Architectural Anamnesis

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ABSTRACT: This paper is concerned with how conceptual frameworks, disciplinary perspectives, and personal and cultural histories shape the available range of solutions to design problems. Two notions central to the argument relate directly to the conference theme: visibility and transparency. In both cases, the terms apply, not to physical or phenomenal conditions, but to the conceptual frameworks that guide design and research activity.

Grounding the visibility/transparency analogy are the related concepts of fitness landscapes and design space drawn from genetics and from evolved hardware. These terms designate the graph of all possible solutions and their degree of optimization with respect to certain criteria. Algorithms and organisms are seen to move across this landscape occupying more or less favorable positions.

In order to illustrate the notion of visibility, I use Thompson's experiments in evolving hardware using genetic algorithms. This allows a comparison of the solution space searched by the algorithm and that accessed by human circuit designers. I show that cultural frameworks, such as the concept of the 'digital', restrict the kinds of solutions that are available to human designers. Cultural frameworks outline the range of visibility into solution spaces.

Transparency is introduced in reference to the digital framework in circuit design as a specific case of a more general property of tools that have been long and successfully wielded. Disciplinary and cultural frameworks that have become transparent through extended use are most difficult to identify and transform, yet profoundly affect the kinds of solutions that can be 'seen'. The recovery and exposure of these invisible assumptions might be guided might be guided by the kinds of problems encountered. My intention, by making explicit the relation between frameworks and design solutions, is that designers will come to actively manage the frameworks they employ in solving design problems.

KEYWORDS: Design space, fitness landscapes, visibility, transparency, anamnesis

INTRODUCTION

Anamnesis, the recovery of memory, has a range of meanings specific to the disciplines that employ it. In medicine, it refers to the case history. In Philosophy, it references the Platonic idea that all knowledge resides in an immortal soul, and so cannot be sought, but must be remembered. Here, I use the term to mean bringing into awareness the underlying epistemological assumptions that guide ones work. I hope to show that this has importance for research and design by showing how underlying assumptions circumscribe the kinds of solutions that can be invented. Further, it is suggested, based on Agre's analysis of Artificial Intelligence, that the kinds difficulties encountered might provide a clue to the underlying tacit assumption that give rise to them.

1.0 FITNESS LANDSCAPES

Sewall Wright, a theoretical biologist, first employed the concept of a fitness landscape in 1932. Wright had been invited to give a relatively short and non-mathematical presentation of his 'shifting balance' theory, to the Sixth International Congress of Genetics. The theory was highly technical and involved a genotype space of 9000 dimensions. He invented the landscape metaphor as a diagrammatic representation of the field of all possible gene combinations, reducing them to two dimensions from thousands, and then using the vertical to represent adaptiveness (Wright 1932). Wright suggested that genetic combinations adjacent in genotype space would have a similar level of adaptiveness, and so, the graph might resemble a landscape with peaks of higher fitness, local optima, separated by relatively lower areas. Wright is then able to explain his theory of speciation in terms of the mechanisms whereby successive individuals move across the fitness landscape. Figure 1.

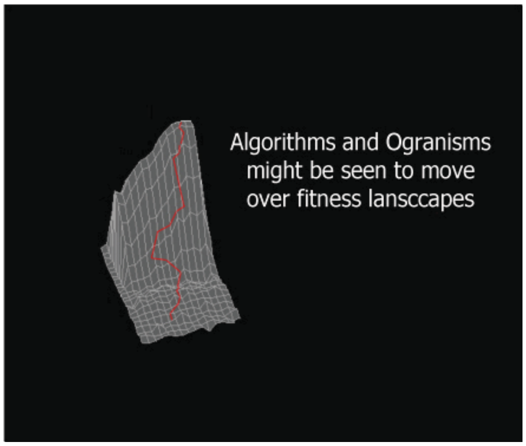

Figure 1. A generic Fitness Landscape

In the present context, I am less interested in the details of speciation than in the ability of the landscape metaphor to facilitate thought experiments, visualizations, and conversation about highly dimensional spaces. Indeed, others were as well. The metaphor was quickly taken up to describe the fitness of populations, adaptive landscapes, and the form organisms take, theoretical morphospaces (McGhee 2007). It has become a standard method of intuiting concepts in evolutionary biology (Kaplan 2008). Fitness of adaptive landscapes is described in terms of their ruggedness, granularity (Stadler 2002) and temporal transformations (Johnson 1999) as well as their topological characteristics. Landscape terms used to describe these topological features include peaks and valleys, holes, benches, plateaus, channels, and discontinuities. Beyond biology, the metaphor has found utility in visualizing how specific computational techniques sample an underlying solution space. In the technique known as simulated annealing, for example, a solution space is initially widely and randomly sampled, and thereafter, the volatility, metaphorically the ‘temperature’ of the sampling, is gradually reduced as better solutions are located and the sampling distribution is concentrated within these local and potentially more productive areas (Reidys 2002).

2.0 DESIGN SPACE

Design activity as implemented in a range of disciplines also operates within highly dimensional space. In addition, it seems to have some elements in common with biology. Highly optimized solutions, with respect to a single variable, are frequently brittle in the face of unforeseen or changing conditions and solutions that satisfy multiple constraints are often the most desirable and robust. In much design work, clusters of solutions of similar desirability can be imagined differing perhaps only in detail or material, suggesting a landscape of rolling hills rather than rugged peaks. Efforts to evolve hardware bridge the domains of design and biology (if only metaphorically), and provide valuable insights to certain aspects of design activity.

In a series of experiments, Adrian Thompson and colleagues demonstrate the application of evolutionary principles to the design of electronics hardware (Thompson 1999) using a Field Programmable Gate Array (FPGA). An FPGA is composed of generic logic gates that can be configured using software running on a host computer. FPGAs are often used build proprietary circuits that have too limited an application to justify producing custom chips. In other circumstances, the ability to configure and then reconfigure, within milliseconds, a fixed hardware resource to accomplish different computational tasks has value. In Thompson’s case, a genetic algorithm controlled the repeated reconfiguration of the gates in a search for a circuit able to distinguish a 1kHz from a 10kHz square wave. In general this is not a difficult task for a human circuit designer, but becomes increasingly so as computational resources are constrained. Thompson allows the genetic algorithm to operate in an area of the FPGA comprising only 100 gates and further does not provide access to an external clock or resistor/capacitor oscillator to coordinate the timing and flow of signals.

Nevertheless, after 4100 generations the output changes from +5Vdc to 0V immediately and reliably as the input signal changes from 1kHz to 10kHz; a successful outcome of the experiment. While the algorithm runs for an additional 1,000 generations, no significant change is detected. Figure 2 shows the evolved circuit with all its connections. By inspection, many of the connections shown do not appear to participate in the circuit, those in the lower right, for example. Thompson and colleagues systematically test and eliminate useless gates and, in the end, find that the 32 shown in Figure 3 are required for the circuit to operate successfully.

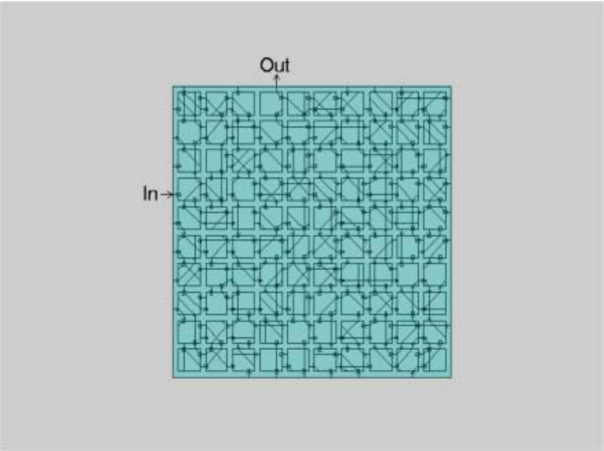

Figure 2. An Evolved Tone Discrimination Circuit (Thompson 1999)

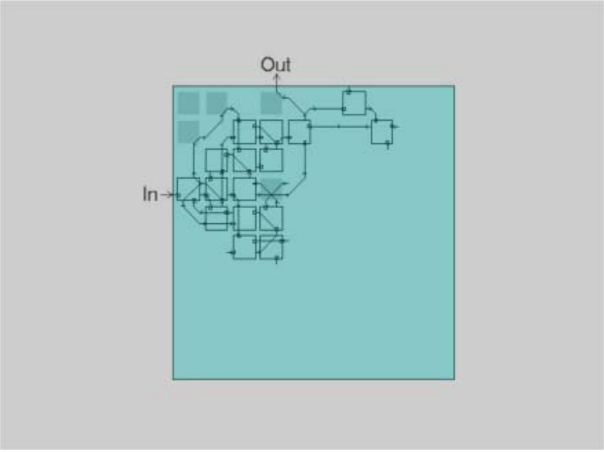

Figure 3. Evolved Circuit Pruned of Inactive Gates (Thompson 1999)

However, the circuit shown does not in any way resemble one crafted by a human designer. The principles on which it operates are not immediately legible. Of particular interest are the cells marked by a grey tone. Even though these cells are not connected to the circuit, it will not operate properly without them. While this result is surprising and intriguing it does not, however, suggest anything mysterious. The circuit operates wholly within the domain of semiconductor physics, but aside the principles of digital design. Thompson and colleagues argue that their evolutionary technique operates in domains of the design space of electronic devices that are not available to human circuit designers operating within the conventions of digital design.

Thompson notes that the genetic algorithms used in his experiments encode certain biases and so do not perform global searches across design space, what is privileged instead is the use of the algorithm to open up previously unrecognized domains of design space with practical value, or to illuminate techniques that are previously unknown and might be incorporated into the human circuit design lexicon. In this the approach is parallel to the objectives of Tom Ray's *Tierra* simulation software. In the 1990s, Ray solicited computer users to run the Tierra program on their desktop machines voluntarily donating unused CPU cycles to a distributed artificial life simulation. The project sought the development of new software 'species' that when recognized and 'domesticated' might produce new useful computational techniques (Ray 1997).

It is interesting to note that the fabrication of the FPGA, the standard methods of configuration, and the intended end use of the device are all predicated on the use of the digital framework. The operation of the genetic algorithm and its highly efficient solution to the tone discrimination problem illuminate the fact that the 'digital' is a cultural overlay atop a material substrate capable of complex and often subtle interactions. These interactions must be carefully controlled, avoided, or interpreted into the discrete binary logic that is the *lingua franca* of electronics. It is, however, exactly these logical assumptions that allow human designers to manage complex tasks. Clearly, by using binary logic, vast ranges of devices and techniques have been developed with extraordinary cultural consequences. So much so that it may seem that the 'digital' is inevitable. But, this is not the case.

3.0 VISIBILITY

Digital, analog, or evolutionary techniques each access different domains of design space. Each has a certain visibility into that design space (Figure 4) based on the assumptions it carries forward. At the same time, the solution space visible to one technique might be in a large measure invisible to another. In the example given, each technique illuminates a portion of design space that is unique or that has very limited overlap with other techniques. I believe that this is true for all design work. In many cases of design activity, assumptions may not result in completely autonomous domains, but rather in domains that differ in salient ways nevertheless, making some frameworks of assumptions more effective for certain tasks than others.

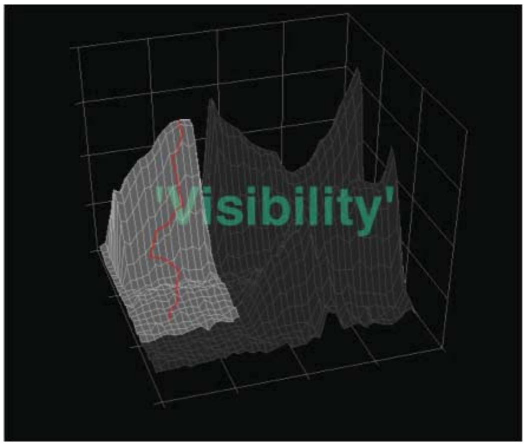

Figure 4. Design Space and Visibility

Without using the term explicitly, Randall Beer takes up the issue of visibility with particular clarity. Beer is a cognitive science researcher employing dynamical systems theory. He writes having noted that researchers from competing disciplinary frameworks have great difficulty in recognizing the legitimacy and value of research in traditions that are not their own. He notes that disciplinary frameworks specify the research questions that will be asked, the kinds of methods that can be used to answer them, the data that will be collected and the techniques that will be undertaken to analyze them. It guides the interpretation of the results, and so ultimately, circumscribes the answers that will be found (Beer 2000). It is exactly the relationship between frameworks and answers that I point to when I use the term visibility in the context of a solution or design space.

The shifting of a conceptual framework may a change a difficult task into simpler one, by suggesting an alternative approach to the problem. A brief example may serve to illustrate this. Since I first saw their wooden frames exhibited in the Sheldon Jackson Museum in Sitka, I have long admired the ingenuity, design and craftsmanship of the *baidarka*, the native kayak of the Aleutian Islands. Eventually I had the opportunity to purchase a modern version rendered in wood and canvas. But the round-bottomed hull, 50cm wide and 5.5M long, was extraordinarily unstable. None of my years of experience handling canoes, even narrow ones, proved to be any help. It was difficult to sit in it and keep it upright especially when encountering broadside waves. Yet, the people who first made these kayaks ranged the open ocean from Japan to Mexico and probably on to New Zealand. How could that be? Eventually I realized that I should not sit in this watercraft, but wear it instead. That is to say, to make it a part of me. Once I understood that, my concern with stability was greatly reduced and I could begin to attend to other things. Rather quickly the kayak became a prosthetic.

This change in my relation to the watercraft allowed a fundamental shift in the dynamics of the system. When I sit in the boat and it is rocked by waves, my center of gravity is moved out of plumb. To compensate, I lean in the opposite direction. Once the initial movement is stopped, reversed and my center of gravity is again above the kayak, I must counter the momentum I now have with precision in order to remain balanced and avoid overturning on the opposite side. If this countering movement coincides with the arrival of the next wave, I add my momentum to its force. I now have the same problem as before, but must exaggerate my previous effort to remain balanced setting up a dangerous oscillation. This way of controlling the boat is reactive. It requires fast reflexes, concentration, and is tiring. The movement is of the head and shoulders. When I integrate with the kayak, I maintain balance by keeping my center of gravity, my head, and shoulders steady and allowing the boat to move beneath me. I accept the lateral force of the waves by movements at the hips and bring the boat back under me when the wave has passed. This approach is much more relaxed and does not require constant adjustments in my relationship to a tipping boat. Quickly it becomes ‘second-nature’ and it happens automatically.

4.0 TRANSPARENCY

I recall a particular moment when learning to draw. There was a point when I was no longer concerned with manipulating the pencil, how it was held, its relation to the paper, its pressure, sharpness or rotation, but only with moving the space, light, and volume within the picture plane. In effect, the drawing instrument and the mechanics of drawing had become completely transparent and the act of drawing was immediate and direct. ‘Finally’, I thought, ‘I’m *really* able to draw’. Michael Polanyi (1958) noted essentially the same thing when he described a blind man and his cane, noting that the man does not feel the cane in the hand, but instead feels the tip of it touching the sidewalk. His focal awareness has shifted from the hand through the instrument to its interface with the world. The cane has been incorporated.

In all these cases the artifact became perceptually transparent because it is reliably coupled to the body. No longer separate, but through habit and effectiveness, it comes to function as part of the body itself. It becomes prosthetic. In fact, there is growing evidence that this is not only experiential, but neurological (Cacola 2012)

5.0 ANAMNESIS

In electronic design something similar has happened with the convention of the digital. For many, it is an assumption that is no longer questioned. Its familiarity and efficacy have rendered it transparent. Disciplinary frameworks take on the same transparency as tools that have been long and successfully wielded. Indeed, they too are tools. They facilitate effective work just as a physical implement. Phil Agre has noted something similar in the field of artificial intelligence. Writing in the mid-1990s, he addressed the difficulties that field had in making progress by looking at the fundamental philosophical assumptions that guided the work. He traces the split between software and hardware to the mind-body dualism of Descartes. In doing so he notes:

> As a result, formalization becomes a highly organized form of social forgetting -- and not only of the semantics of words but of their historicity as well. This is why the historical provenance and intellectual development of AI's underlying ideas claim so little interest among the field's practitioners. (Agre 1995, p 14)

While Agre uses the term forgetting, he intends much the same thing as I do by transparency; the movement from explicit to tacit knowledge. When Agre spoke about institutionalized forgetting it was in reference to conceptual frameworks, tools, and patterns and was from within the domain where the tool or the framework enables. But, the constraints imposed by these frameworks eventually set limits on what can be achieved. At these limits, the once transparent tool regains its visibility. Agre observes, “…technical impasses are a form of social remembering, moments when a particular discursive form deconstructs itself and makes its internal tensions intelligible to anyone who is critically equipped to hear them (Agre 1995, p15).”

Thompson (1999) and Beer (2000) illuminated the relationship between conceptual frameworks and the kinds of solutions that may be found; visibility into solution or design space. Agre (1995) points to a second related, but distinct, kind of visibility, the recovery of tacit assumptions driven by impasses in the work. This kind of visibility is a corollary of the first. Just as disciplinary frameworks and personal and cultural histories enable the invention of certain kinds of solutions, they also constrain the kinds of things that might be achieved. The problems encountered delineate the domain of applicability of the framework. These problems then are not just impasses that need to be overcome, but are information about the domain of design space that is visible from a particular perspective, specifically about how the domain is bounded.

Agre suggested, in the case of AI, that it was an assumption about the primacy of information over material substrate founded in the dualist traditions of Western thought that constrained what the discipline could achieve. Understanding this, brought alternative approaches to light that opened new possibilities for the field. Enactive approaches to cognition, for example, put an emphasis on embodiment and so hardware and tightly coupled interaction with the environment became more prominent.

This same assumption about the primacy of information remains prominent within our culture in many disciplines. When genetics is looked to for answers concerning disease, personality and behavior, achievement and human nature, it stems from this common belief. In Architecture, some practices and many schools foreground form over material. Computational techniques as a principal determinant of form are consistent with this approach. Projects within this tradition tend to require innovation in building technique to achieve the forms required. Alternatively, often additionally, the formal objectives of the project are compromised for buildability. The use of three-dimensional printers for models is common and their development as building-scale form printers is under active development. In these cases, material is neutralized and plays a passive role to information's active one.

My purpose here is not to criticize an information-based approach, but rather to suggest that encountering difficulties in construction, compromises in form, or failures of building systems points out that in certain cases, the limits to the viability of this approach have been encountered. Following the example of the changes undertaken by AI, one might suggest that greater attention to material substrate and environmental conditions may yield access to other domains of design space. These alternatives, however, are subject to their own assumptions and limitations.

6.0 VARIABLES AND CONSTRAINTS

Susan Oyama, a developmental systems theorist, criticizes of the information-processing model of biological development that recognizes an opposition between that which determines variety, the variables, and what determines continuity, the constraints. This is an active vs. passive characterization. She notes, instead, that one way of understanding a constraint is that it is a variable that isn't varying. She also notes that constraints are as interdependent as variables are and that what constitutes an effective constraint depends as much on the properties of the rest of the system as does an effective stimulus. Conceptual and disciplinary frameworks, cultural histories and personal experience all function to shape ones ability to engage in successful design activity. Which of these functions as a variable and which as a constraint? With Oyama, we should consider variable and constraint to be a current and perhaps temporary function of the frameworks we employ. Ones strength as a designer may come from recognizing self-imposed constraints and, instead, employing them as variables when it serves us.

CONCLUSION

I have attempted to show that the underlying conceptual frameworks function both as illuminators of design space as well as restrictors. They can be seen as either depending upon ones intent, but also upon the degree to which they facilitate the design activity at hand. One could see that the domain of effectiveness for each framework differs. Problems that arise in the course of design activity outline the domain of effectiveness of the underlying assumptions that guide design activity. The nature of the impasses may give clues about the nature of the assumptions that give rise to them. Misfits, anomalies, and surprises can be understood as markers outlining the applicability of the framework. Instead of pointing exclusively to the new, they are also capable of delimiting the existing framework. In addition, as Agre noted, problems, especially those that do not yield to repeated attempts at solution, may point to inherent limitations in the underlying conceptual frameworks. As problems outline, define, or circumscribe the domain of applicability of a framework, they give it a 'shape'. The more interesting questions for me concern the conditions under which a framework yields suitable results and those under which it is inapplicable. Given a relationship between frameworks and a domain of effective design activity, how can one anticipate the selection of or a switching to an appropriate framework based on the nature of the design challenge one is facing? Can one develop an ability to understand either by taxonomy or by intuition, the shape and structure of frameworks, or to develop any general notions about their use?

REFERENCES

Agre, P., 1995, The soul gained and lost: artificial intelligence as a philosophical project, Stanford Humanities Review, 4(4), pp. 1-19.

Beer, R. 2000. Dynamical approaches to Cognitive Science, *Trends in Cognitive Sciences*, 4(3) pp 91-99

Cacola, P. and Gabbard, C. 2012. Modulating peri-personal and extra-personal reach space via tool use: a comparison between six- to 12-year-olds and young adults, *Experimental Brain Research* 218(2) p 312 Springer

Johnson, N. 1999. *Importance of Diversity: Reconciling Natural Selection and Non-Competitive Processes*, LA-UR-99-3048, Los Alamos National Laboratory

Kaplan, J. 2008. The end of the adaptive landscape Metaphor? *Biological Philosophy* 23:625-638

McGhee, G. 2007. *Geometry of Evolution: adaptive landscapes and theoretical morphospaces.* New York: Cambridge University Press

Oyama, S. 1985. Ontogeny of Information: developmental systems and evolution, New York: Cambridge University Press

Polanyi, M. 1958. *Personal Knowledge. Towards a Post Critical Philosophy*. London: Routledge

Ray, T. 1997. Evolution as an Artist. In: `*Art@Science*'', Sommerer C., Mignonneau L. [Eds]. New York: Springer, pp 81-91

Reidys, C. and Stadler, P. 2002. *Combinatorial Landscapes*. SIAM Review 44(1) pp 3-54 Society for Industrial and Applied Mathematics.

Stadler, P. and Stephens, C. 2002. *Landscapes and Effective Fitness.* Working papers of the Santa Fe Institute 02-11-062 available at http://www.santafe.edu/media/workingpapers/02-11-62.pdf (accessed 010113)

Thompson, A., Layzell, P. and Zebulum, R. 1999**.** Explorations in Design Space: Unconventional electronics design through artificial evolution**,** IEEE Transactions on Evolutionary Computation, 3(3), pp 176-196

Wright, S. 1932. The roles of mutation, inbreeding, crossbreeding and selection in evolution, In: *The Sixth International Congress of Genetics*, Vol. 1, pp 356-366