Learning from Generative Design System in the 60’s

Case Study of Agricultural City Project by Kisho Kurokawa

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The concept of generative design in Architecture and Urbanism can be found in the 60's before the wide availability of computer technology. This paper decodes one of the urban projects by Metabolist in 1960, which was intended to be a generative system applicable to other sites and evolves over time. Through our analysis, we de-code the formulation process, and verified our hypothesis by re-coding into the program using the software, Rhinoceros and Grasshopper. We found that the determinate factors rule more at the macro level of the project, but the parameters are set by taking the local conditions into account. At the micro level, the system leaves more freedom to accommodate various needs, reflecting the philosophy of the Metabolists. The investigation on this historical predecessor can provide useful insights for parameter settings in future generative system design.

Keywords: Generative Design, Grasshopper, Kisho Kurokawa

INTRODUCTION

The emergence of Open Design is dramatically democratizing the concept of design and its influence has spread into the architectural profession. Architecture had been an authorial discipline; it is expected that all dimensions are pre-calculated, as the architect envisions, on construction drawings, and a building is to be built exactly as depicted in those drawings (Carpo 2011). Thus, the final outcome of the building is determined and fixed in the architect’s drawings prior to construction.

Open Design, however, produces many variations, none of which is original or final, according to the users’ preferences or situations. In Open Design, the design is a generative system, and the role of the designer is shifting towards a developer of systems that enable anybody to adopt and create design, rather than as a creator of a singular perfect object (Atkinson 2011). The generative system became easily accessible with the development of computational technology. It is an especially useful asset to be able to construct a simulation of a complex entity like a city, which requires the processing of numerous variants, including the time-module as the fourth dimension of the space (Weber 2009).

The root for generative design system can be traced back to late 1950s and early 1960s, when a new generation of avant-garde architects, such
as Team 10 and Japanese Metabolists energetically launched new ideas of architecture and urbanism (Smithson 1974). Facing the rapid population increase, they advocated ideas such as mobility, expendability, indeterminacy, and openness for change and growth, which, for them, transcended the more static philosophy of older Modernist architects represented by C.I.A.M. It was a time when some architects were aware of the potential of computational technology to be a strong generative design tool especially for urban design in the future, even though, at that point, such technology was not readily accessible. Kenzo Tange (1913-2005) was one of those who was strongly interested in new computational technology and systematic urban design. In his “Tokyo Plan 1960,” three different parts (Residential Complex, Office and Traffic) were separately but systematically designed based on the same rules and modules by three different teams in his laboratory at Tokyo University (Mizutani 2013). The system was based on many determinate factors, such as population, transportation flow and a set of urban modules, which enabled the smooth collaboration of multiple designers.

As a developer of the generative design system, an important task for an architect / designer would be to define parameters. Even though they may be based on determinant factors, priorities and rules have to be set, and different sets of parameters would result in different outcomes, not just variants. Nonetheless, in the design of a complex entity like a city, the design system may not be able to generate all elements based on determinant factors, but should allow some room for subjective and indeterminate inputs in order to accommodate diverse needs.

This paper treats “Agricultural City Project (1960)” by Kisho Kurokawa, who was one of the founding members of Metabolism, as the subject of the study. Kurokawa advocated a “Master System” for city planning, which he defined as a “Four-dimensional Master Plan,” taking Time Module into consideration (Kurokawa 1967). Kurokawa’s Agricultural City Project, first presented in the Metabolist booklet issued for the 1960 World Design Conference held in Tokyo, is an unrealized, visionary project, which proposed agricultural settlements on an expandable and gridded street network as well as artificial ground, raised four-meters above ground level to avoid damage from river flooding. It was designed as a reaction to Kurokawa’s own experience of the Ise-bay Typhoon in 1959 and its damage to actual agricultural settlements. The project gained international acclaim upon presentation at the World Design Conference, which led it to be exhibited at the “Visionary Architecture” exhibition at the Museum of Modern Arts, New York.

Although the computer was not used for the design, as a member of the design team of “Tokyo Project 1960,” Kurokawa was aware of this upcoming technology and was interested in making architectural and urban forms through writing codes, with which his mentor, Kenzo Tange, as well as other contemporary artists and designers were starting to experiment (Casey 2010). The key concept of Metabolism, the responsiveness to the environment and reproducibility in the cities of growing population, suited well with algorithmic design, and the Agricultural City Project was designed as the Master System.

Kurokawa, on the other hand, had a strong per-
sonal belief in aesthetics, which are also apparent. In this project, he acted as the “parameter-setter (Master Programmer) as well as the designer. His dual roles make it an interesting example to study the balance between determinate and indeterminate factors in architectural design.

THE ANALYSIS OF THE PROJECT
The Project consists of two versions: the prototype and its variation onto the actual site. The prototype has a 5 by 5 grid, of which each square measures 100-meters by 100-meters, and the artificial raised ground was placed in various patterns in each square (Figure 1). This 500-meter square prototype was planned to house an average size of an existing community, approximately 340 households of 1700 people as well as public buildings, such as Shinto shrines, schools, and community centers on the artificial ground. The grid acts as the streets as well as the supply lines for water and electricity.

In the second version placed on the actual site, the edges of the grid stretch in all directions and the formation of each cluster is not a clean square, implying the possibility for the future expansion (Figure 2). We made a hypothesis that some parts of expansion system of the inter-depending communities are planned based on logical design rules as a variation of the prototype, since Kurokawa did not intend this design specifically to this site, but to be applicable to wherever a danger of flood from rivers exists.

The written description of the project claims that the site is in Ama county, Kanie town in Aichi prefecture, which was Kurokawa’s hometown. By juxtaposing the site plan onto the map, however, we found the site of the project was situated in Kuwana city, Tado town in Mie prefecture, which was located 20 kilometers west from Ama county. (We also found out that in the second version, the scale of a cluster was reduced by 60% in order to fit the site condition. For clarity, however, we assumed the dimension was 100% for this analysis.) The strong feature of the selected site is the shape of the river meandering and that it leaves a roughly circular island in the middle. The region that this project was conceived for had a history of flood damage, and one of the protection measures that villagers took was to construct a ring-shaped embankment (Wa-ju) and to make settlements inside of it. Thus, Kurokawa may have intentionally selected this site, which naturally had a Wa-ju like feature, rather than his hometown. This analysis
led us to make an assumption that the shape of the river is an important factor in determining the positioning of the project.

Figure 3
Types of Artificial Grounds

We identified the cluster surrounded by the forked river as the central and initial community, since it is the most complete and similar to the prototype. The center of the cluster roughly matches with the center of the Wa-ju like ring, which we assume to be the “starting point”. It is the farthest point from the river and thus safest from flood damage.

We also discovered by analysis that the horizontal grid lines are parallel to the part of the river which has the least inflection. We defined the line of river which is almost straight a “reference line” for the grid. It also coincides with the angle of existing rice paddy fields, which can be considered an inherent trace of the local spatial characteristics. The second cluster, which is south of the first one seems to be a mirror image of the first on the other side of the “reference line.” We deliberately determined the shifting direction of the other clusters, but the numbers of modules between the clusters are randomly distributed.

VERIFICATION OF THE ANALYSIS
The hypothesis of the design process based on the analysis above was verified by writing an algorithmic program to replicate the project using Grasshopper. The process is as follows (Figure 4 & 5):

Step 1a: The “Reference Line” from the river
The “reference line” which is the basis of the grid is found from the river at the least curved line.

Step 1b: Positioning of “Starting Point”
The “starting point” for the centre of the initial community is defined as the farthest point from the river in the Wa-ju like circle.

Step 2: Formation of Grid
The grid of 100-meters by 100-meters is drawn from the “reference line.”

Step 3: Positioning of Clusters
The initial community is formed on the grid and has the starting point as its centre. The second cluster is formed as a reflection of the first one on the other side of the “reference line.” The shifting direction of the other clusters from the first two are deliberately determined, but the numbers of modules between the clusters are randomly distributed.

Step 4: Placement of Artificial Ground
Although all the clusters seem to be based on the prototype, none of them are a complete 500-meter
Figure 4
Program Flow

Step 1a The “Reference Line” from the river
- Input a curve from river
- Take inflection points of the curve
- Choose a curvature point

Step 1b Positioning of Base Circle
- Make the largest circle inside curved area
- Take farthest point from the river

Step 2 Formation of Grid
- Make a grid same angle to the reference line
- Take center points of each grid cell
- Take closest point to the center point

Step 3 Positioning of clusters
- Make 500×500 grid based on the point
- Reflect the cluster based on the reference line
- Copy and move clusters

\[(x, y) = (1, 3), (3, 2), (2, 2)\]

1 Move the initial point to the direction of \((-\), \(+\) and second point to \((-\), \(-\) and \((+\), \(-\)).
Step 4 Placement of Artificial Ground

1. Make circle in each village area
   \[ r = 200, 300 \]
2. Cut cell point inside the circle
3. Add some cell points around villages
4. Offset grid to make roads
   \[ +5m, -5m \]
5. Place each artificial ground by roulette

Step 5 Bridges

1. Check the density of each village to make axes
2. Make axes to connect each village
   \[ \text{distance} < 3 \text{ then axis width} = 1 \]
   \[ \text{distance} > 3 \text{ then axis width} = 3 \]
square grid, having voids or extending some grids out of the 500-meter square. The sizes of voids are 2- or 3-grids wide or long, and the locations seem to be slightly off-centre. In the program, the shifting direction of the centre of each cluster is randomly selected. Also, the extensions of the grids are randomly regenerated. While we specified six different types of artificial grounds in this project, we could not find apparent rules for their distribution. Thus, in this model, the locations of different types of artificial grounds are decided by the roulette, at the ratio they appear in Kurokawa’s original version (Figure 6).

**Step 5: Bridges**

A pair of bridges are placed where the densities of artificial grounds are highest in adjacent two clusters.

**DISCUSSION**

Comparing the reproduction by Grasshopper (Figure 7) with Kurokawa’s original version, we found the following three layers of design systems in the Agricultural City Project:

At a more macro level, the positioning of the entire project, the main frames of structure and the direction of expansion follow logical rules, responsive to the site and natural conditions, such as the river and topography. The set of parameters at this level can easily be applied to different sites to create another version of Agricultural City.

At the second level, more social factors rule the formation of clusters. For instance, the typical grid and cluster sizes are determined based on the average size of an existing community. The rules for distance between clusters as well as the placement of connecting bridges may also be included in this category. The program could reproduce a similar design to the original at this level. The clear difference of the reproduction from the original at this level, however, is that the clusters in the reproduction are more complete and similar to the prototype. We could consider that Kurokawa’s original version is representing one moment in the process of development, while the reproduction shows a more complete stage. The parameters for this evolution process are not yet apparent, but possibly depend on fluctuating social factors, such as migration.
At a more micro level, the types and locations of artificial grounds as well as the location of individual houses, however, could not be replicated automatically. In the regeneration, we could not exactly replicate the original form without entering specific values to components. The overall image of the project, however, is not affected by the differences. It suggests that their formation is also not based on apparent rules, but on other kinds of input possibly from residents and community. It may reflect Kurokawa’s humanistic approach to the city that it should always be a system, of which self-directed individuals have control (Kurokawa 1959).

CONCLUSION
We analyzed the Agricultural City Project by Kisyo Kurokawa as one of the predecessors for early generative design and verify their system by re-coding using Grasshopper. Though the study, we made the following observations:

The indeterminant factors (the parts that could not be regenerated automatically) appeared at all levels of the project, but this tendency becomes more apparent at a more micro scale leaving more freedom for each settlement’s or resident’s preferences and choices. This idea corresponds to the philosophy of the Metabolists. The algorithmic procedure clarified the two layers of urban systems: the one that regulates more permanent urban infrastructure and the other that generates ever-changing urban elements and functions.

The master system in this project is not designed to be an autonomous and universal system, but the parameters were set by taking the local condition and tradition (i.e. ‘Wa-ju’) into account. It can be a useful reference when we design system architecture in generative design.

In the present work, we could not find the apparent rules to regenerate elements at a more micro level. We speculate that other systems are required to provide inputs for regeneration of the project, such as simulation through a multi-agent or deep learning system. Those social and phenomenological inputs would direct the process of evolution over time and clarify different layers of parameters that affect the urban structure, which is only possible with computer technology. Further development of research would investigate the algorithmic systems for more community and humanistic factors which Kurokawa envisioned but were not technically possible to fully develop at that time.

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