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Classification of Physical Processes for Virtual-Kinetic Art

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Abstract

This paper presents a formal means of classifying physical processes for virtual and physical kinetic art. From such a taxonomy may be derived a language for artistic expression. Additionally, the classification of physical processes facilitates the analysis of existing kinetic works based on their dynamic properties. This is to be preferred over a classification based on a kinetic work's static structural features, because these features do not necessarily reflect the piece's inherent dynamism. Finally, the characterization of physical processes is useful in the synthesis of virtual-kinetic art works, since it establishes a basis from which processes may be described algorithmically.

Keywords: Physically-based modelling, algorithmic composition, procedural animation, kinetic art

1.0 Introduction

> «We must at the outset distinguish basic elements from other elements, viz.-elements without which a work in any particular art cannot even come into existence» Kandinsky [10, pp20].

Just as a painter manipulates and coordinates colours and a composer combinations of sound, kinetic artists coordinate processes. The computer is a powerful tool for the kinetic artist willing to explore the utility of algorithms represented as program code. Yet the kinds of processes which may be modelled need to be studied, just as a painter studies colour [9] and form [10]. This paper presents such a study of physical processes.

Like a blob of clay or a pencil and paper, the computer may be used by an artist as a tool for modelling, for the manipulation of representations. Furthermore, in addition to being the fastest manipulator of representations we have yet devised, the computer may, after an initial period of instruction, carry out manipulations independently of human intervention. These manipulations may simulate a physical process or some aspects of the physical environment. This is known as *physically-based modelling*. The artist using these simulations to create representations of movement is a *virtual-kinetic artist*. The categorization of physical processes for the production of virtual-kinetic art is the concern of this paper.

Prior to the advent of real-time computer simulation, kinetic art may have taken the form of living sculpture (eg. gardens, aquaria) or mechanical sculpture (eg. water fountains, mobiles, clockwork and hydraulic automata). The art of simulation was limited to experimentation with down-sized physical systems representing real-world processes (eg. wave-tanks, wind-tunnels) or abstract

manipulation of figures (eg. calculation of projectile trajectories). The artist intent on using processes such as these, not just in the creation of art, but *as* the art, may find the computer powerful for its simulation ability. In the virtual realm, processes which previously were impractical or impossible to reproduce may be simulated and manipulated. Additionally, interactions which are not usually under human control, or processes which could not possibly occur in the physical world, may be modelled using the computer and given a role in virtual-kinetic art.

The ideas presented in this paper have been drawn from a range of texts (see section 2.0), no one of which has singly provided the impetus for this publication. Rather the sum total of readings below (and others) has led to the conclusion that if there was not a means of categorizing physical processes from an artistic and algorithmic standpoint, such a thing ought to be devised. Why? …for the same reasons that anything is categorized: for drawing out similarities between things; noting their differences; and so coming to learn more about the way they operate.

Additionally, an artist wishing to employ processes in virtual-kinetic works, ought to be able to develop a language with which to express artistic concerns. Such a language can rest upon a set of axiomatic symbols or concepts which may be combined in different ways to achieve the desired effect [10, pp20].

Finally, the categorization of physical processes is useful for understanding existing works and conceiving new ones, and it is of assistance when devising algorithms for physical modelling. It will be shown that all physical processes may be classified in terms of a handful of different classes. These form a basis from which a process may be represented algorithmically.

The following section of this paper presents previous work of relevance to the present essay. Section 3 presents a new taxonomy of physical processes. Following that, the taxonomy is used to analyse the behaviour of water in garden fountains (section 4). The paper concludes with a brief discussion (sections 5,6).

2.0 Previous work

Existing work of relevance includes studies of single processes such as Dawkin's explanations of the evolutionary process [3]. However, more broadly based research assembling descriptions of physical processes with attempts to explain how they mesh also exist, especially when linking physics, chemistry, biology, mathematics and mental processes.

Some notable exceptions to the "here today, gone tomorrow" writings of popular science have emerged. The work of Hofstadter [8] has made a lasting impression. Penrose [13], Prigogine and Stengers [16] have also made their marks. A book by Volk [20] also rewards the reader with ideas of relevance to this paper. Nevertheless, it is to the authors of history which this summary of previous work most enthusiastically turns.

D'Arcy Thompson [18] is an obvious point of reference for those interested in physical processes and biological form. Although many of his ideas have not stood up to modern scientific scrutiny, the text is an enthralling account of a search for the relationship between the forms taken by life and its artefacts, and the physical processes which govern their production.

The notebooks of Leonardo Da Vinci [19] are unique in their breadth and depth. Leonardo's interests in the processes of life were matched by his interest in things purely mechanical. His dedication places him as his time's leading thinker on the utility of physical processes.

Whilst not concerned specifically with new scientific research, but instead with documenting the facts of the natural (and to a lesser extent civilized) world, Pliny the Elder [15] is nevertheless worthy of mention in this context. Lucretius' work [11] is also worthy of consultation for the artist wishing to understand the relevance of process.

Aristotle [2] and Plato [14] have each made a considerable contribution to our understanding of the place of process. Aristotle has much to say about the processes which govern living systems. Plato's writings, if nothing else, highlight the importance of the technology of the day in determining the processes (and terms) by which humankind attempts to understand (and describe) the events which occur in its environment.

There are other writers and philosophers of relevance in this context including Zeno, Galileo [6], Fibonacci and Descartes [4]. In addition, there is no doubt that many philosophers from Eastern countries have made valuable contributions to the philosophy of dynamics and process. This author's knowledge of such readings is sadly deficient.

An entire philosophical movement exists, centred around the significance of process. Based on the ideas of Whitehead [21], *Process Philosophy* has at its core the idea that the essential basis of the universe is a momentary experience. Time is a transition from experience to experience. From experience emerges matter, but not the reverse. This is in stark contrast to the view that experience arises from the interactions of matter, an 'atomistic' view emerging from Aristotle.

Finally, Wolfram's [22] categorization of the behaviour of continuous complex dynamic systems and (discrete) cellular automata (CA) is of specific relevance to the taxonomy given below. He placed the behaviour of CA's into four categories. Those which:

1. move into a homogeneous state (limit-point);
2. move into simple, separated, periodic structures (limit-cycle);
3. produce chaotic aperiodic patterns (strange attractors);
4. produce complex patterns of localized structures.

These categories shall be compared to those now presented in this paper below.

3.0 A Taxonomy of Process

The taxonomy to be proposed shortly is not set in concrete, but neither is it arbitrarily determined. It is an attempt to construct a basis from which physical processes may be employed in the creation of kinetic art. In the mould of Itten's exploration of the interactions between colour and a viewer [9], and Kandinsky's exploration of the interactions between drawn marks and a viewer [10], this paper is a tentative step towards understanding the relationship between physical processes and time-based art.

3.1 Time

At the outset it is vital to understand that a process is something which is *perceived*. Processes are changes *experienced* by observers from within observer-dependent frames of reference. Observers bring with them limitations such as visual and aural acuity, and other constraints imposed by their physical constitution. There are also constraints implied by the concept of measurement. For example, 'movement' and 'expansion' are perceived with respect to a 'stationary' or 'fixed' standard.

The concepts 'perception' and 'process' are entwined with the experience of *time*. Without attempting to define this elusive concept, at least it is clear that the temporal dimension is necessary for perception. Without thought there may (as well) be nothing at all. Abbott alludes to this in "Flatland" [1, pp109] in which he writes of a Point capable only of self-perception. Without his single dimension (the temporal dimension) the Point could not conceive at all. There cannot be thought without time. Maybe there cannot be time without thought.

3.2 Pulse

Time may be perceived as moving rapidly, or it may seem to travel at an agonizing rate. If it is observed at all it is through the observation of a change, a *process*. The first category of process is

a *Pulse*. A Pulse is a repeating set of experiences, a rhythmic procession of events. Pulses such as the regular pumping of the heart or the musical pulse [17, pp14] define the temporal domain.

3.3 Stream

The spacing between events comprising a Pulse may be reduced to create what is perceived as a continuous, uniform *Stream.* Individual locations within this continuum are not distinguishable from one another. (Two snapshots of the system taken at different times will look identical.) The entropy of a system undergoing a Stream process does not change. Streams, although they are forever mobile, are timeless.

Imagine a perfect, white sphere hanging in space. Is the sphere spinning or is it stationary? How can an observer know? There is no unique feature on the surface of the sphere to allow the perception of its rotation. This is an example of a Stream process. Streams are unique because they may not be directly perceived…

A black dot placed on the surface of the sphere (off the rotational axis) breaks its symmetry. The passing of the dot across the surface provides a Pulse by which to measure changes in orientation. This is termed the *marking* of the Stream process (rotation) by the super-position of a Pulse (repeated passing of the dot). Only a marked Stream may be perceived.

For a sequence of events to be perceived as a Pulse, their spacing must be large enough that a continuum is not perceived, and short enough that the space/time between events may be 'gauged' by an observer[1]. If the above-mentioned sphere spins so fast that the dot is perceived as a ring, the rotation will not be perceptible. The result is another Stream process. If the sphere moves so slowly that the dot's movement is not perceptible, a viewer would simply label it as stationary.[2]

3.3 Increase and Decrease

A third form of process called here *Increase* is continuous but it is not timeless. Increase processes attain forever higher levels of some dimension (eg. complexity, orderliness or radius). A

[1] Eg. Humans are able to experience times between seconds and maybe years. But concepts such as milliseconds and millennia are out of direct human experience.

[2] The concept of Pulses and Streams have analogues in the arts. In the aural domain, an accelerated rhythm is eventually perceived as a continuous tone (of pitch determined by the rate of repetition and timbre by the rhythm's form). In drawing, the accelerated placement of dots during a continuous movement across a page gives rise to a line (cf. [10, pp57]).

stage in an Increase process may be measured as being more (or less) advanced than any other stage, by reference to the increasing dimension.

Complementary to Increase is (of course) *Decrease*. Decay and the falling of a ball are both processes of Decrease (in organization and height respectively).

3.4 Complex Processes

The final category in this taxonomy is the *Complex* process. Complex processes forever change into new forms without reiteration. Hence a particular state of a system undergoing a Complex process will be different to all future and past states of that system. The changes the system undergoes may occur in a predictable (but infinite) sequence or they may be random and unpredictable (noisy).

Complex processes differ from Stream processes. Their characteristic measure does not Increase or Decrease, but it is not constant. A Complex process may therefore be perceived without superimposed temporal markers. The change of cloud patterns in the sky over Jupiter is a Complex process.

Streams, in addition to being marked by Pulses, may also be marked by Complex processes. For instance, the white rotating sphere of section 3.3 might have on its surface a swirling mass of dark clouds (like the Jovian atmosphere) which mark its rotation.

3.5 A Further Note

A process is observed with respect to a particular set of changes undergone by a system. Since a system may have many measurable properties, depending on the circumstances it may be described in terms of any of these. For example, a particular system may be described in terms of a change perceived as increasing (such as temperature), whilst it may also be described in terms of another property which is decreasing (such as mass). This same system may be described in terms of a change which is neither increasing nor decreasing (such as colour).

In summary, the five categories of physical process are as follows:

1. Pulse - repeating sequence of events
2. Stream - continuum (may be marked by a Pulse or Complex process)
3. Increase - increasing (in some dimension)
4. Decrease - decreasing (in some dimension)
5. Complex - changing (in some dimension which is not increasing or decreasing)

These categories have some similarity to those used by Wolfram (section 2.0) to describe the behaviour of CA's. Wolfram's limit-cycles are Pulses, his 'complex patterns of localized structures' are the Complex, non-noisy processes presented here (although on a finite grid a CA will eventually form a Pulse). A CA's chaotic behaviour is a Complex noisy process.

Wolfram provides no categorization specifically for Increase, Decrease or Stream. He neglects the first two of these as his interest was in a process' outcome, not the process itself. The Stream process is akin to Wolfram's limit-point. However, the notion of a Stream is preferred in this context to that of a limit-point because it makes clear that although a system may appear static, an underlying process may be perceived if the Stream is marked. The Stream maintains the apparently static form from moment to moment.[3]

As one example of the above taxonomy's utility, it will now be applied to an analysis of garden waterworks.

4.0 Analysis of Garden Waterworks

The kinetic arts are concerned with the manipulation of process parameters and boundary conditions. Processes may result in the movement of a dancer, variation in pitch, timbre and rhythm, reflection of light from a surface, growth of a garden plant, or any of a myriad of other possibilities. From the taxonomy of physical processes presented above, regardless of the art, the palette of the kinetic artist includes: Pulses, Streams, processes of Increase, Decrease, and Complex, possibly noisy, processes. Although the ideas presented in this paper may be applied across the gamut of time-based art, a short example now follows in which the categories are used to analyse classical garden waterworks. (See [5, 12] for further discussion on garden waterworks.)

Continuous Jet - a pressurized jet of water which rockets energetically skywards (Increase in height), slows under the Earth's pull, hangs momentarily in space before plummeting downwards

[3] Such is the case when one of the many stable states with active cells is reached in Conway's "Game of Life" CA [7]. In fact, the identity of an organism is maintained from moment to moment by hidden processes of this kind.

(Decrease in height). The Decrease process of the descent counters the effect of the Increase to return the system to its earlier state. Overall the system is completely balanced and timeless… a Stream.

Surging Jet - a water jet controlled by a valve which opens and closes at regular intervals. Water bursts provide rhythmic Pulses with individual effects similar to those of the continuous jet. However the overall effect is not a continuum, but a Pulse marking time.

Cascade - water which is left to trickle peacefully down a channel, flow over the sides of a dish, rush down the face of a cliff or pour through a rocky ravine in a directed descent. Such processes are of continual Decrease, the Increase is hidden from view in pipes or by evaporation.[4]

Spray - liquid which is ejected from a nozzle under pressure forms a glittering mist which drifts lightly on a breeze. This feature has elements of the Complex process in the swirling motion of the water droplets, or of Decrease as the mist is dispersed and evaporates.

5 Discussion and Future Work

The variations in focus provide the waterworks with different effects, each which may be utilized by the kinetic artist. The meanings associated with Increase and Decrease, with Streams, Pulses and Complex processes, are of course subjective, as is the interpretation of any artefact! Nevertheless, their behaviour may be categorized as a guideline for those intending to employ them in a work.

The development of a garden, the voice of a wind chime, the motion of gears and a pendulum, each may be used to artistic effect. Each contains elements of the five process types given above. Similarly, a composed piece of music has elements of all five processes running throughout it. The composition of any time-based art will also have elements of the taxonomy presented here.

For the programmer employing physical simulation for artistic purposes, the taxonomy outlines the fundamental techniques required to devise virtual-kinetic works. Each physical process to be implemented may be seen as a mixture of the five process types. Hence at a basic level, a process will be related to many others which might also be implemented. The programmer can begin, in-

[4] An observer's approach to a cascade may be a process in which the din of the water Increases. Once the observer has remained at the waterfall for some time, the sound becomes a timeless Stream, or at the macro level, a Complex, noisy process.

stead of with a blank slate, with a process category from which to develop a satisfactory simulation.

To take an example, supposing a programmer were to model the water fountains above (section 3) using a visual model of particles. They might implement firstly a Complex process for the particles: their random generation. After this the ascent and descent according to the effects of gravity might be implemented. The superposition of a Pulse disrupting the Complex process could be implemented next.

Supposing now the same programmer wished to algorithmically specify a piece of music. Using the tools developed for the implementation of the model waterfall, the programmer might adapt their code to randomly produce notes. These might Increase and Decrease in pitch according to some rule (perhaps even in accordance with the movement of a mass under gravity). A Pulse might be superimposed on the Complex process, thereby providing the piece with rhythmic content. These models of music and waterworks are essentially the same, each implementation borrows from the same set of the five process categories.

Visual and aural experiments with the interactions between physical processes of different kinds are under way. These take the form of computer animations and musical accompaniment. The long-term value of the taxonomy remains to be seen, but immediately it provides a new perspective when analysing and constructing time-based art.

6. Conclusion

A classification system for physical processes has been proposed. The categories proposed are the Pulse, Stream, Increase, Decrease and Complex processes. It has been demonstrated by examples taken from music and garden water fountain design that they may be applicable to kinetic and time-based art for its analysis, conception and algorithmic specification.

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