AI Concepts in Architectural Design

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Abstract. Permeating into almost all areas, Artificial Intelligence (AI) is also playing a more important role in architectural field. Based on three schools of AI, this paper proposes an AID Model of architectural intelligent design, aiming at establishing a thinking system to understand the inter-crossing of AI and architectural design. According to AID Model, a series of AI methods applied into architectural design, analysis and fabrication are discussed. By summarizing an overview of AI methods, it is possible to explore the future development of architectural intelligent design and provide reference for future design work.

1. Artificial Intelligence: Three Schools

Owing to the significant changes brought by Internet and IOT in the past decade, since 1960s, researchers' urgent expectations and pursuits in AI's great influence on architectural design have been increasing rather than decreasing. Artificial Intelligence has changed from that 'frightening' new thing to today's popular trend. To briefly review its tortuous development process and three main interwoven schools is our first key to understand the cross thinking between Artificial Intelligence and architectural design.

-Symbolism: expressing the formation of thinking and produces human-like intelligence by logical symbols in mathematics and physics. It is a top-down process including expert systems, knowledge engineering and so on;

-Connectionism: considering intelligence comes from neutral connections, it simulates brain neutral network and its connection mechanism by computer. It is a bottom-up process including artificial neural network, machine learning and so on.

-Behaviorism: based on the perception-action control system, it makes every basic unit optimize, adapt and organize itself. It is a bottom-up process including evolutionary algorithm, muti-agent, cellular automation and so on.

2. AI-Design Model

Based on the above, this paper proposes an AI-Design Model (Fig.1), aiming at establishing an AI concept system in order to make a better understand of the inter-crossing between AI and architectural design (Figure 1).

AI-Design Model:

$T = i \cdot G \cdot E \cdot T$ (Eq.2-1)

or

current solution sTate = index • God-driven • Environment-driven • previous solution sTate (Eq.2-2)

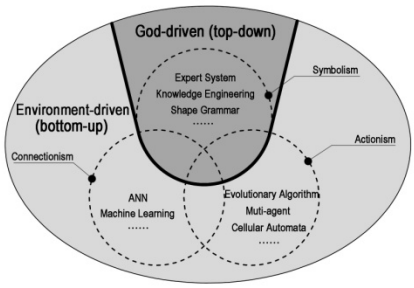

Figure 1. AI-design model

Among these driving forces in AI-Design Model, 'God-driven' is a top-down process in which 'God' could not only be designers, but also be senior roles such as developers and government as well as technical details such as design code and material properties. 'Environment-driven' is a bottom-up process in which 'Environment' could be interactive constraints such as behavioral rules and material properties as well as external factors such as location and climate. In a word, 'God' control design and 'impose' a direction on a macro level, while 'Environment' allows agents to develop freely or even disturbs agents to change their behavioral rules, thus realizing their variation and diversity.

Architects' top-down control plays a leading role in traditional design, the bottom-up process merely relies on the limited inspiration of perceptual thinking and is impossible to go through all possible solutions and select the best one. However, in architectural intelligent design, the bottom-up method of connectionism and actionism make creative design blossom and the top-down method of symbolism control designs' reliability and engineering standardization. Architectural intelligent design realizes high combination of the engineering and the arts.

3. Symbolism: Descriptive Grammar

According to AI-Design Model, a series of AI methods applied into architectural design,analysis and fabrication are then discussed. Descriptive grammar can be classified into 3 types according to different users:

Grammar A: describing spatial elements and components. In 2011, by means of RhinoScript, Eastman C. in Georgia Institute of Technology defined the relationship between high-rise buildings' service area and standard floor area in order to automatically generate a building service core according to its shape [Figure 2].

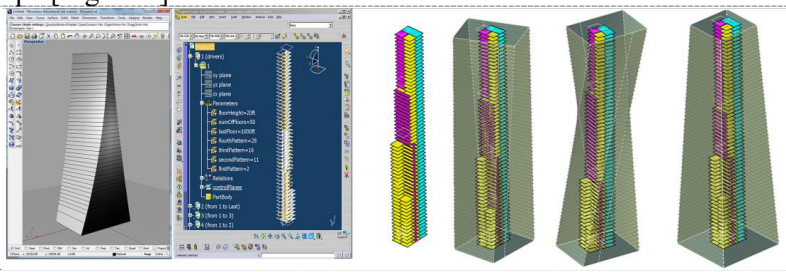

Figure 2. Automatically generated building service core according to its shape

Grammar B: expressing construction quantity, cost and so on. Carnegie Mellon University has done a lot of researches. In 1997, Brown K.N. proposed the descriptive function of component prefabrication plan and real-time material quantities calculation. In 1999, AgarwalM. developed a descriptive grammar of calculating cost as design changes.

Grammar C: generating and optimizing conceptual schemes. With graphic generation and algorithm enhancement function, grammar C becomes the most widely applied grammar. In 2006, Mathieu L. proposed 'wall grammar' based on graphic grammar. He pre-defined several styles of windowing rules and applied Procedural Modeling method to automatically generate architecture façade, roof and windowing layout plans [Figure 3].

Figure 3. Automatically generated façades based on procedural modeling

In 2015, Ligler H. in Georgia Institute of Technology set 3D graphic rules for architectural master John Portman's Entelechy I. and automatically generated a design with similar styles based on Shape Grammar [Figure 4].

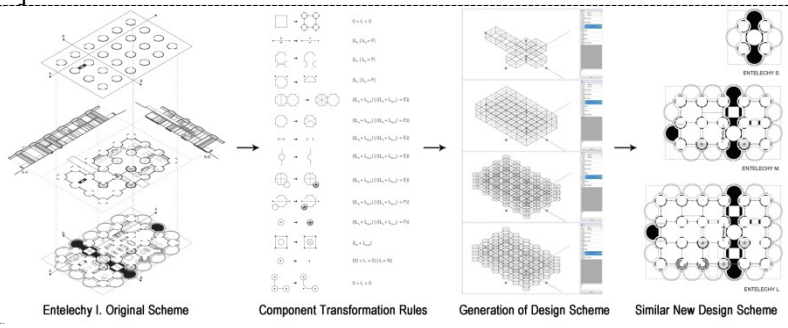

Figure 4. Entelechy I. and the generation of similar styles

The 'rules-implementation' top-down mode of descriptive grammar, a critical human-computer interaction method, is consistent with human thinking habit and has deeply integrated into AID of connectionism and actionism.

4. Connectionism: Artificial Neural Network (ANN)

ANN is also a system of knowledge and rules. There are also explorations on the neutral network in real fabrication. In 2013, with the help of neutral network system, Mehanna R. designed the elastic-structure robot which was adaptive to environment and never fell down. Every neutron is a servo motor directly acting on robots' supporting frames rather than a mysterious element in virtual world. It keeps balance and remains upright of elastic structure like muscle contraction [Figure 5] .

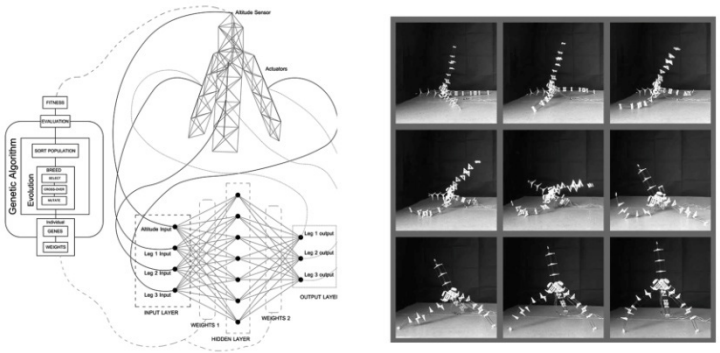

Figure 5. Neutral system of elastic structure and real physical tests

The bottom-up artificial neutral network steps somehow further than descriptive grammar. Rules of descriptive grammar are artificial, while rules of neutral network are defined by machine itself.

5. Behaviorism: Multi-agent

As its name suggests, 'agent' is an interactive as well as distinctive individual. Agent in architectural design could include any aspects such as designer-agent, pedestrian-agent, city-agent, material-agent and robot-agent. In different fields, agent varies as research need changes. In 2010, according to the

concept of life-death correlation near cellular automata in 'Conway's Game of Life', Kuo J. and others in ETHZ served individuals, architecture and community as agents, thus they simulated the natural expansion of cities from the perspective of multi-scale agent network [Figure 6].

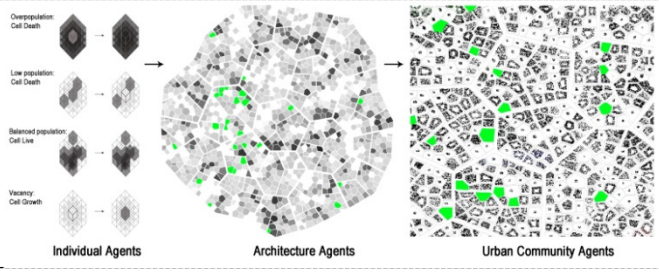

Figure 6. Urban development's simulation of multi-scale agent network

If the multi-agent method mentioned above is restricted to design itself, then the following 'soft robot' based on behavioral and environmental perception completely serve as an agent of overall fabrication process. In 2016, Brugnaro G. gave an example of weaving rattan. Without presetting its action route, the robot equipped with Kinect360 could sense surroundings in real time. [Figure 6].

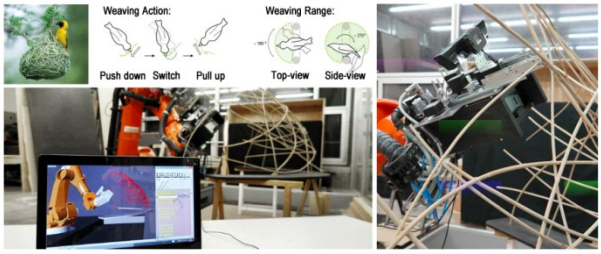

Figure 7. Automatic weaving soft robot

6. Conclusion

From Symbolism to Behaviorism, from controlling every rule to letting it go properly, AI methods make rooms, robots and even the whole design processes become 'conscious' agents. We fully realize that the convenience for architects AI brought and the great potential of technological revolution AI caused.

HarariY.N. says in Homo Deus: A brief history of tomorrow at the end of the book, 'Organisms are algorithms and life is data processing⋯Non-conscious but highly intelligent algorithms may soon know us better than we know ourselves'. From the point of Dataism, we should be more aware that artificial intelligence is historically inevitable. Architects design our world, while AI might design our future.

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