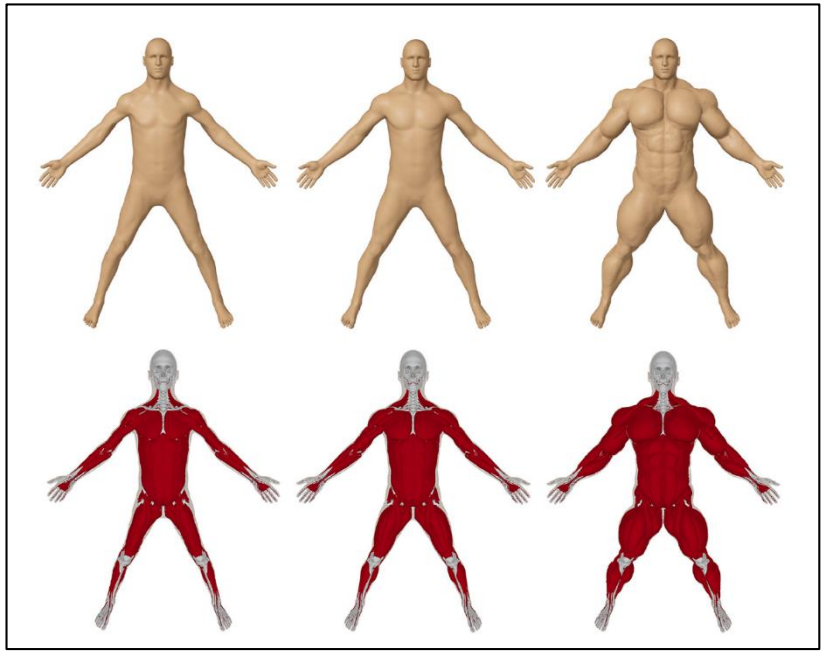
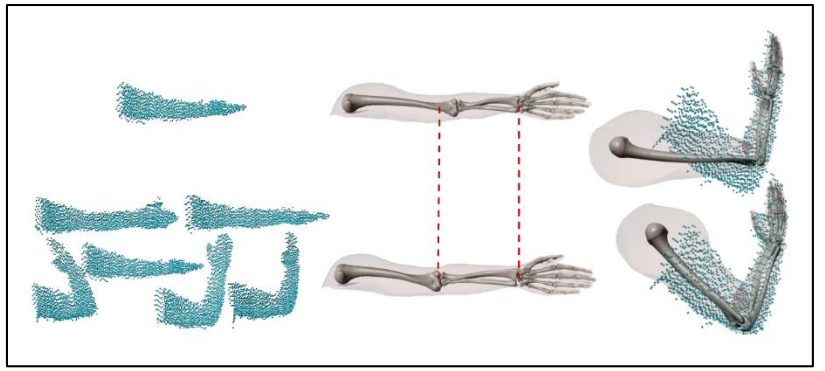
Anatomy registration : state of the art



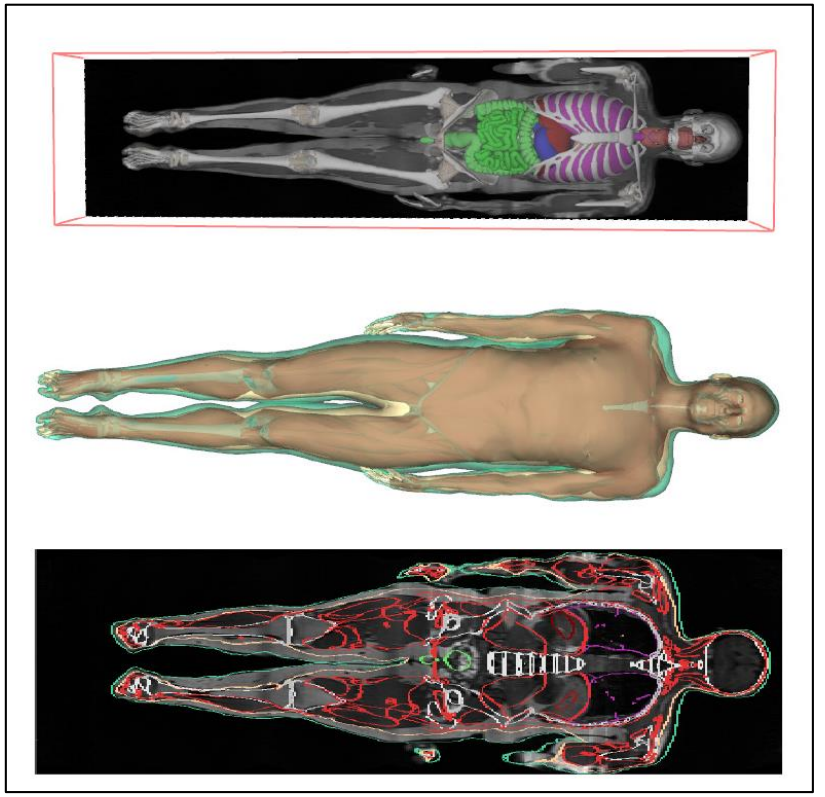
> **Quah et al** [2005]



> **Saito et al** [2015]

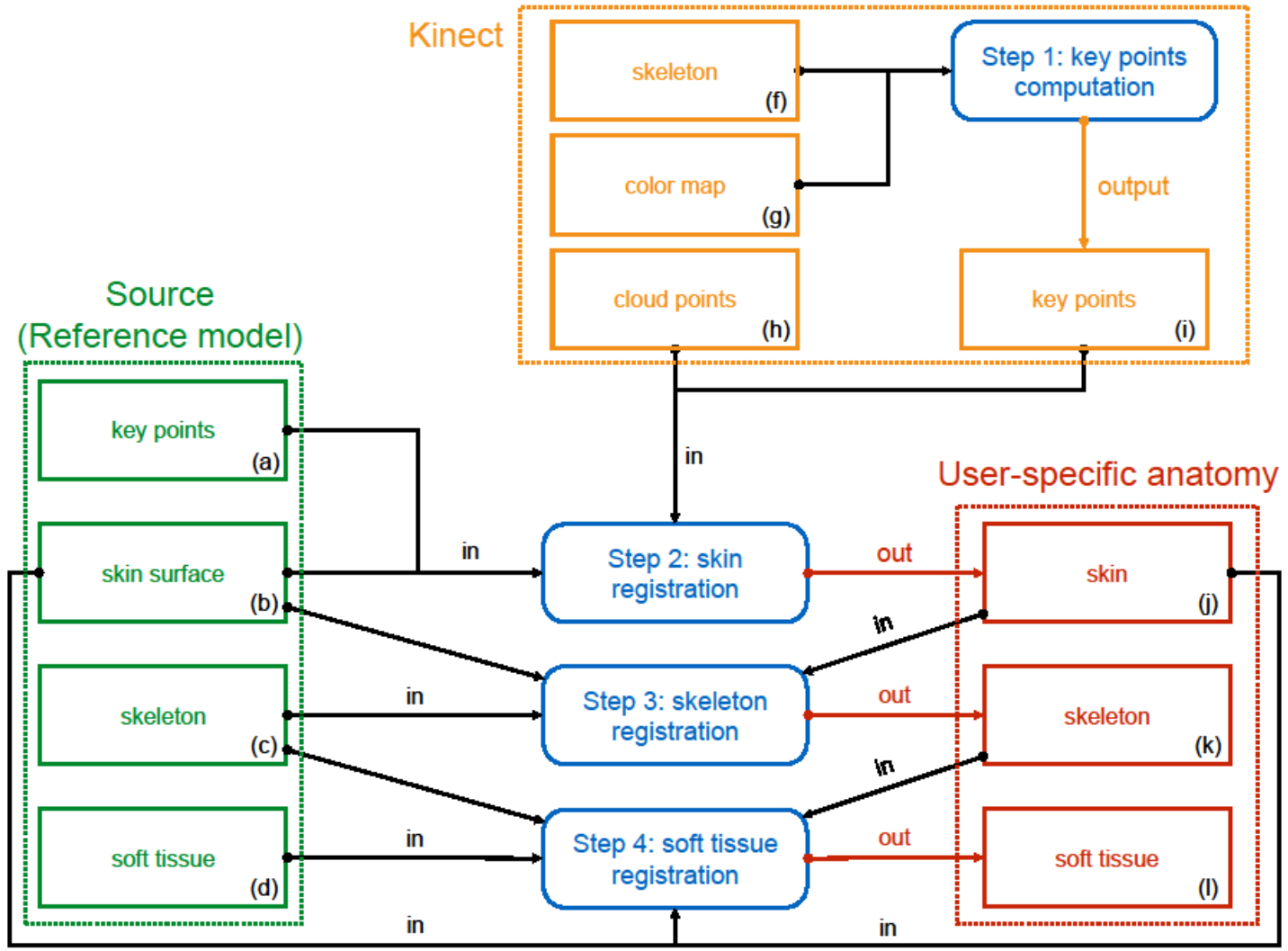


> **Zhu et al** [2015]



> **Dicko et al** [2014]

Our method : registration pipeline



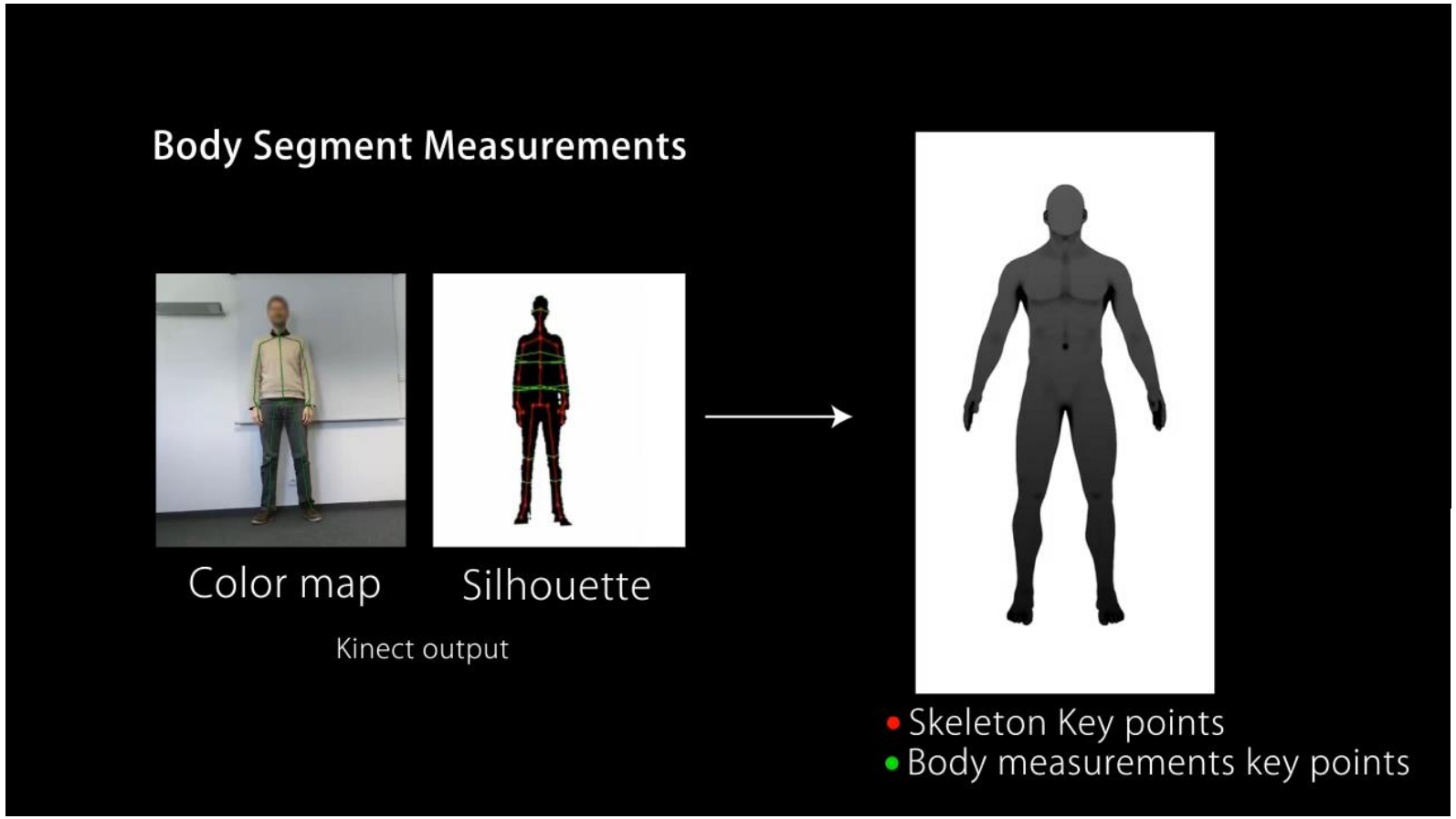
Anatomy Transfer

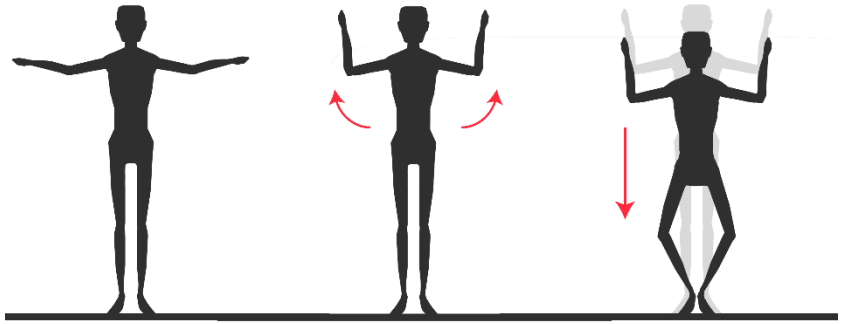
Ali-Hamadi Dicko, Tiantian Liu, Benjamin Gilles, Ladislav Kavan, François Faure, Olivier Palombi, Marie-Paule Cani

ACM Transactions on Graphics (TOG), **2013**

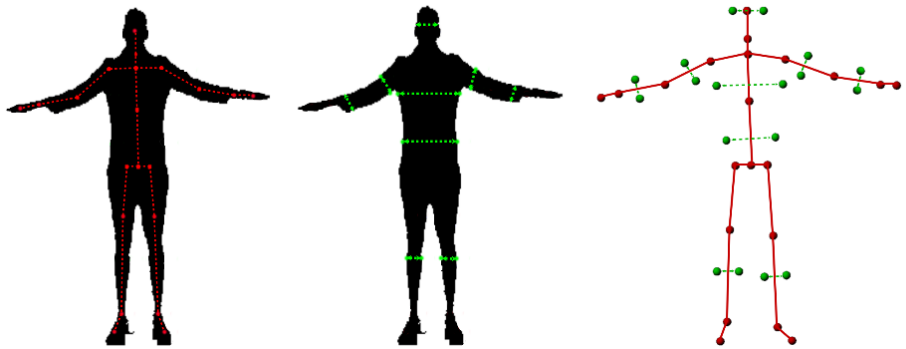
Step 1 : key points computation

Key points are used to define body **joint positions** and **body measurements** for skin registration.



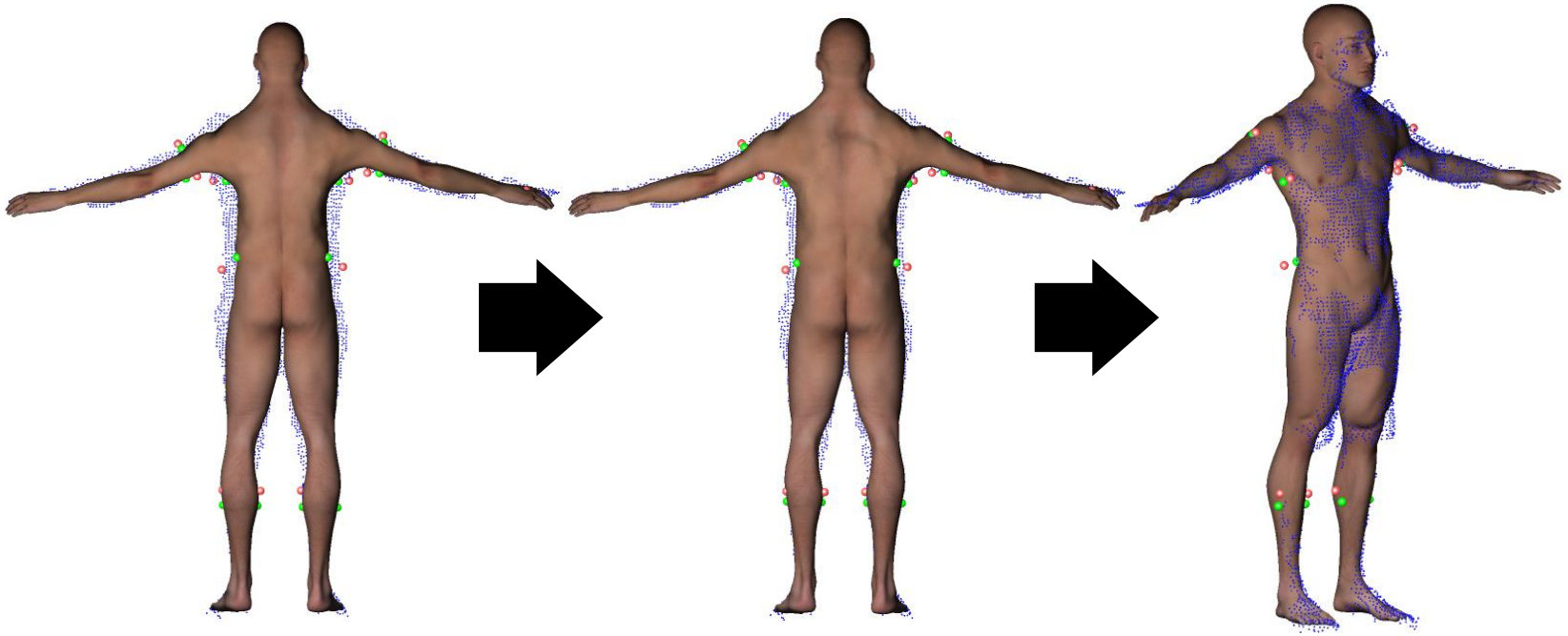


Calibration routine : 3 body positions



User's key points

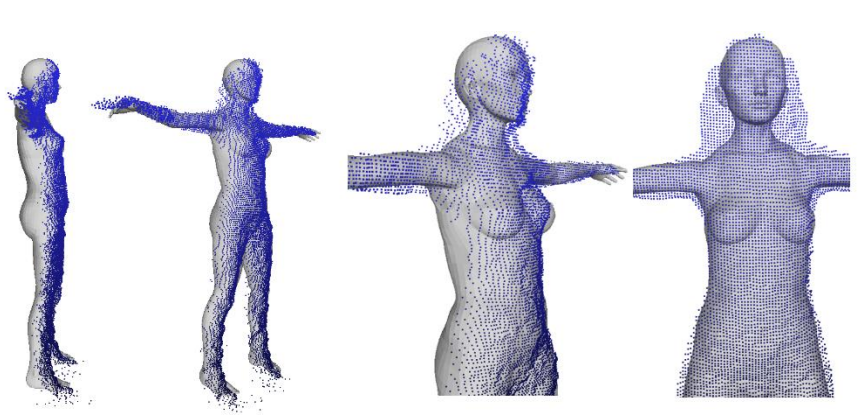
Step 2 : skin registration



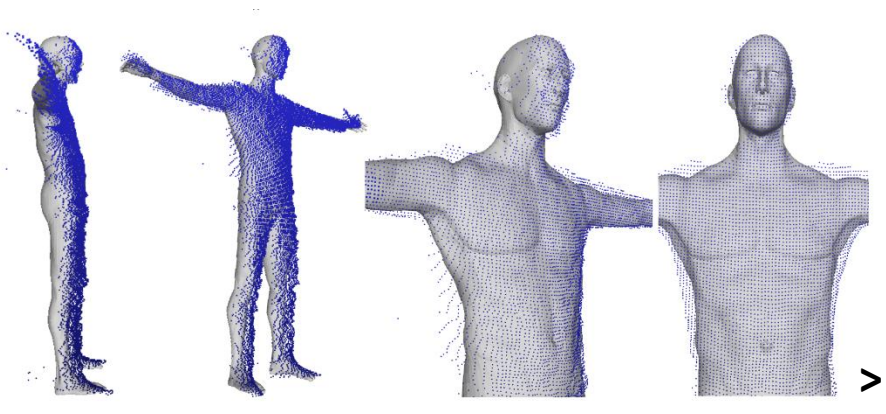
Skeleton key points

Silhouette key points

Point cloud



> female 1,55m



> male 1,85m

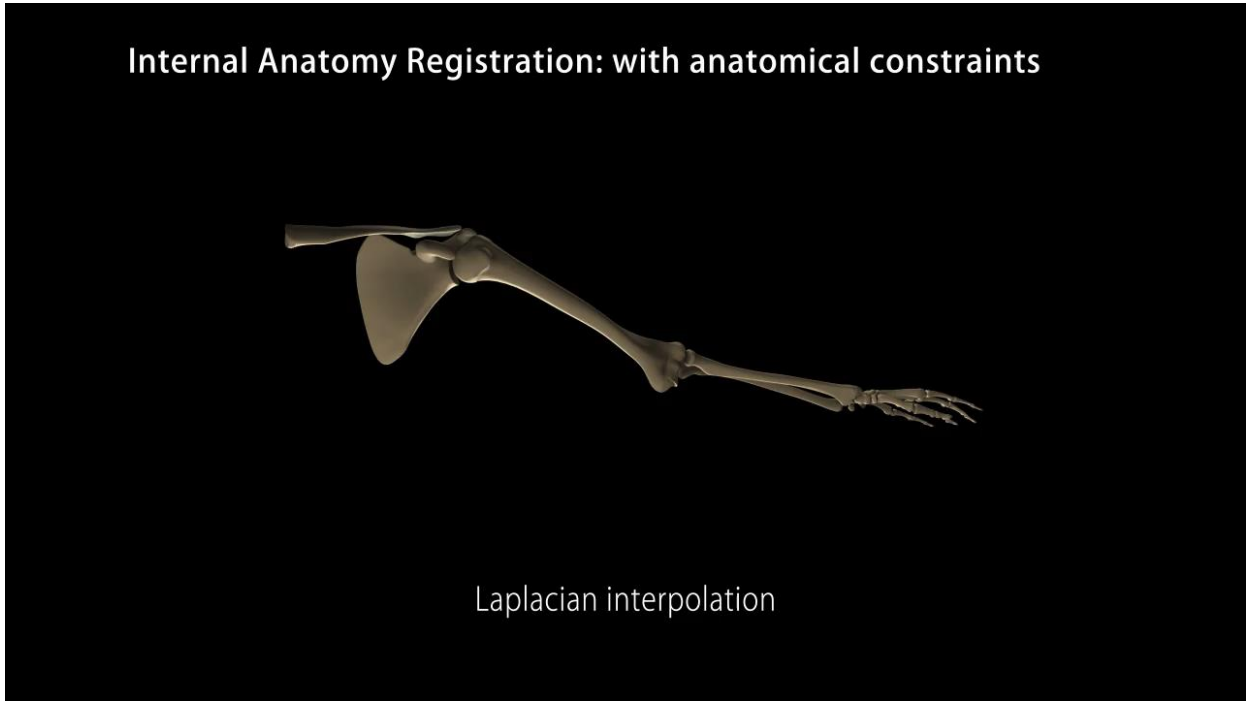
Step 3 : skeleton registration

Anatomy Consistency rules:

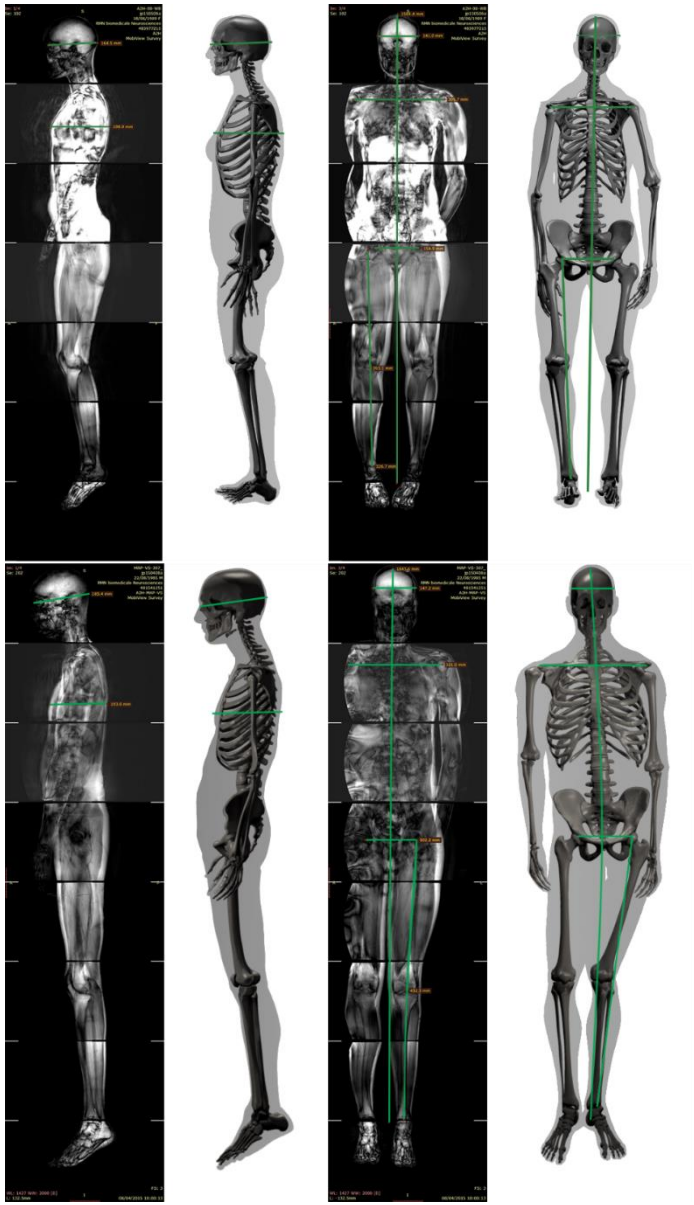
- **R01**: Keep long bones straightness *(no bending or twisting)*
- **R02**: Keep 3D model consistency: the complete set of entities is transferred to avoid holes
- **R03**: Keep bone head consistency
- **R04**: Keep consistency of rib cage and limbs: symmetry with respect to the sagittal plane
- **R05**: Keep body joints consistency: type of joint and movement amplitude

Different types of anatomical bones :

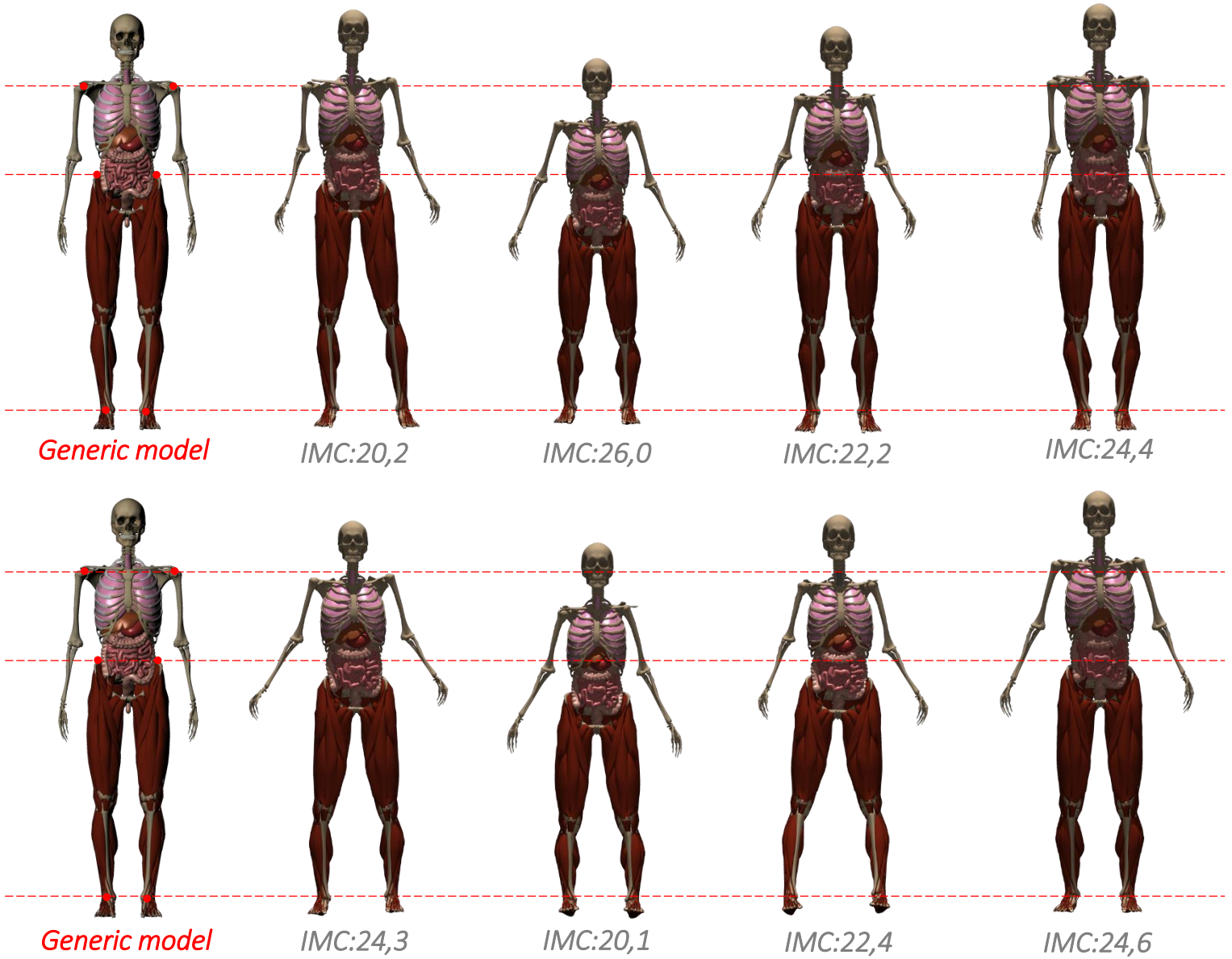
- **Short bones**: 1 frame in the middle
- **Long bones**: 2 frames, one at each bone head
- **Flat bones**: 3 frames equally placed
- **Complex bones**: 3-4 frames equally placed
- **Complete skull**: 5 frames equally placed



Results and MRI evaluation



User-specific Anatomy



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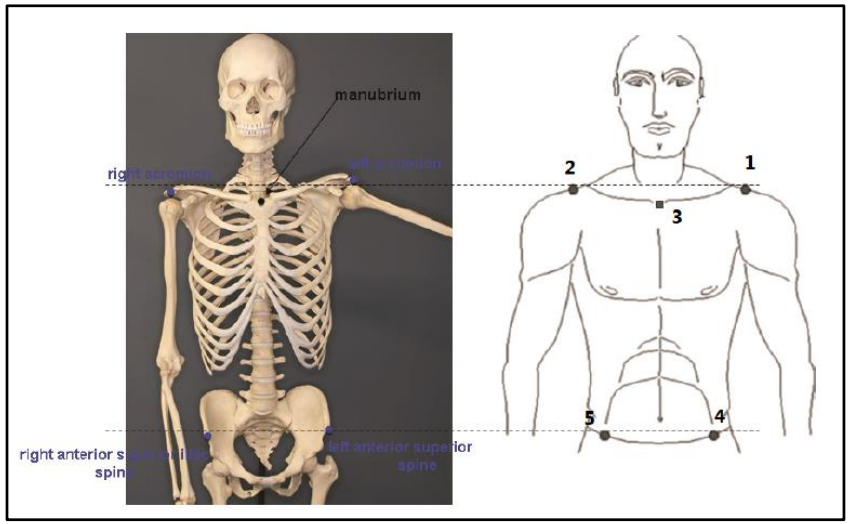
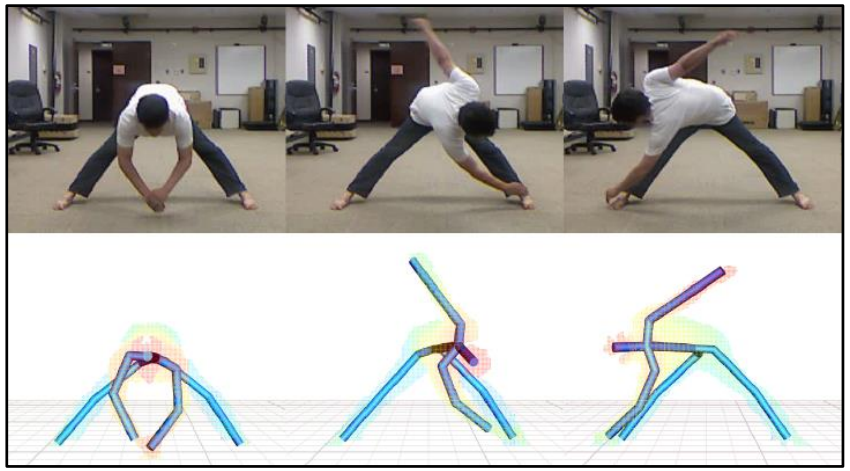
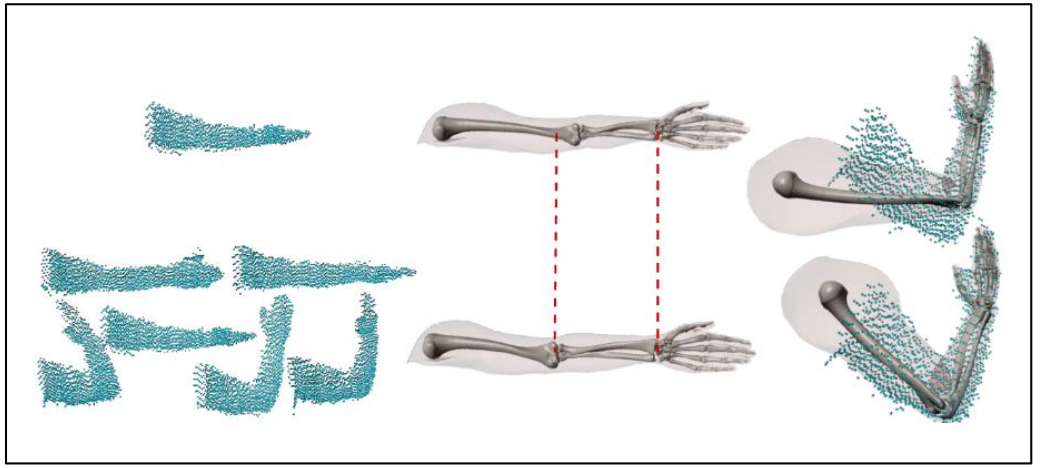
User tracking : state of the art



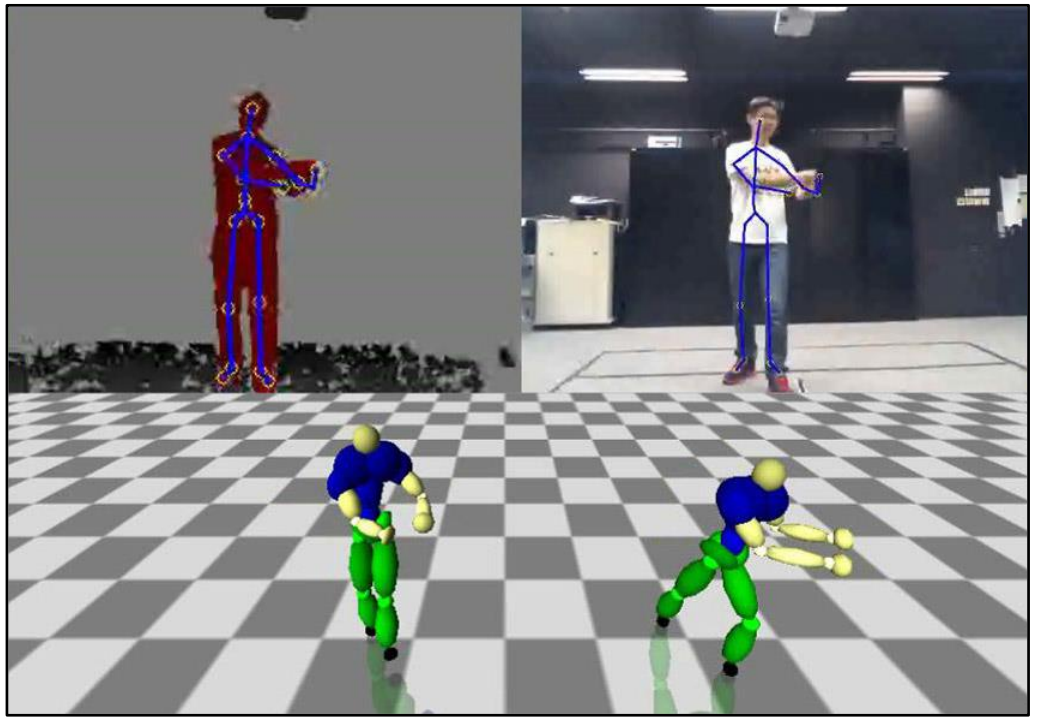
> **Meng et al** [2013]



> **Wei et al** [2012]



> **Zhu et al** [2015]



> **Zhou et al** [2014]

Our method : tracking pipeline

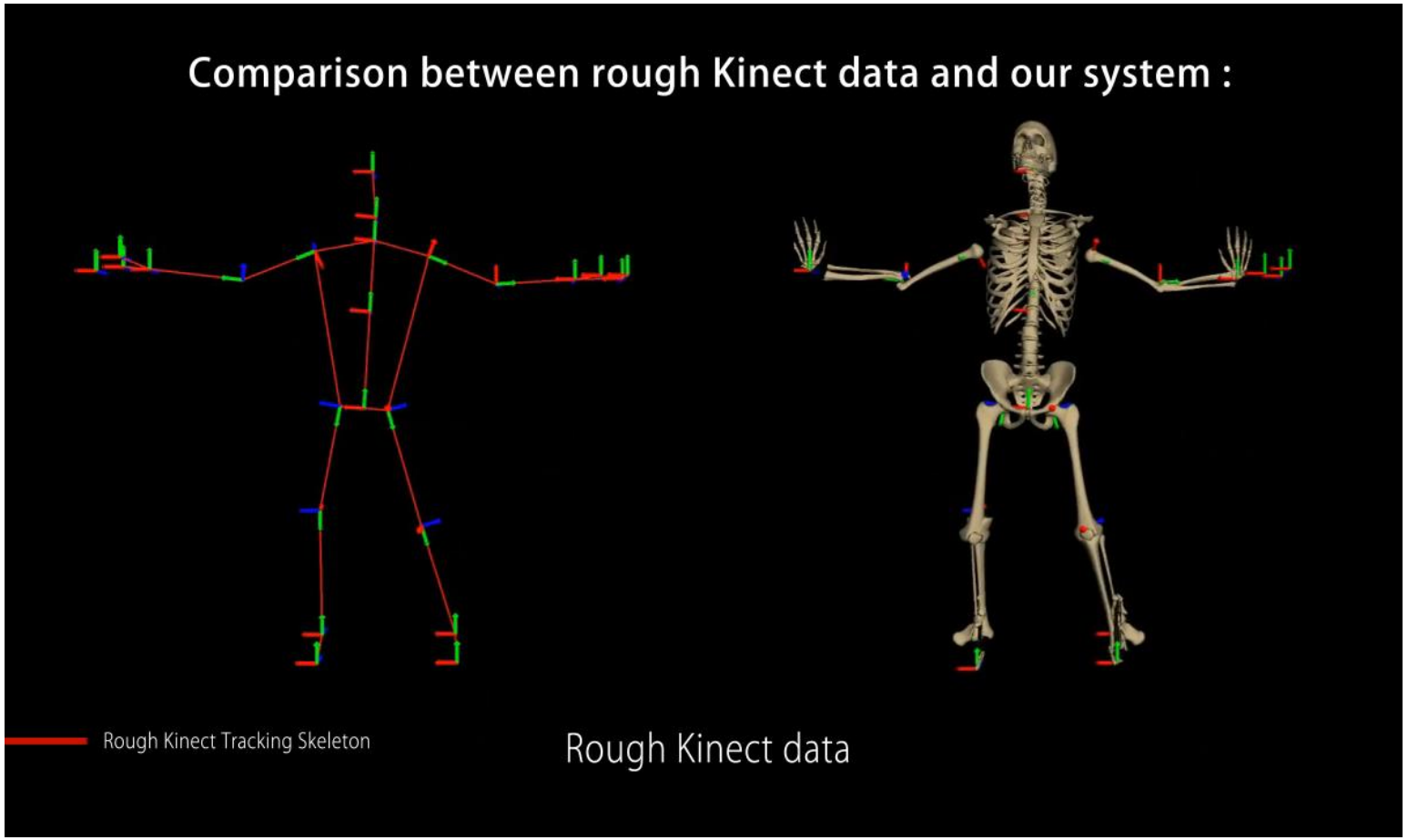
Input : **Body tracking skeleton**
(25 joints positions)

Smoothing of small tracking noise
(Kalman filter on positions)

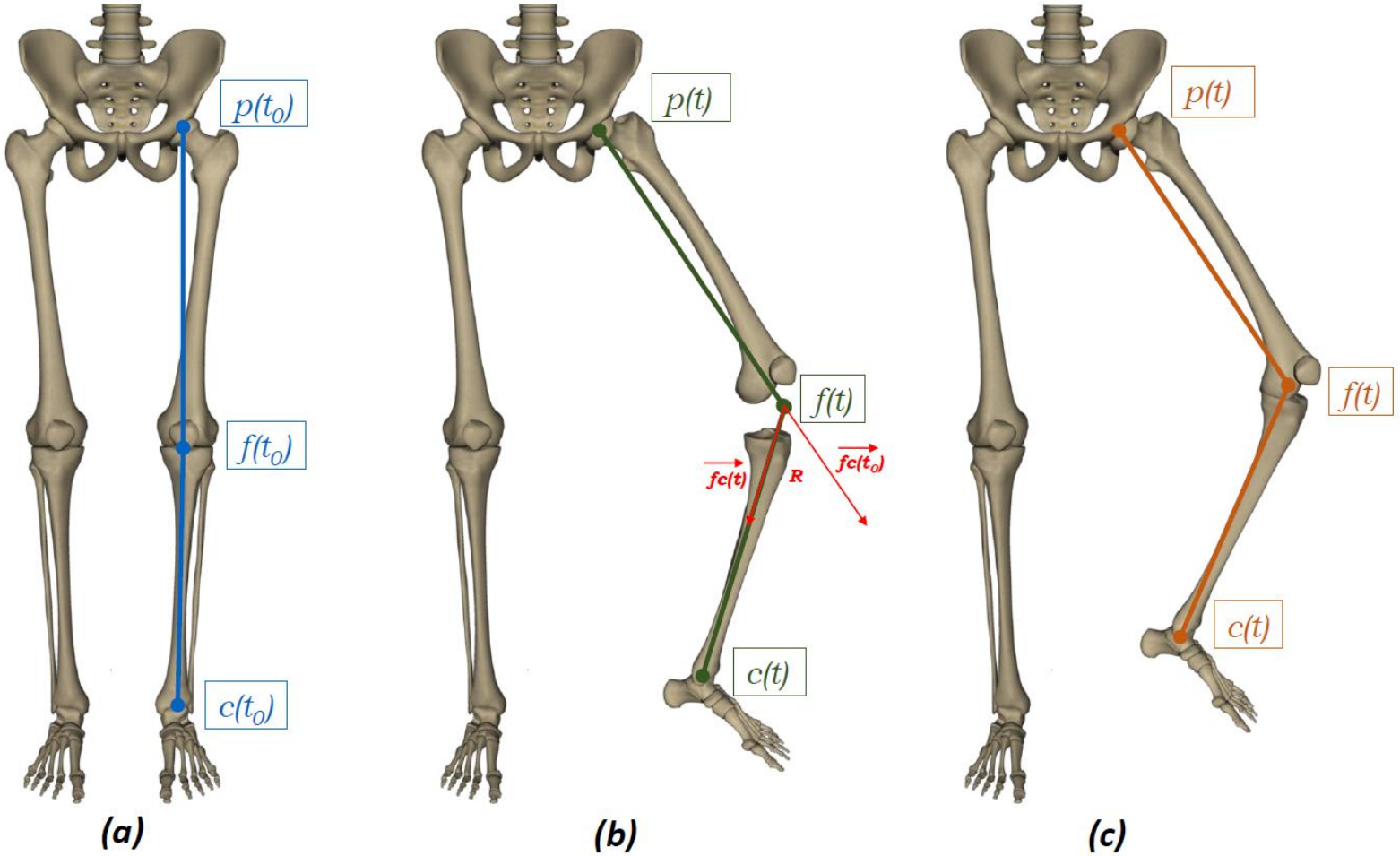
Hierarchical body tracking system
(in-between joint distances)

Anatomically contrained joint Orientations
(dofs and angle limits)

Output : **Realistic body tracking**
(body joints position and orientations)



Hierarchical body tracking



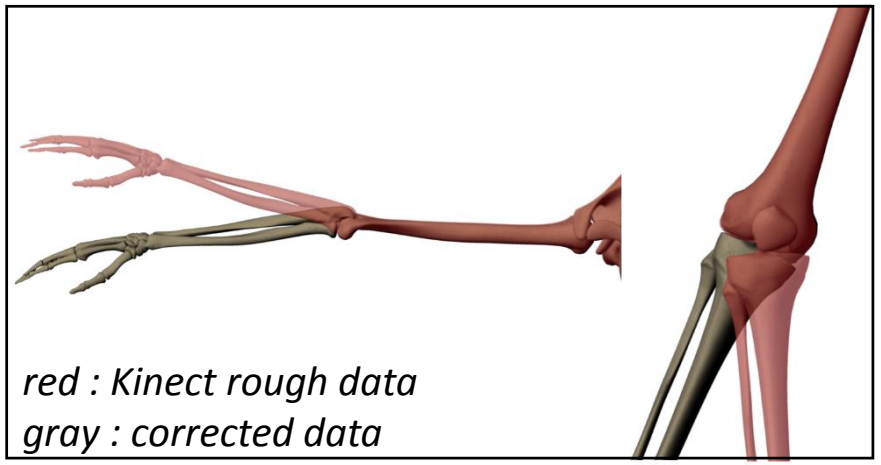
(a): our hierarchical body tracking skeleton at (t0).
(b): Kinect body tracking skeleton at (t).
(c): our result.

The 3x3 rotation matrix R :

$$\alpha = asin\left(\left\|\overrightarrow{fc}(t_0) \wedge \overrightarrow{fc}(t)\right\|\right)$$

$$axis = \frac{\left(\overrightarrow{fc}(t_0) \wedge \overrightarrow{fc}(t)\right)}{\left\|\overrightarrow{fc}(t_0) \wedge \overrightarrow{fc}(t)\right\|}$$

Anatomical constrained joint orientations :



Tracking evaluation : user study

To evaluate the quality of our mirror-like AR system.

	C01	C02	C03	C04	C05	C06
bad (--)	0	3	1	0	0	2
average (-+)	4	10	6	2	2	5
good (++)	16	7	13	18	18	13

The user study group is composed of :

- 13 men between 24 and 54 years old
(average height: 181cm, average weight: 82.6kg)

- 7 women between 22 and 44 years old
(average height: 164cm, average weight: 61.7kg)

***(C01)* Body position range**
motions while standing, crouching or sitting.

***(C02)* Body orientation range**
body orientation from Kinect point of view: facing, profile, 3/4, back.

***(C03)* Motion range**
- *simple motions like Flexion/extension of the knee*
- *complex motions in the extremities (finger motion, etc.)*

***(C04)* Motion fluidity and delay**

***(C05)* Motion consistency**
absence of outliers during motion.

***(C06)* Motion plausibility**
joint DOFs and angular limits.

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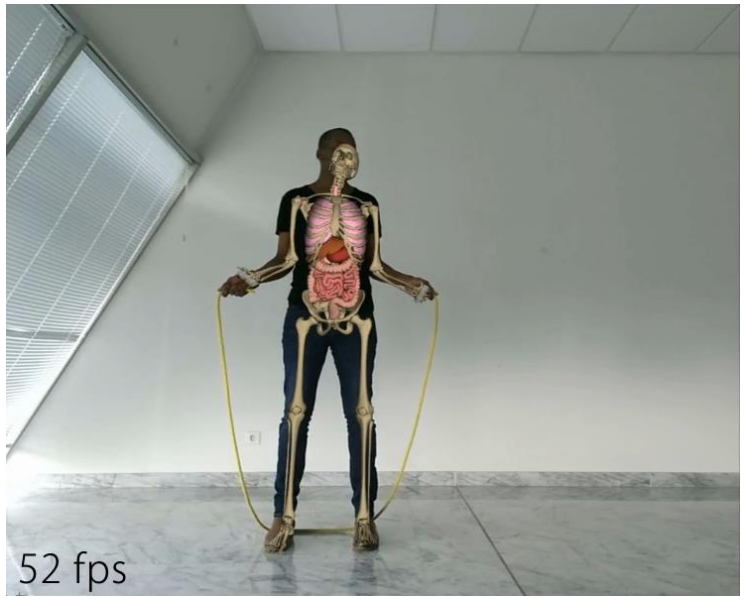
Our results

> Required Motion



> Fitness Motion

> Extreme Motion

> Free Motion

Conclusion

Thanks to the use of **anatomical knowledge**, we significantly **improve AR realism** and **anatomy motion plausibility** with respect to our previous works in the Living Book of Anatomy project.

Future Work :

- Silhouette retargeting : to ensure that the 3D user-specific data always lies within it
- Biomechanical simulation : for more realistic soft tissues deformations
- Inverse Dynamics : for full body muscular activity

Living Book of Anatomy (LBA) Project : See your Insides in Motion!
Armelle Bauer, Ali-Hamadi Dicko, Olivier Palombi, François Faure, Jocelyne Troccaz
Emerging Technologies – Siggraph Asia, **2015**

Interactive Visualization of Muscle Activity During Limb Movements : Towards Enhanced Anatomy Learning
Armelle Bauer, Florent Paclet, Violaine Cahouet, Ali-Hamadi Dicko, Olivier Palombi, François Faure, Jocelyne Troccaz
Eurographics Workshop on Visual Computing for Biology and Medicine (VCBM), **2014**

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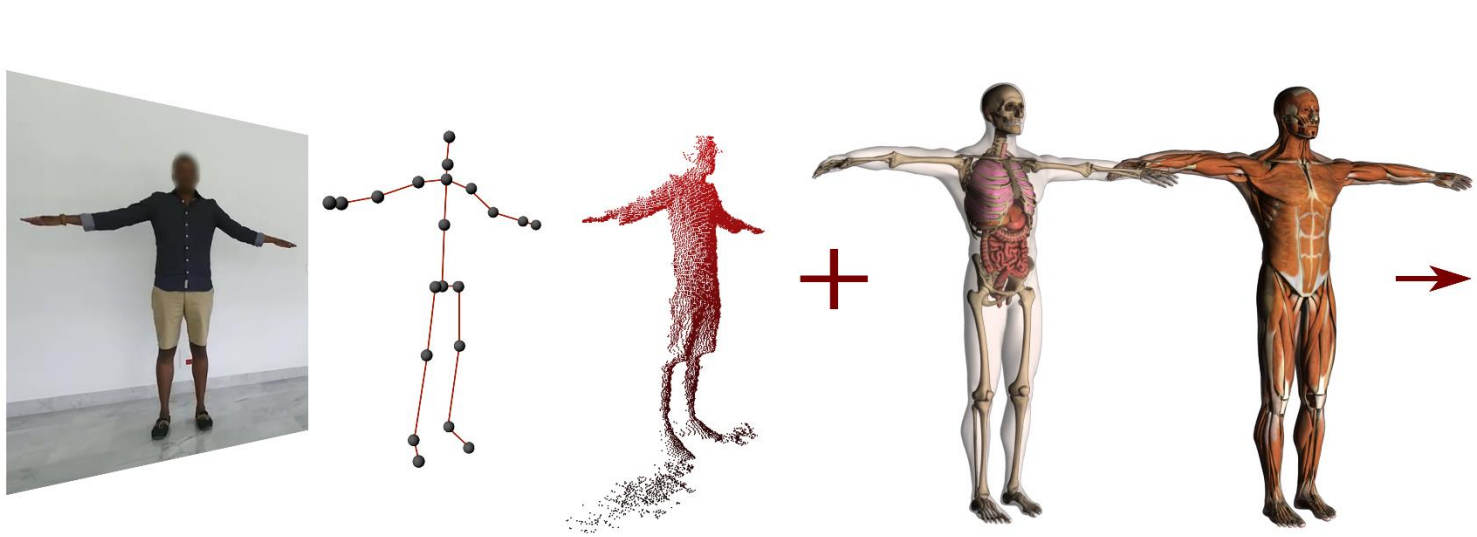

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