archi DOCT

The e-journal for the dissemination of doctoral research in architecture

July 2019

www.archidoct.net

ISSN 2309-0103

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FORCES

Listed in: Scopus®

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

Three-dimensional translation of Japanese Katagami patterns

An investigation through agent-based algorithms applied to architectural elements and space planning

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Abstract

The aim of this ongoing doctoral research is to rely on the incommensurable creativity held in the Japanese Katagami patterns in order to translate them into three-dimensional speculative architectures and architectural components to give architects more design approaches differentiated from the systemic usual 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 the artists work and make their design go beyond time, borders and scope of applicability, all the more the current digital shift has given us more computation power, 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) in order to build bottom-up agent-based algorithms to study the architectural potential of the Katagami patterns as a top-down clean and simple initial topology in order to avoid imitation of standard templates applied during the process of configuring and planning architectural space.

Keywords

Katagami patterns; Digital craftsmanship; Emergent and Self-organizing systems; Art and technology; Agent-based algorithm; Swarm Intelligence

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

1. Introduction

Katagami (型紙) 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 (see Figure 1 and 2); as many layers are necessary to produce one unique pattern, paper is glued together using PersimmonTannin 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 the "point of view"; which makes them new creations and not just a mere reproduction of nature. They are not real representation 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[1], 1972).

Our globalized societies have evolved and are becoming more complex while developing new versatile social modes. As architects, and as human beings before all, we need to focus our current debates on relationships, boundaries, buffer and transition spaces and especially on more inclusive and narrative experiences (Kuma, 2009). All the more architecture is the art that has the most influence on the daily life and social organization of human being; 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, symbolic communication will be easy to incorporate all the more symbols, iconographies and patterns have been codified through various consensus (Dower, 1990). Investigating the expressionist materiality of architecture is the opportunity to find new methods in order to interact with the urban configuration and to converge towards culture (Moussavi and Kubo, 2005). For this, not only new recycling mechanisms, could help in the production of concepts, diagrams, and new ways to see, understand and imagine architectural elements in opposition to the usual space configurations, but translating and recycling the existing production of Katagami Patterns into three-dimensional architectural elements will perpetuate the artists work and make their design go beyond time and borders, which could lead to "another form of Japonisme[2] ". As of today, approximately only fifty Katagami carvers, two businesses that produce paper and fourteen sellers of Katagami are still protecting such valuable cultural assets (see Figure 3)(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) to cite a few. Their design mainly applied patterns on building envelopes by extruding the pattern geometry and remapping it on the wall or ceiling surfaces (Figure 4).

While we also investigate a potential application of Katagami patterns on building facades, our alternative approach focuses mainly on bottom-up agent-based algorithms as it allows greater freedom in creating unpredictable and unconventional space formation while using 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 (see Figure 5).

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

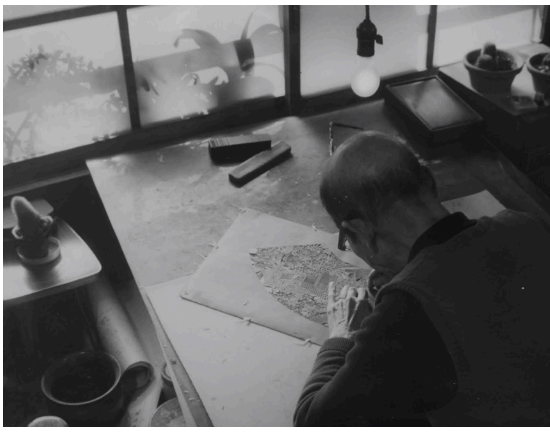

Figure 1.
(Nanbu Yoshimatsu (1894- 1976) working on tsukibori (push cutting)(Photo by Suzuka City)

Figure 2.
(Tsukibori (push cutting)(Photo by Suzuka City)

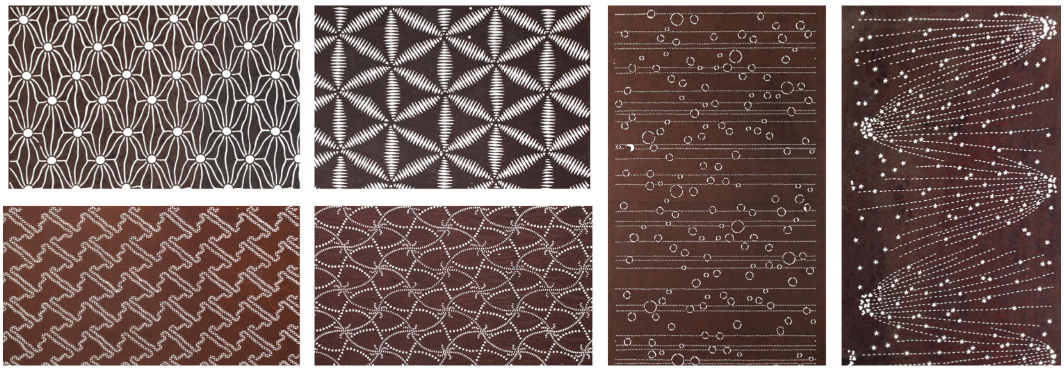

Figure 3.
A sample and preview of the diversity and richness of the Katagami pattern production, from organic to geometrical and multi layered (Ikuta and Maruyama, 2013)

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

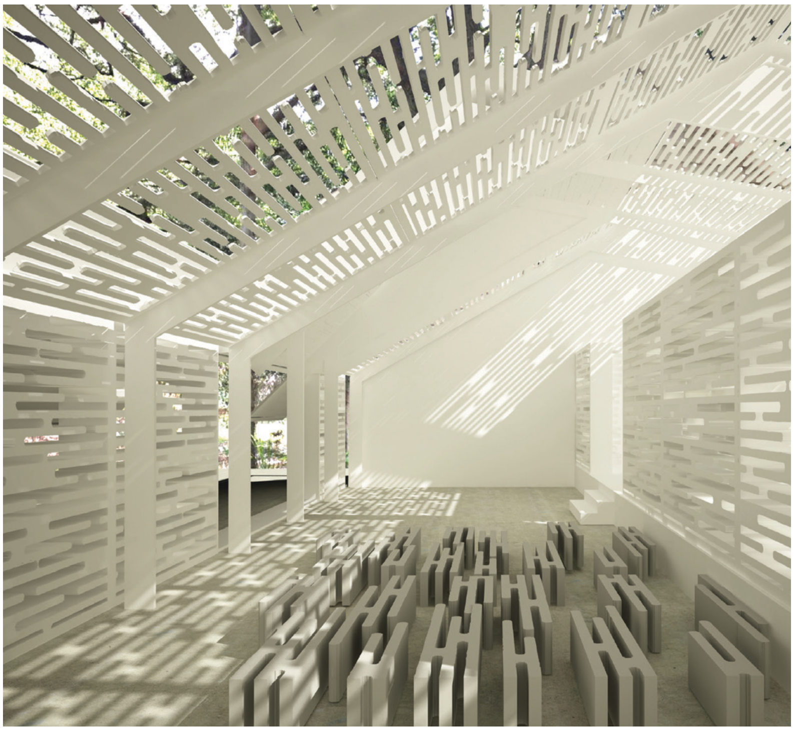

Figure 4.
Example of a Japanese cloud pattern remapped on walls and ceiling surfaces
(A design by Salvator John A.LIOTTA)

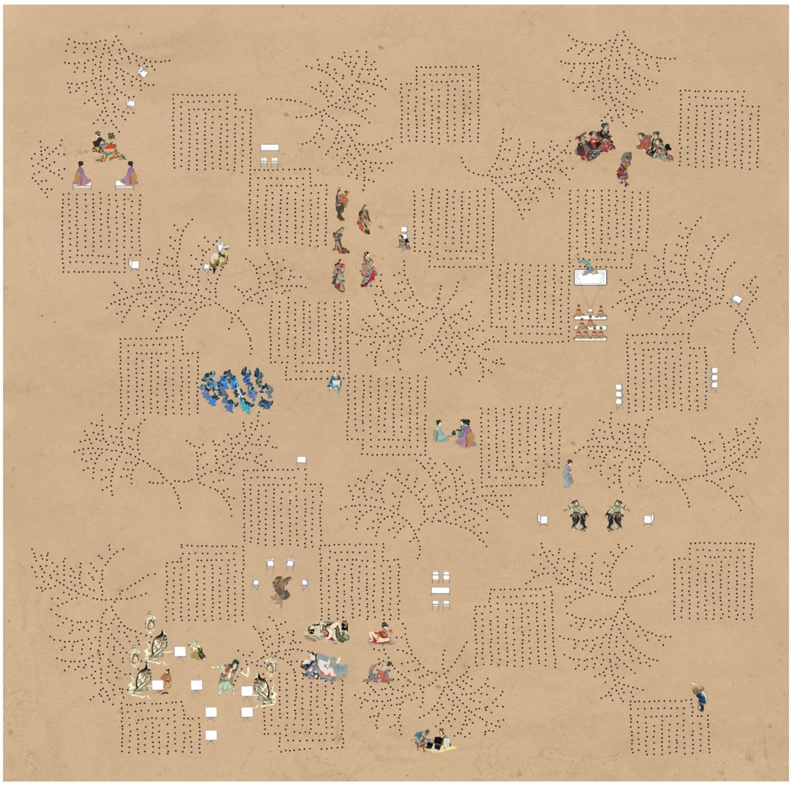

Figure 5.
A conceptual diagram suggesting an imaginary situation of how a Katagami pattern's geometrical topology could be used for implementing activity and usage of spatiality. A different scenario could emerge according to every architect's inspiration and imagination

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

2. Pattern selection and investigation methodology

2.1 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 un-structured) 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 to our agent-based algorithms.

Criteria for such differentiation were based on the ideas of the architect and systems theorist Christopher Alexander who assumed that each system -either artificial or natural- can be analyzed thanks to fifteen properties that help us understand and appreciate its physical and geometrical character (Leitner, 2015). Helmut Leitner, who summarized Alexander's lifetime work on patterns, describes the fifteen properties as the following : scale, strong center, boundaries, alternating repetition, complementarity (when centers expand more and more to fill the available space and come in contact to each other), good form, local symmetry, ambiguity, contrast or difference, gradients, individuality, similarity, voids, simplicity, and connectedness. According to him, some properties are conflicting by character and therefore only up to four or 5 properties can occur within the same pattern.

As a personal assumption, a structured Katagami pattern will therefore have few of the above properties or is made of different layers of sub patterns. Figure 6 is an illustrated example of one of the structured pattern that has been disassembled for layering and geometrical property analysis.

By contrast to the previous example, an unstructured pattern will not be made of layers of sub patterns and will be inspired by nature or depicts a landscape or an every day life scene (Figure 7).

2.2 Basic Setup

The behavior 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, pp 1-2). In the very recent years, various researchers have relied on biological and animal behavior where agents reacts to their environments such as stigmergyc planning (Gerber and Lopez, 2014) and (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 the three dimensions while we store each particle 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.

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

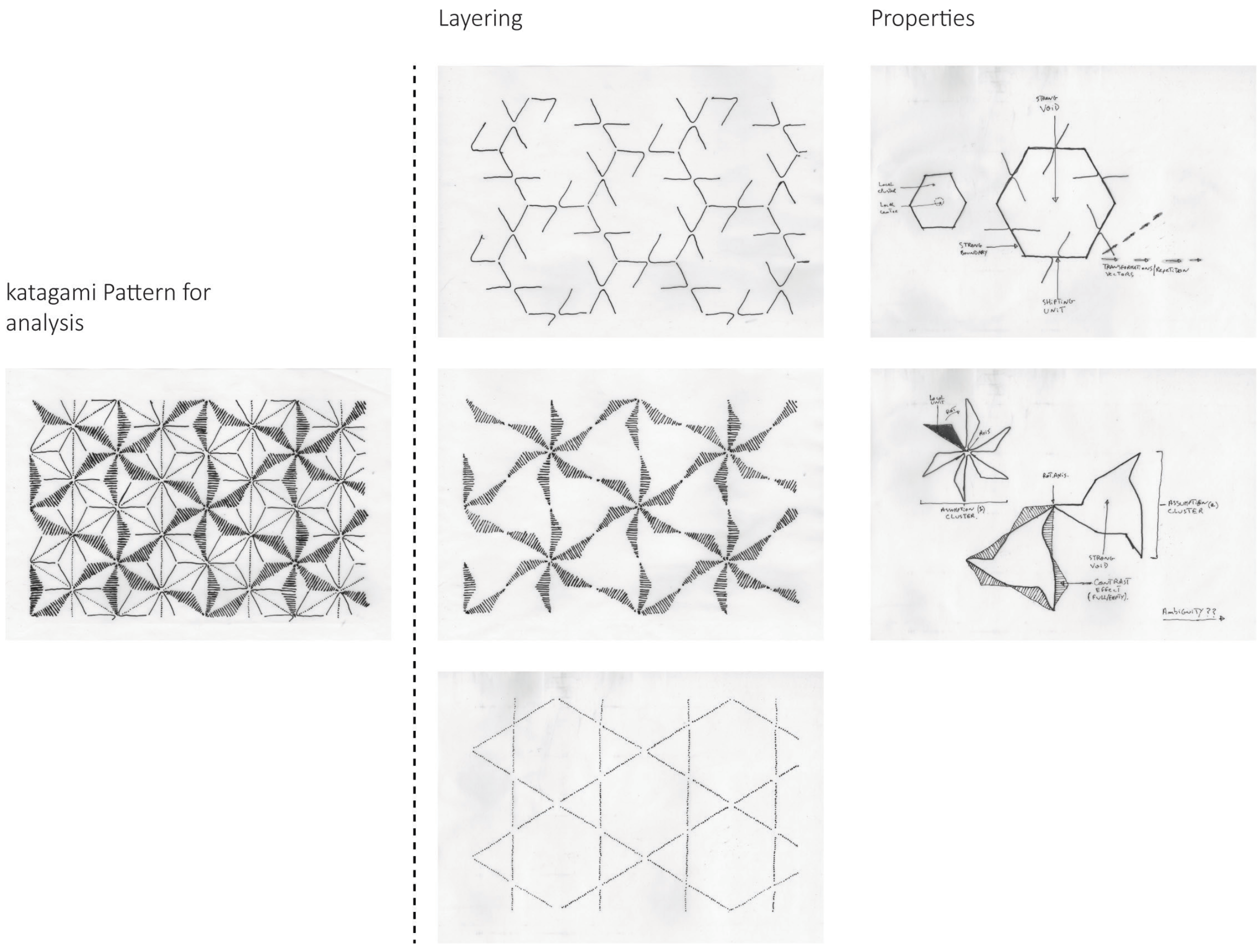

Figure 6.

Ink-Rapidrograph on tracing paper

Figure 7.

Example of two unstructured patterns

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

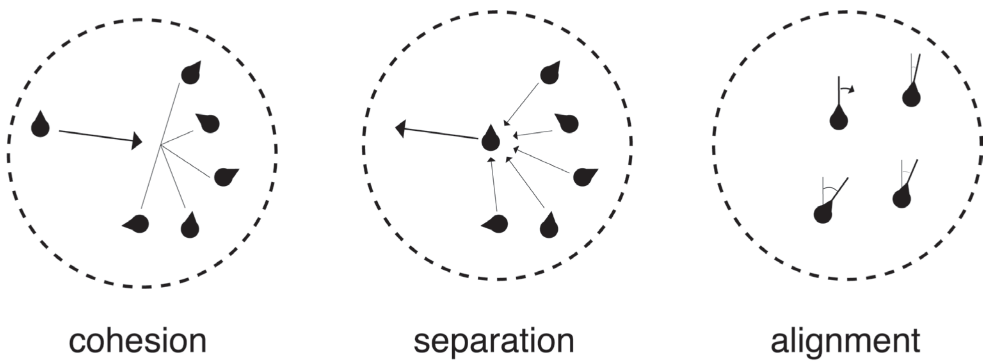

Figure 8.
Flocking behavior explanatory diagram

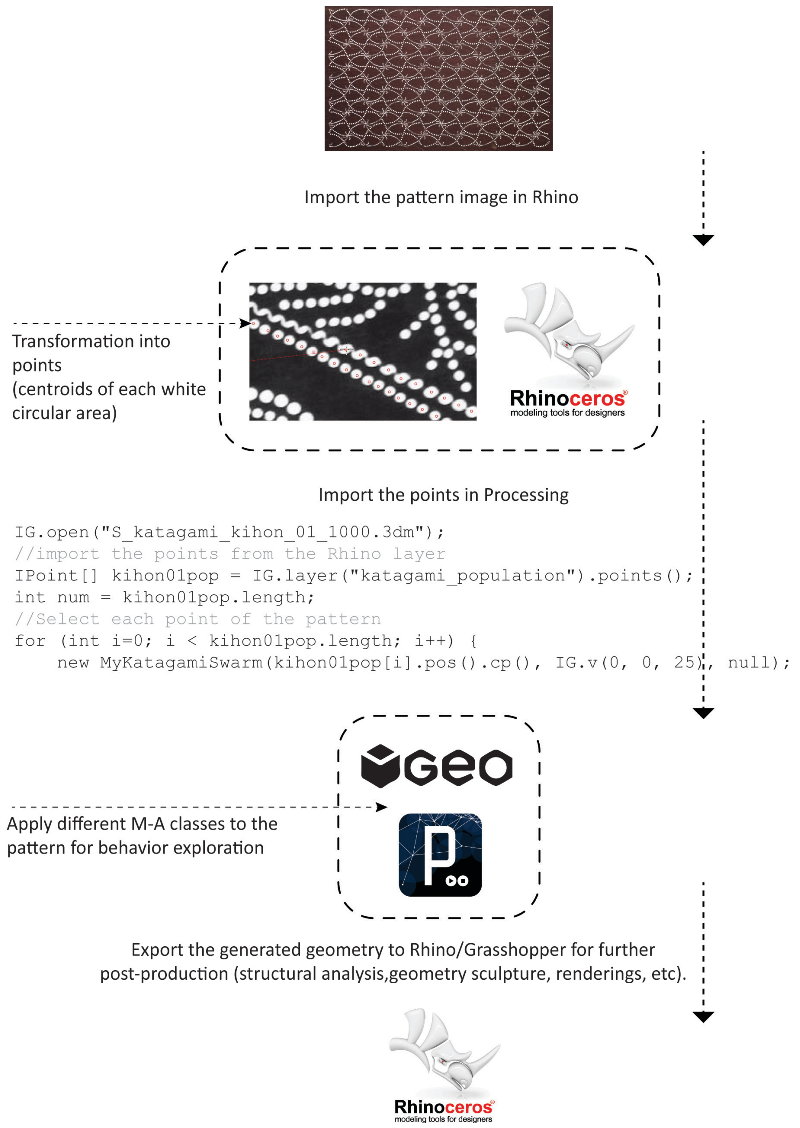

Figure 9.
Katagami pattern's architectural potential exploration methodology

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

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) developed for the Processing environment (Fry and Casey, 2009). Sugihara (2014) developed IGeo in order to fight obscurantism in computation design field and bring more easy and ready to use tools for a larger number of architects and designers by minimizing the coding effort. The website not only offers full training tutorials to get 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 IGeo[3]. The following diagram (Figure 9) explains the workflow for geometry and architectural exploration.

Each Katagami pattern can take from 200 to 8000 points in order to reconstitute it and transform it into particles. They have been manually implemented to keep room for imperfection as an analogy to the Japanese artisans who will never use perfect or regular tool and will appreciate asymmetry and irregularity, a concept contained in the word of "Fukinsei - 不均斉" (Okakura, 1906).

3. Case Studies

In IGeo, the flocking swarm behavior is coded by Sugihara as a Class named "IBoid" that 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:

Input Katagami Pattern	The top down pattern that will evolve through agent based simulation into a non deterministic bottom up spatial formation.
Population	Number of particles that constitutes the pattern.
Number of Frames	Necessary update counts for generating the geometry.
Cohesion Distance	Going to the center of the surrounding agent: agents are considered as neighbors if the distance to the agent is less than the threshold. The center of the agents is calculated by adding their respective position vectors and then divided by their total number.
Cohesion Ratio	The force vector is calculated by taking the difference vector between the agent and the center. The force is adjusted by the Ratio coefficient.
Separation Distance	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.
Separation Ratio	The Ratio coefficient is adjusting the separation force.
Alignment Distance	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.
Alignment Ratio	The amount of the alignment force is readjusted by this ratio.
Initial Direction and Velocity Vector	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.

Table 1. Flocking parameters used in the agent based algorithm

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

Case 01

Population	1000
Number of Frames	150
Cohesion Distance	25
Cohesion Ratio	4
Separation Distance	15
Separation Ratio	3
Alignment Distance	10
Alignment Ratio	2
Initial Direction and Velocity Vector	IG.v(0,0,25)

Case 02

Population	1000
Number of Frames	250
Cohesion Distance	25
Cohesion Ratio	4
Separation Distance	15
Separation Ratio	3
Alignment Distance	10
Alignment Ratio	2
Initial Direction and Velocity Vector	IG.v(0,0,125)

Table 2.
Case 01-02

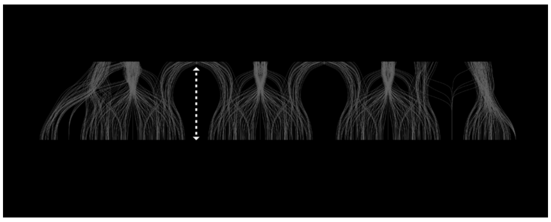

Figure 10-1.
Elevation of the pattern's flocking simulation

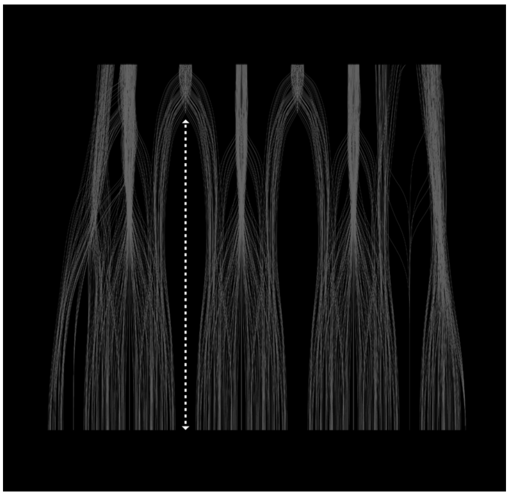

Figure 11-1.
Elevation of the pattern's flocking simulation

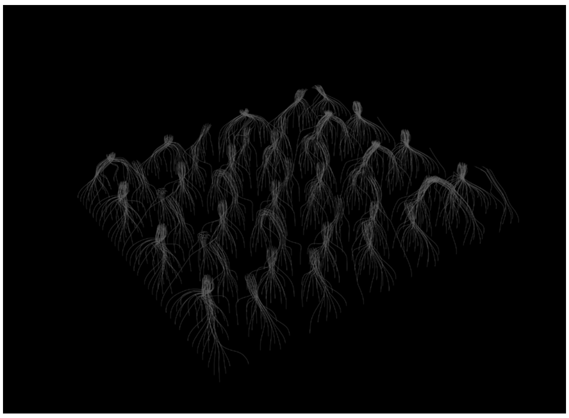

Figure 10-2.
Perspective view of the pattern's flocking simulation

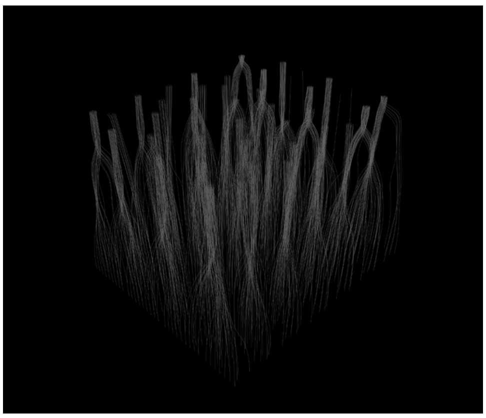

Figure 11-2.
Perspective view of the pattern's flocking simulation

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

For the behavior simulation of the cases 1 and 2, the same pattern has been used. Flocking IBoid class's 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 parameters, the pattern is investigated potentially as a space configured with circulations, enclosures of different heights according to the architectural program needs (see Design Applications chapter).

The cases 03 and 04 investigate potential application as wall surface (see Design Application chapter) 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 frames count.

Case 03

Population	1000
Number of Frames	20
Cohesion Distance	60
Cohesion Ratio	5
Separation Distance	50
Separation Ratio	8
Alignment Distance	40
Alignment Ratio	0.5
Initial Direction and Velocity Vector	(IG.v(IRand.get(20, 40), 0,i%2*100-10).rot(PI*2/num*i+PI/4));)
Branching threshold	10 - 15

Case 04

Population	2500
Number of Frames	5 and 8
Cohesion Distance	50
Cohesion Ratio	4
Separation Distance	40
Separation Ratio	6
Alignment Distance	25
Alignment Ratio	0.5
Initial Direction and Velocity Vector	(IG.v(IRand.get(20, 40), 0, i%2*100-10).rot(PI*2/num*i+PI/4));)
Branching threshold	5 - 10

Table 3.
Case 03-04

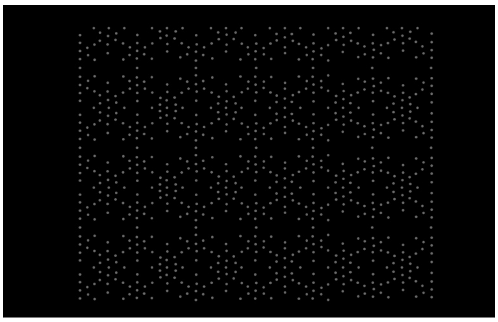

Figure 12-0.
Input pattern

Figure 13-0.
Input pattern

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

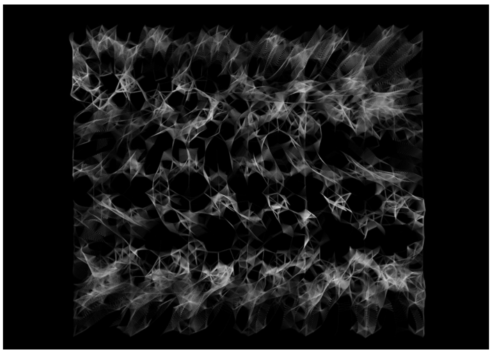

Figure 12-1.
Simulation top view at 20 frames

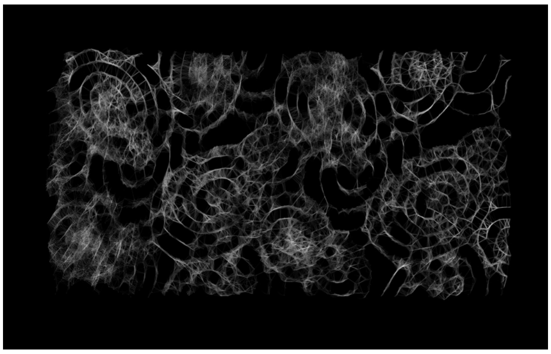

Figure 13-1.
Simulation top view at 8 frames

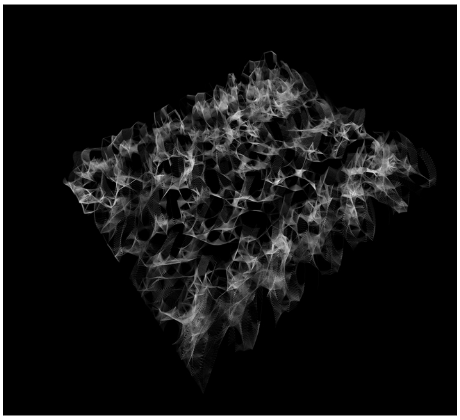

Figure 12-2.
Simulation perspective view at 20 frames

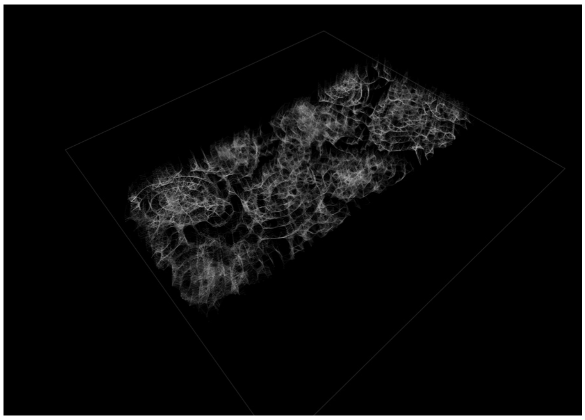

Figure 13-2.
Simulation perspective view at 8 frames

4. 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-photomontages showcase the application on a wall surface representing building facades.

On the other hand, Figures 16 and 17 demonstrate how a Katagami pattern can emerge into a morphology that has the possibility to host circulations, enclosures, open air spaces, galleries and therefore can host diverse activity.

Finally, Figure 18 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 into a unique spatial configuration and therefore each floor can host a different architectural program in the case of a mixed use tower.

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

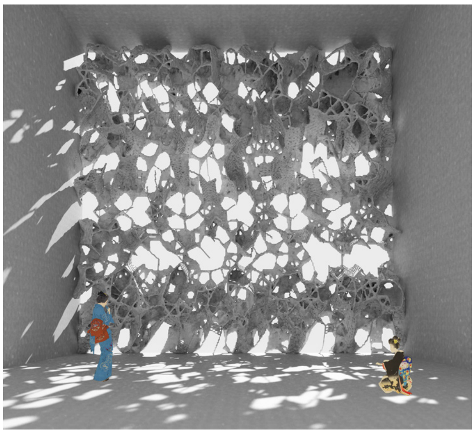

Figure 14.
A Katagami pattern applied to a building facade

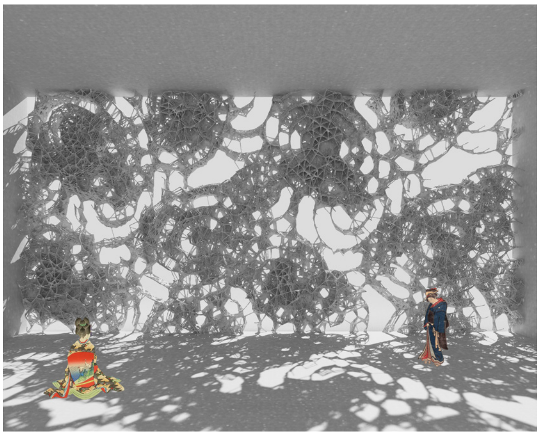

Figure 15.
A Katagami pattern applied to a building facade

Figure 16.
Photomontage of potential user activities within a 3d translated Katagami pattern.

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

Figure 17.
Photomontage of potential user activities within a 3d translated Katagami pattern

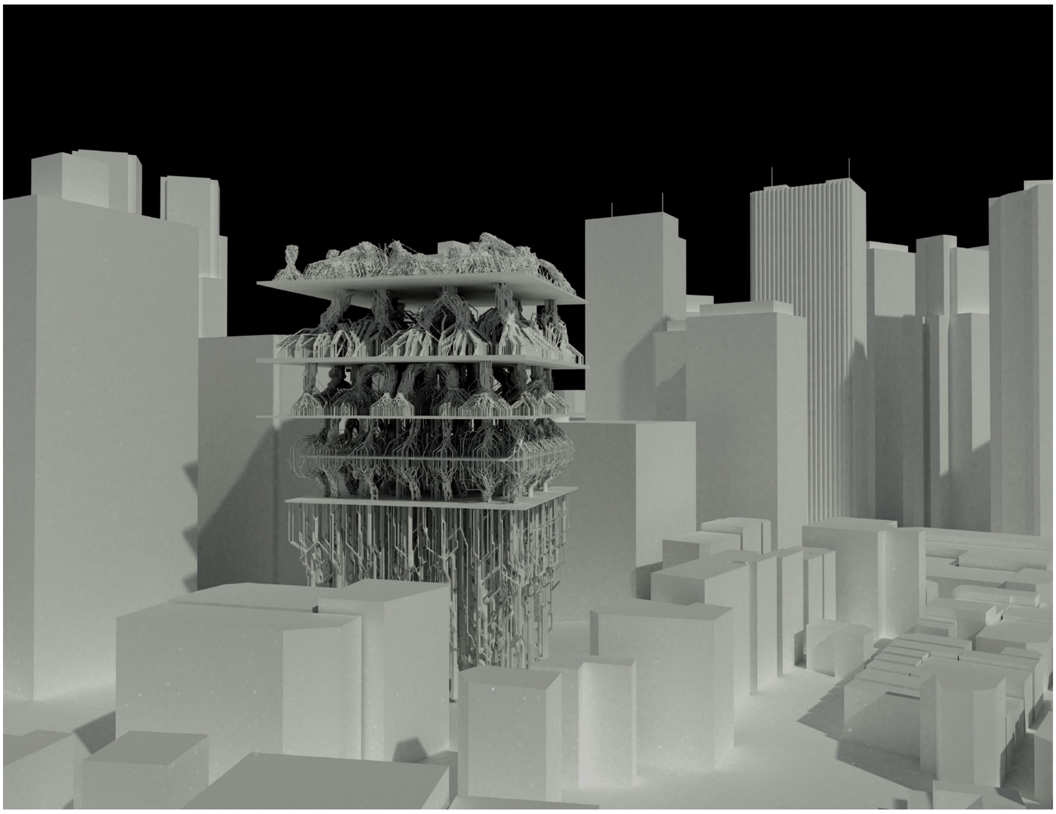

Figure 18.
Mixed-use tower implementing different Katagami morphological configuration at each floor

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

5. Conclusions and future works

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

By contrast to standard architectural process where an architectural planning and design are made following 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). Just after the delivery of the Serpentine Gallery pavilion, Toyo Ito then described Cecil Balmond as someone who used algorithms to produce rules : «He claims that when people try to imagine on their own they run out of ideas very quickly and instead begin to think of conventional spaces. An approach based on algorithms offers greater freedom. It allows you to create unpredictable complexity and hybrid situations».

While we wrongly thought that all patterns behavior can be studied through one same algorithm, up to today's trials showed that each pattern needs its own algorithmic strategy and agent-based model to explore its potential. 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 assumption about structured and unstructured patterns has not shown a satisfactory conclusions. Our future work will tend to study how does the flocking behavior impact the bi-dimensional pattern, and study if the structure or criteria are translated 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 discover 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 18, 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 in the script and launch a new simulation every time. Using control sliders is for now incompatible with 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's layers as a force vector fields.

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

Acknowledgments

The ongoing research presented in this paper is part of doctoral investigations conducted in the architecture department of Tokyo University of The Arts, and is supported by a scholarship funded by the Japanese Ministry of Education (MEXT).

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.

Image credits

Except figures 1, 2, 3, 4 and 7, all images are personal production of the author.

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.

(3) IGeo, 2011. Available at http://igeo.jp/tutorial/32.html.

ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

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ISSN 2309-0103
www.archidoct.net
Vol. 7 (1) / July 2019

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