New Digital Options in Geographically Distributed Dance Collaborations with TEEVE: Tele-immersive Environments for EVErybody

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ABSTRACT
The study of 3D Tele-immersion impact on remote collaborative work represents a very interesting and challenging research topic. In this paper, we introduce the latest accomplishments of TEEVE research which merges computer science with dance choreography. This collaborative research model is ideal for creative, interdisciplinary problem solving. TEEVE offers an entirely new interface for dance choreography as a creative tool and alternative performance venue.

Categories and Subject Descriptors
H.5.5 [**Information Interface and Presentation**]: [Computer-supported Cooperative Work]; J.5 [**Computer Applications**]: Arts and Humanities—Performing Arts

General Terms
Experimentation, Human Factors

Keywords
3D tele-immersive environment, collaboration, dance

1. INTRODUCTION
3D Tele-immersion (3DTI) allows remote users to engage in collaborative activities such as education, artistic and sport performance, entertainment and physical therapy. The 3DTI environment built jointly by research efforts of University of Illinois at Urbana-Champaign and University of California at Berkeley is the first system for extensive 3DTI experiments across Internet2 to study its impact on communication [1].

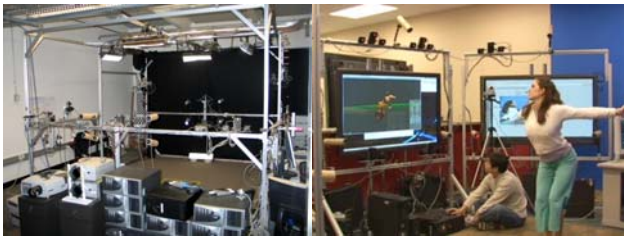

Figure 1. 3DTI Environments in UC Berkeley and UIUC

Figure 1 shows the 3DTI environments featuring multi-camera array, wide field of view (120° ~ 360°) and multi-display rendering. All of those plus the underlying networking infrastructure enable real-time capturing, transmitting and rendering of multiple 3D models in a common virtual space as shown in Figure 2.

3DTI environments offer new creative platforms for dance choreography. We have had two successful live collaborative dance performances in December 2006 and April 2007. These were the first public performances of a long-distance collaborative dance. The dances performed were created across thousands of physical miles. We have proven that our 3DTI system can deliver very stable and synchronized environments for the dancers. As shown by this and prior experiments, the combination of 3DTI technology and choreography makes a strong vehicle for creative development and exploration of interdisciplinary research between the arts and technology [2].

Figure 2. Dancing in 3DTI Environments

2. IMPACT
3DTI technology provides *digital options* for exploring novel dance choreography including remote connectivity between dancers in geographically distributed places, abilities to change the scale, number, spatial placement and appearance of people in the virtual space, pre-scanned 3D cyberspace (e.g., theatre stage), and pre-recorded video (e.g., dancing with self). There is tremendous potential impact on choreography and dance archiving with these digital options which offer an entirely novel platform for the creation and presentation of dance. The live experience of collaborative dancing is dependent on the neurological mechanism of touch and sensory awareness. However, the experience of dancing with a partner in the 3DTI environment introduces the novel concept of *virtual touch*. The feedback mechanism for touch is completely altered when one

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relies solely on visual information to simulate a physical relationship with another body in space. This induces a heightened spatial awareness of self and a more internal sense of the partnering experience. Choreographing on geographically distributed dancers, one is challenged to think outside of the traditional lexicon of dance movements and presentation while exploring the spatial, physical and conceptual relationship among dancers in ways that are unreproduceable outside the 3DTI environment. Furthermore, the limitations of a proscenium stage and the audience perspective become irrelevant when the angles, depth and perspective can be altered easily by the audience with 3DTI, which is not available in live performance. This control is also available to the choreographer, who can determine the vantage point of audience throughout the presentation.

The 3DTI experience raises questions regarding haptic perception, self-identity, concepts of spatial and temporal reality, somatic practices, phenomenology and semiotics. Investigation of those issues will reveal the potential of 3DTI technology in dance performance of a new genre, archiving of historical choreography, education and training, physical therapy and entertainment.

3. TECHNICAL ELEMENTS

From the user's point of view, when she enters the environment her 3D model is captured by an array of cameras (Figure 2). The 3D streams from each remote site are aggregated through high-bandwidth network and rendered into a common virtual space on multiple displays in real time. Thus, dancers at remote sites can collaborate with each other through visual feedback. Behind that, the 3DTI system consists of three main components: *capturing*, *networking*, and *rendering*.

3.1 Capturing

There are 10 to 12 3D camera units mounted inside one environment covering a wide field of view. Each 3D camera unit consists of four 2D cameras (one color and three black/white). The camera unit is connected with an edge computer which performs trinocular stereo algorithm to compute the depth information of image pixels. All cameras are synchronized by a single clock to take images at the same time instant. The frames of all cameras bearing the same timestamp constitute one comprehensive 3D representation of the scene.

3.2 Networking

The networking of 3DTI is managed at two different layers. In the local layer, cameras and displays are registered with the *service gateway* which represents the middle-ware controlling component. At the global layer, service gateways are inter-connected to form an overlay network for session management and content delivery (Figure 3). The most critical task of service gateways is to coordinate the transmission of multiple streams from each environment over the Internet2 with quality of service guarantees. To achieve that, semantic-driven stream selection and adaptation algorithm is applied to make efficient usage of bandwidth while maintaining graceful quality degradation. During one live 3DTI session, the networking topology evolves as well to accommodate the semantic change occurring at the application level.

3.3 Rendering

With accurate calibration, the rendering system allows the user to select her preferred viewpoint of 3DTI environment in a seamless fashion. To facilitate collaboration, multiple displays are installed to present different viewpoints simultaneously. The rendering system can load pre-scanned virtual environment and/or pre-recorded 3D videos. It also supports other digital options such as scaling and spatial placement of 3D models.

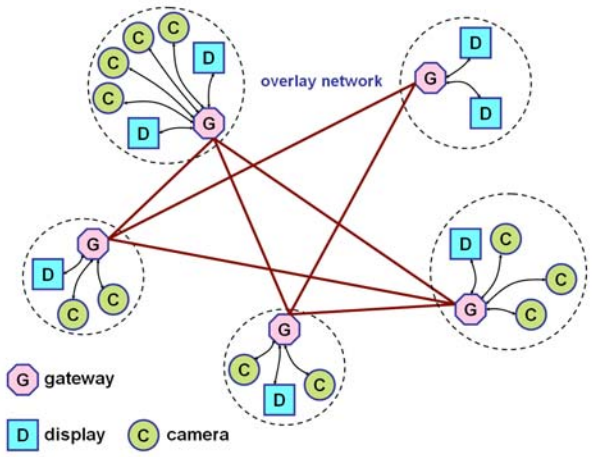

Figure 3. Networking Infrastructure of 3DTI

4. SUMMARY

Over the last 12 months, we have conducted several laboratory experiments [3,4,5] and two public performances of collaborative dancing in 3DTI environment. Analyzing those experiences, the possibilities for how dance is conceived, created and presented, are full of potential for altering current conventions of live performance. The 3DTI-augmented dance choreography is a continuously evolving technique that requires new visual and physical skill sets for dancers and choreographers to use.

Meanwhile, we explore initial interfaces between arts and technology. We are evaluating the effectiveness of 3DTI components and the technical limitations that influence dance choreography. There are many new and much deeper questions presented through the partnering of art and computer science which cross over to phenomenology, somatic practices, and philosophy.

5. ACKNOWLEDGMENTS

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