

Visualizing Audio in a First-Person Shooter With Directional Sound Display

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ABSTRACT

As the popularity of videogames continues to expand in the United States and around the world, it is alarming that the majority of developers are overlooking the needs of players who are deaf. In the US alone, there are close to one million people deaf individuals. Sound is often an integral part of immersing players into a gaming experience. The creation of Digital Sound Display (DSD) was in part motivated by wanting to provide deaf players with the vital, strategic aspects of the game which are usually lost to them. Although users were consulted at various stages of development, we approached the design of DSD with a task-centered paradigm, building the system around providing directional information to deaf players. We targeted the visualization of reactionary sounds (e.g., an enemy discharging a weapon at the player), as those are the ones most often associated as critical in first-person shooter (first-person shooter) games. A Fast-Fourier Transform (FFT) algorithm was used to translate the sound into a visualization in real-time with unnoticeable delay. We showed that DSD was capable of visualizing sound in three ways: *pitch*, *intensity*, and *direction*. In a pilot study, we found that participants most valued preemptive sound visualizations to visualizations of other sound types.

Categories and Subject Descriptors

H.5.2 [Information interfaces and presentation]: [User interfaces]; K.8.0 [General]: [Games]

General Terms

Games

Keywords

accessibility, games, interaction, HCI

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1. INTRODUCTION

In the US alone, there are roughly ten million people who have a severe hearing impairment, and close to one million people who are functionally deaf [6]. Meanwhile, more than half (51%) of adults 18 and over, regardless of race, household income, and locale, play games [5], and nearly all teens play games [4]. Thus, the video game market is expanding – but it is not expanding to deaf individuals quickly enough, as indicated by discussions on the site for deaf players of video games, aptly named *Deaf Gamers*.¹

The purpose of Digital Sound Display (DSD) is to provide a visual representation of audio information for deaf and hearing impaired individuals. Specifically, it determines the direction of sound, as well as the amplitude and pitch, and displays that to the user. It also includes some customization options, such as size, color, and opacity, to allow users to tailor the visualizer to their own specifications. DSD was developed using the Processing programming language.²

DSD was designed to be an overlay for a first-person shooter game, allowing the following compelling affordances over a tool embedded into a particular game.

- *Portability*: A single overlay can be used in a variety of gaming environments, and is not restricted to one particular game.
- *Ubiquity*: An overlay works with existing screen real estate to provide a seamless visualization experience, rather than a separate place where the player must focus his or her efforts.
- *Customization*: The ability to customize the interface is a crucial component to our design.

2. RELATED WORK

Unfortunately, little work has been done in the area of accessibility of games for individuals with hearing impairment.

Sound Sign or Sound Compass is a graphical representation of different types of sounds commonly heard in video games [2]. Benefits of Sound Sign or Sound Compass include the proposed ability to distinguish, for example, between gunshot and helicopter sounds, and to provide a visual representation of the location of those sounds relative to the

¹Deaf Gamers: <http://www.deafgamers.com>

²Processing at <http://processing.org>

player. However, locating the visual cues far from the area of the screen which requires attention during a first-person shooter (first-person shooter) is likely to be cumbersome or distracting for the player: the player’s attention is on the upper portion of the screen, where the fighting occurs.

Other ways of visually displaying sound include the spectrographic visualization of spoken word [3]. The spectrograph is particularly adept at recognizing mechanical sounds, so its utility in a video game application would be apt. However, the spectrograph requires its own physical display and constant attention to fluctuating details, thus breaking game immersion.

There is little research in the domain of video games and hearing impairments or deafness. In a game to teach deaf children proper Polish grammar [8], the authors mention the need for a strong visual guide and include pictures, words, and a talking head to help the child learn the mouth formations of each word. *Rock Vibe*, a modification for *Rock Band* (Harmonix Music Systems, 2007), provides haptic feedback for visual drumming cues [1]. A buzzer vibrates the upper arm or the ankle to indicate the beat to the player. Although this application was intended for blind players, we invite the academic community to extend this application to deaf individuals as well, and note that such a need exists. One deaf gamer noted that, when playing a game that had calm music for normal encounters and low, ominous music for impending danger, “I was able to swap the normal music with a silent MP3 and the danger music with an MP3 of low rumbling that I can feel through a subwoofer at my feet.”³

3. THE PURPOSE OF SOUND

Sound in games provides much more than ambiance and flavor. Frequently, sound gives important clues as to dangers that lie ahead. For example, in an first-person shooter game, sound effects give away the position of enemies, including their direction, distance from the player, and even what weapon is currently wielded. Sound clues tell the player when enemy units are behind doors and walls, and help players differentiate between enemies and allies. Deaf players are unable to pick up these necessary clues.

In the design, development, and testing of DSD, we paired the DSD program with *Unreal Tournament* (Epic Games and Digital Extremes, 1999) to demonstrate a proof of concept. The sounds most important to *Unreal Tournament* fall into three categories: preemptive sounds, reactionary sounds, and feedback sounds. Preemptive sounds tell a player where the enemy or enemies are located before the enemy strikes. These sounds include footsteps walking on different materials, a player jumping or landing from a fall, and distant gunshots. Reactionary sounds indicate to a player the location of an enemy after the enemy has begun to attack but possibly before the player takes damage. These sounds are usually gunshots or explosions. Feedback sounds indicate damage to the player’s avatar, such as when an enemy’s bullets have hit the player or when the player is healing his or her own character. These sounds are shouts of pain, gun shots, picking up a health pack, or from when they jump or land from a fall.

To better understand the purpose of sound for a subset of the target population, we invited seven participants from a

convenience sampling to participate in a focus group discussion about the role of sound in first-person shooter games. The participants were all male, ages 18–21, with extensive experience with playing first-person shooter games. None had hearing impairments. The focus group helped to determine the role of sound in first-person shooter games:

- *Strategy*: Sound effects can provide necessary strategic information during gameplay (e.g., about position of enemy units).
- *Immersion*: Sound enables one to become more immersed in the game.
- *Aesthetics*: Sound adds to the aesthetics of the game.

Several of the participants felt that sound could not be substituted in games, though they did agree that any degree of sound substitution may prove useful for game players with hearing impairments.

4. RAPID PROTOTYPING

This project progressed from concept to user-tested deliverable in 10 weeks. This progression is described below.

Concept. The vision was a stand-alone application to provide visual representation for the direction of stereo sound. A stand-alone application was preferable to an integrated solution for portability to multiple games and platforms. We wished to allow the user to modify the visualization’s opacity, intensity, and color.

Low-fidelity prototyping. To create the low-fidelity prototype, we made electronic mock-ups of the different screens and options available in DSD, as well as a screen capture from *Unreal Tournament*. We printed and cut out the different interactive components and screen backgrounds. Several options present in the low-fidelity prototype were not implemented in the final system as a result of the feedback received when interacting with the low-fidelity prototype. A photograph of the low-fidelity prototype screens is shown in Figure 1.

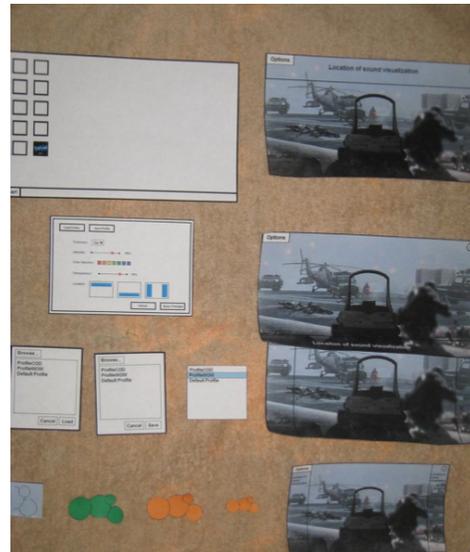


Figure 1: Low-fidelity paper prototype included several screens which were not included in the final version.

³Can bass add an extra dimension for the deaf gamer? http://www.deafgamers.com/an_extra_dimension.htm

High-fidelity prototyping. The high-fidelity prototype was created in Processing and was used as an overlay with a video of gameplay. A screen capture of the high-fidelity prototype is shown in Figure 2. The high-fidelity prototype showed that DSD was capable of visualizing sound in three ways: *pitch*, *intensity*, and *direction*. In the screen capture shown in Figure 2, eight white circles represent the logarithmic pitch averages of the sound input. The size of the circles indicates the intensity or loudness of each of the data points. Finally, the circles are drawn to the left or to the right of the screen center, depending on which side of the sound mix is louder, to indicate the direction of the sound.



Figure 2: High-fidelity prototype with white visualizations indicating enemy gunfire to the left of the player.

To create the visualizations, audio input is taken directly from the game’s audio output. Due to a limitation in Processing, an audio cable is required to feed audio output from the game directly into the computer’s audio input. The audio data is then processed using a Fast Fourier Transform (FFT) and separated into eight frequency bands to provide data for different frequencies. DSD then compares the right and left audio magnitude, per frequency, and determines which of the two is louder and by how much. This data is then displayed in real-time (with unnoticeable delay) by eight circles of varying diameters to the left or right, based on the perceived direction of the audio, and of varying thickness depending on the intensity of the sound.

The options screen shown in Figure 3 allows users to customize three aspects of the visualizer: color, level of transparency, and level of intensity (the size of the visualization). There are four levels of intensity and transparency, and eight colors to choose from.

Heuristic evaluation with Nielsen’s heuristics [7] showed flaws related to user control and freedom, recovery from errors (if errors were to occur), and help and documentation. The options menu (Figure 3) benefitted most from the heuristic evaluation, as the design was simplified: rather than a continuous selection for opacity and color, discrete choices were offered; and the options menu was modified to provide the user with a real-time preview of the user’s settings.

Final system. In the final system, we changed the circles to be rounded bars to help determine the sound direction and intensity. The final system was also usable in real-time with *Unreal Tournament*, a first-person shooter game. However, it was not possible to make DSD a transparent overlay, which we discovered was a shortcoming of the implementation decision of using the Processing language.

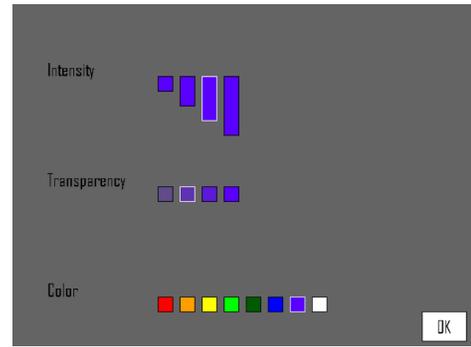


Figure 3: DSD options menu allows the player to change the visualization transparency, color, and size.

5. USER TESTING

The user interface was tested with six participants from a campus of a liberal arts university. A qualitative approach with the question-asking protocol was used to glean the most information about the system given the small number of pilot participants. We used the question-asking protocol to help participants voice their thoughts on the system in real-time, although we recognize that this adds not insignificant cognitive load, especially when playing a first-person shooter game with a new sensory feedback environment.

5.1 Participants

We recruited a convenience sampling of six participants, ages 18 to 21. All of the participants considered themselves avid video game players with above average knowledge of computers in general. Four of the participants were computer science majors, one was a sociology major, and one was a biochemistry major. All of the participants were male.

5.2 Method

The testing took place on March 3, 2010, between noon and 15:00 in an empty lounge at UCSC. Participants came in for testing one at a time.

The participants were asked to play *Unreal Tournament* in Deathmatch mode against AI bots. In Deathmatch, there are no teams, and each player fights all other players to the death. Each participant played for 10 minutes on identical maps while DSD was running in the background. The sound was muted during gameplay to simulate the experience of deafness, as we did not have access to a sample of individuals with hearing impairments.

We asked participants to change the three settings provided on our system (color, intensity, and transparency of the sound visualization).

Lastly, few overall questions were asked due to the in-depth feedback given to us by the participants. Questions also varied slightly between participants, as the questions were based on their prior feedback.

5.3 Data

We collected a large amount of qualitative data from the pilot participants. We found that all participants liked the concept of our program, and could imagine useful applications. Most of the participants experienced moments during gameplay where the sound visualization helped them locate enemies. Finally, all participants found the options menu

easy to understand. Specifically, they understood how each of the settings functioned without any additional explanation from the researchers.

However, the following areas were noted to need improvement. First, many participants experienced difficulties distinguishing between pertinent sounds and background noises, such as ambient sounds and music. The degree of background noise varies from game to game. Some games have the ability to turn off music and ambient sounds, while others do not. Possible solutions include integrating DSD into various games or developing some threshold to try and filter irrelevant sounds. The former is extremely impractical, and the latter could create more problems than it solves.

Next, having the program run in one window while playing the game in another window made it difficult for participants to focus simultaneously on both the visualization and the game. The solution would be to have DSD overlay over the game. Such integration was considered during development of the high-fidelity prototype, but cannot be realized due to limitations with Processing. Integration is possible, but it would require a complete rewrite of DSD to a language with greater flexibility.

Finally, some participants commented that they could tell when sound was coming from left or right, but not from above or below. Again, this problem is beyond the scope of DSD, as it uses the audio output of a user's speakers to determine location. Even switching from stereo to surround sound would still treat sound as a plane. The only solution would be better integration with DSD and the various games, which we addressed earlier.

5.4 Results

We found that most hearing pilot participants were able to locate enemies using the DSD system with sound disabled in the game. Moreover, the pilot participants found the most useful visualizations were for preemptive sounds (e.g., footsteps, distant gunshots), but indicated queerness that they no longer heard certain feedback and reactionary sounds. Participants noted that DSD lacked positional awareness for objects above and below the player. In all, participants were pleased with DSD. Positive pilot study results point to a need for further implementation of the system, including transparent background for overlaying, as well as further study of the system, including deaf participants.

6. CONCLUSION

Our system was a proof of concept, demonstrating the utility of Directional Sound Display (DSD). Our initial plan was to provide the player with a visual overlay of reactionary sound, the player could identify enemy units in *Unreal Tournament* from audio cues. However, the implementation environment was unable to generate a transparent overlay, so we used the visualization in a separate window for our user testing. We found that the visualization afforded the player to identify enemy units using the visual cues of pitch, intensity, and direction of sound coming from the video game. The DSD project particularly targeted reactionary sounds, which indicate the location of the enemy or enemies currently attacking the player. We chose reactionary sounds because these sounds are generally the loudest and lowest pitch, making them the easiest to identify with software. However, our system did pick up feedback sounds, placing them in the center of the display (originating from the center

of the player). Preemptive sounds also appeared in our system, but only faintly and when there were no other sounds present.

7. FUTURE WORK

Future work on this project includes greater integration with game settings. One artifact that greatly diminishes the usefulness of the DSD software is sound in a game that does not convey useful information. If the DSD software were able to integrate with popular games and filter their extraneous audio (such as environment sounds for game flavor), it could then provide users with more accurate information about pertinent audio, expanding user control and freedom.

Another useful extension is having DSD run as an overlay to the game being played. We had planned on implementing this feature, but Processing currently has no functionality to force the background transparent for overlaying over other programs. This feature would allow users to have the freedom to play their games in either a windowed or fullscreen mode, and thus would expand on the Usability Principle of Flexibility.

Finally, handheld version of DSD for smartphones with a stereo microphone would provide users with the benefits of the program beyond of the realm of videogames and further expand user control and freedom by removing the requirement of a computer and a virtual space. A handheld DSD device as a audio aid has the potential to have immense impact on the safety of deaf individuals in real-world environments.

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