Three-dimensional Translation of Japanese Katagami Patterns

potential applications on architectural planning and elements through the flocking behavior algorithm.

ABSTRACT
The aim of this ongoing doctoral research is to rely on the incommensurable potential held in Japanese Katagami patterns in order to translate them into three-dimensional speculative architectures and architectural components that afford architects other design approaches differentiated from systemic and typical space configurations. While many designers are diving in the generative and computational design world by developing new personal methods, we would like to recycle the existing production of Katagami patterns into three-dimensional architectural elements that will perpetuate work of Katagami artists beyond time, borders, and scope of applicability. Given that the current digital shift has given us more computation power, we are broadening Katagami with new fabrication strategies and new methods to explore, produce, and stock geometry and data. In this paper, we rely on the Processing library IGeo (developed by Satoru Sugihara) to build bottom-up agent-based algorithms to study the architectural potential of Katagami patterns as a top-down clean and simple initial topology that avoids imitation of standard templates applied during the process of configuring and planning architectural space.

1. Photomontage of potential user activities within a 3d translated Katagami pattern
2. Conceptual diagram suggesting an imaginary situation of how a Katagami pattern’s geometrical topology could be used for implementing activity and usage of spatiality; a different scenario could emerge according to every architect’s inspiration and imagination
INTRODUCTION
Katagami are the stencil tools that Japanese artisans and artists used in the process of dyeing patterns on fabrics of Kimonos and Yukatas. Japanese Mino-Washi paper is sculpted by material removal through carving techniques (Figures 3, 4) as many layers are necessary to produce one unique pattern. Paper is glued together using persimmon tannin then dyed using the Katazome method that consists of applying a resisting paste developed during the Kamakura period (1192-1333). At the end of his career, an artist reaches a level of accomplishment as he spends a whole lifetime mastering one technique and making his own tools (Ikuta and Maruyama 2013).

Japanese patterns are a result of a “point of view,” which makes them new creations and not just a mere reproduction of nature. They are not real representations but are produced by intuition, imagination, the unreal, and the irrational (Belfiore and A. Liotta 2012). The point of view is what turns raw nature into a content. Especially since everyone is able to see the plant, but not everyone will see it in the same way (Yanagi 1972).

Our globalized societies have evolved and are becoming more complex while developing new versatile social modes. As architects, and as human beings first, we need to focus our current debates on relationships, boundaries, buffer, and transition spaces and especially on more inclusive and narrative experiences (Kuma 2009). Architecture is the art that has the most influence on the daily life and social organization of human beings; it is an art that creates a physical difference (Balmond 2008). In order to meet these needs today, a synthesis between nature, energy, culture, society, user, spatial experience, and technology is essential. In a mono-cultural and metropolitan society like Japan, where symbolic communication, iconographies, and patterns have been codified through various modes of consensus (Dower 1990), it will be relatively easy to incorporate more symbols. Through investigating the expressionist materiality of architecture, opportunities arise to find new methods that interact with urban configurations and converge towards culture (Moussavi and Kubo 2005). New recycling mechanisms help in the production of concepts, diagrams, and new ways to see, understand, and imagine architectural elements in opposition to typical spatial configurations. Moreover, translating and recycling the existing production of Katagami patterns into three-dimensional architectural elements will perpetuate the work of Katagami artists beyond time and borders, possibly leading to “another form of Japonisme”. As of today only a handful of craftsmen and manufacturers—about fifty Katagami carvers, two businesses that produce paper, and fourteen sellers of Katagami—are still protecting these valuable cultural assets (Figure 5), (Ikuta and Maruyama 2013).

The idea of using Japanese patterns in architecture has been proposed in the past and has been studied and explored by diverse architects (Kuma 2010) and researchers (Belfiore and A. Liotta 2012, Obuchi 2012). Their design mainly applied patterns on building envelopes by extruding the pattern geometry and remapping it on the wall or ceiling surfaces (Figure 6).

While we also investigate a potential application of Katagami patterns on building facades, our alternative approach focuses mainly on bottom-up agent-based algorithms that allow greater freedom in creating unpredictable and unconventional space formation that use the Katagami patterns as a well defined top-down input. The role and the impact of the pattern are thus reinvestigated to imagine alternative space organization and are considered as an alternative to standard architectural planning templates (Figure 2).
PATTERN SELECTION AND INVESTIGATION METHODOLOGY
Katagami Pattern Selection
Up to today, Katagami production has been referenced by the Isetan Mitsukoshi Collection and contains more than 1600 patterns (Ikuta and Maruyama 2013). For this ongoing research, a total of twenty patterns were chosen and organized in two groups (structured and unstructured) in order to study their three-dimensional architectural potential with the hypothesis that these two geometry criteria will have different sort of outputs when used as a top-down input patterns for our agent-based algorithms.

The assumption was that a structured Katagami pattern will have few of the above properties or is made of different layers of sub patterns. Figure 7 is an illustrated example of one of the structured patterns that was disassembled for layering and geometrical property analysis. In contrast to the structured pattern, an unstructured pattern will not be made of layers of sub patterns, will be inspired by nature, or will depict a landscape or a scene from everyday life.

Basic Setup
The behavior patterns of various animal species and social insects produce very complex architectures that demonstrate great sense of proportion while fulfilling multiple functions such as protection from predators, humidity regulation, reproductive activities, etc. (Hansell 1984; Jeanne 1975; Wilson 1971 cited in Bonabeau et al. 2000, 1-2). In recent years, various researchers have relied on biological and animal behavior where agents react to their environments, to study phenomena such as stigmergic planning (Gerber and Lopez 2014, Ireland 2010), parasitic behavior (Alborghetti and Erioli 2015), and cellular growth (Klemmt 2019), to cite a few.

In this paper, we will focus on the flocking behavior (Figure 8) described by Craig Reynolds (1999) in order to give our top down initial Katagami pattern the ability of locomotion and self-organization in three dimensions while we store each particle’s coordinates at each time frame update and build geometry on it in order to get a spatial structure that emerges as a consequence of the system’s behavior. As we did not have prior solid skills in computer sciences, we needed to train first and get knowledge of programming languages. We chose to use the IGeo library (Sugihara/ATLV 2011; IGeo 2011) developed for the Processing environment (Fry and Casey 2009). Sugihara (2014) developed IGeo in order to fight obscurantism in computational design and bring easier and ready to use tools for a larger number of architects and designers by minimizing the coding effort. The IGeo website not only offers full training tutorials to get users familiar with the fundamentals, agent-based algorithms, and swarms simulations, but also explains and illustrates in detail different situations for interaction depending on the population number and the computation power needed. The diagram in Figure 9 explains the workflow for geometry and architectural exploration.

CASE STUDIES
In IGeo, the flocking swarm behavior is coded by Sugihara as a class named “IBoid” which has three parameters for
threshold distances and three others for force ratio that control the strength of cohesion, separation, and alignment. For the case studies discussed in this paper, our agent-based algorithms were based on the following parameters:

<table>
<thead>
<tr>
<th>Input Pattern</th>
<th>The top down pattern that will evolve through agent based simulation into a non deterministic bottom up spatial formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Number of particles that constitutes the pattern</td>
</tr>
<tr>
<td>Number of Frames</td>
<td>Necessary update counts for generating the geometry</td>
</tr>
<tr>
<td>Cohesion Distance</td>
<td>Going to the center of the surrounding agents; agents are considered as neighbors if the distance to the agent is less than the threshold, and the center of the agents is calculated by adding their respective position vectors and then divided by their total number</td>
</tr>
<tr>
<td>Cohesion Ratio</td>
<td>The force vector is calculated by taking the difference vector between the agent and the center; the force is adjusted by the ratio coefficient</td>
</tr>
<tr>
<td>Separation Distance</td>
<td>Going away from other agents; this parameter works in the same method as the cohesion distance and is used to determine if the other agent is close enough to get away from</td>
</tr>
<tr>
<td>Separation Ratio</td>
<td>The ratio coefficient adjusts the separation force</td>
</tr>
<tr>
<td>Alignment Distance</td>
<td>Heading towards the same direction of other agents' velocities; vectors of the agent's neighbors within the threshold are calculated; the difference between average velocity and actual position is measured, and the force is added to the direction difference vector of the two velocities</td>
</tr>
<tr>
<td>Alignment Ratio</td>
<td>The amount of the alignment force is readjusted by this ratio</td>
</tr>
<tr>
<td>Initial Direction Vector</td>
<td>A direction/amplitude vector that acts uniformly in space, a vector force that is added to the locomotion of the swarm to help it grow vertically</td>
</tr>
</tbody>
</table>
For the behavior simulation of Cases 01 and 02, the same pattern has been used. The Flocking IBoid class parameters are also identical except for the initial direction and velocity vector. When increased, the enclosure’s height—indicated by the white arrows (comparison between Figure 10 - 1 and Figure 11 - 1)—is stretched as the system agents need more time frames to reach their positions according to the IBoid parameters. Through this, the pattern is investigated potentially as a space configured with circulations and enclosures of different heights according to the architectural program needs.

<table>
<thead>
<tr>
<th>Case 01</th>
<th>Case 02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>1000</td>
</tr>
<tr>
<td>Number of Frames</td>
<td>150</td>
</tr>
<tr>
<td>Cohesion Distance</td>
<td>25</td>
</tr>
<tr>
<td>Cohesion Ratio</td>
<td>4</td>
</tr>
<tr>
<td>Separation Distance</td>
<td>15</td>
</tr>
<tr>
<td>Separation Ratio</td>
<td>3</td>
</tr>
<tr>
<td>Alignment Distance</td>
<td>10</td>
</tr>
<tr>
<td>Alignment Ratio</td>
<td>2</td>
</tr>
<tr>
<td>Initial Direction Vector</td>
<td>IG.v(0,0,25)</td>
</tr>
</tbody>
</table>
Cases 03 and 04 investigate potential application as wall surface and bring another agent class to interact with the flocking IBoid class. A branching behavior was added to create branches between each particle's current position and other particles' previous position within a distance threshold in order to control the density of the geometry and, therefore, the porosity of the facade thanks to the branching threshold and the frame count.

<table>
<thead>
<tr>
<th></th>
<th>Case 03</th>
<th>Case 04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>1000</td>
<td>2500</td>
</tr>
<tr>
<td>Number of Frames</td>
<td>20</td>
<td>5 and 8</td>
</tr>
<tr>
<td>Cohesion Distance</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Cohesion Ratio</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Separation Distance</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Separation Ratio</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Alignment Distance</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>Alignment Ratio</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
| Initial Direction Vector| (IG.v(IRand.
get(20,40),
0,%2*100-10).rot(PI*2/num*i+PI/4));) | (IG.v(IRand.
get(20,40),
0,%2*100-10).rot(PI*2/num*i+PI/4));) |
| Branching threshold     | 10 - 15 | 5 - 10  |

12-0  Input pattern (Case 03)  13-0  Input pattern (Case 04)
12-1  Simulation perspective view at 20 frames (Case 03)  13-1  Simulation perspective view at 8 frames (Case 04)
DESIGN APPLICATIONS

The flocking simulations using Katagami patterns as a top-down input were applied as cited above on two case studies: first, in Figures 14 and 15, the renderings/photo-montages showcase the application on a wall surface representing building facades.

On the other hand, Figures 1 and 16 demonstrate how a Katagami pattern can emerge into a morphology that has possibilities to host circulations, enclosures, open air spaces, galleries, and as a result, diverse activities.

Finally, Figure 17 is a design of a tower put in an urban context, here Shinjuku District. Each floor of the tower is made of a unique Katagami pattern that, using our research methodology, emerged as a unique spatial configuration so that each floor can host a different architectural program and function as a mixed use tower.

CONCLUSIONS AND FUTURE WORKS

The methodology adopted in this paper for morphogenetic experiments has demonstrated the ability to generate, through the translation of Katagami patterns, a wide variety of spatial morphologies and relevant potential for applications on architectural configurations.

By contrast to standard architectural processes where planning and design follow a design brief and constraints, taking inspiration from Katagami patterns using swarm intelligence offers us new possibilities to explore forms of design and architectural composition. Our goal is not to produce algorithmically clean geometries, but to nurture our imagination for early esquisse phases by generating basic data (coordinates at each time frame) before starting to sculpt form using softwares such as Rhino/Grasshopper, creating architecture that offers a new interest in space and forces the user to question his practice and curiosity. In this surrealist method of exploration, we abandon the search for the "best" solution (Ogrydziak 2011) and disrupt rationality, alienation, oppression, and predomination of existing design methods (Eagle 2018).

While we wrongly thought that all patterns behavior can be studied through one same algorithm, to date trials revealed that each pattern requires its own algorithmic strategy and agent-based model to explore pattern-specific latent potentials. As Katagami artisans spend a lifetime developing their tools and techniques to deliver unique mind-blowing patterns, we consider that our algorithms are digital craftsmanship as each agent method must be personalized for each pattern. The purpose is to be able to develop an algorithmic tool that takes advantage of the
pattern structure. For now, our pattern selection and assumptions about structured and unstructured patterns have not yielded satisfactory conclusions. Future work will attempt to study the impacts of flocking behaviors on bi-dimensional patterns and the translation of structure or criteria into 3d. In the 3d space formation, can we still read any sub layers of patterns and therefore layering of space? Despite the fact that all the properties of the pattern are not assimilated at the beginning, the process of trial and error will uncover new generative aspirations. On a programmatic and morphologic level, it would be interesting to also explore how multiple patterns can generate enclosed spaces by blending into each other when growing vertically. For now, as seen in Figure 17, each level, pattern and architectural configuration are separated by simple slabs.

On a more pragmatic investigation level, an implementation of a user interface to control the sensitive algorithm is necessary. For now, input parameters are difficult to control, the process is time consuming, and we are obliged to rewrite the inputs directly into the script and launch a new simulation every time. Using control sliders is for
now incompatible with the IGeo library as explained by Satoru Sugihara via an email exchange: "unfortunately because of my direct use of JavaGL, it hijacks the drawing process of Processing."

Finally, other fields of interest include other agent-based algorithms such as chemotaxis, stigmergy for decision making for real time structural optimization of our spatial morphology, an agent class that constructs a ready 3d-printable mesh on top of the geometry track coordinates, cellular automata, and use of the Katagami pattern layers as force vector fields.

ACKNOWLEDGMENTS
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My gratitude and special thanks goes to my thesis supervisor Professor Mitsuhiro Kanada who has been a valuable interlocutor supporting my research by generous discussions and sharp theory and methodology critics.

NOTES
1. Soetsu Yanagi has been described as the first philosopher and artist who tried to understand, to decode, and emulate theories about Japanese pattern.
2. Comparable to the effect of Ukiyoe on the Impressionist painters.

IMAGE CREDITS
Figures 3 and 4 by Shizuoka City
Figures 5 by Ikuta Yuki and Maruyama Nobuhiko
Figures 6 by Salvator-John A. Liotta
All other drawings and images are production of the author.

REFERENCES


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Ghali Bouayad obtained his Master’s degree in architecture, urban planning and design strategy from the Architectural School of Paris La Villette after spending his final year of studies at the G.S.D of Kyushu University. He has worked among others for Riken Yamamoto, Jakob+MacFarlane, and Christian De Portzamparc where he mainly focused on the development of international competitions of mixed-use programs. In 2015, he was awarded the 2nd prize for his teamwork entry to the Togo Murano competition for the reconversion of the Yahata Civic Hall. In 2017, he was awarded the Japanese Government Monbukagakushou Scholarship to enroll in the architecture doctoral program of Tokyo University of the Arts under the supervision of Mitsuhiro Kanada. In 2018, he was selected as “invited architect” to the Liminal Structures exhibition in Itabashi Art Center; and in the same year, the Architectural Institute of Japan awarded him the Jury Prize for his entry to the Ginza Architectural Grand Prix Competition.