Generative exploration of architectural envelope responding to solar passive qualities

Integral evolutionary design, integrated to early stage of architectural.

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Abstract. This paper deals with the architectural design process and the digital tools able to support a creative activity. Evolutionary devices are expected to support the architect in the initial phase of his work in progress and to stimulate his creativity through analogical thinking. An experimental tool is described, this one is using a genetic algorithm to explore the solution space, and it is based on both solar passive qualities and subjective interaction.

Keywords. Architectural design process; evolutionary design; genetic algorithm; analogical thinking; environmental parameters.

Introduction

The digital tools usually used in the initial phase of the architectural design process seem to be maladjusted to support creativity. We expect that the generative processes and moreover the evolutionary devices could suit the design activity. After we mark that the integral evolutionary tools are not only focused on the search optimisation but also on the creative stimulation, we will characterize the architectural design process. We will note the necessity of the interplay and of the non-deterministic exploration. The notions of creativity and novelty will be specified through the point of view of the design process researcher and of the knowledge researcher. Finally we will suggest and present an evolutionary digital tool based on environmental parameters and designers' requirements.

Related works

Integral evolutionary design

Genetic algorithm is probably the most well-known of all evolutionary search algorithms. Starting from J. Holland in 1975, in order to explain the adaptive processes of natural systems and to design artificial systems based upon these natural systems, there are several examples of the use of genetic algorithms. Caldas (2003) drives optimisation of building envelops through a genetic algorithm to minimise HVAC, lighting energy and construction costs. Malkawi (2003) offers a java environment using a genetic algorithm as an evolution algorithm and CFD performance as an evaluation mechanism. Nishiro (2001) provides an example of interactive evolutionary computation applicable to a creative design process. Other

examples include parametric design generation in order to define initial generic geometry. Genetic generation is then used to drive the design (Krishnapillai, 2004). In general, evolutionary design could be divided into four main categories: evolutionary design optimization, creative evolutionary design, evolutionary art and evolutionary artificial life (Bentley, 1999). We are more interested here in the notions of creative evolutionary design and evolutionary design optimization. Their overlapping is usually called integral evolutionary design. In addition, they can be used as a design aid in stimulating the designer's creativity. They are characterised by:

- A pool or population of design solutions is used rather than a single solution.
- Individuals are selected according to their adjustment to the fitness function.
- New solutions are generated through mutation and crossover of previous elite.

Architectural design

Designing as designing

Designing involves not only a search but a reformulation of the search space; the design space changes over time. New knowledge is learned during the design activity and contributes to reformulate the purposeful of the design process. Guilbert (1987) gave this definition: "Design process is a formulation/resolution concomitant of implicit problem never resolved nor described definitely." The convergence of the solutions is parallel with the understanding of the problem; solutions and problems co-evolve during the whole design process. Boudon (1994) postulates that "the process of conception is a diachronically one that implies a progressive transformation of what a project is". Through a computational point of view, a process of meaning communication between the design system and user emerges. Thus an interaction between the user and the digital tool is necessary.

Perception / design

In order to characterise the architectural process, we would like to take a pedagogic example proposed by Estevez (2007). During a workshop of design, Estevez asks his students to start their design with a "ready-made". With the manner of Marcel Duchamp, students are invited to follow 4 steps: First, they have to make a selection from everyday objects, a construction by assembly. Then they are asked to sharp their glance and to identify some architectural "analogons" from what they have in front of them. During the third step they have to name their construction, and to try to disturb the link between words and things. And finally, they have to re-start from the beginning and to try to highlight the difference. The new is here considered as a remarkable singularity emerged from repeating. We will come back on the notion of new below. We notice here two main characteristics of this process: first the construction of an "object to think", which is to be linked with the "analogical thinking", second, the exploratory and recursive dimension of architectural design process.

Creative thinking

Biausser (2001) identified the main types of creative thinking. She presents the logic thinking based on Aristotle logic, the paradox thinking, the complex thinking, the modelling, the mediation, the contextualization, the imagination, the computation, the systemic thinking and the analogical thinking. She postulates that creative thinking is a dissipative structure, created from a random disorder produced by the opposite influence of our imprinting. It means that a creative thinking convokes all these

concepts in a complex blend, and that the designers drive their design by using them in function of their personal culture and opportunities.

We are more interested in the analogical thinking. This one is based upon a similar connection: a relationship made between things that don't have any links in principle. Analogical thinking makes shortcuts in the logical thinking and evolves profitable creativity. (Chuppin and Léglise, 1997) Analogical schemes participate to the reflexive dialogue between the designer and the situation. Le Corbusier called this "poetical reaction". Cognitivists called this re-mergence. They are function of a mutual link between perception and design. This activity produces analogies, creates links between things that first seemed largely different.

Many historical works focus on the fact that analogical plays a key role in works of major architects and designers. Researchers, working more specially on design process, identified the efficiency of analogical thinking.

About creativity notion

The qualifier "creative" makes reference to something novel, unexpected. The idea of novelty is relative. Boden (1994) suggested to mark two creative families: Psychological creativity (P-creative): a creative idea is apparent to the person in whose mind it arises; historical creativity (H-creativity): the creative idea is P-creative and no one else has ever had it.

Gero and Maher (1993) distinguish between routine, innovative, and novel design using the concept of design variables to make the distinction. In a routine design, the variable and the values associated with the design are known in advance. In innovative design, the variables are known but some of their values remain unknown. In novel design, the designer introduces new variables, defining a new kind of design that was not part of the original search space. (Gero 1990) In a routine design all variables are known, the space of possible designs is known. Here the designer has to locate appropriate design, the result is the best design from this space. In a non-routine design, it means a creative design; the result is the best space of possible designs as well as the best design from this space. Processes that modify the design space could be considered as exploratory processes.

Finally there are numerous other characteristics associated with creative design beyond novelty. These include aesthetic appeal, quality, unexpected, uncommonness, peer-recognition, influence, intelligence, learning and popularity (Runco and Pritzker 1999). This more broadly defines creative design as being more than just novel, and including judgements related to its appeal and usefulness.

We make the assumption that an evolutionary digital tool based on exploratory processes and on an analogical thinking could lead a creative design from which some outstanding singularities could emerge.

EXPERIMENT

Development environment

We focus our point of view on the initial phase of the design process, where the designer is looking for ideas. In our proposition, a generative process has already been defined; an evolutionary process and a solar passive fitness compose it. It means that the designer is searching an appropriate formal proposition to go further in his work in progress. This experimentation is made through the use of 3DS Max® software, maxscript is used regarding scripting and encoding. A Genetic Algorithm had been scripted in maxscript. The final experimentation is being developed. Environmental

parameters are used to drive the evolution. Solar passive evaluation is based on Unified Day Degree method (UDD).

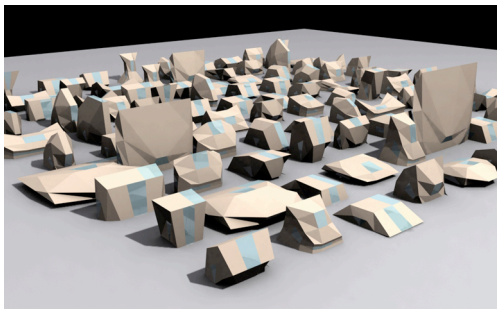

Figure 1
Possible population (06_marin_fig01.jpg)

Initial pattern

The initial pattern is a box. The designer could define its global dimension and topological description.

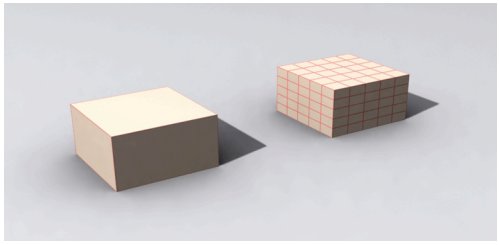

Figure 2
Initial patterns (06_marin_fig02.jpg)

Shape exploration

The shape exploration is based on transformations through operators' execution called "modifiers" in 3DS software. We are using 7 main modifiers: compressing, curving, folding, inclining, torsion, thinning out. Shape explorer takes the initial model as an input to trigger the shape exploration and automatically derives various shapes by simulating natural evolution, through crossover and mutation of the genomes.

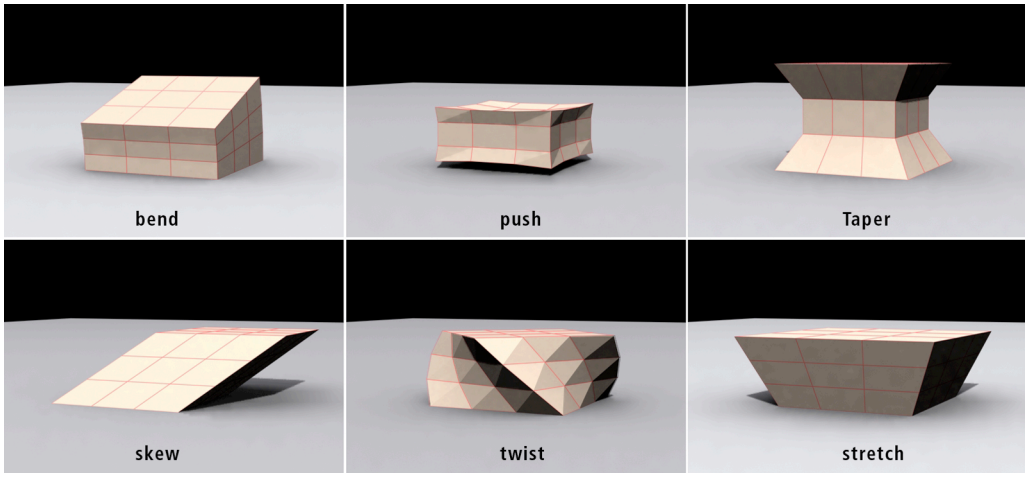

Figure 3
List of modifiers (06_marin_fig03.jpg)

Material exploration

A material explorer permits to modify each facet's properties, regarding opacity and thermal resistance coefficient. These physical qualities are stocked inside an array, and the algorithm randomly assignments an index to each facet. This index refers to physical qualities, which are used by the evaluation engine.

P-type and G-type

Through genetic algorithm, each individual is represented on the one hand by his phenotype (P-type), and on the other hand by his genotype (G-type), an encoded representation of P-Type. The G-type symbolises the genome of the individual. The G-Type represents a recipe that is executed to obtain the corresponding shape. Two chromosomes compose our G-Type: The first one is associated to physical properties of each facet, and the second one represents the description of the shape.

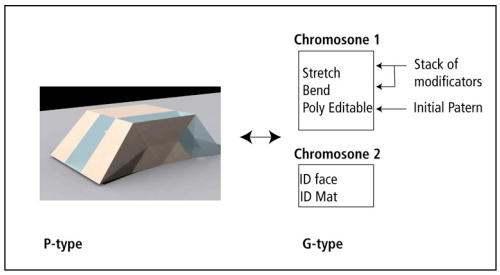

Figure 4
P-type and G-type representation (06_marin_fig04.jpg)

The sequence of our formal chromosome is composed by the initial pattern, described by an editable polygon, and a stacking of modifiers. The designer has the ability to edit this chromosome by simply unfold the stack. In this way, value parameters can possibly be modified.

Crossover and mutation

First, a random population is defined. Each individual is evaluated through the UDD engine. Then two parents at a time are taken, and their chromosomes are cut at a random point, and reconnected together (crossover). These ”children” are then put into

new generation of population, and re-evaluated again, until an acceptable solution is reached, or the set limit of generations reached.

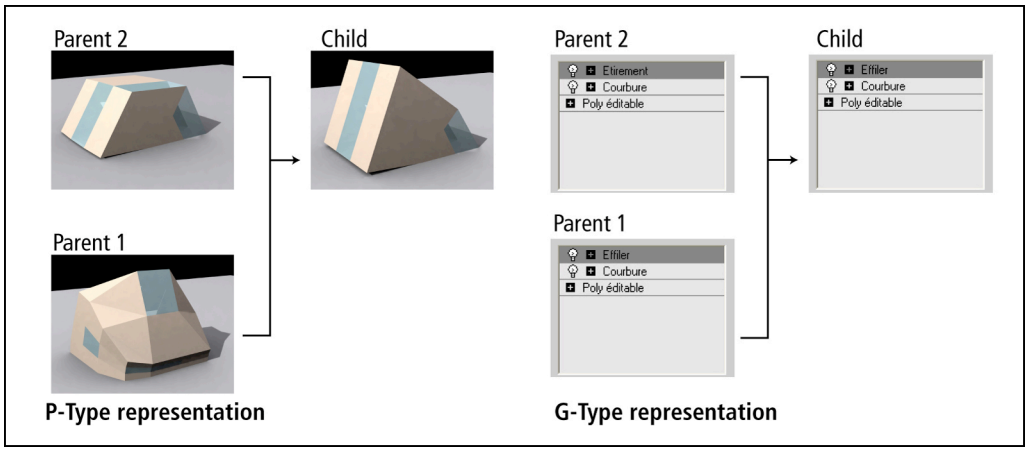

Figure 5
Crossover mechanisms – P-Type representation (06_marin_fig05.jpg)

Mutation mechanisms start from a selected individual and then replace randomly some parameters of each chromosome. This new mutated child is then put into the new generation for evaluation and selection.

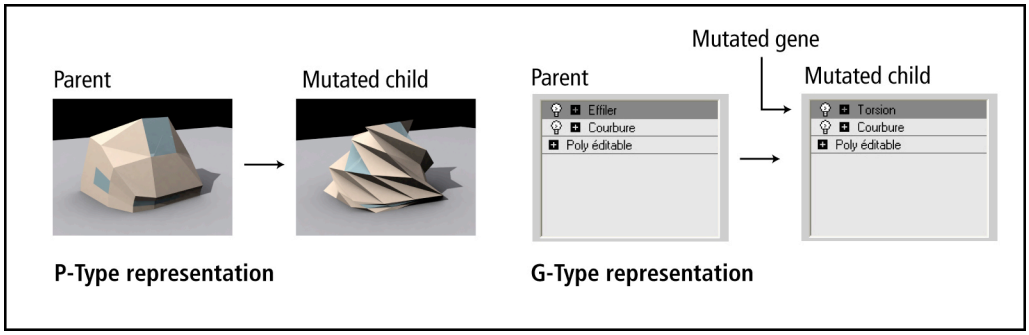

Figure 6
Mutation mechanisms (06_marin_fig06.jpg)

Individual evaluation

In our example, the evolutionary process is used to stimulate the creativity of the designer, and to propose a quite optimal solution regarding passive solar properties.
Solar passive qualities are evaluated by UDD engine. This one is based upon the Unified Day Degree method. This method is selected because of the simplification of the problem it provides. We focus our evaluation on the winter comfort, and the heating needs. The location of the site is in the Paris area. The environmental parameters are stocked inside an array: the solar radiation on a specific tilt and orientation panel, external temperatures, internal inputs, inertial class. Each individual of our population will be evaluated in function of its heat needs. The smaller the heat needs will be, the more the individual will be evaluated.

D = Ht.Dh(Ωa)

D : Heat loss of the building [kWh/year]
Ht : Loss coefficient of the building [W/K]
Dh(Ωa) : Value of degree hour or degree day
Ωa : ambient temperature of record

Ht = Henv + Hrev

Henv : loss of building envelop [W/K]
Hrev : loss by ventillation [W/K]

Henv = ∑(A.U)

A : Wall surface [m2]
U : Loss coefficient of surface [W/m2.K]
Hrev : Neglected

Heat loss (D) are offset by free inputs (AG).

AG = AI + AS

AG : Free inputs [W]
AI : Internal input [W]
AS : Solar input [W]

AS = E.Sv.c

E : Solar radiation function of tilt and orientation [W]
Sv : Glass surface [m2]
c : Transmission coefficient of the glazing

f = AG/D

f : Free input divided by heat loss

μ = f(f, inertia class)

B = D-μAG

B : heat needs [kWh] included free input.

Figure 7
UDD Method - The generic formula applied to calculate heat loss (06_marin_fig07.jpg)

A subjective interaction is added to the evaluation process. The engine displays the best models evolved through generations. The user can find his preferred shapes among them, getting inspirations about how to evolve the shapes to get more appealing ones, and subjectively controlling the evolution process by selecting the preferred one. The final evaluation of satisfactory design solutions is subjective and involves aesthetic or symbolic content.

Conclusion

We expect that an evolutionary digital tool suits a creative activity and that it supports the designer. We started by defining the architectural design process and we marked the necessity of interplay between the tool and the designer through an exploratory process. The computer and the generative process become a designer's partner capable of generating unexpected forms and capable of stimulate design creativity through a non-deterministic exploration and an analogical thinking. We focus on the early phase of the architectural design process and we propose an evolutionary tool based on a genetic algorithm. The evaluation of the individuals is made both by the solar passive qualities and by the personal requirements of the designer.

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