Interactive Augmented Reality for Dance
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"Like the overlap in a Venn diagram, shared kinesthetic and intellectual constructs from the field of dance and the field of technology will reinforce and enhance one another, resulting in an ultimately deepened experience for both viewer and performer." -Alyssa Schoeneman

Abstract

With the rise of the digital age, dancers and choreographers started looking for new ways to connect with younger audiences who were left disengaged from traditional dance productions. This led to the growing popularity of multimedia performances where digitally projected spaces appear to be influenced by dancers' movements. Unfortunately current approaches, such as reliance on pre-rendered videos, merely create the illusion of interaction with dancers, when in fact the dancers are actually closely synchronized with the multimedia display to create the illusion. This calls for unprecedented accuracy of movement and timing on the part of the dancers, which increases cost and rehearsal time, as well as greatly limits the dancers' creative expression. We propose the first truly interactive solution for integrating digital spaces into dance performance: ViFlow. Our approach is simple, cost effective, and fully interactive in real-time, allowing the dancers to retain full freedom of movement and creative expression. In addition, our system eliminates reliance on a technical expert. A movement-based language enables choreographers to directly interact with ViFlow, empowering them to independently create fully interactive, live augmented reality productions.

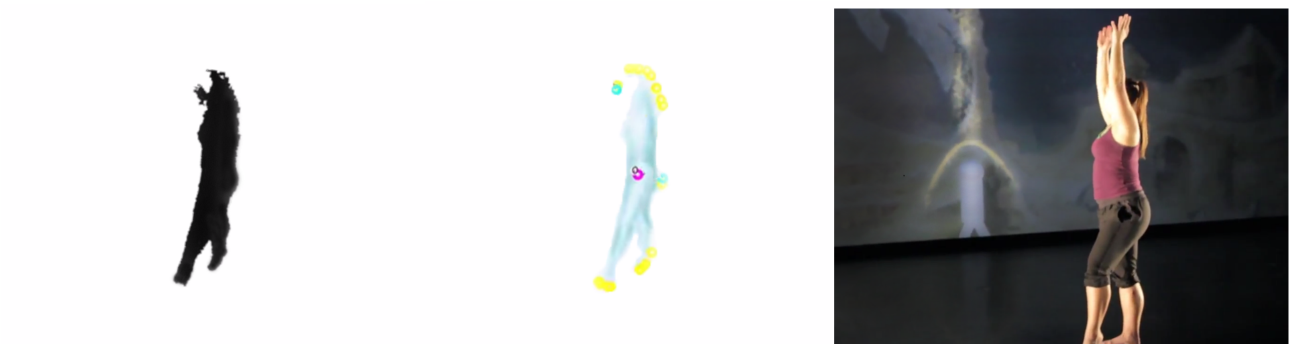
Introduction

Digital technology continues to impact a variety of seemingly disparate fields from the sciences to the humanities and arts. This is true of dance performance as well, as interactive technology incorporated into choreographic works is a prime point of access for younger audiences.

Due in no small part to the overwhelming impact of technology on younger generations, the artistic preferences of today's youth differ radically from those raised without the prevalence of technology. This results in the decline of youth attending live dance performances (Tepper 2008). Randy Cohen, vice president for research and policy at Americans for the Arts, commented that: *"People are not walking away from the arts so much, but walking away from the traditional delivery mechanisms. A lot of what we're seeing is people engaging in the arts differently."* (Cohen 2013). Given that younger viewers are less intrigued by traditional dance productions, dancers and choreographers are looking for ways to engage younger viewers without alienating their core audiences.

Figure 1: An illustration of interactive augmented reality in a live dance performance using ViFlow. Captured during a recent performance, this image shows a dynamically generated visual effect of sand streams falling on the dancers. These streams of sand move in real-time to follow the location of the performers, allowing the dancers to maintain freedom of movement. The system offers many other dynamic effects through its gear-free motion capture system.

Through digital technology, dance thrives. Adding a multimedia component to a dance performance alleviates the need for supplementary explanations of the choreography. The inclusion of digital effects creates a more easily relatable experience for general audiences. Recently there has been an effort to integrate augmented reality into dance performance. The goal is to use projections that respond to the performers' movement. For example, a performer raising her arms may trigger a projected explosion on the screen behind her. Or, the dancers may be followed by downwards streams of sand as they move across the stage (see Figure 1). However, current approaches to augmented reality in professional dance merely create the illusion of interaction. Furthermore, only a few choreographers today have the technological collaboration necessary to incorporate projection effects in the theater space.



(a) Tracking Mask (b) Tracking Identification (c) Performer with an effect behind her

Figure 2: The ViFlow system in action. (a) shows the raw silhouette generated from tracking the IR reflection of the performer, (b) displays the calculated points within the silhouette identified as the dancer core, hands, and feet, and (c) depicts the use of these points when applied to effects for interactive performance in the dynamically generated backdrop image.

Florida State University is fortunate to have an established collaboration between a top-ranked School of Dance and Department of Computer Science in an environment supportive of interdisciplinary creative activities. Where these collaborative efforts have occurred, we have seen a new artistic form flourish. However, the vast majority of dance programs and companies lack access to the financial resources and technical expertise necessary to explore this new creative space. We believe that this access problem can be solved through the development of a new generation of low-cost, interactive video analysis and projection tools capable of providing choreographers direct access to the video layering that they desire to augment their dance compositions.

Augmented dance performances that utilize pre-rendered video projected behind performers on stage to create the illusion of interactivity have several notable drawbacks. The dancers must rehearse extensively to stay in sync with the video. This results in an increase in production time and cost, and makes it impractical to alter choreographic choices. Further, this approach restricts the range of motion available to dancers as they must align with a precise location and timing. This not only eliminates improvisation, but restricts the envelope of creative expression of the dancer. If a dancer even slightly misses a cue, the illusion is ineffective and distracting for the viewer.

A small number of dance companies (Wechsler, Weiß, and Dowling 2004) (Bardainne and Mondot 2015) have started to integrate dynamic visual effects through solutions such as touch-screen technology (see the following section for details.) However, moving away from static video into dynamically generated visualizations gives rise to a new set of challenges. Dynamic digital effects require a specialized skillset to setup and operate. The complex technical requirements of such systems often dictate that the visual content has to be produced by a separate team of technical developers in conjunction with performing artists. This requirement can lead to miscommunication as the language incorporated into the lexicon of dancers differs significantly from that employed by computer programmers and graphical designers. This disconnect can impair the overall quality of the performance as artists may ask for too much or too little from technical experts because they are unfamiliar with the inner workings of the technology and its capabilities.

In this paper we introduce ViFlow (short for Visual Flow[1]), a new system that remedies these problems. Dancers, choreographers, and artists can use our system to create interactive augmented reality for live performances. In contrast with previous methods that provide the illusion of interactivity, ViFlow is truly interactive. With minimal low-cost hardware, just an infrared light emitter and an infrared sensitive RGB webcam, we can track multiple users' motions on stage. The projected visual effects are then changed in real time in response to the dancers' movements (see Figure 2 for an illustration). Further, by requiring no physical gear, our approach places no restriction on movements, interaction among dancers, or costume choices. In addition, our system is highly configurable enabling it to be used in virtually any performance space.

With traditional systems, an artist's vision must be translated to the system through a technical consultant. To eliminate the need for a technical expert, we have created a gesture-based language that allows performers to specify visualization behavior through movement. Visual content is edited on the fly in a fashion similar to that of a dance rehearsal using our internal gesture based menu system and a simple movement-driven language. Using this movement-based language, an entire show's visual choreography can be composed solely by an artist on stage without the need of an outside technical consultant. This solution expands the artist's creative space by allowing the artist's vision to be directly interpreted by the system without a technical expert.

ViFlow was first presented live at Florida State University's Nancy Smith Ficther Theatre on February 19, 2016 as part of *Days of Dance* performance series auditions. This collaborative piece with ViFlow was chosen to be shown in

[1] Flow is one of the main components of the dynamics of movement. In our system, it also refers to the smooth interaction between the dancer's movements and the visual effects.

full production. The final performance is scheduled to take place on April 15th, 16th, 22nd, and 23rd in the School of Dance production of *Days of Dance*. Footage of the use of ViFlow by the performers of this piece can be found at https://www.youtube.com/watch?v=9zH-JwlrRMo.

Related Works

The dance industry has a rich history of utilizing multimedia to enhance performance. As new technology is developed, dancers have explored how to utilize it to enhance their artistic expression. We will present a brief history of multimedia in dance performances, including previous systems for interactive performance, and discuss the application of interactive sets in related art forms. We will also present the most relevant prior work on the technology created for motion capture, and discuss limitations of their application to live dance performance.

History of Interactive Sets in Dance

Many artists in the dance industry have experimented with the juxtaposition of dance and multimedia. As early as the 1950s, the American choreographer, Alwin Nikolais, incorporated quick movement with strobe lighting effects into performance. Over the past decade, more multimedia choreographers in the dance industry have been experimenting with interactive projection. Choreographers Middendorp, Magliano, and Hanabusa used video projection and very well trained dancers to provide an interplay between dancer and projection. Lack of true interaction is still detectable to the audience as precision of movement is difficult to sustain throughout complex pieces. This has the potential of turning the audience into judges, focusing on the timing of a piece while missing some of the emotional impact developed through the choreography.

In the early 2000s, as technology and computers were becoming more accessible, dance companies started collaborating with technical experts to produce interactive shows with computer generated imagery (CGI). Adrien M/Claire B used a physics particle simulation environment they developed called eMotion[2] that resulted in effects that looked more fluid. This was achieved by employing offstage puppeteers with tablet-like input devices that they used to trace the movements of performers on stage and thus determine the location of the projected visual effects (Bardainne and Mondot 2015). Synchronization is still required, though the burden is eased, because dancers are no longer required to maintain synchronized movement. This duty now falls to the puppeteer.

Eyecon (Wechsler, Weiß, and Dowling 2004) is an infrared tracking-based system utilized in Obarzaneks *Mortal Engine*. The projected effects create a convincing illusion of dancers appearing as bio-fiction creatures in an organic-like environment. However, Eyecon's solution does not provide the ability to differentiate and individually track each performer. As a result, all performers must share the same effect. The system does not provide the ability for separate dancers to have separate on-screen interactions. Moreover, Eyecon can only be applied in very limited performance spaces. The software forces dancers to be very close to the stage walls or floor. This is because the tracking mechanism determines a dancer's location by shining infrared light against a highly reflective surface, and then looking for dark spots or "shadows" created by the presence of the dancer. By contrast, we identify the reflections of infrared light directly from the dancers' bodies, which allows us to reliably detect each dancer anywhere on the stage without imposing a limit on location, stage size, or number of dancers.

Studies have also been conducted to examine the interactions of people with virtual forms or robots. One such study by (Jacob and Magerko 2015), presents the VAI (Viewpoint Artificial intelligence) installation which aims to explore how well a performer can build a collaborative relationship with a virtual partner. VAI allows performers to watch a virtual dance partner react to their own movements. VAI's virtual dancers move independently, however, VAI's movements are reactive to the movement of the human performer. This enhances the relationship between the dancer and the performer because VAI appears to act intelligently.

Another study by (Corness, Seo, and Carlson 2015), utilized the Sphero robot as a dance partner. In this study, the Sphero robot was remotely controlled by a person in another room. Although the performer was aware of this, they had no interaction with the controller apart from dancing with the Sphero. In this case, the performer does not only drive, but must also react to the independent choices made by the Sphero operator. Users reported feeling connected to the device, and often compared it to playing with a small child.

Interactivity in performance can even extend past the artist's control and be given to the audience. For LAIT (Laboratory for Audience Interactive Technologies) audience members are able to download an application to their phones that allows them to directly impact and interact with the show(Toenjes and Reimer 2015). Audience members can then collectively engage in the performance, changing certain visualizations or triggering cues. It can be used to allow an audience member to click on a button to signal recognition of a specific dance gesture or to use aggregate accelerometer data of the entire audience to drive a particle system projected on a screen behind the performers.

Interactive Sets in Other Art Forms

Multimedia effects and visualizations are also being used with increasing frequency in the music industry. A number of large international music festivals, such as A State of Trance and Global Gathering, have emerged over the last fifteen years that rely heavily on musically driven visual and interactive content to augment the overall experience for the audience. A recent multimedia stage production for musician Armin Van Buuren makes use of motion sensors attached on the arm of the artist to detect movements, which in turn trigger a variety of visual effects.[3]

The use of technology with dance performance is not limited to live productions. Often, artists will produce dance

[2]eMotion System: `http://www.am-cb.net/emotion/`

[3]Project by Stage Design firm 250K, Haute Technique, and Thalmic Labs Inc. https://www.myo.com/arminvanbuuren

films to show their piece. As an example, the piece *Unnamed Sound-Sculpture*, by Daniel Franke, used multiple Microsoft Kinect devices to perform a 3D scan of a dancer's movements (Franke 2012). Subsequently, the collected data was used to create a computer generated version of the performer that could be manipulated by the amplitude of the accompanying music.

Motion Capture Approaches (Tracking)

Many traditional motion capture systems use multiple cameras with markers on the forms to be tracked. Such systems are often used by Hollywood film studios and professional gaming firms. These systems are very expensive and require a high level of technical expertise to operate. Cameras are arranged in multiple places around a subject to capture movement in 3D space. Each camera must be set up and configured for each new performance space and requires markers on the body, which restrict movement and interaction among dancers. (Sharma et al. 2013)

Microsoft's Kinect is a popular tool that does not require markers and is used for interactive artwork displays, gesture control, and motion capture. The Kinect is a 3D depth sensing camera. User Skeletal data and positioning is easily grabbed in real time. However Kinect only has a working area of about 8x10 feet, resulting in a limited performance space, thus rendering it impractical for professional productions (Shingade and Ghotkar 2014).

Organic motion capture[4] is another marker-less system that provides 3D motion capture. It uses multiple cameras to capture motion, but requires that the background environment from all angles be easily distinguishable from the performer, so the system could extract their performance and build a skeleton. The dancers are confined to a small, encapsulated performance space. As such, the audience would not see them at all were the system to be used for life performance.

Several researchers (Lee and Nevatia 2009), (Peursum, Venkatesh, and West 2010), (Caillette, Galata, and Howard 2008) have built systems using commercial cameras that rely heavily on statistical methods and machine learning models to assist them in predicting the location of contiguous body parts and then building a virtual skeleton. Due to the delay caused by heavy computation, these systems are too slow to react, and cannot perform in real time (Shingade and Ghotkar 2014).

Finally, Inertial Measurement Units (IMUs) track the orientation and acceleration of a particular point in 3D space using sensors that quantify the fluctuation of electromagnetic fields. Xsens[5] and Synertial[6] have pioneered the use of many IMUs into motion capture (mocap) suits. These are placed in a configuration on the performer's body that best match their joints. The data retrieved from the IMUs can then be used to build a 3D skeleton of the performers movement. No cameras are needed for motion capture setups with IMUs. However, IMU systems are often expensive and require that each performer wear the device after it has been calibrated to their proportions. Furthermore, they must also calibrate the location of the dancer on stage to the location in the virtual space. IMU-based systems have not been considered a viable technology for live performance.

[4]Organic Motion - `http://www.organicmotion.com/`

[5]Xsens IMU system - `www.xsens.com`

[6]Synertial - `http://synertial.com/`

Setup and System Design

ViFlow has been designed specifically for live performance with minimal constraints on the performers. ViFlow is also easy to configure for different spaces. The camera can receive information from very different camera setups and is therefore conducive to placement in a wide spectrum of dance venues. By using IR light in the primary tracking system, it also enables conventional lighting setups ranging from very low light settings to fully illuminated outdoor venues.

Hardware and Physical Setup

ViFlow requires three hardware components: A camera modified to detect light in the infrared spectrum, infrared light emitters, and a computer running the ViFlow software. We utilize infrared light because it is invisible to the audience. By flooding the performance space with infrared light, we can identify the location of each performer within the frame of the camera. At the same time, ViFlow does not process any of the visual light spectrum corresponding to stage lighting or digital effects projection because the modified webcam limits the information that ViFlow receives.

Most video cameras have a filter over the image sensor that blocks unwanted infrared light from overexposing the sensor. To modify a standard camera or webcam to make it sensitive to infrared light, we replace the IR filter with a filter that blocks visible light but not infrared light. We used a section of the magnetic disk from an old floppy disk. The magnetic disk acts as a natural light filter, blocking all visible light and allowing infrared to pass through. The total cost of the 0.3 megapixel camera that is used cost a mere $13, and yet this simple webcam is sufficient for tracking all performers on stage.

While ViFlow can also be used with an unmodified camera to track a particular color signature, it is more reliable to use infrared emitters during a live stage production. We used Roscolux [7] Yellow R15, Magenta R46, and Cyan R68 gels layered to make a natural light filter. Gel filters create color by subtracting certain wavelengths of color. Thus, a red filter absorbs blue and green, allowing only the red wavelengths to pass. The process is subtractive, not additive, so it's important that the light source emits a full spectrum. To avoid heat damage to the gels, we utilized a gel extender to place the gels away from the light source in line with the stage, see Figure 3 for an illustration. Additionally, the lights we used were an assortment of 750-1000 watt professional LED stage lighting.

Lights should be placed around the perimeter of the stage inside of the wings (see Figure 4). At least two lights should be positioned in front of the stage to provide illumination to

[7]Roscolux is a brand of professional lighting gels.

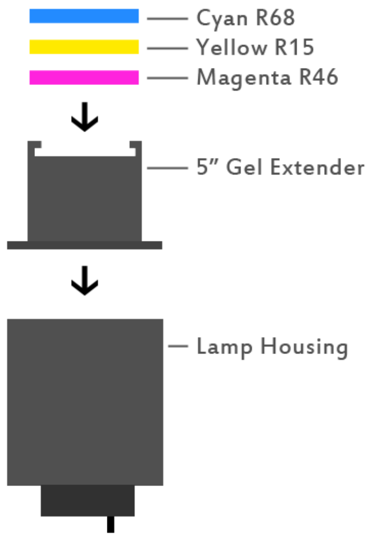


Figure 3: Gels may be placed in any order on the gel extender. We used LED lighting, which runs much cooler than traditional incandescent lighting.

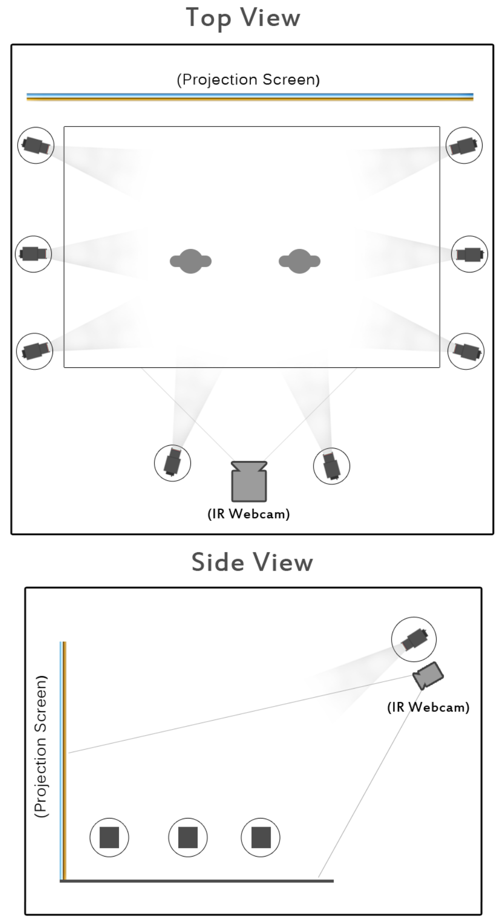


Figure 4: Positioning of the camera and lights in our installation at the Nancy Smith Fichter Dance Theatre at Florida State University's School of Dance. When possible, lights should be arranged such that there is front light, side light, and back light. Depending on the size of the space, additional lights may be needed to fill center stage. (Lights are circled in diagram.)

the center stage area. This prevents forms from being lost while tracking in the event that one dancer is blocking light coming from the wings of the stage.

The camera can be placed anywhere to suit the needs of the performance. However, no matter which position is chosen, occlusions can occur when tracking multiple forms. If the camera is placed above center stage, occlusions will occur near the edge of the frame where the distortion is usually highest. If placed at eye level with the performers, occlusions will happen as performers pass each other. We have camera positioned at a 45 degree tilt from above the stage, hung above the audience (see Figure 4). From there, we are able to maximize our stage coverage. Because of the unique camera perspective, occlusions only occur when dancers get within a few feet of each other. Since we are only using a 2D sensor, we can use the y axis component from the camera to simulate z axis depth data in our rendering program so that everything looks correct from the audience's perspective as dancers move from upstage to downstage.

ViFlow Software

The software developed for this project is split into two components: the Tracking Software and the Rendering/Effect creation software. The tracking software includes data collection, analysis, transmission of positional data to the front end program, where it displays the effects for a performance. ViFlow makes use of *OpenCV*, a popular open source computer vision framework. ViFlow must first be calibrated to the lighting for each stage lighting setup. This profile can be saved and reused later. Once calibrated, ViFlow can get data on each performer's silhouette and movement.

There are some limitations with ViFlow. Since we currently use a 2D camera sensor, this limits how much information we can utilize for gesture controlled input. Fortunately, performances do not rely on very fine gesture precision, and dancers naturally seem to employ exaggerated gestures designed to be clearly visible to larger audiences. In working with numerous dancers, we have found that this more theatrical movement seems to be instilled in them both on and off stage.

Visual Effects

The front end uses Unity3D by Unity Technologies[8] for displaying the visual medium. Unity3D is a cross-platform game engine that connects the graphical aspects of developing a game to JavaScript or C# programming. Unity has customization tools to generate content and is extensible enough to support the tracker. The front end consists of five

[8]Unity3D can be downloaded from `https://unity3d.cpm`

(a) Tracking Output (b) Tracking Mask

Figure 5: Four figures being tracked with our tracking software. Each individual is bathed in infrared light, thus allowing us to easily segment their form from the background. This shot is from the camera angle depicted in Figure 4.

elements: a camera, a character model, an environment, visual effects, and an interactive menu using gesture control which is discussed in more detail in following sections.

The camera object correlates to what the end-user will see in the environment and the contents of the camera viewport are projected onto the stage. The visual perspective is both 2D and 3D to support different styles of effects.

The character model belongs to a collection of objects representing each performer. Each object is a collection of two attached sphere colliders for hand representations and a body capsule collider as seen in Figure 6. The colliders are part of the Unity engine and are the point of interaction and triggers menus, environmental props, and interactive effects.

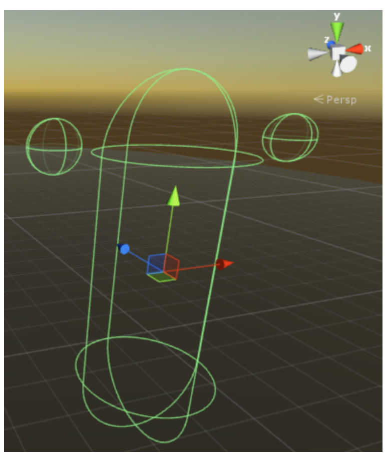


Figure 6: Character Model Object. The small orbs are the colliders for hand positions and the larger capsule is the body collider.

Environments consist of multiple objects including, walls, floors, and ceilings of various shapes and colors. Aesthetic considerations for these objects are applied per performance or scene such as Figure 7. Most of our environmental textures consist of creative usage of colors, abstract art, and free art textures.

The effects are delivered in a variety of methods such as interactive objects, particle systems, and timed effects. Some objects are a combination of other effects designed to deliver a specific effect such as an interactive object that will

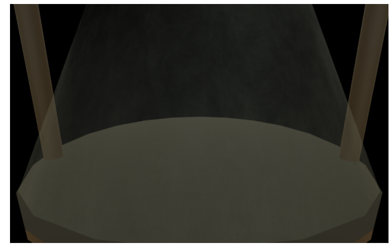


Figure 7: This static environment is the lower part of an hourglass, used in a performance whose theme centers on time manipulation. The dancers in this piece interact with a sand waterfall flowing out of the hourglass.

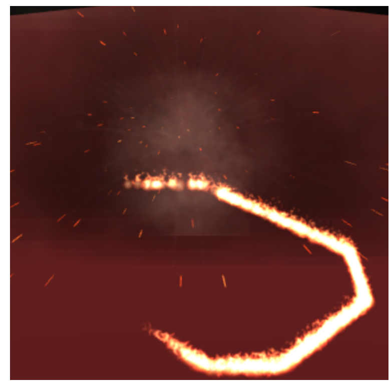


Figure 8: Two Unity particle systems, one used as an interactive fire effect and the other is a triggered explosion.

trigger a particle system explosion upon interaction with a performer.

The particle system delivers ambience and interactive effects like rain, fog, waterfalls, fire, shiny rainbow flares, or explosions. ViFlow's effects provide a set of adjustable features such as color, intensity, or direction. The particle systems have been preconfigured as interactive effects such as a sand waterfall that splashes off the performers as seen in Figure 1 or a wildfire trail that follows the performers in Figure 8.

Some effects involve environmental objects that the dancer can interact with. One effect is a symmetric wall of orbs that cover the lower portion of the 2D viewport. When touched by the performer's Unity collider, these dots have preconfigured effects such as shrinking, floating up, or just spiraling away. The customizations supported for the performers allow them to place the effects in specific locations, change their colors, and adjust to predefined effects.

Lastly, there are global effects that can be both environmentally aesthetic, such as sand storms and snow falls, or interactive such as a large face that watches the dancer and responds based on their position. The face might smile when they are running and frown when they are not moving, or turn left and right as the dancers are moving stage left or right.

Communication Gap Between Dancers and Technologists

Multimedia productions in the realm of performing arts are traditionally complex due to the high degree of collaboration and synchronization that is required between artists on stage and the dedicated technical team behind the scenes. Working in conjunction with a technical group necessitates a significant time investment for synchronization of multimedia content and dance choreography. Moreover, there are a number of problems that arise due to the vastly different backgrounds of artists and technicians in relation to linguistic expression. In order to address these communication difficulties, we developed a system which allows artists to directly control and configure digital effects, without the need for additional technical personnel, by utilizing a series of dance movements which collectively form a gesture based movement language within ViFlow.

One of the main goals of our system is to enhance the expressive power of performing artists by blending two traditionally disjoint disciplines - dance choreography and computer vision. An important take away from this collaboration is the stark contrast and vast difference in the language, phrasing, and style of expression used by dancers and those with computing oriented backgrounds. The linguistic gap between these two groups creates a variety of development challenges such as system requirements misinterpretations and difficulties in creating agreed upon visual content.

To better understand the disparity between different people's interpretations of various visual effects provided by our system, we asked several dancers and system developers to describe visual content in multimedia performances. The phrasing used to describe the effects and dancer interactions of the system were highly inconsistent, as well as a potential source of ambiguity and conflict during implementation.

Dancers and developers were separately shown a batch of video clips of dance performances that utilized pre-rendered visual effects. Each person was asked to describe the effect that was shown in the video. The goal was to see how the two different groups would describe the same artistic visual content, and moreover, to gain some insight into how well people with a non-artistic, technical background could interpret a visual effect description coming from an artist.

The collected responses exposed two major issues. First, the descriptions were inconsistent from person to person, and second, that there was a significant linguistic gap between artists and people with a computing background. As an example, consider this description of a visual effect written by a dancer: *"I see metallic needles, projected onto a dark surface behind a solo dancer. They begin subtly, as if only a reference, and as they intensify and grow in number we realize that they are the echoes of a moving body. They appear as breathing, rippling, paint strokes, reflecting motion"*. A different dancer describes the same effect as *"sunlight through palm fronds, becomes porcupine quills being ruffled by movement of dancer"*. A system developer on the other hand, described the same visual effect as *"a series of small line segments resembling a vector field, synchronized to dance movements"*. It is evident that the descriptions are drastically different.

This presents a major challenge as typically, a technician would have to translate artists descriptions into visual effects. Yet, the descriptions provided by dancers leave a lot of room for personal interpretation, and lead to difficulties for artists and technicians when they need to reach agreement on how a visualization should look like on screen. In order to address this critical linguistic problem, our system incorporates a dance derived, gesture-based, motion system that allows performers to parameterize effects directly by themselves while dancing, without having to go through a technician who would face interpretation difficulties. This allows dancers a new level of artistic freedom and independence, empowering them to fully incorporate interactive projections into their creative repertoire.

Front End User Interface and Gesture Control

Our interactive system strives to eliminate the need for a technician to serve as an interpreter, or middleman, between an artists original vision and the effects displayed during a performance. As discussed above, a number of linguistic problems make this traditional approach inefficient. We address this problem by implementing a direct dance-based gesture control, which is used for user interactions with the system as well as customizing effects for a performance. The system has two primary modes of operation: a *show-time mode* which is used to run and display the computerized visual component of the choreographed performance during rehearsals or production, and an *edit mode* which is used to customize effects and build the sequence of events for a performance. In other words, edit mode is used to build and prepare the final show-time product.

Edit mode implements our novel gesture-based approach for direct artist control of computer visualizations. It utilizes a dancer's body language, (using the camera input as previously described in the System Setup and Design Section) to directly control generation of digital content in ViFlow.

Effects are controlled and parameterized by the body language and movements of the dancer. Various aspects are controlled through different gestures. For example, for a wildfire trail effect, shown in Figure 8, the rate of flame emission is controlled by the movement speed of dancers on stage, while the size of the flame is controlled via hand gestures showing expansion as the arms of a dancer move away from each other. In a different scenario, in which a column of sand is shown as a waterfall behind a dancer, arm movements from left to right and up and down are used to control the speed of the sand waterfall, as well as the direction of the flow. Depending on the selected effect, different dance movements control different parameters. Since all effects are designed for specific dance routines, this effectively creates a dance derived movement-gesture language, which can be naturally and intuitively used by a dancer to create the exact visual effects desired.

When a dancer is satisfied with the visualization that has been created, it is saved and added to a queue of effects to be used later during the production. Each effect in the queue is supplied with a time at which it should be loaded. When a dancer is ready, this set of effects and timings are saved and can be used during the final performance in show-time mode.

Conclusions and Future Work

ViFlow has been created to provide a platform for the production of digitally enhanced dance performance that is approachable to choreographers with limited technical background. This is achieved by moving the creation of visual projection effects from the computer keyboard to the performance stage in a manner more closely matching the dance choreographic construction.

ViFlow integrates low-cost vision recognition hardware and video projection hardware with software developed at Florida State University. The prototype system has been successfully integrated into public performance pieces in the College of Dance and continues to be improved as new technology becomes available, and as we gain more experience with the ways in which choreographers choose to utilize the system.

The use of ViFlow empowers dancers to explore visualization techniques dynamically, at the same time and in the same manner as they explore dance technique in the construction of a new performance. In doing so, ViFlow can significantly reduce production time and cost, while greatly enhancing the creative pallet for the choreographer. We anticipate that this relationship will continue into the future, and hope that ViFlow will be adopted by other university dance programs and professional dance companies. While we have targeted production companies as the primary target for ViFlow development, we believe that the algorithms can be used in a system targeting individual dancers who would like to explore interactive visualizations at home.

Development of ViFlow continues. We have recently purchased a Zed Depth Camera from Stereolabs to expand the capabilities of our tracking system. With the Zed camera, we anticipate being able to use the extra dimension of depth data to improve the accuracy of our tracker and gesture control interface. It will also provide us with much more detailed information on individual forms movement. Although the camera is more expensive ($450 at time of writing), it does not require infrared lights to segment forms from the background reducing setup time and enabling ViFlow to be integrated permanently into the conventional stage platform.

We are also continuing to refine the dancer interface to make effects construction as natural to the artist as we can. Towards that end, we are working with the initial users of this system to improve its usability and gesture control. We are particularly interested in making the system fun and easy enough for anyone to use. We also plan to make the executable of the tracking software and Unity3D interface for the project available for free public use by May 2016.

Additional work will also focus on exploring secondary input methods for the system to be used in conjunction with the primary vision data provided from the camera tracking. These can include, but are not limited to inputs such as voice commands, radio frequency emitters, and unobtrusive body sensors. An expanded set of input sources can make the system more versatile and suitable for a wider audience.

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