VIRTUAL ORGANISM: GENERATIVE TOOL BASED ON MULTI-AGENT SYSTEM

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Abstract. A multi-agent system (MAS) is efficient as it can emulate a variety of organisms in natural science due to the interactions between agents, which make artificial systems responsive and adaptive. In "Bamboo Workshop" involved flexible structures, MAS was employed to create virtual organism in computational environment towards an innovative process in installation design. A generative tool with friendly user interface was developed for both observation and intervention besides debugging. At the same time investigations were carried on the complex behaviours of the system through graphic statistics. Integrated with the generative tool, a construction system made up of bamboo materials was set up to build a series of mobile and flexible installations. This experiment suggests that the virtual organism has the potential for being a part of the design intelligence, beyond a mere digital tool.

Keywords. Virtual organism: multi-agent system; flexible structure; mobile installation.

1. Introduction

Flexible structures were employed to achieve flexibility and mobility as the main principles of the pilot design in "Bamboo Workshop–mobile A+A installation design". The unconventional structures inevitably involved geometry problems which are difficult to be solved by elementary geometry techniques. Thus systematic modelling based on computer programming became the core of the design, which connects to material organisation as well as the dynamical analysis of complex behaviour.

To be precise, multi-agent system (MAS) was found to be ideal for this modelling task and subsequently evolved into an interactive system called "virtual organism". In addition, a generative tool based on MAS was developed for both design and research. It has been suggested that this kind of design process could provide deeper insights into structure study and facilitate form-finding process in design.

2. Flexible Structure

Some forms like "the polygons with eight equidistant sides" constitute a set of infinite forms. It is called flexible structure in our design. Beyond abstract geometry, a flexible structure can be regarded as a particular parametric system which is evolving, in other words, interacting with environments at any time.

There are currently available two kind of basic tools to study such structures. One is classical geometry techniques (powered by CAD drawing software now); the other is constructing physical model as architects always do. The former is incompetent to reveal the nature of structure except to yield dozens of particular examples. Paradoxically, diagrams describing series of candidate solutions are often mistaken as paradigms of form-finding in architectural design, though they are far from the systematic approach to the answers.

Indubitably great inspirations can be drawn from the latter in the context of design. While an architectural model is conventionally oriented to derive a specific solution from a system, it differs from scientific modelling as an abstract and formalized interpretation of a particular problem. On the other hand, it is more facilitating to record information and take further analyses based on the digital model than on the physical model. As a result, computer modelling comes into play.

3. Prototype 0

The modelling commences with a simplified structure termed Prototype 0, a 3-dimensional polygon with eight equidistant sides (Figure 1). It is just an introduction to the complex structure of Prototype 1 described in next paragraph, however, the result shows that it is perfect for developing dynamic analysis which is of great importance in the next stage.

Emulating this structure is not difficult for any physical models which consist of eight slender items. By contrast, it is a tough task to illustrate this structure by classical geometry techniques especially in 3-dimensional space. And the most important work is not to derive candidates, but to highlight their characteristics.

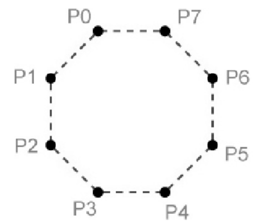

Figure 1. Prototype 0

The mechanism of evolution of organisms breeds an alternative insight. The scheme is to create a system capable of evolving into the required states of Prototype 0. The first step of modelling is to establish a dynamical structure based on agents; the second is to apply rules on the behaviours of agents, which drive the whole system towards the structure of Prototype 0.

Eight points, or nodes, construct the flexible structure in the model. Every node is an instance of a class "Node" and each instance has its unique data and behaves according to its surroundings. To be precise, the node makes continuous movements until its distances from its two "neighbours" both reach the pre-defined value l. The action of the node **P** as a Euclidean vector can be described as:

$$\frac{d\,\mathbf{P}}{dt} = k\,(\mathrm{Q} - \mathrm{P} - \mathrm{L}) \qquad 0 < k < 1 \tag{1}$$

$$\mathbf{L} = \frac{l\,(\mathbf{Q} - \mathbf{P})}{||\mathbf{Q} - \mathbf{P}||} \tag{2}$$

The vector **Q** denotes one neighbour of **P; L** is a vector with the magnitude of pre-defined l and the direction from **P** towards **Q**. Based on all local behaviours driven by the two rules, the system is doomed to transform into a stable state with eight equidistant sides.

The alternative language ActionScript is competent to construct the system. Its object-oriented strategy is in high accordance with the logic of agent based modelling, which makes the scripts straight and concise. The infinitesimal increment of the vectors can be presented based on the machine "time" which was divided into small intervals.

An interface was developed for interaction and investigation based on the system. Each point could be dragged as interactions or interventions at any time through the interface. Figure 2 shows a typical process containing initialisation, equilibrium and user's interventions. The changing value of

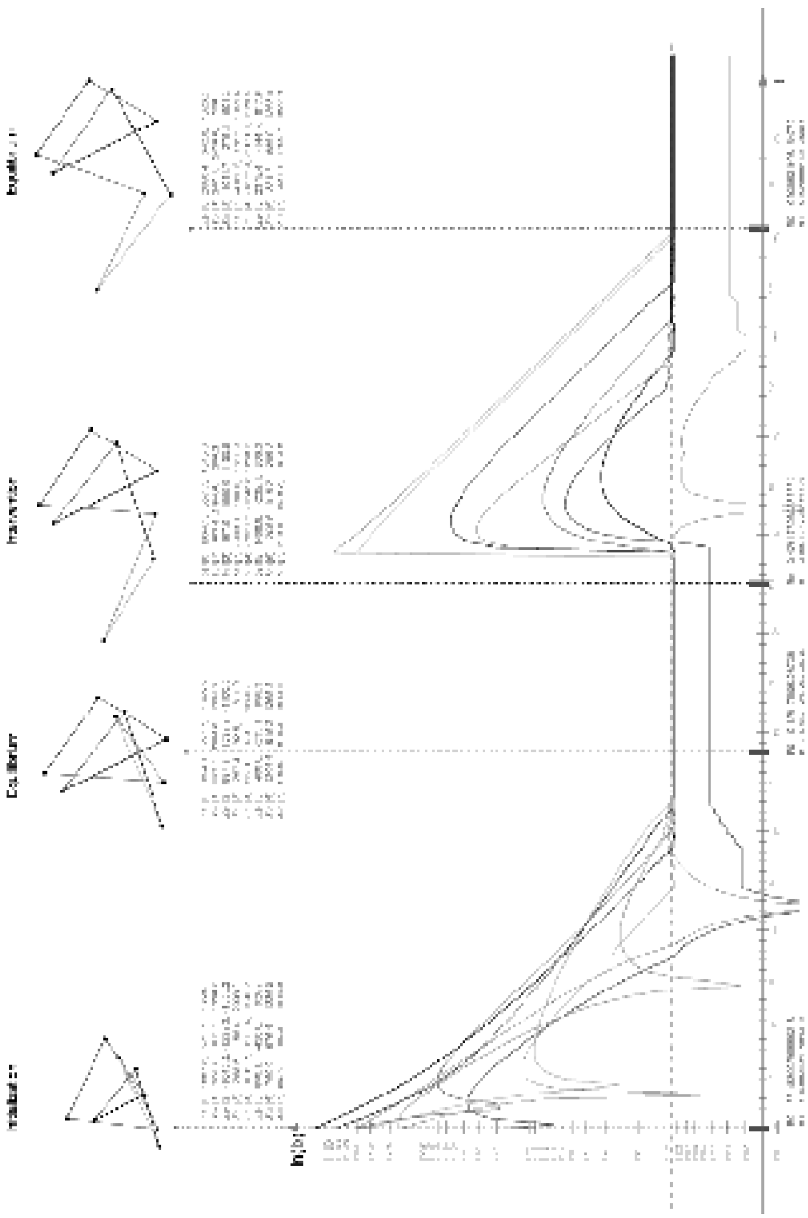

Figure 2. Plotting in (Q – P – L) to machine time, with four key forms of the dynamical structure (Prototype 0)

(Q – P – L) is recorded during the whole process and illustrated by continuous lines as a comparison with the transient forms of the structure.

In the first period following the initialisation, these lines reflect complicated patterns; nevertheless have the same remarkable decreasing trends. The lines become straight and are under the critical line as the structure reaches equilibrium. At the third stage, the lines soar immediately due to the intervention. Finally, the lines return to straight and low for the structure becomes stable again.

A great number of such experiments suggest that there is always a strong trend for the flexible structure towards equilibrium. In other words, this structure succeeds in evolving into a stable state which satisfies the statement of Prototype 0.

4. Prototype 1

The work on Prototype 0 facilitates the modelling of Prototype 1, the real structure evolved in the installation design. As shown in Figure 3, adding four nodes to the structure of Prototype 0 gives birth to a structure of Prototype 1. An addition rule for the new prototype is that the length of new shaped four lines is equal to the length of eight original ones. It means that all twelve sides of the whole structure are of the same length. Moreover, each new node always sticks on one of the quarters on an original side, as in Figure 4. There are three possible positions on one side and there are totally 18 positions in the whole structure for each new node. The initial positions of new nodes are determined by random functions; however, people could change these positions at any time through the user interface.

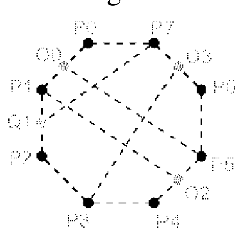

Figure 3. Prototype 1

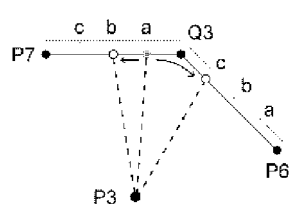

Figure 4.

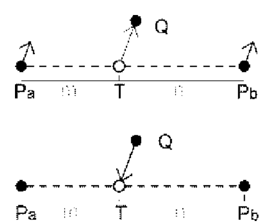

Figure 5.

Before the equilibrium of the system, a new node is more likely to be moving to a target point **T** (Figure 5) placed on the original side rather than be in place (hit point **T**). The reason for this phenomenon is that the "force" keeping the new node in place is "soft", just as the forces between the nodes of Prototype 0. The behaviour of a new node can be described as:

$$\frac{\mathrm{d}\,\mathbf{Q}}{\mathrm{dt}} = k\,(\mathrm{T} - \mathrm{Q}) \qquad 0 < k < 1 \tag{4}$$

The eight basic nodes preserve the behaviour of the equivalent ones in Prototype 0, nevertheless they also move to reduce the distance between the **Q** **T**. The new behaviour of the eight basic nodes is as follows:

$$\frac{\mathrm{d}\,\mathbf{P}_{\mathrm{a}}}{\mathrm{dt}} = \frac{km}{m+n}\,(\mathbf{Q} - \mathbf{T}) \tag{5}$$

$$\frac{\mathrm{d}\,\mathbf{P}_{\mathrm{b}}}{\mathrm{dt}} = \frac{kn}{m+n}\,(\mathbf{Q} - \mathbf{T}) \tag{6}$$

The complex structure produces a code system for itself. As is shown in first item in Figure 6, the node **Q1** (connecting to **P1)** stays at the third (count from 0) side from **P1** in anti-clockwise, so the code begins with "3". **Q1** is placed at the first quarter of the side P4P5, so next letter is "a" (the middle one is presented by "b"; the third quarter is "c").

It indicates that the complexity of a structure could generate a relevant information system reflecting the subject's traits, just like the gene of natural organism. Once the user moves a new node along the sides, the code of the subject is changed. What is happened during this operation is that a new one with distinguishing "gene" has replaced an old one. This is an alternative analogy of natural selection, in which the user plays the crucial role. There are a series of generations evolving towards an unpredictable direction related to interventions. In this sense, Prototype 1 can be regarded as a matrix of virtual organisms. From the viewpoint of architecture, this process allows the designers to induce the main trend of a dynamic system with rich formal articulations.

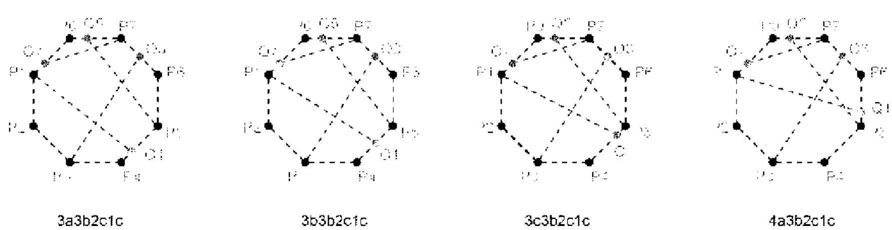

Figure 6. Structure and gene code

Compared with Prototype 0, the new structure has more complicated behaviours, according to the analysis (Figure 7). There are several recognised patterns for the lines during a whole life period of the system. For example, just before reaching an equilibrium state, all lines always undergo a "struggle" phase in which they fluctuate intensely. It can be argued that the interactions between the two types of nodes are responsible for the more complex behaviour.

Figure 7. Plotting ln (Q – P – L) to machine time, with four key forms of the dynamical structure (Prototype 1)

5. Construction System

A construction system is essential for converting the information of dynamical system into physical installations based on bamboo materials. The first rule is that the construction strategy should be consistent with the logic of the flexible structure of Prototype 1. Second, all forms derived from the generative system should be materialised by the same set of the elements of the construction system. Besides, important is the facility of transferring one form to anther, which makes the installation mobile. Anther principle is extending the capacity of the bamboo materials. The details are co-developed with local senior craftsmen working with bamboo materials. Different parts are made of different parts of bamboo with unique techniques, resulting in high performance. Depending on this construction system, several models were built to investigate how they interact with people's activities (Figure 10).

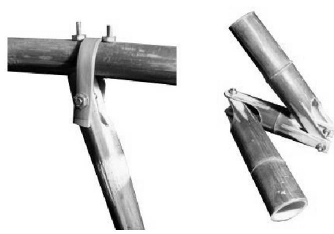

Figure 8. Details of two nodes

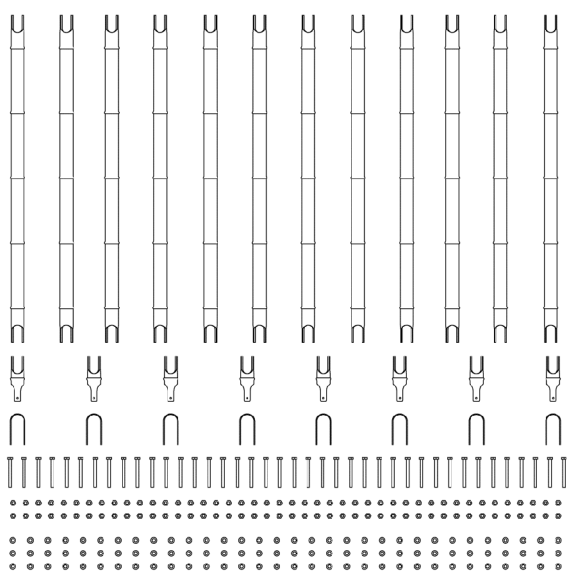

Figure 9. Elements of the construction system

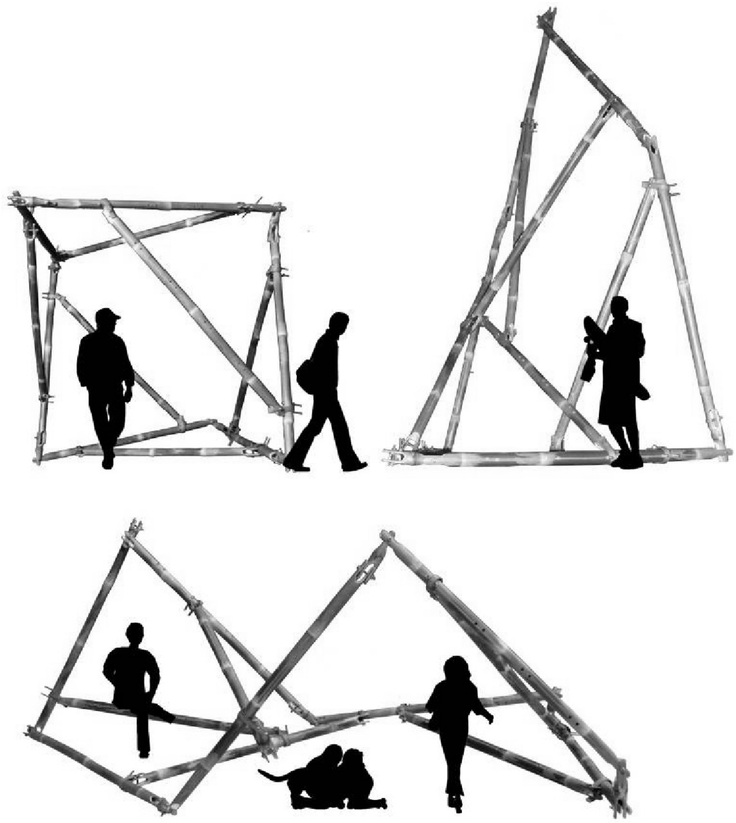

Figure 10. Three models

6. Review

To sum up, the installation system based on bamboo material is presented by a flexible structure built with multi-agent system in computation environment, which supports both the development of modelling and the dynamical analysis. The nature of this mobile installation lies in the agent based modelling towards a “virtual organism”. Generally, it drives material organisation through information manipulations. The design process suggests a new perspective of morphogenesis related to artificial organism, as well as a design method stemming from generative operations.

Sometimes it seems difficult to distinguish whether the architects apply new technology to justify their works or they aim to explore the intelligence of nature by means of design. We remain convinced that generative design is a valid and powerful approach achieving efficiency and intelligence in the built environment, like organisms in the natural environment. It is essential that design research does not just follow, but also runs in parallel with scientific research. In other words, “form generating models developed for architectural purposes may be valuable if they model a phenomenon that scientist are seeking to explain”, by John Frazer (1995). So it seems that architects are as capable as scientists in evaluating their own work.

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