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Aesthetic Fitness and Artificial Evolution for the Selection of Imagery from the Mythical Infinite Library

Alan Dorin
School of Computer Science and Software Engineering
Monash University, Clayton, Australia 3800
aland@cs.monash.edu.au

Abstract. Aesthetic selection and artificial evolution have been two of the more successful companions introduced to the toolbox of electronic image-makers in recent years. This paper examines the niche in which this technique, often associated with the simulation of biological processes, has positioned itself and some of the reasons for its success. Some remarks concerning the meaningfulness of a user's search for images through a genetic space are made and the relationship of this search to traditional artistic practice is examined. Suggestions on how to link other Artificial Life techniques, especially those involving self-organizing and self-assembling systems, with aesthetic evolution and electronic art are also made.

1 Introduction: A Parable

"This thinker observed that all the books, no matter how diverse they might be, are made up of the same elements: the space, the period, the comma, the twenty-two letters of the alphabet. He also alleged a fact which travellers have confirmed: *In the vast Library there are no two identical books*. From these two incontrovertible facts he deduced that the Library is total and that its shelves register all the possible combinations of the orthographical symbols: in other words, all that it is given to express, in all languages", J.L. Borges, *The Library of Babel*

Borges writes of a Library containing every possible book. Take a minute to imagine instead, a giant catacomb in which is stored every possible image, then read on…

Picasso strolls through the entrance of the image catacombs one morning. Upon encountering a librarian at reception he requests, "Please direct me to an image of a woman." Nodding, the librarian leads Picasso by the light of a sputtering candle through musty corridors, twisted and disused staircases. The countless halls and stairwells are drawer-lined from top to bottom, stretching beyond reach of the feeble candle. Occasionally Picasso observes dusty footprints which invariably vanish into the blackness. Each of the timber drawers has affixed to its surface a square of paper labelled with complex symbols. The librarian approaches a chest of drawers, briefly examines its label, then slides it open. After peering inside for a moment, he pulls from its depths a painted canvas. This he holds unsteadily in the candlelight before the great man.
"No, I'm sorry sir", mutters Picasso to the librarian, "That is the Mona Lisa, Da Vinci has already used that one. Have you anything else?" The librarian shuffles across the hallway and opens a drawer on the other side, removing from it another canvas. "Not bad", says Picasso, "What's in the drawer above that one?" The librarian returns the canvas and opens the next drawer in the chest. He steps backward, humbly gesturing that Picasso may examine the drawer's contents personally. Pi-

casso obliges. Thoughtfully he flicks through the neat array of images in the drawer whilst the librarian holds the candle high. "Hmmm, this one *is* different!" exclaims Picasso, "I think I'll call it *The Weeping Woman*. Its blocky, distorted form is full of an anguish which matches my mood today. Fascinating. I'll take it! Do you have any other images in this geometric style?"

Reader, if Picasso, like Da Vinci before him, had wandered through a vast catacomb and, with the assistance of a guide, selected images to claim as his own, would you hold Da Vinci and Picasso in high esteem for the genius they exhibit in their work? Would you label these characters as *artists*? What does the term *artist* mean in this instance? Perhaps the concept of an artist driven by their passion and insight has been replaced by the concept of an *explorer* in search of artefacts to be labelled as his/her "works". These are the main issues which will be discussed in what follows, as will means of employing other A-Life techniques to art-making practice.

2 Background of Aesthetic Evolution

The use of artificial evolution to achieve engineering goals has been discussed at least since Holland published on the topic [1]. Much later, the concept of *aesthetic evolution*, was illustrated by Dawkins' *Blind Watchmaker* software, which accompanied his book of the same name [2]. The concept behind the code was simple–a small population of visual[1] representations (phenotypes) produced from a set of numbers (genotypes) are displayed on-screen. A user selects a pleasing phenotype which gives rise to a new generation whose genotypes are produced by mutation from that of the selected parent. The process of aesthetic selection in this manner continues until a desirable phenotype is produced.
Sims' venture into aesthetic evolution resulted in the construction of images and solid models [3,4]. His system borrowed from Koza's *Genetic Programming* paradigm [5] in that the genotype was a hierarchy of nodes (like those in the parse tree of a mathematical expression) the traversal of which constructs the phenotype. Sims also explored the evolution of cellular automata, dynamical systems and movement of virtual creatures [6,7,8].
Whilst Dawkins' Blind Watchmaker did not include operations for crossover between multiple parents, this has been added by others [7,9,10,11]. Its use is not always required in aesthetic evolution but its inclusion does allow the combination of traits distributed across multiple phenotypes.

3 Advantages of Aesthetic Evolution

The advantages of aesthetic selection have been explored in detail elsewhere [12,13] and are outlined only briefly here. Aesthetic evolution might be considered to have captured interest as strongly as *Boids* [14] and the *Game of Life* [15,16]. Thankfully, the process may produce imagery more diverse than the fractal zooms popular in the 80's! These algorithms nevertheless do share the idea of "complexity from simplicity" which is a theme of A-Life [17] and a goal for much human endeavour.

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[1] Aesthetic evolution need not be visually guided, however the focus of this paper is on the production of imagery using the technique.

In the case of image production, the lag between what can be conceived and what can be realized can be partially bridged if a digital assistant is employed. Some have suggested that a computer may even display imagery *beyond* the imagination of the artist [12]. Those who would like to produce images but are not skilled with brush or camera may also enlist the assistance of a computer to produce complex, "interesting" outcomes.

The popularity of aesthetically-driven evolution lies in its simplicity from an implementation standpoint, the broad range of possible outcomes, and the degree of control a user feels over the process. Further, one characteristic of the technique is that the human need not understand the details behind the construction of "their" images or artefacts – all that is required is a critical eye to assess the merits of the current phenotypes. This is a skill all artists and "artists" have, regardless of their level of formal training. Hence, all-comers may be satisfied by the technique, which is also a powerful image-making tool for those with the knowledge to put it to good use.

4 Roles of Programmers and Users

At one level the advantages of aesthetic evolution seem tremendous. The technique certainly provides help with complex design tasks. What are the drawbacks of working in this way as a user with no programming input? This section gives concrete examples of the restrictions imposed on the user by the programmer of the software.

Whenever one uses software to create an image, the finished product speaks partly of the user's input, but more than most would care to admit, of the constraints imposed by the software and the output it is capable of producing. This is true of traditional media also: the limitations of watercolour on paper influence the kind of work a painter may create; the subject matter, film and lenses available to a photographer limit the work so produced.

U&I Software's *Artmatic*, demonstrates procedural production of 2D images *without* aesthetic evolution. Interactively changing an image's parameters nevertheless reveals countless "attractive" relatives. Elements of the equation specifying the image may also be altered to land the user at distant locations within the image catacomb. The designers have thus far resisted the trend to incorporate evolutionary guidance through the vast parameter space.

Exploring massive pre-defined image spaces in such a top-down fashion is a fundamental change from traditional art's bottom-up synthesis. Creating a work becomes a process of eliminating undesirable qualities from an image, or substituting them for other fortuitously appearing properties. The options are not created by the user, but by the software, and are layed down in the form of a complex "choose your own adventure" book.

Within this constraint is some room for creativity, but rather than an approach where an image is synthesized from a blank canvas and a filled mind, this type of image-making involves selecting from filled canvases (with, possibly, a blank mind). The canvases displayed are selected from a tightly constrained (but possibly infinite[2]) set. Image-making

[2] Infinity can be constrained. E.g. Both the sequence of integers and that of floating point numbers are infinite. Yet the integer sequence is more highly constrained than that of floating point numbers.

by aesthetic selection of two-dimensional textures or by sliding parameter values is even more tightly constrained than photography since the images themselves are presented ready-made to the user. However when a model or texture is created using these techniques it may become a subject which yet requires creative deployment.

In the sea of imagery or models produced by *Artmatic*, the *Blind Watchmaker*, *Mutator*, Sims' Tokyo ICC installation *Galapagos*, *The Artificial Painter* (offered on-line by Pagliarini et al) or the *Animaland Bauhaus* (the author's own software), there is an abundance of "interesting" forms. One might say "Ooooh, that's a *good* one!", but this could equally be said about millions of such images. Unless there is a reason imposed by the artist for choosing one image over another, then gigabytes can be filled with countless "good" images. Where are the "excellent" images? What distinguishes them from the "good" images? Has artist X who employs aesthetic selection ever produced a *masterpiece* which eclipses X's other works in its sophistication? Are all images produced by such tools equally meaningful? If this were the case, there'd be little point in playing with aesthetic evolution in the first place!

If the images are not equally meaningful, or if an image amongst the works of X may be identified as superior, how so? What are its special qualities? These questions remain unanswered. Where is X's *Mona Lisa*, *David*, *The Scream*, or *Guernica*? How can this masterwork be distinguished from the other works produced by X? Is this traditional view of the artist striving for perfect expression of relevance to those who practice this form of art-making? If they are searching a catacomb to find their masterpiece, what will it look like? These days, can anybody tell a masterpiece by the way it *looks*?

The skill of the artist at capturing a feeling, providing comment, engaging with a process or any one of a myriad of *reasons* people produce art need not be ignored completely. The search for an "attractive" image need not begin (nor end) with computer-selected options, but with a human drive to *create*. In the case of evolutionary design, the non-programming artist searches through the space of interest to the programmer for an image which, however clumsily, reflects their artistic goal. This is not a healthy situation for any art...

Evidence for the dominance of programmer over user lies in the results produced by artists using *different* pieces of software. Try to use the *Blind Watchmaker* to evolve an image like one created by *Mutator* and this is immediately apparent. These are different *media*, not the same medium being employed by different artists. Each program, despite its reliance on procedural or evolutionary mechanisms, hard-codes *different* constraints on the user and the forms which may be created. A work produced by one piece of software will have a trademark *style* imposed by the code before any imposition by the user. Whilst a skilled copy-artist may use oils to imitate another oil painter's style, (demonstrating that each is employing the *same* medium), in the case of the *Blind Watchmaker* and *Mutator*, the *programmers* are employing the same medium, software end-users are not.

Specifically, constraints which ensure a trademark style emerges from aesthetic evolution vary but may include the modelling and rendering methods. For example, *Mutator* begins to constrain Latham by its use of Constructive Solid Geometry. This, combined with the repetition of elements along paths and organized in high-level features like ribs, stacks

and horns, gives the images a characteristic segmented appearance reminiscent of the work of Giger [18]. The graphics primitives selected by Latham are usually ellipsoids and torii–these work well to form organic structure–as opposed to cuboids which give a geometric feel to (and simplify the physical simulation of) the virtual creatures of Sims [7,8].
Dawkins' biomorphs retain their segmentary, stick-constructed origins. Dawkins writes "I did allow myself the luxury of using some of my biological knowledge and intuition. Among the most evolutionarily successful animal groups are those that have a *segmented* body plan. And among the most fundamental features of animal body plans are their plans of *symmetry*" [2,p329]. Thereby making clear his understanding of the assumptions he made about the kinds of forms to be produced.
Ventrella's aim was to animate figures by aesthetic evolution and so he predetermined their topology [11]. He writes also, "A *qualitative* physics model is used to constrain motion in these figures. Although it is quaint and home grown, this model does produce most of the salient features of interacting physical bodies". Hence the movements Ventrella's creatures may make are dictated by an ad hoc physical simulation built for simplicity and speed of execution.
The comments above are not criticism, the programmers were *forced* to make decisions/assumptions to write code which met their needs. These have been highlighted to indicate the degree to which the *software* determines the outcome of a user's "art-making" using aesthetic evolution as a guide. Although these catacombs are infinite, they are not so in all directions. Whilst writing software for generating imagery via aesthetic selection might have similar scope to the processes of painting or sculpture, once the program is written, the images implicit in its architecture serve only to bring visual form to the code. Continual application of the software for the generation of multitudes of images reveals only trivial information about the artist and the software. There is nothing more to reveal! It is as if a photographer were obsessively clicking the shutter on a single inanimate subject.

5 Relevance of Software Limitations

A culture develops around those artists who use a particular medium. This culture includes curators who display and collect works. It includes critics who write extensively about artists using a particular medium. It includes communities of artists who explore techniques for working within a medium. Implicit in the culture is the assumption that artists working within a medium have similar constraints within which they work to solve artistic problems. Perhaps nowhere is this more clear than in the battle which raged during the twentieth century over the use of a musical scale of equal temperament [19,20].
Rarely does debate rage *across* media: advances in cinema are seldom compared to architecture (although the two fields may borrow from one another); musical accomplishment is rarely judged by reference to painting. The arts are related to one another in broad terms but it makes little sense to make value judgements between works created under different constraints. Yet *within* a medium, this is exactly the kind of debate which proliferates – people make implicit and explicit qualitative judgements about art and artists. For a historical example see [21, p250-254].

Such a culture exists also within the community of computer programmers. They discuss their ideas for algorithms, swap code and criticize each other's work. Programmers might discuss the merits of including the crossover operation in a program for aesthetic evolution, or the degree and frequency of mutation a genotype undergoes. Similar discussion occurs amongst the users of complex software tools such as Adobe Photoshop to which are devoted discussion lists, text books and magazines. There are of course numerous and broad-ranging discussions and debates amongst those who use specific techniques (such as artificial evolution) on computers for art-making, this paper being one example.

Where is the critical debate about the special tricks for using Latham's *Mutator*? How do different images made with Rooke's [22] software compare to one another? Why are artists not seriously comparing the biomorphs they produced with those constructed by others[3]? The matter that authors claiming artistic merit do not generally distribute their tools for others to use, highlights the answer to this question: there is little to discuss when it comes to *using* the software. There are no subtle tricks, using the software is trivial and reveals no more than did the original output of the tool. All the skill has gone into the programming of the tool, not the use of it. Hence access to the tool is all that is required to make images "in the style of X" where X is the *artist* who is best known for using it.

Any visually-skilled artist, whether they have ten years of experience with aesthetic evolution or one can produce a "quality" image using a properly implemented tool which uses the technique. Unlike painting with a brush and ink, there is no room for improvement. Studying the *use* of these tools for ten years is a laughable pursuit since they may be "mastered" in a matter of hours. There is no means for distinguishing a master from a relatively inexperienced user, in this context the terms are meaningless.

Debate does rage about the outcome of employing aesthetic evolution within the wider context of cinema or image-making. For example Latham's *Bio-Genesis* [23], Sims' *Panspermia* [24], McCormack's *Turbulence* [25], Dorin's *Hydroid Medusae* [26] may be judged as pieces of cinema. It is therefore clear that when combined with talent in the making of cinema (or prints) the raw material produced by aesthetic evolution can be manipulated to produce works of artistic merit. Note however that within the field of cinema there *is* room to improve. A novice film maker and a master may be distinguished from one another. Similarly for a photographer using digital subjects or others. There is always room for even a master to improve and a culture (which includes competitions, critics and reviewers) to comment on this progress.

Aesthetic evolution is a powerful tool, but the imagery a particular implementation may produce is laid down in code–a *creative* process which takes practice to master. The "art" of creating an image using aesthetic selection is indeed mindless. Participation in the process of evolution by clicking on favourite images and playing the role of a garden-weeder

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[3] An online class exercise asked "Try your best to come up with an interesting, attractive (or gross!) result in the final parent frame that will win the immense admiration of your fellow students in your section…. You are encouraged to arrange some sort of contest to judge the 'best' biomorph in each section." It assumed here that value will be attributed by association.

or pigeon-breeder is not a process like that traditionally associated with art-making. Nevertheless, the specific tool and the assumptions its code contains, as well as the manner in which its output is used in a wider context, provide ample scope for the fine artist.

6 Future Applications

Complex systems are again in the research spotlight, no longer because of unpredictability, but due to the spontaneous emergence of order from chaos. Fascination with these processes was behind the fame of the *Game of Life* and the explorations of cellular automata it provoked [15,16]. This section looks at how these complex non-linear processes may be combined with aesthetic evolution for the construction of imagery.

Researchers like Prigogine [27], Maturana & Varela [28] and Kauffman [29] have long championed self-assembly through auto/cross-catalysis as a defining property of life. If technology is to move beyond its current phase in which software/images/music are constructed through an all-knowing controller, then the dynamics of multiple interacting, self-*ordering* primitives must be understood. This is no simple problem, but its impact on art-making will be substantial. It is through the local interactions of countless inanimate components that the universe's most spectacular creation has emerged–the organism. Whilst this is freely acknowledged by researchers in A-Life, little research has investigated the area with any level of sophistication as it applies to the creation of artistic works.

Tolson has created a system where interacting agents leave a trace as virtual brush strokes [12]. The behaviours of these agents may operate under automatic artificial evolution to produce the desired imagery. As mentioned above, Sims used aesthetic evolution to guide the discovery of dynamical systems for the production of two-dimensional imagery. Explorations of cellular automata abound and are naturally displayed in visual form [30,31]. Nevertheless, artists employing cellular automata beyond "the grid of squares" are rare.

McCormack has utilized interacting agents in his installation work *Turbulence* [25] to control pole-mounted pods which signal one another by emitting rings of light. Dorin has created a virtual prism of nodes which initiate musical events as they interact in *Liquiprism* [32]. Brown's mesmerizing tiles rotate to form connected *Sandlines* [33]. In all of these works, the level of signalling is controlled by little more than a creatively implemented cellular automata.

Of course Reynolds' *boids* have also been utilized cinematically [14]. Boids and cellular automata are simple models from which complex behaviour of a discernible style emerges. How may the sophistication of interactions be increased to the point where behaviours which may not be predicted, even in general, arise? Flesicher's *Cellular Texture* generation [34] is an example of how studies of interacting agents for image-making may progress: individual entities follow programs instructing them on movement and behaviour including the release of and response to chemicals in the environment. These units may be used to form complex self-organized pattern. Dorin's *Solid Cellular Automata* operate similarly [35,36]. These virtual solids move through space under attraction and repulsion according to their current state and the state of neighbouring elements. Elements trigger changes of state amongst one another and self-assemble into dynamic or static structures.

In Dorin's and Fleischer's systems, the rules of interaction are laid down by the programmer. This complex task might be surrendered to the computer: the table of floating point parameters which governs the behaviour of Dorin's system could be converted to a Holland-style genotype upon which aesthetic evolution might act; the cell programs of Fleischer might be encoded using Koza's Genetic Programming technique. In either case, the combination of complex dynamical systems and aesthetic evolution seems a promising avenue for further exploration. Unfortunately, the nature of the evolutionary landscape defined by parameters of non-linear systems makes this a difficult task. Attempts such as Sims' to evolve cellular automata rule tables are not as successful as might be hoped for reasons he outlines[6]. Unlike the undulating landscape of "attractive" images, the evolutionary landscape of these systems is not necessarily smooth enough for an evolutionary algorithm to traverse effectively. Instead, the landscapes are characterized by sharp spikes in a bleak plane of parameter combinations producing disorderly behaviour. What is required is an undulating parameter space allowing the search algorithm to find points of local maxima.

For now, it is not clear how this difficulty might be overcome. It is apparent that the physical systems built by natural selection contain a high degree of redundancy, something which may be the key to their evolvability. A system is required in which small genotypic changes produce corresponding small phenotypic variation. Complex dynamical systems are brittle and do not degrade in performance gracefully. Tiny changes within cellular automata rule tables for example, may completely destroy the balance between activity and stasis necessary for complex, orderly dynamic behaviour.

In the case of Sims' virtual creatures, and the work of van de Panne and Fiume [37], huge spaces are scanned automatically for parameters which yield effective locomotion. Such searching is not feasible using a human as sole selector. Ventrella sensibly combines automatic and aesthetic evolution in his software – a somewhat effective means of evolving dynamic systems. Alternatively, an objective means of specifying the "interestingness" of a system is required. Possible criteria include entropy change, the proximity and regularity of elements or behaviour in a model or other related measures of organization.

7 Conclusions

Whilst aesthetic evolution has been applied to the production of various styles of image and model specification, it is yet to make a mark as a control mechanism for the self-assembly/organization of multiple independent elements. The complexity which may arise from carefully orchestrated self-assembly of models and imagery is currently an untapped resource for visual artists.

Aesthetic selection is clearly helpful in the search amongst the possibilities defined by a set of constraints imposed by a particular image-making tool. Once the software has been constructed and a set of images has revealed its form, further rambling through the image space without re-programming is of dubious artistic merit. There is certainly little point in labelling a user of a tool who has no direct or indirect programming input, with the title *artist* due to their lack of control over the image-making process. Yet it is clear that the programmer/software/user combination may produce works as significant as with any other technique. The creative process then lies in the constraints imposed through the software development process on the images which will be produced.

As long as the programmer/user link is strong, aesthetic evolution is a tool with much to recommend it. If this link is severed or weak, the user becomes only a lost soul in the infinite image catacombs. None of the pixel arrays voice the thoughts of the wanderer. Instead, they tirelessly repeat the name of labyrinth.

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