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]
Mirror-like Augmented Reality

**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)

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Pipeline of our system

1. **Generic 3D model**
2. **User’s measurements**
3. **Anatomy Knowledge**

**Steps:**
- **Calibration**
- **Motion Tracking**
- **LBA**
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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.

Body Segment Measurements

Color map  Silhouette

Kinect output

Calibration routine: 3 body positions

User’s key points

- Skeleton Key points
- Body measurements key points
Step 2: skin registration

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- 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]

> Zhou et al [2014]

> Zhu et al [2015]
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 con strained joint Orientations
  *(dofs and angle limits)*

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

**Real-time Motion using a commodity depth camera**

**Comparison between rough Kinect data and our system:**

Rough Kinect Tracking Skeleton

Rough Kinect data
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 $R$:

$$\alpha = \arcsin \left( \frac{\| \vec{f}_c(t_0) \times \vec{f}_c(t) \|}{\| \vec{f}_c(t_0) \times \vec{f}_c(t) \|} \right)$$

$$axis = \frac{\vec{f}_c(t_0) \times \vec{f}_c(t)}{\| \vec{f}_c(t_0) \times \vec{f}_c(t) \|}$$

Anatomical constrained joint orientations:

red: Kinect rough data
gray: corrected data
Tracking evaluation: user study

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

<table>
<thead>
<tr>
<th></th>
<th>C01</th>
<th>C02</th>
<th>C03</th>
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<td>7</td>
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<td>18</td>
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</tbody>
</table>

The user study group is composed of:
- 13 men between 24 and 54 years old (average height: 181 cm, average weight: 82.6 kg)
- 7 women between 22 and 44 years old (average height: 164 cm, average weight: 61.7 kg)

(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

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Required Motion

Extreme Motion

Fitness 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

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**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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