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LeBonGeste: basketball training by entertaining

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Abstract

This paper describes *LeBonGeste*, a device consisting of a basketball basket equipped with sensors, actuators and computers to create a so called **augmented basket**. It is used to train beginner players to the free throw by helping them to achieve the right stance. Thanks to the Kinect depth-sensor, the system delivers realtime feedback to the player. *LeBonGeste* has been showcased two times indoor and outdoor using different communication channels for feedback: visual (screen or LED strips) and audio. Developed as an interactive installation for training by entertaining, the system will be tested soon on basketball courts with experienced players.

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Keywords: Basketball, free throw training, Kinect, motion analysis, interactive installation, Arduino

1. Introduction

LeBonGeste was born in June 2015 with the encounter of the following three entities:

Le centre culturel numérique Saint-Exupéry (Saint-Ex for short) is a place dedicated to digital practices, multimedia resources and contemporary artistic expressions. Member of the UNESCO Digital Art Network and supported by the Ministry of Culture and Communication, it develops innovative and educational materials allowing anyone to experiment digital tools in a creative and sensitive way.

UTILE is a team of the CReSTIC, ICT research laboratory of the University of Reims, focused on *Human Centered Computing*. Hijacking digital devices is one of the topic addressed by UTILE in order to use digital technologies as the support of a new kind of relation between people by augmenting their perceptions or the type of their interactions.

Reims Streetball Kings is an association founded in 2014 that promotes urban culture and streetball, an outdoor variant of basketball. Their streetball tournament organized every June in Reims is one of the most important in France.

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At the crossing of art, computing and sport, this project aims to create an augmented basketball basket by embedding sensors, actuators and computers. This device has been created for the Kinϵstezi digital art exhibition run by Saint-Ex that questions the notion of body, its movements and its role in the creation process: it acts as a trigger that reveals the nature of an artwork. In some ways, it can be seen as an interactive artistic installation that visually demonstrates inner perceptions like balance and stance. Within a sporting perspective, *LeBonGeste* can be also considered as a training device for basketball beginner players. By hijacking gaming peripherals like a Kinect sensor, it provides technical advices by entertaining and challenging the player.

Fig. 1. (a) Indoor version with video projector and speakers (b) Outdoor version with LEDs.

The Kinect sensor has been used in numerous research projects as a low-cost motion capture system: Marquardt *et al.* use it for ballet dancers[1], Lin *et al.* have developed a golf training[2] software based on the Microsoft depth-sensor. Yamaoka *et al.* give a state of the art of recent motion capture strategies[3]. But Kinect has also been mainly investigated in sport sciences and biomechanics. Recently, Choppin *et al.* validated angle measurements with Kinect for slow motion[4,5]. These results make the Microsoft sensor the better device for *LeBonGeste* according to its price and its ease of use. To the best of our knowledge, there are no such digital training systems in basketball except rise 2.0 developed by Nike. But this system which consists in a huge LED display underneath the basketball court and a very sophisticated tracking system is very expensive and was showcased just once in China.

In order to be relevant, our system has to rely on technical criteria that can assess the quality of a free throw. Thanks to an extensive literature on stationary basketball shooting form and technique[6,7], we have identified key elements that contribute to a good free throw:

1. Feet are shoulder width apart for good balance.
2. Shooting foot is slightly ahead of the non-shooting foot in a comfortable position.
3. Flex/bend your knees on every shot.
4. Uncoil your body with your legs, core, and arm power all coordinated.

5. Use your legs to generate upforce.
6. Your elbow and wrist should extend in a straight line to the basket.
7. Hold your follow through position until the ball hits the rim.
8. Your wrists should be floppy (relaxed).
9. Fingers should be pointed at the target (rim)

2. System overview

LeBonGeste has been designed as an **augmented basket** embedding sensors, actuators and computers in order to interact with the player by providing realtime feedback upon her/his posture before shooting. It was first showcased indoor in November 2016 at Saint-Ex (Figure 1a). At that time, we used a video projector to display the skeleton generated by the Kinect sensor superimposed on the color stream. Audio feedback was also produced with speakers to alert the player about her/his stance like a parking aid system: a high-pitched sound indicating a bad flexion, a low-pitched sound indicating unbalance. The perfect stance turned off both sounds. But this first version of *LeBonGeste* have shown several drawbacks:

1. The alert sounds are difficult to distinguish especially in a noisy environment, a crowded place with loud music for instance.
2. The display under the basket distracts the player making him lose focus on her/his shoot.

The second version of *LeBonGeste* has been showcased in March 2017 during nuitnumerique#14, a digital art exhibition organized by Saint-Ex (Figure 1b). During this evening, it was installed outdoor in order to mimic a streetball court. For meteorological and organizational considerations but also to address the issues encountered with the first version, we decided to present a *minimalist* declination of our system with no display and no speakers. A LED strip circulating on the backboard perimeter is used for feedback in a manner of a *double bargraph*, left and right side of the backboard dedicated to a single parameter. As a consequence, **the backboard becomes the screen**. Thanks to that, the player can adjust her/his posture and stay focused on the target (Figure 2a). In the next sections, we describe in what our system is made of in terms of hardware, software and how does it work by describing its algorithm.

2.1. Hardware

In the spirit of the *Do It Yourself* approach, we have chosen to rely on mainstream electronics, making it easy to be reproduced by others. All the components used in *LeBonGeste* can be ordered online on any electronics shop. The whole system has been packaged in custom waterproof cases made of plexiglass and wood, produced by artfabrique laser cutting machines. artfabrique, created by Saint-Ex in 2014 under the <ART>machine</> label, is a place for creativeness, exchanges and of various practices related to computer controlled manufacturing techniques (3D printers, laser cutting machines, plotter cutters, *etc*). Here is the list of the equipments we used (Figure 2b):

- Adjustable infrared sensor (type MC005)
- RGB LED strip (Adafruit NeoPixel type WS2812B)
- Arduino MEGA 2560 R3
- Microsoft Kinect v2
- Windows 10 laptop (Intel Core i7 2.7GHz, 8 Gb RAM)

Plus, for the indoor version:

- Video projector ACER 6500 lm
- Speakers MAudio type AV30

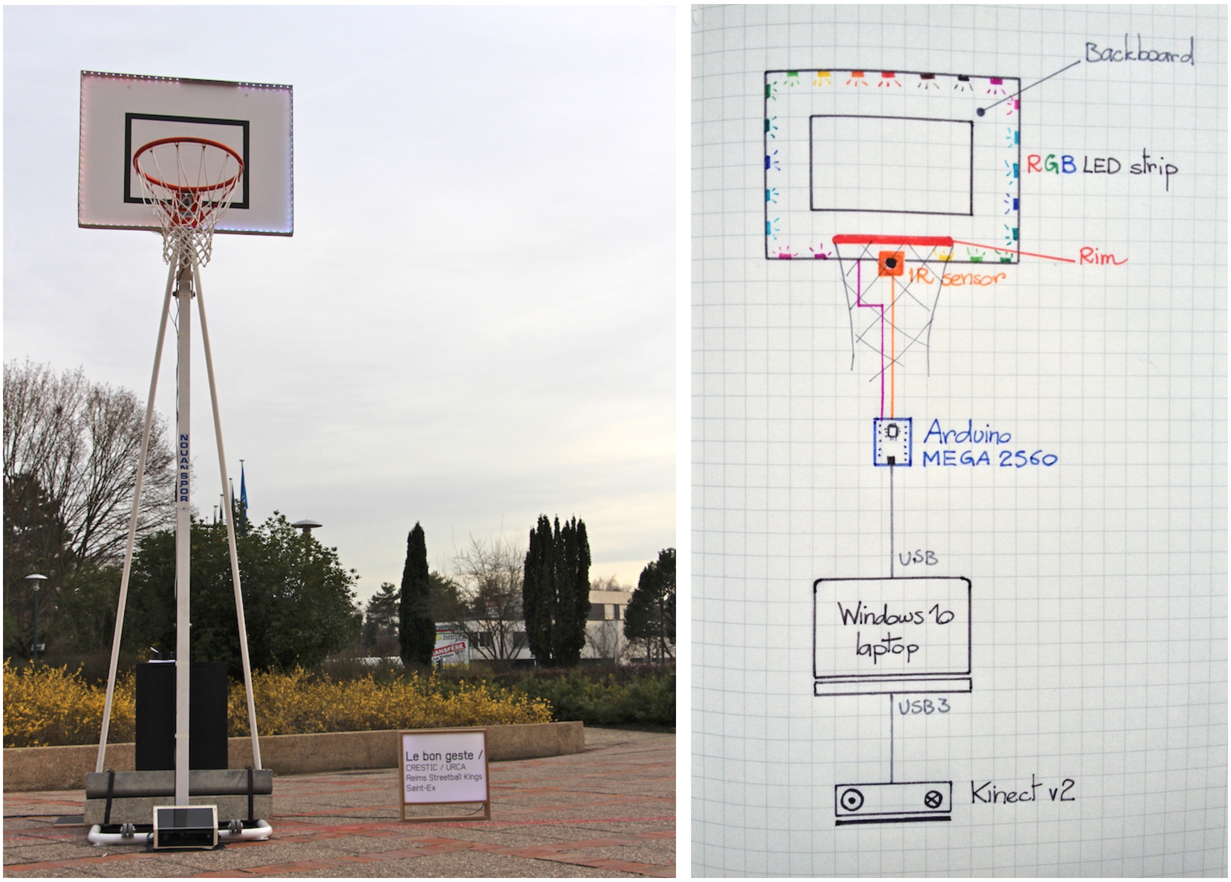

Fig. 2. (a) *LeBonGeste in situ* (b) Synoptic diagram.

2.2. Software

We used the same approach for software by choosing open-source frameworks dedicated to creative coding. These tools, developed by a huge community, are the *glue* between very different software components (Arduino libraries, Kinect SDK, ...) making them interoperate in a straightforward way.

- Arduino [8]
- Kinect for Windows SDK [9]
- openFrameworks [10]

2.3. Algorithm

The whole system can be described by a finite state machine (Figure 3a) whose state transitions are governed by predefined events.

1. The system quits the `Idle` state as soon as a user step inside the tracking zone. Within the `Posture Analysis` state, the system computes in real-time scores related to knee flexion and spine tilt. These two parameters are used to switch on LEDs circulating on the backboard perimeter in a manner of a *double bargraph*, left and right side of the backboard dedicated to a single parameter: **the brighter the basket the better the posture!**
2. When a throw is detected, the system enters the `Bad/Good Gesture` state making the backboard blink green or red (Figure 4) in order to inform the user about the quality of her/his throw.

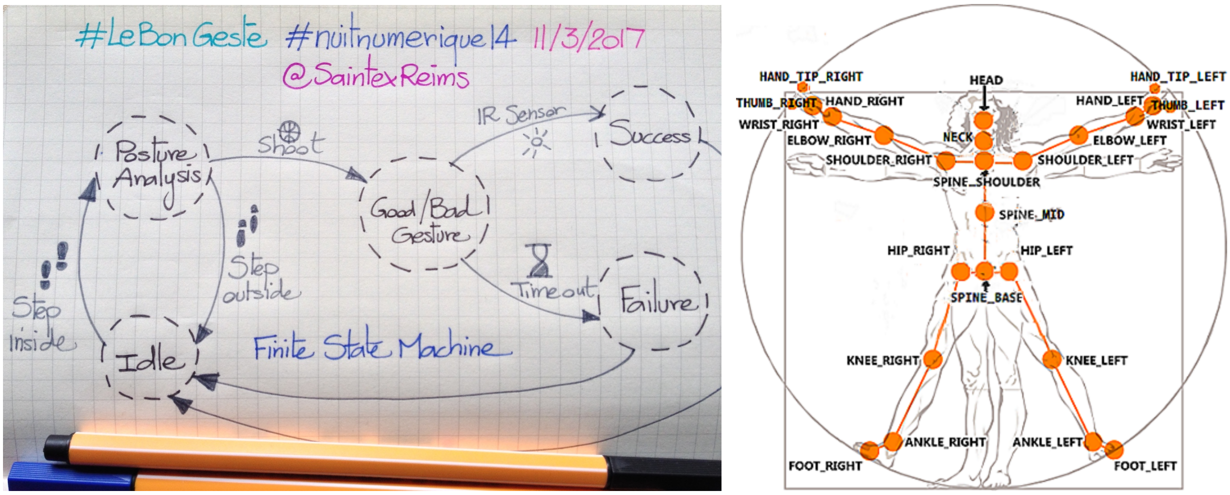

Fig. 3. (a) *LeBonGeste* Finite State Machine visually explained (b) Joint names as defined by the Kinect for Windows SDK.

3. Finally, if the infrared sensor attached to the rim detects the ball, the system enters the `Success` state leading the basket to blink in a colorful way as a reward. Otherwise, a timeout triggers the `Failure` state switching the lights off progressively.

LeBonGeste heavily relies on motion analysis to measure angles and distances, used as scores to assess the quality of the posture. Kinect v2, released in 2012 by Microsoft, brings important enhancements thanks to its new depth-sensing method based on the *time-of-flight* technology. As a consequence, body tracking has been improved, allowing to retrieve 3D position and orientation of 25 joints, including thumbs and hand tips (Figure 3b). Compared to Kinect v1, the tracked positions are more anatomically correct and stable and the range of tracking is broader.

2.3.1. Knee flexion

During a free throw, you have to use your legs to generate upforce[6,7]. Knee flexion is a good indicator to ensure that the ball will be thrown with enough impulse. Let $\mathbf{u}_l$ and $\mathbf{l}_l$ be upward unit-length vectors respectively aligned with the upper and lower leg bone. Joint positions are named using the enumeration type defined by the Kinect for Windows SDK (Figure 3b).

$$\mathbf{u}_l = \frac{\mathbf{p}^{\text{HIP\_RIGHT}} - \mathbf{p}^{\text{KNEE\_RIGHT}}}{||\mathbf{p}^{\text{HIP\_RIGHT}} - \mathbf{p}^{\text{KNEE\_RIGHT}}||} \quad \text{and} \quad \mathbf{l}_l = \frac{\mathbf{p}^{\text{KNEE\_RIGHT}} - \mathbf{p}^{\text{ANKLE\_RIGHT}}}{||\mathbf{p}^{\text{KNEE\_RIGHT}} - \mathbf{p}^{\text{ANKLE\_RIGHT}}||} \tag{1}$$

The score $s_1 \in [0, 1]$ representing flexion quality is deduced as follows from the angle α calculated by the dot product of $\mathbf{u}_l$ with $\mathbf{l}_l$.

$$s_1 = \max\left(0, 1 - \frac{|\alpha - \alpha_0|}{h}\right) \quad \text{where} \quad \alpha = \cos^{-1}(\mathbf{u}_l \cdot \mathbf{l}_l) \tag{2}$$

α_0 corresponds to the reference angle of the optimal flexion and h is the half-width of the observed angle range.

2.3.2. Spine tilt

For reliability and reproduction considerations, the throw has to be performed in a comfortable position with a good balance[6,7]. The spine tilt is another indicator that is strongly linked with balance. Let $\mathbf{s}$ be the upward unit-length vector aligned with the spine and $\mathbf{v}$ the *world* vertical axis expressed in the camera coordinate system.

$$\mathbf{s} = \frac{\mathbf{p}^{\text{SPINE\_SHOULDER}} - \mathbf{p}^{\text{SPINE\_BASE}}}{||\mathbf{p}^{\text{SPINE\_SHOULDER}} - \mathbf{p}^{\text{SPINE\_BASE}}||} \tag{3}$$

Fig. 4. (a) Good gesture (b) Bad gesture.

The score $s_2 \in [0, 1]$ representing spine vertical alignment is deduced as follows from the angle β calculated by the dot product of $\mathbf{s}$ with $\mathbf{v}$.

$$s_2 = \max\left(0, 1 - \frac{\beta}{h}\right) \qquad \text{where} \qquad \beta = \cos^{-1}(\mathbf{s} \cdot \mathbf{v}) \tag{4}$$

2.3.3. Throw detection

Because the ball is not tracked in the body stream generated by the Kinect sensor, the moment when the ball is thrown has to be detected indirectly. According to the coach recommendations, the shooting arm must be stretched (shoulder and wrist extended in a straight line to the basket) and this follow through position must be maintained until the ball hits the rim. So, for our system, the ball has been thrown when the shooting arm is stretched and the elbow is above the shoulder. Let $\mathbf{u}_a$ and $\mathbf{l}_a$ be unit-length vectors respectively aligned with the upper and lower arm.

$$\mathbf{u}_a = \frac{\mathbf{p}^{\text{ELBOW\_RIGHT}} - \mathbf{p}^{\text{SHOULDER\_RIGHT}}}{\|\mathbf{p}^{\text{ELBOW\_RIGHT}} - \mathbf{p}^{\text{SHOULDER\_RIGHT}}\|} \qquad \text{and} \qquad \mathbf{l}_a = \frac{\mathbf{p}^{\text{WRIST\_RIGHT}} - \mathbf{p}^{\text{ELBOW\_RIGHT}}}{\|\mathbf{p}^{\text{WRIST\_RIGHT}} - \mathbf{p}^{\text{ELBOW\_RIGHT}}\|} \tag{5}$$

The system leaves the `Posture Analysis` state when the two conditions below are true:

$$\delta < \delta_0 \quad \text{where} \quad \delta = \cos^{-1}(\mathbf{u}_a \cdot \mathbf{l}_a), \qquad \text{and} \qquad \mathbf{p}_y^{\text{ELBOW\_RIGHT}} > \mathbf{p}_y^{\text{SHOULDER\_RIGHT}} \tag{6}$$

δ_0 corresponds to the maximum bending angle for precision considerations.

2.3.4. Overall score computation

The overall score is communicated to the Arduino microcontroller through the USB cable when the ball is thrown. But at this very moment, the player legs are stretched to generate upforce. So we use a sliding window algorithm to retrieve the best scores among the ten last values recorded. The overall score s_{global} at time t_0 is computed as follows:

$$s_{global} = \left(\max_{t_0 - 10 \le t \le t_0}(s_1^t) + \max_{t_0 - 10 \le t \le t_0}(s_2^t)\right) / 2 \tag{7}$$

This overall score s_{global} is tested against a given threshold to tell if the posture was good or bad. Because the scores s_1 and s_2 are not player dependent (height, weight, *etc*), the threshold value is constant.

3. Conclusion and perspectives

LeBonGeste was showcased during nuitnumerique#14, a digital art exhibition organized by Saint-Ex on 11 March 2017 evening with more than 1300 visitors. A lot of different people experienced the system: children, seniors, sportsmen. It did not crash and resist to the numerous shoots and dunks even if it was not developed for this purpose.

The comments were very positive concerning the relevance and the efficiency of our solution. More specifically, we collected the feedback of 18 randomly selected people at this event. 83% of them estimated that the system allowed easily to understand that the illumination of the backboard was connected to the flexion of the knees. The upright spine position was generally adopted naturally, leading to few needs of corrections, so only 17% of the people reported that they took this parameter into account. The overall evaluation of the system is excellent: 92% of the people stated that the device facilitated the adoption of a good posture, 78% of them found the system useful for learning, and 94% found the experience pleasant.

We are already working on the third version that will be showcased in June during a sport event: a national streetball tournament organized by Reims Streetball Kings. We plan to add an homemade score counter and a video replay. We also want to test *LeBonGeste* on a basketball court with experienced players in order to adjust our parameters according to their profiles.

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