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"Space Explorations"

Broadening binaural horizons with directionally-matched binaural impulse response convolution reverb

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ABSTRACT

More people are listening with earphones than in the history of recorded music. But earphones locate typical audio claustrophobically in-and-around the listener's head due to an absence of localizing information the brain requires to externalize sound. When combined with recent trends to highly compress music, the results are an unnatural and unhealthy listening experience—a dumbing-down of the auditory faculty. But the rise of earphones has also brought binaural technology onto the radar. While most binaural music productions have been limited to capturing live performances within a single space, the pioneering application of directional binaural impulse response convolution reverb paired with directionally-matched binaural studio recordings restores acoustically diverse spatialization to music.

1. INTRODUCTION

1.1. The Sound of Space

Today, more people listen on earphones than in the history of recorded music. Deemed for decades as too niche for its reliance on earphones, binaural recording is gaining acceptance due to the unprecedented dominance of earphones, and is becoming a cornerstone of the immersive audio field.

Binaural audio also presents a solution for a growing hazard.

Our environment is becoming ever more infiltrated with noise—from traffic, relentless advertising, unsolicited background music, etc.—causing people to put on earphones and tune out the noise.

But overly compressed stereo music delivered without spatial quality (aka non-binaural over earphones) is also an assault on the sense of hearing. Collectively, we are training the brain to disregard environmental noise and the absence of space, resulting in a daily dumbing-down of the auditory faculty.

1.2. Transcending Transaural

In the 1990s, binaural research led to transaural processing which provided the simulation of binaural sound deliverable on home stereo speakers via phase manipulation. Roland's RSS System, QSound, and Desper's Pro Spatializer among others, significantly enabled the expansion of the stereo sound field.

Supported by the National Research Council of Canada, and Lon Neumann of Sony's SACD Hollywood division, we pioneered research at Bryan Adams' Warehouse Studio in Vancouver, B.C., applying transaural processing to 5.1 surround music production.

The results yielded greater immersion through the transaural expansion of the left-right sound stage in both the front and rear stereo channels.

1.3. New Technologies, New Opportunities

Just as the phantom center channel was discovered when audio evolved from mono to stereo, so too can we now seek out opportunities to evolve binaural recording to a higher level.

Binaural recording, the godfather of transaural processing, is a far more effective format for immersive audio (on earphones), and if adopted as a viable music production format, provides an opportunity to advance immersive sound while restoring a sense of space to recorded music.

2. EXPLORING BINAURAL BOUNDARIES

For those working in binaural, there is always a struggle between what we think should be possible, and what is actually effective.

Psycho-acoustic factors limit what is achievable. But other limitations are self-imposed by the notion that binaural recording is only useful for recording live performances. It is as if the binaural microphone were perceived as an old analog camera only capable of photographing a moment in time.

Binaural does excel at capturing the characteristics of an acoustic space hosting a performance with excellent—and sometimes startling—accuracy. But how can this attribute be exploited so that different spaces can be applied in varying degrees to different instruments within a binaural mix, just as we do with typical studio reverb?

To address this question, research commenced—first with DIY dummy heads equipped with DPA 4060 mics, then the Kemar binaural system, and finally (and most successfully) the Neumann KU-100 microphone—to record binaural sounds and spaces separately.

3. SPACE ADVENTURES

3.1. Binaural Convolution Reverb

Convolution reverb is usually created by recording a sweep tone—a tone played back through a loudspeaker, which gradually increases through the range of audible frequencies from 20Hz to 20kHz—within a reverberant environment such as a church or concert hall.

Software is then used to compare the original sweep tone with the recorded result to extrapolate the differences. This is contained in an Impulse Response (IR) file that can then be applied to any sound recording, effectively inflicting the reverberant characteristics of the space where the sweep tone was recorded.

The concept of recording a sweep tone using a binaural microphone is not new, but audio examples of binaural IR convolution reverb are not readily available (nor are binaural IR files).

More interestingly, there seem to be no recordings of binaural convolution reverb applied to binaural sound recordings.

My initial research set out to prove or disprove the effectiveness of binaural convolution reverb itself. Does an impulse response extrapolated from a binaurally recorded sweep tone actually yield binaural convolution reverb? And if so, does binaural convolution reverb effectively enhance and expand a binaural sound field?

3.2. Dissecting the Digilog Impulse Response

The first test occurred in a basement in Taipei, Taiwan, beneath an analogue synthesizer store called Digilog. The basement measures 16 square meters, with floor, walls and ceiling fully tiled, and is nearly square, possessing a surprisingly long reverb time of 7 seconds.

The first binaural impulse responses definitely yielded a positive result. When applied to a binaural studio recording of a Yamaha C7 grand piano, the results proved more spacious than the original piano recording.

Tests were posted to YouTube, and feedback was very positive. People affirmed the piano sounded extremely spacious and pleasing. The director of the Music Business Program at Hofstra University declared this work “absolutely groundbreaking,” recording studios praised the piano recordings as the most natural they'd heard, and students of audio engineering schools emailed to say their curriculum was incorporating the videos as the “best demonstrations of binaural recording available.”

But in my critical review, it was difficult to confirm whether the Digilog convolution reverb was truly binaural. The definitive “out of head” experience binaural offers was not precise, possibly due to the overwhelming character of the Digilog reverb.

Binaural live recordings were made in the basement of Digilog and compared to binaural studio recordings with the Digilog binaural convolution reverb applied.

This confirmed that there was no less binaural effect in the convolution reverb applied to the studio recordings, as there was in actual binaural basement recordings.

3.3. Finding Religion

Because the Digilog space was acoustically overwhelming, I felt more tests were needed. These commenced at Holy Family Catholic Church in Taipei, Taiwan; and at Saint John the Divine, Saint Andrew's Cathedral, and Christ Church Cathedral in Victoria, BC, Canada.

These impulse responses all yielded greater acoustic complexity and clarity, and the resulting reverb seemed to lift the roof over the listeners' head when directly compared to non-binaural convolution and algorithmic reverb (even when applied to non-binaural sound recordings). Binaural music recordings blossomed naturally and dramatically into the larger spaces.

When non-binaural convolution reverb was substituted, binaural music recordings seemed to collapse inward, while the binaural convolution reverb succeeded in adding reverberance to binaural recordings while preventing the collapse of the binaural sound field.

With satisfactory confirmation that binaural convolution reverb was effective and “out of head,” my research advanced to another level.

4. MATCHING DIRECTIONAL BINAURAL IMPULSE RESPONSES TO DIRECTIONAL BINAURAL RECORDINGS

4.1. Showdown At High Noon

Convolution reverb is essentially a virtual echo chamber. When recording a sweep tone, the microphone's position is where you'd want the listener to be positioned within an acoustic space, while the speaker position broadcasting the sweep tone is where you'd like the performer to be projecting from, within that space.

Positioning the speaker directly in front of the microphone—at the 12 o'clock position (aka the center panned position)—is standard for capturing stereo impulse responses.

But when considering the binaural overdubbing of musicians separately from the application of reverb, it seemed probable that the binaural reverb effect would be optimized if the IRs were captured one by one, from speaker positions placed in locations similar to those where studio musicians would be positioned around a studio binaural microphone.

For example, studio musicians would likely occupy positions at 9 o'clock, 10:30, 12 o'clock, 1:30, and 3 o'clock around the binaural microphone (rear positions are excluded here for the simplicity of explanation).

If those musicians were actually performing live around the listener within a reverberant space, each performer would trigger a different reverberant character within the space—their reverberance would initiate from different locations around the listener and would bloom differently.

If studio musicians were each occupying a different position around the binaural microphone, and all were sent to a single 12 o'clock binaural impulse response convolution reverb (as 12 o'clock is typically the only position captured for convolution reverb), it would surely restrict the complexity of the musicians' combined reverb as perceived within the simulated space. It could also preclude the brain's ability to extrapolate directional cues needed to sustain a binaural sound field.

To explore this concern, experimentation began by recording sweep tones at 9 o'clock, 10:30, 12 o'clock, 1:30, and 3 o'clock. These directional binaural impulse responses were applied to studio recordings captured at matching positions around the binaural microphone.

4.2. Realism In The Results

Sending binaural studio recordings to their directionally-matched binaural impulse responses yielded more lifelike results.

For example, if a 9 o'clock studio recording is sent to a 12 o'clock binaural impulse response convolution reverb, it sounded better (and more “out of head”) than if sent to a non-binaural reverb.

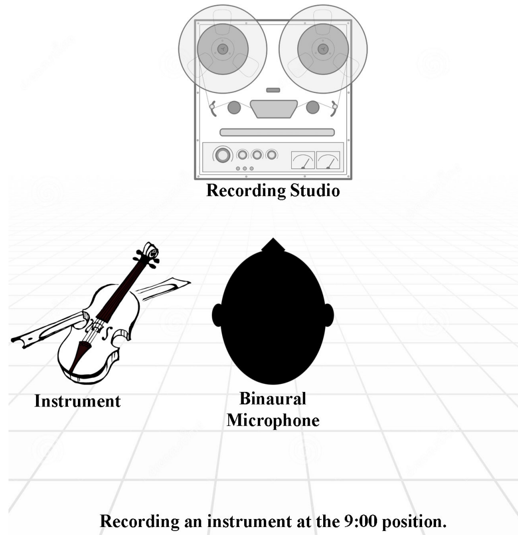

Figure 1. Recording an instrument at the 9 o'clock position, in relation to the binaural microphone.

But sending a 9 o'clock recording (shown in Figure 1) to a matching 9 o'clock directional binaural impulse response convolution reverb (shown in Figure 2) felt more realistic, and the reverb more glued to its source.

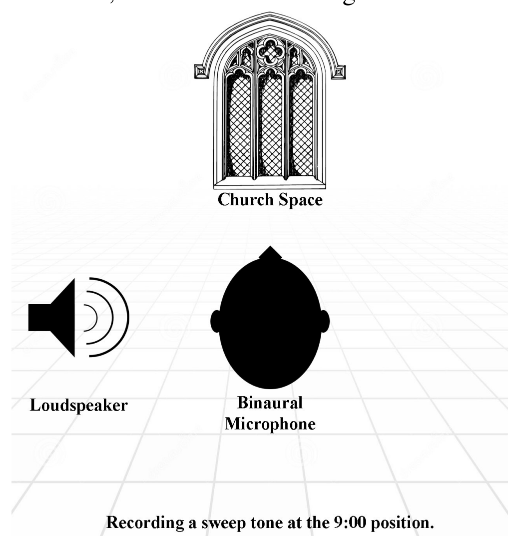

Figure 2. Recording a directional impulse response at the 9 o'clock position, in relation to the binaural microphone.

And finally, when mixing multiple overdubbed studio recordings, each paired to a directionally-matched binaural IR, there was greater clarity, cohesiveness, complexity and realism.

5. DIFFERENT FACES, DIFFERENT SPACES

Having confirmed that directionally matched binaural impulse response convolution reverb was effective in enhancing overdubbed binaural studio recordings, the door was opened to more possibilities for sculpting sound in binaural space.

For example, binaural IRs from different spaces could now be used within a mix. For example, IR's recorded at 10:30 and 1:30 in a large reverberant space could be applied to violins positioned at 10:30 and 1:30 in the studio; while 9:00, 12:00 and 3:00 IRs from an intimate space could be applied to vocals recorded at 9:00, 12:00 and 3:00 in the studio.

This positive conclusion and subsequent possibilities seem to be an element that's been missing from binaural music production. Binaural no longer needs to be confined to live performances in a single space.

In recognition of these results, directional binaural impulse libraries are being recorded at Stift Kremsmünster, Stift Admont, St. Florian Monastery, Wallfahrtskirche Frauenberg, and the Mariazell Basilica in Austria; St. Martin's Church in Canterbury (the first Christian church ever built in England in the 6th century); and Abbey du Thoronet in the south of France.

6. CONCLUSION

The ability to apply detailed and layered degrees of binaural reverb lifts binaural music production to a level comparable to typical studio music production, because greater control of a mix is achievable when instruments can be recorded without reverb. In this context, compression, EQ, pitch correction, etc., plus an endless selection of directionally-matched binaural reverbs, can all be applied individually to elements within the binaural mix.

With a growing embrace of binaural technology in music production, the exploration of space is sure to continue.

7. ACKNOWLEDGMENTS

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8. REFERENCES

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[2] To view the video showing the original IR recording session, see here: http://youtu.be/bmOvHjSBlnc

[3] Capturing the 3D Sonic Fingerprints Victoria's Sacred Spaces - Capturing sonic fingerprints (impulse responses) in three of Victoria, BC's greatest acoustic spaces, using 3D (binaural) recording equipment, with the final result demonstrated in the end of this video. https://youtu.be/Be9u-8oP30E?list=PL2rZHduA-UHjIO3AXBeCsUCk4FwXJvp8r