From the Editor's files

A closely related human sense to sight, hearing can impart tremendous information to the warfighter if it is presented in a 3-dimensional spatial sense in what's called an "audio display". In this Part One of a two-part article, the benefits of using audio information on the battlefield are examined. Next month, Part Two will examine the requirements for effective 3D sound generation in military applications.

Editor.

Part One:
3D Audio Relieves Military Information Overload

An in-depth look at 3D audio and how it can improve military applications by creating "audio displays".

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Today, our military forces must operate complicated multi-modal watch stations, cockpits and vehicles full of sophisticated gadgetry. They must work with an abundance of devices computing and relaying essential bits of information. The key to using these advanced systems at peak efficiency is effective information transmission to the operator. Given the vast quantities of information being presented, it is a wonder that soldiers are able to use only sight and limited audio cues to focus their attention on the important things while successfully completing the task at hand.

Although we receive information through all five senses, visuals, hearing, haptics (feel), smell, and taste, most technologies deliver information visually. Would further improving the already overloaded visual displays help relieve information overload? Even better would be to efficiently utilize more of our senses.

Now Hear This

The most obvious sense to supplement vision is hearing. Even when we communicate daily, our visual and aural senses work together simultaneously. While utilizing audio displays might seem to be a tough challenge, as an analogy, the advent of the computer monitor brought about similar challenges. At first, not only was the display content in its infancy, but we were also not used to viewing all the things we now see on a computer.

Much time and labor was spent generating complicated graphics programs acting as visualization aids. Additional effort was thrown toward making more life-like visuals with graphics that could represent real objects and be interpreted as such. Still, viewing a monitor came naturally because after all, the only requirement was sight!

Similarly, the only requirement for aural displays is hearing. In fact, this transition to hearing information should be a very easy one because aural cues are known as the primary alerting or awareness cues used by the brain to grab the person's attention. In other words, in evolving as a species, we have been trained (it is natural for us) to first hear something and then look in the direction of the sound.

Very basic attempts at implementing audio displays quickly proved that an advanced 3D audio technology would be necessary to process the maximum amount of information. 3D audio *spatially* organizes sound allowing you to process more. If the sounds are not presented in 3D audio, simultaneously occurring sounds will not be discernable and instead will sound scrambled and incoherent (Figure 1).

Previous attempts at developing 3D audio technology to supplement information transmission failed because the technology was either insufficient or too

cumbersome, and hence not deployable (see sidebar: "3D Audio History"). The questions that remain are: What kind of 3D audio is sufficient for maximizing information transmission, and how can the deployable technology be integrated to best serve mission-critical military applications? Part Two of this article will address these technology-specific questions. For now, let's look at the utility brought by 3D audio to mission-critical applications.

Figure 1a

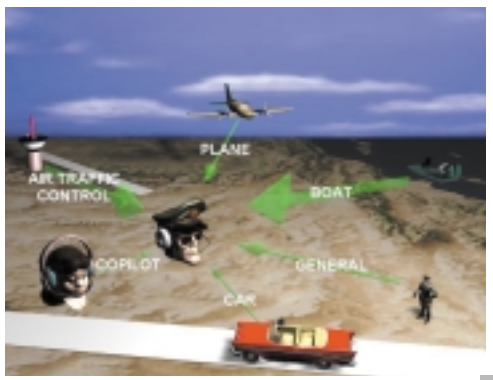

Figure 1b

Without 3D audio, the sounds are indiscernible in Figure 1a. However, Figure 1b shows how 3D audio separates sound spatially to achieve the clarity of accurately positioned sounds.

Benefits

Though often cumbersome and not deployable, high-end research-oriented 3D audio machines offer tremendous value by improving information transmission and processing, while focusing on the military benefits of 3D. Yet, while research continues to find new uses for 3D audio, current technology already provides numerous benefits that more than prove the worthiness in military applications.

3D audio can deliver information without a word: inherent spatial cues can provide listeners with information on direction, distance, intensity, speed and many other metrics. With little training, listeners can learn to associate simple beeps and ticks from particular directions as cues for a variety of events. For example, a beep that sounds for half a second can indicate to a listener that "Special Forces Unit 138 has reached its checkpoint and is continuing on", and the perceived location of that beep in three-space can indicate where that checkpoint is relative to some operational area outlined on a map.

The following are a few of the benefits derived from adding 3D spatial cues to sound, as suggested by researchers from industry, academia and the military:

- Adds realism to simulations
- Faster response time—more natural reactions
- Improved aural perception and comprehension
- Increased situational awareness
- Perceptual reinforcement
- Reduced fatigue
- Increased information capacity
- Reduced manning
- Fewer critical and costly human errors

Audio "Display" Applications

There are many settings where communication between numerous military personnel is required. Accurate 3D audio can facilitate these communications by enabling the sounds of many different peoples' voices to be distinguished directionally instead of competing and causing confusion. This spatial orientation is particularly useful in mission-critical communication systems such as those used in advanced command and control centers, fully duplex field radio systems (for mounted and dismounted soldiers), and dispatch centers (Figure 2). Additionally, teleconferences and all wireless or wired communication transactions can benefit in the same way from 3D audio.

This feature of independent discrimination and sound localization can be used to better process multiple non-human sound sources as well. There are many types of data that can be sonified, or made audible, and transmitted through the aural display to military personnel. Some examples are: warnings such as low fuel, gauges such as altimeters, engine RPMs (something that some of us are used to hearing/listening for already), ally and enemy locations (mapping radar type information to sound beacons), target tracking systems and many attention-alerting devices.

For example, coupled with voice recognition and synthesis technology, soldiers could simply ask for various bits of information to be voiced in the 3D audio "display" without losing focus on enemy troop movements being presented as audible beacons. That information could be command orders, the weather forecast, the status of an ally troop, or details on the mission. Using the same technology, civilians can obtain information such as the time or news, stock quotes, phone messages and even calendar or appointment data relayed to them by a virtual assistant.

Mission-Critical and Wearable

In mission-critical military applications, non-human and human inputs must be processed simultaneously. A perfect example of this is in an aircraft cockpit. Aural location and information organization systems can help not only with localizing communication transmissions of surrounding planes and air traffic controllers but also with the sonification of various instruments and warnings. For example, in today's complicated cockpits with a multitude of illuminated blinking knobs and various LCDs flashing information, 3D audio can direct the attention of the pilot to the critical low fuel warning buzzing in the lower left corner of the central instrument panel—right where the pilot perceives the sound as coming from.

Down in the tower, air traffic controllers can perform their jobs more efficiently if the sound of communicating planes actually emanates from the relative direction indicated on their radar screen or the actual direction in the air

3D Audio History

The concept of 3D audio has existed for sometime, but only recently has modern computing technology enabled the real-time processing needed to deliver 3D in mission-critical applications. The first major real-time use came when NASA wanted the technology for astronaut communications. A space-walking astronaut out repairing a satellite needed to be in constant communication with many different information-providing support personnel. Because 3D audio allows sounds to be perceived as emanating from different locations, it was considered to be the gemstone for enabling less confusing simultaneous communications between the astronaut, the researcher in-lab with the satellite manual, mission control and the crew inside the shuttle. In that case, speakers appeared to be heard at different locations, allowing the astronaut easy in-context understanding of who was speaking.

Around this same time, many different sound-processing technologies began to emerge calling themselves "3D audio." Large software companies began developing their very own simplified "3D audio" just for the sake of throwing the buzzword into their products. The vast differences in these technologies, however, led to much confusion about the actual capabilities delivered. In an effort to differentiate themselves from one another, the various technologies were sold under different catchy names including positional, direct, localized, spatialized and surround sound/audio.

Over the next few years, video gamers became aware of the technology and their demand set the stage for the first mass-market adoption of "3D audio." Game makers latched onto technologies that were simple, quick, easy and computationally cheap for providing an effect that could present the illusion of 3D audio. As there was and still is no comprehensive system for rating various 3D audio, the game makers were also heavily influenced by manufacturers' reputations and the cost. The technologies they chose turned out to be highly imprecise and not interactive like the 3D audio developed for NASA. Unlike gaming, precision and interactivity, along with good versatility, are required in mission-critical applications such as life-critical communications, air traffic control, training simulators, cockpit systems and other military applications.

But even while "3D audio" designed for gaming had taken the consumer spotlight, advanced technologies were evolving from the earlier more precise and interactive NASA 3D audio. Unfortunately, when military application developers attempted to incorporate COTS 3D audio technology, they too borrowed the well known but inferior "3D audio" from the gaming industries. Even using higher-end gaming audio, military designers often ran into difficulties because the systems were inflexible, very expensive, difficult to use and too voluminous (not easily deployable). Ideally, there will emerge a systematic approach to distinguish these various 3D audio technologies: and yet while a rating system for 3D audio would be technically challenging to devise, it is possible and may surface in the future.

Recent advances in high-end 3D audio have overcome the major problems of minimal versatility, inability to scale, large size and the enormous costs that plagued early systems. Unfortunately, the reputation formed from these early modified gaming systems with not-so-great qualities has led to skepticism that has scarred the general image of 3D audio. Therefore, many military application developers have been reluctant to adopt the more advanced 3D audio technology that is now ready for its own mass-market military debut. With new 3D audio differentiated from gaming technologies and designed for military use, mission-critical application developers are strongly encouraged to re-evaluate the technology.

space surrounding the controller. This way, the air traffic controller does not need to spend time retrieving location information and visually locating the transmitted coordinates. In a similar fashion, the communication transmissions of fellow controllers in the same room can be presented to correlate spatially with their physical location.

Since 3D audio is optimally delivered using headphones, it can service applications well beyond the stationary environment and is perfect for integration with most mobile or wearable technologies. The technology can easily service vehicles—cars, planes and boats—with active driver assistance (including beacons) and warning cues. Taking this one step further, the technology can be used to enhance remote operations of everything from troops to vehicles. Instead of simple remote control cars and robots with video cameras, 3D audio enables operators to not only see but also *hear* the environment surrounding the vehicle.

Land Warrior

An in-depth look at a perfect wearable application for 3D audio, the networked US Army Land Warrior, reveals incredible utility. The technology can provide the ultimate means for communication and information display anywhere on the battlefield. First and foremost, 3D audio provides the necessary information display mechanism when soldiers put on protective hearing gear, a necessity often looked down upon. Hearing protection is, however, the armor for ears that enables soldiers to continue to fully participate throughout a battle.

As any combat soldier will testify, without hearing protection, after the first shot is fired, they might as well be deaf. Combining 3D audio with recently available noise-clipping ear buds enables soldiers to hear not only the surrounding environment normally under non-fire situations, but can drastically attenuate the deafening sounds of close fire while adding piped-in information through the 3D audio system. This is effectively an augmented hearing environment.

The utility of this system is best illustrated by taking a close look at a battlefield scenario where the soldier has such vital information as troop positions, and

(Courtesy of Robert Hamburger, ICE lab, Dahlgren, VA, NSWC; http://www.manningaffordability.com.)

Figure 2
In this multi-modal watch station, 3D audio is used to organize incoming communications and quickly alert or direct the operator's attention to different locations on any of the four monitors.

potentially, enemy locations available to him or her. Communication and display of this information between all allies is very important; 3D audio can be there to give the soldiers an unequivocal advantage. That's because the land warrior can hear and locate the communication transmissions of fellow soldiers and sounds throughout a battle.

In fact, 3D audio displays enable a soldier to interpret the location of an officer who is one hundred yards away and whispering commands over the communication network, even if the officer cannot be seen due to obstruction or darkness. The "silent" location cues embedded in 3D sounds heard by the soldiers eliminate the need to always relay position information or look into a heads-up display to get the information. "Friendlies" can be quickly determined by a quick whisper in a particular direction. Cries for help from fellow soldiers will immediately alert other networked soldiers as to the whereabouts of the crisis.

What's Next

Although audio provides an excellent supplement to visual information, by itself it's not nearly enough. Without 3D audio technology, simultaneously occurring sounds will not be discernable and instead will sound scrambled and incoherent. The possibilities for military use are endless. In fact, 3D audio not only helps relieve information overload but also should be considered as the ultimate "display" for myriad information. The end result will be to increase overall operational performance.

In Part Two of this article, the specific features of 3D audio needed to achieve military benefits described will be discussed. By taking advantage of high quality 3D audio technology, the military will improve communication systems in air traffic control towers, mobile dismounted infantry, simulation-based training systems and cockpit/vehicle operator information displays. ■■

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