An Emergent Form Generation Method for Supporting Conceptual Design

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Abstract: Evolutionary design methodologies generally aim to present new form-finding processes, where nature-based approaches are used, such as self-organization, genetic algorithms etc. This paper aims to present a new architectural design approach that focuses on integrating these different evolutionary methods in an emergent process. The main goal is to achieve a high-level of integration where lacking qualities of each evolutionary method are completed by the other one in a synergic and especially emergent behavior. A multi-level design approach is described in this study. Points highlighted are concerned with the pre-design phases. Within a bottom-top simulation, an infinite high-level solution cluster is revealed from behavioral interactions and collectivity of the low-level entities: agents. Simulated design process is visualized by a determined project area in Istanbul: Kuruçeşme Island on the Bosphorus as an exhibition center. Programmed in 3dsMax, simulation phase supports the creative design process in early phases.

Keywords: Evolutionary design; bottom-top approach; self-organization; agent; emergence.

Introduction

Design idea is one of the oldest accumulations of human being. Several concepts and approaches emerged since this idea was handled as a process. A look at contemporary examples in architecture would introduce a decisive struggle about projecting the golden ratio between self-organized natural phenomenon and mechanical (as Newton described cosmos like a regular machine) artificial order. Put another way, design systems, being congested within limited, rule-based and top-down constraints are being rebuilt in accordance with the nature inspired approaches. Such kind of system based metamorphosis undoubtedly triggers questions about evolving designs in the light of natural concepts like chaos, order-disorder, equilibrium, self-organization, emergence etc.

Nowadays contemporary design methods, especially the ones which are directed by a bottom-up approach are used in different manners by several designers. Built up within nature’s existing system principles, these methods are preferred by an ascending number of users through their capability of systematizing design process in holistic evaluation, focusing moreover on details than the other approaches and generating a huge solution domain with quality. Another reason generated by Evolutionary Design
Methodologies for this delayed attraction is the probabilistic selection method which directs the random generative process towards meaningful and satisfactory results and the diverse test & generates area supported by computers (CAAD, AI etc.).

As perceived, there is one unique design solution diagram in common design approaches which generally emerges. Indeed, architectural design is a multi-level algorithmic process where sometimes opposite but epistatic phenomena fight to form a complex, in contrary organized formation as well (Gurer, Cagdas, 2006a). This research briefly aims to establish a new multi-level design system, based on a dynamic fusion of different architectural design processes which focus on taking the design matter in hand within a natural bottom-up approach. The point to be reached in this study is to stimulate hierarchically all design systems used, in order to generate a perfect order at solution step and a well-funded relation between system and environment, as perfectly happening in nature. Simulation, agents, self-organization and emergence are handled as the basic strategies of this conceptual form generation system.

Innovative design strategies

It is more helpful to explain first of all, the basic structure of the proposed design system. Form generation processes are a huge area of investigation for evolutionary systems. Natural phenomena actually play a key role of inspiration during the generation of design structures, shapes and most recently processes (Gurer, Cagdas, 2006b). One of the most important key points of this research is to generate a co-related design process which finally gives a rich variety of mature as design solution instead of taking a simple physical copy of nature-based shapes. In order to reach this goal, the multi-level form generation process is supported by some specific methods highlighted below.

Virtual agents are autonomous elements composed for a determined system in order to solve one or more specific problems. They generally have a simple mission-based character with determined rigid rules. On the other hand, in a generated virtual environment, any social achievement can’t be reached without a collective assumption secured between the smallest elements (agents) of the system. A self-organizational attribute should be structured. Agents are consequently loaded with collaborating behaviors such as attracting, repulsing etc. They are not used anymore as ordinary problem solvers within this approach. They react, collaborate, and have autonomy to be self-organized. This organizational phase between agents should obviously happen in a virtual simulation. The idea is to construct the computational devices (known as agents with some properties) and then, simulate them in parallel to model the real phenomena. The process gives birth to a kind of emergence from the lower (micro) level of the social system to the higher level (macro).

Testa (2001) summarizes this emergent concept first as the investigation of a design problem’s elements and their inter-relationships and also a process of solution composition that works bottom-up and is guided by considering the design elements as a collection of interacting agents that give rise to emergent global coherence. Emergence, in this study, is a main purpose which is aimed to be derived from all these structural organizations in the name of design process. Accompanied behavioral interactions between low level elements (agents), a global high level solution cluster is intended to emerge.

The simulation was programmed in 3dsMax to visualize the results in real time and three dimensions. Project area was partially modeled and topographical maps were taken from Google Earth.

A computational design model

To be more specific in observations during the process and the final solutions, a project location was chosen: Kurucesme (Galatasaray) Island (Figure 1). This is a human-made artificial land situated on Bosphorous, in Istanbul between the two bridges
original behavioral character depending on agents’ quality and quantity. Like every simulation-based process, this one is stopped at a determined time which varies due to the users’ approach. The main approach here is to end the simulation whenever it tends to take a vicious circle aspect in the name of agents’ interactions.

During the process, agents which will be involved into simulation are classified. There are 2 types of agents which act:

1. Mono-behavioral circulation agent: This is amenable to form the circulation trajectory and service areas of the exhibition center with a follow behavior. Any other action or interaction is not loaded. It just pays a visit the virtual attraction points disposed on determined points of the project area and returns back. A virtual block at 20 meters height from the island is disposed to control the height coherence for the agents (Figure 2).

2. Multi-behavioral local agents: These agents are determined to generate different exhibition spaces (open, closed etc.) with the ability of interacting each other in the light of loaded behaviors such as attract, repulse. To reach an intersection with the circulation trajectory, each agent is loaded with the behavior of contacting at least once to the circulation trajectory (Figure 3).

The complexity of the design process is related
to relations that will occur between these agents. Each agent has a direct access to the whole project area. The basic behavioral interactivity model consists of 3 steering behaviors:

**Repulsing**: Gives agents the ability to prevent from crowding to closely together and to scan a wider area. Cohesion risk between agents is minimized. A large and complex movement trajectory is estimated.

**Seeking**: Contrary to repulsing behavior, this gives agents the ability to lose interactional distance with others. Without seeking behavior, there is always a risk for agents to be widely dispersed in the simulation area having lost the organizational ability predicted in the system analysis.

Degree of the behavioral complexity determines agent interaction level. That’s why hierarchical arrangements are involved into agents’ behavior. The concatenation of behavior makes agents evolving during the simulation. For example a multi-behavioral local agent can start the simulation with a character of seeking others. But since the degree (it depends on the distance with the target) of the present behavior declines, next behavior replaces it (Figure 4). This change affects the trajectory this agent has followed until this time. With this, a possible monotony in the name of agent trajectory is prevented.

Accompanied with one or some of the behaviors analyzed above, unpredictable and complex movements can be obtained from agents added to the simulation.

**Implementation of the model**

After having determined behaviors of the agents, simulation sequence of 100 steps prepared in 3dsMax is started (several observations showed that after a hundred steps, simulation makes repetitions, so 100 steps are chosen to prevent a possible vicious circle). From the beginning to the 100th step, all movements made by the agents are first memorized and then converted to NURBS (Non-Uniform Rational B-Splines) in order to obtain trajectories as splines before making surfaces (Figure 5).

The morphological phase of the design process focuses on associating paths (traces) left by agents in order to generate exhibition areas around the circulation trajectory (Figure 6 and Figure 7). Surfaces are made by the splines around the circulation area.

**Summary of the process**

After having obtained final results of the system, a brief can be organized about the whole multi-level design process (Figure 8). First agents are chosen for the simulation sequence. They are then loaded with different behaviors. In order to reach maximum complexity, the number of multi-behavioral interactive agents can be augmented. A more complex behavioral hierarchy can also be prepared. Simulation phase is then ready to be started. Simulations with a differentiation of agents’ quality and quantity may produce different solutions. The unique similarity is the process, where initial agents tend to evolve...
by interacting each other accompanied by several behaviors. Indeed, as Grassé (1959) wrote, individual behavior modifies the environment, which in turn modifies the behavior of the other individuals. Absolute epistasis is the key and end point of the simulation before the emergence of morphological aspects. Self-organized agents give emergent trajectories at the end of the simulation. These trajectories, enabled to be transformed to non-uniform curves in the morphological phase are then taken to form generation phase. They are associated with each other, in order to obtain 3d surfaces.

**Conclusion**

Generating new form-finding strategies by focusing on the system process, instead of the formal solutions clarifies that new dynamics are ready to be explored in order to open new design spaces in architecture. Evolutionary design systems with their bottom-up attribute are an impressive medium to make the design process more transparent and more analyzable for both the designer and the user. This study especially focuses on generating a dynamic fusion of different design approaches, where interaction and evolution trigger emergent solutions. Agents, simulation, self-organization, emergence and shape morphology are the basic strategies being focused on. One of the infinite solution clusters was analyzed to be more specific and coherent with the proposal system. More complexity is added to the design process, more variety in computational creativity was gained in results.

**References**

Gurer, E., Cagdas, G.:2006a, Nature Inspired Approach: An Emergent Form Generation Method, in Proceed-

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**Figure 5**
Examples of agents’ movements in NURBS format

**Figure 6**
Different views of the exhibition and the circulation areas