Wearable Sound System for Dance and Music

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ABSTRACT

While there has been a considerable increase in the use of spatial audio tools in the last decades for various creative applications there have been very few examples of reliable wearable sound systems to be used in different kinds of performance environments. An original wireless body-worn loudspeaker system for dance and music performance is presented with an original costume design and hybrid loudspeaker system. The architecture and acoustic performance of an original prototype was optimized using data gathered from anechoic measurements and interviews with performers and audience members. Future developments of the wearable sound system will consider the design and implementation of an extended multi-channel performance platform to control the sound of several travelling performers.

1. INTRODUCTION

The use of multi-channel sound systems for the presentation of films, games and music has increased awareness among audiences about the importance of spatial audio tools [1, 2]. Due to the availability of wireless technology in recent years composers, performers and technology developers have started to integrate mobile loudspeakers as part of music and dance projects [3, 4]. In this paper the design, implementation and acoustic optimization of a body-worn sound system is discussed taking into account the technical and artistic demands of dance and music performance.

2. PILOT TESTS WITH HAND-HELD COMMERCIAL LOUDSPEAKERS

The first attempt to create a composition with travelling performers carrying wireless loudspeakers was carried out by the author for a music theatre piece commissioned by *Base Theatre* for the 2007 Edinburgh Fringe Festival [5]. Two portable CD players were carried out by singers and actors as part of a hybrid multi-channel setup especially designed for the performance of the dance theatre piece *To have done with the judgment of Artaud*. The music was composed as a four-channel composition soundtrack using two portable CD players manually synchronized with the stereo PA system of the theatre venue. The advantages of this low-fi system were the affordability of the technology used and its flexibility to adapt to different performance venues. The main obvious limitations of the system were the need for manual synchronization between fixed and mobile sources, the size and weight of the portable radios and their poor acoustic response. Due to the synchronization problems of the system mentioned above new tests with travelling performers using two pairs of commercial wireless loudspeakers and a quadraphonic sound system were carried out [6]. In this case the quad system surrounded the audience and the two pairs of wireless loudspeakers were carried as props by a dancer and an actress during the performance.

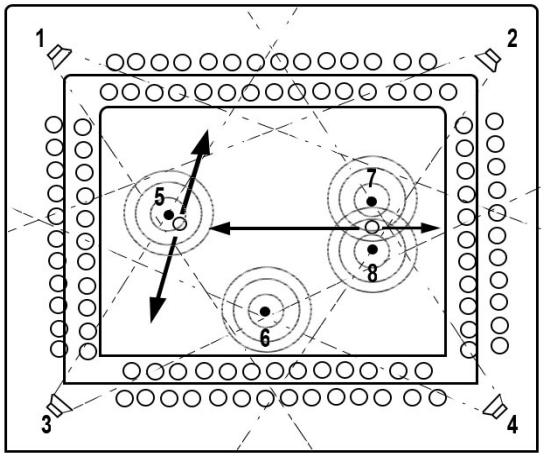

Figure 1. Setup for tests carried out at Lancaster University using an 8-channel mix played through a fixed quad system surrounding the audience and two pairs of commercial *Rimax* loudspeakers carried by two performers.

The system was synchronized using an 8-channel mix played through a laptop with a multi-channel soundcard that fed quad system and the two pairs of speakers' transmitters. Figure 1 shows the setup used at a performance at Lancaster University using an 8-channel mix played through a fixed quad sound system surrounding the audience (channels 1-4) and the two pairs of *Rimex* wireless loudspeakers carried by performers (channels 5-8). The use of synchronized mobile speakers allowed the possibility of creating a flexible and immersive sound environment and the possibility of exploring intricate spatial relationships between performers'

movements with the sonic props and sound textures panned between the two pairs of external speakers. The main limitations of this hybrid system were the size of the portable loudspeakers, their limited acoustic power and poor sound quality and the unstable signal transmission of the commercial wireless loudspeaker system.

3. WIRELESS BODY-WORN SYSTEM

Taking into account the technical and practical limitations of commercial wireless loudspeakers mentioned above it was decided to design and implement a prototype of a body-worn sound system in collaboration with the company Greenlight AV [7]. The main goal behind the design of the prototype was to create a robust and acoustically reliable system that could be easily adjusted to the requirements of dancers and musicians in different types of performance environments. The system included two loudspeakers located in the front and back of the performer's torso, a two-channel Maxim 25 Watt amplifier fed by 12 Volt batteries and a two channel 2.4 GHz Bluetooth transmitter and receiver set. The volume of each torso loudspeaker cabinet was 456.3 cm^3 and included a 2" *Audica* full-range loudspeaker unit. One of the challenging aspects of the prototype design was to find small loudspeaker cabinets that could be confortable enough for performers to wear and at the same time provide enough sound power to cover a medium size performance space. Figure 2 shows the dancer Victoria Harper testing a prototype of the system at Lancaster University.

Figure 2. Dancer Victoria Harper during trials with a prototype of the Body-worn system at Lancaster University.

4. SYSTEM OPTIMIZATION

Various practical tests with the wearable prototype were carried out with dancers in order to assess the flexibility and robustness of the system. After testing the system in different performance venues dancers were satisfied with the overall design and weight of the system, but had concerns regarding the position of the back speaker. One dancer noted that the position of this loudspeaker restricted considerably the range of movements on the floor and also suggested that it could be an interesting idea to give some kind of control to the performer over the sounds radiated by the system. Taking into account these suggestions it was decided to modify the architecture of the system by replacing the back speaker with two smaller loudspeakers on the forearms of the dancer [8]. The new optimized system considered a pair of 2-inch full-range Vifa NE65W loudspeaker with small cabinets for both arms. The next goal was to find a suitable cabinet size for each forearm loudspeaker unit. On the one hand it was important to maximize the acoustic performance of these loudspeakers but on the other hand it was also essential to make the size of the loudspeakers small enough to allow the needed arms' flexibility for the performer. Anechoic measurements using the Vifa NE65W loudspeaker with various cabinet sizes showed that for volumes below 250 cm^3 the variations in the frequency response were marginal. It was therefore decided to build the smaller cabinet size that would fit the Vifa NE65W loudspeaker. The dimensions of the chosen cabinet were 5.9 cm x 6.8 cm x 2.5 cm (L, W, H) and its final volume 100.3 cm^3. The measured sensitivity of this system was 79.9 dB (1m/1w). The final body-worn hybrid system included the original torso speaker driven by one channel of the amplifier and the two forearm speakers driven by the second one. Figure 3 shows the frequency response of the torso speaker and one of the forearm speakers with the cabinet selected. Figure 4 shows the dancer Ignacio Díaz wearing the optimized body-worn system during tests at Universidad Austral. In order to improve the overall performance of the body-worn system other aspects of the system were also optimized. The 12 V battery units of the prototype were replaced with lithium-ion batteries, which extended the functioning time of the system in 30 minutes and were considerably lighter than conventional commercial rechargeable batteries. Another aspect of the prototype that was optimized was the built-in audio amplifier of the system. A new, more powerful, amplifier with 30 Watt RMS per audio channel was added to the system in order to improve the performance of the system and allow the possibility of adding more loudspeakers to the system in the future. Table 1 shows a comparison of the main features of the original prototype designed by Greenlight AV and the hybrid optimized system.

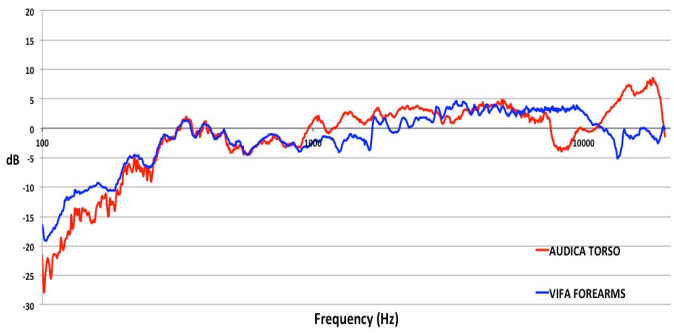

Figure 3: Frequency response of torso and arms' loudspeakers.

	Prototype	Optimized system
Audio channels	2	2
Loudspeaker units	2	3
Loudspeaker positions	Front and back torso	Front torso and forearms
Loudspeaker cabinet volume	2 x 456.3 cm^3	1 x 456.3 cm^3 2 x 100.3 cm^3
Loudspeaker sensitivity (1m/1W)	82.5 dB	82.5 dB (torso) 78.8 dB (forearms)
Battery duration	60 minutes	90 minutes
Amplifier power	25 Watt RMS	30 Watt RMS

Table 1. Compared technical features of the prototype and the optimized system.

Figure 4. Dancer Ignacio Díaz testing the optimized body-worn system with one speaker on the torso and two speakers on the forearms.

A demonstration of the optimized body-worn system took place at the IX Ibero-American Congress on Acoustics in Valdivia, Chile. A short dance improvisation was performed by the dancer Ignacio Díaz in a room of the size of a small dance studio (200 m^3). The dancer used the stage and corridors of the room to exemplify numerous types of movements related to various kinds of sound materials reproduced by the system. After the demonstration five members of the audience were questioned about the body-worn system presented [8]. All respondents commented favorably about the striking effect of the integration of sound and movement and the highly expressive nature of the system. Questioned about the acoustical power of the system, all respondents said that the acoustical power of the system was more than enough for the room and several thought that there were also other sound sources on stage at the time of the demonstration. Questioned about the sound quality of the application opinions were mixed. Three respondents were positive about the quality of the sound reproduced while two noted that the quality of the reproduced sound was highly dependent on the type of sound material reproduced. Several respondents also noted the intimate character of reproduced sound when the dancer was in close proximity to the audience. Soft sounds reproduced near to the audience seemed to have a greater impact than loud noises performed on the stage area. The dancer Ignacio Díaz was also interviewed after the demonstration. He noted on one hand a considerable improvement in terms of movement flexibility in comparison to the original prototype, but on the other hand would have liked smaller loudspeaker units on his

arms to increase movement flexibility. The dancer also observed that that the communication with the audience was enhanced with the possibility of controlling the radiated sound through his arms and torso. He mentioned the fact that the sensing the vibrations through his chest and arms inspired him to a completely different approach towards the dance and he started conceiving his role in the piece as a blend between a musician and a dancer.

5. DISCUSSION AND FUTURE WORK

The current project has shown that there is great potential for the development of spatial audio creative applications that can effectively balance technical and artistic performance requirements. Tests with performers using the body-worn system have shown that the application opens interesting possibilities for devising novel interdisciplinary projects with an emphasis on spatialised sound. The effect of the system on audiences invites for a reflection about the role of the composer, choreographer and performer in a new creative framework where the performer becomes effectively the embodiment of radiated sound. Another interesting aspect of the project was the impact that the body-worn device has on audiences. Further studies should consider ways of assessing this impact by devising informal listening tests with trained listeners and audiovisual tools that will allow subjects play an active role in the creative process of a piece.

The use of two or more performers wearing the body-worn systems within a multi-channel loudspeaker platform could also be an interesting development of this project. Several mobile sound sources on stage synchronized with a four or eight-channel loudspeaker diffusion system could provide a new ground for exploring spatial relationships between natural and virtual sound sources on and off stage.

Acknowledgments

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6. REFERENCES

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