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# Living Book of Anatomy (LBA) Project : See your Insides in Motion!

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**Figure 1:** Our system starts by generating user-specific anatomy using a deformed bounding cage and the anatomy transfer method (a). This model is used for visualizations of : the lower limb musculoskeletal system (b), muscle activity during knee flexion (c), the complete skeleton (d) and rib cage organs (liver, lungs, stomach, intestines, etc) in (e). In (f) we present our interactive point and click anatomy education game. See more at <http://lba.inrialpes.fr/>

## 1 Introduction

The complexity of human anatomy makes learning and understanding it a difficult task. Using the Embodiment Theory<sup>1</sup> as foundation we present the living book of anatomy project, an AR system for teaching anatomy, specifically anatomy in motion.

Using a Kinect sensor, we superimpose our 3d highly-detailed anatomical model onto the user's color map and we use skinning to animate it. The user can visualize in real-time his anatomy moving together with himself as if he was able to look inside his own body. We designed this work to show different and interesting anatomical knowledge for non-specialist people, as shown in Figure 1.

The remainder of the paper is organized as follows. In Section 2, we briefly survey related demos. We then describe the inner working process of our demo in Section 3, which is explained in Section 4. We present and discuss our expectation of Siggraph Asia attendees in Section 5. We finally conclude by presenting possible applications of our work and under development features in Section 6.

**Keywords:** Augmented Human, Anatomy Learning, Real-time, Motion Capture, Embodiment, Augmented Reality (AR).

## 2 Related Work

The last few years, AR applications increased in the medical education fields [Kamphuis et al. 2014]. Figure 2 present comparisons between state-of-the-art demos and our work.

	[Blum et al. 2012]	[Maitre 2014]	[Zhu et al. 2015]	[Borner and Kirsch 2015]	[Bauer et al. 2014]	Our demo - 2015
Real-Time	Green	Green	Red	Green	Green	Green
User-Specific model	Red	Red	Green	Red	Green	Green
Anatomical data animation	Red	Yellow	Green	Green	Green	Green
AR - Position Registration	Yellow	Red	Red	Red	Red	Yellow

**Figure 2:** Comparison between state of the art demonstrations, first LBA version and current LBA version.

Our work improves on the Magic Mirror [Blum et al. 2012]. Our work is not limited to a body area and can be used to visualize bones and organs as well as muscles. Another important point is that by using mainly CT scans data, the Magic Mirror is fairly static.

The Digital Mirror [Maitre 2014] uses non deformable scans data. Unlike the Magic Mirror, it shows the entire body to the user but the visualization is not superimposed onto the user. A simple tracking is applied to follow the user's position in space.

The Anatomical Mirror [Borner and Kirsch 2015] was created by students in artistic fields. Just as our work, it shows bones, organs and muscles in real-time. The vialization is fluid and of high-quality. However, the 3d anatomical data is not user-specific and is not embedded onto the user color map.

Most of the works coupling depth sensors and anatomy deals with bone motion, such as [Zhu et al. 2015]. This work is rather interesting and seems to obtain good results but does not work in real-time.

We can also cite [Bauer et al. 2014], a previous work of our team. Results are similar to Figure 1 (b), but done with a better filtering

<sup>1</sup>In a nutshell : our motor system influences our cognition [Lusk and Atkinson 2007]

and depth sensor. The biggest improvement is the AR visualization.

### 3 Technical working process

Figure 3 synthesizes the workflow of our demo. First we generate the user’s anatomy, then we track him to animate it and we embed the anatomy onto the user’s color map.

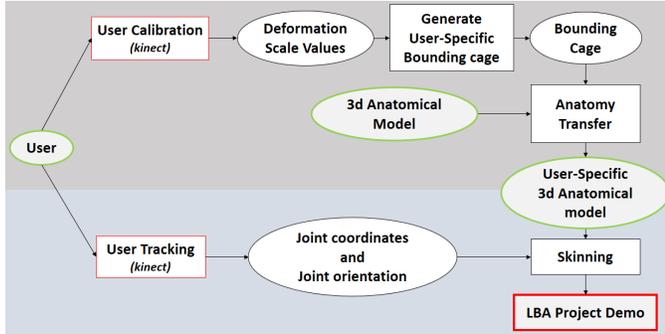


Figure 3: Simplified pipeline of the LBA project working process.

#### 3.1 User-specific anatomy generation

To generate a user-specific anatomical model we use "Anatomy Transfer" [Dicko et al. 2013], a semi-automatic method to transfer a reference anatomical model from an input skin mesh to an arbitrary target.

Knowing the fact that it is complicated with a single depth sensor to obtain a skin mesh, we decided to work with a simplified bounding cage. Using bounding cages is also more convenient for our data because then, anatomy transfer will work even with people wearing large clothing.

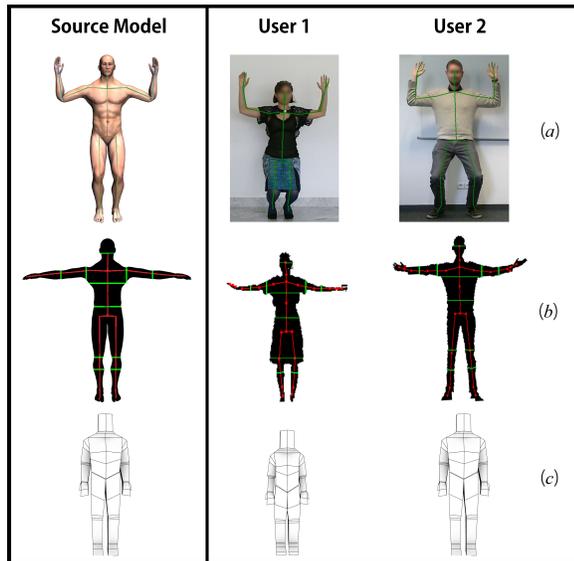


Figure 4: Source and user data ((a) and (b)) to find scale values and deform source bounding cage to obtain user-specific cages (c).

To create a user-specific bounding cage, we deform the source cage according to scale values (ratios between source and target bounding cages). The deformation is applied on an animation skeleton made of 23 shear-less affine transforms (DOF : translations, rotations and scales only) using linear blend skinning. In Figure 4

(c) we present the source bounding cage on the left and two user-specific bounding cages on the right. The Kinect technical specification defines Kinect joint orientations (see Figure 5).

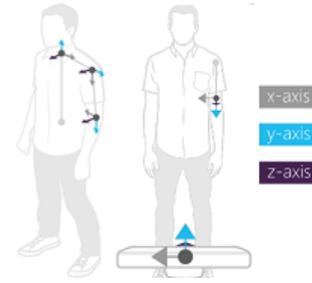


Figure 5: Joint Orientation : y-axis point towards the child joint. x-axis and z-axis depends on the kinect world orientation.

To find the x-scale values, we use joints provided by the Kinect API projected onto the user’s silhouette and the silhouette itself, in red in Figure 4 (b). We compute the normal to define a straight line equation and we use Bresenham’s algorithm to find the silhouette edge pixels along it. Using the Kinect 2d-3d mapping system, we find the silhouette thicknesses. By comparing them with those of our reference model, we compute x ratio values.

Knowing the y-axis point towards the child joint, we compute in-between joint lengths and compare them with those of our reference model to find out y-scaling values (see 4 (a)).

With a single Kinect, it is not easy to find z-scale values, we use the x/y ratio of the reference model to infer them.

Because working on a single Kinect position is too arbitrary to define the scale values, we defined extreme poses to have real lengths of upper/lower limb parts and then compute scale values.

Applying anatomy transfer method on the user bounding cage, allows us to obtain the user-specific anatomy within 15 seconds.

#### 3.2 User-specific anatomy results evaluation

To evaluate our algorithm we propose to compare the obtained skeleton with a reconstructed MRI skeleton for two of our users. The results show various similarities like the size of bone, their shapes or their proportions, which is enough for our needs, as shown in Figure 6.

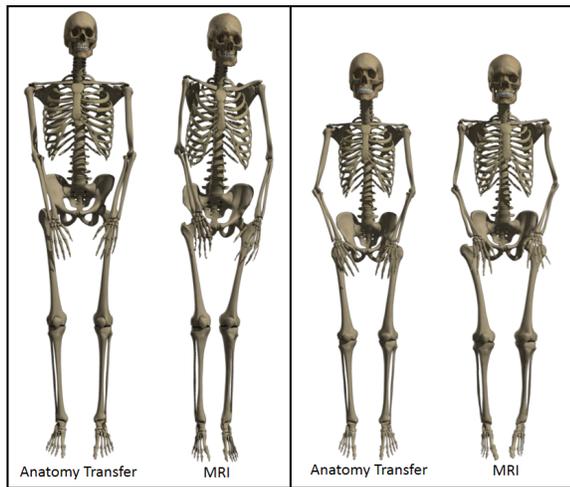
We compared full skeleton, limb length and rib cage width between the MRI skeleton and our skeleton. With our bounding cage system, we provide anatomical data similar to the real user’s data (for a healthy user). In the left example of Figure 6, the tall person squeezed himself to fit into the MRI scanner, which explains the shoulders differences.

#### 3.3 User Tracking

The Kinect Sensor gives a rough animation skeleton recalculated at each frame. After user calibration, we compute distances between joints. These distances are used to constraint the Kinect data and to prevent 3d elements to be separated at articulation points. A simple trajectory smoothing filter is applied before we use Kinect data. This filter could be improved.

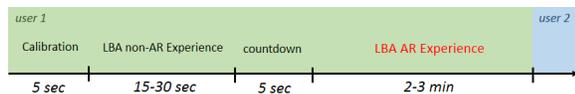
### 4 Demonstration on site

Our demo is based on the use of a depth sensor to do real-time motion capture. With it, we create an AR experience based on the



**Figure 6:** Comparison between Anatomy Transfer generated anatomy (on the left) and MRI reconstructed anatomical data (on the right) for two users.

visualization of anatomical structures. Our work is designed to be mirror like and shows one person at a time : it will ignore the surroundings.



**Figure 7:** Timeline of the demonstration.

As we can see in Figure 7 the calibration routine is about 5 seconds long and will be followed by a non AR LBA Experience, providing us enough time to generate the user-specific anatomy by launching the automatic anatomy transfer procedure. After a 5 seconds countdown, the real experience will start. During the overall duration of 2 minutes, the user will see his anatomy through different visualization setups with smooth interpolations inbetween. We block the user experience to 2 minutes to avoid long waiting time.

The complementary video can be useful to fully understand this demo details.

## 5 Attendees feedback and work evaluation

We think that this demo will be well received by Emerging Technologies attendees because of the curiosity everyone seems to have for their own anatomy. At the end of the demo we will ask the user to complete a user study to keep general feedback. Because the main goal of our demo is to help learning anatomy, our demo will be firstly tested with medical 1st year students in september. This will allow us to have first user's feedback to gain robustness and to upgrade our demo if necessary.

With the user consent, a video of the experiment will be added to the project website (with blurred faces) and will be sent to the user by email.

## 6 Discussion and conclusion

We present the first live demo of personalized anatomy in motion. Superimposing the anatomy onto the user's image allows us to create a real-time augmented reality experience. In future work, we will work on inverse dynamics [Murai et al. 2010] to show full

body muscular activity for every possible body motion. We also will work on increasing the overall quality stabilization : mesh texturing, better embedding of the 3d elements on the user color map, etc.

More ahead in time we want, in addition to the AR visualization, display anatomical content : text, images, videos, etc. We also think about adding simulation and having more realistic deformations, especially for soft tissues (muscles and organs).

Our work is designed to be used as a tool for anatomy learning for medical and sports students. But it could also be used to communicate between a medical practitioner and his patient, about surgery, rehabilitation or any health issue. Novel artistic content might also be produced using our technology.

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