

Physicality and Notation, Fundamental Aspects of Generative Processes in the Electronic Arts

Alan Dorin

School of Computer Science and Software Engineering
Monash University, Clayton, Australia, 3168
aland@cs.monash.edu.au

Abstract

This paper discusses some fundamental aspects of digitally produced, process-based visual and aural art. Specifically these are its basis in the physical world; its representation using formal abstract notation; and finally its re-emergence into the physical world as an event or artefact to be experienced by a human observer.

Notations for representing temporal and spatial events are discussed in light of their contribution to process-based art making. Parallels are drawn between the specification of musical notes and the specification of locations in physical space using abstract sets of symbols. It is shown how the development of notation paved the way for the digital synthesis of artefacts and events.

Finally, this paper speculates on a future direction for process-based art—the development of computer-controlled *form*—and shows that conceptually it is an extrapolation from existing computational techniques for event and artefact synthesis.

Keywords: generative art, algorithmic art, procedural modelling, algorithmic composition

1.0 Introduction

«The line is made up of an infinite number of points; the plane of an infinite number of lines; the volume of an infinite number of planes; the hypervolume of an infinite number of volumes. ...No, unquestionably this is not—*more geometrico*—the best way of beginning my story.» Borges [2]

Humankind has long played the role of creator. No other creature on earth shares our obsession with bringing novel artefacts into existence. This places us in the unique position of not only *being* (the result of) a physical process, but being a physical process obsessed with bending other processes to its own.

A process is any connected sequence of events or actions, it is closely linked to the concept of an algorithm, a sequence of steps for carrying out some task. The concepts of *process* and *algorithm* are linked with those of dynamism and change, with *becoming*.

When a process creates a new entity or brings about a novel circumstance, it is a *generative* process. Generative processes, and their representation in computer programs as algorithms, are of particular interest in this paper, and in the papers and other works documented in this volume of the proceedings of *First Iteration*. Generative processes cause sand to form dunes; they produce ripples on a pond, the raging flames of a bushfire and the wind that fans them. All living organisms are defined by the dynamics of generative processes.

Frequently, a stage in a generative process is labelled as its 'final result'. This may be an anticipated static structure, such as a marble sculpture of Galatea [6]. The processes which construct these artefacts have a state after which the constructor steps back and says, "It is done". Not all processes, particularly natural processes, are labelled like this.

A garden for example is never 'complete', it continues to re-invent itself. The garden is intrinsically dynamic, always in a state of *becoming*. The generative process which creates (or *is*) a garden continues like an arrow through time.

This essay is linked primarily by a thread running from physical reality to representation, and from representation back to physical reality, an idea which shall be explained in more detail shortly. This path is an alternative that runs counter to the most common approach, that adopted by the engineers of recent visual-simulation technology. Virtual reality technology attempts to eliminate the final return from representation to solidity by replacing solid objects with two and pseudo-three-dimensional representations.

This 'majority' path is the now familiar track that leads to the conclusion that the human body and the laws of the universe are a hindrance to be overcome. The alternative path taken by this paper emerges from the notion that the physical properties of the universe are *essential* to our concept of existence and experience. Hence the possible future of process-based art presented below seems at odds with the approach taken by the majority of researchers. It is a different branch stemming from the age of physical machines.

2.0 Physical and Abstract Processes

Art is taken in this essay to be any artefact or event produced for amusement, comment, expression, experiment etc. and examined in light of a particular set of aesthetic values (which in practice may be any). ‘Art’ here is not intended to indicate the aesthetic judgement of an elite, but rather to indicate the role of an artefact within a culture or sub-culture. Where ‘art’ is mentioned in the text, the reader may therefore prefer to think of this simply as ‘artefact’. A further discussion of the issue is outside the present scope.

The intent here is to focus on two types of processes and the ways in which they have been applied to art making. They may be categorized for convenience as *physical processes* and *abstract processes*.

Physical processes are those that depend for their path on the properties of matter and the universal laws that govern its interactions. These include the non-interpenetration of matter, the acceleration of masses acting under force and many, many others. Physical processes are further discussed in [4]. Since our sensors, effectors, and brains are physical systems, physical processes are the only processes that can be *experienced*.

Abstract processes are those which involve the manipulation of symbols or representors¹. Although the substance (such as ink on a page or pebbles on a table) of a symbol or representor is forced to obey the laws of matter, the *meaning* of a symbol such as an ink mark or pebble may be any. It is determined only by consensus amongst a group of observers. Abstract processes are therefore changes to a system of representors whose interpretation is made by *convention*. An abstract process cannot be *experienced*. It is a conceptual entity, not a physical one.

3.0 Taming Physical Processes

Perhaps one of the earliest examples of process-based art has adorned shrines across Asia since ancient times. The wind-chime consists of several pieces of metal, glass, seashell, wood or pottery suspended in a location where they may jangle against one

¹ A *representor* is “the thing doing the representing”, a *representee* is “the thing being represented”. Together a representor and representee form a representation. The term *representation* will also be used here in its common form as being indicative of either the representor or the combination of both representor and representee.

another in a breeze. A variation consists of a collection of tubular bells with a central clapper. The clapper is driven by a sail into the suspended columns, causing them to vibrate. Wind-driven clappers may also strike single bells.

The wind-chime is not a device for automatic performance of a pre-arranged work; it is a machine for providing aleatory in composition. Hence it deserves a special place in the history of generative music. Note that the wind-chime's structure dictates the timbres and pitches that it is capable of creating. Although it is capable of producing an infinite variety of sound-events, it may not produce *any* timbre or sound-event. Is there an equivalent artefact in the world of visual art?

A collection of objects suspended on wires and rods so as to be moved by air currents is called a *mobile*. Mobiles were introduced to the modern art world by the kinetic artist Calder [8]. Like wind-chimes, mobiles may form an infinite number of random patterns in their primary domain of interaction with a viewer. Like the wind-chime, the mobile may not produce *any* arbitrarily specified physical form. It is constrained by the lengths of its rods and wires, the position at which they are linked, as well as by the kinds of suspended objects it includes.

If there is any common ancestral technology between generative musical composition and generative visual art, it might well begin with the harnessing of the wind in the wind-chime and mobile.

4.0 Abstraction in Process-based Art

4.1 Musical Notation

Music is ephemeral and therefore subject to the metamorphoses and catastrophes of oral and aural processes of communication. The art of sculpture does not suffer from this difficulty. A sculptural work may survive the harshest of conditions, without the assistance (or despite the hindrance) of fallible humans.

To circumvent the difficulty of preserving and transferring musical compositions, formal systems of notation developed. One of the first forms of musical notation dates back to around 200 B.C.E. It was employed by the Chinese to record the music for their seven-stringed zither, the *ch'in* [5]. Various other notations have also been developed including of course the familiar staff-based notation of Western music.

When combined with the appropriate instrument, and a skilled musician versed in the conventions for its interpretation, musical notation provides sufficient detail for the accurate reproduction of a series of sound-events.

Recall that an abstract process was described as one in which *symbols* are manipulated in accordance with their conventional meanings. Hence musical notation provides a formalism from which *algorithmic* musical composition may develop. This is not the only way process-based music may be created, but as shall be shown below, algorithms and notation are necessary for composition within the digital realm.

The wind-chime and the mobile are both solid artefacts. They may survive the ravages of time and operate forever in essentially the same manner. They may stand for themselves. They may be transported and admired across many lands and times. What need is there for a detailed, abstract representation of the form of these or *any* solid objects? Is there a notation that might be employed for solid artefacts?

Of course sculptors, designers, engineers and architects have long drawn plans of their solid artefacts on flat sheets. Clearly this *is* a notation for sculptural works. Various conventions exist for the interpretation and production of drawings. Orthogonal views, isometric and other forms of perspective drawing are used as appropriate to convert three-dimensions into two.

The reduction of three physical dimensions into a series of two-dimensional markings on a page, like the process of creating a musical score, is a process of abstraction, the reduction or removal of details. In the case of an orchestral score for example, an enormous amount of information (which nevertheless affects the final sound) is omitted from the document. For example, there is not usually mention made of the techniques for constructing the musical instruments used in the performance. It is assumed that their properties are predetermined.

Similar conventions exist for the interpretation of drawings. A great deal of fore-knowledge is required about the nature of solid objects, none of which appears in an architect's or sculptor's plan, all of which is necessary for its sensible interpretation. For example, the knowledge that solid objects occlude one another is required, yet it is not stated in a plan.

In the last few hundred years of Western musical history, the individual musical event has found an ‘elemental’ character, the *note*.² The elemental nature of the musical note facilitates its specification using abstract symbols. Musical works can be represented by placing a selection from a finite alphabet of marks on a page in one of an infinite variety of possible combinations, usually with a selection from a finite alphabet of modifier symbols. What results is (ideally) an unambiguous description of a particular series of sound-events from an infinite variety of possible compositions.

To return now to the drawing or plan, there are an infinite number of possible drawings, but there are also an infinite number of possible lines, points and other marks which may be made on a page. There is no guarantee that a drawing will be ambiguous, nor that its meaning may be deciphered at all. The relatively unconstrained drawing is therefore not a suitable equivalent for musical notation. What is required is a means of specifying the form of a solid object using a well-defined alphabet, an unambiguous notation, a *spatial staff*.

4.2 Spatial Notation

If the musical note is the atom of (most) Western music and the staff the measure against which it is recorded, the Cartesian point and axis are their spatial counterparts. The Cartesian coordinate system (or any equivalent that specifies a unique location in space with respect to some origin) therefore provides a basis for notation in visual art. Once a location in space can be identified by a conventional notation, representations for solid objects may also be constructed and manipulated.

Certain constrained objects may be represented quite simply in terms of a few properties and Cartesian coordinates. For instance a mobile’s configuration can be specified in terms of the end-points of each of its rods and wires. If the items suspended beneath the rods are circular discs, these may be specified in terms of their position, radius and the orientation of a surface normal-vector.

More complex shapes require more complex means of representation, but the Cartesian point retains its usefulness. A solid form may be specified in terms of the

² Much music has nevertheless deviated from this path, especially in the exploration of electronics for the synthesis of new timbres and forms, but also for acoustic music. For the sake of simplicity, such notations are not discussed here, although equivalent statements may be made concerning their importance for generative art.

volume it fills, or in terms of its surface extent. Each of these schemes may be specified in terms of points in space defining volume-element locations; polygons or spline-patch control-points or in a variety of other ways.

Points and notes then provide a basis from which representations for physical and musical form may emerge. These elements may be utilized in algorithmic composition, the topic of the following section.

4.3 Algorithmic Notation

The digital arts are unified by the underlying manipulation of binary switches. These are not (usually) conceived of as switches at all, but instead as sequences of ones and zeros. More curiously, it is not (usually) the ones and zeros that are of interest in the electronic arts, but the things they *represent*. The digital arts are therefore concerned purely with representation! What's more, in many cases the representation of interest is only a representation of a representation...

For instance, switching patterns may be represented as ones and zeros. These may represent characters from the ASCII set, which may in turn represent a pitch, timbre and velocity, which may eventually be converted to an analogue signal played on an electronic musical instrument and emerging from a loudspeaker as physical vibration. The switching patterns therefore are many levels removed from the experience of a piece of digitally conceived music.

Nevertheless, removed as it is from physicality and therefore experience, the algorithm that manipulates representations of representations (of representations) is the foundation of all computer-based art. Algorithms for the manipulation of digital representations (switching patterns) may themselves be represented as a series of switching patterns. Since switching patterns are not convenient for human manipulation, these are actually determined by higher levels of representation, which take the form of *computer programs*. The human user may completely ignore the many layers of representation and specify an algorithm using a high-level programming language.

Computer programs deal *only* with the manipulation of switching patterns. But the user need never know this because the machine's output may be given as aural or

visual stimuli... the user remains blissfully unaware of the state of the many millions of switches in the beige (now in five yummy flavours) desktop box. The workings of the box and the switches it contains are invisible to the user. Their attention is focused on (what they perceive to be) the manipulation of processes and the elements which control them. The machine is the *interface*. It is not the focus of the manipulation.

5.0 (Wild) Speculation: The Future of Generative Processes in the Electronic Arts

From here springs the world of “generative processes in the electronic arts”. Aural and visual works may be represented conveniently using an abstract language. Processes for manipulating representations may themselves be represented in an abstract language. These languages may be represented by switching patterns in a computer, and these may be completely ignored by the human user who deals (predominantly) with imagery, sound and high-level programming code (text). In many circumstances, the graphical user interface supersedes even the textual aspect of algorithm/human interaction.

As touched upon in the introduction, one possible future is the ‘body-less future’, a universe where physicality ceases to be of relevance. In this future, representation has the final say. The worlds humans are presented with are virtual realities in the form of two-dimensional images representative of three-dimensional physical spaces. This is the path along which the quest for photo-realistic images and virtual reality lies [7]. With VR tools the human is given the *impression* that they are free of universal physical law.

The author sees this possible future as valuable, but a pale shade of grey when compared with the alternative. It is hoped instead that when future horizons broaden beyond the flat screen, VR-headset, (microchip implant?) and beeping loudspeaker, it will not be due to a direct connection with the world of two-dimensional representations. But due to perfectly transparent machines that operate entirely in the physical world. The world of representation will then be completely removed from the human observer.

In such a future, sculptural works might be experienced directly on some form of transparent interface. This might go far beyond representation in two or pseudo three-

dimensions. The sculpture would appear as a solid which may be manipulated like clay, whilst still retaining the added property that it may be manipulated by some algorithmic means—a kind of computer-controlled lump of matter.

With such a device, a human could mould a shape by hand, or alter it algorithmically. This new computer (a machine of architecture quite unlike those we presently use) could trivially smooth blemishes or make holes in its solid form, or it could completely transform itself into new shapes, oscillating and producing sound. Not only is the computer-controlled form of value to the visual arts, it is capable of shaping itself into any conceivable instrument for sound making.

Although in practice we are currently unable to build such a machine, conceptually it is an extension into the third dimension of existing technology. The computer already assists in the smoothing of hand-drawn *Flatland* [1] curves on a graphics tablet by ironing out bumps and rounding edges with infinite precision. It also creates drawings completely by algorithmic specification. If the next step into the solid world of *Sphereland* [3] is made, the possibilities for generative electronic art are endless.

6.0 Conclusion

Generative processes in the electronic arts depend primarily on the abstract, formal representation of physical phenomena. This is because it is physical phenomena that humans experience, and it is abstract representations (instantiated as physical switches) which are manipulated within computers. It is the power of the notation used by a human/computer to represent the physical world that governs the kinds of processes that it is possible to simulate.

The histories of visual and aural algorithmic composition have taken separate routes to the same destination. It was observed however that two simple machines, the wind-chime and the mobile, might be considered as equivalent devices in each of these arts. Also it was shown that works of aural and visual art can be represented in the form of musical and spatial notation respectively. The existence of these notations facilitates the manipulation of the elements of these art forms (notes and points) in the digital realm and hence is the basis on which algorithmic specification of generative processes for art making rests.

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