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Cyber performances, technical and artistic collaboration across continents☆

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HIGHLIGHTS

- We conducted several experiments of playing music together over distance.
- The maximum acceptable delay is between 15 and 30 ms.
- Order of importance for performers is good sound, feeling other musicians and good vision.
- Good sound means similar acoustic space characteristics of the local and remote sound.
- With higher delay, distributed music and dance can be successfully contributed to a common performance.

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ABSTRACT

Our objective was to verify whether modern computer network and audiovisual technologies can enable collaborative work between performing artists when they are distributed across large distances and what the requirements and limitations are. Such distributed collaborative environments will bring new opportunities both for the artists and the audience.

We describe our experiences gained from laboratory experiments and during cyber performances at APAN meetings that took place in Korea and Taiwan.

1. Introduction

The development of information and communication technologies (ICT) has transformed the world. We cannot talk about anything without mentioning ICT in all disciplines, in science, engineering, economics and even art. The eCulture group in the Asia-Pacific Advanced Network (APAN) investigates options for applying ICT to Humanities and Social Sciences, to enhance education and collaboration possibilities among people, spanning physical distance and cultural differences.

It was shown that if we can share audiovisual content with small latency between end points, we can enable real-time collaboration in multiple fields, including medical training [1] or media processing [2].

The maximum acceptable latency between end-points depends on a particular application. We wanted to explore whether real-time collaboration is possible between performing artists in music and dance across large distances, what the requirements are, the

☆ Fully documented templates are available in the elsarticle package on CTAN.

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limitations and practical solutions to overcome obstacles in performing over networks, such as the relationship between stages and/or actors in order to accommodate network delays.

Such technology can enable creative collaboration in learning, training and performances between people of different cultures in different parts of the world. Cultural exchange can enhance their experience and artistic invention. There are also practical benefits, such as a possible reduction of travel over large distances. The experimental results can be considered as a suggested workflow for collaborative performance over large distances.

The structure of this paper is as follows. In Chapter 2 we refer to important related works. Chapter 3 is the main part of the paper describing our experimental work. In Chapter 4, we provide our summary and views about future work.

2. Related work

Video and audio transmissions have been used for many years for discussions through teleconferencing and for distance learning. Teleconferencing has spread from company management to daily use by people in mostly technically oriented fields. Distance learning through real-time and pre-recorded video transmissions have been most widely adopted in medicine. Surgery transmissions to medical symposia are now common [1].

Remote collaboration in science and industrial design has been pioneered by some institutions and companies, usually making use of large visualization devices, such as CAVE [3] and SAGE [4]. The latter has been designed to support transparent visualizations of remotely executed applications from multiple locations.

At the lower end of added latency, 4K Gateway [5] is an FPGA-based device developed for low-latency streaming of high-definition video up to 4K (4096×2160). The added processing latency can be as low as 2 ms in uncompressed transmission for the sending and receiving device combined. Additional buffering can be configured for higher resilience to network jitter. It has been used for remote collaboration experiments in several fields, including architectural design and remote access to 3D models of museum artifacts [6].

LoLa software [7] developed by GARR is now used at musical institutions around the world for musicians to remotely play together or lectures. Lola runs on a Windows PC, uses low-latency sound adaptors and achieves added latency for sound around 6 ms.

Ultragrid [8] is an open-source software, maintained and primarily developed by CESNET and Masaryk University, for video and audio transmissions up to post-HD resolutions on a PC platform, equipped with grabber cards and graphic adaptors. A range of compression codecs is available with some accelerated using GPU devices. The software runs on Windows, Linux and MAC.

We used 4K Gateway and Ultragrid for our cyber performances and LoLa for our experiments in playing music together.

The Network Performing Arts Production Workshop (NPAP, formerly NPAW)[1] is a yearly event coordinated by TERENA and Internet2 where network researchers and performing artists can meet and discuss possibilities and issues when performing music, dance and other forms of artistic expression over computer networks.

The Internet Society has organized a Workshop on Internet Latency[2] as a result of communication latency being increasingly important for many network applications.

Chris Chafe has performed several experiments to measure the effects of time delay on rhythmic accuracy for ensemble playing [9]. The measurements used relatively simple sounds such as hand clapping by non-musicians and the differences were precisely measured and statistically evaluated. The subjective effects on musicians and their audience were not considered.

3. Experimental work

We conducted several laboratory and real-network experiments to better understand the effects of transmission delays on remotely connected musicians and dancers. We used real pieces of music and asked musicians and sound engineers about their feelings after playing, including the effects of visual contact by simultaneous video transmissions. We then organized two distributed cyber performances for audiences for the APAN workshops in Korea and Taiwan in 2013 and 2014.

3.1. Effects of delay on musicians

The speed of acoustic sound propagation is approx. 1 m per 3 ms. The size of a symphonic orchestra can be more than 10 m across, which means a delay of over 30 ms. But, the musicians can synchronize to their close sitting neighbors and can therefore tolerate the acoustic delay within the whole orchestra. They can also use visual clues from the director. However, computer networks and the transmission equipment can add significantly higher delays.

In a first experiment at the Music and Dance Faculty of the Academy of Performing Arts in Prague (HAMU), one musician played a harp and another a flute in two separate rooms while connected by an audio and video transmission with artificially introduced delay [10], see Fig. 1. We increased the delay from 5 ms to 30 ms in steps of 2.5 ms. We used the 4K Gateway device for audio and video transmission, utilizing its ability to precisely configure the added delay. At some stages the musicians did not know the delay setting. At 10 ms small concentration was required for synchronization, at 12.5 ms stronger concentration was required, but after a few goes 15 ms was still considered acceptable without significantly affecting the performance. The delay of 30 ms was "playable", but it felt by the musicians like a "sports event" and the quality of the musical experience was affected, the focus on synchronization eliminated possibilities of tempo rubato and other expressions.

We then conducted two additional experiments of playing together between musical academies in Prague, Trieste and Edinburgh using LoLa software as part of the eMusic project[3] over the Géant network, where the delay between end-points ranged between 15 and 30 ms (network propagation delay plus software delay). We prepared a questionnaire of approx. 35 questions for the musicians about their feelings and experiences to be asked during and after the experiment [11]. The overall experience was comparable to the first experiment with artificially introduced delay. The maximum delay tolerance appears to lay between 15 and 30 ms, with lower values acceptable for chamber music, playing for an audience and better expressive options, whereas the higher limit can be tolerated for popular music, rehearsals and after acquiring some experience with remote playing together.

For the accompanying video transmission, we tried both SD and HD resolutions and 30 or 60 fps. Obviously, HD resolution at 60 fps was considered a better telepresence of the remote partner and it made the interaction easier. However, the importance of visual contact was still considered surprisingly low. In common arrangements, the other musicians may be aside or behind one another. However, in addition to the delay characteristics of remote sound other factors were considered very important, such as comparable loudness, dynamics and echo. It is also clear that acceptance of such a musical telepresence also depends on the personalities of the musicians. We collaborated with musicians who had a positive attitude to technology and experimentation.

[1] https://www.terena.org/activities/network-arts.
[2] http://www.internetsociety.org/latency2013.
[3] http://www.geant.net/opencall/Applications/Pages/eMusic.aspx.