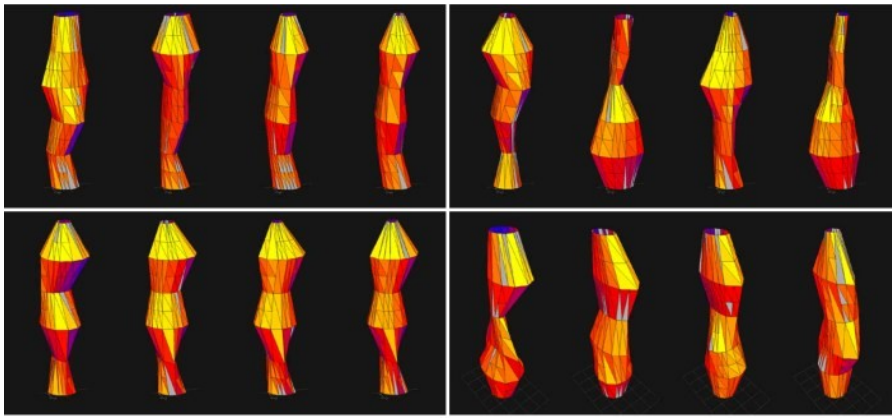
Architectural evolutionary system based on Genetic Algorithms



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Introduction:

Genetic Algorithms (GAs), a computational technique of evolution, recently have been used in architecture to solve the complicated functional and formal problems. The purpose of this paper is to discuss the advantages of GAs as an architectural design tool to use on the architectural evolutionary system. First, this paper will show the process of GAs to understand how they works. Next, several essential elements in GAs will be analyzed to demonstrate the connection between GAs and adaptive architecture. Several architecture design examples based on GAs will be used to evidence the argument. GA is one of many approaches for the optimization and evolution, and I think it is beneficial to the architectural area. Because GAs could not only generate numerous adaptive methods as the adaptive solutions, but also be able to keep the evaluating criteria dynamic with the surroundings to achieve the long-term optimization.

Keywords:

Adaptive architecture, Genetic Algorithms, architectural optimization, evaluating criteria

1.The Adaptive Architecture and Evolution Algorithms

The adaptive architecture is expected to explore the possibilities of buildings to improve its performance according to humansâ€™ demand and natural parameters. [6] These demands and natural parameters are dynamic and changing continuously with the passing of time. Correspondingly architectures need to be â€œa living and evolving thingâ€ (Gordon Pask) [2]. The adaptive architecture is a multi-disciplinary research. So far, scientific and technological developments in computing, electronics, communication, materials and robotics lead to an acceleration of that. As kinetic buildings can fit a wider range of uses, improve their performance and extend their life span, [1] the kinetic architectural structures are the basic element to achieve the adaptive movements.

Various researchers have examined adaptive kinetic structures to improve buildingsâ€™ performance according to peopleâ€™s requirements [1], such as the Fun Palace (Cedric Price, 1970), the Smart Shell project(by Stuttgart University, work in progress) and the Furl(Soft Pneumatic Pavilion, Becky Zhang, 2014). However, most of the intensions of this kind of constructions are fitting the environmental changing by pre-calculated behaviors, which is responsive merely instead of evolutionary. In my opinion, the short-term architectural adaption could be a real-time response, and the long-term architectural adaption should be an evolutionary optimization.

2.Genetic Algorithms

Genetic algorithm is inspired from the natural selection, using the reference from Darwinianâ€™s evolution theory. It works on many disciplines such as optimization, machine learning, social systems etc. â€œGenetic Algorithm is developed primarily for problem-solving and optimization in situations where it is possible to state clearly both the problems and the criteria to be fulfilled for their successful solution.â€ (John Frazer) [2]. In the process of Genetic Algorithm, there are several basic elements â€“ population of chromosomes, selection according to fitness, crossover to produce new offspring, and random mutation of new offspring [13]. Selection, Crossover and Mutation are the three essential procedures.

The single loop of typical algorithm basically operates from initial Selection, via Crossover, to Mutation in turn. If the result does not fit the criteria, the algorithm loop will restart, using the new offspring as the initial population of chromosomes. Given is the Picture1 shows the logic that how GAs works.

According to the logic of this algorithm, we can find that the GA works as a parallel way. The operator ranks and generates populations one by one in every loop. As a result, It is able to choose the fittest chromosomes from a large population and use them as the database to generate new candidates with slight mutations to keep the database active. After that, a new loop starts. It is a class of highly parallel, evolutionary, adaptive search procedures [2], which offers various possibilities for the architectural evolution and optimization. However, this kind of parallel working method may lead the algorithms to a sever delay when the number of elements is large. [13] To make this problem tractable, we could break down the multiple contextual elements to several simple representations, and set the mutation value as a relatively low number.

Picture1

How can we use GAs in the area of designing the architectural evolution and adaption? Actually, Genetic Algorithms offer an effective solution to this problem by searching problems and optimizing solutions, operating on a population of achievable resolutions.[2,5] When the architectures are at the point needed to be adaptive to the surrounding, it is possible that GA could search for numerous adaptive possibilities and find the fitting solution , providing methods for kinetic architectural structures to behave efficiently. GAs could address well-defined building problems, such as structural, mechanical, and thermal and lighting performance. [5]

So far, GAs have been used in many scientific and engineering problems and models. Different with other disciplines that address the certain target, many architectural problems are undefined. In Liddamentâ€™s article â€œThe Computationalist Paradigm in Design Research) argues that though computational tools, such as GAs are powerful in scientific domains to solve many problems, they do not sufficiently fit the practical design activity. Because design process is usually an undefined problem. Even if the design intentions are coded by the designers, this coding would not be enough to guarantee a effective and successful design result. [10] Assuredly, architecture is a synthetic discipline of design performances, including spatial, structural, lighting, acoustic and thermal elements. [5] However, GA, as an optimization tool, has the ability to generate a large range of possible solutions by crossover and mutation operator. Meanwhile, the selection operator could continuously seek and the fitter chromosomes(solutions) by evaluating the criteria that can be fixed by the environment dynamically. GAs have the potential to make all these architectural elements engage in the optimization process to lead to a global optimization and a successful adaptive solution.

3.Genetic Algorithms and other approaches for architectural optimization

Besides Genetic Algorithms (GAs), there are several other ways for optimization and evolution, such as Hill Climbing (HC), Simulated Annealing(SA), Artificial Neural Network(ANN), etc. To some extent, all these approaches, including Genetic Algorithm, are involved in artificial intelligence. Their common destination is to find a way for optimization and seeking for a fitting result, even though their inner computing methods are not same with each other.

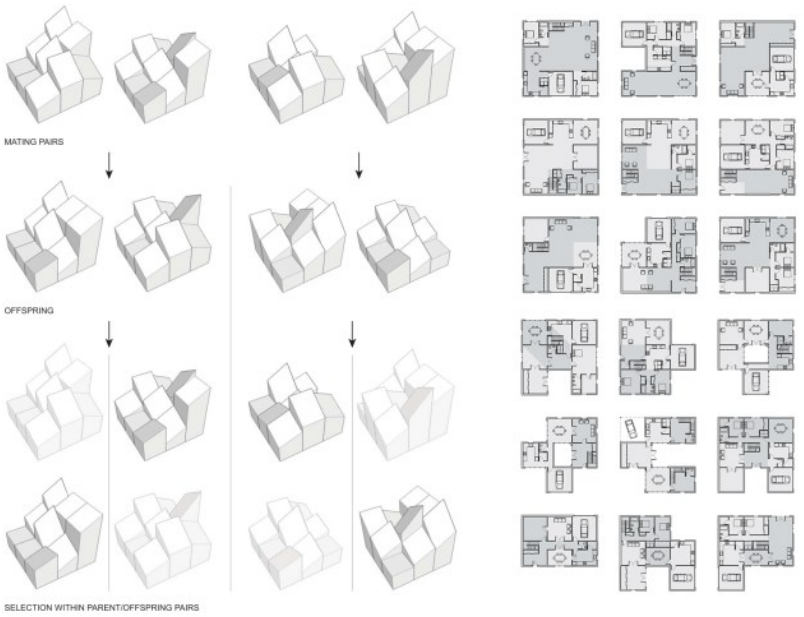
Comparing with the other methods for optimization, I think GA is more suitable for the architectural adaption and evolution. From one hand, in the complex and unpredictable architectural context, GAs could initially seek for the fitter solution for optimization. Comparing with this, ANN need a fixed database as a priori reference, though it can be used for predicting the behavior, materials and structures [1]. On the other hand, GA is a self-evolving computing method and able to find the global optimum, because the evaluating criteria and random crossover filter the population and make it active. This is the ability that most other algorithms, such as HC and SA, do not have. GA is not the only algorithm that is able to work on the architectural adaptive cybernetic, but it is an effective one, as it has the functions to satisfy architectural optimization and evolution.

4.The advantages and related applications of Genetic algorithms for architectural adaption

As an approach, I consider Genetic algorithms have two main advantages for the adaptive architecture, especially the long-term evolution. The first one is that GAs could guarantee the fitness of optimization result by seeking for a large amount of possibilities randomly. People may argue that the random seeking method is unconsidered, without contextual cognition. However, I think because of the elimination system based on the fitness criteria, not every random chromosome is able to evolve to participate in the next computing loop. The fitness criteria are also the second advantage of GAs, as a principle to control the final result. Even though there would be new random chromosomes created by the cross operator and mutation operator, the weak candidates could not evolve too long. Therefore, the fitness criteria is an crucial element for human to control the computing process, in order to achieve the architectural evolution and optimization.

4.1 The multiplicity of candidates and Selection system

As the former analysis, GA is especially suitable for solving optimization problems with a very large number of possible solutions. [1] I consider the multiplicity of candidates and selection system of Genetic Algorithm benefit the architectural evolution process.



Picture2

An example (Picture 2) shows that Nathaniel Louis Jones used GAs as a evolution tool to create the fitter generation of houses, which are ranked by the lighting, heating and functional criteria. â€œAfter a few runs of algorithm, the architect has many fit design options to choose fromâ€¦ A few solutions discovered by the GA are notable for their display of machine creativity, adaptations that seem particularly well thought-out evenÂ though no human intelligence is behind them [3]â€ , said by N. Jones.

Besides creating new offspring, the crossover rate controls the possibilities of crossover, which means not all chromosomes are able to evolve. This is the function of selection system that only adaptive chromosomes are able to survive. After selection, the new candidates could be created by the crossover and mutation in every loop. Instead of considering how to find the optimum, we can care more about the evaluating criteria. Consequentlyï¼Œwe do not need to make the pre-calculating adaptive behaviors for kinetic architectural structure. Numerous random solutions will be tested to ensure the final optimization to be fitting to the architectural context, which is an advantage of GAs for architectural adaption.

Picture3

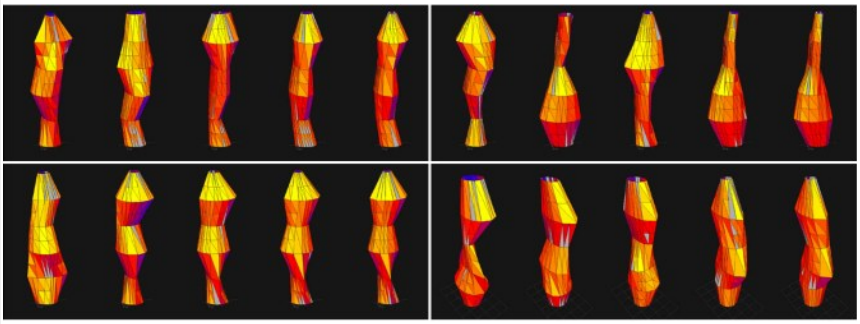
The Performance Ecology (Ruairi Glynn, Picture3) shows an evolutionary process with the multiplicity of solution and selection system in GAs. The movements and color-changing start from a random population. Facial recognition to assess attention levels (fitness) is used to filter the chromosomes. The fittest chromosomes representing dancersâ€™ behavior and color get crossover and evolution to realize the global and long-term optimization. [15]

In my opinion, the architectural evolution is dynamic, because it is based on the sophisticated architectural context. Accordingly, a dynamic system is composed and controlled by several elements. In the GAs process, chromosomes could be constructed by several part, representing various functions or restrictions. The crossover with chromosomes represents the mating of fitter features, which boosts the evolution process to achieve global optimum.

4.2 The variability of fitness criteria and Continuity of evolution

In the process of architectural evolution, buildings should be kinetic to adapt the external or internal conditions, leading to buildings or building components with variable mobility or geometry. [9] At this point, following questions are raised: how de we define the kinetic building movements in regards to surroundings? What are the selection criteria? I suggest that, with the interaction between the changing context and fitting criteria, Genetic Algorithm could make the architectural evolutionary process adaptive to the multi-parameter surrounding constantly over a long period of time continuously.

The Picture 4 below shows an optimization example of a hypothetical Tower made by K. Besserud. [14] In order to maximize solar radiation for a 300-meter tower, the designer used GAs to get 75 different tower forms by 75 generations. Later, he used the floor and skin area as the second criteria to find the optimal shape from them. Additionally, he also texted the lighting and thermal values with the simulated day-night and season changing that are dynamic, in order to realize a complete optimization.



Picture4

GA plays an important role in this study as the form-search engine and evolution program to show the practical possibility for the architectural evolution. For sure, to achieve this kind of evolution, the kinetic structures are compulsory. However, on the other hand, this is still a goal-oriented design. Even though the fitting value is based on environmental performance changing with the sun, the adequate lighting and thermal levels are the fixed goal. Peopleâ€™s demand for buildings is more than a regular and simple changing circulation. We could treat the interaction between people and buildings as the fundamental elements to accelerate the evolution. If we do so, the target could be undefined clearly before the algorithm starts. At this point, people could interact with the evaluation criteria, which also need the buildings to equip the kinetic structure and dynamic plans, and buildings are not a static form. It is also possible to write the dynamic criteria code in one or parallel genetic algorithms.

5.Conclusion

This paper presents the probability and advantage of Genetic Algorithms as a generative tool to apply in terms of adaptive and evolutionary architecture. Several relevant practical examples are shown to explain the architectural optimization and adaption, using GAs-based method. In the process of GAs, selection, crossover and mutation provide a large range of solutions to get the evolution for global optimization, which guarantees the qualification of final result. The evaluating criteria (fitness) is an important dynamic value, which could be interact with architectural context.

Genetic Algorithms is one approach to lead the kinetic architectural structures to behave efficiently. At present, most behaviors of kinetic structures are based on the pre-calculation target, which is not dynamic. Several questions could be study in the next step. How to combine various architectural contexts as the evaluation criteria? Which part of buildings could behave according to this kind of criteria? Furthermore, relevant theories could also be considered together with GAs to make the optimization more intelligent and be able to achieve self-learning, such as Artificial Neural Network and Learning Classifier System.

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