Aesthetics of Decision

Unfolding the design process within a framework of complexity and self-organization

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Complexity-grounded paradigms and self-organization based strategies promise enormous potential when channeled in a design process, but their current stage of development (while delivering groundbreaking results in recent years) hasn't significantly impacted yet the widespread architectural practice. Still, the tendency (in the development of technology and society) is clearly towards an increase in complexity and distributed intelligence, henceforth it is of primary importance to adopt a design approach that allows the harnessing of such potential and convey it in the creation of outcomes that favor a richer and heterogeneous ecological entanglement. To tap this kind of potential in an open-ended process requires a design approach that re-defines the distribution of control, choices and information throughout the whole process (including materials and fabrication processes). The paper explores the possibility of such design approach in the territory that links education and research through a series of Master Thesis developed at the University of Bologna and comparing them to other case studies developed worldwide.

Keywords: continuity, tectonics, architecture, mereology, multi-agent systems, theory, robotic fabrication, computation, simulation

INTRODUCTION AND BACKGROUND

Complexity is undoubtedly one of the most powerful paradigms of contemporary age; the idea of emergence and self-organization in particular, that complexity can stem from the interaction and feedback over time governed by simple rules capable to produce stable, coherent organizations is of particular interest for its potential implications in architecture.

Prior to the discoveries that led to the formulation of this paradigm, it was taken for granted that the role of the designer was that of a mastermind able to conceive a complete model of the entire project; an immediate consequence of such condition is that the highest complexity achievable coincides with the one conceivable by the mind of the designer. Automation of simple tasks (the hallmark of the industrial revolution) was only implemented in a linear fashion without the possibility of feedback, therefore precluding any form of endogenous adaptability or self-adjustment in the system, strengthening
further the divide between design and making first theorized centuries earlier by Alberti. The design process thus sedimented a clearly hierarchical decisional pattern based on the division of labor where the divide did not only involve design and making, but branched further the design process itself separating (save for few remarkable exceptions) conceptual ideation and constructive thought as two consecutive moments. The technological acceleration and the evolution of scientific-philosophical paradigms usually do not go hand in hand, with the first setting foot first in unknown territory while still carrying the ways of the old ones: the first application of new technologies almost always happens as an extension of old paradigms (it happened with concrete in architecture, or with the desktop and file metaphor in computers); it takes some time and adaptation before our mindset is changed by it and starts to envision the true, inner potential and its consequences.

So the advent of computers in architectural practices happened as a substitute for the drawing board first and in the power of calculation slightly after (again, with few remarkable exceptions, see [1]). Problem solving oriented processes were early adopters, due to the inevitable osmotic exchanges from computer science and reliance on measurable performance, and contemporary instances already benefit from agent-based strategies, genetic algorithms and neural networks (since they deal with measurable performance henceforth naturally evolving towards greater efficiency through technology and technique). Still, the tendency (in the development of technology and society) is clearly towards an increase in complexity and distributed intelligence that, for its own nature, exceeds and transcends any definition of “optimal” as always context-biased and resists reduction to accommodate a plurality of functional and communication patterns.

It is of primary importance to adopt a design approach that allows the harnessing of such potential and convey it in the creation of outcomes that favor a richer and heterogeneous ecological entanglement. To tap this kind of potential in an open-ended process requires a design approach that re-defines the distribution of control, choices and information throughout the whole process (including materials and fabrication processes).

The work presented in this paper situates itself after precedents in the use of agency and complexity in architecture such as the work and research by Kokkugia ([3] and the recent independent developments both in academia and practice by its respective founders Roland Snooks and Rob Stuart-Smith), Jose Sanchez (Plethora Project) and his work with Alisa Andrasek at the DRL and the Bartlett (one exemplar case: [4]), as well as other numerous other cases in those and other relevant schools. What all those cases share in common is an heuristic use of agency and multi-agent system as a way to embed performative coherence and navigate it in search of novel and richer tectonic (spatial-structural, as well as perceptual) expressions. The predictive use of multi-agent systems such as modeling user behavior in architectural spaces is not of interest and while its reliability in some cases is acknowledged it is also not relevant in this context.

**IMPLEMENTATION**

The methods adopted in the theses rely on iterative computational simulation implemented in several programming and modeling platforms coupled with material experimentations and (in most cases) multi-agent system and robotic fabrication: such phases are interwoven with and not subsequent to computational simulation.

Although simulations might well start by trying to reproduce certain processes or behaviors (using role models from biology/geology/physics/-chemistry for their inherently elegant complexity) their potential resides in their endogenous coherence. Once the relations regulating the system are established so is the metric of the system’s output, despite little or none is known about the final outcome. They operate in a state of vagueness, driven by internal logic but open in determination and their outcomes, being consequence of a coherent set of
operations, are endowed with the property of being a structure of communication in themselves. Internal logic is not an overarching imposed principle, governing form and function from the outside, but an embedded feature of relations and objects that blossom into organized complexity. Logic becomes an aesthetic operation that cannot be subjected to complete synthesis or axiomatics, it operates in an irreducible complexity. Simulations also do not need to refer to a role model anymore, moreover their potential lies exactly in the possibility to explore the unknown by inventing alternate modes of reality, or hyperreality, as Baudrillard (1983) calls it. This capacity of abstraction is very different from the Albertian notation system that separated conception from realization, freezing all dynamics in the representation to which material processes should subdue; it is an abstraction of principles, one that conveys the distance between the design intent and the artifact at the level of instructions. Algorithms should then be considered as actual modes of thought (which extends Baudrillard's precession of simulacra to the algorithmic world) that symbiotically evolve with us; more concisely and to reconnect the notion of logic as aesthetic operation, what we need (in the words of Shaviro) is "an aesthetic of decision" in a framework of self-organization and emergence [2]. The expression touches a very important part of the design process that has to do with authorship, intentionality and the possibility, in the particular case of generative design, to drive self-organizing system in order to better explore and harness their undisclosed potential. According to Roland Snooks (2012) authorship in generative design can be traced in the pattern of two contrasting kinds of decisions: criteria (which frame the possible realm of the output and are inherently stable) and procedure (which regards the condition of operation, therefore is inherently speculative and processual); simulations enable the possibility of emergent outcomes through the interaction of design procedures.

There is then a shift from the explicit design of form and organization towards the choreographing of intensive processes of formation through the design of the material and geometry behaviors regulating them. The architect programs the decisional pattern shared by the individual agents and makes decisions on the shape and topology of their body (thus defining their affordances) as well as their sensorium, the range of accessible and processable data and its form (i.e. reading solar radiation in form of vertex colors on a 0-255 value range, or a generated data field not necessarily connected to a particular physical variable). Global form, collective behavior and tectonics emerge from their interaction over space and time. There are two important points that should again be stressed: the environment is designed (when constraints are chosen and data to be read is organized) and the designer is a player in a more extended ecology involving machines (analog, digital or biological) that operates not only through human-machine dialog but also by machine-to-machine communication or "the correlation of technical beings among themselves" (Simondon 1958, 181). Ontologically speaking, the relation between code and being is perpetual: differently from the Deleuzian diagram/assembly where the former only provides a topological scheme for the latter but ceases to operate once the latter is formed, the code continues to inform and operate on beings as they mutually interact and alter their own code (Spuybroek 2008).

This approach to computational simulation promotes an alternative understanding of control and interaction between top-down and bottom-up processes, without giving in to the easy production of highly ephemeral systems that champion random accidents nor reduce its exploration to the safe haven of algorithms with stable indexical relations to their formal results. While computational design has straightforward advantages in the automatization of processes and designing the structural and organizational aspects of a project, if our intention is to harness the inherent potential of non-linear complex systems it is not enough to simply apply a picture of complexity to essentially modern objects; complex
systems are equally adept at engaging with form, as the emergence of form can be understood as the organization of matter itself.

**CASE STUDIES**

It is the case of Oxymoron (Figure 1), a thesis project where Topology Optimization (usually employed as a reduction device to optimize structure in given conditions) is used for its inherent rationality in computing form according to stress distribution patterns as a mean to explore opulence and a richer spatial expression. The iterative exploration of non-reductive constraints patterns (for which the condition to respect stress-response criteria was necessary but far from sufficient) in the design of a tower for Shanghai was a key factor in maximizing the spatial expression and transcend the typical bone-like structural figuration of Topology Optimization algorithms. Iterative subdivision of simple triangular façade elements in relation to the distribution of stress patterns reinforces and further articulates the visual heterogeneity and complexity.

In other cases, systems are modeled around object-oriented strategies, extending the classical multi-agent system model theorized by Reynolds (1987) and comprised of the basic local rules of flocking (direct communication between agents by cohesion, separation and alignment) with the stigmergic model (an indirect communication protocol that occurs through the environment) based on the theoretical premises in Jones (2010) and occasionally custom made rules for direct/indirect interaction, with or through the environment. Interaction between different agent "species" can be of collaborative or competitive nature; the latter provides the conditions to strengthen and stabilize the former.

Environmental perturbations do not alter directly and/or proportionally the morphology of the system but affect the agents behavior, which pattern of propagation through the system is not an indexical image of the perturbation field. The environment itself is coded as an anti-object, (Repenning 2006) an active part of the simulation that carries and computes multiple discreet information in each of its voxel cells, doing most of the heavy-lifting in the computational process. It acts as common substrate for data exchange through which the multi-agent systems is communicating by reading/writing. The information in the environment is then encoded as data map in the voxel field, selectively accessible by the agents in 3 possible ways: data retrieval from the nearest cell, value interpolation from n nearest cells (with different degrees of anisotropy), direct calculation from the field general formula.

This common setup is then implemented (with significant differences) in three more case studies: The Red Queen Hypothesis, Ari3dne and Homeorhetic Assembles. In all of them the decisional pattern is twofold: on one side the definition of environmental constraints and conditions (i.e. a "pheromone" gradient that induces anisotropic behavior) as well as specific interaction rules, the output evaluation and refinement of initial conditions on the other. Changes in these initial conditions do not lead to a proportional response but a non-linear propagation and feedback that might result in a heterogeneously densified phylogeny in terms of system expression (highly volatile variations may occur in narrow parameter spaces whereas large subdomains might show a "flat" variation landscape). Functional performative criteria as well as unapologetically aesthetic reason can drive the selection pattern that then feeds back into the algorithm in an increasingly serrated and convergent exchange. These systems' internal logics provide solid coherence and the mapping of function onto form does not precede the project development not privilege specific relations over equally possible alternatives in an open spectrum.

In The Red Queen Hypothesis (Figure 2), the competitive behaviors of two different sets of agents fighting for resources fosters the generation of an interlocking spatial negotiation that reaches homeostatic stability over time. The strategy is applied at the scale of tectonic development of a structural skin.
Figure 1

Figure 2
The Red Queen Hypothesis - thesis project by Paolo Alborghetti - advisor: Alessio Erioli.
Figure 3
Ari3dne - Thesis
Project by Daniele Colombati - advisor: Alessio Erioli - co-advisor: Gabriele Evangelisti.
Figure 4
Figure 5
Ari3dne (Figure 3) aims to embed constructor agents as part of the architecture, mutuating its tectonic expression from the ridged web formation process of the Euplectella Aspergillum; the agent have the capacity to read and write situated data in the environment and on the built material organization and operate both as constructors or destructors according to seasonal, use and circulation pattern variations. As a result, the project blurs the traditional boundary between construction and maintenance process as well as challenges the notion of a fixed object with a "final" configuration while retaining as strong identity and presence.

Homeorhetic assemblies (Figure 4) incorporates the dynamics of beehive formation and simulates the evolution of material viscosity and its hardening over time while constructor agents perform a stigmergy-based deposition in a data-rich environment.

In both cases assemblies are dynamic and strongly redundant as they perform a variety of functions and exhibit several possible affordances that transcend the mere structural capacity. In the simulations that involve constructor agents, their behavior is conceived with specific constraints and operations tied to a machine (such as a robotic arm, 3D printers, etc.), its body topology and capacities, and a material system. Thus, the relation with fabrication and material goes both ways: simulations talk directly to machines as constructor agents (directly writing machine code as output) and physical outcomes and simulations are precious sources of information that then feedback into the simulation programming as design constraint and parameters (body size and movement constraints, material behavior).

These principles constitute the foundation of another thesis project, Swarm Constructability (Figure 5). Here the research spanned low-cost robotic construction, material system and behavioral programming. In order to better detect the potential emergence of self-organizing properties and artefact qualities as a result of the system interaction and not of the individual unit sophistication, the behaviour of the single robot has been reduced to the bare minimum of movement (upside down thanks to magnetic wheels so to not interfere with the deposition), avoidance, signal emission and detection, stigmergy-based steering. The key parameter affecting how the others play out is the minimization of energy consumption for the single unit: the chosen material works at room temperature, allowing to use for movement also the energy otherwise required to keep it above the state change threshold. The peers coordinate with each other and choose when pouring material through a signal deposited in the environment (light stored and slowly released by a sensitive coating in this case).

**DISCUSSION**

The desire to talk to machines is not merely driven by a necessity to optimize a design to production pipeline; rather, it is directed towards "the development of reciprocity between designing and making" (Maxwell and Pigram, 2012). Matter itself can produce tectonics, as it is able to process information and spatially organize as a consequence of those processes; material qualities are also translated into properties of the interacting elements within the simulation; as system behaviors, they become rules for the emergence of form as a consequence of material arrangement which cannot be included in the simulations. In the iteration among simulation, agency, constructive behavior and material effects, the aesthetics of choice implemented by the designer affects the trajectory and convergence of the design process in ways that aim to challenge the established linear conception-realization sequence. While the intentionality and subjective contributions can be traced as the pattern of choices and how these are distributed into the process, the non-linear nature of the process itself (and thus the impossibility of establishing clear cause-effect predictive relations on a global scale) leaves authoriality as an open question.
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