A real-time dance visualization framework for the design of mappings that favor user appropriation

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ABSTRACT

In this paper we present a real-time dance visualization framework with the goal of easily mapping motion data from an accelerometer and a gyroscope into visual effects that users can compose and appropriate to their own dancing style. We used this framework to design a set of dance-to-visuals mappings through a user-centered approach. As a result, we conclude with a list of factors that help users to understand how to interact with a real-time dance visualization with no prior instructions.

Categories and Subject Descriptors

H.5.m. [**Information interfaces and presentation (e.g., HCI)**]: Miscellaneous

General Terms

Design, Human Factors

Keywords

Interactive dance visualization, real-time interpolated animations, accelerometer, gyroscope, smartphones as wearables

1. INTRODUCTION

Nightclubs and parties have attempted to engage attendees by complementing music with visual media in many ways: music videos, abstract video loops, 3D projections inside nightclubs or music visualizations that are automatically animated by mapping features of the music signal (such as its loudness and frequency spectrum) to different graphic representations. We argue that the best way to engage people with technology is through interaction, and this inspired the "Canvas Dance" project: an interactive dance visualization for large-group interaction in nightclubs and parties.

"Canvas Dance" was designed to engage dancers by inspiring patterns of contagious dancing behavior (i.e. imitation among dancers and collective dance moves such as fist-pumping or jumping all together). While in previous publications we focused on the design for large-group interaction [4, 5], in this paper we will focus on the design decisions we took in order to give users clear feedback on how each of them is contributing to the overall experience. We describe the real-time dance visualization framework used for designing the mappings of "Canvas Dance" and the evolution of these mappings from the first prototype to the current design. We believe that the insights gained from this user-centered design process can be useful for future projects on real-time dance visualization.

Previous dance visualization projects for nightclubs used computer-vision techniques to obtain motion input from the overall crowd of dancers[7]. Our framework uses individual visual representations for each user [4], so we need to rely on a technology that enables an affinity between every dancer and their representations on the screen. Previous interactive dance projects used wearable sensors to provide accurate motion data from each dancer in artistic contexts[6] and also for parties and nightclubs[3]. Today, we can take advantage of the wearable and wireless motion sensors that our audience already owns: the accelerometer and gyroscope in their smartphones. Therefore, our interactive dance visualization takes the motion input from the smartphones of the users.

2. A DANCE VISUALIZATION FRAMEWORK

The system takes input from a mobile application that builds a *dance motion* signal composed of 3 axes of angular velocity and 3 axes of acceleration (Figure 1). All axes values are relative to the smartphone's coordinate system, except for the $\mathbf{dm_{accel}}$ **y-axis**, which is relative to the Earth coordinates system. In this way, we can identify the vertical component of every dance move (which usually marks the rhythm of the music) regardless of the position of the body.

A server application receives the *dance motion* signal from every user's smartphone, and maps each dance *beat* to a visual effect on each of their visual representations on the screen. The **blinking lights** (Figure 2) is an example of a dance-to-visuals mapping.

Our dance-to-visuals mappings link each *dance motion* signal axis to a different visual effect. Each peak of the signal triggers a visual effect on the visual representation of the dancer. This strategy enables users to compose visual effects on their "spheres of lights" in the same way they combine different body movements to perform a *dance move*. By avoiding the recognition of predetermined signal patterns, these

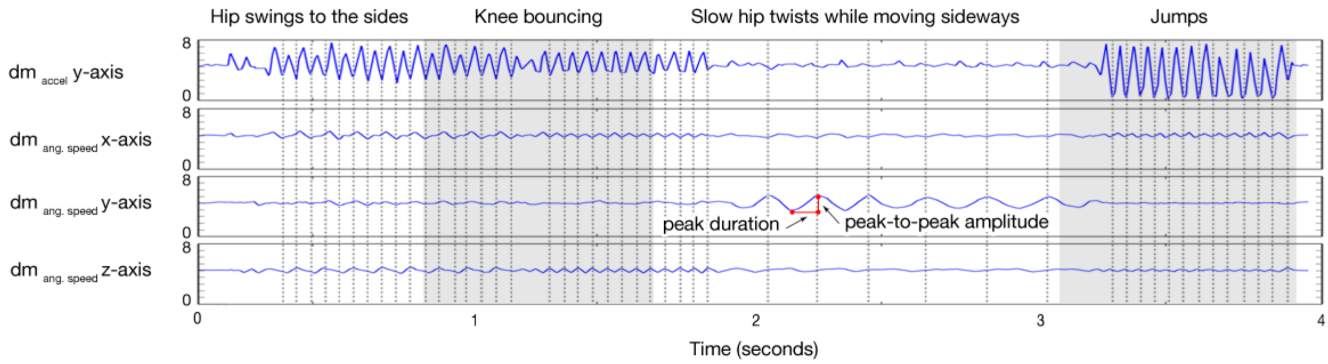

Figure 1: Plot of a subset of the 6-axes *dance motion* signal during repetitions of 4 different dance moves, wearing the smartphone on the back pocket of a pair of jeans. The vertical dotted lines mark each repetition of a dance move. Each peak of the signal represents a dancer changing the direction of her movements. We call these peaks the *dance beats*. The `peak-to-peak amplitude` is the distance between two opposite peaks. The `peak duration` is the time elapsed between two opposite peaks.

mappings can visualize any dance move, allowing dancers to appropriate the visualization for their own dancing style. We can consider basic dance moves as a repetition of opposite movements (e.g. swinging the hips to the left, then to the right), where the *beat* is marked when changing directions. In order to visualize this, we can map the *dance beats* themselves and the body movements between them. Additionally, the strikingness of the visual effects and the duration of their animations can be proportional to the *intensity* of the dance moves (the `peak-to-peak amplitude`) and the time between *dance beats* (the `peak duration`) respectively (Figure 1). This idea was inspired by the work by Enke et al. on dance rhythm analysis [2]. For representing a *dance beat*, the duration of the visual effect can be fixed. For body movements that occur between *dance beats*, this design uses animated visual effects that *follow* the movement of the body in real time (e.g. while the body goes up, the sphere gets bigger; while the body goes down, the sphere goes back to its initial size, as seen on Figure 2). We expect this kind of visual effects to expose the connection between the body movements and the animations on the screen, so users can easily understand how to interact with the visualization without detailed instructions.

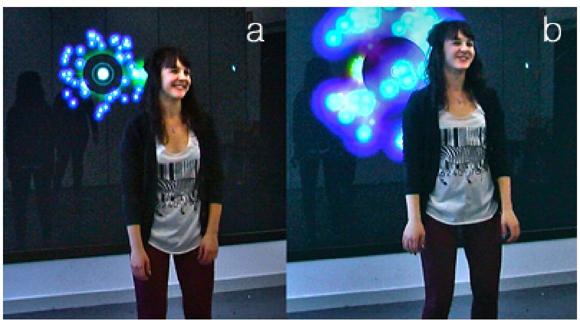

Figure 2: The "blinking lights" visual effect maps the ds_{accel} y-axis of the dance signal. (a) Little blue lights during a soft bounce. (b) Big blue lights on a bigger sphere during a jump.

The signal produced by our movements is not as smooth as we might feel, and it also carries some noise from the smartphone moving inside the clothes. If we directly map each *dance motion* value as soon as the server receives it, the visualization will present "broken" animations. Instead, we interpolate the animation between two values to achieve a smooth transition, for which we need an initial and final point, an interpolation function and a duration in time. The interpolation function (e.g. Linear, Cubic, Sinusoidal, etc.) depends on the kind of visual effect the designer wants to achieve, although we suggest avoiding the use of *ease-in* interpolations, as they can be perceived as delays in the start of the animations that degrade the real-time experience.

This poses a challenge: generating an interpolated animation that *follows* in real time the same body movement that triggered it. Taking the "horizontal slide" as an example (Figure 3): how can we know how much should the sphere move to the right the moment a dancer starts rotating to the right, if we cannot know beforehand when she will stop? Our workaround is based on assuming that every *dance beat* is similar to the previous one (Figure 1).

With that assumption, we can use the `peak-to-peak amplitude` and the `peak duration` from the signal of each *beat* respect to the previous one, and use them as arguments of an interpolated animation: from the current state of the "sphere of lights", the final point of the interpolation is proportional to the `peak-to-peak amplitude`, and the duration of the animation is the `peak duration`.

3. DESIGNING USER-CENTERED DANCE-TO-VISUALS MAPPINGS

In this section we summarize how the design of the "Canvas Dance" evolved from a first set of mappings to the current ones, supporting the changes on the design with insights from evaluations with users.

3.1 First design of dance-to-visuals mappings

The user-centered process started with an arbitrary mappings design based on how the designers felt that common dance moves observed in parties and nightclubs could be visually expressed. This first set of mappings are the "blinking

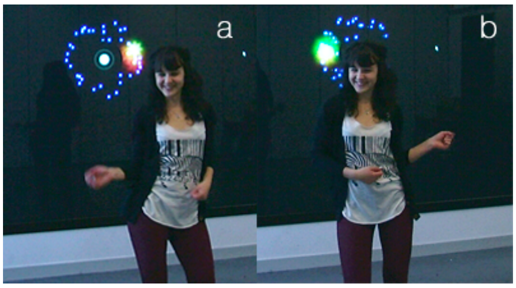

Figure 3: The "horizontal slide" and "color flashes" dance-to-visuals mappings. (a) The sphere moves to the right and flashes colors on the left after a twist and swing of the hips to the right. (b) The sphere moves to the right and flashes colors on the right after a twist and swing of the hips to the left.

lights" (Figure 4-B), the "shrinking and expanding sphere" (Figure 4-C) and the "side stars" (Figure 4-D). This design assumed that users were wearing their smartphones in one of the back pockets of their trousers.

3.2 Experiment Design

The evaluations on the prototype had the following formative goals: a) verify if the mappings were intuitive enough to let the user understand how to interact with the visualization with no instructions, b) understand how the users expect the visualization to react to their dance moves, and c) find out if users enjoyed the experience of visualizing their dance moves.

Each experiment was performed with one user in front of a computer screen showing the visualization and playing music. Participants were asked to wear a smartphone given to them in one of the back pockets of their jeans, and then dance while observing the visualization with no instructions on how to interact with it. After two songs, a semi-structured interview about the experience took place in order to know in detail which mappings were clear, which were not, and how would users expect to visualize their dance moves.

3.3 Redesigned dance-to-visuals mappings

The following redesigns were the result of a user-centered process involving 6 different users along 3 iterations of evaluations and re-designs.

The "Blinking Lights" effect mapping the $\mathbf{dm_{accel}}$ **y-axis** proved itself the most evident and engaging, and had very few changes over the whole design process. All users understood that intense vertical movements triggered "big lights" following their rhythm. Only one user fully appropriated this mapping, aware that the *blinks* mapped her rhythm and the size of the lights mapped the intensity of her *dance beats*. This inspired many comments in support of associating the strikingness of visual effects with the intensity of the body movements, such as "It would be nice to see (...) that everything explodes when youre giving it all" and "I like that during economic dance moves the screen looks chill, and when you spin or jump it explodes with colors". In the current design, the range of sizes that the lights can get is wider, and on very intense vertical movements such as jumps or deep squats the whole sphere "pulsates" along the blinking lights (Figure 2).

The "Shrinking and Expanding Sphere" that was mapping the $\mathbf{dm_{ang.\ speed}}$ **y-axis** was kept during 2 iterations. Despite the visual effect caught the eye of the participants of the experiments, from 5 participants only one of them was able to understand how the effect was triggered, although she suggested to use that effect to visualize jumps instead of twists (rotations). Other comments on this mapping illustrated that the visual effect chosen for twists of the body was not intuitive: "Does it expand with the music?", "When I *step to the sides* the lines get longer and shorter", and "soft moves make the sphere shrink and expand, and strong moves make the blue lights bigger". As a result of these evaluations, the $\mathbf{dm_{ang.\ speed}}$ **y-axis** was associated with a different visual effect: the "Horizontal Slide" (Figure 3), and the expanding effect was added to the "Blinking Lights" mapping for intense vertical movements (Figure 2). The "Horizontal Slide" maps twists and torso rotations in proportion to the intensity of the body movements: the wider the twist the further the sphere slides to the sides.

The "side stars" mapping the $\mathbf{dm_{accel}}$ **x-axis** were the least popular mappings of the first design. During the first evaluation, users noticed the white stars spreading away from the center of the sphere, but could not understand how to control them. For the second evaluation, we added colors to the "side stars": soft movements produce yellow stars, mid-intensity movements produce yellow and green stars, and high intensity movements produce yellow, green and red stars. The size and brightness of the stars is also proportional to the intensity of the horizontal movement that triggered the effect. Despite the participants of the second evaluation enjoyed the colors on the visualization very much, it was still unclear how to control this mapping. Then, we did further changes to this mapping for the third evaluation: the spreading "side stars" became "color flashes" on the sides that did not spread, and instead of mapping the $\mathbf{dm_{accel}}$ **x-axis**, this color flashes were mapping the $\mathbf{dm_{ang.\ speed}}$ **z-axis**. This change allowed the last participant to better relate every *flash* with each swing of her hips (Figure 3).

In general, participants enjoyed the aesthetics of the visualization and found them familiar to the ones in nightclubs. Some of the general suggestions collected from these single-user experiments are recognizing specific dance moves (e.g. hip rolls) and associating the strikingness of the visualization with the intensity of their movements. Finally, after the last re-design, it was possible to observe the last participant appropriating the visualization to her dance moves (e.g. combining body twists with hip swings or knee bounces to produce the combined visual effects).

The resulting design was used in a group experiment with 3 users, who were friends that agreed to participate together. In the experiment, they were invited to dance to several "radio hits" usually found in nightclubs after installing the "Canvas Dance" application on their smartphones, but they were not told about the interactive capabilities of the visualization. Participants noticed that the visualization was interactive on their own while *doing the twist*, observing how their representations moved to the sides with them. Then, they discovered the "blinking lights" while jumping. The kind of dance moves they liked using did not trigger many "color flashes". On the other hand, they checked if there were special effects for spins and hip rolls, which had no special mappings associated as "Canvas Dance" does not

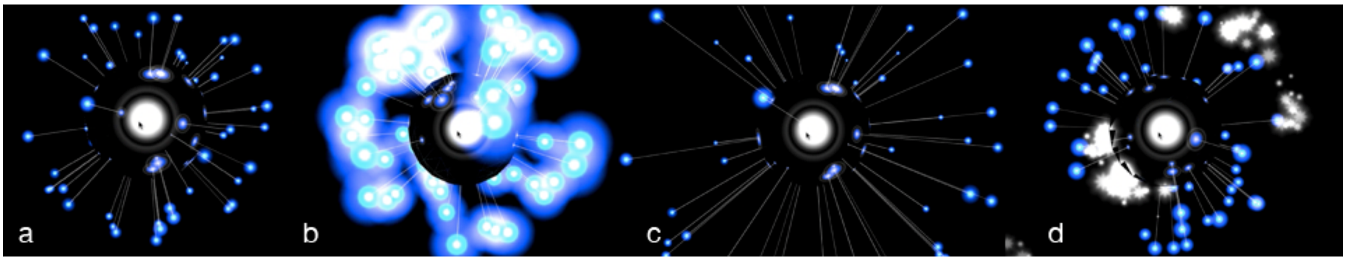

Figure 4: First set of dance-to-visuals mappings. a) The "sphere of lights" representation for each dancer. b) The "Blinking lights" map the dm_{accel} y-axis (vertical movements such as jumps and knee bounces). The blue lights blink on each *beat*; the stronger the movement the brighter the lights. c) The "Shrinking and Expanding Sphere" maps the $dm_{ang.\ speed}$ y-axis (torso and hip twists to the sides). It shrinks the sphere when rotating the body to the left and expands it when rotating to the right. d) The "side stars" map the dm_{accel} x-axis (horizontal movements such as steps to the side or hip swings). On each *beat*, some stars would start spreading away from the center of the sphere towards the direction of the body movement.

recognize dance steps. Some examples of appropriation were observed during the experiment: one participant combined twists with up-and-down movements sliding across the room, as she enjoyed observing how her sphere's lights were blinking while moving sideways; another jumped while spinning on the air; and all of them together took their smartphones out of their pockets and did "the wave" with their arms.

4. CONCLUSIONS

The user-centered approach provided very valuable insights about the real perception that users have towards the visualization in relation to their dance moves. While the first design of the mappings focused on assigning different visual effects to different directions of body movements, the experiments showed that dancers do not think of their dance moves in the same terms. Through the 6 evaluations over 3 re-design iterations, we found that in order to help users understand the connection between their dance moves and the visualization, the design of the visual effects should:

- Reflect the intensity of the dance moves they are mapping (e.g. soft vertical movements trigger soft blinking lights, intense vertical movements trigger *exploding* lights).
- Evoke similar movements than the ones performed by the dancer (e.g. rotating the body to the right moves the representation to the right, rotating to the left moves it to the left).
- Make every mapping easy to differentiate from others by using visual selective properties[1] in contrast to other mappings (e.g. the "blinking lights" rely on color, motion and size; the "horizontal slide" on motion; the "color flashes" on color).

5. DISCUSSION & FURTHER WORK

This design mapped different *dance motion* signal axes separately with the goal of letting users take appropriation of the visualization and compose different visual effects with their own dancing style. Nevertheless, users think of their dance moves as atomic "dance steps" instead of a combination of body movements in different directions, so besides the visual effects they can compose with the current design, they expect certain popular "dance steps" to trigger particular effects (such as hip rolls, spins or side-to-side steps). Future designs could explore the possibility of combining this dance visualization framework with pattern recognition of popular "dance steps". Then, a new challenge emerges: what two dancers might consider the same dance move might actually produce very different signals.

On the other hand, if the goal of this visualization framework is enable user appropriation: why is the design of the mappings assuming that users wear the phone in their back pockets? Future prototypes should explore the trade-offs of designing visual effects that are tailored to the motion signal produced from specific parts of the body against mappings that visualize dancing rhythms regardless the location of the smartphone.

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