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Distributed Interactive Audio Devices: Creative strategies and audience responses to novel musical interaction scenarios

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Abstract

With the rise of ubiquitous computing, comes new possibilities for experiencing audio, visual and tactile media in distributed and situated forms, disrupting modes of media experience that have been relatively stable for decades. We present the Distributed Interactive Audio Devices (DIADs) project, a set of experimental interventions to explore future ubiquitous computing design spaces in which electronic sound is presented as distributed, interactive and portable. The DIAD system is intended for creative sound and music performance and interaction, yet it does not conform to traditional concepts of musical performance, suggesting instead a fusion of music performance and other forms of collaborative digital interaction. We describe the thinking behind the project, the state of the DIAD system's technical development, and our experiences working with user-interaction in lab-based and public performance scenarios.

Keywords

Internet of Things, Spatial Audio, Sensor Network User Interfaces, Sonic Art.

Introduction

With the rise of ubiquitous computing technologies [1] come new possibilities for experiencing audio, visual and tactile media in distributed and situated forms, disrupting modes of media experience that have been relatively stable for decades. The DIADs (distributed interactive audio devices) project explores creativity and experience in the context of portable, networked, sensor-equipped audio devices. We have been working with an experimental set of devices over the past two years [2], innovating interaction design contexts in which electronically produced sound is both the product of a centralized performance, but also of multi-user participation.

With the reduction in size and cost of electronics, fully fledged computers are beginning to occupy roles formally served by dedicated electronics hardware, or microcontroller systems such as Arduino, particularly for prototyping contexts. This can make it simpler to program the Internet of Things (IoT), by making use of the advanced libraries, languages and tooling available for modern computer operating systems, not least because programmers can work in their creative environment of choice. These devices also

Figure 1 - Natural interaction affordances with DIADs

make it possible to use rich audio and visual media in novel and diverse spatial situations.

The DIAD system is an experimental design for creative sound and music performance and interaction using multiplicities of networked, portable computers. Made from cheap off-the-shelf components, they can be programmed to run small, dedicated audio programs. A system for remote-controlling and remote-live-coding these devices from a central computer has been developed. This acts as an experimental platform to explore the techniques and tools with which one can creatively produce content for such networks of devices, and implement the novel interaction, exhibition and performance scenarios they make possible, particularly relating to synchronized audio played over multiplicities of devices. The devices have primarily been developed for musical performance contexts, but by their nature they do not conform to traditional music concepts, instead suggesting a fusion of music performance and other forms of collaborative digital interaction.

This paper presents the background to our present project, which we categorize under the umbrella term "media multiplicities". We present the DIAD design and our techniques for creating content and performing with them, reflecting on how creating content for media multiplicities can best be achieved. Finally, we reflect on the creative interactive opportunities that DIADs offer.

Background

DIADs are an example of a growing field of creative technology activity that we call "multiplicitous media". Wherever digital devices are used in number in some coordinated fashion, we may describe this as a "media multiplicity". The consistent progression of computing technology towards *ubiquitous computing* [1] highlights the emerging importance of media multiplicities, which will require new conceptions of performance and composition, with, we believe, adaptive software behavior playing a pivotal role in achieving scalable, reconfigurable and context-sensitive goals. Media multiplicities allow media experiences to be less monolithic, involving both the closer integration of media elements (sounds and moving images) into existing or virtual environments (such as building façades, living rooms or performance spaces), and the distribution of content across multiple media elements, as an extreme continuation of work in multi-screen and multi-speaker environments. With the emergence of "second screen interaction" (e.g., watching a live TV show and interacting with that show via Twitter on a tablet), media multiplicities are already common in everyday experience. Our work imagines how rich multi-device interaction may play out.

Electronic music production has enabled the dislocation of the source of the sound from the device producing the sound signal. This has meant that sound can be produced that is unrelated to its physical source (unlike an acoustic musical instrument for instance), but this has the effect of limiting the clarity of the link between the sound object and the sound it produces. For example, the tacit physical knowledge that a listener builds about what sound will be produced when a drummer hits a drum with force is not the same with an electronic music experience.

Similarly, spatial sound reproduction is now commonplace, but is almost exclusively produced using sets of loudspeakers that have a fixed position (although there do exist some notable exceptions, e,g. [4]). By contrast, using movable, portable sound sources such as DIADs significantly complicates the control of a sound field, and in this new musical context typical spatial audio formats (eg. surround standards such as Dolby's 5.1) are unlikely to adequately capture the expected experience. New design processes and vocabulary may be required; the interactive nature of the spatial sound experience extends a more physical metaphor to the devices, and instead of the precisely positioned sound images that are prevalent in recorded music, for DIADs performances the sound image tends to be either located directly with each device itself, or within the 'swarm' or multiplicity of devices.

As a creative platform the DIADs build on research in network audio and networked music performance [5], which has become a significant field through the strong interest in laptop and mobile phone orchestras (e.g., [6]). Whilst the smartphone or tablet is already capable of everything our devices can do, our interest is looking at dedicated media device networks with alternative deployment and user experience connotations. There are reasons why a person may not want to use their personal device as a component in a media experience, such as an audience-interaction-based work. These include privacy, system security, personal space, battery life, and conflicting uses (such as wanting to use a social networking app or take photos). Additional obstacles to using personal devices may include the effort of logging onto a network, configuring system settings, ensuring device compatibility, and downloading large software files. Dedicated media devices such as DIADs can be designed for purpose, preconfigured and fully charged and do not pose conflicts to the user regarding the use of their personal equipment. They can also be made for as little as $100, thus easily accumulated in large numbers for dedicated events. As such, they join a plethora of dedicated low cost IoT devices.

Distributed Interactive Audio Devices

Our current DIAD system uses simple off-the-shelf components: a Raspberry Pi as a host computer, a standard USB WiFi dongle, an off-the-shelf Moshi Bassburger self-powered speaker, a Pololu MiniMu-9 IMU sensor (inertial measurement unit, consisting of accelerometer, gyroscope and compass), and an off-the-shelf mobile phone battery charger as a power source. The DIADs are pre-configured to automatically connect to a local WiFi network, and register with a server running on a central controller computer. Any DIAD that comes onto this WiFi network then becomes part of the DIAD multiplicity and can be remote controlled.

Once charged and activated, DIADs can be operated portably and remotely within the range of the WiFi network. They can be handled by people, incorporated into the environment and, depending on how robust they are, can even be thrown and bounced.

Software Design

The focus of DIADs development has been on the creation of a reusable software platform that allows creators to develop interactive audio content that can be rapidly and easily deployed across multiple devices. We have created a client-server architecture using Java. The Beads library for Java[1] is used for digital signal processing (DSP) on the Raspberry Pi's. Code written on a controller computer can be compiled and sent to the DIADs while they are running. The code is executed as soon as it is received, and this does not require the device to restart audio or be rebooted [2]. In other recent work we have started to incorporate realtime video as well as video streaming into our system.

A network synchronisation system loosely synchronises the timebase of all the DIADs so that timed events can occur in sync. The controller computer also runs a program with a graphical user interface that enables direct control of the DIADs, either in a group or individually. Code sent to the DIADs can access both the sensors on the devices but can also listen for, and respond to, open sound control (OSC) messages on the network. This means that, for example, it is easy to write a program that causes the on-board sensors to modulate the frequency of a filter, or that responds to incoming commands to play a note from the controller. Commands can be hand-typed by the performer on the controller computer, which makes for a versatile interface, or might be linked to physical interface devices.

[1] http://www.beadsproject.net

Importantly, rather than only transferring simple note instructions (as MIDI does for instance), a complete algorithmic composition, incorporating an associated interaction mapping system, can be transferred over the network to be executed imediately by the running DIAD, as is typical in "Live Coding" performance. This means that a performer can decide when to initiate an algorithmic composition, and on which devices, based on their engagement with the improvised musical context and the audience themselves. With this flexibility the toolkit allows powerful creative control in a multiplicitous media context. One of the main goals of our research, therefore, is to understand how creative practitioners will go about creating content and experiences for such contexts, and what future design improvements could be made to such an authoring and deployment framework.

Interactive Experience & Audience Responses

Within the research team, we have explored some of the interactive possibilities of the DIADs for individual and group play. Tangible interaction made possible through the physical form of the devices influences the way one thinks about composing interactive experiences with the DIADs. Spheres have an obvious appeal, and were part of the original conception of a set of interactive "sound balls". The sphere's affordances are self-evident, and they inspire an immediate association with games and playful interaction, fitting seamlessly into the theme of digital interactivity in gameplay found, for example, in the work of composer Jon Rose[2]. But we immediately began to explore deviations from the sphere, in order to see how the physical behavior of the device, when rolled or rocked, would itself form a pattern-producing system that could feed into the digital sound design. Hence the first proper prototype set of shells takes the form of various egg and rugby-ball shapes that allow limited and idiosyncratic forms of rolling along some axes while rolling more regularly along others.

Such affordances establish a user interface that differs significantly from a typical mobile phone or other consumer electronic device. At first glance there are no clear cues for how to interact, and the audience must explore the capabilities of the device by holding and manipulating it, looking and listening for changes that occur as they move, rotate or shake the device. Additionally, depending on the algorithm deployed to the device, these actions may have various effects at particular times in the performance, meaning that the exploration process is likely to continue throughout a composition.

In a pilot study, we gathered some provisional insights into the physical and social affordances of the current DIAD design. Of particular interest was the potential to retain the partially unpredictable and ambiguous character of the movement-to-sound relationship. Participants reported that the device shifted between seeming autonomous and being responsive to their movements. The lack of obvious interactive affordances meant that people were curious to experiment with different kinds of movement to get an effect, once they had realized that the devices actually were responsive to their actions. The tactile form and texture gives the DIADs an intimate quality; people want to hold them and just listen. The social collaborative aspects were less well developed and participants reported either a tendency to personal, individual engagement or a lack of motivation provided by the devices for collaborative interaction, although different responses were observed in the concert scenario, as described below.

The sound of the devices is conspicuously different from high-fidelity audio. The cheap consumer Moshi Bassburger speakers have limited frequency response and volume, and the audio performance of the Pi is sub-CD quality. Consequently, it matters a great deal to the effectiveness of the sonic experience what sounds are played through them. Noisy broadband sounds carry well and create nicely ambiguous spatial effects. The speakers struggle to compete with voices in noisy environments, except when producing high frequencies, but in quiet reverberant spaces eight speakers are able to make a great deal of noise. Their inability to fill space, however, can become an opportunity, in the way that this necessitates more intimate listening experiences, as explored by composer Miriama Young, through the study of intimacy in storytelling [2].

As tangible devices, the DIADs naturally provoke users to explore the relationship between the sound source and the body. Since the devices also include IMU sensors that respond to movement and affect the digital audio processing, interaction with the devices occurs with respect to both physical and digital affordances. Participants engaged in various gradual movements, focusing on producing slow and subtle changes. They placed the devices in different positions with respect to their own ears and to other people, including in contact with different parts of the body. They spun, threw, rolled and engaged in other rapid movements with the devices, obtaining a sense of the movement of the sound source, including Doppler effects.

In one instance, the devices were programmed so that they would only make sound when shaken, with the speed of playback of the sound influenced by the speed of shaking. The sound of an Australian kookaburra was used in one case, and a nightingale in another. This mode of interaction pointed to an obvious metaphor of a rattle or a bell, and resembled an interactive sound toy for children. More generally, this configuration establishes the metaphor of interaction with inanimate physical objects, which do not make sound unless interacted with. In other experiments the device was programmed to make sound regardless of what the user did, for example as a result of a live performer operating the devices remotely, with the user's actions only modifying the sound, not causing it. The user's conceptual model of the sonic interaction differs between these two cases. In the latter case, the device inevitably takes on an agentive relationship to the user: it does things, rather than having things done to it, or with it, and as such fails to satisfy the expectations of an instrument or physical

[2] http://www.jonroseweb.com/f_projects_ball.html

sounding device. This was reflected in participants' responses, as noted above.

We have yet to fully chart the design space that exists between these categories, how we might suspend the user in a state that combines active and passive elements, or can be shifted seamlessly between them. Thus a next step in design is to categorize the simplest cues that establish the user's sense of control.

Figure 2: Audience passing DIADs in concert. Image courtesy of NIME2014 organizers.

Concert Performances

The devices have been presented at different concerts and exhibitions during 2013 and 2014. The most recent concert, at the New Interfaces for Musical Expression (NIME) conference (Goldsmiths, University of London, July 2014), explored the performance potential of handing the devices to the audience to pass around as part of the performance. This was presented through the proposition that "the speakers were being taken down from the walls and placed in the hands of the audience". The devices were handed out at the beginning of the concert and audience members were simply asked to explore and pass them on as they wished. A set of pre-prepared sonic scenes was remote-controlled in realtime from a laptop on stage. Sensors in the devices made minor modifications to the sounds, so that the composition maintained its coherence whilst allowing simple interactivity. Thus the predominant nature of the performance was that the on-stage performer was controlling the devices. Unlike certain audience-interaction experiments, there was no suggestion that the audience were involved in creating the work. Only minor modifications, such as changes in filter frequency or slight detunes of the source sound, were made possible through audience interaction. The musical content was largely drone-based in nature, focusing on the spatial sound-world enabled by distributing the droning devices throughout the space, but it included other simple musical structures that were designed to work in a distributed manner, such as simple arpeggiated melodic patterns running at different tempi.

The audience response, as observed on video recording of the performance, included amusement and engagement, and a range of playful interaction behaviors was observed. People explored different modes of passing, rolling and throwing devices between each other, as well as posing for fun in front of others, and shaking, rotating and so on, to explore the sonic interactive potential of the devices. Since one could also cup one's hand over the speaker or cover it using a piece of clothing, this mode of acoustic interaction was also explored frequently. One person held the device to his mouth to modulate the sound, whilst another walked one of the devices up into the auditorium gallery to provide even more spatial spread. The playfulness with which the audience took to the interaction could be said to create a transformation of the mood in the performance space, with all attention inward onto fellow members of the audience. With the eight small devices scattered and constantly moving around the space, individuals were peering, turning around in their chairs, standing up and whispering to each other, with pockets of activity around each device as it moved around the space.

Conclusion

This paper has given a brief overview of the DIADs project, and has described its artistic motivations, the technology, the design challenges, and some of the informal outcomes of our creative work. Whilst we acknowledge the incomplete and speculative nature of many of our observations, these observations offer clear conceptual directions for further research and development. The work highlights the need for a more rigorous technological and user-focused understanding of emerging multiplicitous media experiences, which is our current theoretical focus.

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