A House Design Method of Normative Modules adopting Hanok and Traditional Building Framing Skills

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ABSTRACT

In this paper, we try to verify a normative module based house design procedure consisted of several sequential steps. The first step is to suggest formalization of designing so that we could clarify each phase and operation we are adopting in our design process. The second step is the clearing up the conceptual schema of traditional skills that we adopt and utilize from traditional Hanok framing techniques. The third step is to formulate adequate modular kits for the assembly of house design solutions for the schematic, conceptual and preliminary phases of designing. The fourth step is to implementing our ideas and methods to a proper computational platform such as Unity3D. The final step is to verify our symbolic descriptions of design formalization with the output of our experiments so that we have better understanding of design reasoning characteristics such as in house design.

Key words: Normative Design Modules, House Design, Hanok, Unity3D, Polyomino, Design Formalization

1. INTRODUCTION

We look forward, in this paper, to propose a normative module based house designing procedure consisted of several separate steps discrete to each other, so that we form a sequence of these discrete steps into a meaningful whole. Firstly, we start with our suggestion of symbolic formalization of designing so that our symbolic descriptions fit better than existing others. The conceptual design level descriptions are then ramified into three branches and/or categories of refined symbolic descriptions upon which we depend the distinctions of their differences and characteristics of various design operations in this paper. Secondly, we describe generally consented compositional principles and/or rules in Hanok such as three-tier composition and Dori-direction extension.

In the third and the fourth steps, we handle the essence of our designing procedure: the normative modules, their conceptions and the implementation. We explain the basic of normative design modules starting from the roof, then the flooring and the polyomino representation of generic and conceptual space arrangement patterns. We use assets in Unity3D for the implementation of our modules to be deployed in a scene view. Using our symbolic descriptions, we try to categorize the binding and/or combination types for the clearer understanding of design operations in the process. This is followed by our final step, which is to verify the normative module based house designing method and to try to draw lines of demarcation between two different categories of bindings through characteristic design operations. Future studies include the normative module based representation of 'break-up joint' in Hanok which is a unique 3D composition that could only be described as a bio-

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logical bond of two separate frame sections.

2. SYMBOLIC FORMALIZATION OF DESIGNING

2.1 Symbolic Formalization of Conceptual Designing

We set the root of our design formalization attempts on two main tracks of design theoretical trends before us. One of the main design theoretical tracks we rely on is that of J. Gero, such as 'design prototype theory' and 'PBS design model'. According to J. Gero, a designer is an agent who changes the world. We follow his emphasis on the verbal aspect of designing as the mappings of design variables in different state spaces in terms of 'F → B → S' and adopt his usage of diagrams to understand design process in a way that designing is a procedure of changing state spaces so that state space from 'A' to 'C' occurs where 'A' in which people are unsatisfied and having a desire for the change and 'C' is where those modifications and changes are given satisfying related design constraints. The second track of design theory we rely on is that of G. Stiny who provides 'shape grammar' concepts for symbolic and graphic understanding of grammatical interpretation of 2D shape and 3D form compositions. Based upon these two precedents, we establish and suggest our formalization of designing starting with the primary symbolic expressions. The prototype of conceptual formalization of designing is in (f1.0), implying design process is characterized as the change of state spaces from 'A' to 'C' as 'before' and 'after'.

\[
\begin{align*}
A & \rightarrow C \quad (f1.0) \\
C & \rightarrow A \quad (f1.1)
\end{align*}
\]

The symbolic expressions of the primary design formalizations in (f1.0) and (f1.1) are the mappings between two different state spaces of 'before (A)' and 'after (C)' in (f1.0) and the reversal to each other in (f1.1). (f1.0) is the easy flow of designing, implying the 'composition' and 'design synthesis' whereas (f1.1) is the reverse direction of the (f1.0), implying 'decomposition' and 'design analysis'. This primary expression clarifies that designing is a directional process like a flow so that there is an initiative, following moves, obvious design goal(s), a direction to be achieved, adequate design constraints and requirements to be carefully examined during the process. It extends into more specific and sophisticated secondary formalization of designing as shown in (f2.0).

\[
\begin{align*}
A \circ B & \rightarrow C \quad (f2.0) \\
C & \rightarrow A \circ B \quad (f2.1)
\end{align*}
\]

The top most abstract expressions of (f1.0) and (f1.1) are extended into the next hierarchy of symbolic expressions as shown in (f2.0) and (f2.1), adopting the algebraic expressions where symbols and the rules for manipulating those symbols matter as we know from G. Stiny's 'shape grammar'.

The secondary symbolic expressions in (f2.0) and (f2.1) distinguishes algebraic elements and operators in such a way that a designer is performing a type of designing by combining and/or binding two elements through design operator 'o'. Character symbols 'A' and 'B' refer to sets of design elements. They indicate design modules, categories of design modules, and/or design components to be combined. The operator in the secondary expressions refers to a generic algebraic operator that plays just as any operator in shape grammar rules by G. Stiny. (f2.0) and (f2.1) are reverse to each other and (f2.0) extends (f1.0) in a way telling that design composition is not only a state space change but also the change occurs by the algebraic operation performed on design elements.

2.2 Three Combination Categories and Symbolic Descriptions

The secondary symbolic expression expands also into subordinate formula of the third design formulations.

\[
\begin{align*}
A \oplus B & \rightarrow C \quad (f3.1.0) \\
C & \rightarrow A \oplus B \quad (f3.1.1)
\end{align*}
\]
A ⊗ B → C \quad \text{(f3.2.0)}
C → A ⊗ B \quad \text{(f3.2.1)}
A ⊗ B → C \quad \text{(f3.3.0)}
C → A ⊗ B \quad \text{(f3.3.1)}

The third design formalizations from (f3.1.0) to (f3.3.1) are our further specifications of the previous (f2.0) and (f2.1). We propose three sub-categories for the design combination operators. The generic operator 'o' referring to any possible compositional bindings of design elements, progresses into three comparative sub-ordinate categories of 'physical', 'chemical' and 'biological' bindings and/or combinations, depicted by '⊗', '⁺' and '⊙' operators. The generic operator 'o' could be, for example, 'addition' or 'subtraction', then we see 'how' they are bound to each other. Those bindings could be 'physical', 'chemical' and/or 'biological'. The first type, 'physical combination' is the basic mixture of elements as shown in connections of wooden parts in traditional woodworking carpentry. We name it mixture '⊗' meaning physical binding. The second type, 'chemical binding' is the fusion of two separate design elements into a more stable bound complex with an expense of some sort of energy. This design creation results in a new bound complex and a mutated form and chances are that it could be grotesque. We name it fusion '⁺' meaning chemical bond of two separate design elements. The third type, 'biological bond' is the combination of two individuals of an equivalent class producing a design element inheriting characteristics just like a child from the parents. We name it 'biological bond', or 'consilience', '⊙'. Reverse of the former expression as a 'composition' matches into its 'decomposition' pair.

2.3 Framing Rules of Traditional Composition and Extension

We have our focus on traditional framing skills for wooden structuring. Two main features we took from the traditional framing skills are firstly, the three-tier composition and/or three-layered composition of Hanok space frames and secondly, the dori-direction extension of frame sections as illustrated in Fig. 1.

The first feature, as shown in the left of Fig. 1, we adopt from the traditional Hanok framing skills is the three-tier composition principle, which has been maintained since at least 10th century. Three composition parts are a) the foundation (base, footing and stylobate), b) the flooring (body, bay, compartment), and c) the roof (attic, pediment) from the bottom up. The second feature, as shown in the right of Fig. 1, is the dori-direction extension of the frame section. This is a unique feature found in traditional Korean buildings. Frame section and its orthogonal direction (dori-direction) extension forms a unique building block called 'chae' or 'wing' that adds up into a separate building. Hanok is a complex of these buildings as one residence (Gaok). Fig. 2 illustrates typical Hanok composition with three-tier composition principle in three
3.1 Normative Roof Modules: the Basic

As the base of all the design modules, we start with the normative roof modules, i.e., the 2D plan-view set of roofing compartments. This normative roof design modules are those graphic pieces that are combined into a whole house roof design. We use Unity3D platform for implementing and verifying the normative roof modules. Unity 3D, which is popular, easily accepted platform by developers, education society as well as general public, is basically a game development tool allowing users easy, fast and intuitive interface for creating and editing 2D and 3D objects, that we could use as design modules in the form of assets in a scene view. Fig. 3 illustrates an exemplary process of a simple Hanok design case, its decomposition into a series of normative roof modules. It also shows their naming rules.

We examined and generalized Hanok roof modules into three basic assembly compartment types. As shown in Fig. 3, we have a) Pyongyang roof (rectangular) module, which has one directional extension to each other. b) Chunyo roof (triangular) module, which occurs in the outer corner of the roof forming a pair to complete a corner of the outer roof, and c) Hoechum roof (triangular) module, which occurs in the inner corner of the roof and as a pair, as well. If we look at the roof modules as in Pyongyang modules, the double line signifies as the ridge of the roof, meaning the higher part of the slope. The right of Fig. 3 shows how each roof modules are named following the rules of Roof_[Chunyo/Hoechum/Pyongyang]_OO_O, where OO refers to extension direction and O refers to the position of a pair using N, S, E, W symbols. Fig. 4 shows three categories of normative roof modules implemented as Unity3d assets. Unity3d assets are considered to be the building

Fig. 2. Illustration of three-tier composition in three separate frame sections and dori-direction extension to form 'wings' and then a building.

Fig. 3. (a) An exemplary Hanok design, the assembly of normative roof modules and (b) the naming rules of roof modules.
assembly blocks so that users could construct a scene view, just as in a game composition event. 2D images called ‘sprite 2D’ are edited using image editing tools such as Photoshop into 2D normative design modules. We use several other sprites for the building site, landscape elements such as trees and surrounding walls and gates. We use physics engine in Unity3D to set collision detection to each asset of 2D sprite. The combination of normative roof modules is in the state space of Fig. 3.1 ‘A ⊕ B → C’ of designing, meaning that it is in the realm of a physical combination or mixture of design elements creating no significant synergy effect as a result.

3.2 Deploying Normative Roof Modules for House Design

We consider the main task of house design as a problem-solving of a generic space arrangement, in which we go through design stages from the very abstract description with, for example, a polyomino or a graph, to more specific and meaningful design descriptions through diversification (1 to many mapping). A polyomino is a simple repetition of square cells to make a sequence of polyforms or plane geometric figures. Fig. 5 shows a series of possible roof patterns to satisfy an exemplar spatial arrangement problem in the form of four square cell tetromino.

The ‘L-shape’ pattern is a simple and typical case in Hanok house designs. A simple L-shape spatial arrangement problem:solution is described here as a four cell tetromino, which diversifies into a set of equivalent floor plans with different roof types, presented with different set of normative roof modules as shown in Fig. 5. It shows different roof types, showing features such as types of a) no Heochum and no Chunyo, b) one Heochum and one Chunyos, and c) one Heochum and five Chunyos. Heochum roof is only possible in the inner corner of the L-shape roof. Chunyo components, characteristic feature with folding fan rafter arrangements, show more liberty at locations.

3.3 From Roofing to Flooring

Roof patterns are more sophisticated and the oldest in appearance among the frame section trio. Even though frame section stands from the bottom to the top, say ‘foundation - flooring - roofing’, the order of ontogenesis of the three in history is the ‘roof (the oldest) - floor - foundation (the newest)’ in Hanok. Column placing is important issue

Fig. 5. Deployment of normative roof modules to comply with the polyomino representation of spatial grids in the form of four square cell tetromino.
in the conversion so the Fig. 6 and Fig. 7 shows the sequence of replacing the roof modules starting from the outside and inside corners such as Chunyo and Hoechum parts followed by Pyongyon parts using four sets of normative floor modules (Pyong columns, Guy columns, Hoechum columns and Min columns).

4. UNDERSTANDING TYPES OF SYMBOLIC DESCRIPTIONS

4.1 Polyomino Representation of Conceptual Design

Depending on the type of tools we choose as shape and/or form representation, differences stands out in their coverage and ranges. It is even more evident in the conceptual stage of designing. Some of the favored representation methods for the architectural drawings and design entities are graphs and polyominoes, showing equivalent capabilities in handling topological relations among spatial entities. Our preference is the polyomino method, because of its capability to contain meta arrangement information for normative module series including roof and floor. Fig. 8 shows two sets of polyominoes with three rows of selections: 1) normal hanok plan group, 2) possible hanok plan...

Fig. 6. Four sets of normative floor modules,

Fig. 7. Icheon and Yangju Hanok and their normative module representations,

Fig. 8. Polyomino generations of possible 18 pentominoes and 35 hexominoes,
group, and 3) less possible hanok model group with some deficiencies.

So now we can possibly reduce a conceptual Hanok house plan design to some type of a search or an exploration process with design constraints to be satisfied, and we might consider polyomino representations, as shown in Fig. 8, as those possible meta solutions of spatial arrangements. Korean folks, traditionally, have shown a set of strong preferences on selecting Hanok plans, that could play as design constraints for better fitting house designs for latent house consumers. Firstly, there is a strong favor on single layered plans, so that double layered alternatives, as in the third rows in both polyominoes in Fig. 8, are not likely to be chosen. Chances are that single layered plans, when chosen, possibly provide better contact with outer environment. Secondly, some show dislikes on patterns with irregularity and improper enclosure with unhealthy correlation between buildings and yards. Other trends of consumer preferences would play as requirements and constrains that might help designers to narrow down for their optimum selection.

4.2 Understanding the types of our symbolic descriptions

Results of enumeration and exploration through module-deployments show some match to symbolic descriptions of design formalizations. We have a formal representation of designing ‘A → C’, and its reversed expression of ‘C → A’, where two different state spaces could refer to any design aspects in many phases of a design process, say ‘A’ as in polyomino form of design and ‘C’ as in a roof pattern. Fig. 9 shows one example of ‘A → C’ as a mapping from a polyomino, in this case a straight pentomino, to a combined suggestion of a specific roof and a floor pattern.

The mapping pattern ‘A → C’ reveals us a new direction in Hanok typology. The reverse of ‘A → C’ is ‘C → A’, and it might extend to the secondary design formalization of ‘C → A o B’, meaning that the specific polyomino (pentomino) space arrangement conceptual design solution is the result of applying specific category of designing operators ‘o’ in this case the category of chemical combination (β) of two different state spaces roof and floor, forming a stable combination of concrete roof and floor pattern suggesting a particular design meaning as a whole, and by some expense of energy for a particular synergy. We could translate it as a specific fusion of two different compositions of roof and floor modules. Thus the expression ‘A (β) B → C’ is understood as the assimilation operation by making a fusion of two different design elements. Then Hanok typology might be treated as a matter of handling design formalization ideas in the form of polyomino patterns matching with specific architectural meanings.

4.3 Biological Bond (β)

We have been using 2D projection method for modular house designing covering most of 2D designs. We look forward to expand our research toward genuine 3D composition problems that we have some limitations with our 2D based modules. Most of the 3D routine design composition problems in 2D realms are sufficiently covered using our 2D modules. However, there are always some specific and difficult 3D composition problems. Joint composition of two frame sections, in other words the break-up joint part of Hanok design is
one of those difficult 3D problems. Hanok has strong favor and choice tendency toward two compositional characteristics: 1) one is the 'single-layered plan' and 2) the other is the mono-triangle pitched roof proportionally adequate to other flooring and foundation parts. The stubborn fixation on these compositional features leads Hanok to quite a unique form of one directional extension (dori-direction, orthogonal to beam-direction) of a frame section to form a wing building segment called 'chae', which becomes the main distinction of Hanok design and composition. A specific 3D composition occurs when the two separate frame sections meet each other to form a composite mixture, which is called the 'joint' or 'break-up joint' part. Fig. 10 displays several cases of break-up joint parts in Hanok.

Base A © Body A © Roof A → Frame section A
(f4.1)
Base B © Body B © Roof B → Frame section B
(f4.2)
Frame section A © Frame section B → Break-up joint A-B
(f4.3)

Fig. 10 shows 'break-up joint' example of a Yoon Jeung residence inner building, where west wing of '0.5-1-0.5 bay' pattern frame section A meets with middle maru-chae '1-1 bay' pattern of frame section B. The understandin of this kind of 'break-up joint' leads us to our formal definition biological bond '§' of design elements as in (f4.3). A frame section pattern repeats throughout in a chunk of building mass called 'chae' or a wing as a sequence. A pair of frame sections and a 'bay' inbetween form a 'Shil' or a room (space unit) in a building. Two different wings may contain different sets of frame sections to form a joint. A joint is a complicated 3D composition challenge because two different sets of design variables must merge into a harmonious one, and this has become a specialty to a named traditional master-builder in Korea. Two frame sections might have different ground levels to start with, different base heights, different design elements of wooden structuring in terms of heights and widths, to form a specific combinatorial design choice in 3D. Combining these two individuals into a harmonious hybrid is considered as the matter of biological bond '§', because this is just like a matchmaking – the arrangement of a marriage between two separate and characteristic individuals to make them a parent and to produce a specific combination output as a child, the 'break-up joint' case.

4.4 Future Studies

We include this complicated 3D composition problem of 'break-up joint' in house designing as one subject of our future studies. Our normative design modules in 2D projection modes will be extended to cover up complicated 3D compositions.
such as 'break-up joint' in future studies.

5. CONCLUSION

In this paper, we have bespoken a sequential design procedure consisted of discrete phases as 'steps' starting from the formalization of designing concepts, the polyomino based summary of conceptual space arrangement solutions of house designing, the normative design modules in the form of assets for a scene in the Unity3D platform and to the assembly and representation of house design solutions using ND (normative design) modules just like putting building blocks together. These ideas are best understood based upon three types of combination and their distinctions as we suggest in the third set of design formula. It is interesting to distinguish each combination type in terms of physical combination (mixture, ①), chemical combination (fusion, ②) and biological combination (biological bond, ③), and the increasing difficulties found in the direction from 'mixture' to 'fusion', and from 'fusion' to 'biological bond'. We exemplified the 'mixture' case with those combining equivalent normative modules, the 'fusion' with combining or assimilating different normative modules to form a space arrangement solution, and the 'biological bond' with case examples of 'break-up joint' of two different frame sections. We hope in this paper to initiate a theoretical and methodological understanding of Hanok house designing such that now the Hanok construction industry, which seems to rely too much on old and traditional master-disciplinary Ecole de Beaux-Arts type design learning and practice, could start modern design discourse of design thinking on centuries-old our DNA stamped subjects of Hanok house design and construction. The normative modules would be extended into more specific subjects such as Ondol - the floor heating technologies in near future studies.

REFERENCE


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