Composers' views on mapping in algorithmic composition

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Mapping concerns the connection between gestures, or structures and audible results in a musical performance or composition. While this is of intense interest to performers of new instruments and instrument designers, it has also been an area of interest for some composers. Algorithmic composition is sometimes the process of imagining a gesture or structure – perhaps physical or visual – and then applying a mapping process to turn that 'gesture' of the conceptual domain into sound which may display the original conception in some way. This article looks at mapping from the point of view of algorithmic composition, particularly where persistence is an issue, such that the gesture (conceptual domain) is embodied and perceptible in the musical result.

1. INTRODUCTION

Mapping in instrument design has been an area of concentrated investigation. Mapping as part of algorithmic composition has not been so thoroughly investigated. This is possibly because it is usually an integrated part of the algorithmic composition process and not seen as a discrete stage of practice. Mapping in algorithmic composition is different from mapping in instrument design because composition is a process of planning and instruments are for realtime music production. The use of mapping which is integral to an instrument has both differences and similarities to the mapping that is an inherent part of algorithmic composition. This paper investigates how composers use mapping in their practice.

2. DEFINITION OF THE AREAS OF INTEREST

The term 'gesture' has many meanings. Even a cursory reading of the literature will show that the term is imbued with multiple, even contradictory, meanings within single disciplines and a single context (Cadoz and Wanderley 1999). For the purposes of this paper, gesture is a musical concept; it is not a physical movement.

A musical gesture is a planned change (randomness can be planned) in musical parameters as part of a piece of music. The parameters could be, for example; timbre, density, intensity, timing, pitch and so on. A compositional gesture is the underlying conception, structure and planning of the musical gesture. As such, a compositional gesture can be a kind of abstraction of a musical gesture or a group of musical gestures. Thus compositional gestures can be directly related to (possibly complex) musical gestures, possibly as an abstraction.

Readers interested in the various definitions of the term gesture would be best served by consulting the references as a thorough treatment of the area is beyond the scope of this paper. Further, organisation strategies in algorithmic composition may not fit a definition of even a compositional gesture, but there can still be a mapping requirement to move from the conceptual organisation of data to the required musical parameters. 'Conceptual domain' is a term that will be used to cover the entire conceptual area of compositional practice, which includes other organisation strategies as well as compositional gesture. Further uses of the term gesture, unless otherwise specified, will implicitly mean a compositional gesture.

3. MAPPING ITSELF AND HISTORICAL EXAMPLES

Algorithmic composition can sometimes be the practice of composing music through manipulating a number of compositional gestures to produce a musical piece. The manipulation is usually part of the compositional process, where a multitude of gestures are arranged and then through another process, possibly very direct, musical parameters are extracted. It is possible to do this from the micro scale of sound synthesis through to the macro scale of the structural model of the piece. Mapping is the process of extracting the musical parameters from the compositional gestures or structure, such that one set of data is mapped onto another. It should also be noted that algorithmic composition may use specific organisations of data that do not necessarily require 'gestures', for example, Markov chains, finite-state machines, fractals and space grammars. These constructs may also require significant mapping processes to output musical data.

There may appear to be some similarities between the methods of mapping in algorithmic composition and the

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mappings used in the general practice of the sonification of data. This may sometimes be a valid observation with some pieces of music. However, as the intent of sonification is to illustrate a process or some data, it is primarily instructional. This type of mapping is not the focus of this paper, which is primarily about composition and mapping. The closest sonification comes to composition, what Larry Polansky calls 'manifestation' (Polansky 2002), is where the intent is to creatively use a type of sonification of a formal or mathematical process to create a musical idea. For the purposes of this paper, that process will be included as a part of composition.

Many composers use mapping, either explicitly or implicitly, in their compositional practice (as will be seen later), but well documented and detailed examples of exactly *how* mapping is used are very rare. This is possibly because it has not been identified as a separate step in compositional practice. Two well-known pieces are discussed below and these are important historical examples of compositional uses of mapping, showing how it has been used by composers. In section 4, some contemporary composers discuss how they use mapping.

3.1. Historical examples

A famous example of the mapping process is the part of *Pithoprakta* (1955–6) as reproduced in Formalized Music (Xenakis 1991: 17–21). Xenakis used the Brownian motion of gas particles, combined with Bernoulli's Law of Large Numbers, as his basic model for the cloud pizzicato glissandi section. After calculating, statistically, over 1,000 velocities of gas particles as given instants of time (as the measurement of this was impossible), he then graphed them on an X–Y plane and directly mapped the straight lines of the velocities to glissandi for forty-six string instruments. Xenakis divided his graph vertically into fifteen pitched sections, each corresponding to a major third. This was then mapped to the ranges of the string instruments. The mapping was directly of pitch in the vertical direction. This is a particularly direct and concrete example of mapping. All intensities and durations are the same, but to ensure the sensation of a cloud of particles, Xenakis used a complex temporal arrangement of overlapping timing subdivisions that are factorially-unrelated. This is a complex mapping of linear time, designed to represent the instantaneous nature of the movement of the gas particles. Along with many other algorithmic composers, the mapping phase is implicit in much of Xenakis' work. He often uses direct mapping as a result of the deliberate organisation of one set of data in such a way that it maps directly to musical parameters.

Another famous example of algorithmic composition and mapping is Charles Dodge's *Earth's Magnetic Field* (1970). Here, Dodge uses data from the effects of the radiation of the sun on the magnetic field of Earth. A Bartels diagram showed fluctuations in the Earth's magnetic field for 1961 and this data formed the basis for the piece. Dodge mapped this data, the Kp index (a measure of the average magnetic activity of the earth) to pitches and rhythms. From the program notes of the recording of *Earth's Magnetic Field* (Dodge 1970), we may glean an insight into the mapping used:

> The succession of notes in the music corresponds to the natural succession of the Kp indices for the year 1961. The musical interpretation consists of setting up a correlation between the level of the Kp reading and the pitch of the note (in a diatonic collection over four octaves), and compressing the 2,920 readings for the year into just over eight minutes of musical time. (Dodge 1970)

While the pitches appear to be a fairly direct mapping from the Kp index, some elements of the composition such as the timbres were chosen purely for aesthetic effect. An arrangement of the data that plotted the length of sections of the data against the maximum amplitude in the section was used to determine the speed and direction of the sound spatialisation and also the rhythms. The data was also sometimes read multiple times to generate the musical parameters. That, combined with the similarity of the fluctuations in the Kp index to 1/f noise data, contributes to the aspects of self-similarity in the piece.

The two previous examples contrast different approaches to mapping. It may be linear and direct, but it may also be nonlinear and more complex. Both examples use the data as a structural component and the music achieves some structural unity for that.

3.2. How composers use mapping

There has not been the same formalisation of algorithmic composition and mapping as there has been for other musical composition. Additionally, there is little formal analysis of music in terms of compositional gesture and mapping. As there is no set method for defining the gestures or the mappings, each composer tends to use their own methods for their own reasons.

Compositional gestures and mappings are also used differently by different composers, thus making this a problematic area for analysis and study: For example, while gesture and mapping is often used as a structural model for a piece of music, it will have different applications for a composer who is focused on, say, spectral composition in contrast to another focused on some other form of algorithmic composition. There are also other organisational strategies for the conceptual stage of a composition and these may also require mapping to output musical data.

It is clear from the descriptions of how composers use mapping between the conceptual or abstract domain and the musical domain, that it is sometimes used in a similar combination of ways to how it is used in instrument

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design. That is; mapping one compositional gesture to many music parameters, mapping many compositional gestures to one music parameter and mapping many compositional gestures to many music parameters. Additionally, there is another parallel between instrument designers and the composers, the mappings themselves may be linear mappings or nonlinear mappings (Hunt and Wanderley 2000, Hunt, Wanderley and Kirk 2000). However, in compositional mapping there is the additional possibility of repetitive nonlinear mappings and most importantly, each composer has their own combination of mapping techniques. Examples of these possibilities appear in the composers' contributions below.

4. A VARIETY OF APPROACHES

To illustrate the broad range of approaches to mapping in algorithmic composition, a number of composers were asked a series of questions about their approach. The composers were; Richard Barrett (RB), Charles Dodge (CMD), Larry Polansky (LP), Agostino Di Scipio (ADS), Rodney Waschka (RW) and Paul Doornbusch (PD). The questions, along with the answers from the composers are below. Some of the responses have been very lightly edited for reasons of readability and flow.

4.1. Collated responses

(1) Can you comment on the abstract, with respect to your own practice of algorithmic composition and the mapping component of that?

RB: I wouldn't consider the 'gesture' as separable in any way from the sound, even conceptually. When, as for example in much of the solo music I've written for string instruments, the composition process involves creating trajectories (defined as mathematical functions) along and across the fingerboard, the resulting structures outline different zones within the 'sound-space' of the instrument, within which further layers of musical structure can be articulated. These further layers may or may not themselves involve some aspect of physical mapping, for example the disposition of the fingers within an overall left-hand position which itself is a point on a trajectory, and so on.

CMD: I have used mapping in algorithmic composition in a couple of different ways. The above analysis of mapping in my *Earth's Magnetic Field* (*EMF*) is accurate and just, I think. I haven't found myself doing any mapping where performance gesture is concerned.

LP: I think that the emphasis, for me, on words like gesture and performance has a lot to do with a kind of recent memory syndrome, and very user-friendly and relatively new programs like HMSL and Max and Supercollider which made those kinds of connections possible. Mapping of musical idea, or of any idea, into sound and composition is much older, and nearly universal culturally and historically. That said, I would tend to focus, for convenience sake, on the recent history, considering people like Schillinger a sort of ancient ancestor, and using Hiller, Koenig, Tenney, Matthews (I think of him as one of the most interesting algorithmic composers even if he can't abide his own experiments in that area), and so on as early workers (Ames has written beautifully on this history, and I certainly put people like him and me in the next generation of those people). As for myself, I don't think in gestures, usually, but in ideas. And I try to make those ideas as deep and resonant as possible. Sometimes those ideas have clear and intricately connected sonic manifestations inherently obvious in them (the *Four Voice Canons* are a good example), sometimes they don't (that is I work on ideas independently of sound, such as the metric and mutation functions, which came from a deep, sort of philosophical interest in the whole notion of change). Mapping ideas is different than mapping data, though it is clear to me at some level that data and ideas are the same (and I'm thinking in sort of a Chaitin-esque mode here). My way of working is to come up with fertile ideas and explore them a lot, usually playfully, since that's my nature as a musician. Sometimes I feel like the conceptualist in me is a kind of wholesaler to the musician – one gives the other raw stuff, and the other makes music out of it. Sometimes these two are the same person, and that's when the pieces, to me, are the best.

ADS: It seems to me that mapping is really a crucial element in all composition, not only algorithmic composition. In algorithmic composition it becomes more evident because it is dealt with as a technical problem. And yet, all composition entails the search for some sort of mapping, that is, a 'transfer function' from a general idea to the actual sounding shape, for example from one domain of experience to another. I think, however, that this is also the case with the reverse approach: a transfer function of some sort is needed to turn a living, experiential sonority of some significance, or any 'found sound', into a musically relevant event or concept. In short, the body of data being mapped can be either an idea that is waiting to be turned into actuality, or an actual sonic phenomenon which is listened to closely in order to map its properties onto a more conceptual configuration. Roughly speaking, these reflect two very general and widespread approaches on composition. In both, it is implicitly assumed that something pre-exists, that something already exists prior to actually composing, be it something of an abstract or more material nature. While this may seem obvious, I am not certain whether, when I start composing, I really lean on abstract, internal ideas or some material and external object. I am not even certain that I rely on anything existing before the act of composing. I have the feeling that somehow I start from the mapping method itself, focussing on its quantitative and qualitative properties, and then I try a body of input data to feed into this mapping function, such that the output somehow testifies to the transfer operation itself, in its consistencies and contradictions. This may seem odd to say, as it may convey the notion that I start with a special concern for something commonly understood as very technical and, taken per se, void of musical significance, void of experiential content. But that is not so, if you just think that a substantial aspect of composing represents the dialectical, controversial invention of techniques, the designing and testing of 'ways to do' – composing cannot be reduced to the actualisation of pre-determinate aesthetic goals, of ideas dictating their own empirical manifestation. If we regard the technological

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element proper to the making of art, *means and ends always influence each other*. If we agree on that, then it is not too strange to add that *not all means are desirable to reach desirable goals*. What defines your actions, your composition practice, is not only the final object, but also the methods and techniques invented to create that final object. The final object bears audible traces of the peculiarity of the particular means. To the extent that any mapping operation is a means used to turn data from one domain to another, it is crucial to all composing. Algorithmic composition brings special attention to this aspect proper, compared to composition in general. In algorithmic composition, mapping becomes central to the compositional effort, either implicitly or explicitly.

RW: In some works I have attempted, through the mapping process, to make clear the nature of the object or gesture being mapped. In other works, it has been completely unimportant to me. I have paid close attention to mapping procedures in my own work and that of other composers, noting what I considered to be successful and unsuccessful techniques.

PD: I am not sure if I think that it is important, in my work, that the compositional gestures are somehow transmitted to the audience. In a way it is, but mostly I'm trying to give the audience a powerful musical experience, so as far as transmitting a gesture or structure is important for that, then yes it is important. I try to map from compositional gestures to musical parameters in such a way that the gesture is evident when I listen to the result. This may or may not translate to the gestures being perceived by the audience, but I must be able to hear it. Having said that, most of the compositional gestures I use are abstract concepts and I usually have movement in three or four of them simultaneously, otherwise I find the result boring musically.

(2) Musical instruments tend to have consistent but complex mappings between physical gestures and the resultant sound. Do you have a consistent approach to algorithmic composition and mapping or does it vary and why?

RB: It varies firstly according to which instrument or instruments I'm considering. In a solo composition, I tend to begin work from some kind of sound-image which unifies the particular poetic or expressive quality I want to reach with a particular viewpoint on the nature of the instrument and its relationship to the player. Thus the 'mapping' aspect is probably further in the foreground than in a work for more than one instrument, where another level of musical correspondences comes into being, or where my material emerges from a consideration of the ensemble as if it were a single complex instrument. My ensemble music is often structured on the basis of tensions between idiomatic individual activity and idiomatic group activity, where a 'group' can consist of any number of individuals from two to the entire ensemble, and an instrument could also as it were be playing in more than one group simultaneously. Again this is something which proceeds from an initial apprehension of sounds, textures, tendencies and so on, and the 'meta-instrument(s)' of such an ensemble (as for example in most of my orchestral piece *Vanity*) are actually defined, are brought into being, by their sounds.

CMD: Again, in my compositional mapping I have usually mapped from data or algorithmic computation directly to some musical parameter. In *EMF* that was data to pitch. In a group of works from the 80s (*Profile, Viola Elegy, Roundelay*, for example) that was a computed result, often 1/f noise or some close variant, to various sonic parameters such as frequency, amplitude, register and so on.

LP: I don't agree about musical instruments, but I'll leave that for a different discussion. I don't have a consistent approach to algorithmic composition (I don't even really accept or like the term, but I'll use it here since we all 'kind of know' what we are talking about). The reason I don't have a consistent approach is by my very nature as an experimental composer I am trying to avoid a consistent approach. I think that experimentation should go on at every level. It would be a lot simpler for me if I had one program, one score package, and just kind of cranked out pieces for instruments using a set of ideas in some consistent technology. In fact, it would probably be the sane thing to do. But I don't do that. I experiment, continually, with every aspect of the concept, technology, and realisation process. I do this not cavalierly – in the 80s I worked very hard and consistently to evolve, via HMSL and my own works, live interactive intelligent music, and also to work on a lot of computer aided compositional stuff that I hadn't been able to do. In the early 90s, mainly due to a change in lifestyle, I started to write a lot more scores using HMSL (while still doing a lot of performance work, but not as much). Recently, I've been moving in some new directions. I always take a kind of 'what if' approach, and try to do new things. It makes me happy, and I get irascible at myself when I feel like I'm repeating myself out of laziness or out of not knowing why. Other times, I will explore things at great lengths (I have a 'series' of works like the *Four Voice Canons*, the *Psaltery* set, the *Cantillation Studie*, etc.), but I like to have fun and invent new worlds within the context of my own universe.

ADS: No, it depends on the particular generative or transformation model I set to use. It also depends on my reactions to the audible results, on the perceptual properties of the output sound or sound structure. Usually, I would first try to adopt linear mappings of the numerical data of the model, in order to keep things simpler, but then I may change it significantly. One technical aspect of mapping that always comes to the fore, in my experience, is quantisation.

RW: Sometimes I have used a consistent approach over the time it took me to compose two or three works using similar algorithms, but in general I have no consistent approach. The variation in approaches, in my work, comes about, in part, because of changes in the type and scale of the musical material I wish to generate. Questions of pitch or frequency determination are often treated differently from choices regarding large-scale form.

PD: I think I would have to say that I do not have a consistent approach to the mapping of compositional gestures to musical parameters. It will certainly change from piece to

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piece. I have recently used linear, logarithmic and chaotic mappings for time, instrumental pitch, synthesis pitch, timbre, density and other parameters in a piece. I prefer this approach as I find it produces a more interesting result than using a single technique. This may be particular to the types of models I use, for instance when I have had very complex data to map to musical parameters I usually find that a more linear mapping allows for a better result, than a non-linear mapping.

(3) When implementing a mapping strategy for (part of) a composition, do you organise this in a particular analytical way, decomposing the problem in a technical manner, or in a more creative and holistic way for a purely aesthetic result?

RB: Analysis and composition are often confused with each other, and the results do no credit to either. I have no time for abstractions. I want only something I can use, something I can get involved in. I want to create situations for myself where I am engaged with the musical matter as intensely as possible, rather than producing generalisable demonstrations. On the other hand I'm fascinated by the idea that composition, and therefore performance and listening, could generate real discoveries about reality, which means that I'm not sure whether I would call my approach 'purely aesthetic'; actually I'm not even sure what that means.

CMD: I use the more creative and holistic way for an aesthetic result.

LP: I use play, and humour, and oftentimes reference. Like *Roads to Chimacum*, where the most sophisticated software I've ever written is transforming a fiddle tune (or *51 Melodies* is another good example, where the mutation process transform two 'found' guitar licks, both of which I just wrote in a few minutes). I try not to be dogmatic about the mapping (I don't think it's reasonable to do that, or healthy), and I try to use what you are calling the 'mapping' but what might be called 'realisation' or even 'orchestration' (in fact, I've got a whole set of pieces, the *Four Voice Canons*, which is based explicitly on that). To me, this 'stage' of the process, which often comes into my mind even before the idea, is a good place to relax and have a beer and have fun. In a certain sense, it's arbitrary (I think of, as a good example, what would have happened had Steve Reich decided to use complex, thorny atonal chords in his early works, instead of minor ninths like in Piano Phase? – they'd be the same concept, but a very different, much less accessible sound). Mapping a mutation onto *Roads to Chimacum* is isomorphic to mapping the mutation to *Hard Day's Night* (as Dirk Rodney, the great English experimentalist from the 1960s, seems to have done). The idea, in a lot of my works is sort of independent of the 'medium' through which it's transported to sound. However, mostly what other people hear is that medium (in 51 Melodies, screaming guitars; in *Four Voice Canon* #4, gentle marimbas; in Roads to Chimacum, fractured fiddle tunes, etc.). So those media are, on the other hand, crucial. I've very deliberately chosen elliptical, obscure, or even deceptive media, not wanting to make it too easy. If I wrote a piece that mutated gentle and lovely marimba chords into gentle and lovely but different guitar sounds, all would be very happy and I'd be working with the exact ideas that I've often used. But I'm sort of contentious by nature, and I feel that I would be sort of tricking people into liking something that is by nature sort of difficult, and requires a lot of effort and thought. Sort of sugar coating, which is fine in life but music is a place where even the wimpiest of us can dare to be courageous. I respect Ames' music a lot for this reason (and David Feldman is a wonderfully extreme example of this): Charles, throughout his work, has been obstinate in couching the most elegant, beautiful and sophisticated ideas in the most recalcitrant and unfriendly of media. Nick Didkovsky, another composer who I admire tremendously, has found a nice synthesis of media and idea, and I think that's because media is something he's actively a participant in (he's a great guitarist and musician, and when he steps up to play, he wants to play something that appeals to him on that level, not just the conceptual one). There are diverse approaches to this, and all interesting, and many admirable, but in the end I think it boils down to personality. We all have our own communication styles, and those may or may not be related to our concepts. That's why the gods gave us poetry.

ADS: I start with what you might call an intuitive, holistic way of going, however that does not mean that there I am pursuing purely aesthetic ideas either. Then, an analytical view may be necessary to cope with particular problems, especially when dealing with the computer implementation details of the overall process. Let me clarify this question of the relevance, or irrelevance, of aesthetic results to the compositional process, including mapping as an element internal to such process. By experience, I know that my ears are always there, ready to provide their appreciation and judgement regarding the sound brought about by the compositional model. Now, for that reason I think I can allow myself to only focus on technicalities that apparently seem to have little relevance to the final, audible results. Rational efforts are needed to cope with the things of which we are scarcely aware. Mapping is no exception. More generally, efforts in algorithmic composition are no exception. I pursue them in order to learn about sound and music, as well as about myself and about listeners, and about myself as a listener, that is, in order to focus on those aspect of composing that I don't understand well. Therefore, while the composition of timbre, and that of special timbrel constructs like sound textures, as well as what I call 'sound powders', or 'dust', or 'turbulence', and other audible by-products, is central to my own musical work, the main question for me is not *what timbre*, or *what kind of sound should I pursue, now*? But – more properly – *how can timbrel shapes emerge from the interaction of lower-level details in the sound material*? I turn from the 'what' question to the 'how' question, and focus on the latter simply because the 'what' is 'out of question', so to say. Again, I need to focus on what I do not know, rather than pursue insistently what I already know or can imagine beforehand. Because of this focus on 'how', mapping becomes a primary concern.

RW: I am aiming for a result that I believe will be interesting and aesthetically pleasing. I am analytical in the sense that I think carefully about which of the many possible

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mappings might work for the piece. I do this not by thoroughly decomposing the problem, but by considering the kind of output the gesture or object seems likely to give me. Then I try various mappings moving from one to another via intuition. I try not to intervene in the results produced. For me, the need to regularly intervene indicates there is a basic problem with the mapping.

PD: I do not often use an analytical approach; I prefer the creative approach with its greater freedom. For me, the music is the main goal. I will intervene in the process to achieve the aesthetic result I want. If I find that the mappings are not working and that I need to intervene continuously, I will revisit the mapping, not the overall structures as these are fundamental to the musical idea. Typically, by this stage I have a structure and data in place that I think is important for the composition, so the mappings will be manipulated to get the music.

(4) Is the mapping component of your compositions something that you think might be perceptible by a listener, or of interest to them and why?

RB: It is certainly perceptible, I think, because it's so intertwined at every level with the poetic identity of the music. I don't intend that it should be explicit all the time, of course. For example in the first half of my piano piece *Tract* you become gradually aware, over the course of twelve minutes, that there's an accelerating movement of both hands traversing the keyboard. As the speed and extent of these traversals increases, this process almost imperceptibly comes into the foreground. Previously this process has only been intermittently perceptible as such, unless you are interested in listening out for it. One might of course experience this just as an escalation in intensity, it just depends on the listener's perspective. Most people would aver that the 'mapping component' is of no interest to them, but actually if you experience this piece as something powerful and expressive, that's what you're hearing. Think of Xenakis. It took him many years to convince listeners that while his statistical procedures *are* on a certain level what the music is 'about', he chose to use them as a result of *musical* priorities. Different types of statistical distributions applied, say, to an orchestra, are different sounds, different atmospheres.

CMD: In *EMF*, the mapping is very obvious to the ear. The melody goes up to reflect higher reading in the data, and so on. Thus, it reaches the listener on different levels – aesthetic, but also the physical correlation of the data.

LP: It's hard to perceive, certainly impossible at the level of complexity that it's conceived, but not impossible. In all my pieces, since I'm kind of a formal purist, or rather, sort of shy of ornamentation and drama for their own sakes, one hears clear processes, deliberate formal trajectories. Often, as in *51 Melodies* or the *Casten Variation*, it's more or less obvious what's going on, but not in detail. That's one of the reasons I write so much about my work, because I think that's necessary, and not in a bad way, or because I think the work is incomplete. I think the world is incomplete in the way that often ideas are written off as ancillary because they can't be conceived or felt immediately. We don't immediately perceive differential equations, but they're both beautiful to understand on their own and consequential to our existence. Neither does per(e(xc))ception of the rules and usages of English rules/grammar in every sentence used in detail explicit itself as us, but boy do we, feel, them, if used by us irregularly they are(ent). In any case, I believe strongly in sound, in music and in idea, and feel no need to give any of them a lack of respect.

ADS: To tell the truth, I am not sure I understand this question. Or, better, I see many implicit assertions in it that must be questioned. I don't think any mapping operation can be at all perceptible *per se* – unless you present the listener with several different mappings of one and the same body of data, repeatedly, such that he or she can make a comparison, so to say, between different mapping criteria. In such a particular instance, mapping may become the very object of musical experience. Yet, even in that case the comparison itself depends on the perceptual relevance of the phenomenal domain of the map. In some compositions dating back to the late 1980s and first 1990s, I have used mathematical models of nonlinear dynamical systems (chaos theory) in order to shape the overall formal configuration, or structure, of the work. Clearly, the final structure *is* directly connected to the constructive details, including mapping. But I don't presume that it might be *objectivised* by listeners, that it can be perceived and recognised as the mapping of such and such body of data obtained by such and such model. That would be the case with the sonification of data. The relevance of sonification depends entirely on mapping criteria. In music composition, this is far less critical, because eventually all the distortions caused by the mapping operation may be accepted, if they suggests musically relevant by-products. It is well known that in composition, all errors or noises are potential bearers of additional information – that would not be acceptable in the sonification of scientific data. In music, the mapping remains a scientifically arbitrary operation, but maybe reflects a compositional necessity. I am not interested in projecting the properties of some mathematical model on to some audible phenomenon in such a way that the model be recognised as the generator of some musical shape. No, I am interested in the emergence of musical form, or timbre for that matter, that would be the case of algorithmic microcomposition, for example, the automated granular synthesis or other direct synthesis methods. It's the emergent properties of the mathematical model which are the very object of the mapping, which should inform the audible phenomenon, be it extended musical structure or single sound event. Listeners may be interested in the model and in the mapping technicalities, but I don't presume that in the listening experience the emergent properties of sound can be perceived as a linear connection to the model or the mapping operation.

RW: Some of my mappings have been so obvious that if the listener has read the program note and is awake, they cannot help but notice the mapping. On the other hand, most are not perceptible. I suspect that most listeners who are interested in the mapping component are people who want to compose works in an algorithmic manner.

PD: I think that at least some of them are perceptible to the listener, but there are typically many so I do not expect

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that all of them would be perceptible. I cannot say if it is of interest to the listener or not, perhaps it is to a few – it is important to me in as much as it leads to musical concept that I'm trying to convey. Perhaps the mappings are somehow perceptible in the oppositions and tensions that I set up in a piece, although I use the mappings to try to make such tensions and explorations palpable, not to be perceived in themselves. I will often want the listener to perceive a sensuous, multi-dimensional surface or space, so in the manner that the mappings transmit this from the conception to the music and the listener, I think they are perceptible.

(5) Is the mapping component of algorithmic composition something that is pre-determined for you or is it part of a process of exploration?

RB: I try to predetermine as little as possible. As I mentioned before, I want to retain the same high level of involvement throughout the process of making a composition. When I can identify some kind of 'principle' at work, I will then always try to imagine and indeed to realise something which contradicts this principle, since I don't want to get into thinking of 'right' and 'wrong' ways of doing things in composition. It's a different kind of logic. It might lead to contradictions, but it's there that one can sometimes glimpse the possibility of new ways of thinking. Often my relationship to algorithmic composition is of being influenced by it rather than doing it, particularly in electronic music. In a score one is always dealing with the relatively small number of parameters which can be encoded in notation, and which interact with an interpreter to produce a complex, 'living' result. In using a recorded 'natural' sound in electronic music, for example, one is already immersed in this complexity, which often isn't reducible to a parametric description. Also in vocal music which uses a text, there's a structural layer of the eventual composition which is pre-existent in all its semantic multidimensionality. So a strictly algorithmic approach is one extreme point that my work can occupy, as opposed to a 'strictly' intuitive approach; of course these extreme points don't exist as such, everything occurs somewhere between them or is in motion in one direction or the other. The exploration is the important thing, regardless of what kind of vehicle one uses.

CMD: In *EMF* it was predetermined, in the other works I spent a lot of time exploring musically useful and interesting limits to the mapping.

LP: To me, it's the latter – exploration.

ADS: I think it's part of the exploration.

RW: I don't usually start with a set idea about the kind of music or sounds that will make up a piece, and if I do have some general idea, it is extremely vague. I tend to have a 'working' mapping in mind for each type of material I consider for the piece. The mapping I use may change, as described before. I try to find a mapping that suits the material, not necessarily a mapping that will produce particular, previously designed ideas about the sounds of the piece. Since I very often don't stay with the original 'working' mapping, the choice of mapping is part of the exploration.

PD: Mapping is definitely part of the process of exploration. I tend to have a conception of a piece and the structures within it. I work at this level for some time and when the foundations are well laid and solid I start working on the mapping to generate the audible result I want.

(6) Do you use individual mapping strategies for individual parameters or is there reuse of mapping strategies or a global system? (i.e. are they monoparametric or multiparametric?)

RB: I am naturally drawn to 'global systems' which contain an internal network of relationships and symmetries, which themselves relate to the structural symmetries of a composition. When I was working on my chamber opera *Unter Wasser*, which uses a text by the Austrian writer Margret Kreidl, I didn't want to change a single word of the original to fit my compositional desires, but instead I imagined that the text itself was constructed according to the same principles as I would use for the music, although of course it wasn't, so that in the end the text and the music should appear as if they both emanate from the same complex of symmetries and proportions. That kind of strategy might be seen to encapsulate my commitment to establishing a deep unity between all the processes and elements which constitute a composition – even between algorithmic and nonalgorithmic aspects.

CMD: I use individual mapping strategies for individual parameters.

LP: Depends. I don't like the historical reference of this question, because it seems to me to have evolved as a kind of a political question, and as a way of composers making rather historicaly pernicious statements of self-annointment. It just depends on the piece.

ADS: Well, neither would actually reflect the way I approach it. I try to explain myself more precisely in the answer to the next question.

RW: Some of both. In some cases it might be true that using the same or similar mapping strategies across parameters helps unify a piece.

PD: For each 'line' of gestural or structural control I tend to use a single mapping, at least for the period of that compositional gesture, but this will be different from other mappings in the piece. I will also sometimes vary the scale of the mapping according to another parameter. For example, in a recent piece I varied the resynthesis 'stickiness', how easily a new harmonic would be triggered, with a gestural parameter, but the resynthesis range was controlled by another gestural parameter with another mapping. This is a somewhat unusual case for me. Also, at the same time, I needed to intervene for a period of a few seconds so that I achieved the required result at a critical point in the piece. This intervention actually was not with the mapping, although it could have been, but with the sensitivity of the resynthesis system at that moment. Of course, this is impossible when dealing with instruments so in such cases I need to adjust the mapping, or to intervene directly.

(7) What elements do you control algorithmically in a composition and can you comment on the function and

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importance of these? Is the mapping consistent within these elements or not?

RB: It depends on what we mean by control. I certainly try to be aware of as many parameters as I can, although not in a reductionist sort of way where various things are evolving in isolation from one another, as for example in some early serial music. Returning to the question of perceptibility, there does come a point where overall tendencies become more important than the elements which constitute them, so that it makes more sense (Xenakis again!) to work directly with those tendencies. However, both approaches have their place for me. I'm fascinated by the idea of a music which teeters between them, between differentiation and proliferation, between being able as it were to see the atoms moving and being able to feel the temperature of their summed movements. I'm always working with a combination of deterministic, random and intuitive influences which together form the music. The balance between them is 'controlled'. 'Out of control' is also a possibility, as is 'inconsistency'. I don't want to exclude anything before I begin.

CMD: Elements – frequency, amplitude, spatialisation are the main ones I have used. Yes, the mapping is consistent within a parameter for a given piece.

ADS: I would use different approaches of algorithmic composition, also within the very same work. Let me point out three different examples, which often intermingle in my work. First, for simplicity, consider a single instrumental part. I would sketch out a number of short, separate musical gestures or events, completely worked out in their pitch or internal rhythm structure. I would have a whole set of such instrumental events or gestures – sometimes I've called it a vocabulary of pre-composed musical events. This is an ordered discrete set, where musical parameters show some linear change from any item in the set to the next (for example, rhythmic complexity would somehow linearly increase, minimal in the first item, maximal in the last item). The set may be a single array, or it may be a two-dimensional array, a matrix, of short, pre-composed events. Then I would use some iterative mathematical model, for example, a number of iterations of a nonlinear function, as a pointer to that array, so I pick-up single musical events, and arrange them one after the other to make a new sequence. The sequence thus obtained represents a rearrangement of the original data, or a selection within the original data. It reflects the behaviour of the model and it usually can be translated directly into the score. This is because the mapping, in such a case, is already done at the very moment when I sketched the ordered set of musical gestures. Sometimes I leave duration aside, as it may be handled either with a different formalised procedure, or more empirically. Clearly, some quantisation occurs in order to project the numerical interval of the iterated function onto the discrete set of data. This is critical. The larger the number of instrumental gestures in the original data set, the more precisely the output of the mathematical model can be tracked. To conclude with this first example, let me add that in most of my works, including an algorithmically generated instrumental line such as *fractus* for viola and tape from 1990, *plex* for doublebass and tape from 1991, or *6 studies* for piano and interactive computer processing from 1996, the sequence of events thus generated represents just the first or last section of the piece. Then, that is taken as a set of data onto which a new selection is applied, again using the iteration of nonlinear functions. That generates a new sequence, that is, a second, or penultimate, section in the final piece, which in turn is used as the new data set onto which another selection is applied, and so on. I stop the process when, due to the redundancies introduced by the iterated numerical mapping, no more significant variations are introduced in the passage from one sequence of events to the next. That is, I stop when a fixed point has been reached, such as one particular instrumental gesture is repeated, or when a limit cycle has been reached, for example two or more gestures repeat all the way through. I tend to use nonlinear function parameters that are not so close to their function attractors, such that fixed points are reached after a few iterations of the process. Clearly, this will result in global musical form with a particular behaviour. As a musical form of its own, it may be well recognised by the listeners. As the musical projection of a hidden process, with its own dynamics, I don't think it can be apparent to them. As a second example, I'll move to granular synthesis. Suppose you have as the initial set of data an audio file with a sine tone sweeping from 20 Hz to half the sample rate. Then you point into such an audio file, with a pointer driven by the output of some iterated function system. Each time, you take n samples within a time span surrounding the selected sample and make a grain out of them, that is multiply them by some gaussian or other envelope shape. Clearly, the frequency contents of the output grain sequence will depend of the pointer history across the audio file. The timbre of the output will depend on both the frequency contents, and the temporal relationship among grains. *Mutatis mutandis*, that is a simple application of the same principle as illustrated before, now in the realm of sound synthesis: while in the former case of macrocomposition, the process translates into musical form, in the latter, microcomposition, it translates into texture or other tumbrel phenomenon. At that point, I would re-iterated the overall operation, again using some nonlinear function iteration to travel across the generated stream of grains, picking-up new samples to arrange into a new stream of grains, and so on. To turn granular *synthesis* into granular *processing*, you simply replace the sine tone in the first audio file with a sampled sound or any other sound material. It could even be an entire musical phrase or complex sonic event, with its own internal development. The time structure of the output stream of samples will reflect the behaviour of the iterated operation, following mapping principles that have been set, depending on file length, and so on. Now, that time structure is, in the end, the basic level out of which timbre emerges: different time arrangements of grains determine different tumbrel by-products. That's an example where *algorithmic composition* and *timbre design* merge. As a third example, consider now that the overall process I've just illustrated can be applied to a set of data consisting of nothing else than sample levels, that is, an array of digital ticks of different amplitude. Clearly, another mapping strategy would be needed, and surely a different model to rearrange the sequence of sample ticks. Conceptually the operation is the same, but now it becomes

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the implementation of a scientifically arbitrary, and hopefully compositionally necessary, direct sound synthesis method. That's the case for most of the non-standard synthesis techniques. My functional iteration synthesis is a case in point. This approach of algorithmic micro- and macro- composition, I've followed for many years, starting in 1987, with a granular tape piece called *Punti di tempo*. On one occasion I have used it for a purely instrumental piece, *Ektopos*, for guitar, or many guitars in unison, from 1997. At some point, around 1994, I felt the need to study if and how it could help me in the composition of live electronic contexts.

RW: I try to control the most important elements of a particular composition algorithmically. The mapping of individual elements tends to be consistent.

PD: Everything! I try to control as many elements as possible, but that control may be more of a general direction, so perhaps I am not such a control freak. I do use a lot of controlled randomness in both structures or gestures and the mappings. The importance of them varies from piece to piece and even within a piece. I suppose I could say the mapping of each element *tends* to be consistent unless I have a case such as previously described, but I also might build in some inconsistencies.

(8) Are the mapping schemas you use mostly linear mappings or nonlinear in some fashion, and why?

RB: That depends entirely on what's being mapped into what, and why.

CMD: I use nonlinear mappings for frequency and amplitude; space, too.

ADS: As I said, I try to keep the mappings linear. This is because, most of the algorithmic models I use are already by themselves nonlinear, and often behave in very complex, chaotic ways. In the piano and computer work mentioned above, *6 studi*, I resorted to a different strategy. The entry point of an instrumental gesture would be determined by a different mapping of time values, ranging from one triple-crotchet note, in the order of few tenths of a second, to longer values. Thus the temporal map could change, resizing for each datum to be mapped. The actual time scale adopted was made dependent on the complexity of the particular instrumental gesture being considered; the more complex the gesture, the longer the time lapse before the next instrumental gesture, that is, the broader the time scale considered for that mapping. Had I not considered this resizable time scale approach, two gestures could eventually overlap and become impossible to perform. As an additional solution, I suggested that the performer freely varies the tempo depending on density and complexity of instrumental gestures, so as to perform complex gestures at a slower tempo and simpler ones at a faster tempo. This establishes a special connection between different aspects of the final, audible, phenomenon, a link of an 'ecological' nature, in a sense, which is clearly audible in the performance momentum, although possibly unconsciously for most listeners.

RW: I use a combination of linear and non-linear mappings as the materials and performance medium seem to demand.

PD: I use a combination of linear and non-linear mappings, depending on the data and the musical parameters to be output. I think I tend to use linear mappings when I have very complex data and non-linear mappings when I have simpler data. I do this because I think it sounds much more interesting in the music.

(9) Can mapping be considered a composition technique in itself?

RB: I would describe it as a tool rather than a technique.

CMD: Yes, mapping can be a very interesting and useful compositional technique.

LP: Yes. Perhaps, in a sense, it is the most important.

ADS: It could, although that is not the case with my approach. Consider, for example, John Cage's *Etudes Australes* and other works where graphical structures are turned into music. In *Etudes Australes* the composer precisely determined how a sky map could be turned into a musical score. In works such as *Fontana Mix*, instead, the performer has to take the responsibility to create a graphical structure and to translate it into music according to a number of indications provided by the composer. In such pieces the score indications essentially consist of mapping rules. The consistency of such works lays less in the identity of the audible results, which may considerably vary at each performance, than in the application of precisely those mapping rules. The algorithmic nature of some of Cage's works appears in such examples.

RW: Yes. However, one must be extremely clever or lucky to achieve an interesting piece by simply defining a mapping of a body data.

PD: I think that mapping is only part of the technique of algorithmic composition. Certainly, someone could take some predefined data, such as weather data, and use mostly mapping techniques to generate a piece of music. However, I tend to think very abstractly about most of my music and thus I like to construct the compositional gestures and data from the outset.

(10) Can you give a concrete example of how you use mapping in your practice of algorithmic composition?

RB: I've briefly touched on a few, but it's difficult to isolate one example without linking it to all the processes and connections which bear on it, which would occupy a great deal of space. I've written more extended treatments about composition methods from time to time, most recently in an essay about *Liebestod* for recorder quartet and electronics in the *Tijdschrift voor Muziektheorie* (but in English!).

CMD: I think the previous example and explanation of *EMF* is fine.

LP: I have covered this above, and in my case, I've tried to write about every piece that does this kind of thing, so I'll refer the reader to my work.

ADS: I have previously referred to works that I composed in the decade 1987–97. I will discuss some more recent works now, efforts that I started already in 1994 with *7 variations on the cold*, for trumpet and signal processing

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computer, available on the Ars Electronica 1995 CD. These works are what is usually called interactive music, or live electronics is an older term. I have to say that I use these terms with profound perplexity. For me, a more useful perspective would be that of an 'eco-systemic' view of composition, according to which a composer focuses on the irreducible interrelationships among the many components that gather together to make a 'system' – that is, on the actual interdependency of forces put together to bring forth a *sys-thema*, a reunion or assemblage of things or processes. Therefore, for me it is a matter of composing the interaction, or, to say it better, to create a meaningful connection between nodes of a network, all of which have links to all other nodes in the network. As a simple, and rather general, example: node A (say, a performer playing flute or any other music instrument) is influenced in its activity by, and itself influences the activity of, node B, say, a computer algorithm which is either sound synthesis, or to transforming the flute's sound; at the same time, nodes A and B are both determined in their development by node C, while simultaneously influencing the development of node C. This is a very general, triangular exchange schema, creating a man-machine-environment feedback interaction network. I feel it necessary, for the purposes of this topic, to highlight that all nodes in such a network are linked in the medium of *sound*: I tend to avoid MIDI synthesisers, as well as footswitches and all sorts of mechanical or visual triggering. I have the computer algorithms change their behaviour depending on properties detected in the instrumental sounds and in the hall acoustics; at the same time, the instrumentalists change their playing nuances depending on what they hear in the sound texture arising from the computer processing. This in turn causes a new response in the hall acoustics and the instrumentalists, and so forth. A low-frequency feedback system. All information circulating in the network consists of differences in the shape of sounds, of their different internal articulation. *Timbre* becomes not only the form or emergent morphology of sound, but also a vehicle of dependency rules, the bearer of a qualitative syntax, where syntax means the qualitative regulator of linking together. In practical terms, this requires that control signals in the computer algorithms be extracted from the live sound input, either the instrumental or the ambience sound. That raises many different questions concerning mapping. For example, how can I map the amplitude curve of the room's resonances onto the density parameter of granular processing algorithms? However, it also requires some decisions concerning the score material. How will the perceived brightness in the computer-generated sound determine some qualitative change in the instrumental parts? Here mapping becomes crucial, even more so when you consider that it refers to phenomena happening in realtime. My *5 difference-sensitive circular interactions* (for string quartet and computer processing, 1998; available on the ICMC2000 CD) is entirely based on that notion. As a general concept behind that work, the mapping strategy is meant to maintain a certain equilibrium between the components. For example, the performers slow down their tempo if the computer is generating very dense sonorities, such that the decreasing density of instrumental events will in the end determine, typically within a controllable time span, a rarefaction in the computer output. In a different example, when the computer 'hears' that higher frequencies are prevalent in the room acoustics, depending on instrumental material being played and the particular room's acoustics, it will avoid processing the input high-frequency material coming from the instruments, such that there will be a balance between higher and lower frequencies in its output. In a sense, the role of the instrumental score here is to provide material for perturbating or stimulating an equilibrium situation; the computer and the instrumentalists have ways to manage the perturbation, so that it will be smoothed out to reach a balanced situation. This is worked out in more improvisational ways in *Texture-Multiple* (for 3 to 6 instruments and interactive signal processing), a kind of work in progress started in 1993, which only recently I seem to have 'finished', thanks to the Ensemble Mosaik and their very good performance in Berlin, February 2002. In such examples, the details concerning mapping would be too many to illustrate. Furthermore, they are entirely comprised at the level of digital signal processing, which I usually manage by programming the Kyma system, which lends itself well to such tasks. It would be impossible to illustrate the details without entering many technicalities. However, I hope this overview gives an idea that mapping in such a situation becomes the very object of composition, because in the end it implements a system, or to say it better a network, where each component influences all other components. What is peculiar is that the body of data being mapped, and the results themselves of the mapping, are both comprised of sound itself. Something like an 'audible interface' is implemented, as opposed to a graphical interface.

RW: In a piece called *Help Me Remember* (available on Volume 14 of the Consortium to Distribute Computer Music Series, Centaur Records CRC-2177) I used a number of mappings. The work is scored for performer (vocals and shaker) and computer music system. In the first movement, 'Listening', the pitches used by the speaking performer are mapped in a nonlinear fashion to generate a synthesised part. In the second movement, 'Looking', and in the third movement, 'Dancing', two different dynamical systems are mapped to produce melodic structures and gestural/timbrel events. In *Saint Ambrose*, a one-person chamber opera for saxophonist and computer music, (forthcoming on Capstone Records) various types of music were mapped to produce music for both the saxophonist and the synthesised sounds.

PD: Previous examples were from a piece called *Continuity 3* for percussion and computer, that explores fragmentation and continuity of musical space. I composed a number of gestures, a simple overall gesture for the main structural element of the piece such that it went from continuous through extreme fragmentation to continuous and then repeats that cycle more quickly. Many gestures were composed to organise parts of the piece, such as timbre, pitch, instrument, technique, processing technique, processing parameters and so on. Because of the multitude and layering or 'polyphony' of compositional gestures, there was a multitude of mappings. Each gesture was mapped to

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the parameters in such a way that the required result was achieved. This did require some experimentation and 'trial and error' to achieve the desired result.

6. TYPES OF MAPPING

From the composers' descriptions of how they use mapping, it seems that there is no set method for mapping data from the domain of the conceptual, gestural or structural to the musical domain. Linear and simple mappings are *sometimes* used by composers, but it can be gathered from the responses that it is used significantly less often than more complex mappings.

Simple mappings have been most clearly described as ratiometric (Polansky 2002). In this type of mapping a doubling of the data to be mapped results in a 'doubling' of the musical parameter. This could be, for example, an octave pitch displacement or a doubling of the loudness. Note that this second linear mapping might be perceptually linear to a particular person under particular conditions, but it would be mathematically nonlinear. Because ratiometric mappings are the easiest to perceive they are particularly useful when the composer has some data, gesture or concept that should be translated as directly as possible for the listener. The previous example of the pitch mappings from Xenakis' Pithoprakta is an illustration of this. This particular example is musically successful because the data to be mapped is very complex from the outset. Simple mappings can be less musically successful if the data to be mapped is very simple.

Complex mappings may be regularly nonlinear, such as an exponential law. For example, a square law will produce a fourfold increase in the musical parameter from a doubling of the data to be mapped. If this is perceptually based it can be perceived as a more extreme or less extreme mapping with changes in the data to be mapped. Other types of complex mappings are as varied as can be imagined. They can sometimes be related to a complex arrangement of the data to be mapped, or other potentially chaotic functions can be involved. This may obscure the original concept, compositional gesture or data, or it may embellish it and give it another dimension. However, there is clearly a limit to how far such complexity in mapping can be taken before all sense of the original data is lost in the mapping. Polansky convincingly suggests that the cognitive weight of complex mappings degenerates rapidly and nonlinearly such that beyond a certain point everything is just 'complex'.

It has been a repeated outcome from instrument design research that humans prefer complex mappings (Hunt and Kirk 2000). This would appear to translate somewhat into the domain of composition, given the previous situation that linear mappings may be most appropriate for very complex data.

In one way, the variety of sophisticated, creative and exploratory approaches to mapping, as embodied in the works of algorithmic composers, is a wonderful outcome and it ensures the variety of music from algorithmic composition. In another way, it means that mapping strategies are reinvented by every composer and young composers do not have easily accessible models to work from. If someone created a categorisation of compositional mapping strategies and a catalogue was built of mapping techniques, then other composers could refer to this and build on it in their own practice. This would be of particular use to student composers (Polansky 2002). In this way, mapping in algorithmic composition could be demystified and more complex, varied and musically appropriate practices could be developed by building on the work of others. The counter argument to this is that there is something valuable in the effort of developing sophisticated mappings for oneself. There is certainly interest in the effort required to play an instrument and how mapping relates to this (Ryan 1992).

Something which has not been explored here, but which would be of interest to some composers, are cultural associations with mapping. For example, are there culturally invariant mappings with some parameters such as pitch or intensity with height? One example from instrument design that has caused problems is the original Theremin mapping of intensity with proximity to a horizontal antenna such that to make a louder sound the performer would bring their hand *down*. This was done for practical reasons so that without a performer there is no sound, but modern theremins allow this to be swapped because of the cognitive dissonance caused by the playing action.

7. CONCLUSIONS

The foregoing indicates that composers who use algorithmic techniques certainly use mapping from one domain to another, often in very sophisticated ways. Also indicated is that there is no ideal solution or single method, but that it is often a process of exploration. Very simple or obvious mappings are sometimes problematic in composition probably because of the oversimplification, but they may be appropriate under some circumstances such as with very complex data. More complex mapping strategies are more common and more musically useful, but very numerous and their application and musical usefulness appears to be an aesthetic judgement of the composer. There seems to be almost as many approaches to mapping as there are composers. It is the character of composition, being an expansive and creative activity, that if ever a theory provided a 'standard', 'optimised' or 'ideal' mapping technique or repertoire, that composers would ignore it and go beyond that. Having said that, there would appear to be *something* to gain by creating a catalogue of historical and current mapping practices, even if only in a pedagogical sense (Polansky 2002). The nature of composition

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and composers means that there will never be a 'solution' to the mapping problem in algorithmic composition, that it will remain a part of the exploration.

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