The Visual Aspect of Artificial Life

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Abstract

This paper takes examples of virtual, visual artificial life and discusses the relationship between the important aspects of the simulations and their visualization. It is hoped that this discussion of visualization's *particular* importance to a-life, will encourage authors to give this aspect of their research proper consideration and that they will come to treat the visualization, not as additional decoration for conference presentation slides, but as an intrinsic part of effective research. This will help other researchers understand the advances made, and will assist the authors themselves to more clearly comprehend their own work.

1 Introduction

"The eye which is the window of the soul is the chief organ whereby the understanding can have the most complete and magnificent view of the infinite works of nature" da Vinci.

Much of what it is to live, concerns the ability of an organism to classify, to make *connections* between events, people, inanimate objects, concepts, action and reaction, stimulus and response. It is through these connections that organisms are able to function effectively and reason about their environment [23, p50]. As humans, the connections we recognize are primarily acquired using *sight* – entailing the use of the eye and brain in concert. Humans construct a visible world and its components from an ambiguous, two-dimensional pattern formed on our retina. We construct and compare contours and edges, positions, orientations, shapes, shades, colour, textures, movement, size, and countless other abstractions [9]. All of this we perform subconsciously, accurately, rapidly, and far more effectively than our best artificial vision systems.

Memorable examples of a-life study such as Conway's Game of Life [8], Reynolds' boids [18], Dawkins' biomorphs [4], Langton's loops [10], Sims' virtual creatures [20] and Prusinkiewicz's L-system plants [16], provide a visible and intuitive face to the field. In these early endeavours the links between visualization and computer-based a-life were firmly set. Since our knowledge of real-life is gleaned through visual reasoning, the same might be true of a-life. This is the basic premise behind scientific visualization across all fields – information presented visually will be assimilated more effectively than might otherwise be feasible. One need only flick through the pages of D'Arcy Thompson's *On Growth and Form* to experience the wealth of information the author conveys through his drawings [21].

Here then seems to be an ideal model for describing a-life models. This is not to say that a-life need always represent abstract virtual life in ways reminiscent of real-life (although as Prusinkiewicz and Dawkins have shown with L-system plants and biomorph insects respectively, this too has a role to play), but that new ways of representing complex interactions need to be found also (as Conway, Wolfram and Langton have shown with their CA representations and Ray with his early Tierra block diagram [17]).

In artificial life especially, taking a narrow view of sub-systems and their interactions in the hope a big picture will "emerge" may be unworkable not only in practice, but *in principle*. A discussion of this idea follows in subsections which discuss the relevance of visual information presentation to understanding emergence and spatio-temporal relationships in the context of well known a-life examples.

2 Emergence

The philosophical concept of *emergence* (or supervenience) we shall loosely define as the appearance of properties or behaviours of a set of components which may *in principle* be unpredictable by reference only to the rules governing their individual interactions, but which nevertheless arise through these same rules [3][15]. For debate over the meaning of *emergence* in the philosophical context consult [7][13]. The definition above will suffice for our purposes.

A frequently cited example of a software-based emergent phenomenon is the virtual flocking behaviour (and the flock itself) of Reynolds' *boids* [18]. This is said to be emergent from the interactions of the individual agents, none of which explicitly contains instructions for constructing a flock or its behaviour. Secondly, the *gliders* on Conway's Game of Life Cellular Automata grid [8] are also emergent since there are no rules specifically encoded in the CA system to produce their virtual topology and "movement" [5].

Leaving aside the philosophical problems surrounding emergence in these instances, the flock and the glider are recognized by visual inspection of their respective simulations. It may be that each of these simulations is only comprehensible to human observers *because* it can be grasped visually. That is, if *in principle* the flock or glider can only be understood by reference to its structure at the higher level (and not the low level interactions of the components) then the concepts of "flock" and "glider" can *only* be comprehended when all of the important interactions are *simultaneously* compared and connected by an observer. As Tufte has emphasized, "Comparisons must be enforced within the scope of the eyespan" [23, p76].

This means that the properties of, and relationships between all boids and CA cells, and the way these change, must be "held in mind" together before the concepts *flock* and *glider* can be understood. Unless this occurs there may not be any emergent phenomena for a human to behold. Visualization is an ideal means, perhaps the only means, of portraying these relationships simultaneously. The following sections individually examine the relevant features of the phenomena in need of simultaneous visualization.

3 Spatial relationships

A single snapshot of a flock of boids reveals it to be a group of individuals spread uniformly through a volume. If instead of using perspective-projected imagery, an orthographic projection was used, or indeed if the position of the boids at a particular moment was tabulated, even an experienced researcher would gain no clear understanding of the volume or density of the flock.

What of the glider? Again, a list of the positions at a given time-step reveals little about groups of cells, because these are only recognizable when projected into a specifically dimensioned space. Any topology which is discernible from the two dimensional view, cannot be reasoned about visually once the neighbourhood relations are obfuscated, despite the cells being considered as logical neighbours for the purposes of the simulation. A glider's "topology" in this case is purely logical. Reasoning about it will be serial and ineffective. Essential information is not being conveyed.

Beside a drawing of a heart showing veins and arteries, da Vinci asks, "O writer, with what words will you describe with a like perfection the whole arrangement of that of which the drawing is here?" [24, p158] and he might equally well have been describing an image of a flock or glider, simply represented by points and lines on a page.

One further aspect of conveying spatial relationships spatially is as follows. Boids and CA cells may be examined for their immediate neighbourhood relations, or a viewer may step back and examine subgroups within the flock or small collections of cells such as the glider. A further step outwards plainly reveals the flock or "on"-cell area/shape and its density. "Panorama, vista and prospect deliver to viewers the freedom of choice that derives from an overview, a capacity to compare and sort through detail" [23, p38].

4 State-based relationships

Whilst considering a view of spatial characteristics at the closest level, individuals may simultaneously be examined for their *state*. Important boid state variables include orientation and speed. These may be visualized simultaneously in a static image by drawing them as line segments (vectors) with a point or increase in weight to indicate their head, much as has been done since Halley's trade wind depictions of 1686 [22, p23]. What of the state of the flock as a whole? Will its orientation and speed, be deducible directly from the individual velocity vectors of the boids, or should it be visualized individually? This is left for the reader to consider.

In the Game of Life, CA cells in the "on" and "off" states obviously need to be distinguished from one another. This is usually achieved using colour or shade, but shape might also suffice to make such a distinction.

5 Temporal relationships

The essential elements of (virtual) biology are *processes* rather than static entities and relations [12]. Phenomena such as flocks and gliders are relevant to (a-)life studies because of the complex processe of interaction between their components and their relationship to the dynamics of the whole. Whilst in simple cases a process may be discussed by reference to (a series of) static states, the most effective methods for understanding dynamic processes are through tools which explicitly render the changes the system undergoes. Whilst Duchamp skilfully abstracts a "Nude Descending a Staircase" on canvas [6], Calder takes an alternative approach and builds a "mobile" which has movement as an intrinsic property [19].

One common method of visualizing the changing state of a system in print is through the use of a *time-series plot*, a graph with the horizontal axis indicating units of time and the vertical axis the change in a single parameter. This style of chart was reported to account for more than 75% of graphics in newspaper print [22, p28]. (Correspondingly the "Fitness versus Generation Number" time-series might well be the most common graph in a-life literature and also, in the vast majority of cases, the single most useless graph to include if the GA is working correctly.)

Animation provides a powerful two-dimensional temporal display. This is how boids and the cyclic pattern of cell states which comes to be identified as the "topology" of a glider are recognized. Wolfram has visualized the progression of linear CA's by depicting changing cell states as a progression down a page [25]. This is effective because the initial 1D cell array is easily represented on a 2D page with time running vertically. It is somewhat more difficult (although not impossible), to represent a 2D Game of Life array in pseudo-3D on a 2D page. But this visualization is not nearly as effective as an animation.

Plotting the paths of flocking boids in virtual 3D space results in an indecipherable net of lines. Mapping this to 2D is even more confusing. However, the concept of path plotting is not without its uses. Barrass [1] has visualized the paths of virtual ants following pheromones in an aesthetically pleasing and insightful manner. The differences between the agent interactions in the ant and boid simulations are in fact highlighted by comparing the two agent group path plots. Braitenberg has also used simple path plots to compare the trajectories of his vehicles [2, p18].

A sequence of postage-stamp sized snapshots called "small-multiples" [23, p67] has made Muybridge rightfully renowned [14]. This method is somewhat effective in the case of boids and gliders and is presented in [11]. However even this does not give the sensation of the flock so vividly portrayed using animation.

6 Conclusion

There is little above which seems anything other than patently obvious regarding the display of boids and gliders. This is as it should be! The reasoning behind clear visualization of simulations should, in hindsight, be simple to follow. Although this author is not privy to the thinking which gave rise to these simulations, it appears likely that it was, from its origin, of a visual nature. Visual beginnings, experiments, and outcomes – there was never any need to invent visual representations for the models since this is how they were conceived all along.

In many different contexts however, the principles applied to visualizing the above phenomena are equally relevant. Patterns apparent to the eye may go completely unnoticed in charts, graphs and tables. Of course even animations may be uninformative frame rates may be too low, or too high to follow the relevant motion. Colours may be inappropriately selected, masking important relationships or confusing viewers about the identity and history of agents and their components. As with all forms of communication, images may distort, confuse and obfuscate the truth [22, pp53-77]. Authors need to experiment with techniques for visualization each and every time they are confronted with a problem to ensure their presention is enlightening, and not misleading or incomprehensible. A reconsidered visual approach just might provide an answer which would otherwise go unnoticed.

The tenacity with which printed publications remain dominant limits the freedom of authors to include time-variable media in their research documentation and enforces page restrictions. The space required for colour printed imagery is costly, something which is alleviated on CD-ROM or the WWW. These considerations should not limit a researcher in their study! Nevertheless, with care and consideration, authors can use effective graphic methods to convey their ideas in print. *Effective*, not *pretty* – the application of sound visual design is not a decorative art, but a science in its own right. One in which every researcher should play an active role by being sufficiently well-versed in its principles to ensure they are able to solve problems relevant to their work using this valuable tool, and convey its most important findings to others.

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