# *REMNANT*: EXPLORING PRESENCE AND ABSENCE THROUGH ACOUSTIC DISTURBANCES IN SPACE PROCEEDINGS, ICMC 2019

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## ABSTRACT

*We describe* remnant*, a sound installation and a live electronic music piece, along with its realization. In* remnant *we explore presence and absence by revealing the acoustic disturbances caused in an interior space when bodies occupy it. Through sound alone, we can sense the presence of others by the subtle changes their bodies make to the environment. In this work, we use those sonic disturbances to make an oblique statement of presence and absence, making the absent bodies themselves audible as acoustic reflections and shadows. To simulate the process by which sound is scattered off the bodies of the musicians, we design a novel measurement setup, also described here.*

## 1. INTRODUCTION

As musicians, we know that the presence of an audience can affect the acoustics of a concert hall, because any sound propagating through the air scatters off the bodies of everyone within hearing range as it travels from the source to the listener. If, for example, the absorption of the audience's clothes is greater than that of the seats they shadow, the overall liveness of the hall decreases.

We also hear the directionality of acoustical disturbances, as when we sense, sometimes consciously, the presence of a person or other body in our vicinity, not by their own sounds, but by their reflection of the ambient sounds that we depend on to hear the geometry of our surroundings. In the absence of ambient sound, we can't hear the space we're in, and this is perhaps part of why it is so disorienting to be in an anechoic chamber. One even hears the scattering of ambient sound by one's own torso, which is why binaural recording systems usually include not only a head but an upper torso to recreate this scattering; otherwise the listener might hear the unreality of listening without their own torso present.

Of interest to us here will be the audible presence of musicians' bodies, considered as part of the overall sound of a musical performance. Whenever a musician plays, we hear not only the incident sound radiated from the instrument, but also the sound of the instrument as it is scattered off the musician's body. If more than one musician is present, we also hear the sound of each instrument scattered off the bodies of each of the other musicians as well.



Although it's known that, under optimal conditions at least, the musicians can detect the presence of each other's bodies acoustically, as far as we know nobody has tried to isolate this scattering from the incident sound so as to elevate it to manipulable musical material in its own right. The research and musical experiment described here takes this idea as its premise.

The catalyst for this work was a residency offered by ensemble mise-en, which offers a unique opportunity to produce new works of sound art in the context of a professional new-music ensemble. As we understand it, most takers of this residency work purely in the sound art domain, but the availability of top-notch and highly committed musicians encouraged us to make something that could function as a concert piece for four musicians, as well as a sound installation.

In either situation, several (preferably at least eight) loudspeakers play a non-deterministic sequence of short recordings of individual instrumental fragments. Each fragment is pre-recorded in six channels, organized as three stereo pairs. One such pair is chosen. Instead of playing the recording directly, its reflection off one of the other musicians is simulated using a procedure described below. The simulated reflections vary depending on the position of the reflecting musician and the directionality of the reflection itself, as if the reflection itself were recorded in the room with a second, variable microphone pair. Finally, a choice is made of two speakers in the real space where the reflection will re-emerge.

Each of the four instrumental parts is treated in this way independently, with silences separating the playback of the various phrases, so that sometimes two or three playbacks overlap, and sometimes a phrase is heard in isolation. Each phrase is thus heard from a different speaker pair, as it was recorded from a different direction of reflection from a different microphone pair, off a musician moving along a path. The result is highly figurative. Even though we never hear these reflections in isolation (without the incident sound also present and presumably much louder than the reflections), we do not get a plausible reconstruction of a real acoustical situation but rather a poetic re-imagining of a tapestry of wandering, shadowy sounds.

## 2. ANTECEDENTS AND MOTIVATION

Through a lifetime of listening to speaker-mediated music and sound, we all become quite unconscious of the strangeness of hearing someone's voice or a musical instrument when, in fact, the person is not present in the room. This is brought to the fore quite beautifully in Janet

Cardiff's *Forty-Voice Motet*[1], for example, in which the act of listening to a choir is defamiliarized by substituting a loudspeaker, mounted at head height, for each individual singer. In a different vein, a famous piece of computer music, Charles Dodge's *Any Resemblance is Purely Coincidental*[2], brings the ghost-voice of Enrico Caruso to the stage in a sort of seance. Here we make a similarly touching but more oblique statement of presence and absence by literally making the absent bodies themselves audible as acoustic reflections and shadows.

The consequences of working with these types of phenomena and sounds also resonate with artists such as Florian Hecker[3], who uses psychoacoustic phenomena to create new spaces. In his work the originating sonic material is synthesized electronically for carefully controlled auditory illusions. Similarly, Rolf Julius[4]'s "small sounds" require listeners to attend to very quiet stimuli. It is this attention that our piece seeks to engender, but with the added dimension of presenting people who are absent.

## 3. MEASURING SCATTERING BEHAVIOR

We wish to measure, in the form of impulse responses, the way a body scatters incident sounds. This scattering depends both on the direction of incidence and that of the scattered sound (and also on distance). To measure the impulse responses we place a loudspeaker and one or more microphones in the acoustic space. (For the moment, we neglect the acoustical properties of the space itself but this will be important later.) As shown in Figure 1, scattering in directions different from that of the incident sound can be thought of as reflections, and are sometimes plainly audible depending on the reflecting body. More subtly, in directions close to that of the incident sound, the scattered sound interferes with it to make an acoustic shadow. This shadow is most pronounced close to the scattering object, and, because sound at higher frequencies is less prone to diffraction than at low ones, the shadow is most pronounced at high frequencies. The scattering signal itself may sometimes emphasize high frequencies more than lower ones.

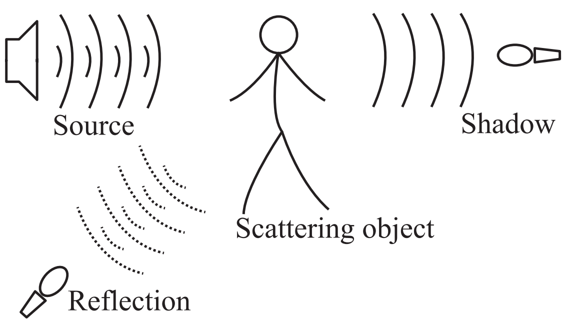


**Figure 1**. Scattering of an incident sound off a body. Sound scattered back toward the source can be thought of as a reflection, and sound traveling in the same direction interferes with the incident sound to make a shadow.

In a real situation the acoustical environment affects the measurement, because the microphone picks up not only the scattered sound itself but the acoustical space's response to it. This situation is depicted in Figure 2. The signal picked up by the microphone not only reflects the position of the scattering body but also the room's response to sound radiating from that position. If several microphones are present, each picks up this scattering behavior from its own location differently, allowing us to compute the scattering and its room response from multiple points of view.

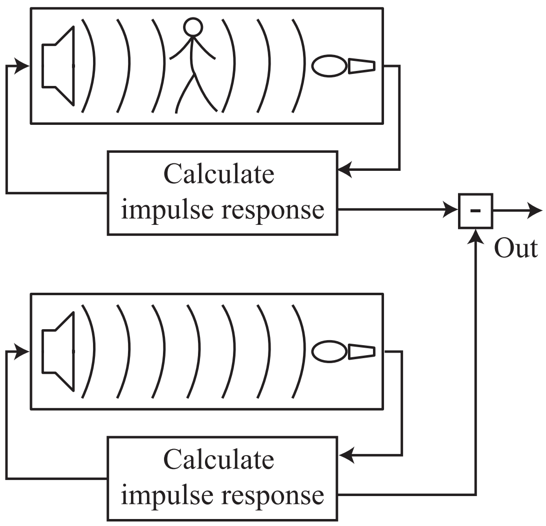


**Figure 2**. Computing the contribution of a body to scattering in a room. This measures not only scattering of the body itself, but also the room's response to the scattering.

In our case, the acoustical space was `MISE-EN_PLACE`, a large and comfortable gallery space provided by ensemble mise-en. We decided to obtain scattering impulse responses from each of four musicians who would also provide the musical sounds used in the installation and perform in the live piece. Since we wished to obtain the scattering responses taken from a variety of physical locations, each musician was asked to move along a path through the space, at each point of which we would obtain a new response. The recording setup is as shown in Figure 3.

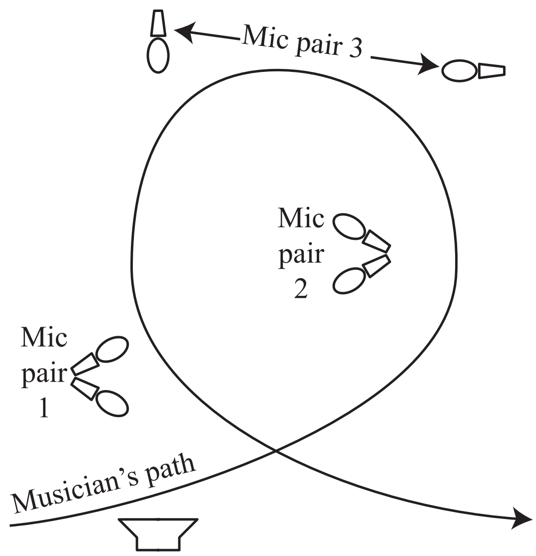


**Figure 3**. A recording setup to measure scattering by a musician, as they move through the space, and as picked up by three microphone pairs.

Originally we had planned for the instruments themselves, as well as the musicians, to be part of the measured impulse responses; but for various reasons we ended up with two non-portable instruments (piano and percussion) and dropped this idea in favor of allowing the musicians to be measured from more than one physical location.

## 4. IMPULSE RESPONSE MEASUREMENT

Since we wished to make a series of measurements for each musician as they moved through the space, we chose the maximum-length-sequence technique[5] (over, for example, the swept-sinusoid technique) since it requires only a relatively brief measurement period. If $m(n)$ denotes an MLS of length $N$, with $0 \leq n < N$, its circular convolution with its time-reversal $m(-n)$ is an impulse $\delta(n)$. We played the MLS repeated end-to-end over the course of about 100 seconds and then (non-circularly) convolved our recording with the time-reversed MLS. If the room impulse response (with or without the musician) is $r(n)$, $n \geq 0$, the result of playing the MLS repeatedly, recording the result, and convolving with the time-reversed MLS is:

$$(\cdots + m(n-N) + m(n) + m(n+N) + \cdots) * r * m(-n)$$

$$= \cdots + r(n-N) + r(n) + r(n+N) + \cdots$$

where $*$ denotes linear (non-circular) convolution. Since this process is linear in the impulse response $r$, we can measure the difference (i.e., the scattering contribution to the impulse response), which will also be wrapped around every $N$ samples. Although the room response of the scattering will be wrapped around in the same way, the directly scattered signal should be very short in duration, on the order of the diameter of the object divided by the speed of sound, in our case less than 10 milliseconds. We should thus be able to resolve this component of the scattering effect from the less time-localized room response component. The direct scattering contribution will be more salient as the length of the MLS is increased, reducing the amount of room reverberation that wraps around on top of it.

On the other hand, if the musician isn't perfectly stationary over the $N$ samples of the MLS, the deconvolution step will not work exactly. In practice, the result of a time-varying impulse response is to add non-time-localized parasitic noise to the measured impulse response, in proportion to the amount of change that occurs over the $N$ samples. This is a reason to keep $N$ small, and this consideration must be traded off with the problem of wrapped-around room response. In practice we found a workable compromise at $N = 4095$ samples, about 0.1 seconds at our sample rate.

In order to get a clean succession of impulse responses as the musicians moved through the room, we asked them to alternately take a step and then stop, repeatedly, as they traversed the room in a looping path (different for each musician.) We obtained 996 impulse responses, some of them with the musician relatively stationary, and some as they moved. We had planned to subtract from each of these an empty room impulse response, but soon discovered that it was more interesting to subtract from each response the one computed from between two and five frames previously, thus superimposing each impulse response with its slightly time-delayed negative. In this way of working, the stationary moments became near-silences. On the other hand, the periods of motion, in which the impulse response measurements weren't reliable, nonetheless were heard as clearly spatialized moving sonic images as they were picked up by the recording microphones, suitable for convolving with instrumental sources.

## 5. INSTRUMENTAL MATERIAL

Practical considerations almost exclusively determined the instrumental material. Given the nature of the residency, only four members of ensemble mise-en were available for the dates and durations required for recording and performing. Therefore, we scored the work for alto flute, trombone, piano, and percussion.

Since the instrumental sounds are later convolved with our measured scattering impulse responses, wide-spectrum sounds were emphasized, such as taps, scrapes, multiphonics, and breath sounds. These are not only more easily spatialized than steady instrumental tones would be, but are also better at making the scattering responses individually audible.

Additionally, musical materials for each instrument were composed for both congruency and contrast. Some gestures, such as coloring breath sounds by embouchure shapes or repeated trills or tremolos, were carried through multiple parts. Other materials, such as pedal tones or jet whistles, were selected for their uniqueness to the instrument. Some example fragments are shown in Figures 4–9.

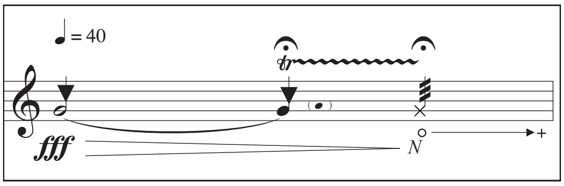


**Figure 4**. An alto flute fragment indicating an air sound mixed with a pitch transitioning into key clicks.

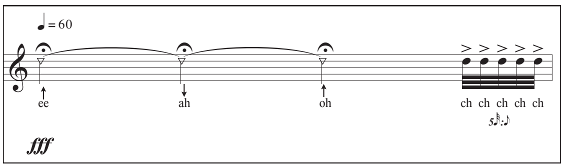


**Figure 5**. An alto flute fragment with modified air sounds.

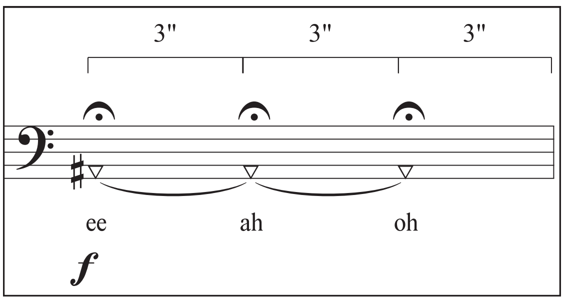


**Figure 6**. A trombone fragment with modified air sounds.

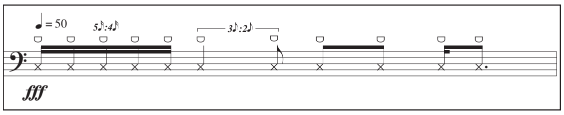

**Figure 7**. A trombone fragment with a variation of a rhythmic gesture performed by striking the bell with the pads of the performer's fingers.

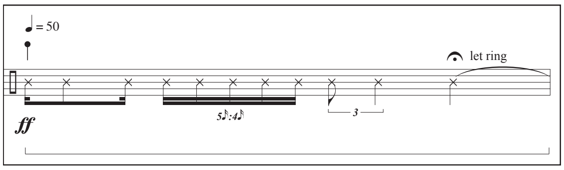


**Figure 8**. A piano fragment with a variation of a rhythmic gesture performed by striking the soundboard with a hard percussion mallet.

Uncontrollable circumstances shortened the turn-around between the confirmation of available instruments and the residency dates. We decided to construct the work from 8 to 10 musical fragments for each instrument, ranging from about 7 to 49 seconds in duration. This facilitated the installation design and ensured that the musicians could perfect their parts quickly.

Each musical fragment was recorded in six channels, using stereo microphone pairs, chosen to be as heterogeneous as possible; typically, this meant two close spot mics, an ORTF stereo pair a few feet away, and two omnidirectional mics at different heights and distances from walls.

In installation form, the piece was set up using eight loudspeakers of two different types, some on the floor and some on stands, one in an alcove, one under a couch, two in the entry hallway, and so on. Each fragment could be played, as recorded using one of the three available mic pairs, then as bounced off one of the four musicians as they moved along a portion of their path, then as picked up by one of the three mic pairs in that musician's scattering response measurement setup, and finally projected over any two of the eight installation loudspeakers. For this last step, any combination of loudspeakers was permitted without regard to its appropriateness as a speaker pair, so that, for example, a hallway speaker could be paired with the one under the couch.

The fragments were also arranged into a fixed piece of about nine minutes' duration. The arrangement was deliberately kept fairly sparse, since it is not intended to be heard except with the installation as accompaniment. There is no synchronization between the installation and the performed version of the piece; that is left to chance. The piece was performed and recorded during the opening of the installation, but can also be played, with the installation as accompaniment, in a concert setting; in this case we would lose the heterogeneity of the speaker arrangement but would keep all the other forms of spatial variation as they were in the gallery setup.

Since the installation used multiple recording positions, the relative balance of the individual instruments did not figure into the musical materials. We normalized the recordings for the installation. However, in the live concert arrangement, the alto flute was amplified with as little electronic or acoustic coloration as possible. Given the performance space, we used two close microphones at the embouchure and lower keys of the alto flute, which were then mixed and sent to a stereo pair of small monitor speakers, comparable to Genelec 8010A, at the performer's feet.

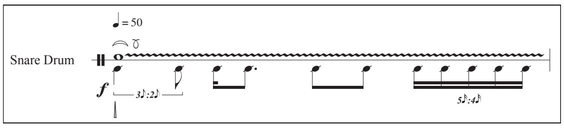


**Figure 9**. A snare drum fragment with a variation of a rhythmic gesture performed by striking the rim of the drum while the performer scrapes circles on the drum head with a fingernail.

## 6. CONCLUSION

It can't be claimed that we have made a careful study (or, much less, reconstruction) of the complicated and barely perceptible interactions between the instrumental sounds of an ensemble and each others' bodies. As our project took shape, the possibility of real, three-dimensional realism came to appear much less interesting than the possibility of putting on an auditory shadow play in which the spatial relationships were constantly shifting in ways that paid no heed to physical reality or even possibility.

The installation is highly portable, requiring only a computer (running any OS) and several loudspeakers, and, if a live performance is desired, four musicians.

### Acknowledgments

We are deeply grateful for support we received from ensemble mise-en, who offered us a two-week residency and presented the first exhibition and performance of *remnant*.

## 7. REFERENCES

[1] J. Cardiff, "Forty Part Motet," 2001, [Sound Art Installation] New York: Museum of Modern Art.

[2] C. Dodge, "Any Resemblance is Purely Coincidental," 1989, on New Albion Records (NA043cd).

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[4] R. Julius and H. Kunstverein, *Rolf Julius, small music (grau)*. Kehrer, 1995.

[5] M. R. Schroeder, "Integrated-impulse method for measuring sound decay without using impulses," *Journal of the Acoustical Society of America*, vol. 66, no. 2, pp. 497–500, 1979.