OutsideMe: Augmenting Dancer's External Self-Image by Using A Mixed Reality System

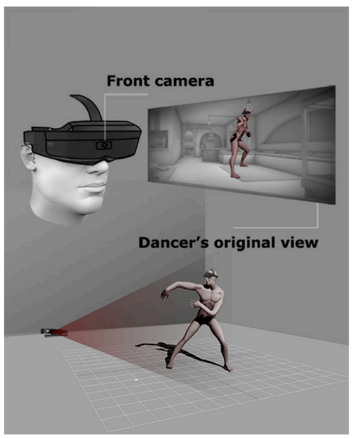

Figure 1. OutsideMe concept includes captured body movement and augmented external self-image.

Shuo Yan
shuoyan@bit.edu.cn

Gangyi Ding
dgy@bit.edu.cn

Zheng Guan
guanzheng@bit.edu.cn

Ningxiao Sun
ningxiao@bit.edu.cn

Hongsong Li
lihongsong@bit.edu.cn

Longfei Zhang
longfeizhang@bit.edu.cn

Beijing Institute of Technology
5 ZhongGuanCun South Street
Beijing, 100081 China

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Abstract
External self-image is often used as an effective tool to enhance dancing technique, choreography, creativity, and expression. The traditional tools of presenting external image, such as mirrors or videos, are limited in their mobility, perspective, and immediacy. To address the issue, we present OutsideMe, a vision-sync mixed reality system that enables dancers see their body movements as external observers through a head-mounted display (HMD) device. This system captures dancer's posture and blends it into scenes from the dancer's original field of view in an interactive frame rate. The dancers can observe themselves without distracting their presence identities. In this research, we develop four work modes for supporting dancer's training, and carry out a feasibility study and a user study. The feedbacks from the participants performing various dancing styles are analyzed and discussed. The preliminary experimental results support our design.

Author Keywords
Mixed Reality; External Self-Image; Augmented Human; Visual Blending; Choreography

ACM Classification Keywords
H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities; H.5.2 [User Interfaces]: Training, help, and documentation.

Figure 2. Modified the HMD with wide-angle lens camera.

Figure 3. The wearable wireless transmitting system.

Introduction

Using external self-image is regarded as an effective way to improve a dancer's ability [2]. The external self-image involves imaging from the perspective outside the dancer's body, as if observing oneself on video [11]. Traditional training and presenting tools, such as using mirrors and video replays, are limited. Mirrors provides only one perspective and video replays prevent dancers from observing themselves in real time. The limitations of these tools make dancing training a time-consuming task.

In this paper, we describe our efforts to create an external self-image mixed reality system. The system captures body movement, blends into the dancer's original front view, and displays the mixed scenes via a head mounted display (HMD) device, as illustrated in Figure 1.

OutsideMe has three main design goals. First, the dancers should be able to observe themselves from the external self-image in real time while they are practicing. Second, the dancers should be able to recognize their presence identities even though they are viewing through an HMD device. Third, extra virtual characters can be added into the dancers' views as supporting materials to help them practicing. For practical usage, the system should have good mobility and low cost. In our case, the prototype system is built with off-the-shelf equipment. We believe OutsideMe is able to help the dancers by providing real time external self-image of their own body movement and expanding their perspectives. With such a tool, a dancer can learn new moves faster. To prove our design, we carry out a feasibility study and a user study of the proposed system.

Related Work and Motivation

There has been a number of research concerning about providing external image to help learning motor skills in recent years. However, most of the studies are concentrated on sports training, such as jogging, swimming, or playing soccer [5,7,8,14]. They usually use an escort robot [7,14] or an aerial vehicle [5,8] to follow the athletes and capture their self-images, then present the captured images on nearby display or hand-held device. However, such external image would distract presence identity because it was not captured from the athletes' perspectives. It is unusual experience for representing both ego-centric visual information and intrinsic kinesthetic information [8].

Another category of related work is research on augmented field of view. Combined with cameras, the head mounted displays (HMD) could extend user's view in various ways. FlyVIZ system combines an omnidirectional camera on an HMD to extend user's field of view [3]. Virtual Chameleon allows user to operate two cameras separately as free-moving eyes to observe the environment [13]. These studies require long training time to adapt the extended view because it is not the normal way for users to perceive the world. SpiderVision by Kevin Fan [9] maintains user's ordinary front view and augments the view behind one's back. The alpha values are adjusted so that the merging images are translucent. But visual confusion would occur when both environments changing dynamically.

Due to the aesthetic and theatrical dimensions of dance art, the dancers have unique needs. A distinction between the ways imagery is used in dance versus sports is that dance images are needed while the dancers are moving or standing still [12]. For dancers,

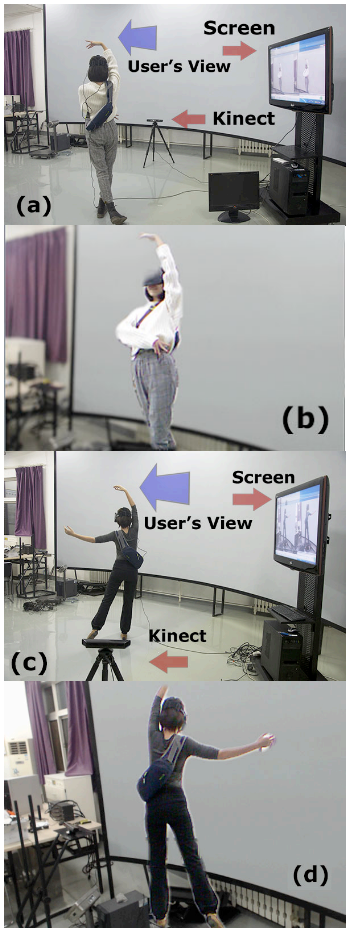

Figure 4. Example of self-practicing. (a) Scene 1; (b) Mixed views of scene 1 displayed on HMD; (c) Scene 2; (d) Mixed views of scene 2 displayed on HMD.

specific postures are as important as continuous dynamical movements. Most of the research on HCI in dancing focus on learning dancing steps [1,4,6] or enhancing stage effects [10]. These learning systems use virtual instructor presented on a screen or attach sensors to teach beginners some basic steps. There are few studies about providing external image for dancers while they are self-practicing and training.

OutsideMe is different from the studies above by (1) providing external self-image without distracting dancers' performance, they can still retain their normal vision (2) presenting a 360-degree perspective of body movements continuously during dancers' self-practicing (3) providing virtual character for dancers to support self-training and cooperative rehearsal.

OutsideMe

The system consists of a head-mounted display (HMD), one camera attached to the HMD device for capturing dancer's front view, a motion tracking system, and a computer system for providing mixed reality feedback during the dancer's performance.

We modified the HMD (Oculus Rift Development Kit1) by attaching one camera (Logitech C920) on the front (see Figure 2). The HMD has a field of view of 100 degrees and a resolution of 1280×800dpi, and a weight of 380g. The camera is equipped with a wide-angle lens (0.67X). The total weight of the modified HMD is less than 500g, which is acceptable for the dancers for long-time wearing. In order to provide a 360-degree free movement, we developed a wearable wireless transmitting system. The system consists of a ZINWELL WHD 200/WHD200U HDMI transmitter and receiver, an Oculus dk1 connection box, and two 11000mAh 2A USB batteries. It is 1.95kg weight and allows for almost 4 hours of wireless dancing time (Figure 3). We placed these modules in a shoulder strap to help dancers wear it easily. The camera captures dancer's view and streams to the HMD, which act as a video see-through device. The dancers' RGB, depth, and skeleton tracking data were obtained from Microsoft Kinect. The background in the real time depth data is removed so that only the color and depth data of the dancer is left as the self-image of the dancer. We blended self-image into the front view with openCV. Thus, the final scene displayed by the HMD is the self-image of the dancer on top of his/her front view. We setup a 5m×5m space as test ground. A 46-inch TV screen was placed aside for presenting the real time rendered mixed reality scene and for video playback.

We first tested the feasibility of our system. The participants were from our research team. The main findings were that the participants were able to focus on their external self-images without image delay or lost their presence identities. With the hardware system presented above, we developed four work modes:

Self-practicing *(as shown in Figure 4)*
In this usage scenario, dancers observe only themselves. The dancers can choose their view angle by adjusting their orientation in front of the Kinect. The dancers could determine their body sizes in mixed reality scene by adjusting their distance from the Kinect. This setup allows the dancers to observe themselves from any direction, such as from the back, without turning their head.

(a) Learning from a virtual leading dancer.

(b) Following move one (HMD view).

(c) Following move two (HMD view).

Figure 5. Training with a virtual leading dancer.

Training with a virtual leading dancer *(as shown in Figure 5)*
A virtual leading dancer could be augmented in the mixed reality view so the dancers could observe both themselves and the virtual character. Dancing steps of the virtual leading dancer are pre-captured from the professional choreographers. Dancers could define different training speeds by using a client application before start. In addition, they could choose either a real human shape or a skeleton model. The virtual character could be placed at any position in the view. Dancers could follow the steps continuously without switching the perspective.

Rehearsing with an extra dancer *(as shown in Figure 6)*
OutsideMe enables rehearsing with an extra dancer. The dancers could practice or create dancing steps by using the pre-recording body motion from their dancing partner.

Video feedback
When the dancers start to do self-practicing or dancing with a virtual character, the system records the mixed reality scene. The dancer could practice and learn the dancing steps with OutsideMe, and then study from the video playback for further posture correction.

Preliminary Study

We conducted a pilot user study to determine dancer's acceptance and application scope of our system. We picked eight participants took part in our study, and they practiced various dance styles. The participants' information is summarized in Table 1. All participants had no previous knowledge of using this system. They were asked to try different work modes and compared their training experience with their regular dance training. Each of them completed 2 or 3 complete dance moves for each work mode. The entire testing process took around 50 minutes.

P	Age	Sex	Grade/Experience	Dance Styles
1	22	F	3 grade	Ballet
2	28	F	6 grade	Chinese Folk
3	19	F	5 grade	Jazz
4	25	F	2 years	Modern
5	32	F	15 years	Chinese Folk
6	20	M	2 years	Hip Hop
7	24	M	3 years	Street
8	26	M	7 years(Bronzes)	Latin

Table 1. Participant demographics and dance styles.

We handed out a questionnaire to the participants to obtain both positive and negative aspects for each prototype. Using a 5-point Likert scale (5=totally agree, 1=totally disagree), we found positive feedback of our system and it could adapt various dance styles (Figure 7).

All of them said that they would like to use OutsideMe as a self-training system during their dance practicing (average = 4.33, standard deviation = 0.75). They said the system presents a 360-degree view, which is the most useful feature for dance training because there is always a blind area in regular training (4.50, 0.76). They could correct and improve movements in real time while have the ability to observe their surroundings (3.67, 0.74). Training from a virtual character and dancing with partner were also received positive feedback (4.0, 0.58), (4.17, 0.50). For beginners, they liked to follow the virtual character step by step in a user-defined slow motion. In this case, a real human

(a) Rehearsing dance with partner.

(b) Views from HMD.

Figure 6. Rehearsing with an extra dancer.

shape was highly recommended than a skeleton model. Combined with our system, the video playback was considered more effectively because they could use it for further posture correction (4.67, 0.47).

Slight blurry image from the front camera would be a problem when dancers' head moving fast. At the beginning, some dancers said that they usually need 10 to 15 seconds to adjust views to focus on their body shapes. We could solve this problem by modifying with a Flea3 USB3.0 (Model: FL3-U3-13S2M-CS) camera that has a maximum frame rate of 120fps to reduce the vertigo problem. Although there would be a 0.3s delay for each frame of the external self-image stream, it is acceptable for dancers to observe themselves smoothly.

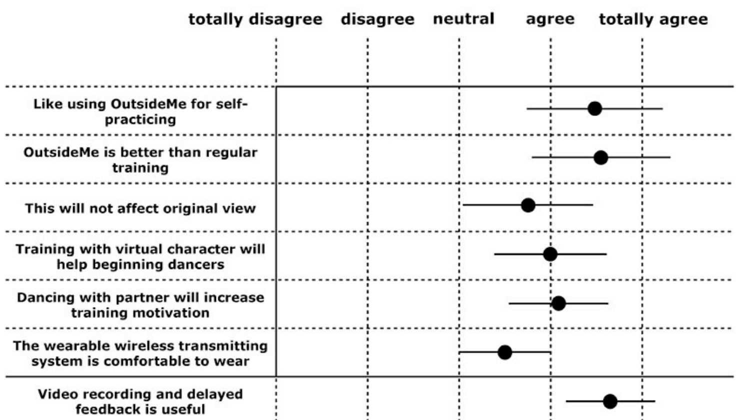

Figure 7. Questionnaire feedback. The short horizontal lines indicate the standard deviation from the average value.

Most participants have the requirement that they would like to choose their watching perspectives or the system could present both front and back self-images on the HMD. It would be more convenient if they don't need to turn their body to get different views. Audio effects are also requested from several dancers due to the cooperative rehearsal.

Discussion and Future Work

In this paper, we introduce the concept of OutsideMe, and present several prototype work modes. Augmenting external self-image in real time and playback are proved to be useful tools for the dancers. Our work studies and explores how to help dancers improve their practicing efficiency during self-practicing and training sessions with our presented system. An augmented virtual dancer as an instructor or a partner, dancing with the dancer's external self-image, would enhance dancer's cooperation and increase training motivation. However, adjusting training speed to achieve synchronous learning is the key for practicing with augmented virtual character. It should also be studied on how to present specific and valuable feedback depending on dancers' different levels. Also, our system could be used for those activities that need time for posture correction and self-training in a closed environment (martial art, boxing, e.g.). In our future work, we plan to extend our system so that the dancers could switch among multiple view angles by using multiple body tracking systems. For the wearable wireless transmitting system, we are working on a more comfortable shoulder strap, which ranged with our custom modules by using 3D printers.

Acknowledgements

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