The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory.

Architects who keep up with the new designs demanded by the building industry will remain at the forefront of the design process in our information-technology based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

The other message of our slogan is “Back to command”.

In the expanding world of IT applications there is a need for the ready change of preliminary models by using parameters and scripts. These approaches retrieve the feeling of command-oriented systems,

Why CAADence in architecture?

“The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation.”
CAADence in architecture
Back to command
Edited by Mihály Szoboszlai
CAADence in Architecture
Back to command

Proceedings of the International Conference on Computer Aided Architectural Design

16-17 June 2016
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Faculty of Architecture
Budapest University of Technology and Economics

Edited by
Mihály Szoboszlai
Theme

CAADence in Architecture
Back to command

The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory. Architects who keep up with the new design demanded by the building industry will remain at the forefront of the design process in our IT-based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

Our slogan “Back to Command” contains another message. In the expanding world of IT applications, one must be able to change preliminary models readily by using different parameters and scripts. These approaches bring back the feeling of command-oriented systems, although with much greater effectiveness.

Why CAADence in architecture?
“The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By definition, a cadence is a solo that precedes a closing formula, in which the soloist plays a series of personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation.”

Nowadays sophisticated CAAD (Computer Aided Architectural Design) applications might operate in the hand of architects like instruments in the hand of musicians. We have used the word association cadence/caadence as a sort of word play to make this event even more memorable.

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Members of our local organizing team have supported this event with their special contribution – namely, their hard work in preparing and managing this conference.

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Reinhard König studied architecture and urban planning. He completed his PhD thesis in 2009 at the University of Karlsruhe. Dr. König has worked as a research assistant and appointed Interim Professor of the Chair for Computer Science in Architecture at Bauhaus-University Weimar. He heads research projects on the complexity of urban systems and societies, the understanding of cities by means of agent based models and cellular automata as well as the development of evolutionary design methods. From 2013 Reinhard König works at the Chair of Information Architecture, ETH Zurich. In 2014 Dr. König was guest professor at the Technical University Munich. His current research interests are applicability of multi-criteria optimisation techniques for design problems and the development of computational analysis methods for spatial configurations. Results from these research activities are transferred into planning software of the company DecodingSpaces. From 2015 Dr. König heads the Junior-Professorship for Computational Architecture at Bauhaus-University Weimar, and acts as Co-PI at the Future Cities Lab in Singapore, where he focus on Cognitive Design Computing.

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Minka, Machiya, and Gassho-Zukuri
Procedural Generation of Japanese Traditional Houses

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Abstract: Minka (traditional folk house), machiya (historic town house), and gassho-zukuri (farmhouse conserved in the World Heritage villages) have individual characteristics in terms of their geometric shapes and are strongly affected by the local landscape in Japan. These houses are the archetypes of Japanese residences and their genotypes are alive in contemporary designs. This paper presents the procedural generation of these three types of Japanese traditional houses. Minka’s distinctive characteristics in appearance can be found in the roof combined with hip and gable shapes, called irimoya. Machiya’s characteristics can be found in the configuration of traditional lattice windows, called koushi-mado. Gassho-zukuri has a unique shape of a steeply inclined roof, which looks like praying hands. All of these procedures are implemented in CGA shape grammar language and are used in conservation design processes of traditional settlements. They are also planned to be used in the reconstruction design process from the Great East Japan Earthquake.

Keywords: traditional folk house, historic town house, World Heritage villages, CGA

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INTRODUCTION
The basic concept of shape grammar was proposed by Stiny and Gips in 1971 [1]. It has been researched as the theory of spatial analysis and shape generation in the academic field of architecture. Mitchell precisely described the shape grammar of generating Palladian Villas [2]. Aoki critically improved it and proposed the individual expression as a simplified language (SAL) to describe the floor plans of folk houses [3]. In the early stage, these research studies about architectural design language had been explored mainly as desk studies and then they were implemented as the practically executable application systems along with the rapid development of computer technology. Watanabe proposed a unified framework of representing architectural design knowledge (AKM) and constructed its system in the Smalltalk environment (OOAMS) [4, 5]. Müller implemented CGA language to process shape grammar [6]. Recently, with an increased interest in GeoDesign by Steinitz, the methodology of generating architectural shape with procedural descriptions is receiving attention again [7]. Watanabe made the study of shape grammar implicit in Japanese modern urban planning with the analysis of landscape elements in Tsukuba Science City [8]. Kumakura
used CityEngine as the communication media to share the memory of the past in an attempt to reproduce the landscape lost by the Great East Japan Earthquake [9].

The essential matter in these research studies is to explicitly express the regularity suitable for every geometric shape of the same class, and these procedural descriptions can be regarded as the very knowledge of architectural masters. This paper explains the grammars for generating Japanese traditional houses requisite for our urban and rural landscape simulation.

SHAPE GRAMMAR AND CGA

First, the definition of shape grammar (SG) is reconfirmed as the following 4-tuple:

$$SG = (V_T, V_M, R, I)$$  \hspace{1cm} (1)

This is inspired from the phrase structure rules that Noam Chomsky introduced in linguistics. Chomsky’s grammar generates one-dimensional strings defined by the alphabet of letters, whereas shape grammar generates 2- or 3-dimensional shapes. That is, $V_T$ is the alphabet of shapes, $V_M$ is a maker to conduct shape generation, $I$ is the initial state of shape, and $R$ is a set of rules which defines the transformation of an existing shape and can be described as follows:

Left-Hand Side (LHS) \rightarrow Right-Hand Side (RHS) \hspace{1cm} (2)

Basically, these rules are adapted in a top-down process like a tree structure; however, new LHS shapes, which satisfy requirements to adapt the rule, may come into existence across branches and also are acceptable in SG definition. CGA stands for Computer Generated Architecture, and can be used in CityEngine. The basic idea of CGA is the same as SG and its syntax is as follows:

PredecessorShape ---> Successor \hspace{1cm} (3)

Humans effectively find Left-Hand Side (LHS) in a visual way but the detection of PredecessorShape in 2- or 3-dimensional world is not possible with computers. Adaptation of rules needs to be conducted by the symbols of PredecessorShape explicitly given in Successor. The generation process only expands branches of shapes in a tree structure; consequently, they are not able to join branches together like a semi-lattice structure in CGA. In this meaning, CGA can be regarded as a subset of shape grammar. Additionally, the commands of handling shapes are limited to a small number of fundamental functions such as extrude, split, comp, translate, and rotate. The procedural modeling of CGA requires a description of all generation processes only in the rules of combining these functions with dexterity and ingenuity. However, this differs from the interactive modeling where operational objects are sequentially selected by hand.

As an example, the three rules of drawing a symbolic acrylic painting CG1 mentioned in the pioneering paper [1] can be written in CGA as follows:
// Rule1 and Rule3 ---------
MShape -->
    case i < level :
        set(i, i + 1)
    LShape
else :
    NIL

// Rule2 -------------------
LShape -->
    t(0, 0.1, -scope.sz/7.5)
    s(scope.sx / 7.5 * 8.5, 0, scope.sz / 7.5 * 8.5)
    i("Uiform.obj") Urform
    split(x) {
        ~0.3 : split(z) {
            ~0.5 : rotateScope(0, 90, 0) MShape |
            ~0.5 : rotateScope(0, -90, 0) MShape }
        ~0.3 : split(z) {
            ~0.25 : MShape |
            ~0.3 : rotateScope(0, -90, 0) MShape |
            ~0.3 : rotateScope(0, 90, 0) MShape }
        ~0.25 : split(z) {
            ~0.5 : MShape |
            ~0.5 : rotateScope(0, -90, 0) MShape }
    }

Figure 2: Generation Process of Irimoya

MINKA’S GRAMMAR
Minka’s distinctive characteristics in appearance can be found in the roof combined with hip and gable shapes called irimoya. The basic shape of these roofs can be generated with the roofHip and roofGable commands in CGA. By using these two commands, sketch volume of irimoya can be described as the script in Figure 2.

With this script, the roof has to be divided into upper and lower parts. As previously mentioned, the CGA rules constitute the top-down tree structure; however, the individually generated faces cannot be merged into the single face even if they lie in the same plane. The precise shape of traditional irimoya roofs can be generated with additional grammar of detail elements such as verge, main ridge, corner ridge, and rafters.
Figure 3 shows the different types of folk houses automatically generated from simple footprint polygons with the single CGA script. The windows are also arranged automatically according to the orientation of each wall but they are rarely inconsistent with the shape of roofs as shown in a rightmost house in Figure 3. This is because roofs and windows belong to different branches of the tree structure and it is difficult to determine the conflicts between shapes and solve them automatically.

**MACHIYA’S GRAMMAR**

In Japan, each region has the particular design of machiya (historic town house), but their common characteristic in appearance can be found in the configuration of traditional lattice windows, called koushi-mado. The lattice windows are not the universally unique design motif. There are many previous studies on the geometrical configuration of regional lattice windows. For example, Stiny mentioned Chinese lattice windows and described the shape grammar of their tilling patterns and the parametric shape grammar of their dividing rules (Ice-ray) [10].

In lattice windows of machiya, tateko (vertical members) and yokosan (horizontal members) are arranged according to their individual rules. Their configuration represents the running business of the house, for example, sakaya-koushi means a liquor shop, gofukuya-koushi means a tailor’s shop, and shimotaya-koushi means out-of-business [11]. The basic framework of their grammar can be described as the following script:

```
KoushiWindow -->
  offset(-0.045)
  comp(f) {
    inside : YokosanArrange TatekoArrange |
    border : extrude(-0.08) Frame }

YokosanArrange -->
  split(y) { ~scope.sy / 4 : NIL |
    { 0.016 : Muntin |
      ~scope.sy / 4 : NIL } * }
```
In this example script, parameterize numerical parts and add the grammar of structural members for de-koushi (extended window) and tsurigane-koushi (oriel window), then various types of lattice windows can be generated in detail as shown in Figure 4.

The machiya generally has a short frontage and a long depth, and the ridge of its gable roof is parallel to the frontage direction called hirairi. On the other hand, the roofGable command automatically determines the ridge of the roof in the long direction, which is orthogonal to the desired one. To solve this problem, the virtual volume, which is expanded N times in the frontage direction, is introduced to generate the right direction of the gable roof and resize it as shown in Figure 5.

Figure 6 shows the typical town houses automatically generated from simple footprint polygons with the single CGA script.

**GASSHO-ZUKURI’S GRAMMAR**

Gassho-zukuri is well known as the farm house conserved in the World Heritage villages of shirakawa and gokayama located in a heavy snowfall area. Most of the gassho-zukuri along the Shō River were pulled down or sunk in dam lakes during the period of rapid economic growth. Today, people miss this lost landscape.

Gassho-zukuri has the unique shape of a steeply inclined thatch roof, which looks like praying hands. This is ancient wisdom to prevent the roof from collapsing under accumulated snow. Today, the gable sides are often extended to adapt to modern lifestyle.

Figure 7 illustrates the variation of gassho-zukuri generated by the implemented CGA script. The basic shape of the roof can be described by the simple roofGable command containing the grammars of characteristic detail elements such as muna-gaya (thatch of ridge) and kanzashi-gaya (thatch of ridge end) to look like gassho-ukuri.

**GasshoRoof**

```plaintext
roofGable(55.0, 1.2, 0)
comp(f) {
    horizontal : NIL |
    vertical : Gable |
    all : Thatching |
}
comp(e) { ridge : Ridge }
```

**Thatching**

```plaintext
s(scope.sx + 1.2 * 2, '1, '1)
center(x)
extrude(0.6)
alignScopeToAxes(y)
split(y) {
    ~1 : comp(f) {
        all : ThatchTexture } |
    0.6 * cos(55.0) : NIL }
```
Finally, Figure 8 shows the landscape image from the famous observatory of the World Heritage village, in which all traditional houses are automatically generated with the CGA scripts introduced in this paper.

CONCLUSION

Constructive principles of architectural design, which have been inherited historically and culturally, are mentioned in various forms such as writings, drawings, and physical models. However, they are not often implemented in the procedural format and are rather executed more practically in a computational manner.

This paper introduced the characteristics of traditional Japanese architecture, and presented the outline of their procedural generation. All of these scripts are implemented in CityEngine, and are used in conservation design processes of traditional settlements. They are also planned to be used in the reconstruction design process from the Great East Japan Earthquake. However, the rules described in the system are only part of the design knowledge of traditional Japanese architecture. Many shortcomings are identical and will be improved in our future studies.
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The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory.

Architects who keep up with the new designs demanded by the building industry will remain at the forefront of the design process in our information-technology based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

The other message of our slogan is <Back to command>. In the expanding world of IT applications there is a need for the ready change of preliminary models by using parameters and scripts. These approaches retrieve the feeling of command-oriented systems, although, with much greater effectiveness.

Why CAADence in architecture?

"The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By definition, a cadence is a solo that precedes a closing formula, in which the soloist plays a series of personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation."