Waiting and Uncertainty in Computer Music Networks

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"The difficulty is to realize the groundlessness of our believing" (L.Wittgenstein, On Certainty, §166.)

Abstract

The authors have been holding a series of seminars exploring the practical and theoretical implications of using Granular Synthesis and Just In Time Coding for group performance in computer networks. Most of the aspects that emerged as central can be discussed in terms of uncertainty; from the fundamental uncertainties in audition, the continuum between deterministic control and independent behavior of artistic instruments, the social phenomena arising, such as perception of self and others, to the phenomenon of waiting in different time scales.

1 Introduction

Perception often seems embedded in a floor of uncertainty - and there are situations that seem to be more productive in this respect than others. Especially artistic practice often aims towards situations that cannot be reduced to a single explanation. While holding regular network sound seminars, we found that this type of human interaction causes a great variety of uncertainties which we decided to explore further.

As the Heisenberg principle and its application to acoustics by Dennis Gabor shows its nature especially well in granular synthesis, we decided to employ a series of focused seminars, an experimental setup combining network music and explorations in microtemporal sound structures. These seminars were also intended for a more in-depth learning experience for both students at KHM Cologne and guests.

Both Warteraum seminars used just laptops and the SuperCollider3 language [1]; Warteraum1 (The acoustical Particle-Wave-Dualism and the Frontiers of Waiting, held May 2003) used a small set of extensions to the SuperCollider3 language called BroadcastServer [2], and Warteraum2 (Just In Time Coding, held Nov. 2003) continued in the direction of live coding with the JITLib (Just In Time Library) system [2] and the SharedProxySpace extension to it [3]. The most recent related event, a Symposium at HfbK Hamburg, Changing Grammars, led to the founding of TOPLAP [4], the Temporary Organisation for the Proliferation of Live Audiovisual Programming (or similar, acronym expansions vary).

2 Gabor and the Limits of Certainty in Acoustic Perception

In his 1947 paper [5] Dennis Gabor answers the question "What do we hear?" in an unusual way: instead of illustrating wave mechanics with acoustical phenomena, he takes the opposite course - Gabor applies a formalism from quantum physics to auditory perception and thus is able to apply the uncertainty relation to sound. By treating signal representation, which knows nothing of frequency, and fourier representation, which knows nothing about time, as extreme cases of a more general particle-based view on acoustics, he introduces quanta of information that represent the entity of maximum attainable certainty (or minimum uncertainty). In this way he provides a formalism to describe the relation between the statistical and the deterministic - a relation that is not only of empirical importance, but as we will see, artistically relevant. Also, it might imply further consequences regarding the role of the observer:

According to the quantum mechanical interpretation of the law of entropy, any deterministic view is limited to an unobserved system. Here it is observation itself that introduces statistical uncertainty (see e.g. [6]); one could hold the pessimistic view that the attempt of investigation principally is in vain. Generally a more optimistic interpretation is held, that the quantitative relevance of these laws vanishes for macroscopic scales. Nevertheless, the success of Gabor's application of quantum formalisms to auditory perception should raise our attention; maybe in perception and social interaction such formalisms can unexpectedly prove to be useful.

2.1 Frequency - Time

In acoustics, the notions of' 'what' (happened) and 'when' (it happened) are fundamentally blurred: sound cannot be held still in order to be examined. Obviously a wave's content, the 'what', exists only as a function of change of pressure in time and location. As Gabor showed, there are limits to the precision with which a sound's properties (in terms of frequency distribution) and its temporal localisation can be observed. He described this limitation as a rectangle with sides in time and frequency dimensions, whose minimum area is constant while the lengths of its sides may change.

In practice, this means that the shorter the time frame of observation, the less accurately can we obtain frequency information; and vice versa, in a longer time frame, we can observe frequency more accurately, but it can not be located in time with higher precision than the time frame allows. On a psychoacoustic level, this relation describes a fundamental uncertainty in perception - an uncertainty that is not at all beyond normal experience, but is in fact a building block which informs all perceptual distinctions and judgments.

In SuperCollider3 code, here is a simple approximation to Gabor's fundamental unit of sound synthesis which can be used to explore this uncertainty:

```
SynthDef("gabor_grain", {
	arg out = 0, freq=800, sustain=0.01, amp=0.5;
	var env;	// an approx. to gaussian:
	env = Env.sine(sustain, amp);
	Out.ar(out,
		SinOsc.ar(freq)
		* EnvGen.ar(env, doneAction:2)
	)
}).send(s);
```

2.2 Location - Space

In acoustics, the notions of 'when' (something happened) and 'where' (it happened) are fundamentally intertwined: As a sound travels, subsequent parts of the wave intersect with an assumed location in space. For this reason, the limit of temporal precision is at the same time a limit of spatial precision. Furthermore, the auditory system uses interaural time differences between sound events in order to determine the direction and location of a sound source (see also (5)).

Another level of complexity, due to the relatively long wavelength of sound in air, is the presence of reflections and diffractions of sound waves, all superimposed. The ear can decode these into more precise source location and an impression of the acoustical properties of the surrounding space. This adds a rich variety of possible ambiguities or uncertainties to the world of auditory perception, which like the other uncertainties, is interesting material for artistic purposes.

2.3 Grouping - Streams

Proximity can have many dimensions. Whether auditory events are perceived as belonging together or not depends on many factors, most importantly temporal proximity and similarities of properties between individual events. A time sequence of sound events may be attributed to a single 'source', or might be segregated into different parallel streams, i.e. groups formed in the act of perception according to their similarity. The relative importances of different sound properties for grouping is the subject of many research projects in psychoacoustics. In fact, many auditory models assume a complex arrangement of local feedback loops, loops that go across adjacent levels, as well as loops connecting multiple layers.

The higher the level of perceptual complexity, the more personal perception becomes, as it depends on attention, context, expectation, and previous experience. Of course the above (2.1, 2.2) mentioned relations also play important roles in this respect.

2.4 Causality - Intention

In order to investigate, perception usually tries to follow the chain of cause and effect in a backward direction.(E.g. a sound is heard - where did it come from - what physical source made it - how - for what reason - is it communication, or music - etc.) The emerging semantic level has a fundamental influence on perception itself; this is easily understood when e.g. considering language understanding in noisy situations.

Many important perceptual uncertainties arise when questions of motivation and intention come into play (- who said it - what did s/he say - what did s/he mean - why did s/he say it - etc.). Note that it is not always clear what role the observer or the method of observation plays here. In all, this opens up a wide field of possible misunderstandings fruitful to the artist and scientist alike.

3 Uncertainty in Musical Instrument Behavior

The attempt to gain control over physical phenomena, such as sound, finds its limit in their observability - and any uncertainty in perception also means uncertainty in action and in control. It is because of this simple fact that most tools, in their usual purpose to increase control over physical phenomena, provide ways to increase both possibility of action and certainty of perception (e.g. cars and rear-view mirrors). In the most common view, musical instruments are understood to be tools in this sense, i.e. they are expected to provide a maximum of predictability and reliability between action and its acoustic result. Even so, learning to play an instrument involves a considerable degree of experience (a.k.a. practice), in order to learn to control the causal relationships well enough, and to compensate for idiosyncrasies of the particular intrument one plays. However, many musicians find it quite appealing that real instruments diverge from the ideal of a fully controllable device in interesting ways, be it by non-linearities (often even intentionally introduced by preparation), or by other inconsistencies of some kind.

Thus, a diametrically opposite perspective comes into consideration: An instrument can also be seen as an artificial environment that shows independent and somehow interesting behavior, and while it can be influenced from outside input, it retains a certain sovereignty. (Note that in this perspective the 'instrument' includes the musician's body, perceptive and motoric actions).

Learning an instrument then would be better described as learning how to navigate under unforeseeable circumstances than how to precisely control. From here it is easily understood that the certain stubborn, unpredictable quality an instrument provides is part of a generally desirable often physical feedback. One could even describe this as 'resistance of the material' (Adorno), in fact a microtemporal waiting time, introducing a gap of uncertainty into the sensomotoric cycle.

In computer-based musical instruments this relation between control and automatism plays an important role. Because here there is a constant interaction of calculation and sensomotoric activity, combined with the computer language as a constitutive element, the border between engineer and artist cannot easily be drawn (see e.g. [7]).

In programming environments, the notions of "means" (the necessary tools) and "products" (resulting works of art) are of limited value; an instrument may already be considered a work of art which can produce more works of art. Specially in computer music it seems that a deliberately independent, idiosyncratic musical environment can often be more interesting than aiming for an optimal translation of virtuoso mechanical movements to 'hyper'-controllable instruments.

4 Groups, Audiences and Uncertainty in Social Interaction

While musical instruments can be seen as systems of altered causalities, this extends to music, or artificial sound, itself as well. The musician, being able to explore the physical and perceptual laws of acoustics, can create systems that contrast or even contradict common experience. Similarly, an experienced listener can 'read' sounds by interpreting them in an independent system of explanation. It is typical of an artwork, showing altered causality, that we cannot safely predict from experience what something means or what will happen next. Therefore, uncertainty is not something artistic practice tries to eliminate, but rather to cultivate and develop. This does not mean, however, that there is no desire to find out about causes and their effects and to develop a good intuition what might happen next - the tension of expectation and the joy of more and less failing prediction is an aspect of music shared by both audience and artists.

One of the most basic uncertainties is the uncertainty of oneself. It seems that music played in groups often produces a characteristic feeling of either merged or multiple identity (beyond the common case of parallel identities that is). A well known example for this is the emergence of inherent patterns in amadinda xylophone music [8]. Due to the fast interlocking strokes and the fact that one instrument is shared by all musicians, the song pattern is clearly an interpersonal phenomenon. In a computer network it is possible to build algorithmic musical instruments such that each instrument can be accessed by all players.

A physical instrument inhabits one physical location, and usually an instrument is triggered somehow by physical contact, so it is assumed that the cause for a sound (be it a person or a mechanism) is spatially close to its source. This physical coincidence is a very strong perceptual assumption in everyday life. In network music, this relation becomes merely a convention; this means that the question whether a sound was caused by my own activity or by someone else's becomes an immediate problem.

Another uncertainty is closely related: as a musical algorithm most frequently shows aspects of a system with its own, to a degree independent, behaviour, it is to be asked if the sound I hear is caused by a local (my own) or a remote (someone else's) algorithm or even someone else's physical activity (e.g. repeated evaluation of code etc.). Trying to find things to play that one can identify as being played by oneself quickly becomes an integral part of the resulting music. One strategy that came up while playing resembled phenomena known from bio-acoustics: leaving acoustic space for others in time and frequency, and finding auditory niches for communication in the overall sound environment.

5 Temporal Uncertainty ("Waiting")

Trying to gain certainty of something usually implies that we investigate something that is present. Of course it cannot be neglected this view has its limitation, especially when talking about perception and even more obviously when talking about sound. The following brief overview of acoustic time scales shows a first layer of phenomena that has proved to be of relevance to us. For an in-depth discussion of musical timescales see [9].

Assuming a very brief impulse, a mild version of the dirac impulse:

```
SynthDef("dirac", { arg out=0, amp=1.0;
    var i;
    i = Impulse.ar;
    FreeSelf.kr(i, Out.ar(out, i * amp));
}).play
```

When two of these impulses coincide close enough in time, only one source is perceived, which is usually located somewhere in the center between the sources if they have the same loudness. Due to our ability to relate phase differences on both ears to the direction of the sound source, a small latency between the two impulses causes the impression of a spatial dislocation towards the direction of the first wave front (0 - ca. 0.6msec, see e.g. [10]). Increasing the delay, a puzzling dislocated impression takes over, which could be described as spherical, like a space without location.

From ca. 20msec delay on, it is possible to distinguish two sounds and it is interesting that in most cases they cause either the impression of the first impulse being the cause and the second the effect, like an echo, or of an entity that moves from one location to the other, like a ping-pong ball. The more the delay is increased from here on, and the more the delay time becomes unpredictable, we get the impression of some kind of hidden mechanism, or even, some kind of dialog between the two locations, similar to the call and response schema not unusual in music. The impression of an answer being given is strengthened by unpredictable waiting times. One assumes some sort of contemplation to be the cause for an unpredictable waiting time - this might be due to the fact that we expect (or hope) that such inner mechanisms be non-deterministic ('alive'). Note that this is not entirely unrelated to the halting problem in turing machines.

To summarize, a continuum of the following four impressions can be attributed to the different degrees of latency or waiting: stereophonic merge - delocalisation - movement - conversation.

It proved in our workshops that, as expected, these latencies or waiting times play an important role in the way music develops in a networked sound synthesis environment. Already in the beginning we encountered the relativity of timing: When sending a message to the synthesis engine, it is possible to plan for a maximum network latency and send a time tag which schedules the command to be evaluated at a precise point in time in the future rather than immediately whenever the message happens to arrive. Of course this presupposes that the clocks on different systems are synchronized correctly. This synchronization, achieved by a network time server, itself, is subject to the same delays network transfers involve; achieving better than several msec synchronicity is not trivial. In short, we found out that trying to synchronize resulted in much larger asynchronicity and decided to let the LAN contribute its own delays to the music. In our case these delays fell either in the category of delocalisation or stereophonic merge, which means that sending a short sound grain to all computers caused the impression of a single sound with a very strange location:

```
r.broadcast.sendMsg("/s_new", "gabor_grain", -1,0,0,
    "freq", 3200
);
```

As expected from psychoacoustics, this identity more or less falls apart when we create grains with different frequencies in each location:

```
r.broadcast.do { arg addr;
    addr.sendMsg("/s_new", "gabor_grain", -1,0,0,
    "freq", 3200 + 1000.0.rand)
};
```

Waiting is a fundamental experience when working with computers and networks; one can even consider them structured waiting tools. In fact, nearly every program knows how to wait - and to make us wait in more or less intentional ways. The temporal continuum of disintegration can easily be explored by introducing waiting times:

```
Routine ({
    r.broadcast.do { arg addr;
        addr.sendMsg("/s_new", "gabor_grain", -1,0,0,
                "freq", 1600);
        0.01.wait;          // equal times in seconds
    };
    }).play;

    Routine ({
    r.broadcast.do { arg addr;
        addr.sendMsg("/s_new", "gabor_grain", -1,0,0,
                "freq", 1600);
        0.02.rand.wait;   // random times, avg. 0.01 sec
    };
    }).play;

    Routine ({
    100.do({ arg i;
        r.wrapAt(i).sendMsg("/s_new",
                "gabor_grain", -1,0,0,
                "freq", 1600);
        (1.05 ** i * 0.01).wait; //exponentially growing
    };
    })
    }).play;
```

All the examples above play their groups of events distributed over all computers known to the Router ("r"). When more than one person plays similar algorithms at more or less the same time, the authorship uncertainty becomes evident. E.g. it would difficult to distinguish between one person playing:

```
Routine({
    4.do { arg i;
            r[i].sendMsg("/s_new",
                    "gabor_grain", -1,0,0,
                    "freq", i % 2 * 200 + 400
            );
            1.0.wait;
    }
}).play;
```

or two people sending this at about at the same time:

```
Routine({
    2.do { arg i;
      r.sendMsg("/s_new", "gabor_grain", -1,0,0,
            "freq", 600);  // second plays 400
```

```
			2.0.wait;
		}
}).play;
```

Languages in general open up the field of semantic uncertainty; here, the synthesis function called with the keyword "gabor_grain" (in this case) can be interpreted differently, dependent on what synth definition is locally stored. This gives rise to considering a very elementary law of information: a receiver can interpret a message in its own way. This shows how polymorphism in an object oriented language is relevant to conversation and music: Misunderstanding is not necessarily an error, but a basic feature of messaging.

6 Conclusions

It seems that there is really no end to the possibilities of uncertainty - keeping in mind that there is no doubt without belief, this is a field that is of relevance to empirical investigation as well as to development of systems employing alternative causality. We hope that we have been able to demonstrate consistently that error, delay, uncertainty and ambiguity are not side products, but, quite opposite, central elements of perception, action and music.

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References

[1] The current distribution of SC3 is available at: http://sourceforge.net/projects/supercollider/

[2] JITLib and BroadcastServer are part of the SC3 distribution. For a discussion of live coding see: Collins et al. (2003), *"Live Coding Techniques for Laptop Performance."* in Organised Sound 8:3

[3] http://swiki.hfbk-hamburg.de:8888/MusicTechnology/630

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