Procedural Composition
An Overview

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Each reader reads only what is already inside himself. A book is only a sort of optical instrument which the writer offers to let the reader discover in himself what he would not have found without the aid of the book.
- Marcel Proust.

I believe that at the end of the (20th) century, the use of words and general educated opinion will be altered so much that one will be able to speak of machines thinking without expecting to be contradicted.
- Alan Turing.

Part 1: brains, computers and language

Introduction

The roles played by the silicon computer in algorithmic or procedural music composition[1] (discussed in [Worrall 1990]), are changing and are at often, at best, misunderstood. By procedural composition I mean composition of works, in whatever media, that are composed by programs or scripts, ie. notations that specify the formal directions and procedures necessary for their making. For this type of artistic enterprise in the Western world today, computers, although not the only means, have become essential tools for both artistic conceptioning and expression.

In procedural composition there is an importance on the process of making: it emphasises an aesthetic of procedure and process over time-invariant final "products", "objects" or "works", (on which Lydia Goehr [Goehr, 1992] has some interesting insights) and computers are more often than not integral to the realisation of the works themselves. Of course the proceduralist movement has its historical precedents, some as far back as early tribal ritual practices. Some of the more contemporary precedents are outlined by Rosebush for the visual arts [Rosebush, 1993], and Loy for music [Loy, 1991].

Because of the overt use of computers in the composition process, the movement has its critics who delight in raising all sorts of "reasons" why computers can't compose. In order to address this, I discuss present and possible future relationships between computers and humans, as well as the nature of the brain and the role of abstraction, imitation, objectivity, logic, and ambiguity in creative work in order to contexturalise a summary of the main features of proceduralism. Needless to say this topic covers a wide range of disciplines and so I've included an extensive bibliography for those interested in pursuing the topic further.

Computers: just machines?

There has been a general mistrust of new technology since the industrial revolution. This is understandable but misdirected towards the machines instead of the people that use them less than honourably. There is a kind of machine karma: as mankind creates machines, these machines in turn shape their creators and users. Also, just as machines are part of our evolutionary process, there is also a machine evolution (machines making machines).

However as Brand explains [Brand 1987], during the three centuries leading up until World War II the model for technology was a mechanical one, ie. organized around energy in the physical meaning of the term. Since the end of the war however, the model of technology has become the biological process, where events inside an organism are organized around information. This is part of a more general process of the blurring of distinctions between the animate and inanimate: Today we live in a world in which the distinction between the real and the manufactured (including by genetic manipulation) is unclear. A world in which animate and inanimate are becoming indistinguishable; in which 'reality' is becoming defined differently.

The word "machine" is becoming to be out of date. For centuries, words like "mechanical" made us think of simple devices like pulleys and levers and later locomotives and typewriters, but we ought to recognise that machine development is still in its infancy, and we have little idea of what they may become. Present-day computers have millions of parts and work on a scale never before thought possible and yet, we continue to use old words as though there had been no change at all: the term "machine" is no longer a useful classification.

For example, as Minsky explains [Minsky, 1985], we are likely to make the mistake, even with today's moderately complex machines whose design is based on neat, logical principles, of expecting the machine to behave in a similarly neat and logical fashion. The mistake is that we confuse what goes on inside the machine (how it "works") with our expectations of how it will appear to behave in the world. Being able to explain in logical terms how a machine's parts work does not automatically enable us to explain its subsequent activities in simple, logical terms.

To a certain extent it's true that machines can do only what they are designed to do but this does not preclude designing machines that think. For

[1] Unless otherwise indicated, I use the terms "composer", "composition" and "work" as generic terms, for all the arts, not just music.

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example there is nothing to prevent us from using logical language to describe illogical reasoning and so by extension, works of art that don't appear at all logical can be created with logical reasoning!

In real life , we use logic to simplify and summarize our thoughts, to explain, to persuade and to reformulate our ideas but we don't often use it to suggest new ideas or actually solve problems. We use logic to separate the essential parts from the tangles of thoughts and ideas in which they first occurred, in order to "clean things up" after we have constructed or "got" them in other ways. In any such process, logic can be only a fraction of the reasoning; it can serve as a test to keep us from coming to invalid conclusions, but it cannot tell us which ideas to generate, or which processes and memories to use. Logic no more explains how we think than grammar explains how we speak; both can tell us whether our sentences are properly formed, but they cannot tell us which sentences to make. Without an intimate connection between our knowledge and our intentions, logic leads to madness, not intelligence. A logical system without a goal will merely generate an endless host of pointless truths. As John Cage used to say, "any system that is completely rational is irrational in the extreme".

Are brains machines? Many people object when their mind is likened to a computer because they say that they don't feel like a computer. Yet clearly, if they're not a computer they don't know what it feels like to be one. Knowing how to use something is not the same as knowing how it works. This is like saying "I sing*, therefore I know how* my voice *works*". Importantly though, there is a qualitative difference between what brains do and what simple machines do. Brains *change themselves and* this means the processes and products of the brain cannot be separated. Specifically, brains make memories and these memories have an influence on later ways of thinking. A major *activit*y of brains, then is to *mak*e changes in themselves. Computers, even though they are still in their infancy, are complex machines and are perfectly capable of changing themselves and each other. Whilst Minsky's analysis of the similarity of brain and computer is extremely lucid, he makes some rather large leaps between brain and mind. I concur though, that there is not the slightest reason to doubt that brains are anything other than extremely complex machines with an enormous number of parts that work in perfect accord with physical laws. The serious problems come from our having had so little experience with machines of such complexity that we are not yet able think effectively about them.

Abstraction

Because nature cannot truely be observed but only approximated, there is no purely objective reality, every "thing" we perceive is partly our own creation. If it were possible to perceive how things "actually are" it would be as useless as to watch the random dots on an untuned television screen. What is important, is being able to see what things *look like.* Yet things are no more what they "are" visually than aurally. Perhaps this point is clearer if you close your eyes and imagine your world using sound as the only perceptual domain.

The very idea of an object involves making many assumptions such that it has substance and boundaries, that it existed before we perceived it, that it will remain afterward and that it will act like other objects. Though we never see every side of an object at once, we always assume that its unseen sides exist. This is why, much to the dismay of the solipsists, our brains have special machinery for representing what we see or hear in terms of distinct "objects".

Abstraction and ambiguity

Just as words and sounds are merely catalysts for starting mental processes, so too are real things: we can't sense what they really are, only what they remind us of. U*nless we make assumptions, the wo*rld would simply make no sense. This was also Proust's insight (as quoted in the introduction). Language builds things in our minds, yet words themselves can't be the concretion of our thoughts because they have no intrinsic meanings by themselves (except perhaps for onamataopoeic words and mantra), they are just marks or sounds. Words don't denote or represent, they control: each word makes various changes to our thoughts. Our thinking-in-words reveals only a fragment of the mind's activity and we do this with no conscious understanding of where and why those words originate or how they proceed to influence our thoughts. The words seem to hover in some abstract void: we understand neither the origins of the signs and symbols nor the way they lead to thoughts. This is why words can seem magical: they work without our knowing how or why. At one moment a word can seem meaningful, at the next it can seem no more than a sequence of (imagined) sounds. Try this little thought experiment: Think about anything you like, but don't think about "elephant". (Careful now, satori awaits!). It is precisely the underlying emptiness or at least ambiguity of words and other symbols (their abstractness) that gives them their potential versatility. The less meaning there is associated with the them, the more meaning can be attached to them.

The idea that languages do not have to mean is a paradox. What are languages if not a devices for communication meaning? As they shed meaning,

languages begin to touch the universals of communication, and this universality is an aspect of its transparency. When languages are pushed by various strategies towards transparency, they seems to abandon their capacity to mean in the normal sense of the term. You might say their poetry becomes the poetry of nothing. This is the attraction of glossolalia (speaking in tongues), the writings of the mad and particularly the autistic: they allow participants to touch a more fundamental more ego-less Self.

We often find it hard to "express our thoughts"-- to summarize our mental states or put our ideas into sounds, or images or words. It is tempting to blame this on the sounds, images or words, but the problem is deeper than that as Minsky points out: "t*houghts themselves are ambiguous!* In order to "express" your present state of mind, you have to partially anticipate what some of your agencies are about to do. Inevitably, by the time you've managed to express yourself, you're no longer in the state you were before; your thoughts were ambiguous to begin with, and you never *did* succeed in expressing them but merely replaced them with other thoughts. ...It is an illusion to assume a clear and absolute distinction between "expressing" and "thinking," since expressing is itself an active process that involves simplifying and reconstituting a mental state by detaching it from the more diffuse and variable parts of its context".

Abstraction and universality are qualities also associated with science and mathematics (which even from ancient times was that most abstract of the arts). The primary tenet of Pythagorean doctrine for example, was the belief that numbers are the ultimate constituents of reality [Heninger, 1974]. By number they meant a form determined by an arrangement of points where number exists, independent of space, as an abstract concept. The number is pure form (in the abstract, divorced from matter), uncreated and unchanging, non-physical and atemporal. They felt that if the divine was manifested, it would be in geometry and number, not in matter. Matter is appearance, number is reality. Gödel of course was able to prove that the presence of ambiguity in any formal system was an integral part of the system!

Werner Heisenberg in his essay *The Tendency to Abstraction in Modern Art and Science*. [Heisenberg, 1952] says

> We live in an era of world culture and Art must depict this situation.. In doing so it must move in the direction science has taken in the description of nature... "The tendency ... answers to the tendency in science to regard the whole of nature as a unity... The realisation of this program has pushed the sciences on to ever higher levels of abstraction, and the relation of our life to the whole spiritual and social structure of the earth will also be capable of artistic presentation only if we are ready to enter into regions more remote from life. (ie. more abstract).

Part 2: some features of proceduralism

Computers are here to stay!

Now that computers have become an integral part of our lives, now that it is just considered "quaint" for someone to protest that the pen is mightier than the processor, now that even the most traditional of artists are prepared to admit the usefulness of computers in designing Art (from furniture to orchestral scores), it is necessary to be specific about the ways the computer is used in an artistic undertaking for the term "Computer Arts" to serve any useful purpose.

Even so, most of those who engage in procedural composition have experienced the disbelief in people, including and especially many "art workers", that art can be made with computers or that a computer can make artistic decisions, or at least that the results of these decisions are somehow devoid of emotion, "mechanical" and inhuman. When it is suggested that one day we will have machines that compose music, dance, write plays and poems and create retinal images as emotional expressions of their mind states, most people fold their arms and mentally confine you to the "fairies at the bottom of the garden" looney bin. Yet, I do not believe this to be at all fantastical as I believe most of this fear arises out of false assumptions about the interrelationships between computer, brain, language, emotions, creativity ambiguity and originality that I mentioned in Part 1.

Command and control

Procedural compositions are made using a command and control structure: not simply with predefined tools to simulate classical composition methods (automation), but in the innovative design and use of new tools in order to expand the procedural possibilities of the art. For example, programming fractals on a computer and producing images and sounds is procedural because it introduces an entirely new class of compositions and compositional parameters compared to a through-composed work.

Procedural composition enables the composer to consider music and animation as worlds defined by (mathematical) spaces - particular aggregates of items inhabiting a situation that can be altered according to a certain number of variables rather than as a traditionally defined discursive argument drawn from linguistic images.

Fundamental shifts in attitudes towards forming processes results in changes in form. The

influence of biological processes on contemporary thought: the acceptance of change as normal - and thus the increased importance of transience vs permanence, of process, results in artists being less concerned with the production of finished objects that reflect well-established structural models. The formalised nicety of clearly defined beginnings and endings is often discarded. Experiences tend to evolve gradually (sometimes beginning arbitrarily) and end simply by fading away. The listener "samples" a process that existed before and will continue to exist after the immediate occasion has passed. Clearly defined forms of experience seem arbitrary to many artists who opt for the less constraining sample skillfully selected.

Composing with abstraction

Composing with the use of abstract languages is an essential part of composing procedurally. It affects the very essence of the creative process as the aesthetics are bound up with complexity as ambiguity and with "removing control". The use of abstract languages and processes tends to lessen the still powerful bourgeois link between art and ego: to encourage the surrender of the self to the half-seen, gliding beautiful things glimpsed in a moment of reverie. Xenakis puts it like this:

> The listener should be "griped and drawn willy-nilly into the circle of notes, without any special training being necessary. The sensuous shock must be as palpable as that of heaving thunder or looking into a bottomless chasm.

Emphasis on relation over object

Today procedural art of a considerable and previously unimagined complexity can be made. Whilst the procedures may be either relatively concrete or very abstract, proceduralism almost always involves modelling. The subject matter may be abstract (eg. distribution of random events) or it may be realistic (eg. simulation of hair or singing voices). Whereas in the past composition was restricted to a certain repertoire of generative and accompaniment figurations defined by the prevailing common practice (sonata form for example), one may now select almost any human or environmental factor as the basis for an independently established continuity for composition.

The proceduralist's construction process is different from past approaches in that it does not attempt to create the "object" directly but by formulating commands and procedures that describe the behaviour of a conceptual model. The resulting image/sound is manipulated conceptually by manipulating these rules and their arguments. The reduced importance of the object is fundamental to proceduralism and continues the conceptual art movement more in that direction. This move away from objectivity (and I include such sterile movements as visual arts post-modernism) is not to be underestimated because as Lévi-Strauss observes [Lévi-Strauss, 19??]

"It is this avid ambitious desire to take possession of the object for the benefit of the owner or even of the spectator which seems to me to constitute one of the outstandingly original features of the art of Western civilization."

Spontaneity

The spontaneity of this aesthetic is one of its most striking - and also its most serious feature. The playfulness is like that of a science that produces game theory and virtual particles and black holes and the uncertainty principle. An ever playful, youthful power that makes order where it wants and having made it, is quite capable of demolishing it and beginning again, purely , as a child in play might with a set of blocks.

Yet amidst all that, individual style still comes through, independent of calculations. Any choice presupposes some arbitrariness of choice because it is human construction which is not always arbitrary in some way. Spontaneity can be had simply by relaxing conscious control as in the chance operations of Pollock, Ginsberg, Coltrane, Cage etc. The inertia of subconsciously governed process is not so easily disrupted. Choosing by "taste" is simply a strategy of using forms that lie beneath the surface of our thoughts. Such decisions might seem more constrained if we were aware of how they're made.

Procedural composition by computer affords the opportunity to relax the conscious controls even more, indeed this is a common criticism of procedural composition: The composer gives up the ability to know his material intimately. Messiaen puts it this way [Xenakis, 1985]:

> I can't write out the millions and millions of permutations ... and yet I must write them out in order to know them and to love them (I insist on the verb *to love*!). In your case, a machine will give you the millions of permutations within a few minutes: its a cold and unexplicit list. How can and do you choose directly from within this immense world of possibilities without intimate knowledge or love?

Xenakis' reply is revealing:

> The question of having to love something in order to have to use it naturally implies an initial taming. ....When I look at a starry sky, I love it in a certain way because I know it in a certain way; but if I must know the successive stages of astrophysics, well that may happen without love.

> Love would here be surpassed by a kind of revelation which is beyond the epiphenomenon called love. Consequently I can handle the concepts of things themselves without being in direct possession of them, under the condition that I may conceive of them and feel them from within in some way. ... This is fundamental. ... Even if I am incapable of dominating a certain phenomenon, I am capable of obtaining a truth which is inherent to the conceived or observed phenomenon, thanks to a kind of immediate revelation. Henceforth I can accept and use this in an as itself. When I tape-record a sound I don't know exactly what is in this sound. I perceive things which interest me and I use them. Therefore , I cannot love the things within this sound which are so refined that I cannot totally perceive them. I am not consciously or unconsciously capable naming them, but I accept the whole, in itself, since I am attracted by that. .... Man's two crutches are revelation and inference. In the artistic realm both are valid. In the scientific domain inference takes precedence.

Whilst for Messiaen it is a difficult problem to choose amongst a vast number of possibilities when in fact the ears, eyes actually function in that manner: they receive an enormous quantity of information and choose amongst the millions of possibilities "off the cuff". The cuff of the ear or the eye functions in the same manner as a computer, it receives 50 million bits sequentially that it sorts out and faithfully transmits to the brain. Consequently there is no opposition between what is called power, inspiration, event, "sensorality" and making a choice among a vast number of elements.

The top down approach

In more traditional composition one starts with the detail and then brings into play processes of development. With these new ways of structuring one can't always do this. One must establish an overall conception of the work and afterwards choose material and "massage" its elements one against another conjointly or independently until it becomes organized. With the aid of computers the composer becomes a sort of pilot and composition becomes the making of "aesthetic instances".

Traditionally, music compositions have been by linear addition. Computer programming has opened up speculative horizons: one can try out ideas from a broad range of possibilities that it was previously impractical or impossible to test. One can go beyond exploring the orderings and patterns of events using a series, for example, to more general processes such as patterns of change (gradients and deviations) and divergences (relative size of deviations). Issues of continuity and discreteness (in pitch, time, timbre etc) can be examined in a way never before possible.

Given the levels of daily noise to which each of us are subjected, selection (filtering) rather than construction or development is a more common social activity and the found-object and procedural composers can explore this paradigm freely. The composer and/or audience can subtract rather than add: adapt rather than determine, persuade rather manipulate and this fundamentally challenges the idea of art as a message-bearing medium. Roger Reynolds [Reynolds, 1975] cites Ben Johnson:

> We have more use today for the ability to concentrate in the midst of distraction than for the intellectual ability to follow intricate patterns. Value accrues not to the production of detailed textures but to the human selective capacity. The computer is the first instrument to enable the presentation of a multitudinous amount of data effortlessly. In the past, economics, taste, and the practical barriers to rapid transfer of information and large-scale retention all served to limit the composer. They no longer do so.

Consequences of new procedures

When you shift perspective from how information is sent to how it is sought, different patterns takes shape. Once discovered, many of these notationally mediated variables reveal combinations and domains that are simply absent from traditional artistic experience. Whilst it is true that an illustrator could conceptualise a "Bucky" Jitterbug opening and closing to allow flocks of minimal birds to fly through it, it is the practice of exploring what one can do with texture-mapping or transformation geometry that prompts many of these kinds of realisations. That is, the process of manipulating the sound or image procedurally involves a type of creativity that would not be present if the problem were approached in a different way: Invention does not happen in an abstract intellectual way, it happens during the process of solving real problems. Our tools shape our thinking and clearly notation is a tool for thought[Iverson, 1980], so different tools encourage unexpected ways of thinking.

The future of proceduralism

A focus of concern for composers wishing to expand the useful scope of their activities is in structures more fundamental than sonic and/or visual realisations (for example in outside-time structures)[Worrall, 1982] . The computer is the natural tool for such investigations because of its usefulness in trend investigation and it will encourage a return to the abstract "spatial" concerns of earlier and non-western musics.

Loy [Todd & Loy , 1991] observes the likely reason for the failure of prescriptive composition based on attempts to project from analysis is the "ungraceful" handling of ambiguity. Structural ambiguity is very common in most forms of music

(a tensioning device) due to its inherent parallelism (melodic/harmonic, rhythmic timbral dimensions).

The idea of music as the interweaving of expectation and surprise was developed by Meyer in 1956. His ideas were strongly influenced by the original work in information theory by Shannon and Weaver. His idea was that it is necessary to have tension between different formal structural dimensions to acheive sustained attention. Although probability is ideally suited to dealing with surface structures (textures), it fails to engage parallel structures on a deep level. However, the modelling of biological processes and the training of neural networks to produce new levels of structure, new compositional environments, seems very promising.

Conclusion

It is regrettable that some critics are waiting for the 'computer arts' to mature, because in reality, it is clear that its major aesthetic themes already exist. In practice, the proceduralist computer arts are amongst the most contemporary products of our culture and will increasingly be appreciated as a major movement in the arts by future generations.

Silicon devices are very new. They are evolving rapidly, and there is no reason to believe, at least for the moment, that their evolution is about to reach a dead-end. Many of the intellectual abilities of carbon man have already been modelled in them, and a great deal of what is important to the spirit of carbon man will probably be modelled in silicon before very long (on an evolutionary timescale). To me, this sounds more like the birth of humanity than the death of mankind; another part of the search to find out who or what we are and where or when we're going.

References

Blakemore, Colin & Greenfield, Susan (eds.). *Mindwaves : Thoughts on Intelligence, Identity, and Consciousness*. Oxford, UK ; New York, NY, USA B. Blackwell, 1987.

Brand, Stewart. *The Media Lab: Inventing the Future at MIT*. New York, N.Y. Viking, 1987.

Burtt, E.A. *The Metaphysical Foundations of Modern Science* . Doubleday, 1954.

Goehr, Lydia. The imaginary museum of musical works : an essay in the philosophy of music. Oxford University Press, 1992

Hardison, O.B Jr. Entering the Maze: *Identity and Change in Modern Culture* . OUP, 1981.

Hardison, O.B. Jr., *Dissapearing through the Skylight. Culture and Technology in the Twentieth Century*. Viking Penguin, 1989.

Heisenberg, Werner. "*The Tendency to Abstraction in Modern Art and Science*". in *Philosophic problems of nuclear science.* tr. F.C. Hayes. London, Faber & Faber, 1952.

Heninger, S.K, Jr. Touches of Sweet Harmony - Pythagorean Cosmology *and Renaissance Poetics*. The Huntington Library San Marino, California. 1974

Iverson, Kenneth. N*otation as a Tool for Thought*. The 1979 ACM Turing Award Lecture, Communications of the ACM vol 23 #8, 1980.

Jaynes, Julian. *The Origin of Conciousness in the Breadown of the Bicameral Mind*. Houghton Mifflin Company, 1976.

Lévi-Strauss, Claude. Conversations with Charles Charbonnier, tr. by J. and D.Weightman. London, J.Cape, 1969.

Lewis, Aerhur O. Jr. *Of Men and Machines* . E.P. Dutton, 1963.

Loy, D Gareth. "Connectionism and Musiconomy", in Todd, Peter and Loy, Gareth Loy (eds) Music and Connectionism, MIT Press, 1991.

McEvilley, Thomas. *The Opposite of Emptiness: On Spirit in Art*. Art Forum, 25 March 1987, pp. 84-91.

McCorduck, Pamela. *Machines Who Think*. W.H Freeman and Company, 1979.

Marinetti, F.T. *Selected Writings,* tr. R.W. Flint et al. Farrar, Straus and Giroux, 1971.

Milic, Louis T. "Winged Words" , *Computers and The Humanities, 2* . Sept. 1967.

Milic, Louis T. "The Possible Usefulness of Poetry Generation" *Institute of Applied Linguistics*, 11 (1971)

Milic, Louis T. *Erato* . Cleveland State University Poetry Centre, 1971.

Minsky, Marvin. *The Society of Mind*, Simon & Schuster, 1985.

Minsky, Marvin & Papert, Seymour Perceptrons, MIT Press, 1988.

Perloff, Marjorie.*The Poetics of Indeterminacy: from Rimbaud to Cage.* Princeton UP 1981.

Reynolds, Roger. Mind Models. *New Forms of Musical Experience.* Praeger, N.Y. 1975.

Rosebush, J. "The Proceduralist Manifesto". Languages of Design Vol #2, Lauzzana, Ray & Penrose, Denise (eds). Elsevier, Amsterdam, 1993.

Searle, John R. *Minds, Brains and Science : the 1984 Reith Lectures*. London : Penguin, 1989.

Tzara, Tristran. *Approximate Man and other Writings*, tr and ed. Mary Ann Caws Wayne State UP, 1973.

Weizenbaum, Joseph. *Computer Power and Human Reason : From Judgment to Calculation.* San Francisco : W.H. Freeman, 1976.

Worrall, David. *Getting On With Time*. Procedings of the Conference on Music Analysis, Melbourne University, Oct. 1982.

Worrall, David.*The Computer as Alter-Ego: The Use of Computers in the Composition of Music.*

Procedings of the Australian New Music Conference, Brisbane, Aug. 1990.
Xenakis, Iannis. *Formalised Music*, Indiana University Press, 1971
Xenakis, Iannis. *Arts/sciences : alloys*. New York : Pendragon Press, 1985.