Sense: an electroacoustic composition for surround sound and tactile transducers

Panayiotis Kokoras
University of North Texas
panayiotis.kokoras@unt.edu

ABSTRACT

This paper describes the construction of a system for tactile sound using tactile transducers and explores the compositional potential for a system of these characteristics. It provides a short overview of the technologies involved and the composition methods and studio techniques developed to implement this project. *Sense* for fourteen discrete channels includes a surround 5.1-sound composition, the development of a six-channel tactile transducers system and the demonstration of the compositional methodology used in the piece. The purpose of the project was to create a holistic listening experience where the audible listening experience is combined with the tactile experiences ultra and infrasound.

1. INTRODUCTION TO TACTILE SOUND

When a classical guitar player plays the guitar besides the strings vibrates the whole body of the guitar. Those vibrations are also sensed via the body of the performer in the form of vibrotactile stimuli. As the performer plays the guitar, he or she feels the vibrations through the chest, foot, fingers and sometimes through the jaw or zygomatic bone when one leans his or her head on the top of the guitar side. The last posture is not part of the standard classical guitar technique, but guitarists, including myself, have done that while practicing. Most of the instrumental players will have a similar experience, depending on the acoustic and physical characteristics of the instruments they play.

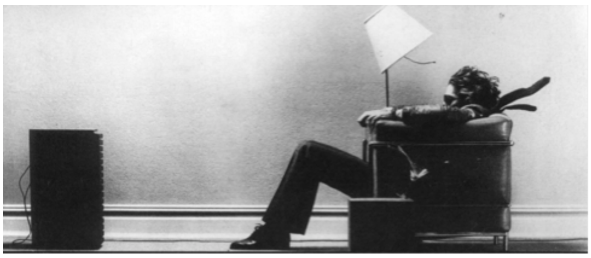

Figure 1. Photograph by Steven Steigman (1978), known as the Blown-away Man, for a Hitachi Maxell ad. The ad shows a man being blown back by the tremendous sound from the speakers in front of him. The photo was instantly a hit; it was a powerful statement that sound has power and force you can feel.

However, what a performer experiences during his or her recital is something totally different from what the audiences perceives because the only channel of communication between the sound of the guitar and the audience is their ears. In other words, they are missing all the tactility of the sound, which is not possible to transmit via air.
How can one provide the same level of experience to the listener? Is it possible for a composer to use tactile sound as a compositional tool?

2. PRESENTATION OF SENSE

According to Leman [6], music experience engages all the senses to varying degrees. In *Sense* the aim is to explore the use of tactile vibrations as an extension and counterpart to the music. The project demonstrates a synesthetic experience in which the listener, on one hand, can hear the sound, and, on the other hand, can feel it through the body. We are surrounded by natural and mechanical sounds that we are unable to hear due to their extreme frequencies, beyond our perceptual capabilities. In humans, the audible range of frequencies is usually 20 to 20,000 Hz. An elephant is capable of hearing sound waves well below the human hearing limitation, between 10 and 35 Hertz and dolphins can go as high as 150KHz. The far-reaching use of low-pressure infrasound and high-pressure ultrasound opens their spatial experience far beyond our limited capabilities. Ornithologists or seismologist often transpose the signal to the audible range for further research. [1]

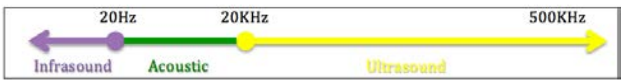

Figure 2. Acoustic frequencies transmitted through air

The *Sense* project proposes the conversion of these extreme frequencies into tactile stimuli received from the body. Interfaces that deliver sound energy, motion and vibration directly to our bodies have been developed recently for 4D theater movies. [10] However, this approach aims to enhance the existing audible sound and to make it more impressive. In *Sense*, the tactile stimuli are specifically composed in a musical context and aligned, or not, with the audible part extending our listening experience far beyond our traditional confines. As a result, inaudible soundscapes are revealed that have not been heard before, let alone, in a musical context. As a result, the listening experience is a composition of both audible musical sounds as well as structured tactile energy, feeling direct throughout the body.

For this novice compositional approach, there is very limited literature investigating compositional techniques aimed to support the functional integration of tactile stimuli with audio in a musical context. [11] In the piece, I have developed compositional strategies and audio manipulation tools through a composed score. Thus, I was able to control and integrate into the work infrasound and ultrasound material. Both of them were converted into tactile stimuli in a coherent and functional way that were contributed musically and equally to the audible part of the composition. For instance, a soft resonant midrange drone was combined with soft accelerating tactile vibrations, or a highly rhythmical audible phrase was combined with air-born ultrasound tactile sensation of centrifugal motion that was the structural vehicle to move the piece to the next section.

Figure 3. A visitor listens *Sense* on an early prototype of the chair at the Perot Museum in Dallas, Texas.

In order to test and explore the above compositional concepts, I have developed a simple interface with emphasis to tactile properties of the sound. This interface integrates into a customized chair with various types of tactile linear actuators[1] and transducers. Especially for the very high frequencies, above the human hearing range, I use a number of ultrasonic transducers. They generate a strong pressure field that can be sensed by the skin as tactile vibrations. The pressure field resembles the frequency structure and rhythmic characteristics of a part of the composition that is not audible otherwise. Ciglar [1] says, "…the hypersonic audio signal is directly mapped onto the tactile domain. As a consequence of soundwave propagation through air, an interesting side effect occurs."

3. THE FIVE PATHWAYS TO PERCEIVING SOUND

In addition to the sound perception through our ears, experiments by Bolanowski [2] have identified four channels that mediate tactile (mechanoreceptive) sensation. The four channels work in conjunction at threshold to create an operating range for the perception of vibration that extends from at least 0.4 to greater than 500 Hz. The four main sensation mechanisms are:

[1] Through the Cochlea via bone conduction
[2] Through the skin via tactile sound reception
[3] Through the deep tissue via movement
[4] Through the skeletal joints via movement

For each of the four different paths, a particular transducer has been used at a specific frequency range. The range of the classification and function of the cutaneous mechanoreceptors is described by Bolanowski, [2] Weinstein [12] and Wilska [13].

Pathway	**Transducer Type**	**Range**	**Sense**
Through the Cochlea via bone conduction	Cochlear Tranducer	Audible range	Conductance
Through the skin via tactile sound reception	Ultrasonic Tranducer	Inaudible range	Touch
Through the deep tissue via movement	Tactile Sound Transducers	In/Audible, Infrasonic	Kinesthetic
Through the skeletal joints via movement	Tactile Sound Actuators	Inaudible range	Haptic
Through the ears via air-transmission	5.1 Speakers or stereo headphone reduced version	Audible range	Hearing

Table 1. The table above shows the five pathways to perceiving sound, the type of transducer implemented in each case for the *Sense* project, the frequency range and the sense involved.

According to Weinstein [12], the sensitivity of tactile perception on our body differs significantly depending on the location. Other parameters that affect the sensitivity are the sex and the temperature.

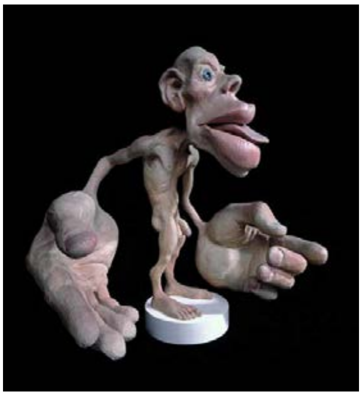

Figure 4. Wilder Penfield's Sensory homunculus.

The figure above shows what a man's body would look like by visualizing the proportional sensory perception mapping of the body surfaces in the brain.

[1] Linear actuators are piston-like electromagnetic devices that transmit motion in a direct fashion rather than transferring vibrations.

4. TOWARDS A HOLISTIC LISTENING EXPERIENCE

The customized chair consists of one tactile actuator transducer in the front and one in the back, one tactile transducer on the seat and one at the back, one ultrasonic transmitter for the left palm and one for the right, respectively. In addition, there is a 5.1 system that surrounds the chair and a pair of cochlear headphones. The cochlear headphones transmit the sound through bone conduction directly to the inner ear. For the headphones audio, a stereo reduction of the 5.1 versions has been realized.

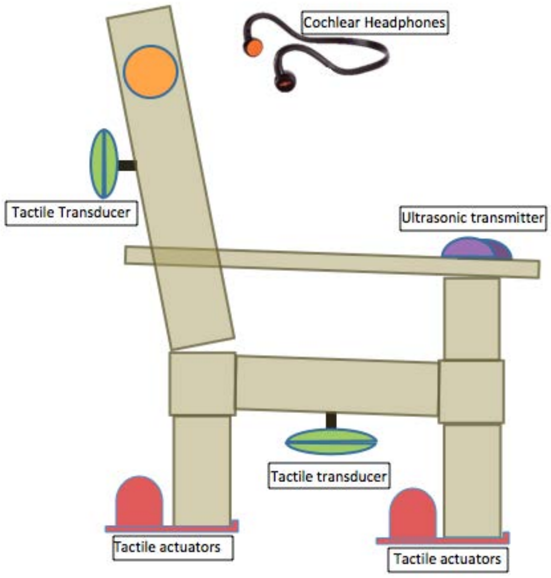

Figure 5. Illustration of the chair and the placement of the tactile actuators and transmitters.

All of the transducers were purchased from specialized shops except the ultrasonic transducer that I was unable to find a commercial one. As a result, I implemented my own using eighty ultrasound transducers arranged on a parabolic dish surface following the paradigms of Ciglar [3] and Hoshi [5]. The acoustic energy of all of the transducers was focused at the center of the dish, about 10 inches high. The beam was sensed as a tactile sensation of the sound waves via the skin of the palm and the fingers.

4.1 Software

For demonstration purposes only, I have developed a reduced version, which displays the audible sounds separately in the middle of the figure below, shows the ultrasonic sounds at the top, and mixes together the infrasonic soundtracks at the bottom.

Part of the goal was to use only audio signal to compose and control the piece. Thus, the whole project has been developed using a standard DAW at 192kHz-sampling rate and 24-bit depth. The first six tracks used only the human frequency range. The Cochlear 1 and 2 channels used a stereo reduction of the 5.1, covering the same frequency range but projected by the cochlear headphones and sensed via bone conduction.

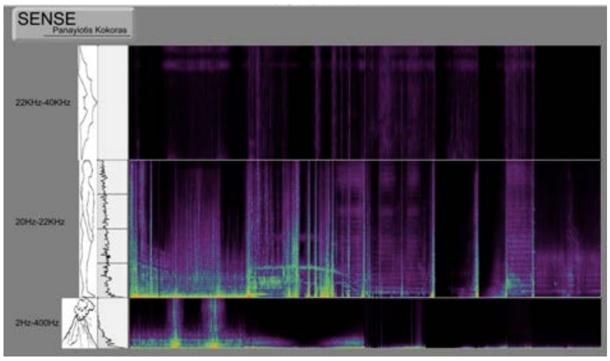

Figure 6. Max6 patch implementation of the three different sound ranges: infrasound, audible sound and ultrasound.

Both of the pathways play the same music. The advantage of this system is that it provides more depth to the listening experience because the listener hears at the same time via bone conduction and air transmission.

Figure 7. DAW track arrangement for *Sense*

The other two tracks (ultrasound) drive the two custom-made Ultrasound transducers. The audio material is specially composed to deliver tactile sensation to the palms of the listener. The output of the tracks routed to an amplitude modulation effect with center frequency at 40kHz [3]. That step was necessary to make possible the tactile sensation on the palms from the ultrasonic transducer. The rest, four tracks, were playing frequencies below 20Hz or up to 500Hz in some cases. Similarly, the tracks were specially composed not to be heard but to be felt as tactile vibrations.

5. CONCLUSIONS

The aim of *Sense* project was firstly to develop an environment where the listener will have a similar experience as a performer. Secondly, I investigated different compositional strategies to inform the listener's brain using all the sensory paths that enable us to feel the sound. A detailed technical and compositional analysis of the techniques and technologies used in the project is out of the scope of this paper.

Potential uses of the project may include experiments with deaf or hearing-impaired individuals, setups for immersive sonic environments like sound installation, video game, and experimental intermedia artworks.

Finally, another development of the project is the use of the chair and ultrasonic and infrasonic specialized microphones to playback the ultra/ infrasound around us converted to tactile stimuli. This way one can truly experience the soundscape in its true full range.

6. REFERENCES

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