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Morphological Analysis of Cultural DNA

Tools for Decoding Culture-Embedded Forms

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ISSN 2214-2541 ISSN 2214-255X (electronic)
KAIST Research Series
ISBN 978-981-10-2328-6 ISBN 978-981-10-2329-3 (eBook)
DOI 10.1007/978-981-10-2329-3

Library of Congress Control Number: 2016948274

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #22-06/08 Gateway East, Singapore 189721, Singapore

Preface

Many research works in computational design field implement shape grammars or space syntax for morphological analysis; since my appointment to Graduate School of Culture Technology at KAIST in 2007, I strived to apply the abovementioned scientific and rule-based methodologies to cultural aspects. This effort led me to explore computational design field from the perspectives of a meme, a socio-cultural analogy to genes. While trying to comprehend the concept of a meme from the cultural aspects of design and the notion of a genetic algorithm, the term 'cultural DNA' naturally became a keyword of the attractive new area of research.

A motivational event was when I organized an international workshop in 2009 focusing on the analysis of Korean and Spanish patterns using shape grammars called, 'Visual Exploration of Cultural Style in Design (VECSiD)' and another cross-cultural workshop in 2012 at Sultan Qaboos University, Oman, called the 'Cultural DNA for Islamic Art and Architecture Workshop'. After the great success of the two workshops, our research group started to apply extensively the concept of the 'cultural DNA' and the rigorous methodologies to the domain of the city morphology, industrial design from the perspectives of brand identity, and the bio-inspired designed artifacts. However, is there such a thing as a 'cultural DNA' common throughout various domains? How can the computer-assisted tools and methodologies play a role in probing the cultural DNA? What kinds of mechanisms and what kinds of procedures should they follow for the cultural DNA to be established as a new research field? To discuss the questions, I decided to organize a one-day workshop entitled, "The 1st Cultural DNA Workshop 2015" at KAIST in Daejeon, Korea.

This book consists of some selected papers presented as first drafts at the workshop. The papers include topics from three different perspectives: insightful analysis, intelligent synthesis and cutting edge tools to better understand cultural DNA. It is this diverse perspective toward cultural DNA that makes this book special and suggestive. I expect that the book will be suggestive especially for the designers trying to find the very essence, the archetype, and the building blocks of our environment for the incorporation of social and cultural factors into their designs.

I would like to thank many people who were involved in the preparation of this book, in particular, the program committee of the workshop, Kyung-Hoon Hyun as a main coordinator of the workshop, Deedee Aram Min for helping me with the proofreading and paper works, and Sungeun An for providing prompt assistances to our program committee members. Second, I would like to thank BK21+ Postgraduate Organization for Content Science, the Daejeon International Marketing Enterprise and International Relations Team from KAIST for funding. Without these supporters, organizing the workshop would not have been possible. Third, I want to show gratitude to the all contributed authors who are all happy to travel overseas and share their works.

I hope the series of the cultural DNA books continue to provide useful insights and thoughts.

Daejeon, Republic of Korea Ji-Hyun Lee
September 2016

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Part I
Theories for Cultural DNA Research

Chapter 1
From Human Inspired Design to Human Based Design

Mathew Schwartz

Abstract From the invention of concrete to the yield point of steel, it is common knowledge that building design has been dictated in great part by the knowledge and capabilities of the available materials. Culture has also found a place in design, having strong influence of colors, space, and shape. Perhaps less discussed is the influence on building design from the cultural and scientific understanding of the human. As the methods of human simulation develop, so too does the understanding of the human. In this regard, computation is bringing yet another change in the influence of the human form on design. This paper provides a perspective of key historical points on the human form role in architecture and discusses the new role the human form plays with, such as the advancements of computation and simulation in regards to the usage of computational techniques for form finding. This discussion brings about the turning point for when design is inspired by humans to when it is based on humans.

1.1 Overview

While architecture is almost always dealing with creating a space for human use, the inclusion of the human form in the design process has not always been apparent. Instead, prescriptive measurements for building codes based on human needs and manufacturing standards have dictated much of the human related aspects. It is with these standards that much of the computational design field works around, developing genetic algorithms [1] or form finding tools [2] that explore new shapes and aesthetics brought on by a variety of influences only recently possible through the advances in technology. In the physical space, industrial robotics has shown to be an important aspect in pushing the physical limits of building design and construction with conferences such as the biennial RobArch appearing in 2012 [3].

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_1

With these advancements, the human form becomes less prominent in the architectural design process; a situation this paper discusses need not be the case.

Human form as an integral part of architectural design has been documented as early as 1 BCE [4]. However, this aspect of the human in design is not thought of as often today in terms of ergonomics but instead, as the human form in and of itself. Essentially, the view of the human proportion had shaped the motivations of aesthetic choices for which to base architecture. Over time, an important progression on the relationship between the human form and architecture developed, including the mapping and understanding of the human genome. Through understanding this progression, we are able to see the potential for another shift in which the human becomes a vital aspect to the development of architectural design and formation, in which architecture is not only inspired by, but benefits, the human. This shift has further implications within the architectural practice such that prescriptive building codes designed to set a minimum standard can instead be replaced with performative building codes in which the architect achieves a specific performative measure in regards to humans and accessibility.

This paper frames the usage of societal and genetic understandings for design in a historical context belonging to a lineage of human based design. A historical overview of the key points in which design has been greatly influenced by a new cultural or societal understanding of the human is presented. This is followed by a short discussion on the current state of human related design. The paper is concluded with a discussion in which the way newer understandings of the human, and that which are still not yet fully understood, will provide more opportunities for computational design.

1.2 Historical Context

1.2.1 Vitruvian Design

In 1 BCE, Marcus Vitruvius laid the groundwork of a significant stance in which architecture is modeled from the human. His work entitled De Architectura was broken into 10 books dealing with various aspects of architecture. The first chapter of the third book states,

> Without symmetry and proportions there can be no principles in the design of any temple; that is, if there is no precise relation between its members, as in the case of those of a well shaped man. [4]

This viewpoint of the human shape as an integral aspect of the design process was a critical aspect of the religious work that was to follow in the renaissance. Vitruvius continued to lay the groundwork of what Leonardo da Vinci would later make infamous through his drawing by describing the proportional relationship of man,

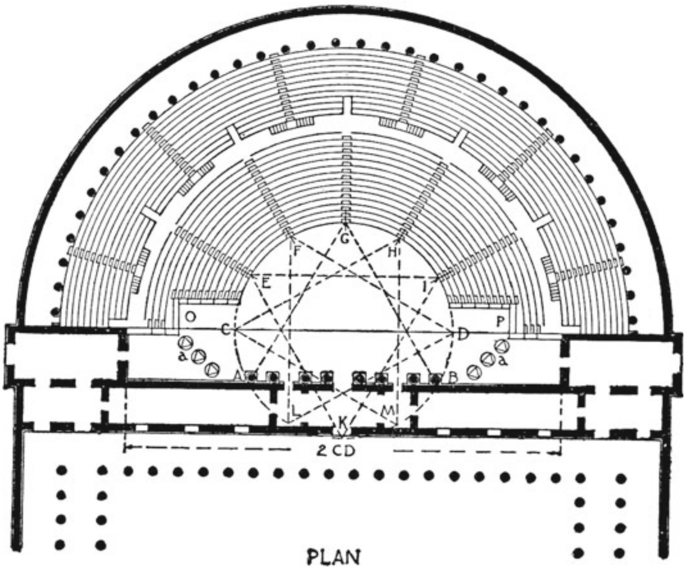

Fig. 1.1 The Greek theater according to Vitruvius. The design is based on the human proportions described in the books, with *circle* and *squares* dictating the form

> For if a man can be placed flat on his back, with his hands and feet extended, and a pair of compasses centered at his navel… to the outstretched arms, the breadth will be found to be the same as the height, as in the case of plane surfaces which are completely square. [4]

This explanation of the human form is brought on by the perspective of human proportion, and it is this proportion that drives the design. Leon Battista Alberti De re Aedificatoria outlines nine geometries that fall in line with the circle the Vitruvian man inscribes. While using the circle as a base, the proposed geometries are based off this circle with varying angles of the geometry based on the radius of the circle in which they inscribe. [5]. Given the amount of geometric derivation from the human body, it is possible to view these proportional descriptions of the human as an early sign of shape ontology. This becomes increasingly apparent by not only discussing the forms of the Vitruvian man, but in the architecture resulting from it, as shown in Fig. 1.1.

1.2.2 Organic Design

In the early 1900s, Le Corbusier began to create a universal measurement diagram. His work on the Modulor attempted to set a standard for design in general. Le Corbusier, however, was not necessarily looking at a geometric model that would constrain the designer entirely. Instead, he was looking at the modernization of manufacturing and its widespread reach. With the basis in proportion, Le Corbusier

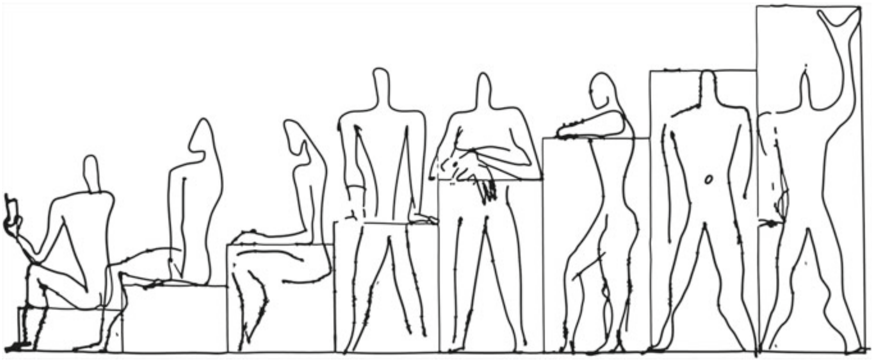

Fig. 1.2 A redrawn representation of the Modulor design methods of varying reference points for the human. While these proportions seem reasonable, the variety of humans render this specific variation useless and instead becomes inspired by human proportions, rather than cater to humans

began to create a system in which measurements could unify the different unit systems. Le Corbusier's goal was to create

> …a common measure capable of ordering the dimensions of that which contains and that which is contained… [6]

Similar to Vitruvius, Le Corbusier theory of form and shape was directly applied to the proportions used in design. While seemingly ergonomic, the underlying theme in Fig. 1.2 shows a forced relationship between the desired proportions of a human (of only one human type) and design.

The use of proportions and ergonomic representations gave the designer freedom to work within a constraint, and in doing so, focusing on the form rather than trying to understand how the form would function. This led to a different school of thought: the belief that the use of these constraints limited the natural flow of a design, in which Hugo Haring championed.

Hugo Haring argues that all forms are based on an internal path, as

> even crystals and geometrically-shaped [forms], which allows each to develop according to its own inner plan. [7]

This is contradictory to the work of the Renaissance in which the total form is the representation of the human. Haring proposes,

> If a man set out without knowledge of planning concepts but in identification with nature and thus nature-like, he will always act creatively. [7]

The relationship between a plan and nature draws back to the problem Le Corbusier attempted to resolve: the emergence of the meter. While a design based on the Anglo-Saxon measurement of foot and inch were derived by the person directly, the meter is an abstract representation of distance. Haring makes the case that the creation of a diagrammed system of measurements in its very nature hinders the natural flow of a design. He states that the men who act creatively through natural understandings are

> in contrast with the men from geometric cultures, who, obsessed with order and limited in their planning concepts, could work fruitfully on so long as their creative effort was poured into the forms of geometry, subordinated to its laws and rules, and so constrained and destroyed… [7]

These two perspectives on the role of constraints and human based measurements introduce a struggle in design to balance the predefined rules and creativity. In one aspect, the use of computation and algorithms for deriving shapes in design is possible through the control variables given in the beginning. This control is what allows for exploration in form (as it provides a base starting point), yet at the same time, is the reason in which computational searching is needed, as it has distanced the designer from the natural understandings of the function. There is no doubt that computation can benefit the design and form finding process, yet the area in which computation is needed is currently ambiguous. In the assumption that the human belongs to a single space and ability, computation is able to assist in form finding with the human as the control. However, the human is a complex system in which a wide range of abilities and disabilities exist, neither of which is currently understood at the functioning level enough to create a baseline or control variable. In other words, while Vitruvian and Corbusier show an understanding of the human in terms of proportions, they did not truly understand the human in terms of anatomy and ergonomics, and as such, their methods of form finding and design decisions bear resemblance if taken at a larger scale of understanding in the variety and ability of humans.

1.2.3 Performance Versus Prescriptive

The most recent major human-based design movement is Universal Design (UD). While there are many alternative names, the concept remains the same. Universal Design can be understood through its seven principles [8]: (1) Flexibility in use; (2) Tolerance for error; (3) Low physical effort; (4) Simple and intuitive; (5) Equitable; (6) Perceptible information; and (7) Size and space for use.

The Universal Design principles are not specific to disabilities. The principles are meant to help all people through design. More importantly, UD is relevant to all people since everybody is different and everybody ages. As fast as people grow out of clothes, they also grow out of certain designs and into new ones. People also vary based on ethnicity. For example, the leg length of the average US black male is 2 longer than the average Japanese male [9]. Although 2 of leg length while standing may not matter, a chair designed for a US black male could result in a Japanese male not being able to place his feet on the ground. A more extreme example, a customized design for an average Northern Nilote would be far too big for a Pigmie, as their averages are different by 15.4 [10].

In contrast with the previous design platforms, UD is segmented into functionality, independent of a specific person. By targeting the principles to function, UD remains open to new understandings of the human body. This openness has helped break down discrimination against people with disabilities, and has done so without idealizing a specific situation as both Vitruvius and Le Corbusier had. In terms of form finding, UD acts as a principal and not a set of rules, as with the proportions previously described. These principals can then be thought of as the equations to be solved for, or in a way, minimized for error. However, the variables are currently not yet fully understood.

While UD is based on the principal of performance related standards, societal regulations have often dictated prescriptive codes, and although well intentioned, have not always fostered an atmosphere for finding creative solutions. As with one case in point, in 1990 the creation of the American with Disabilities Act (ADA) [11] made architects and employers legally responsible for accessibility. Outlined in a series of legal provisions and diagrams by the Department of Justice, the ADA set a new standard requiring equal access for people with disabilities. Unlike Universal Design, the ADA needed to consist of specific examples in order to insure a suitable implementation (Fig. 1.3). These examples are considered by the ADA as the minimum requirements. In an indirect way, these requirements became the control variables of form finding. At the same time, the requirements dismissed the need to understand the human ability and disability by quantifying it in specific examples and numbers such as the distance and length of a hand rail to be installed in a handicap accessible bathroom. Accordingly, the computational design approach to the bathroom becomes an equation using the measurements as the control instead of the ability to access the toilet as the error to minimize.

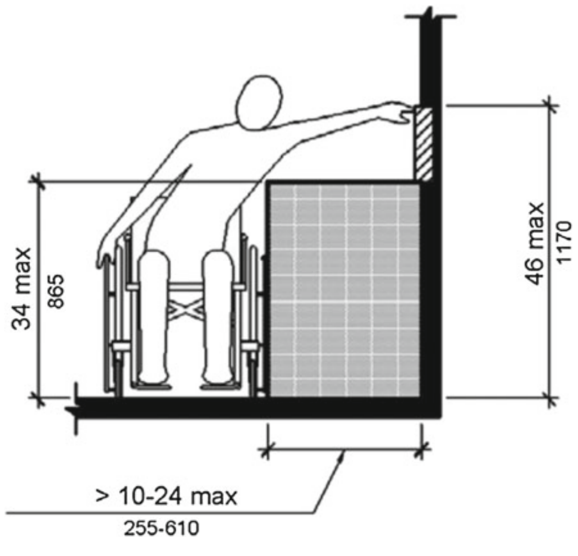

Fig. 1.3 Excerpt diagram from the ADA showing architects why specific heights and widths are required. However, this only shows one type of wheelchair, with one type of person, and without knowledge of why the person is in the wheelchair. All of these items must be known to provide the best performative design, rather than this current prescriptive design (http://www.ada.gov/regs2010/2010ADAStandards/2010ADAStandards_prt.pdf)

1.3 Current

In the current state, cultural views of understanding human biology can be seen in the architectural field today. By understanding the human genome, society is fascinated by the human lineage and evolution. The idea of genetic mapping and tracing the roots of the human species has been one the most significant discoveries of the last century, with multiple Nobel Prizes being awarded for work in this area [12]. Architectural work in form finding has clearly taken hold of the current state of biological understandings. The use of Genetic Algorithms is constantly a topic in conferences, and has been developed into large plugins for design tools [13]. Yet again, the understanding of the human form has influenced the methods in which architecture creates. Just as Vitruvian and Corbusier before, the current use of the gene in architecture is not out of a true understanding of the human gene, but instead as a tool, or baseline that has been dictated by the understanding of the human itself; a mass defined by the gene.

Likewise, the understanding of the human as a resulting product of genetic lineage is as meaningful to the actual human experience of architectural space as the idea of divine proportions of the human. Yet, before a fully developed crowd simulator or ergonomics analysis program was developed, there was a genetic algorithm for form finding. This seems to be the current downfall for informed design. As the architecture discipline is embracing computation and scientific research, it is showing little sign of true interdisciplinary work that benefits future users of architectural space. While implementing current understandings of human movement into shape grammars, architecture is left waiting for the current to become the past and hoping others will develop meaningful research that can one day be used by architects and designers. Unfortunately, it is not the goal of biomechanics to develop models and understanding of how human factors relate to architectural spaces, and more practically, it is rare for someone dedicated to biomechanics to even understand the problems and desires of the architectural discipline.

Similarly, Building Information Modeling (BIM) has shown potential to solve many of the workflow problems in the actual implementation of architecture, but is largely outside the conceptual design process. Although the area of BIM has grown to include numerous aspects of building and construction in a manageable way, it still lacks any sign of humans themselves. The same holds true for nearly all three dimensional design programs. In times when architects do want to include humans in the design process, a custom framework is usually created, most often one relying heavily on game engines or extensions to the design program [14]. While these extensions embrace the state-of-the-art computational practices, there is rarely any true collaboration toward the biomechanical research needed to truly make these programs effective or meaningful for the end user.

Past research has alluded to the use of human motion as inspiration for shape grammars [15]. However, the work acknowledges the lack of current knowledge in human motion and the ability to truly build a computational framework to simulate the motions. Outside of architecture, a notation for human motion has been developed [16], which resembles the motion aspect of [15]. The idea of deconstructing human motion to a rule based system is not unique to architecture nor dance. Recent developments in robotics research have shown the concept of Synergies effective in translating the complex mechanics of the human hand into a subset of motions for a robot [17]. By not only taking inspiration from this type of work, but actively pursuing collaborations in which research topics such as Synergy mapping can be applied to design and architectural practice, works that leverage computation of human motion can thrive.

It is important to note the explicit difference in the use of Synergies as a mathematical tool to aid in complex biomechanical simulation, and the use of a motion database [18] which demonstrates an early implementation of motion envelopes in which multiple live motion studies were conducted with video recording. By overlapping these studies, such as a person standing up from a chair, a layered zone of the required space can be created. Implementing numerous studies such as this can create a database of useful information on how humans use the built environment, and what is required of it. However, even with the advent of motion capture technology, the usefulness of this work is limited to predefined known motions. For example, Fig. 1.4 shows different resolutions of a person sitting in a chair from motion capture. While these three-dimensional forms are useful for a designer to understand the general shape of the motion, it is highly localized and cannot be extrapolated to different physical abilities or even other chairs.

Fig. 1.4 Four densities of the human form sitting in a chair from motion capture data. The model is built from laser scan data of the motion capture subject

1.4 Future

To move beyond the idea of a single solution mechanical value as the early laws regarding disabilities created, architecture can utilize the principles of universal design with the human again as a creative channel. As more research is conducted on the way the human body works, new understandings of the human, as a structure, develop. In time, there will be enough information on how the human mixes chemical and mechanical systems to create a cohesive and efficient system. It is this fusion of systems that can inspire computational architecture to understand the building as more than a sum of its parts.

As the human grows and naturally develops new functions and abilities such as crawling, walking, then running, the initial developments of the integrated systems continue to dictate future performance. In other words, instead of the form finding process and computational design step being the start point of the architectural process, they become an integrated process that continues throughout the building lifetime, a step that has begun with building lifecycle management with BIM.

The reason this paper argues this is a possible future is due to the lack of knowledge about these systems in current society. While it is generally understood that a symbiotic relationship exists in this process, it is still unknown to what degree, and how, it exists. The brain has remained elusive as to its method of storing and computing information and the nervous system is still not fully understood, as work into spinal cord injuries shows. In fact, many fields of research have dedicated years to solving these very questions. The opportunity, then, is for architecture to become an explorer into these systems.

The two aspects required for architecture to truly adopt this type of workflow are in design as well as construction. Both of these aspects must evolve enough to benefit from each other. When robotic fabrication becomes the norm, informed design decisions on the human must exist to avoid arbitrary design due to a *'because we can'* attitude. Therefore, at the same rate that architecture is embracing customized and automated fabrication, it must too embrace the pursuit of biomechanics and human factors.

Research into human factors has shown up in the architectural field has a few times [19, 20], yet is still a small topic. By architecture practitioners beginning to move into deeply collaborative labs, integrating chemistry, biology, mechanics, etc., understanding the building as an integrated system that will grow and develop over its lifespan will also lead to smart buildings in which users can understand more about the space around them. In the near future, before a unified system of understanding and control of both humans and buildings, multiple human scale ergonomics issues can be brought to a building scale, creating a multiple equation situation. Then, the question begins as to what solutions are to be solved from in priority, which is the role of the architect along with the client in regards to the users and usage of the building. When these types of solutions are being solved, the building begins to truly be smart, not just through electronics, but through the design process itself, and the technology as a result of biomechanical or anthropological understanding. This provides the opportunity for building ratings, just as energy efficiency is rated, the ergonomics of the building too can be rated. These ratings can include the efficiency of energy to go to not just emergency exits, but to the bathroom, or rates of eye glare caused by lighting, or the difficulty in opening doors based on the newton force required for various people.

Although the past has shown the abstraction of current understandings of the human into architectural practice have not been associated with a better experience for the user of the space, it is not to say that it has been useless. There have been clear benefits, and this work has been to contextualize the repeated shifts in where the motivation for design comes from a regard to the human form. However, if architecture can act as a field for exploration and research on the human as well as gain inspiration from the human, architectural space can thrive in both creativity and use.

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Chapter 2
A Short Exploratory Essay on the Term 'Cultural DNA' from the Perspectives of Physical and Virtual Architecture

Deedee Aram Min and Ji-Hyun Lee

Abstract Today, information sharing is faster than ever. From this, we face fragmentation of information about ourselves in virtual spaces such as in online communication, social network, and storage services. A problem we face today is that because the locations of our behavior spaces are integrated that sometimes we get lost in our own virtual behavior spaces. In this exploratory paper, in order to find ways to ameliorate the segmentation of behavior spaces, we attempt to identify how virtual spaces can become more manageable at a human scale by making analogies between physical and virtual architectural components. To investigate what kind of components should be considered in physical space and how spaces have evolved in different countries to the modern times, and onto virtual spaces, we apply the concept of cultural DNA into account. We first clarify what cultural DNA is by organizing the ideas of many scholars; make our own definition of cultural DNA in design field; apply the definition to physical architecture, and finally end with making analogies between the physical and virtual architecture.

2.1 Introduction

With fast information transmission occurring today, we face fragmentation of information about ourselves in virtual spaces such as in online communication, social network, and storage services. These information transmission platforms can be considered as one of a behavior space where social interactions and transmissions of information occur. A problem we face today is that because the locations of our behavior spaces are integrated that sometimes we get lost in our own virtual behavior spaces. For instance, people have accounts in Google+, Facebook, Instagram, Twitter, Pinterest, Kakaotalk and WhatsApp mostly for information sharing and socializing.

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_2

With so many behavior spaces, sometimes people forget where they have posted their picture; where they got the information; and in effect, they have difficult times retrieving the information when wanted. So far, one of the ways to deal with fragmenting behavior spaces was to integrate all services where information in Google+ synchronizes with Pinterest, and the information in Instagram synchronizes with Facebook. However, in this paper, we take a rather different approach. Instead of making the services all share the information about the users which sometimes gets out of control because the spread of information is fast and not stoppable, we suggest dividing up behavior spaces clarifying what sort of information is shared in what sort of spaces given that we have done so in human history.

Before the online communication and social network services in virtual spaces, physical spaces—and still today, just not as much—act as a behavior space. In terms of social spaces in buildings, people generally gather and communicate in rooms that are large in area, are located in the center of the buildings, and sometimes, have high roofs. In terms of private spaces in buildings, people generally talk in small groups or take care of personal business in rooms that are small in area, and are located at the edges of the buildings. One of the reasons why the behavior spaces in physical architecture are easier to identify and to deal with is because the spaces are visibly separated where the boundaries between spaces are clear. In other words, the function and the form allow people to identify how to occupy the space and what kind of information to share. Without such clear boundaries and clear coupling between form and function in our virtual behavior spaces, the users of the net will continue to face fragmentation of themselves in numerous spaces.

In this exploratory paper, in order to find ways to ameliorate the segmentation of behavior spaces, we attempt to identify how virtual spaces can become more manageable at human scale by making analogies between physical and virtual architectural components. To investigate what kind of components should be considered in physical space and how spaces have evolved in different countries to the modern times, and onto virtual spaces, we took the concept of cultural DNA into account. Currently, however, the concept of cultural DNA in the design field is yet to be concretized, although the notion has been clarified in the psychological field. In this paper, we clarify what cultural DNA is by organizing the ideas of many scholars; make our own definition of cultural DNA in design field; apply the definition to physical architecture; and finally end with making analogies between the physical and virtual architecture.

2.2 Literature Reviews

2.2.1 Cultural DNA

There is a need to clarify what cultural DNA is. When cultural DNA is explored, many different keywords appear in a non-hierarchical manner making it difficult to understand what it exactly is, as shown in Fig. 2.1.

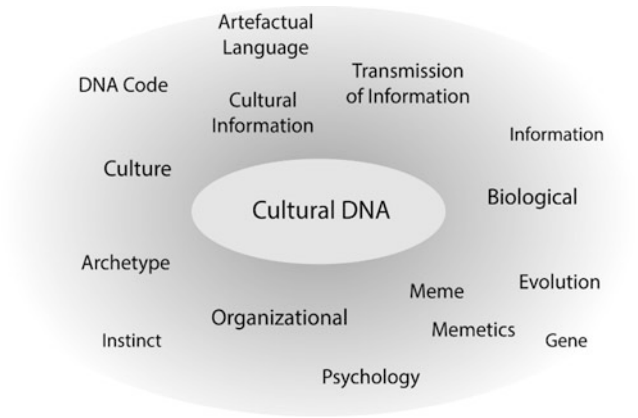

Fig. 2.1 Cloud of keywords related to 'Cultural DNA'

When the literatures are reviewed, the term, cultural DNA is perceived from two different fields: organizational and biological. The exact term, 'cultural DNA' has actually been identified from the organizational point of view. It begins with a strong foundation of in-depth studies of culture by one of a renowned social psychologist, Geert Hofstede. His research offers a chance to learn about cultural differences and their impact in our society. In his book, Cultural Consequences: Comparing Values, Behaviors, Institutions, and Organizations Across Nations (2001), Hofstede presents a research work where he collected the data from a multinational organization, IBM in 72 countries by surveying twice around 1968 and 1972 producing more than 116,000 questionnaires. From this research, he identifies five dimensions or factors—power distance, uncertainty avoidance, and individualism, and masculinity/femininity, long-term and short-term orientation—that affect human thinking feeling, and acting, as well as organizations and institutions [1]. When looking at the five dimensions, it is evident that research is from the perspectives of organizational management. Following this research line, very recently, a book entitled, Cultural DNA: The Psychology of Globalization (2015) by Gurnek Bains has been published. In this book, the author makes a point that the idea of DNA in his terms comes from work in the area of an organizational culture. Under this stance, the author applies this type of DNA analysis to eight of the world's cultures which he lists as Subsaharan Africa, India, the Middle East, China, Europe, North America, Latin America, and Australia. Bains mainly uses primary data accumulated over 25 years of working as CEO for the psychological consultancy YSC, which has 20 offices globally covering the eight regions mentioned above. The consulting company also systematically assessed 30,000 people working in a range of organizations across the world for forming a hypothesis about cultural differences. The main reason for his research is to find out why such differences exist in the first place. There have been a number of researches written about cultural differences, but why. Overall, he covers cultural differences in the psychology of people in the regions from an organization and business point of view [2]. As can be seen, extensive researches that investigate what culture is and what causes cultural differences are from the psychological and sociology field.

From the biological field, by making an analogy with genes in genetics, an evolutionary biologist, Richard Dawkins (1976) introduced a term, meme as a unit that carries the cultural information copied from person to person by imitation [3]. From this idea, memetics community was formed where the concept of a meme has been used in fields such as evolutionary theory, religions, and myths, and been explored for its concretization [4]. For example, a psychologist and memeticist, Blackmore (2001) claims that the theory of memes plays a more fundamental role in understanding how and why human brains evolved differently from other species. The central argument that Blackmore makes is that memes "appeared in human evolution when our ancestors became capable of imitation" and "from this time on two replicators, meme and genes, coevolved" making humans produce and understand language, songs, dances, and other cultural activities [4]. However, according to Edmonds (2005), the study of memetics was a "short-lived fad" where too much abstraction and over ambition caused obscuring of fields [5]. Edmonds illustrates the fad of memetics in academics using a trend graph shown in Fig. 2.2.

As illustrated, the number of papers mentioning 'memetic' increases and decreases at fast rates with the year 2002 as its peak. However, the central idea of memetics that cultural information is copied from one person to another evolving throughout human civilization also referred to as the cultural evolution is becoming more concrete. As Distin (2011) mentions, "although a burgeoning optimism about cultural evolution is

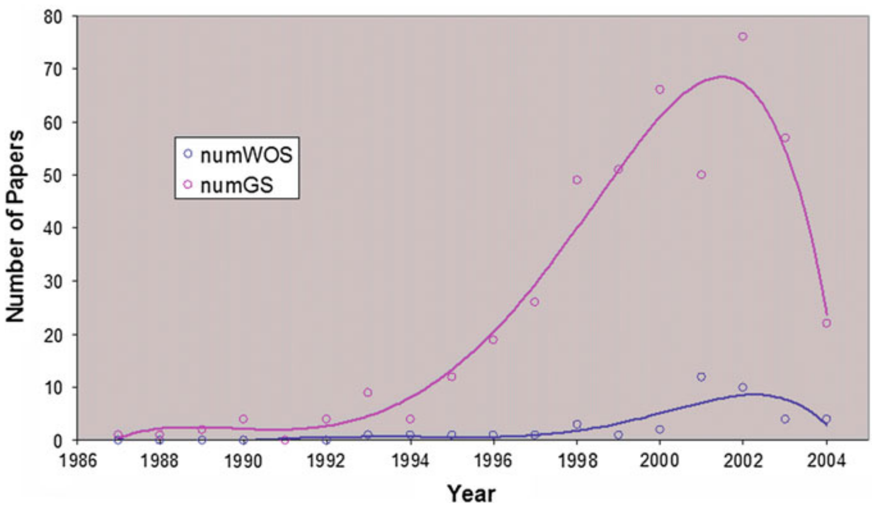

Fig. 2.2 Number of papers mentioning "memetic*" (but not "memetic algorithm*") each year according to Google Scholar (numGS, *pink circles*) and on the ISI's citation index (numWOS, *blue circles*). *Lines* are 6th degree fitted polynomial trend lines of the respected series (Image taken from [5])

detectable across a variety of disciplines, memetics has been widely criticized and perhaps even more widely misapplied to a variety of irrelevant subjects" [6]. In fact, Distin explicitly mentions in her book, Cultural Evolution (2011) that she didn't use the word 'memetics' throughout the book because there are people who are in the habit of dismissing works with the word 'memetics'. In the book, Kate Distin introduces the concept of artefactual languages which are artifacts made by humans such as writings and musical notions. Her basic idea is that these languages help humans to receive and transmit cultural information thus the evolving of the culture. She also suggests how understanding such artefactual languages help scholars understand the origin and development of human culture [6].

In this paper, Kate Distin's concept of cultural evolution is adapted to define what cultural DNA is. If artefactual languages carry the cultural information evolving as humans receive and transmit the information, and if the complete forms of artefactual representations are composed of units or components, then the notion of DNA in the term 'cultural DNA' can equal the units or components of these artifacts.

2.2.2 Architecture as Artefactual Language

From a very abstract notion of the meme, and to a more concretized definition of how cultural information copies from one person to another through artifacts, we can start to identify the cultural DNA of physical spaces by considering architecture or buildings as the complete forms of artefactual representation. In fact, theoretically and philosophically, buildings are artefactual symbols that store and manipulate the excessive cultural information of human dwelling.

According to Heidegger (1971), as human beings, we cannot fail to dwell because the essential existential core of human being-in-the-world is to dwell. And the term dwell, means to build. Building environment is crucial because it supports and reflects a person's and group's way of being-in-the-world. This suggests that buildings are a symbol of human's innate quality to existing as well as a symbol of individuals and society's culture [7]. In other words, buildings or architecture can be described as a footprint of cultural value acting as an artefactual language. The most prominent reference for this concept that buildings embed cultural values is *House Form and Culture* (1969) by Amos Rapoport. The forms of houses are determined not only through climatic reasons but also due to the availability of the materials and the construction technologies, the character of the site, need for protection, economics, religion, and also the socio-cultural reasons. Rapoport stresses the socio-cultural aspect of dwelling form over physical and by 'socio-cultural', Rapoport adapts Max Sorre's term, *genre de vie*, which includes all the cultural, spiritual, material, and social aspects. He mentions that "houses and settlements are the physical expressions of the *genre de vie*, and this constitutes their symbolic nature [8].

2.2.3 Archetypes

With the architecture as artefactual language, we need to find out the common units or the components of architecture because they will serve as the starting point of behavior spaces. This is why archetypes are investigated. In this section, the idea of an archetype is explored from various perspectives.

The concept of an archetype is one of the most important, if not the central concept of analytical psychology. In fact, the origin of archetypal hypothesis dates back as far as Plato in his work, Theory of Forms. He suggests that pure mental forms are imprinted in the soul before people are born into the world. Archetype indicates the collective sense of characteristics that are fundamental to things [9]. In modern times, Carl Jung is renowned for advancing the concept of psychological archetypes. According to his definition, archetypes are innate and are the collective unconsciousness. From a most religious different perspective, Eliade (2003) suggests that an object or an act becomes real only if it repeats through imitation. Anything that lack repetition or participation lacks reality. In other words, human feel real when we repeat the imitation of archetypes [10].

In one of the recent work by Roesler (2012) from the field of analogical psychology, it summarizes some of the attempts to reformulate the concept of the archetype [11]. According to the author, so far, the most sophisticated reformulation of the archetypes concept is Jean Knox's (2001) theory of image schemas. Image schemas also known as archetypes are a representation of features formulated when humans interact and organize the environment [12]. In Roesler (2012)'s terms, the transmission of archetypes can only by theorized by means of culture and socialization, not genetic.

A coherent use of the concept is based on an understanding of archetypes as universal patterns producing meaning and guiding development. While Jung referred to archetypes as an inheritance via the transmission of genes like a blueprint for development, the archetypes referred to by researches are generally complex symbolical patterns as we find them in myths, fairy tales, dreams, etc.

Combining the works of [10–12], we can narrow down that archetype is:

- imitated by people in repetition for their sense of reality/existence [10]
- transmitted only by means of cultural and socialization [11]
- an image schema which is a representation of features in the environment crucial to survival [12].

Conclusively, archetypes are features in the environment that are repetitively imitated throughout human history transmitted through cultural and social acts. From this, more complex representations are built. If archetypes are defined as above, we can say that we need to find features in the environment that are repetitively imitated throughout human existence transmitted through cultural and social acts in order to discover the archetypes of architecture.

2.2.4 Archetypes in Architecture

According to Thiis-Evensen, the term, archetype was first used systematically within the architectural theory by Paul Zucker in his book, Town and Square from 1960 [13]. He described five square archetypes, using specific examples to show how history chooses that form what is appropriate and how these typologies, owing to dissimilar functional characteristics, vary from antiquity into the present day. The theory of archetypes was further developed in the 1960s, with the Aldo Rossi's book The Architecture of the City from 1982 [14]. During 1970s, the theory of archetypes has increasingly been utilized as a basis for architectural practice. One of the goals for defining archetypes in architecture was to show that there is a common language of form which we can immediately understand, regardless of individual or culture [15].

As one of the example, the theory of archetype has also been investigated in the architectural fields that investigate the repeating features in architecture [16]. As a student of Norberg-Schulz, one of the existentialists, Thiis-Evensen investigates a repeating feature in our environment common throughout different cultures. He concluded that any building can be interpreted experientially in terms of floor, wall, and roof and that they separate that architectural life world into interior and exterior. Thiis-Evensen argues that these three architectural elements (wall, floor, roof) are common to all historical and cultural traditions. The essential existential ground of floor, wall, and roof, he argues, is the relationship between inside and outside. Just by being what they are, the floor, wall, and roof automatically create an inside in the midst of an outside, though in different ways: the floor, through above and beneath; the wall, through within and around; and the roof, through over and below [17].

- Floor: directs people, demits a space, support by providing a firm footing
- Wall: draws exterior inside, or interior outside, has a window that express the interior to the world at large
- Roof: separates spaces of what is over and what is below

Here, these three elements (floor, wall, and roof) are the archetypes that are transmitted by means of cultural and socialization, imitated by people in repetition for their sense of reality/existence, and it is an image schema crucial to survival.

2.3 Problem Definition

2.3.1 Virtual Space as a Behavior Space

As we become immersed in virtual communities, it can be said that we live in a virtual environment. Currently, researches that investigate the concept of dwelling in a physical environment are on-going from the perspectives of architectural elements as well as social and cultural elements. On the other hand, there are few researches that investigate the concept of dwelling in a virtual environment (in social networking services and mobile instant messaging applications) [17, 18]. These researches approach the concept of dwelling from the social perspective (such as social boundaries) rather than architectural perspectives. However, living in the virtual community is becoming a part of our lives [19] and our society is shifting from living in "little boxes" to living in networked societies [20].

We raise a question whether living in networked societies is innately natural to humans. For a long time, people have dwelled in spaces where the forms and functions are clear making it easier for people to navigate. However, in virtual behavior or dwelling space, there is a fuzzy boundary between form and function. That is why people get lost in their virtual behavior space and if this keeps up, the users of the net will continue to face fragmentation of themselves in numerous undefined spaces. While there have been attempts to unify all information about the users by data synchronization, we make an argument that by making the analogies between physical architecture and virtual architecture, we might have a chance of understanding how people innately and intuitively want to occupy space categorizing their lives and information.

2.3.2 Analogies Between Physical Architecture and Virtual Architecture

Using the three components that strengthen the quality of dwelling in a physical space as a guide, the elements related to the floor, wall, and roof mentioned by Alexander (1977) are subcategorized as shown in Table 2.1. For instance, a floor

Table 2.1 Identifying archetypes in physical space in virtual space

Archetypes	Sub-categories	Physical space	Virtual space
Floor	Function	Directs people, separates spaces, provides firm footing	Directs people, separates, provides firm footing through hyperlinks
	Layout	From structure follows social spaces	Is this true that a virtual environment also have social spaces through different system structures? If so, what kind of structure creates social spaces?
	Surface	Clear distinction between public and private using surface types	What would happen if a concept of surface is implemented in a virtual space? (Making users aware of where they are)
	Foundation	Ground floor slabs support walls and roofs	Does the infrastructure (fiber optic cables, IP address, routers, and etc.) that allows internet also have a structure like that of a ground floor slabs?

(continued)

Table 2.1 (continued)

Archetypes	Sub-categories	Physical space	Virtual space
Wall	Function	Draws exterior inside, or interior outside	Draws others to you, or you to others
	Half-open wall	Too closed prevent social flows, too opened does not differentiate the events. Adjust the walls, openings, and windows until you reach the right balance between open, flowing space and closed cell-like space using columns, half-open walls, indoor windows, sliding doors, low sills, porches, sitting walls—a barrier which functions as a barrier which separates, and as a seam which joins at the same time	Do virtual social spaces allow the adjustment of the openness and closeness? Currently there are ways in the privacy settings however, it might be better if they are visualized. For the posts that are only for me, enclose them in a concrete box, for the posts that are only for my friends, enclose them in a sliding doors, for the posts that are for everyone but not wanting to share should be enclosed surrounded by columns, and the posts that you really want to share should be in the porches
	Thickness	Smooth hard flat walls allow people to express their own identity of a dwelling on thick walls. People keep their belongings, place furniture, post memories	Wall in Facebook is the most direct analogy. But does Facebook wall have thickness? How can a thickness of a virtual wall be quantified?
	Structural membrane	Supports the structural solidity of the building creating rigid connection between columns, beams, and the floors. But there are curtain walls where it defines space but do not keep structure letting the frame do all the work	What creates a rigid connection between the users and the service providers? Is there such thing or is virtual space composed of curtain wall membranes only? Flexible and adjustable?
	Outside walls	The main function of outside wall is to keep weather out. And it does so by joining the materials in a way that they cooperate to make impervious joints	Do Facebook administrators have such thing where they make impervious joints to keep hackers out?
	Inside walls	Inside surfaces should be warm to touch, soft enough to take small nails and tacks	How can we make Facebook users feel more pleasant? What does it mean by making the inside walls soft? The walls facing the user should be soft and interactive?
Roof	Function	Separates spaces of what is over and what is below	Separates spaces of what is accessible and what is not
	Heights	The heights of the roofs determine the social meanings	Does Facebook have different roof heights? Is the level of accessibility different for different spaces?
	Layout	Place the largest roofs—those which are highest and have the largest span—over the largest and most important and most communal spaces; build the lesser roofs off these largest and highest roofs; and build the smallest roofs of all off these lesser roofs, in the form of half-vaults and sheds over alcoves and thick walls	What is the arrangement (size, network) of the administrators?

has a layout (large rooms have higher social importance), surface types (soft/warm = private, hard/cold = public) [21], and base structures that support the walls and the roofs. Then for each sub-category, physical explanations and possible hypothesis from the perspective of a virtual environment are brainstormed.

2.4 Future Works

This exploratory essay is to serve as a mind map to solve the problem of fragmentation of ourselves in virtual space. Considering that we dwell in virtual spaces as much as we dwell in physical spaces, and that we innately have been dividing and categorizing our physical spaces in human history, we want to investigate how humans use what kind of space (in terms of form) for what (function) then apply these coupling between form and function onto the virtual space for a more manageable and instinctive design of virtual space. But in order to that, we realize that we need a common unit of structures in physical space to investigate the differences of form and functions in cultures, that is, if the differences exist. When a code that couples form and function in our physical space is created using the archetypes of architecture, we can then make analogies with the components of virtual space to provide guidance to how to make the boundaries between virtual behavior spaces clearer. Being at a very early ideation stage of formulating a path to solve a problem, there are much more works to be done.

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Chapter 3
Architectural Conservation Based on Its Cultural DNA

Shang-chia Chiou

Abstract No two buildings in the world are alike. This is because their *Cultural DNA*, defined by the combination of the building's setting (environment), the owner, the patron (master/designer), and the craftsman (workman), is unique. Based on the cultural context of an architectural heritage, the attributes can be categorized into three aspects: architectural technology, socio-cultural and associate environment, and physical environment. These three aspects can be also referred to the threefold of human being between environment, supernatural, and human being (other people). It provides a possible consideration for applying the cultural DNA to architectural conservation.

3.1 Introduction

> Culture consists of group norms of behavior and the underlying shared values that help keep those norms in place. …Where does culture come from? It usually comes from the founders of the group. For whatever reason, they value certain things and behave in ways that seem to help the group succeed. Success is key. So it seeps into the group's DNA.[1] (by John P. Kotter, 1947–)

No two buildings in the world are alike. This is because their *Cultural DNA*, defined by the combination of the building's setting (environment), the owner, the patron (master/designer), and the craftsman (workman), is unique. This is why even identical competing buildings are fundamentally different.

The former President of Harvard University (in office 1909–1933) Abbott Lawrence Lowell (1986–1943) mentioned, "There is nothing in the world more

[1]See http://www.forbes.com/sites/johnkotter/2012/09/27/the-key-to-changing-organizational-culture/ (2015/10/1).

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_3

elusive than culture. One cannot define or circumscribe it, for it has no precise bounds. One cannot analyze it, for its components are infinite. One cannot describe it, for it is Protean in shape. An attempt to encompass its meaning in words is like trying to seize the air in the hand, when one finds it is everywhere except within one's grasp" [5: 553]. English anthropologist and the founder of cultural anthropology Edward Burnett Tylor (1832–1917) provides a definition of *culture* which is one of his most widely recognized contributions. Tylor [6] said, "Culture or Civilization, taken in its wide ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society. The condition of culture among the various societies of mankind, in so far as it is capable of being investigated on general principles, is a subject apt for the study of laws of human thought and action." The *UNESCO Universal Declaration on Cultural Diversity* (2001) reaffirms that "culture should be regarded as the set of distinctive spiritual, material, intellectual and emotional features of society or a social group, and that it encompasses, in addition to art and literature, lifestyles, ways of living together, value systems, traditions and beliefs."

On the other hand, according to the knowledge of biology, DNA (deoxyribonucleic acid) is a type of macromolecule known as a nucleic acid. It is shaped like a twisted double helix and is composed of long strands of alternating sugars and phosphate groups, along with nitrogenous bases (adenine, thymine, guanine and cytosine). It is organized into structures called chromosomes and housed within the nucleus of our cells. DNA contains the genetic information necessary for the production of other cell components, organelles, and for the reproduction of life.[2]

Based on the definitions of culture and DNA, it is not hard to understand the meaning of cultural DNA. Cultural DNA contains the genetic information necessary for the production of culture embedding knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society.

3.2 The Production of Space/Cultural DNA of Space

> The thirty spokes unite in the one nave; but it is on the empty space (for the axle), that the use of the wheel depends. Clay is fashioned into vessels; but it is on their empty hollowness, that their use depends. The door and windows are cut out (from the walls) to form an apartment; but it is on the empty space (within), that its use depends. Therefore, what has a (positive) existence serves for profitable adaptation, and what has not that for (actual) usefulness.[3] (Chap. 11, The Dao De Jing (道德經) by Laozi)

[2]The definition of DNA is quoted from http://biology.about.com/od/geneticsglossary/g/DNA.htm (2015/10/1).

[3]The original text in Chinese is "三十輻,共一轂,當其無,有車之用。埏埴以爲器,當其無,有器之用。鑿戶牖以爲室,當其無,有室之用。故有之以爲利,無之以爲用。"(《道德經·第十一章》).

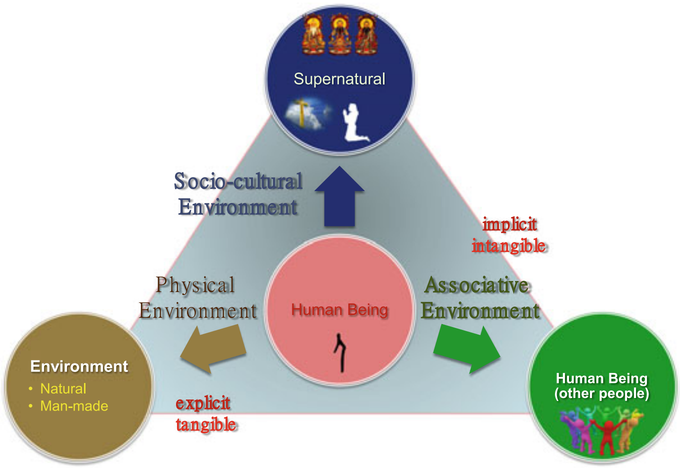

Fig. 3.1 Threefold of human being between environment, supernatural, and human being (other people)

The above quotation clearly defines the virtual (void) and real of space, and also expresses the duality of adaptation and usefulness of architectural spaces. It is also considered to respond to the ideas "(conceived of as) having no name, it is the Originator of heaven and earth; (conceived of as) having a name, it is the Mother of all things (無名天地之始;有名萬物之母)" (Chap. 1, *Dao De Jing*), "it is that existence and non-existence give birth the one to (the idea of) the other (有無相生)" (Chap. 2, *Dao De Jing*) and "all things under heaven sprang from It as existing (and named); that existence sprang from It as non-existent (and not named) (天下萬物生於有,有生於無)" (Chap. 40, *Dao De Jing*). Thus, existence and nothing (void) are both the origin of the world including architectural space.

Besides the production of space, architecture is a place based on the needs of daily life and producing, that is shaped from the collective consciousness of people and the formation of culture gradually. Therefore, the form of architecture and human settle is differential. The built environment is developed or adapted from the natural environment based on the thoughts of people where they live. Human being is the core of the threefold which shows the relationship between human being and environment, supernatural, and other people (Fig. 3.1). Furthermore, it constructs all of results including explicit (tangible) and implicit (intangible); namely the representation of culture. The physical environment is shaped by the relation between human being and environment, which is a sort of place attachment and becomes a sense of place based on personal or colonial experience. The relation of human being and supernatural creates socio-cultural environment including customs, religion, values, aesthetic concepts, and so on. The relation between human being and other people makes associate environment based on the interaction of people and community attachment.

In China, there is a saying in the book called *Yuanye* (*The Craft of Gardens*)[4]: "Generally, in construction, responsibility is given to a "master" (*zhu*, 主) who assembles a team of craftsmen; for is there not a proverb that though three-tenths of the work is the workmen's, seven-tenths is the master's? By "master" here I do not mean the owner of the property, but the man who is master of his craft."[5] The master and craftsmen play the important role on the architectural construction based on the thoughts of the threefold above.

3.3 Architectural Conservation

In late 19th century, how to preserve the production of the interaction between human being and environment has become an important issue. French architect Eugène Emmanuel Viollet-le-Duc (1814–1879) raised the idea of stylistic restoration for *Notre Dame de Paris*, English art critic John Ruskin (1819–1900) and artist William Morris (1834–1896) believed in anti-conservation movement, and Roman architect Gustavo Giovannoni (1873–1947), one of the authors of the *Athens Charter*, stated that "The intention to restore the monuments, both in order to consolidate them repairing the injuries of time, and to bring them back to a new living function, is a completely modern concept, parallel to the attitude of philosophy and culture which conceives in the constructive and artistic testimonies of the past, whatever period they belong to, a subject of respect and of care" [3: 354] and divided restoration activities into four types or categories: restoration by consolidation, restoration by recomposition (anastylosis), restoration through liberation, and restoration through completion or renovation [3: 355].

In 1931, seven main resolutions for architectural conservation were made in the *Athens Charter* which was adopted at the First International Congress of Architects and Technicians of Historic Monuments. The *Venice Charter for the Conservation and Restoration of Monuments and Sites* (1964) affirmed that "The concept of a historic monument embraces not only the single architectural work but also the urban or rural setting in which is found the evidence of a particular civilization, a significant development or a historic event. This applies not only to great works of art but also to more modest works of the past which have acquired cultural significance with the passing of time." (Article 1, the Venice Charter) Some principles

[4]*Yuanye* (園冶, *yuán yě*), translated as *The Craft of Gardens*, is a 1631 work consisting of three volumes on garden design by Ji Cheng (計成, 1582–1642) of the late Ming Dynasty in ancient China. It is considered the definitive work on garden design of the many produced during that period, and has been labeled as the first monograph dedicated to garden architecture in the world, and among the great masterpieces of garden literature (see https://en.wikipedia.org/wiki/Yuanye (2015/10/1).

[5]The English translation refers to Kile [4: 145–146]. The original Chinese quotation (世之興造, 專主鳩匠,獨不聞三分匠, 七分主人之諺乎?非主人也,能主之人也。) is from the beginning of the first volume titled "On Construction" (興造論) of *Yuanye*.

for architectural conservation were raised in the charter including authenticity, none-conjecture, distinguishability, reversibility, diversity, and integrity. Now these principles have been the basic guidelines for architectural conservation and all of these strongly are related to cultural DNA of each building.

Bernard Melchior Feilden (1919–2008) published his classic book in 1982 titled *Conservation of Historic Buildings*. Feilden [1: 6] raised five ethics of conservation: (1) The condition of the building must be recorded before any intervention. (2) Historic evidence must not be destroyed, falsified or removed. (3) Any intervention must be the minimum necessary. (4) Any intervention must be governed by unswerving respect for the aesthetic, historical and physical integrity of cultural property. (5) All methods and materials used during treatment must be fully documented. Undoubtedly the ethics of conservation are based on the cultural DNA, particularly authenticity and integrity.

3.4 Summary

In 1964, the *Venice Charter* mentioned that "Imbued with a message from the past, the historic monuments of generations of people remain to the present day as living witnesses of their age-old traditions. People are becoming more and more conscious of the unity of human values and regard ancient monuments as a common heritage. The common responsibility to safeguard them for future generations is recognized. It is our duty to hand them on in the full richness of their authenticity." The *Nara Document on Authenticity* (1994) affirmed that "Conservation of cultural heritage in all its forms and historical periods is rooted in the values attributed to the heritage. Our ability to understand these values depends, in part, on the degree to which information sources about these values may be understood as credible or truthful. Knowledge and understanding of these sources of information, in relation to original and subsequent characteristics of the cultural heritage, and their meaning, is a requisite basis for assessing all aspects of authenticity. Authenticity, considered in this way and affirmed in the Charter of Venice, appears as the essential qualifying factor concerning values" (Article 9 and 10, The Nara Document on Authenticity). The article 82 of the *Operational Guidelines for the Implementation of the World Heritage Convention* (WHC. 15/01, 8 July 2015) [7] provides the ways to understand the conditions of authenticity, which can be considered how to apply the framework of cultural DNA to architectural conservation:

> Depending on the type of cultural heritage, and its cultural context, properties may be understood to meet the conditions of authenticity if their cultural values (as recognized in the nomination criteria proposed) are truthfully and credibly expressed through a variety of attributes including:

- form and design;
- materials and substance;
- use and function;
- traditions, techniques and management systems;

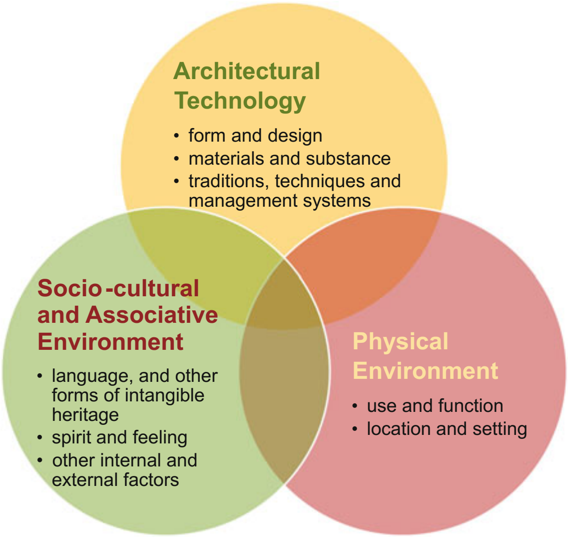

Fig. 3.2 Attributes for applying the cultural DNA to architectural conservation

- location and setting;
- language, and other forms of intangible heritage;
- spirit and feeling; and
- other internal and external factors.

Based on the cultural context of an architectural heritage, the above attributes can be categorized into three aspects: architectural technology, socio-cultural and associate environment, and physical environment (Fig. 3.2). These three aspects can be also referred to the threefold of human being between environment, supernatural, and human being (other people) which have discussed before. Therefore, it provides a possible consideration for applying the cultural DNA to architectural conservation.

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Part II
Morphological Analysis at Architectural Scale

Chapter 4
Finding Housing Genotypes by Graph Theory: An Investigation into Malay Houses

Kyung Wook Seo

Abstract Finding cultural characteristics of housing has been a subject in many disciplines. Most of their approaches, however, were qualitative rather than quantitative since even those houses with a similar style exhibit a wide variety of morphological solutions with varying shapes and sizes. As a result, researchers tended to focus on materials, decorations and layouts that are relatively easy to analyse. In recent decades, many attempts have been made to quantify built environment. Space syntax and shape grammar are two representative theories that radically systemised this approach. They highlighted, however, only one side of the reality; space syntax on spatial configuration and shape grammar on formal composition; thus could not suggest the holistic understanding of it. To overcome this limit, this research suggests a new graph representation where the information of both form and space are retained. What is the cultural DNA of Malay houses? We often try to relate this kind of question to traditional houses, but DNA is something that transcends time by transferring itself from an old generation to a new. To find this persisting genotypical element, modern apartment floor plans were converted to the new graph representation and then analysed to filter out the most common spatial elements in them. Through the interpretation of these commonalities, culture-specific properties from the past were revealed.

4.1 Transformation of Malay House

The traditional houses in Malaysia can be defined as a timber-framed structure on stilts that has evolved to adapt to the tropical climate [1]. To keep the structure undamaged from dampness and floor, houses were elevated from the ground using piles. In the hot and humid climate, this raised position also helps ventilation for human comfort as it allows air flow under it. The space underneath is also used for

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_4

storage or for breeding livestock. In fact, this elevated dwelling form can be defined as the most generic architectural feature throughout the South-East Asia. Before going up to the main floor via a staircase, people leave their shoes on the stone slab below, and wash their feet. At the top of the staircase, there begins a sequence of spaces, from the public male area to the private female area. The *anjung* and *serambi* are public spaces; the former is the covered porch where residents rest or chat with visitors, and the latter is the reception area for male guests. Next, the *ruma ibu* is the main private area of the house; here family members do all kinds of everyday activities including praying and sleeping. Passing through the passageway, or *selang*, one reaches the back portion of the house, the *rumah dapur* where women gather and cook. From this female area, one goes out to the back yard. Simply put, the whole domestic configuration can be categorised into three zones, i.e. formal reception, private living, and female cooking (Fig. 4.1).

What is remarkable here is that the functional spaces are arranged in a sequential manner without partitions. Hence, each functional space is experienced by the change in space volume or floor levels [2]. It can be said that the spatial organisation of the interior is based on an 'open sequence' from the front porch to the back kitchen. It is obvious that open plans enables unobstructed ventilation, but it may also reflect Malay people's preference for open space over partitioned space due to their collectivistic life style in their domestic living [3].

Malaysia experienced fast urbanisation and was ranked fourth (72.8 %) in urban population rate in Asia in 2012 survey [4]. Due to a radical increase in housing demand and scarcity in usable land inside major cities, apartment housing has

Fig. 4.1 Traditional Malay house (*Photo* by the author)

Fig. 4.2 Typical apartment block plan in Malaysia

become an unavoidable choice of dwelling type in the market. The proportion of apartment housing in Malaysia is 19.9 % but it goes up to 66.6 % in Kuala Lumpur which has 1.4 million population in a 243 km^2 area [5]. In the typical middle class apartment block plan, units are connected on each side of the central corridor (Fig. 4.2). To maximize ventilation, it normally has void spaces between the corridor and unit plans which is called 'air-wells' and external facades also have deep cut-outs or indents between units to provide maximum exposure to the open air. These unique void spaces enable a wide range of variations in Malaysian apartment configuration. There are two radically different formal characteristics in apartment housing when compared to traditional Malay houses. First, it has a restricted condition in spatial layout due to its packing and stacking method in construction. For example, a unit plan in the middle of the block has to face party walls on each side and can only provide a single entrance open to the corridor side. Second, in contrast to the simple open sequence of domestic space in traditional houses, modern apartment units have many separate functional rooms with partitions as seen in Fig. 4.2.

4.2 A Graph-Theoretic Method to Find Culture-Specific Characteristics

In the discipline of architecture, the dualism of form and space dichotomy has prevailed for a long time. Recently, this division has been more articulated by more refined theories, the space syntax theory [6] and shape grammars [7]. The former effectively captures spatial relations by means of graph theoretical methods, but strips out shapes and sizes that are essential for formal description. Conversely, the latter focuses on the definition of complete form while relegates spatial connectedness to a minor significance. In both, an effort to highlight one dimension inevitably sacrifices the other with no effort to bridge them. In a typical design environment, space and form interacts constantly from the beginning to the end. Hence, as Boast describes, spatial and formal measures "cannot be defined without reference to the other and they are, therefore, separable only in analysis and not in practice" [8]. Typically, modern collective housing has a bigger volume of building block that encloses individual dwellings and this enforces higher-level geometric constraint to the planning of units. In this context, to distill the cultural traits of housing design, in terms of spatial configuration, it is crucial to count in the higher-level geometric conditions of building block. In Tabor's definition, when a unit plan is designed within the constraints of boundary geometry, it is called 'permutational approach' in contrast to 'additive approach' where the unit can grow or change its form without any friction with the boundary [9]. March and Steadman explored the way where an empty rectangular plan is filled in by rooms based on 'adjacency requirements'. Unlike other graph representations such as a justified graph in space syntax theory where only the relation between rooms are focused, they suggested a graph that corresponds to the four compass directions of the surrounding exterior space as in Fig. 4.3 [10]. Inspired by Steadman's idea, Seo suggested another type of more 'easy to read' representation that suites to the analysis of modern multi-unit housing in Seoul (Fig. 4.4) [11].

This graph can represent the spatial connectedness between rooms by highlighting access and adjacency relations while preserving the boundary shape of individual units. Those four corner rooms in the grey zone are vertices of rectangular interior zone that excludes balconies. By using this representation, it becomes possible to analyse the syntactic configuration of domestic space in close relation with the building structure. When it is applied to the typical Malaysian apartment plan, however, some problems arise. As can be identified in Fig. 4.2, with some void spaces around each unit, Malaysian plans cannot be represented by normal

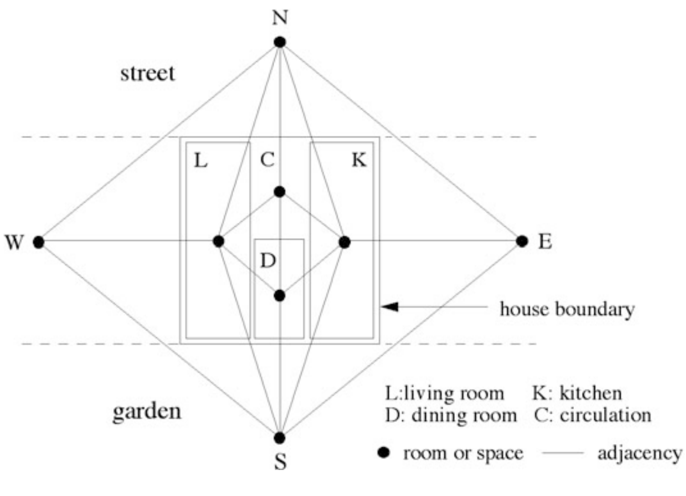

Fig. 4.3 Graph representation for the unit of English terrace houses [10]

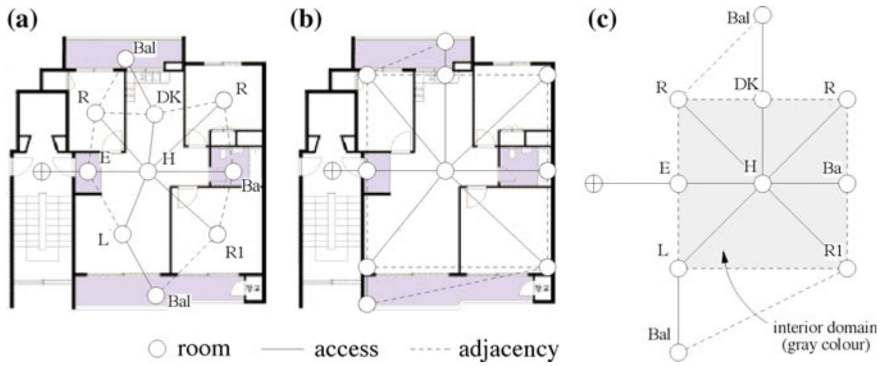

Fig. 4.4 Typical apartment unit plan in Seoul and its graph representation [11]

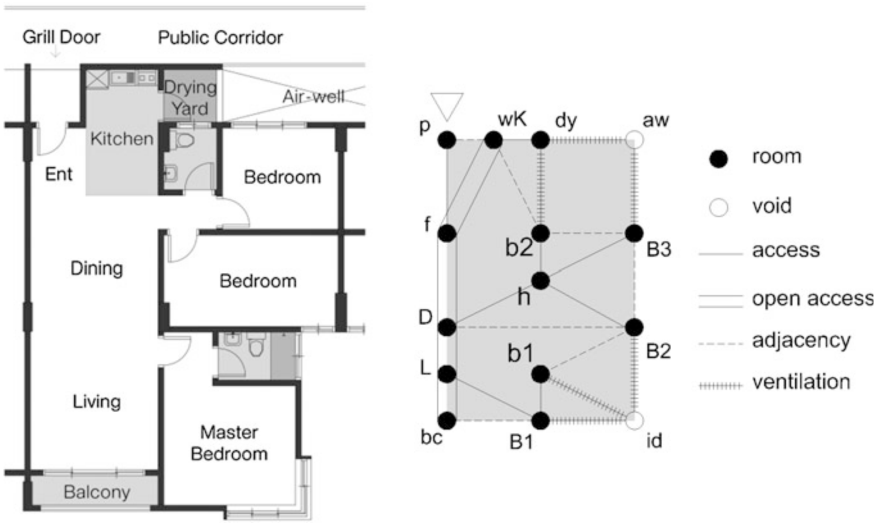

Fig. 4.5 Typical apartment unit plan in Malaysia and its graph representation (*p* porch, *f* foyer, *dy* drying yard, *aw* air-well, *id* indents, *b* bathroom, *h* hall, *bc* balcony, *B* bedroom, *L* living room, *D* dining room; numbers attached to room labels are to count the same functional spaces)

rectangular boxes. To solve this problem, a concept of ‘dummy cells’ is used to represent voids such as air-wells or cut-outs in the façade (Fig. 4.5).

In the figure, black dots represent rooms and unfilled dots voids—thus dummy cells. Now there are four different connections between rooms: access, open access, adjacency and ventilation, each with a different line type. ‘Open access’ with the symbol of double lines indicates that two rooms are connected without door, or with the minimum width of the size of two doors, i.e. approximately 1.8 m. It is to show how actively two rooms are making a close link to facilitate the internal circulation of

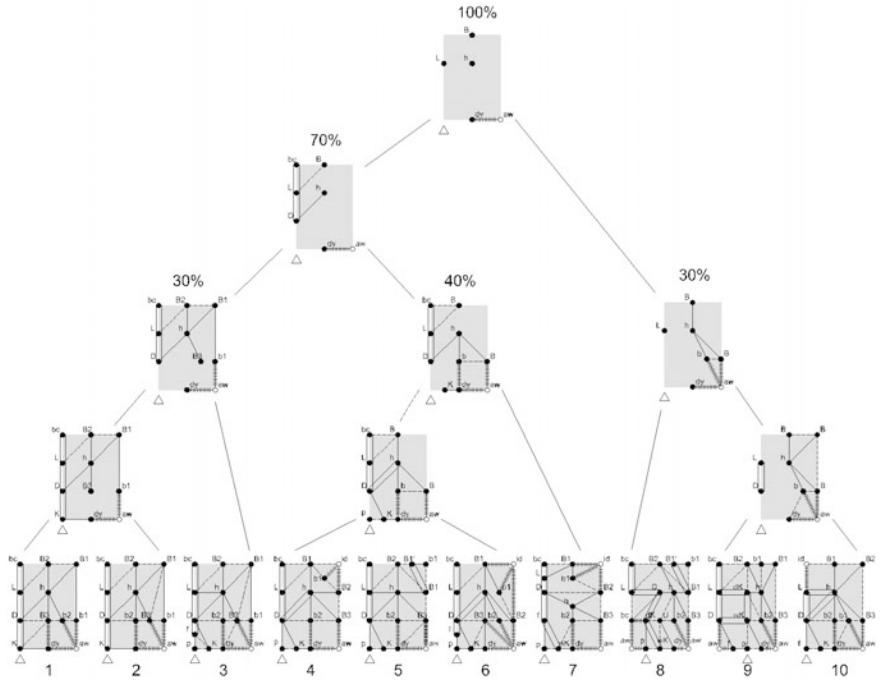

Fig. 4.6 Bottom-up process of finding common spatial elements within the original plan graphs

movements. ‘Ventilation’ with the symbol of railway indicates the connection between a room and a void space; it is always the connection to either air-wells (aw) or indents (id) on facades. Compared to the previous graph in Fig. 4.4, this graph includes more detailed information of the plan. Now, using this more refined graph technique, a methematical analysis of a multiple number of plans is possible. By sorting out common sub-graphs from the whole sample of plans, it is possible to filter out the culture-specific elements in the modern houses. From the property website in Malaysia, we collected apartment plans in Kuala Lumpur that have three bedrooms and positioned in the middle of block plans to give them an equal condition. As it was difficult to collect floor plans directly from developers or local authority, we tried to identify as many plans from Malaysian property websites that are 3 bedroom mid-block units. Converting 35 plans that satisfy this condition to graphs, it was revealed that these all geometrically different plans can be categorised into 10 different graphs. Then these 10 graphs were analysed by the suggested process of finding common denominators (Fig. 4.6). Put simple, it is a bottom-up process of generating sub-graphs that are shared by a multiple number of original graphs. By stripping off some nodes and lines, 10 original graphs are gradually merge into the upper sub-graphs, and finally arrive at the single most common sub-set at the top of the graph tree. Unlike other graph representations such as the justified graph in space syntax, our method allows individual room cells remain in isolation from others in the sub-graph;

it is because the boundary rectangular box (hatched dark) still keeps the information of their locality within the plan even after they lose their connections to other rooms. The graph on the top can be regarded as universal, so marked with 100 %. In this graph, it is identified that one of three bedrooms is always on the outside periphery of the plan and the living is always on the party wall side on which the entrance is also located. At the bottom of the plan, on the public corridor side, is the air-well, always connected to the drying yard. These two spaces are the most unique features of the Malaysia apartment plan that appears in every plan we collected. It is owing to the existence of the air-well that the drying yard, which works as a utility balcony, could be located on the public corridor side.

Amongst the ten original plans, those seven plans from 1 to 7 share more common elements than the remaining three graphs from 8 to 10. It can be said the seven plans are typical ones in the market and the last three atypical. Looking at the original graphs at the bottom, it is also recognised that all have the 'open access' connection between the balcony, the living room and the dining room, embedded within the graphs, except for the last plan that has no balcony. We used this graph representation to find out the spatial logic of Malaysian plans under the restriction given by the block plan condition, but now it may be useful to investigate the syntactic connectedness of rooms regardless of the boundary condition. Figure 4.7 shows two different graphs that shows the spatial connections of functional spaces. They are subsets of various original graphs that possess statistically meaningful information. The graph on the left shows all possible connections to the universal pair of 'air-well and drying yard'. Starting from the air-well at the bottom, this graph shows how other spaces make relationship to it in terms of topological depths. Three spaces are connected to the air-well; they are drying yard, a bedroom and a bathroom but with differing percentages. The drying yard unexceptionally (100 %) have a direct connection to the air-well but the bedroom and the bathroom don't always have their link to it—yet as highly probable as 90 and 70 % respectively. The air-well is acting as a quasi-exterior space to support bedrooms, bathrooms and drying yards for ventilation. At the next level of depths, the drying yard also makes three possible connections, but it is the kitchen that is 100 % connected to it like a rule. A bathroom is often connected to the drying yard while a bedroom is rarely connected to it. In sum, it is evident that there is a universal link of three spaces, i.e. the kitchen, the drying yard and the air-well. In the previous graph tree analysis, because the kitchen's position varies from one plan to another, it disappeared during the bottom-up process of finding common elements. It can be said that every apartment plan has this 'K-dy-aw' link, but it is only the 'dy-aw' subset that has a fixed position in the Malaysian apartment building.

The graph on the right in Fig. 4.7 shows all routes from the entrance to the balcony. As highlighted before, the living room and the dining room make a universal connection in every plan. The reason why the balcony has only 90 % is simply because one graph had no balcony; so whenever a plan has a balcony, with no exception, there exists a fully open access route of 'bc-L-D'. The connection from the entrance to the dining room has four different routes and no route seems to dominate the sample. It used to be a single linear open connection from the porch to the back yard in the

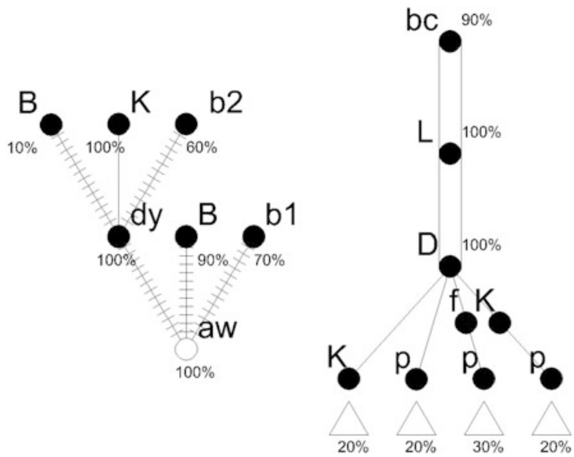

Fig. 4.7 Spaces linked to the air-well (*left*) and the sequence from the entrance to the balcony (*right*)

traditional house, but now the strong linearity has been weakened due to the various types of entrance design. In many cases, however, as we have seen in the graph tree analysis, there are clear efforts to provide open feeling by putting the open living area on the party wall side that is close to the entrance door, and this entails the clustering of partitioned rooms on the farther side of party wall from the entrance. What is another unique Malaysian feature is that every plan has to go through the dining room first before getting into the main living space of living room. In the traditional house, the domestic space followed the order of the male-living at the front and female-cooking at the back, but now it has been reversed due to the new boundary condition of the apartment house. As the living room is placed on the outside periphery of the building block near the balcony for better natural lighting and view, its location had to be separated farther away from the entrance. Consequently, the only entrance door became more like a back door in the traditional house that connects the outside and the kitchen. Now in the viewpoint of a person entering the house from the public corridor, the sequence is following the order of female-cooking in the front and male living at the back, although the periphery of the building where the living room is located is regarded as the front or façade. These findings from the graph-theoretical analysis are important evidences that allow us to make a more objective interpretation of the Malaysian housing genotypes.

4.3 Further Interpretation: Walking into the Malaysian Apartment House

The typical entrance door to the Malaysian apartment unit has an iron grill door added to the original door. It is a supplementary feature for security as well as to help ventilation when the original door is open. On hot and humid days, residents

Fig. 4.8 Integrated public zone seen from the entrance (*left*) and the drying yard (*right*)

can open the entrance door for ventilation while having this grill door shut as barriers to prevent theft. Entering the entrance door, an open interior zone appears (Fig. 4.8). It is an integrated living zone combining the dining room and the living room, and sometimes the kitchen, without partitions. Linked directly to the entrance, it creates the feeling of unobstructed spaciousness which exactly resembles the traditional 'open sequence'. Unlike the traditional house, however, this open zone integrates the living and dining more tightly without transitional spaces. It is true that this is not just a Malaysian phenomenon but a global trend to combine communal functions in modern homes, but in Malaysian case, there exists a strong tendency to align this zone on one side of party walls, nearer to the entrance, and locate the partitioned private rooms on the other, farther from the entrance. This is an environmentally sound solution because when the entrance door and balcony windows are open at the same time, this configuration allows much better ventilation.

A clustering of three essential service spaces, i.e. the kitchen, the drying yard and the air-well, is another defining feature in Malay apartments. It has been revealed from the graph analysis that they are always connected to each other to support various domestic activities. The drying yard is primarily used as a backup space for the kitchen, sometimes equipped with an extra set of gas ranges and sinks as well as washing machines and drying racks (Fig. 4.8). In some bigger apartment units, it is easily found that there are two kitchens, i.e. a dry kitchen and a wet kitchen to provide this backup in a proper manner; thus in compact apartments, the drying yard takes the role of the wet kitchen. In earlier days of apartment construction in Malaysia, front balconies were utilised as a drying yard, to support the function of washing and drying of cloths, but in recent decades, the function has been pushed backwards by devising a new space, the drying yard. Thus it was inevitable that the drying yard made a new grouping with the kitchen and the air-well to maximize its effect.

Air-wells and indented cut-outs in the façade are important features in Malay apartments which allow more rooms to be exposed to the open air. The architectural code of Malaysia demands that all water closets, latrines, urinals or bathrooms be equipped with openings for continuous natural ventilation [12]. It is not easy to design a balcony-access apartment unit that allows all three bedrooms exposed to the open air without problems. In normal planning approaches, one or two bedrooms need to have their windows facing the access balcony or the communal corridor, which typically causes noise, visual privacy, and security issues. In Malay apartments, these problematic issues have been cleverly solved by having air-wells and drying yards on the access balcony side and the indented cut-outs on the front facade.

4.4 Conclusion

As the traditional Malay house can be characterised by the 'open sequence' of functional spaces, the modern apartment partially adopted this genotype by providing an open spatial continuum from the dining-kitchen zone on the entrance side to the living room and balcony on the front side. These unobstructed family living zone can create open feeling and facilitate natural ventilation. Regarding the design strategy for the room arrangement, Malaysian plans exhibit a clear intention to maximise the open-air contact for ventilation by providing air-wells and deep indents on building facades. Having voids within the building mass, apartment units can overcome the usual limits in room configuration and achieve more depths and flexibility in planning. By using the graph-theoretic method, the cultural elements in their housing form and space could be more clearly quantified and analysed for better interpretation. The remaining question will be how to construct an algorithmic logic of processing the graph representations to speed up the mechanism of filtering out the cultural DNA with more clarity and precision.

Acknowledgments This research is a part of the research project, 'Development of Incremental SI (Structure-Infill) Housing for the Low-income Population in Malaysia' by Northumbria University and Universiti Teknologi Malaysia supported by the Newton Fund, Institutional Link Grant from the British Council (Application ID: 172733176).

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Chapter 5
Frieze Symmetry as an Underlying Principle of Housing Elevation Designs

Jin-Ho Park

Abstract This article deals with the seven frieze groups of symmetry that works as guiding principles for the analysis and synthesis of housing elevation designs. The mathematical notion of symmetry serves as a tool for analyzing frieze patterns of various symmetries and for constructing new symmetrical designs in housing facade.

5.1 Introduction

Almost any culture around the world has a wide range of repeated patterns. At times, these patterns seem to be complex or atypical regardless of their cultural background. For certain patterns, one can easily recognize their differences or similarities at first glance. In some other cases, their order of patterns is difficult to recognize because of their complex nature. When various symmetries are manifested at the global level, the local patterns are difficult to recognize. Even if one is an expert in pattern recognition, one can hardly recognize the type of superimposed patterns without full attention to the constituent parts. The reason is that different layers of partial designs are highly integrated in one pattern by distinct computational rules. These complex patterns of a certain order may differ from one another. Notably, they share some type of underlying logic behind such patterns. Therefore, defining the hierarchies of such complex patterns would be interesting.

Symmetry principle has been used in order to create harmonious and balanced architectural designs [1]. In mathematics, the symmetry group in two dimensions is either finite or infinite. Point groups are finite symmetry groups where symmetric transformations take place in a fixed point or line. The transformations involve rotation about the point and reflection along the lines, or the combination of both. Infinite groups are the symmetries of infinite patterns. In the infinite symmetry group, spatial transformations occur where the basic movement is either translation

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_5

or a glide translation. In this group, designs under one directional translation are called the frieze group, and designs under two directional translations are called the wallpaper group. Subsymmetries arise from a curtailment of some of symmetric transformations, thus selecting subgroups from the group of symmetries [2, 3].

Early studies on the point groups of subsymmetry in architecture have been conducted by Park [4, 5]. This study focuses on the patterns of the frieze groups of subsymmetry in the analysis and synthesis of architectural designs. The method of the frieze groups of symmetry is delineated to help read the global and local hierarchical structures of symmetric patterns. Then, the method is utilized for the creation of new architectural designs. In particular, the potential use of the subsymmetry method is tested in order to develop housing façade designs.

5.2 Frieze Patterns in Arts and Architecture

A frieze pattern consists of two-dimensional motifs repeating in one direction only. The frieze patterns can be found in many designs of cultural objects, such as pottery, architecture, quilts, and many other forms of art in any culture, from the ancient Greek and Roman temples to Hindu and Mayan temples, Asian potteries, and Hawaiian *tapa* quilts.

The ancient Greeks used a number of frieze patterns in their temple designs. For the Greeks, temples are places of worship and symbolize their culture. Accordingly, they represent a significant cultural and historical asset as well as the craftsmanship of the society. They carefully designed the frieze with bas-reliefs as part of a stone entablature. The Parthenon frieze is particularly well known and it forms a continuous band with sculptures in relief that cover the upper exterior wall of the cellar as shown in Fig. 5.1 [6]. A relief frieze spiraling around the column may also be found. Wall friezes are frequently found in Hindu Temples in India. Hindu Temples are places of worship and a symbol of religious and cultural identity of Hinduism. Ancient Indians used similar patterns of sculptural relief in their temples. For example, the facade of the Hindu temple is filled with rows of intricate sculptures that depict mythological episodes and perhaps gods in frieze patterns.

Frieze patterns are also found in ancient pottery and quilts. Ancient pottery, particularly the Chinese blue and white porcelain, is unique in the long tradition of ceramic history. Its diverse marks and inscriptions appeared in porcelain from the Tang Dynasty and the Song dynasty. Interestingly enough, all seven frieze patterns are identified in porcelain. Frieze patterns are typically found at the top rim, body, and base ring of porcelain [8]. Traditional Hawaiian patterns appearing in quilts and bark cloth, known as *kapa and tapa*, respectively, have long been appreciated for their beauty due to their unique design patterns [9]. Hawaiians began to decorate their fabrics not only to represent Hawaii's natural beauty but also their culture. Frieze symmetry reflects the use of bamboo stamps used long ago to create designs.

Fig. 5.1 Ancient patterns that can be found across countries from the east and the west (*Top* Parthenon Frieze patterns, Greece; *Bottom* Frieze carvings on the base of Hoysaleswara Temple, India) (*bottom image* retrieved from [7])

Geometric designs such as lines, triangles, circles, and other symbolic motifs carved onto bamboo are used to repeat patterns. Symmetrical patterns created by repetition show patterns that are reflected, rotated, and translated along a line. The prolific repetition of the patterns in a single item creates rich designs as shown in Fig. 5.2.

Owen Jones's book entitled *Grammar of Ornament* best exemplifies decorative vocabularies from different cultures around the world. In the book, styles and patterns differ from each other because they have evolved from different time periods among cultures. However, each pattern shares similar repetitions and symmetric juxtapositions.

A different study of the building façade in regard to the hybrid use of symmetries is found in Preston Scott Cohen's book, *Contested Symmetries and Other*

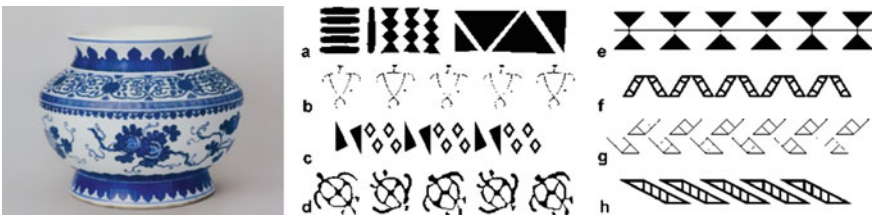

Fig. 5.2 *Left* the Chinese *blue* and *white* porcelain; *right* various frieze patterns found in Hawaiian Tapa (*left image* retrieved from [10])

Predicaments in Architecture [11]. He analyzed the facades and plans of the Palazzo Gambara and found the considerable complexity of the facades is observed in multiple levels. Such complexity arises from a multiple superimposition of symmetries with architectural elements. A staircase with windows added in the building acts as a key compositional element for the facade juxtaposition. He identified that although not externally expressed, its unconventional type, placement, and orientation in a building create a different symmetric dynamism on the front as well as the rear facade of the building [12].

A frieze pattern is based on some types of symmetry. Different types of frieze patterns can be found from different symmetrical operations. Architects or artists must have known and played with all seven of these symmetry groups for thousands of years. However, it was not until the 19th century that mathematicians were able to prove that every frieze pattern could be classified by one of these seven frieze groups. As frieze patterns sometimes prove to be difficult to classify, classifying the pattern using mathematical methods to identify them is recommended. Seven different frieze patterns are possible. These patterns rely on symmetrical operations and their combinations, such as translation, rotation, reflection, and glide reflection. These methods help to uncover the logic behind where the apparent complex systems can be found. It guides our search for regularities and helps make these regularities intelligible. Moreover, diverse new designs are also possible because of these methods.

5.3 The Method: Seven Frieze Symmetry

There are seven distinct groups that can be the symmetry group of a frieze in an infinite sequence of equidistant points arranged in a linear series on the Euclidian plane [13, 14]. Every frieze pattern belongs to one of only seven mathematically possible patterns. Five types of isometries occur in frieze groups: translation (T), half-turn (S: rotation through 180°), vertical reflection (Rv), horizontal reflection (Rh), and glide reflection (G). Different possible combinations of above isometries form seven distinct symmetry groups together.

The complete list of the seven frieze groups in plan includes: Pmm2, Pma2, Pm11, P1m1, P1a1, P112, and P111. The use of letter "p" denotes the one-dimensional frieze pattern. The following three notations, let's say 'xyz' after 'P' denote symmetry operations in the frieze direction. Right after 'p', an 'm' or '1' shows the presence or absence of mirror reflection respectively on the perpendicular axis to translation. Mirror or glide symmetry along the axis of translation is given in the second space to the right of 'p'; the symbol, 'm', means a reflection exists in the axis of translation; 'a', means a glide reflection exists in the axis of translation. The third space to the right of 'p' is 1 or 2; the presence of half-turn rotation is indicated by 2, and the absence of half-turn rotation by 1.

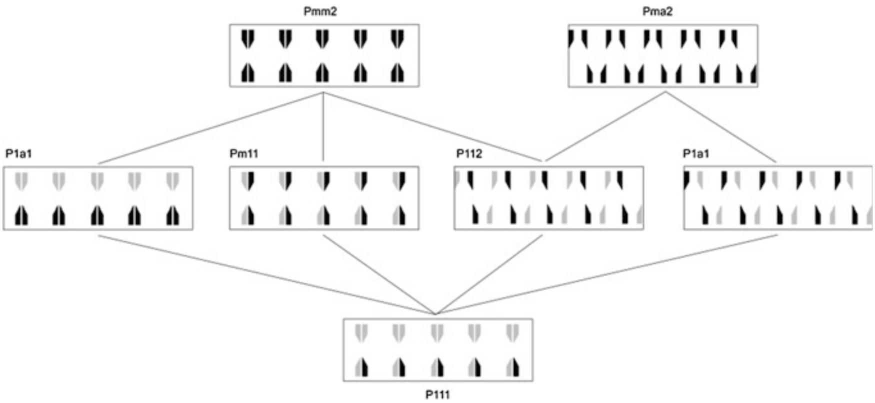

Fig. 5.3 Seven frieze patterns classified with regard to the frieze groups and their subgroup relationship among the groups

The seven frieze patterns can be classified with regard to the symmetry group. Different patterns are to be created along the axis of translation while using the same motif repeatedly. It is noticeable from the observations of the patterns that the subgroup relationship among the groups can be hierarchically structured in order similar to the point group subsymmetries. Each distinct frieze pattern of the symmetry group and its subgroup relationship is adequately summarized in the lattice diagram.

In the diagram (Fig. 5.3), the motif in ways that destroy some of its symmetries is highlighted. In the top row, there are two frieze groups: one is Pmm2 that contains reflection on perpendicular and parallel to translation, and half-turn rotation; the other is Pma2 that contains a half-turn and reflections in two mirrors at the right angles to it. The frieze groups in the second row each have two motifs in a serial pattern of their symmetry groups: P1a1 is the only frieze group containing a glide reflection but no reflections; Pm11 contains reflection in the translation axis; P112 contains a half-turn in the translation axis; p1a1 contains a glide reflection along the translation axis. The bottom row is P111 containing only one translation of a motif along the translation axis.

5.4 Applications

On the one hand, the method helps to uncover the logic behind where apparent complex systems of patterns found in any culture underlie. On the other hand, it can be used for the development of new designs. The most repetitive use of the frieze groups on a building façade prevails in rows of terrace houses where an identical house is repeatedly lined up along the street. Accordingly, the role of the architects for the building type is so limited to ensuring as diversified of a façade design as possible. It is typically due to that more than three housing units are joined together and are sequentially arranged repeating in one direction. These are also placed parallel to the street, side by side, thus creating the uniform street façade. The following shows an analytic example of an existing architectural design and a synthetic example of an abstract design with regard to the frieze groups of symmetry.

5.4.1 Analytic Example

The most repetitive use of the frieze groups on a building façade can be found in rows of identical terraced houses, with one house repeatedly lining up along the street. More than three housing units are joined together and are sequentially arranged repeatedly in one direction. These housing units are also placed parallel to the street, side by side, to create a uniform street façade. Therefore, the role of architects in such a building type is limited to ensure a diverse façade design.

Rows of terraced houses are the most efficient and commonly built housing types worldwide. Many architects design this building type, as it is a method of laying out and constructing cost-effective housing with efficient land use. Most units rely on a typical style of a living room extending the entire depth of the house with windows on both ends. A narrow and mezzanine loft for the living space is the most common form of houses. The arrangement is so simple and redundant that a typical unit can easily be lined up along the street in sequence.

Conversely, other architects try to overcome the conventional layout of such repeating patterns of housing by using the notion of symmetry. Therefore, they sometimes elaborate and diversify building façade patterns. For example, an architect, Mark Mack, provided an application of the frieze groups of symmetry in a row of house façade designs. Bay Cities Artist Lofts, Venice, California are initially designed based on two different types of three-story loft prototypes, ranging in size from 2500 to 2900 ft^2 (Fig. 5.4). Each of the two lofts shows no symmetry as a motif. Each loft is reflected along various vertical local axes, while all eight lofts are

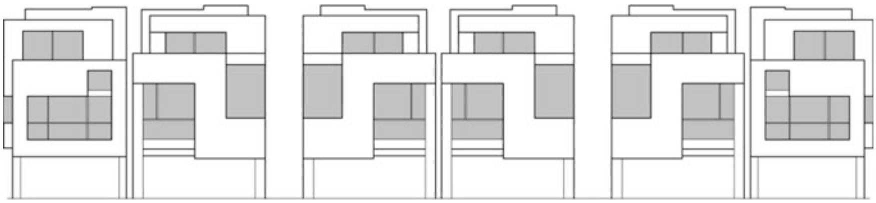

Fig. 5.4 Mark Mack, Façade of Bay City Lofts, 2004 (redrawn by the author)

arrayed in a row along a central bilateral axis. The façade front and back walls are vividly articulated with different colors and materials, creating an exquisite symmetry in its design. A number of different designs are easily found throughout the world.

5.4.2 Synthetic Example

A finite series of design elements including doors, windows, balconies, recesses, stairs, etc. are considered to create a row house façade. The designs of each element may be unique depending on each architect's own style, since each architect may have a different set of design ideas when it comes to designing a building. Anyway, these elements in multiple layers will be aligned and superimposed on top of each other with respect to the seven frieze groups, creating a global asymmetric facade. The façade is constructed in such a way that the elements associated with respect to the symmetry coincide respectively. It is easy to imagine that rows of houses on a regularly divided lot along a street façade are designed. Then, those elements on the façade are arrayed with respect to the frieze symmetry.

Proper positioning of each symmetric element produces an orderly superimposed pattern of seven distinct symmetry operations. When overlaid all together, separate building elements dissolve in a façade, making each underlying layer invisible. When rendered, each element and its underlying principle are embedded within the fabric of the whole façade. Its asymmetrical design does not reveal its underlying geometry. Its identity forms a unique pattern as shown in Fig. 5.5.

Either a few distinctive or all types of seven frieze groups of symmetry with different types of architectural elements can be used for its distinctive character. The application results in enormous design possibilities. It is easy to imagine that depending on the choice of design elements in different symmetric orders, a wide range of varied new designs can be generated. Depending on how to overlay different parts of elements on the façade, the expression of the final design will be different, although it may look as if various elements are permutated, shifted, and positioned. By applying such design principles to rows of terrace house designs, it would be possible to design a series of unique as well as dynamic house facades for rows of houses (Fig. 5.6).

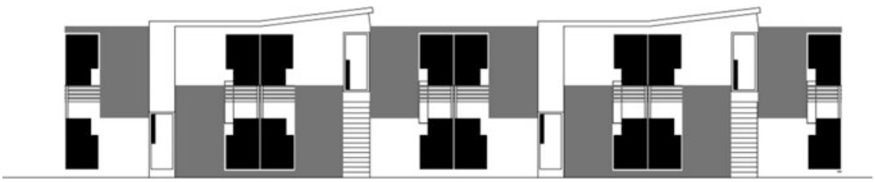

Fig. 5.5 A design where all elements seven frieze groups of symmetry are superimposed to form a housing façade

Fig. 5.6 Three-dimensional volumetric computer model in abstract is depicted on a streetscape

5.5 Summary

To sum up, this article has sought to highlight the potential for the seven frieze groups of symmetry to serve as guiding principles for creating unique facades of rows of houses. The mathematical notion of symmetry serves for the analytic tool of frieze patterns of various symmetries and also for the construction of new facade designs of building. The constructed housing façade leads to the conclusion that with the seven frieze groups of symmetry, a new possibility in creating a variety of dynamic housing façades is shown. By combining a set of different design elements with the principle, a variety of designs can be further generated. When a series of row houses are designed and combined as such, the street facade of the pedestrian level can become more elaborate, providing dynamic townscape.

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Chapter 6
Unpacking the Cultural DNA of Traditional Chinese Private Gardens Through Mathematical Measurement and Parametric Design

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Abstract Traditional Chinese private gardens have unique cultural significance for the world's architectural and landscape heritage. To compliment the existing qualitative understandings in the field, this chapter presents a computational approach to unpacking the DNA of this important cultural heritage—capturing and applying the essential spatial characteristics of traditional Chinese private gardens—through mathematical measurement and parametric design. The chapter demonstrates that the computational approach is applicable and effective, through the analysis and generation of two different categories of traditional Chinese private gardens—with Yuyuan Garden and Wangshiyuan Garden as the typical historical example for each category respectively.

6.1 Introduction

Traditional Chinese private gardens have unique cultural significance in the world's history and heritage of landscape architecture. The history of private gardens in China can be traced back to the 11th Century BC in the form of private hunting

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_6

grounds with artificially constructed landscape elements. The records of actual private gardens emerged from around 800 AD in the Tang Dynasty. The practice and the artisanship of traditional Chinese private gardens matured and peaked during the 16th Century AD and 17th Century AD. Since then traditional Chinese private gardens have become a unique type of landscaped places, and these historical gardens are now renowned for their spatial complexity, intricacy and variety in the design, which are often closely associated with traditional Chinese aesthetics, philosophy and culture [18, 20]. This research presents a computational approach to unpacking the DNA of this important cultural heritage—to formally capturing certain key aspects of spatial characteristics of traditional Chinese private gardens, and reproducing new design instances that share the same characteristics as measured from the originals. This computational approach is supported by two fundamental algorithms, they are Space Syntax [7] for the mathematical measurement and analysis, and parametric design [12, 21] for the computational design generation.

The rationales for such formal and quantitative studies on the subject area are due to the needs for complimenting and extending the currently limited understandings in the field. Except in few cases [4, 14], current knowledge about traditional Chinese private gardens has been investigated and debated using qualitative approaches, where scholars describe, interpret and theorise these architectural and cultural phenomena based on the historical records and events, as well as personal experiences of visiting, understanding and preserving the actual gardens. With the emergence of computational methods and technologies, the socio-spatial properties of traditional Chinese private gardens can now be mathematically analysed, and formally measured and generalised. As demonstrated in the second half of this chapter, the computational approach is applicable and effective in the analysis and generation of two different categories of traditional Chinese private gardens—with Yuyuan Garden and Wangshiyuan Garden as the typical historical examples for each category respectively. The results enable more direct clustering and comparison of the spatial characteristics, and provide new insights about this important cultural heritage. Through parametric design, the quantitative knowledge about these historical gardens can also be directed for design generation, to preserve, inherit and extend this important cultural heritage through computational means.

6.2 Theoretical Foundation

As the theoretical foundation of the developed computational approach, this section discusses works that lead to the research conceptualisation of the approach. They are (1) traditional Chinese private gardens—two categories by scales, (2) spatial analysis—mathematical measurement with Space Syntax; and (3) computational design generation—parametric design.

6.2.1 Traditional Chinese Private Gardens—Two Categories by Scales

Traditional Chinese private gardens are often know as the “Southern” style of traditional Chinese gardens, distinguished from the “Northern” style which often refers to the imperial gardens. A traditional Chinese private garden is typically constructed on a compact but dense network of paths/covered corridors, paved squared/courtyards and other purposefully defined/divided spaces. They are carefully arranged to be surrounded by and intersected with landscape features of ponds, streams, small hills and vegetation, all of which are planned and constructed on a relatively small and clearly defined site (see selected images in Fig. 6.1). There are two typical categories of traditional Chinese private gardens—large-scale gardens (>20,000 m^2) and small-scale gardens (<6000 m^2). The miniature landscapes of small-scale gardens differ from the much larger counterparts in several ways, the most important of which is probably their partial inversion of the figure-ground plan. The large-scale gardens in essence feature freestanding buildings in an artificially constructed landscape, whereas the small-scale gardens are more reliant on structures that surround and thereby define landscaped courtyards. As a consequence of such differences, in the large-scale gardens circulation is primarily facilitated along paths, whereas in the small-scale gardens, courtyards fulfil much of this function. Typical historical examples of large-scale gardens include Yuyuan Garden, Zhuozhengyuan Garden and Liuyuan Garden. Typical historical examples of small-scale gardens include Wangshiyuan Garden, Yiyuan Garden and Tuisiyuan Garden. The small-scale gardens are also called the small gardens of Suzhou because most of the well-known examples from this category are located in the Chinese city of Suzhou.

Research on traditional Chinese private gardens has largely been conducted qualitatively. Keswick [10], Tong [20], Zhou [22], Hunt [8] and quite a significant number of other researchers in parallel, have extensively explored the spatial

Fig. 6.1 Two views of selected traditional Chinese private gardens. *Photo Credit* Rongrong Yu

characteristics of selected gardens from historical, social and cognitive perspectives. In comparison, a much smaller number of studies have been conducted quantitatively. For example, some progresses have been developed to understand the rich spatial planning and arrangement in selected garden examples, using selected Space Syntax techniques [4, 13], and by combining syntactical analysis with grammatical composition [14]. Overall, traditional Chinese private gardens have rarely been formally and quantitatively studied and measured. Without such clearly defined mathematical measurements, their spatial properties cannot be critically interpreted, explicitly compared and eventually generalised to direct future design. The computational approach developed and demonstrated in this chapter represents one of the first attempts to not only mathematically measure and analyse the historical examples of traditional Chinese private gardens, but also generate new design instances of these gardens that share the same spatial characteristics of the originals, through computational means. The two computational algorithms for supporting the analysis and generation are introduced below.

6.2.2 Spatial Analysis—Mathematical Measurement with Space Syntax

In this chapter, spatial analysis of the traditional Chinese private gardens is achieved through Space Syntax. Space Syntax comprises of a formal suite of techniques for analysing the topological properties of space, for example, permeability or intelligibility, through graph theories [7]. Space Syntax techniques are relatively mature and reliable as they have been developed, refined and extensively applied over a number of decades, in a wide range of areas such as urban planning, architectural design and landscape design. The majority of the formal Space Syntax techniques start by abstracting the structural relationships of a plan into a graph—a diagrammatic system for representation of sets and connections between them [3]. Then, using graph theories and mathematics, the properties of the plan can be formally measured and compared. Thus, one important capability of the Space Syntax approach for design analysis is that it provides a formal way of critically understanding spatial configurations by translating their properties into topological graphs, which can then be mathematically analysed [17].

Syntactical techniques for analysis produce for example Convex Graphs, Adjacency Graphs or Permeability Graphs, from a set of nodes (that represent spaces) and the connections between them, representing a type of boundary condition that may be trafficable, permeable or visual depending on the chosen application. There are multiple variations of this technique including those pertaining to visually-defined spaces (convex spaces), functionally-defined rooms, or functional/typological zones in a plan [2, 7, 15]. In the basic version of this technique, the convex spaces in the plan are translated into the nodes of a graph while their connections are typically converted into the edges of the graph. Connectivity, in this technique, is a property of both adjacency and permeability, which refers to the availability of direct access (by way of an opening) between two spaces [19]. These defined spaces and the connections between them are collectively described as a "map", but in mathematical terms, they are also a graph and can be analysed as such [11]. Thus, in a convex map, the step depth of each node in the graph can be mathematically determined, subsequently the Total Depth (TD), Mean Depth (MD), Control Value (CV), Intelligibility (I) and *integration* (*i*) values can be calculated for each node. These values reflect the relative role of each space within the larger structure of the plan. For example, the TD suggests the connectivity distance from the entrance node. MD is the average depth for each node, which represents the degree of isolation of the spaces. I is defined as a Pearson correlation between integration and the connectivity values of all vertices. It is an indication of how easy it is to navigate through an environment, which indicates the overall clarity of the system (the garden in the case of this chapter) as perceived by a user within [11, 19]. The degree of integration is suitable for comparing each space with other parts in a distributed plan and can be used to develop an "inequality genotype", which is a hierarchical determination of the structure of the spaces in the plan [1]. The results of this process of creating an inequality genotype, whether expressed as ordinal rank of spaces or their actual *i* values, may be compared to other plans of buildings (or gardens in the case of this chapter).

6.2.3 Computational Design Generation—Parametric Design

Parametric design defines a rule-based process wherein multiple design solutions can be developed that confirm to defined sets of conditions [21]. A parameter is a value or measurement that can be altered during the process. By changing the parameters, particular design instance can be created and altered from a potentially infinite range of possibilities [12]. Using parametric tools, designers can develop rules that reflect the performance requirements of a design and then generate multiple variants that fulfil these conditions. This is advanced because it supports the solution-finding process in design with increasing flexibility and control [5]. In this chapter, we apply this rule-based process to generate new design instances of traditional Chinese private gardens that fulfil the conditions of matching the spatial characteristics of the originals as measured by Space Syntax.

Contemporary parametric design software includes GenerativeComponents, Digital Project and Grasshopper. Scripting tools include Processing, RhinoScript, Python, and DesignScript. In our demonstration, Grasshopper has been used for the generation of the new garden designs. Few research has attempted to combine or connect parametric design with Space Syntax. Jeong and Ban [9] have presented computational algorithms to evaluate design solutions using Space Syntax. Nourian et al. [16] have also developed a computational toolkit “SYNTACTIC” (as a plugin for Grasshopper) for evaluating architectural design using Space Syntax. Despite of these attempts, the significant volume of research on parametric design has been focusing on generating novel designs using parametric systems, their use to reproduce existing or historical cases remains uncommon and there are very few examples of parametrically generating socio-spatial properties of a design.

6.3 A Computational Approach

The computational approach to analysing and generating traditional Chinese private gardens contains three major processes. Each of the three processes has been described below. Although this approach and the Space Syntax techniques are capable of addressing a wide range of spatial qualities of traditional Chinese private gardens, for the purpose of clearly presenting and demonstrating the approach in the remaining of the chapter, the focus has been placed on one main spatial quality—connectivity. Therefore the analysis and generation do not concern the exact location of specific landscape and architectural elements, but the larger network of typical spatial relations amongst the accessible areas of the garden. Thus, this computational approach mathematically measures the spatial characteristics of the garden using connectivity graphs [6, 7] only, based on the 2D plan of the garden.

6.3.1 Mathematical Measurement with Space Syntax

To conduct the connectivity analysis of a traditional Chinese private garden, a plan graph is firstly developed. Connectivity or permeability graphs are normally constructed to represent and study the relationships between either visible zones (convex spaces) or functionally-defined areas. In our demonstration, the analysis does not take into consideration of artificial ponds and hills, each node is therefore (1) a functionally-defined space or (2) an area within specific size ranges in the garden that can be physically entered (accessed). The analysis commences by identifying different spatial types (as defined by the two methods above) in each selected garden then determining how they are linked. After linking the nodes the graph is generated. From this generated graph, the step depth of each node, then TD, MD and i values can be calculated.

For a large-scale garden, to conduct the connectivity analysis a variation of the functionally-defined-space method is chosen to define the nodes. Thus, regardless of the precise shape and location of a space, if it has a single function it is regarded as one node in the graph. In order to graph the connectivity patterns of these gardens, six distinct spatial types have been identified: (1) large rooms, (2) small rooms, (3) pavilions, (4) yards/squares, (5) covered corridors and (6) pathways. Large and small rooms are physically and often visually defined in plan by extensive walls and landscape elements. Large rooms are those, which each provides a relatively complete and independent living space, whereas small rooms, even if they are close to the size of their larger counterparts, do not have these features. Pavilions are covered or semi-enclosed spaces (typically without extensive walls). Yards/squares are small paved zones, which are open and less clearly defined. Covered corridors, and pathways are two variations of a distinctive type of long and narrow space, with pathways often being uncovered and more open. The analysis commences by identifying these six spatial types in the selected garden then determining how they are linked.

For a small-scale garden, we use the other method to define the nodes by dividing the garden as areas within different size ranges. The reason is that in small-scale gardens, the functional spaces are not as diverse as those in large-scale gardens, which makes the types of functionally-defined spaces too few to generate statistically-sound results. To standardise this process, similar to large-scale gardens, there are also six spatial types classified in small-scale gardens, Types 1–4 are "rooms" divided based on their area sizes. Type 5 is corridors and Type 6 is courtyards.

6.3.2 Parametric Design System Development

The purpose of the parametric design system in this research is to generate new garden designs that capture the original styles. This requires us to develop parametric rules to rapidly produce and explore multiple variants of traditional Chinese private gardens that fulfil the conditions of matching the spatial characteristics of the originals (as measured by Space Syntax following the process outlined above).

For large-scale gardens, the following steps are taken:

- Firstly, mathematical measurements of spatial characteristics for different spatial types derived from the original cases are used to direct the parametric rule development in Grasshopper. For instance, a pavilion typically has only one connection; a proportion of a yard is typically connected to large garden rooms, etc.
- Secondly, the average numbers of different spatial types such as the average number of large rooms or small rooms are set as input parameters.
- Finally, a pre-determined entrance, generic site boundaries and the main path for circulation are selected. The distance ranges of the nodes to the main path are also defined.

For small-scale gardens, the following steps are taken:

- Firstly, a parametric script is authored to produce a set of nodes of each spatial type as identified in the original cases. The central courtyard is generated, followed by secondary courtyards within the site. Then other spatial types are generated with their sizes and numbers being randomised within the ranges of the parameters identified.
- Secondly, the script is then expanded to produce a set of connections between the generated nodes that conform to the mean TD, MD and *i* values for each spatial type. The number of spaces and their connectivity patterns are now topologically described (in the form of a graph) after the first two steps.
- Thirdly, the scale and context are defined to transform the developed graph into a garden plan. Thus, the script is augmented with the addition of a pre-determined entrance, generic site boundaries and the main path, as well as the inclusion of a defined "central" courtyard.

6.3.3 Design Generation and Testing

With parametric rules developed and input parameters defined, the parametric design system can be operated to generate new garden designs. Each alternative of the newly generated plan suggests a possible spatial (connectivity) planning schema reflecting on the spatial characteristics of the originals.

Finally to verify the designs generated, the *i* values of each newly generated garden design (in the form of a parametric diagram) is calculated and tested against the inequality genotype produced for the originals. During the testing, the more similar values and orders found between the two, the more closely the new design captures the original style.

6.4 Application and Demonstration

This computational approach to analysing and generating traditional Chinese private gardens is demonstrated through the following two applications, Yuyuan Garden (application one) and Wangshiyuan Garden (application two). Both gardens are selected because they are very well recognised as typical examples of traditional Chinese private gardens. Yuyuan is categorised as a large-scale garden with the approximate size of 20,000 m^2. Wangshiyuan is categorised as a small-scale garden with the approximate size of 5300 m^2. In literature, they match the typical planning structure and characterisation of the two garden categories respectively (as briefly described in the theoretical foundation above). Because of the fundamental differences between the two categories of gardens, this computational approach defines different steps for both the analysis and generation to suit the different garden categories, which have been exemplified in the two applications below.

6.4.1 Application One—Analysing Yuyuan Garden

Situated in Shanghai, China, Yuyuan Garden was initially constructed in the 16th century. Parts of the garden were destroyed during World War II, although they have since been restored. Yuyuan Garden is particularly known for its subtle planning, as well as for the elegance of artificial hills and water features located at the centre. Figure 6.2 shows the plan of Yuyuan Garden.

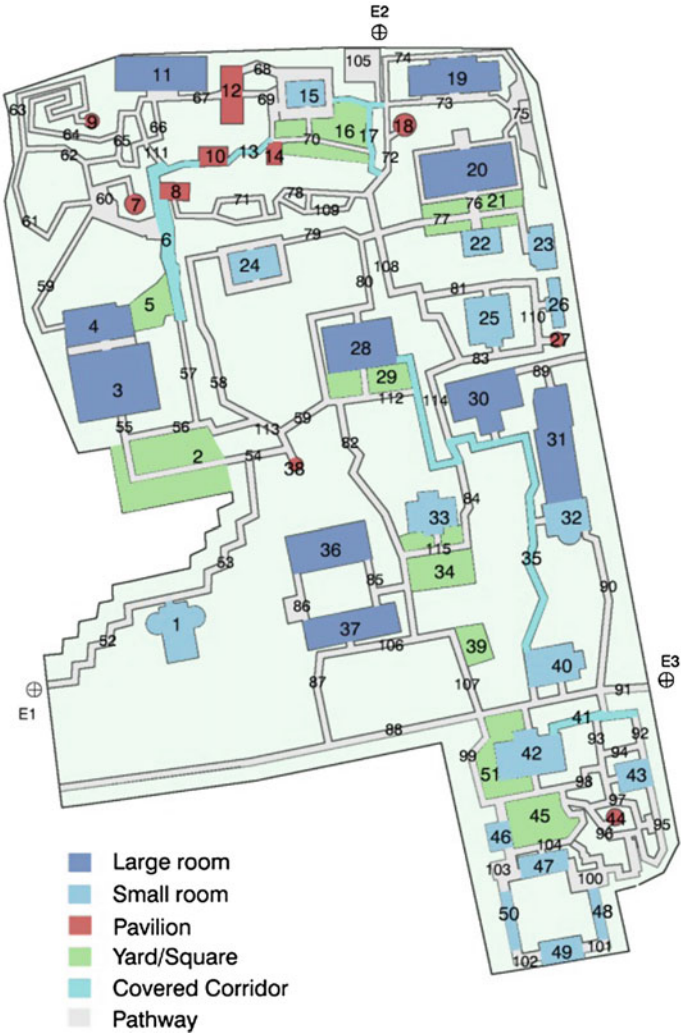


Fig. 6.2 The plan of Yuyuan Garden (notated with six functionally-defined spatial types)

To graph the connectivity patterns of Yuyuan Garden, we adopt the six distinct spatial types identified for large-scale gardens: (1) large rooms, (2) small rooms, (3) pavilions, (4) yards/squares, (5) covered corridors and (6) pathways. The connectivity analysis results (see Table 6.1) show that the pavilions have the highest MD value (MD = 4.73), and therefore are identified as the most isolated spatial type. The results also reveal the pathways as the most integrated spaces, having the highest integration value (i = 12.04). These match the common expectation because in traditional Chinese private gardens the pathways often provide the major connections to other spaces. The least integrated spatial type is the covered corridors (i = 0.67). An inequality genotype, is a ranking of (in this application) spatial types in the order from the highest to the lowest i values [1]. The inequality genotype arising from the data is as follows: pathways > small rooms > pavilions = large rooms = yards/squares > covered corridors.

To complete the analysis, we apply the parametric design system to generate new design instances of garden plans that match the spatial characteristics of Yuyuan Garden, as mathematically measured above. For demonstration purposes, a particular design instance was selected through this final process of design generation and testing.

Figure 6.3 illustrates the parametrically generated and tested connectivity diagram of this newly generated design. In the diagram, the six spatial types of a small-scale garden together with the entrance symbol are represented. This diagram is then translated into an actual garden plan on a specified site (see Table 6.4).

Implemented with Grasshopper, our parametric design system is used for both the design generation and testing. The testing criteria can be flexibly adjusted to suit different selection needs. For example, in Table 6.2, the selected new design generated by the system passes the inequality genotype test as it have the same inequality genotype ranking as the one of the original Yuyuan Garden (defined in Table 6.1).

Table 6.1 Connectivity analysis results of Yuyuan Garden

Spatial types	Number of spaces	Total depth (TD)	Mean depth (MD)	i value	Inequality genotype ranking
Large rooms	10	39	4.33	1.20	3
Small rooms	18	79	4.65	2.19	2
Pavilions	12	52	4.73	1.34	3
Yards/Squares	7	22	3.67	0.94	3
Covered corridors	5	13	3.25	0.67	4
Pathways	63	219	3.53	12.04	1

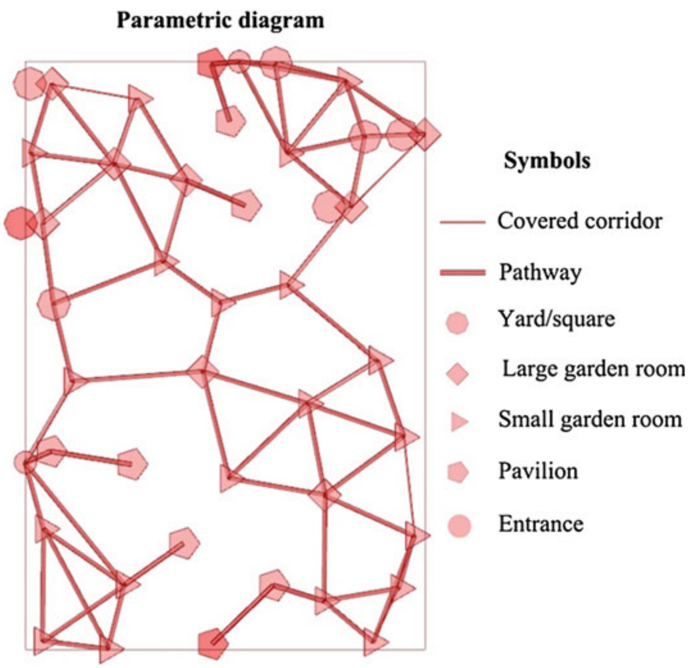


Fig. 6.3 A parametrically generated and tested connectivity diagram

Table 6.2 The selected new garden plan and testing results

Selected new plan	Spatial types	*i*	Inequality genotype ranking
	Large garden rooms	0.75	3
	Small garden rooms	3.00	2
	Pavilions	1.25	3
	Yards/Squares	2.33	3
	Covered corridors	0.43	4
	Pathways	11.27	1

6.4.2 Application Two—Analysing Wangshiyuan Garden

Situated in the Southern Chinese city of Suzhou, the origin of Wangshiyuan Garden traces back to the Song Dynasty (around 1127–1129 AD), although its current form is largely due to the restoration from the Qing Dynasty (around 1751 AD). Wangshiyuan Garden is famous for many of the small courtyards that are scattered throughout the garden, surrounding the central courtyard. Water features are another highlight in Wangshiyuan Garden. Figure 6.4 shows the plan of Wangshiyuan Garden.

To graph the connectivity patterns, Wangshiyuan Garden as a small-scale garden, adopts of the sets of six spatial types different from those for large-scale gardens. Types 1–4 are different rooms divided based on size ranges of the areas. Type 5 (corridors) and Type 6 (courtyards) are more general on the other hand.

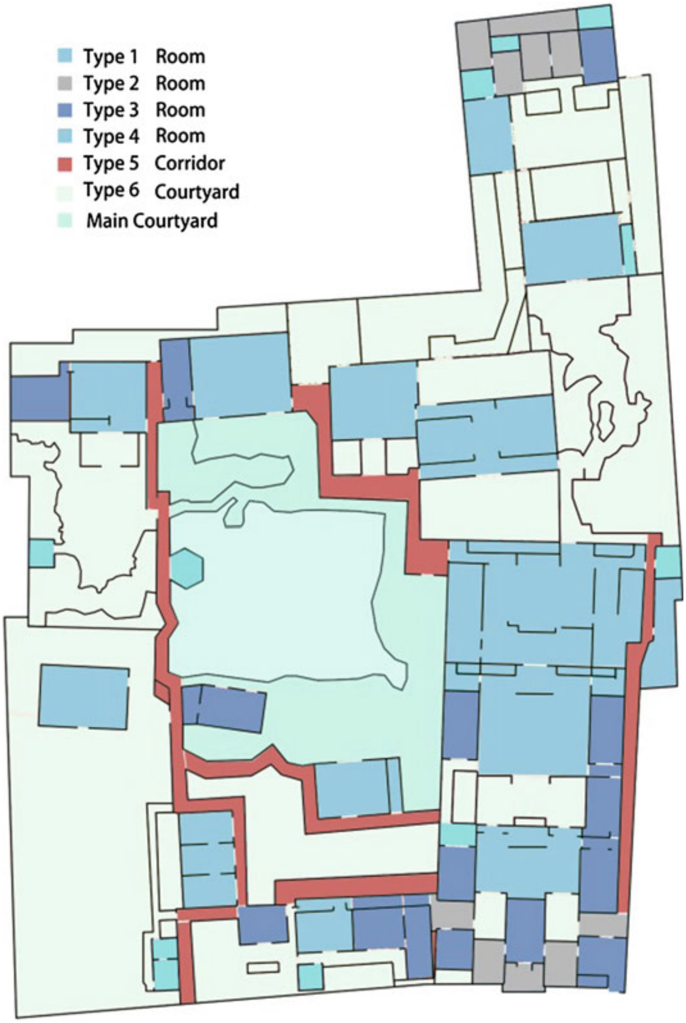


Fig. 6.4 The plan of Wangshiyuan Garden (notated with six spatial types largely according to size ranges of the areas)

In a small-scale garden, most rooms do not possess distinct functions, instead they are scaled to accommodate a range of social groupings and temporary activities. The four room types are used to capture such nature, based on their area sizes. The division of the four room types is achieved by using interquartile ranges to produce a balanced distribution. The details of these four spatial types of rooms together with corridors and courtyards for Wangshiyuan Garden are listed in Table 6.3.

Table 6.4 highlights the connectivity analysis results of Wangshiyuan Garden. From the table we can see that corridors (Type 5) have the highest integration value (i = 1.179). Thus, this spatial type is central to the socio-spatial structure of

Table 6.3 Six spatial types in Wangshiyuan Garden and their area size ranges

Spatial types			
Type 1—Rooms	Number of spaces		11
	Mean area (m^2)		8.32
	Std. deviation		1.92
Type 2—Rooms	Number of spaces		10
	Mean area (m^2)		15.45
	Std. deviation		1.93
Type 3—Rooms	Number of spaces		15
	Mean area (m^2)		25.62
	Std. deviation		3.05
Type 4—Rooms	Number of spaces		14
	Mean area (m^2)		84.24
	Std. deviation		62.99
Type 5—Corridors	Number of spaces		7
	Mean area (m^2)		37.00
	Std. deviation		22.98
Type 6—Courtyards	Central courtyard	Area (m^2)	614.38
	Other courtyards	Number of spaces	18
		Mean area (m^2)	125.22
		Std. deviation	128.67

Table 6.4 Connectivity analysis results of Wangshiyuan Garden

Spatial types	Number of spaces	Total depth (TD)	Mean depth (MD)	i value	Inequality genotype ranking
Type 1	10	435.091	5.801	0.825	3
Type 2	7	452.100	6.028	0.773	4
Type 3	6	384.400	5.125	0.945	3
Type 4	9	341.214	4.550	1.077	2
Type 5	30	325.143	4.335	1.179	1
Type 6	11	344.421	4.592	1.079	2

Wangshiyuan Garden. Courtyards (Type 6) have the second highest integration value (i = 1.079), which is also not unexpected, given that courtyards make up a large proportion of the visually accessible spaces of the garden. The inequality genotype arising from the data is as follows: corridors > courtyards = Type 4 rooms > Type 3 rooms = Type 1 rooms > Type 2 rooms.

To complete the analysis, we apply the parametric design system to generate new design instances of garden plans that share the same spatial characteristics (as mathematically measured above) of Wangshiyuan Garden. This demonstration selects a particular design instance below from the design generation and testing process.

Figure 6.5 is the parametrically generated and tested connectivity diagram of this newly generated design. To generate this diagram, a parametric script has been authored to produce a set of nodes of each spatial type as identified in Wangshiyuan Garden. Firstly, the central courtyard is generated, followed by secondary courtyards. Next, other spatial types are generated with their area sizes and numbers being randomised within the ranges identified. Finally, this diagram is also translated into an actual garden plan on a specified site (see Table 6.5).

Table 6.5 shows this selected new design generation and its testing results. This new garden plan passes the inequality genotype test against the results of the original Wangshiyuan Garden (see Table 6.3).

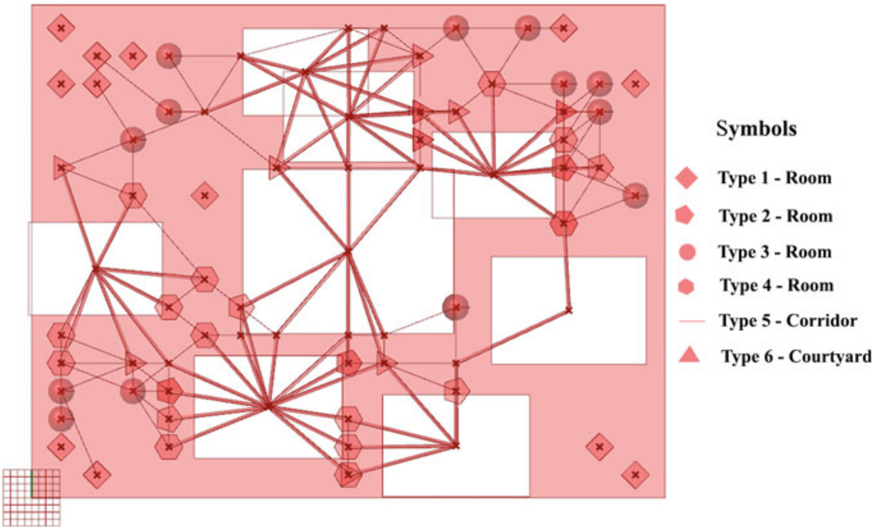
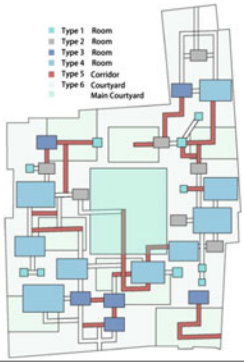


Fig. 6.5 A parametrically generated and tested connectivity diagram (showing specific courtyard structure)

Table 6.5 The selected new garden plan and testing results

Selected new plan	Spatial types	*i*	Inequality genotype ranking
	Type 1	0.837	3
	Type 2	0.7894	4
	Type 3	0.833	3
	Type 4	1.037	2
	Type 5	1.45	1
	Type 6	1.2857	2

6.5 Summary and Future Studies

To compliment the current understandings about traditional Chinese private gardens, this research has developed a computational and quantitative approach to unpacking the cultural DNA of these historical gardens through mathematical measurement and parametric design. The application and demonstration of this approach commences with a Space Syntax analysis of two typical examples—Yuyuan Garden and Wangshiyuan Garden—representing two distinct categories of traditional Chinese private gardens. Next, mathematical measurements derived from the analysis are used as the basis to capture essential socio-spatial patterns in these two garden categories. These quantitative results are then used to direct the development of parametric design systems to generate new design instances that share the same spatial characteristics of the original gardens. The two applications has shown that for the two different categories of traditional Chinese private gardens, properties of spatial planning and design in these gardens can be formally measured, compared and clustered to reveal and generalise essential characteristics. More importantly, these quantitative understandings can be directed to support parametric design of new design instances that share the historical styles.

This research has a number of limitations. Thus they will form the foundation for future studies in order to refine the research. The first limitation is that for demonstration purposes, the focus of the Space Syntax analysis has limited to one spatial quality of these gardens and exemplified through connectivity analysis and on the 2D garden plan only. The ultimate goal of the research is to consider a wide range of spatio-social qualities of traditional Chinese private gardens. Our current direction is to enrich and diversify the analysis to mathematically explore other socio-spatial properties in traditional Chinese private gardens, for example, those associated with "transparency" and "mystery". The visual and permeable properties are being explored using an extensive set of Space Syntax techniques supported

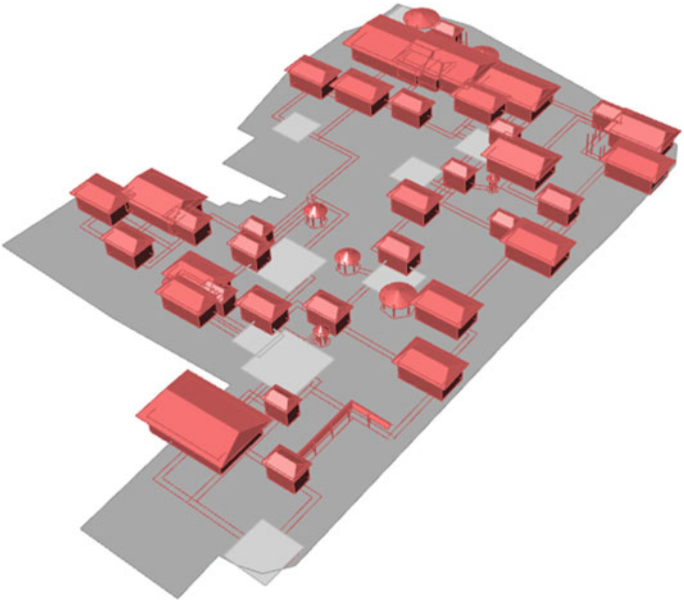


Fig. 6.6 A parametrically generated "new" Yuyuan Garden in 3D

with comprehensive measurements including Intelligibility, Control, Isovist Occlusivity, Isovist Jaggedness, Drift Magnitude, etc. We are also exploring the extension of the research into 3D. Figure 6.6 is a 3D design generated by the current prototype system that aims to capture the socio-spatial characteristics of Yuyuan Garden. The 3D aspects will be thoroughly explored in terms of both the analysis and the generation in the future study.

This chapter has only explored one typical example from each garden category. In the future study, to better validate the research and to strengthen the generalisation of the findings, a larger sample size will be used. Finally more complex and refined mechanism for testing the newly generated designs will also be explored. For example, the current testing demonstrated in this chapter has been conducted against only the inequality genotype of the original garden. However, the further comparison between *i* values can reveal differences about those spatial types. This will require further studies in order to more adequately accommodate and interpret the complex result sets.

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Part III
Morphological Analysis at Urban Scale

Chapter 7
Morphogenetic Habitation Group Formation and View Parameter

Jong-Jin Park

Abstract By observing cities, numerous regular and repetitive structures appear obviously. They mainly reflect simple spatial organizations based on multiplied habitation groups. The interesting thing is that those are intimately related to the history and culture of each place. More complex forms have arisen from the reproduction and transformation of the groups through their own interactions. Diverse urban dynamics following group formation on a local scale can be observed and developed. In addition, the dynamics can be represented by simple elementary figures and symmetry operations. The study as a part of urban morphogenesis contributes to urban morphology analysis and simulation. The view parameter in particular can newly define urban dynamics as a new cultural element in contemporary cities.

7.1 Introduction

In the history of mankind, "habitation" doesn't signify only a place for dwelling but also a sort of transcendent cultural heritage. The habitation has been developed on similar or different cultural backgrounds in a specific place. Here, we emphasize the scale of group. This scale reveals the most basic spatial structures of the habitation. On the basis of the scale, many complex structures can be represented in simple geometrical manner. Furthermore, we consider the act of seeing as a particular condition, which is one of the most basic and usual human needs. The value of view can be highly treated in global cities related to high density, safety, and other environmental constraints. Otherwise, it can be applied to some specific physical situations or social conditions. The view can be a specific parameter to define the characteristics of particular habitation group arrangements.

Firstly, we define some conditions of habitation groups and classify them into a few basic figures. Secondly, we clarify group formation process based on the figures' transformation. The transformation represents more complex built envi-

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_7

ronment with the notion of Morphogenesis. In particular, in terms of cultural value, new investigation of the group formation with view parameter will allow new organization forms of habitation groups. It is not so long time ago that natural environment was a negative element for humans. And it was an inevitable factor to overcome. Otherwise, one of the essentials for today's top residential condition is whether people can perceive the natural environment or not. The view quality is one of the luxurious and valuable subject in modern everyday-life. The Hedonists' romanticism has taken a large cultural value of the Swiss daily life today by achieving visual connection with nature through the specific habitation group organizations. The paper is mainly composed of new theoretical notions for urban group dynamics based on cultural phenomenon of cities.

7.2 Habitation Group and Dynamics

7.2.1 Definition of "Group" and "Invariant Form"

Today's cities seem to be a chaotic universe. In reality, however, we can notice the presence of regular and repeated structures. Many residential buildings, that constitute a great proportion of the construction environment, compose similar spatial organizations based on limited simple geometric arrangement. In this analysis, we will focus on a scale of 'group' that takes a part of new multi-scale model. The group can be defined as a set of components having certain common properties. In our model, the habitation group is conceptually defined from a set of residential buildings (entities) that have certain common properties: the program, proximity and geometric shape. Thus, in language of sets, a group is defined by: $HG = \{Hn/n \geq 3\}$, n is the number of buildings of the group. Two similar entities in proximity form a couple and require a third one to form a group. By observing the phenomenon of group related to urban sprawl, are easily identified certain regular and repeated figures.

We present some simple geometries such as line, triangle, square and circle as "invariant forms" to represent spatial organizations even though in reality they are sometimes difficult to perceive or transformed into complex shapes. These organization figures adapt themselves to needs and requirements of society. Across the generations, people search for symbolic values from the organizations. Particular geometric figures appear and adapt themselves according to the anthropological value, the society, the need and the symbolic value [1].

7.2.1.1 The "—", Straight Line: Individuality, Efficiency and Orientation

"Straight line and minimum distance from one point to another". This type is one of the most common configuration. A linear space can be maintained by regularly

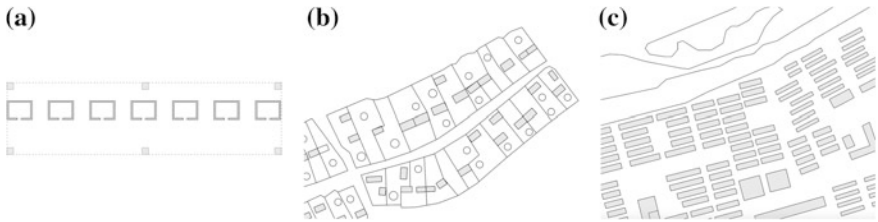

Fig. 7.1 **a** Plan of Yokuts Tule Lodges, South America. **b** Houses in Ulaanbaatar. **c** Apartments in Seoul

disposed cells as a whole (a). Otherwise, it is often emphasized by linear distribution element such as alley or gallery (b). It becomes an effective typology for collective housing with simple corridor space. The bar-type housing can be oriented toward the south to maximize climate benefits. It also corresponds to inherent cultural aspects (c) (Fig. 7.1).

7.2.1.2 The "Δ", Triangle: Diagonal, Communication, View and Symbol

"Three points and three sides", a triangular figure in primitive farm house is obtained by connecting three cabins; respectively used as a dwelling, a barn and a granary (d). On the lakeside, repetitive triangular configurations reduce vis-à-vis problem and maximize visibility towards lake Léman (e). In case of the L'Enfant plan for the city of Washington, triangle setting according to the principle of Baroque is applied to main axes integrating symbolic monuments of the city (f) (Fig. 7.2).

Fig. 7.2 **d** Primitive hut, Africa. **e** St-Sulpice, Switzerland. **f** Plan of Washington, USA, public domain, Wikipedia

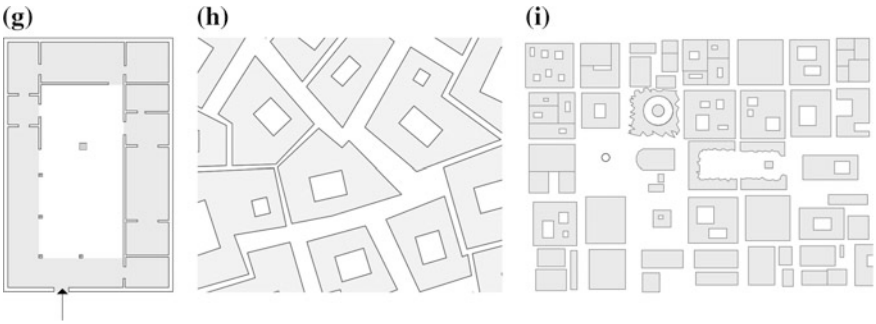

Fig. 7.3 **g** Courtyard and iwan, Uzbekistan. **h** Houses with courtyard, Morocco. **i** Lots of Guadalajara, Mexico

7.2.1.3 The "□", Square: Inside/Outside, Rationality, Flexibility

"Rationalization of space with right angles", the square is the most universal figure for habitation. This form enables a useful clear space. In addition, a symbolic center of universe appears from the square. The iwan is the heart of house: a box volume, raised above the courtyard, supported by one or more columns [2]. The iwan house in Uzbekistan (g) makes sense with its square figure. "Y" branch typed self-organized housing with inner courtyard appear on group scale. The courtyard allows, for example, a sort of visual privacy profoundly related to Middle Eastern culture (h). On the other scale, repeated square blocks on perpendicular layout are applied to collect land and harvesting taxes in a rational way. The layout is often found in many colonial cities in Latin America with more varied patterns (i) (Fig. 7.3).

7.2.1.4 The "○", Circle: Focus, Defense, Control

"Focus and equidistance", a circle can signify an image of the cosmos. The form of the first shelter that primitive men often took is the circle. In Mongolian nomadic society, the yurt, where all functions are grouped in a circle under one roof enables an easy and effective system based on the modular constructive element (j). The Amazonian tribes arrange their houses in a circle around a central common area. The circle was one of the first configurations that defined their culture [3] based on hierarchy, security and community life (k). The form of circle had been mainly applied for defense in the Middle Ages. Several circular type villages had appeared on the stiff mountain or sometimes on the field. The "Suncity" for the elderly also has circular configuration in order to force visitors to pass to the center of the circle where public facilities are grouped together. It permits to make an effective collective control system for security (l) (Fig. 7.4).

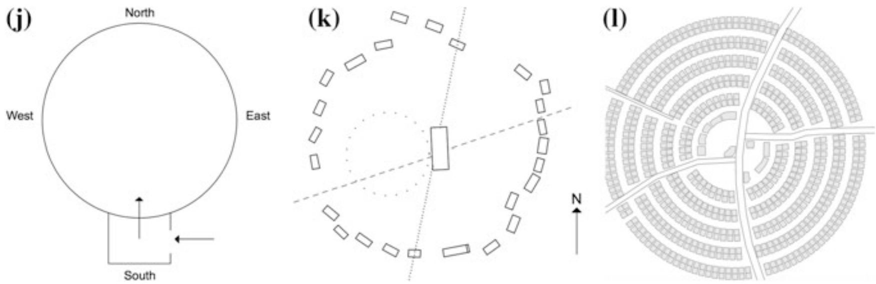

Fig. 7.4 **j** Yurt in Mongolia. **k** Village of Mukanza, Amazonia. **l** Sun City, Arizona, USA

Before studying geometry application to urban Morphogenesis, the meaning of the simple geometries in history was distinguished as above. Consequently, we suppose that the very elementary geometrical figures such as line, triangle, square and circle can be introduced as representative morphological invariants for habitation organization. The notions of group and invariant will take an important role in urban simulation.

These concepts will be used for the abstraction of geographic information and group detection (It has been tested by the algorithm proposed by Dr. C. Plazanet, 2008). This will facilitate to visualize the reproduction and transformation procedure of the geometries related to the group formation. It becomes possible to reconstruct a sort of overall urban morphology by combining well the elementary organization forms and symmetry operations: reflection, translation, rotation, scaling.

7.2.2 Morphogenesis Growth Laws and Group Dynamics

7.2.2.1 Growth Laws

Morphogenesis, that is to say all the mechanisms explaining the reproducible appearance of structures and controlling their shape [4]. Here, Morphogenesis growth laws reinterpreted by lab. UTA-EPFL are conceptual regularities or principles related to urban morphological transformation. The laws allow us to explain, experiment and predict certain urban dynamics or group expansion results. The following descriptions can be also useful for automatic simulation for actual cities in transformation. Otherwise, the applied method using successive maps is archaic but effective to establish the laws.

Process to define the laws:

- *chronological observation (1900–2000) focused on habitation groups' transformation*
- *selection and reconstitution of transformations*

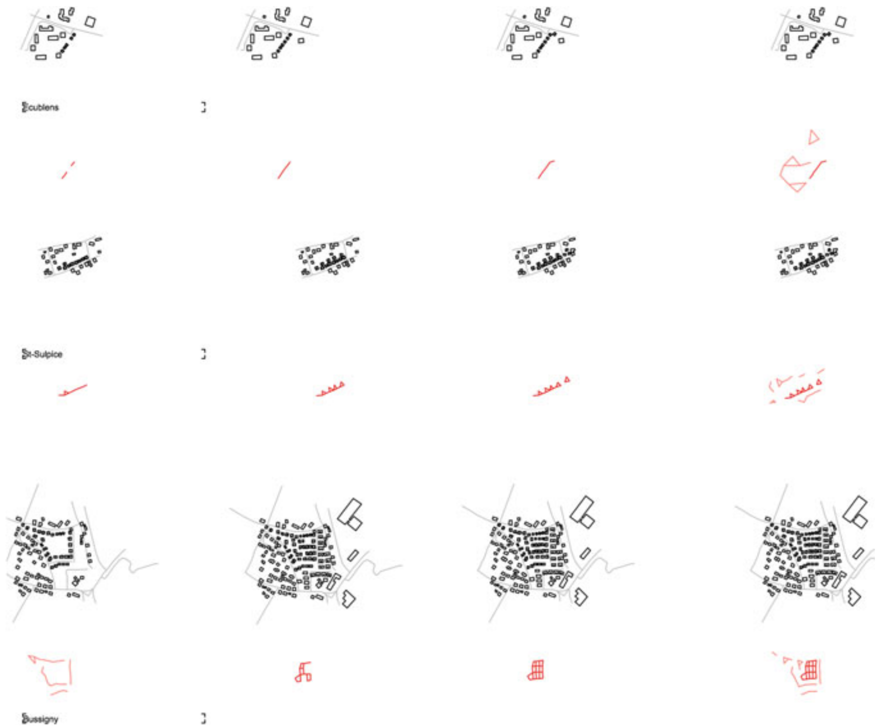

Fig. 7.5 Observed representative group transformation examples in West-Lausanne

- *classification and generalization of regularities*
- *designation of "laws"*

We could observe some regularities from representative cases in West-Lausanne agglomeration area, as shown in Fig. 7.5. They allowed us to generalize four characteristics.

- ***completeness****, completion of continuity to determine a group*
- ***extension****, growth at the ends of a group*
- ***densification****, filling up a defined group*
- ***dissociation****, decomposition of a group according to the presence of external or internal factors*

7.2.2.2 Group Dynamics

The groups continue their dynamics by adding or removing adjacent entities. The transformation of the groups is constant both in time and space. The synthesis of the group dynamics below can be characterized by the reproduction of entities. The

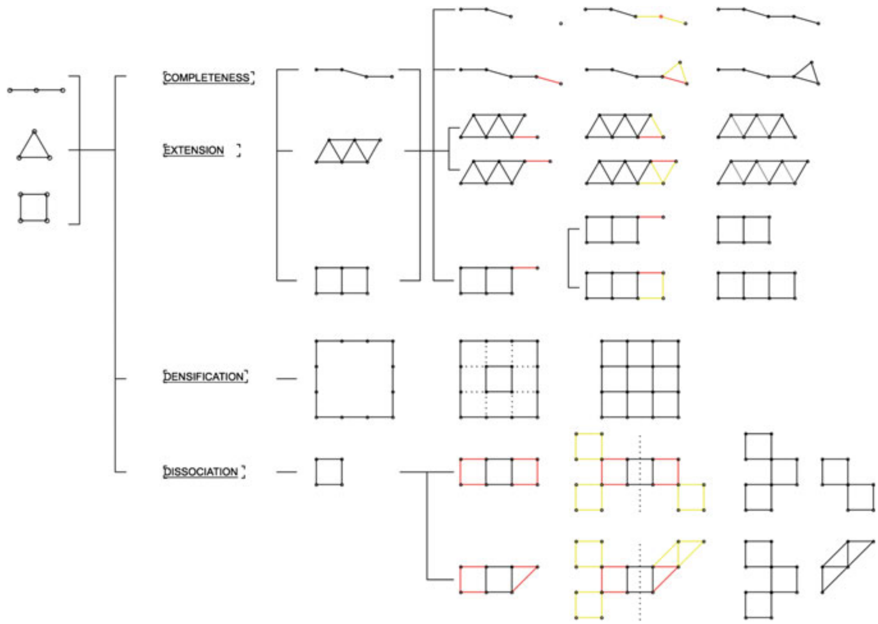

Fig. 7.6 Simple elementary figures with reproduction and transformation

three figures (line, triangle, and square) "grow up" by the successively attached entities or groups nearby. Basically, the location of new entities may be influenced by the group evolution governed by the growth laws, as shown in Fig. 7.6.

The organization form of groups becomes more complex. But it can be explained by symmetry operations. For example, the extension case based on the regular triangle above consists of two symmetrical operations (translation + inversion). The case of densification defined by projection operation is more particular. Consequently, we could simulate the urban transformation in group scale by identifying the different growth patterns within the urban environment and applying symmetry operations. The formation of "wallpaper" groups [5] based on motif and pattern also help understanding the group transformation with symmetry operations. A distinguished observation can be notified from the analysis with the four laws proposed: habitation groups try to recompose themselves by searching a regular distance between the components to achieve the quality of balance and continuity resulting certain density of their environments. This is the notion of "equidistance". The concept will be significant to optimal urban simulation later. The equidistance is thus a decisive property of the group dynamics in nature and in the morphology of cities.

Furthermore, the presence of environmental context is very significant on the group dynamics. It is necessary to add three factors influencing directly the group dynamics: "resource, limit and proximity".

- ***resource***: *symbolic elements or distribution networks can improve or lead growth of groups, e.g. a street, a park, a lake* etc.
- ***limit***: *elements that restrict or prevent growth, e.g. an express highway, railroads, a lake,* etc.
- ***proximity***: *effective distance allowing group's continuous growth.*

7.2.3 View and Dynamics

We present here particular group formations related to "view" parameter. The view represents an important new value in contemporary cities with density phenomenon. People search for open-area or higher floor for a better visibility, even if it costs more. In Switzerland, the hedonistic tendency called "a room with a view" became an issue of great importance for a decency. Most lakeside areas have been transformed into attractive but expensive zone for habitation [6]. Many of immobile agencies consider carefully the tendency with modern life style. It's evident cultural aspect around qualified natural environments for everyday life in Switzerland.

Three characteristics related to the view subject differentiate the optimal geometry organization;

- *question of visibility (toward the attractor)*
- *security question (see without being seen)*
- *density matter (lower or higher)*

On this paper, we principally discuss the question of visibility toward symbolic attractor, as an important resource for habitat group formation and transformation. We observe that the symbol has a power to organize programs in a radical way. We will illustrate it through some case studies. The dynamics that results from the visual connectivity between the symbol and other entities relies mainly on the notion of perpendicularity with symmetry rules.

7.2.3.1 Symbol and "Circle" Type Dynamics

The form of most cities and villages in the Middle Ages has its origin in protection and trades. It can be represented by a circle with a focal point as a main building, for example a cathedral or a castle. Around this hyper symbolic power building, other entities are organized compactly and organically (Fig. 7.7).

The other entities try to seek the best location to have direct visual link with the central building. A sort of hierarchal location of buildings is done around the symbol. It results from the notion of perpendicularity. In reality, this perpendicular angle changes slightly in response to the morphology of site such as the slope, contour, limit. The most habitations follow this rule to benefit the symbolic view. And, the increase of construction can be described by rotation symmetry operation

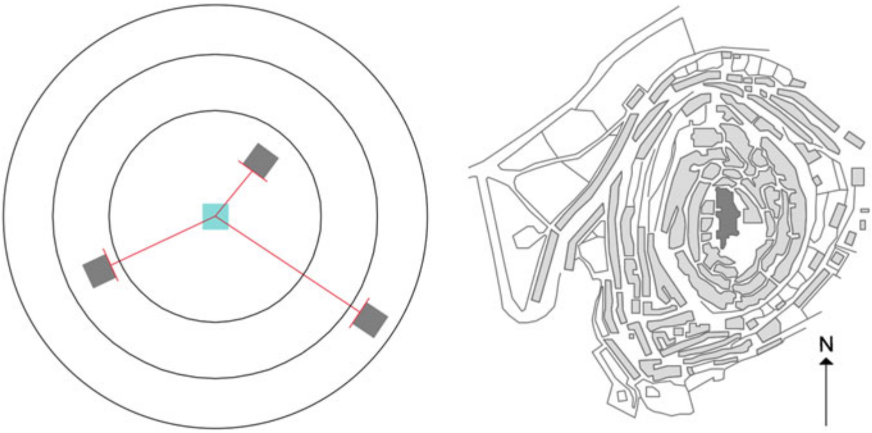

Fig. 7.7 Analysis scheme, Palombara Sabina, Rome

to a certain limit. Many ancient villages on the mountain in Europe were formed with this phenomenon. Otherwise, in case of Zermatt, Switzerland, a singular mountain summit called 'Matterhorn' has reoriented housings and accommodations. In most of cases, the buildings are seeking a maximized and direct view towards the summit. It supposes that the value and effect of a symbol can be very significant for the urban dynamics today.

7.2.3.2 Visibility and "Triangle" Type Dynamics

We perceive lakes as an attractive environment in everyday life thanks to several values; the quietness, contemplation, leisure, sport and promenade etc. The St-Sulpice (West Lausanne) confirms distinguished dynamics of the attractor with notion of perpendicularity and translation. Many built entities are spread quickly around the lake with a simple rule: have a maximum clearance and acquire the very best view. Thus, the houses try to find a possible right angle towards the lake and spread themselves linearly (Fig. 7.8).

We propose to zoom-in a residential quarter. We can observe numerous houses grouped by triangle figure. This is a particular case of the urban growth model. The triangle organization ameliorates the quality of view in the lakeside area of low density. For example, at the edge of St-Sulpice village, we identify some essential elements such as the lake, distribution axis, and smooth slope influencing the location of housing groups. A simple geometry driven from the quality of view toward the attractor was established (Fig. 7.9).

If we suppose to not consider the quality of view, a square type organization can be appeared. But, in reality, the houses are naturally shifted to maximize visibility between the neighbors. Thus, the clearance for visibility produces a zigzag organization along the distribution line, as shown in Fig. 7.10. The distance and slope

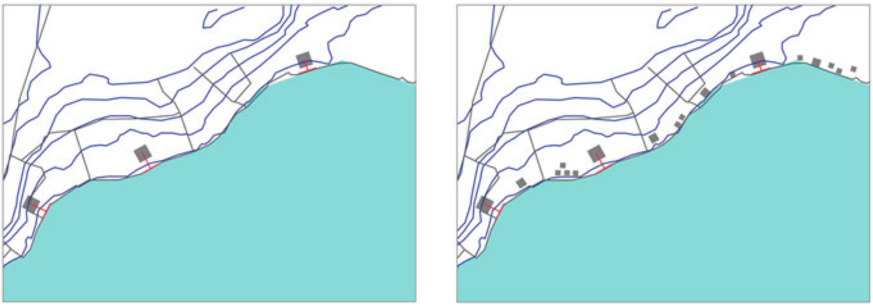

Fig. 7.8 Perpendicularity and translation of houses

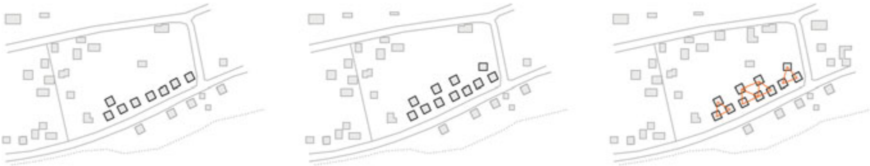

Fig. 7.9 Extension of villas by triangle group formation, St-Sulpice

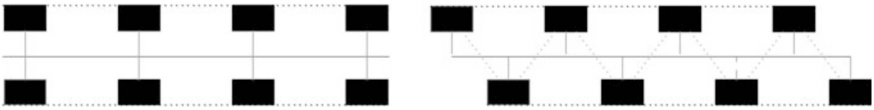

Fig. 7.10 Optimization and zigzag shape to increase quality of view

rate modify slightly the zigzag shape to fit the environment. The triangle group formation could be widely spread on the lakeside owing to the particular conditions.

7.2.3.3 Topography and "Square" Type Dynamics

The sprawl of housing groups has an influence directly on urban form on a local scale. For example, several housing entities come together gradually according to certain logics in the immediate vicinity of the Grand-école, EPFL. They can dialogue with divers factors such as topography, orientation, view, infra-structures, attractors and etc. The physical factors make an influence and initiate an effective organization for an ideal group formation on the site. For example, the main road in red connects vertically with secondary networks. Several groups start to occupy the site along the secondary distribution. At the same time, it requires a sort of regularity following the notion of perpendicularity. The stiff slope engages with enough clearance of visibility towards attractors such as EPFL, Jura and lake Léman.

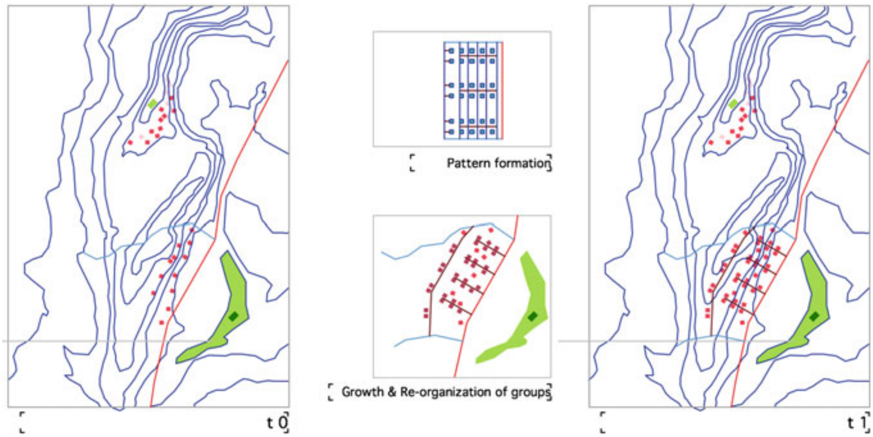

Fig. 7.11 Dynamics illustration with topography

It permits mainly square type group organization unlike the triangle system near the lakeside. The suitable topography considering the view quality enables thus to produce the square-type formation of optimal habitation groups with fully integrate the environment (Fig. 7.11).

7.3 Discussion

Through the historical research focused on space organization, we proposed the following simple elementary figures, "—, Δ, □, ○". The geometric properties of the figures allowed to describe diverse habitation group organizations. Furthermore, the reproduction and transformation of the simple figures based on Morphogenesis laws was important to develop four urban dynamics: "completeness, expansion, densification and dissociation" and three environmental factors: "resource, limit and proximity." In addition, we supposed that the "view" as a cultural parameter took a particular place for urban dynamics. Particular geometric organizations in West-Lausanne where is intimately related to the suburban lakeside environments were analyzed by the notion of perpendicularity and symmetry rules. The group formations based on the "view" parameter could be developed more profoundly by mathematics and algorism integration. The research contributes to the alternative urban morphology theory and simulation to describe transformation of cities. Furthermore, the 'habitation group growth simulation' (developed by Vitor Silva) [7] and 'urban growth simulation with(without) visibility parameter' [8] based on a local scale were developed. The results demonstrate the self-organization of new entities seeking their ideal location in responding to other entities. Those simulations are still in simple demonstration versions. Divers realistic simulations should be developed and validated profoundly with more precise parameter applications.

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Chapter 8
From Open Plan to Public Space: 'Seine-Arche' Project and Urban Morphological Evolution in France 1960–2020

Jérôme Treuttel

Abstract DNA and origin of ideas which have generated the major urban design project of "Seine-Arche" near Paris in the 2000–2010's years. The radical break that occurred in the 1980's in the urban ideas have seen the pictorial references from cubism and abstract art change reference to classical garden and Haussmann design. This is not only a formal change but also a policy reversal, the public space has become the major element of urban composition.

8.1 Introduction

This lecture deals with projects' DNA and the origin of ideas which have generated present urban forms. The construction of a new part of the city results from a complex process which involves many different actors. Building cities is both slow and gradual. Nothing happens by accident, the conception and design of what will be actually realise cannot be done in a isolation. It must be the result of a complex process that we need to clarify step by step.

The analysis and the detailed description of a major project such as 'Seine-Arche' (Fig. 8.1) might be useful to understand the complicated genesis of urban forms. The architect is one of the many links in this chain.

The plans and projects designed by TGTFP use a number of guiding principles which come from recent history of ideas in the field of the urban planning development.

In order to explain the main ideas that guided 'Seine-Arche' project, it will be necessary to first go back over the history of urban planning in France. It is especially important to mention the radical break that occurred in the 1980s. During this period, the modern urbanism theory during which real estate objects were

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_8

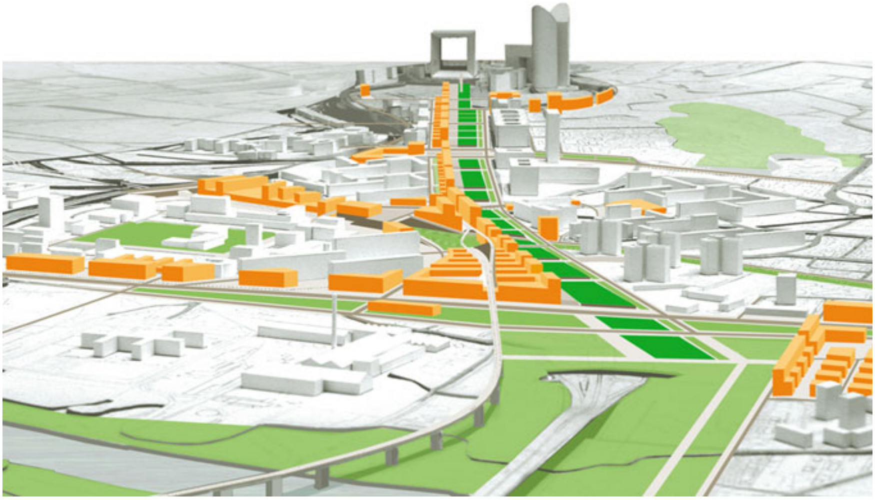

Fig. 8.1 Nanterre city, 'Seine-Arche' project, TGTFP. How to explain the genesis of this urban form

floating in the greenery stopped. It was replaced by a return to historical urban forms such as alignment along the streets, axis and perspectives in urban spaces.

This Copernican revolution within the urban theory results also from political issues. Indeed, the 'glorious thirty' took place in a context of a triumphant liberalism and economical dynamism. The 1980s took interest in urban space in all its aspects. This reversal had some significant impact because urban designers have devoted themselves to draw empty spaces (the public ones) and to regulate the construction of the full spaces (the real estate programs).

Symbolically and politically, the project of 'Seine-Arche' results from the resistance of the popular neighborhood of Nanterre City against the development of the Central Business District (the most powerful of Europe) called la Defense.

This lecture will be illustrated with twelve illustrations and divided into three parts:

8.2 The Urbanisation of the 1960s and the Open Plan

Planning according to real estate programs, empty and full spaces. Pictorial references from cubism to abstract art.

The 30 years period that followed the second world war has been very productive in terms of construction and transformation of European cities, especially in France. The reasons for this intense activity are related to destruction of war and above all to the rapid transformation of society i.e., the postwar baby boom, the rural exodus as a result of progress made in agriculture, the decolonization that caused the return of numerous French citizens from Africa, etc. It must also be said that, between the two wars (from 1920 to 1940), very few constructions had been built in France. Therefore, in 1945, our urban landscape have changed very little since 1900.

The period of reconstruction (from 1950 to 1980) was a real opportunity for architects and urban planners. They were quite exited to apply their urban theory which have been born during the 1930s. Those ideas had been summarised within a essential document, entitled the «Charte d'Athènes». This paper was drafted by a group of avant-garde architects and it was published by Le Corbusier in 1947.

This dogmatic document proposed to raise buildings and to split the urban functions into four categories, which are living, working, moving and playing.

The implementation of those very simple theories has been especially violent. The historical and old city was doomed to destruction, except for the most significant monuments. The «plan Voisin» (Fig. 8.2) for Paris was the first example illustration of this new urbanism.

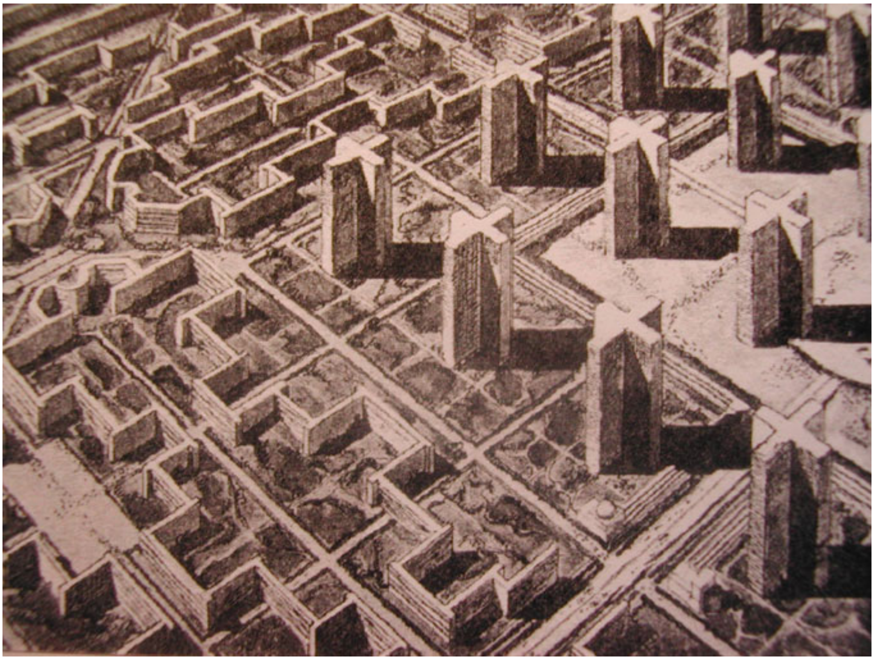

Fig. 8.2 The urban theory which have been born during the 1930s: Paris city, 1925, «le plan Voisin», Le Corbusier. Twenty years later, those ideas have been summarised by the «Charte d'Athènes»

In order to draw their plans, architects were not referring to the traditional city but to modern art. Plans were inspired by master painters as Mondrian (Fig. 8.3) and Aléchinsky (Fig. 8.4) or Jean Arp.

Some significant projects which were highly publicised, provided the inspiration for architects of the time. For example, the «plan Voisin» for Paris by Le Corbusier

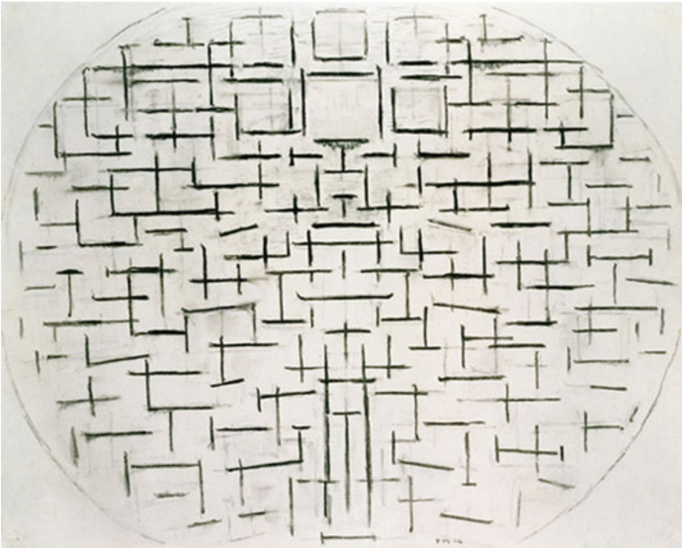

Fig. 8.3 Piet Mondrian «composition» 1914. The drawing of new city referring at the abstract pictural art

Fig. 8.4 Alechinsky

Fig. 8.5 Drancy (near Paris) citée de la Muette 1935, Marcel Lods architect. One of the first application of the «charte d'Athènes» theory

(Fig. 8.2) and the «Cité de la Muette» in Drancy by Marcel Lods (Fig. 8.5). This latter was the first huge residential complex built within the suburb of Paris a little bit before the war. Marcel Lods was an avant-garde architect. He was co-editor of the «Charte d'Athènes».

The Emile Aillaud project for Grigny «'La Grande Borne» (Fig. 8.6), the «cité des Froides Bouillies» (Fig. 8.7) and many other projects (Fig. 8.8) were directly inspired by pictural models.

8.3 The New Urbanism

Taking into account public space, designing empty spaces before the full ones. References to the art of gardens and to the classical city.

From the beginning of the 1970s, the urban planning of the 1950–1960s had been questioned by the population, by politicians and finally by architects them-selves. After a brief period of hesitation towards an utopian futurism, architects went back to the past and cities' history. This was translated into a return to the streets, to the «haussmannian» boulevards, to the avenues (Figs. 8.9 and 8.10), to the large public spaces and to regular lines and the french gardens of Le Nôlte (Fig. 8.11). There was a return to the Baroque and classical old town inside which the empty spaces are planned before the buildings them-selves.

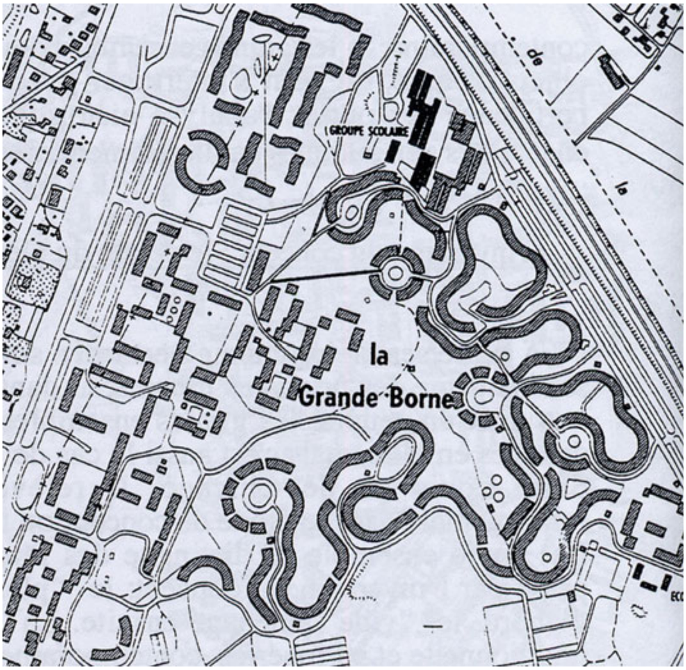

Fig. 8.6 Grigny (near Paris) citée de la Grande Borne, Emile Aillaud architect. Inspiration from Alechinsky or Jean Arp?

Fig. 8.7 Ris Orangis, «cité des froides Bouilliées», a typical nex district of the sixtie's in the middle of suburban houses

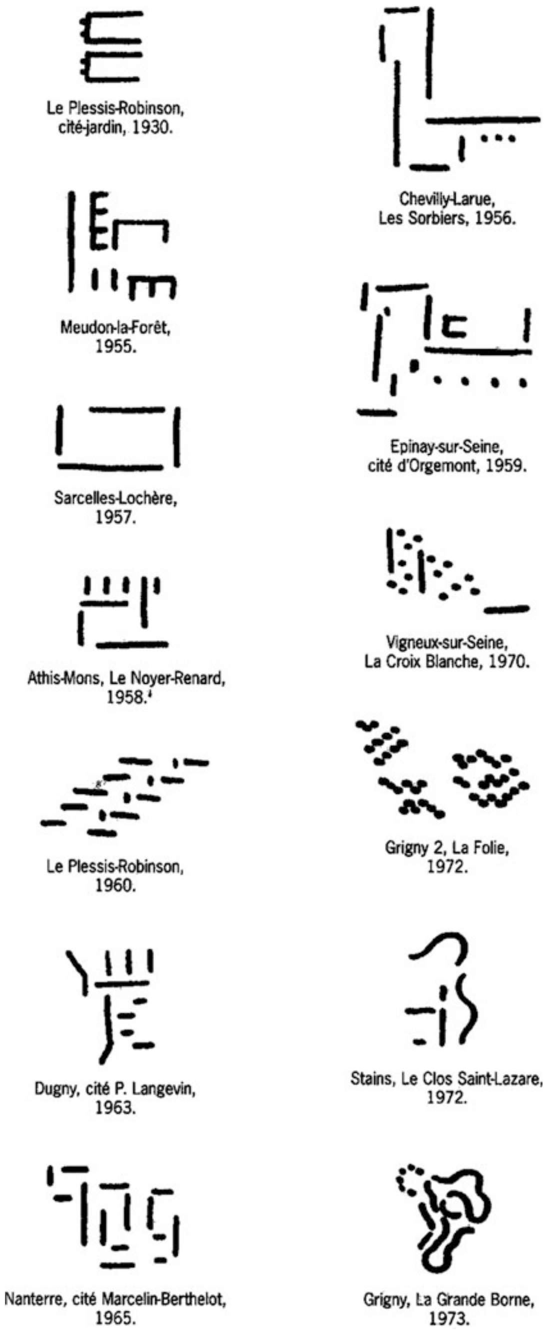

Fig. 8.8 Comparison morphologic of twelve new district constructed during the sixtie's' near Paris

Fig. 8.9 Paris, Haussmann boulevard Saint Germain

Fig. 8.10 Paris, Haussmann avenue de l’Opéra

Fig. 8.11 French garden of Le Nôtre, the reference of a perspectival vision

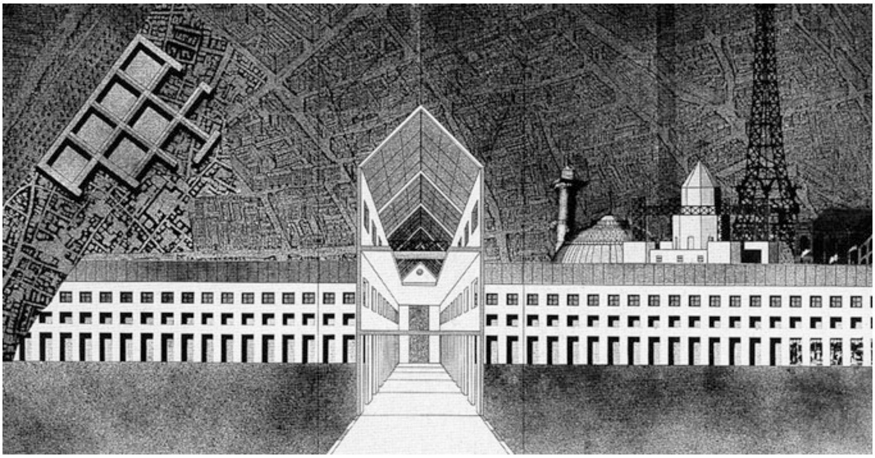

Fig. 8.12 Architects went back to the past cities' history: Aldo Rossi, project for the Halles district in Paris, 1973

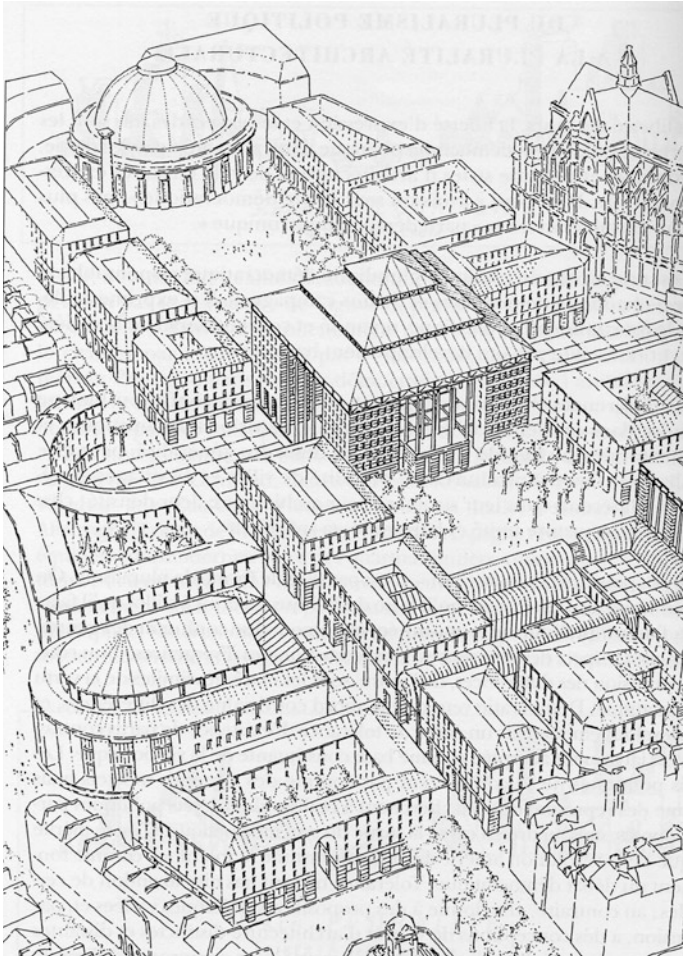

Fig. 8.13 Robert Krier, project for the Halles district in Paris, 1973

All the new generation of architects in the 1980s, questioned the previous ideas and gave up the «grands ensembles» i.e., high buildings complexes freely put in green spaces and wrapped by speed-ways all around. Architects decided to re-build what the cities from the 19th century had slowly established in Europe, Some significant projects and emblematic urban competitions brought some new names, such as Aldo Rossi, Robert Krier to light. One example is the huge idea competition launched for re-planning the old market building in the city centre of Paris.

The classic style of Haussmann period of Paris (Figs. 8.9 and 8.10) was rehabilited, place and monument, régularity of the constructions was the new way of thinking urban design.

In terms of artistic references, a return to the regular lines of gardens occurred. Architects replaced the abstract art by a perspectivist vision. (Figs. 8.12 Aldo Rossi and 8.13 Robert Krier architectural competition for the Halles district in Paris 1973).

8.4 The 'Seine-Arche' Project

A legacy of French gardens' drawings and Haussmann.

The special feature of 'Seine-Arche' project is to be located in the continuation of the development of the business district of la Défense. It is in a exceptional situation regarding to a historical axis which was designed by Le Nôtre: the «Champs Elysées».

The business district of «La Défense» was built during the glorious years (1960–1980). Its urbanism is obviously modern. Indeed, it is composed of very high buildings freely positioned in a concrete slab and not in a garden. Underneath the slab, there are all the speed-ways and the transport infrastructures network (Fig. 8.14).

Fig. 8.14 The site of the Seine-Arche project. In front of the image: the modern district of sixtie's, block plan as Mondrian design

When the City of Paris decided to pursue its business district's growth beyond the Great Arch, a very furious debate about urban shapes occurred. Several competitions were launched and finally, the «Terraces of Nanterre» project was chosen. This choice is directly related to the change in ideas and mentalities within the all stakeholders in the city.

The project is based on creation of a major public space. Seventeen terraces spread out from the Great Arch to the river (Fig. 8.15). The buildings are built to serve the public space. Their height and their size was defined in advance. Programs

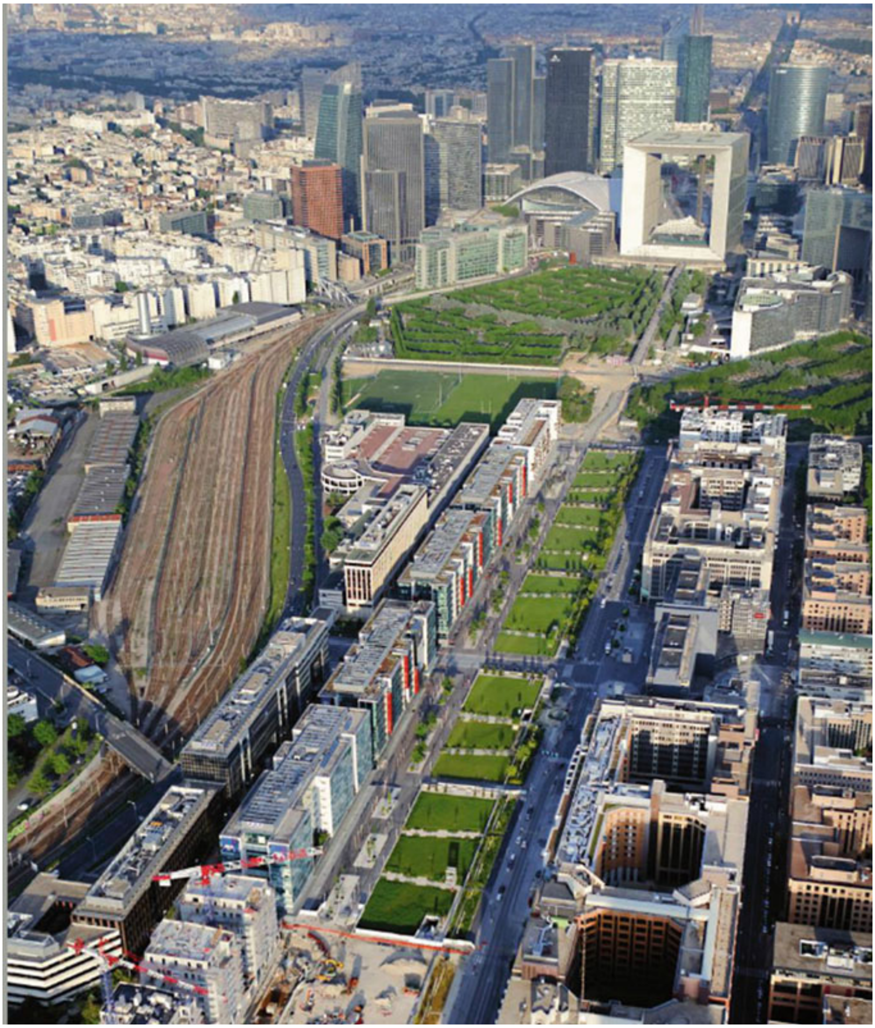

Fig. 8.15 Seine-Arche project: «Les terrasses de Nanterre» A new classical and perspectival vision

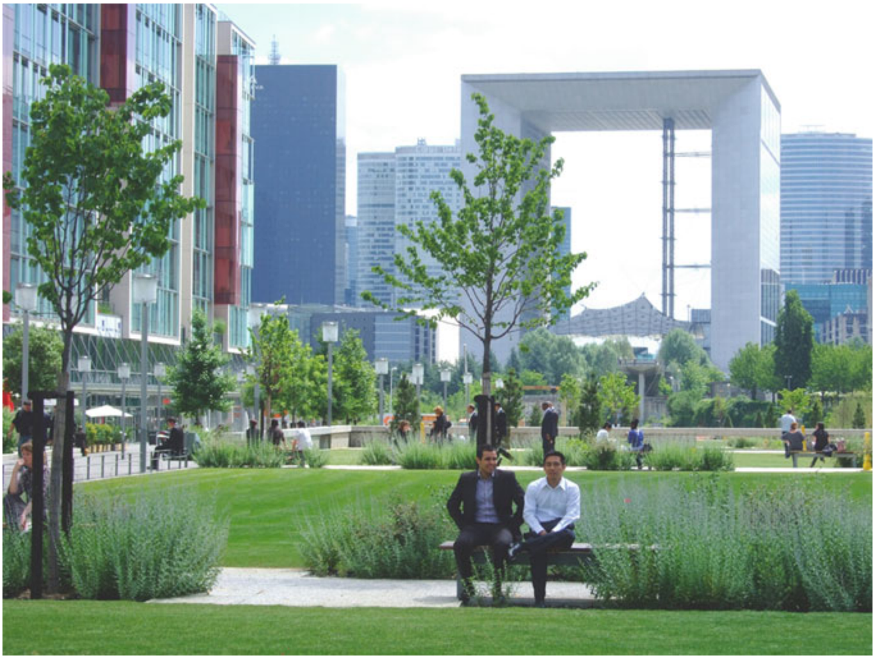

Fig. 8.16 Seine-Arche project: «Les terrasses de Nanterre» urban gardens

must necessary slot into volumes which are designed in advance even if their activity is very different i.e., housing, offices, hotel, even huge concert hall.

The link between the terraces and the aligning of buildings takes inspiration from the art of Le Nôtre's gardens (Fig. 8.16). Le Nôtre was use to pay close attention to issues of leveling and perspectives. The buildings them-selves are coordinated in order to generate distinct continuity for inhabitants.

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Chapter 9
Imagining the Paths of Cities: A Case of Korean City

GwangYa Han

Abstract This paper presents a model for Korea's cities that describes the characteristics of growth pattern and morphological transformation. To do so, it uses the case of 'HanJoo (한주 韓州)', a hypothetical in-land city on Korean Peninsula, which is developed based on a set of preliminary studies of several Korean cities. The narrative model using illustrations is intends to examine the process of four-staged developments in the central urban area: (1) walled town to regional center (675–1890); (2) town expansion via grid blocks (1890–1945); (3) industrial district and factory complex linked by inter-city highway (1946–1994); (4) new community development and massive suburban growth (1995–present). The study, anticipating further subsequent work in the future, attempts to identify the growth, change and decline mechanism of the built environment in both old and new cities. The findings can help guide decision-makers whose public actions are likely to influence a city's development process and direction, with more informed planning alternatives within both larger city and larger region.

9.1 Introduction

It is interesting to consider a city as a 'growing object' and understand the process of its change. This is because cities do not expand in a singular direction under one set of circumstances. Rather, they evolve by compromising multiple social values with authoritative structures over a long period of time. How were Korean cities formed, and how have they developed? Under what process have ancient cities, old cities, and new cities that we come across in our daily lives been built, and what

A set of contents included in 3. The Growth Phases of HanJoo are translated in English from [1] which was published in Korean.

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_9

relationships do they have with each other? What characteristics do Korean cities have, and how are they different from other cities around the world?

Considering the aforementioned questions, this paper aims to present a narrative model for Korea's cities using a morphological perspective to describe the characteristics of growth and change of a city. It introduces the case of "HanJoo (한주 韓州)," a hypothetical in-land city on the Korean peninsula, which was developed based on a series of preliminary case studies of several medium-sized historical Korean cities [1]. The HanJoo model intends to examine how central urban areas change—a common phenomenon observed in Korea's historical cities—by using a set of illustrations of ongoing development to demonstrate how a city is born, grows, and deteriorates.

The model, based on historical research and field surveys of several cities, explains the characteristics of HanJoo's physical form and considers the following three aspects: (1) the functional relationships that HanJoo has with adjacent cities; (2) the physical and natural characteristics of the environment in which HanJoo was founded and grew; (3) the sequenced change of structural organization revealed by HanJoo's ongoing growth.

This study views the cities as being shaped and reshaped by historical inertia as well as social and cultural values. Thus, cities are the residual products of constant, yet conflicting, changes in broad geographical contexts. Meanwhile, the shapes of cities are generated by both organic arrangement and deliberate intervention of major public and civic programs in a city's center.

In the hypothetical setting, HanJoo was a town created in the pre-historic era and it developed into a hub of local influence and administration during the "Three Kingdoms" period followed by the unification led by the dynasty of Shilla (one of the three kingdoms). HanJoo then became a regional administrative center of the centralized government of the Goryeo and Joseon dynasties. The walled town expanded based on an urban grid system during the Japanese occupation. The growth of HanJoo in the modern era was accelerated by land development, firstly for national government-led industrial purposes on the outskirts of cities, followed by city-county government-led residential development in agricultural areas.

Based on these findings, this study characterizes the development paths of Korea's cities as follows: (1) the gradual yet distinct form changes, ranging from fortress town to regional center (ancient town in 675–1890); (2) the intervention of city grid blocks for city expansion (old town in 1890–1945); (3) the development of industrial complexes along with residential zones for factory workers (1946–1994); (4) new developments on the outskirts of cities (new town in 1995–present). Finally, it tries to understand the case of NamWon (남원 南原), GuRye (구례 求禮), SunChun (순천 順天) and YeoSu (여수 麗水) whose development pattern and growth form have not only featured the characteristics of HanJoo, but also have collectively shaped a regional identity along SeomJinGang River (섬진강 蟾津江) in the southern Korea.

This study, while anticipating future morphological research of the formation of cities, attempts to identify the growth, change, and decline mechanism of the built environment in both old and new cities. The findings can help guide decision-makers and city planners, whose public actions and planning intervention are likely to influence a city's development process and direction, with more informed planning alternatives in both larger city and regional contexts.

9.2 City as Evolving Body: Process of Changing Form

A group of previous city planning studies have viewed cities as "growing objects" and tried to explain quantitatively their expansion process. They aimed to estimate the size of new development sites at a proper scale, located in a suitable direction and distance from an existing urban center, using metrical analyses.

However, cities have evolved, far from being a singular product of a particular time, they are a composite of multiple, yet conflicting, social values and governing authorities massaged in a continuous timeframe. Thus, understanding how a city's physical forms shift over different phases is worthy of study [2].

There have been a few meaningful attempts to build a growth model from an architect's view. Key research includes a visual model that details the particular phases of architectural transformations of major buildings in medieval German cities from 1250 to 1750 [3]. In addition, research has been conducted on the cities of Paris and Vienna, which had reshaped themselves in response to the dismantling of fortresses and the introduction of railroads in the mid-19th century [4].

There are cases that explain the process of some elements in cities in a phased approach. A model called "The Story of Paradigm University" uses a series of illustrations and comments to detail the general growing process of American university towns from 1797 to 1997 [5]. Besides, a type of waterfront model using a five-phased sequential development process in the time flow, described the transformation of city waterfronts [6].

Furthermore, an effort was made to understand the relationship of a city's changing structure with the citizens' changing values and ideals based on a case study of Boston [7]. It is also worth noting that a set of illustrative efforts, with explanations of a phased development of ports and roads, was developed as educational material for the general public [8]. This is an advantage, since a city's physical changes can be understood from the perspective of the passing of time.

Meanwhile, few theories have explained how Korean cities were formed and developed during the transition of "ancient city-old city-new city" in a consistent and consecutive manner. Many historical observations have attempted to understand the characteristics of geographical location and physical configurations of Korea's towns and cities whose morphological arrangement were assumed to be guided by a set of underlying ideas, beliefs, and principles, often in comparison with those of China and Japan. In addition, many studies have revolved around the transformation of castle towns and increasingly port cities during the Japanese occupation.

From a cartographic aspect, a limited number of spatial data and maps exist that describe how Korean cities changed over time. In fact, city maps made prior to the modern era were considered conceptualized drawings that portrayed abstract spatial relations of the natural environment, based on 'feng shui (風水)' interpretations, not on measured distance and direction. Thus, there are few modern and contemporary maps that incorporate ancient and old establishments in Korean cities.

In addition, the growth of Korean cities in the modern era was closely guided by both the national government as well as city-county government, mostly for large-scale residential and industrial development purposes in agricultural areas. However, there has also been a lack of theoretical interpretation of such massive land development, mostly centered on the outskirts of cities. Thus, it is difficult to understand how Korea's ancient towns transformed into the old cities under Japanese authority, and how such old cities have evolved into the contemporary ones during the modern era.

9.3 Growth Phases of HanJoo

9.3.1 Location

Korean Peninsula can be geologically divided into inland and coast, with inland noted by its steepness despite of its proximity to coastlines. Thus, rivers on Korean Peninsula with relatively short length, cause frequent flooding, particularly in rain season in summer, which in turn develops large areas of inundated land.

Cultivation of rice on inundated land from 'HanJoo River (한주강 韓州江)' started around 500 B.C. Apart from its rice paddies, 'HanJoo Village (한주마을 韓州村)' was settled below an inland hill with streams and wells. HanJoo Village was located in the midstream of HanJoo River where it changed its course from southwest to northwest as the river passed through 'Π'-shaped valley. As one of major rivers in the Peninsula, HanJoo River passes by HanJoo and turns west, joining 'JinJoo River' and providing the only passage connecting HanJoo with lower lands and coastlines.

HanJoo Village took 'HanJoo Mountain (한주산 韓州山)' located on the village's northeast area as its guardian mountain. On the village's west, north, and east, a series of hills standing 200–700 m, surround HanJoo, blocking cold winter wind from northwest in winter. In addition, southeast winds in summer allowed river boats to sail north from southern lower lands against the flows of JinJoo and HanJoo rivers.

HanJoo Mountain was the only source of energy for HanJoo villagers as it provided firewood. Thus, the amount of firewood available from the Mountain was the fundamental element in determining the size of population as well as the village. Also, HanJoo villagers took foaming spring at a hill in the Mountain as their 'Holy Spring (영천 鈴泉)' where they prayed for rain in draught and held 'HanJoo Holy

Spirit Worship and Festival (한주제 韓州祭)' for prosperity and safety of the village. The Festival eventually developed over the years into an annual event in HanJoo.

'DongBook Citadel (동북산성 東北山城)' located on HanJoo Mountain northeast of HanJoo Village effectively functioned as a citadel against invasions from northeast [1]. Market in was irregularly held at the riverbank around 'HanJin Port (한진포구 韓津浦口)' near Gom Quay (곰나루). Farmers in HanJoo did not possess land tenure for rice production, which was instead owned by local nobles and governments. Thus, farmers were not much motivated of excess production which might have accelerated the development of permanent market. Also, high level of humidity in summer resulted in early adaption of salt as a preserving agent, and distance from nearby village to prevent the spread-out of plague.

9.3.2 Ancient Town and Town Wall (675–1890)

By 676 A.D. as Shilla Dynasty unified southern regions of Korean Peninsula, town hall complex (치소 治所) was formed at high grounds of inundated land as a regional administrative point 1 km away from HanJoo village. This government complex was designated as 'West Town (서경 西京)' which functioned as an administrative base for the lands Shilla Dynasty newly acquired. Later this complex changed its name to 'HanJoo Bourg (한주성 韓州城)' following Chinese naming principles.

HanJoo Bourg is located on major inland route connecting the north and the south of Korean Peninsula. Thus, HanJoo Bourg has been historically a border and military key point during the Period of Three Dynasties. Unified Shilla relocated locals, nobles and commoners from the territories of GoGuRyo and BeakJe to HanJoo Bourg. Population of HanJoo Bourg is estimated around 2500 during Unified Shilla.

HanJoo Bourg lies on plains that stretches from riverbank on southwest and hills on the east, and is sided by HanJoo River on the west. Also, NamJoo Stream and BookJoo Stream on south and north of the Bourg, respectively, functioned as the city perimeter and moat for defense. HanJoo Bourg is comprised of three by five square blocks '(방 坊)' of 150 m in length.

At the center of the city lies SungAn Road (주작대로 朱雀大路) from south to north. On the eastside of the road is located residential area, and on the westside is farmland that stretches to the riverbank. Block structure of HanJoo Bourg is very similar to not only Xi'an (長安-西安), the capital city of Chinese Tang Dynasty (唐朝, 619–907) but also to Castrum of Roman Empire.

The overall form of HanJoo Bourg is a rectangle that spans 750 m from north to south, and 450 m from east to west. Its walls are 3.5 m high, composed of stone and earth. HanJoo Bourg is also known as the inner wall (내성 內城), and DongBook Citadel on the north and outer wall (나성 羅城) on the nearby hills provided primary defense. On each sides of the Bourg were gates which connected the town to other major points of the region. Southern gate, known as ‘HanJoo Gate (한주문 韓州門),’ is a two-story structure which suggests that HanJoo Bourg had close relationship with southern regions.

HanJoo Bourg had SungAn Road (now renamed into HanJoo Ro), a central road connecting north and south and defining administrative center of the town. At northwest of SungAn Road was located local government complex, and on the east was ‘HanJoo Buddhist Temple (한주사 韓州寺)’. At the center of the temple was ‘HanJoo Pagoda (한주탑 韓州塔),’ which was the first monument on sight as one entered through the southern gate.

HanJoo Bourg continued to function as regional administrative center for HanJoo region through GoRyo Dynasty and Joseon dynasties. Especially GoRyo Dynasty reorganized newly reunified lands into 12 districts, and renamed its western foothold, HanJoo Bourg as HanJoo Town (한주목 韓州牧). Also, in 990 GoRyo Dynasty conducted major reconstruction of previous HanJoo Bourg, establishing HanJoo Town Wall (한주읍성 韓州邑城). HanJoo Town Wall was rebuilt after Mongolian Invasion of 1230, and after Japanese Invasion of 1590 as well.

Around 1630s, HanJoo Town was connected with foreign cities. Following NamSeok Bridge beyond the southern gate and current National Highway 777 to seaport, HanJoo was connected with Nara (奈良-平城京 Heijo-Kyo), Kyoto (京都-平安京 Heian-Kyo), Osaka (大阪) and Kobe (神戸-兵庫津 Hyōgo) of Japan. Also, along the HanJoo Wooden Bridge and current National Highway 44 to coastline, HanJoo was connected with inland Chinese cities such as KaiFeng (開封), NanJing (南京), and coastal Chinese cities such as Shanghai (上海).

HanJoo Town Wall had four gates in every cardinal, among which HanJoo Gate on the south was the most magnificent with three-story height. During this period SungAn Road took major changes. At the center of the town was located a town complex (관아 官衙) of governor’s office (동헌 東軒), town council (향청 鄕廳) and prison (형옥 刑獄), and with king’s residence (객사 客舍) to the north.

HanJoo Town’s central layout plan followed Tang Dynasty’s city layout principles on its capital city Xian. Known as ‘JooRyeGoGongJe (주례고공제 周禮考工制)’ and ‘JaJoWooSa (좌조우사 左祖右社)’, the royal palace was located on the center facing south. On the east side of the palace was JongMyo (종묘 宗廟), a shrine dedicated to the precedent kings, and on the west side of the place was a sanctuary (사직단 社稷壇) for prosperity. However, hills inside the HanJoo caused hindrance for exact same layout.

Especially in the center of the HanJoo Town Wall, formation of king’s residence caused former ‘+’ shaped block structure to change its shape to ‘T’. This meant that former simple and open grid block was changed to a fortress-styled block designed for effective defense against any invasions. Also, on the eastern side, HanJoo Buddhist Temple was replaced by town shrine (성황당 城隍堂) and barrack (병영 兵營).

At that time total thirteen wells were located inside the HanJoo Town Wall, and the wells were the center of everyday life. Population is estimated around 6000 including residents outside the walls. From the center, nobles resided in the eastern side, and commoners lived in the western side in small neighborhoods. Also, during GoRyo Dynasty 'HanJoo HyangHak (한주향학 韓州鄕學)', a public school was set up in 1127 inside the walls. Later, during JoSeon Dynasty, private schools including HanBeak School (한백서원) and HanSan School (한산서원) were formed along the valley outside the wall to educate noble students around 1570.

In 1392, JoSeon Dynasty established 'HanJoo HyangGyo Gymnasium (한주향교 韓州鄕校)' to replace former HanJoo HyanHak. HanJoo HyangGyo taught commoners Confucianism, the political principle of JoSeon Dynasty. Complaints of residents inside the Walls and the need for larger educational compound led the HyangGyo to relocate near Gyo Stream where it was rebuilt in larger scale. The Gymnasium had beautiful view over the Wall towards HanJoo plains afar. With clean water flowing from WooAm Mountain, the area along Gyo Stream soon developed into finest noble neighborhood in HanJoo. At the NamSeok Bridge near the southern gate, HanJoo Market was relocated from the former location from the north and began to grow slowly.

From 980, GoRyo Dynasty operated a country-wide post and horse station system (역참 驛站) in Korean Peninsula, and 'ChungSoo Horse Station (청수역 靑水驛)' was established in current National Highway 777 over HanJoo River. 'ChungSoo Horse Station (역마 驛馬)' provided transportation, board, and office to the central government officials dispatched to the region. Also, the station was closely related to 'ChungSoo Inn (청수원 靑水院)' and 'ChungSoo Tavern (청수주막 靑水店)' which provided board to travelers. This lead to growth of 'ChungSoo Ville (청수역촌 靑水驛村)' which became a major point of transportation of people entering HanJoo region. Eventually ChungSoo Railroad station was established near the Ville during Japanese colonial era.

In 1582, Kim Cheol, governor of HanJoo, constructed a large-scaled formal garden (정원 園林) near HanJoo River. Envoys from HanJoo visited Nanjing (난징 南京) and Shanghai (상하이 上海) of Ming Dynasty of China (명조 明朝) and were especially impressed by beauty of 'YuYuan Garden (豫园, 1577)' near city market (豫园商城) in Shanghai. After their return from China, envoys created 'HanJoo Garden (한주루원 韓州樓苑, 1582)' modeled after YuYuan at a swamp near HanJoo Market in 1582. In 1626, HanJoo Garden was rebuilt in larger scale after Japanese invasion. A pond was created inside the garden by constructing an artificial canal from nearby HanJoo River. At a similar time, a romance novel 'HanJoo Love Story (한주전 韓州傳)' was written based on HanJoo Garden. HanJoo Garden soon became a beloved visiting place for merchants and travelers from every corner of Korea.

Also by 1550, a giant man-made forest was implanted at the riverbank of HanJoo River. Known as 'HanJoo Forest (한주림 韓州林)', the Pine tree forest was based on geomancy which prevailed at that time. The forest (비보숲 裨補林)'이 while blocking evil spirits from entering the town, pragmatically reduced agricultural loss by preventing flooding and strong wind. The Pine trees implanted in two separate areas on northern and southern perimeter of HanJoo not only implies the size of the town, but with 'HanSoo Pavilion (한수루 韓水髏)', also functioned as a public open space for citizens to rest and interact.

HanJoo was largely destroyed three times by Mongolian invasions that continued for 40 years starting from the 1230s. Later, Japanese invasions in the 1590s and Qing invasion in the 1630s played their parts as well to sack HanJoo. HanJoo was located in the middle of a major route of foreign invasions particularly from both north and south. Thus, HanJoo became a cruel battleground in any foreign invasions and much segment of HanJoo Town Wall was destroyed.

After two major Japanese invasions, JoSeon Dynasty established a military command controlling all foots and horses of the region at riverbank of HanJoo River near cow market. Also, HanJoo Town Wall was reconstructed, with 5 m wide moat (해자 垓字) directly connected with NamJoo Stream and HanJoo River as well.

On the northwestern and southeastern hills near HanJoo Town Wall were constructed HanJoo Pavilion and on their peaks, light signal towers (봉수대 烽燧臺). Sights were secured as the hills provided clear view of the HanJoo plains, light signal towers and pavilion worked closely with military command, the Town Wall, and nearby light towers to form a central communication network.

In 1632, JoSeon Dynasty issued 'DaeDong Royal Decree (대동법 大同法)' that replaced specialized local products as form of tax provided by local administration to the central government by rice. This decree brought change as rice began to function as exchangeable money. Later in 1678, government-issued currency known as 'SangPyung Currency (상평통보 常平通寶)' began to replace rice as currency. From 1650, HanJoo developed, thanks to the growth of thriving HanJoo Market, into one of the leading towns in Korean Peninsula. HanJoo's ground connection with other towns in the regions became stronger after the Japanese invasions in the 1590s and Qing invasion in the 1630s. As a consequence, traditional river-trading routes were slowly replaced by land routes.

HanJoo Market's geographic location with both direct access to the inland valley as well as the coastal regions allowed merchants to trade a variety of products ranging from herbs, fruits, vegetables to fish from nearby mountains, plains, and coastal areas along the river. HanJoo Merchants who took HanJoo as their main trading ground, operated every 5-days market while looping around the other markets developed with 20–40 km (50–100 리) distance between each other in the region. This distance was determined by both merchants' daily pedestrian movement as well as maximized preservation duration of natural products (Fig. 9.1).

9.3.3 Railroad Station and Modern Grid Block (1890–1945)

As Japanese colonial era started in the 1890s, HanJoo underwent significant changes that other cities in Korean Peninsula took as well. Such change particularly in city's physical shapes driven by Japanese government, transformed the former regional administrative center with outlying agricultural compound into modern city filled with factories connected by railroads. HanJoo residents were largely unsatisfied by sudden changes led by Japanese government.

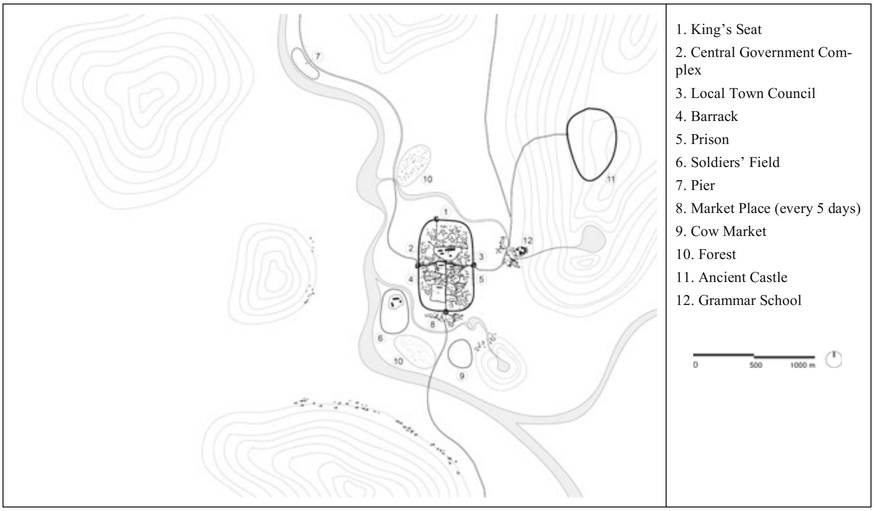

Fig. 9.1 HanJoo, Model Korean City: Walled Town (675–1890) (image taken from [1])

Especially in late JoSeon Dynasty, anti-feudalism and anti-foreign atmosphere caused 'DongHak Pageant Civil War (동학농민운동 東學農民運動)' to erupt in southwestern corner of Korean Peninsula. The rebellion soon overtook HanJoo, but was eventually defeated by Japanese army. JoSeon Dynasty issued 'GapOh Revolution (갑오개혁 甲午改革)' in 1896, and dismantled local armies that were conventionally stationed in local government basis. Thus, DongBook Citadel where the rebellion occupied was demolished, and northeastern segments of the Town Wall was torn down as well.

HanJoo Town Wall was dismantled in phased way, starting from the 1900s. Southern walls were gradually torn down, followed by western walls as well. Demolition of the Wall brought heavy resentment of residents, and signature HanJoo Gate was spared. Large amount of stones from the Wall was used to lay out the basis of roads and railroads connecting HanJoo with nearby cities. HanJoo Railroad also functioned as a dike to prevent flooding of HanJoo River.

New roads were established in 1910 between HanJoo and nearby cities in parallel proximity to current National Highway 777 as well as National Highway 44. Also, as the Japanese Government-General of Korea opened railroad system, 'HanJoo Line (한주선 韓州線)' was installed from the north to south along the riverbank down to the northern gate of the Wall.

'HanJoo Station (한주역 韓州驛)', the central railroad station in HanJoo was opened, and later bus terminal nearby was constructed as well. At the gate entering the HanJoo Station, 'HanJoo Station Plaza' was located in semicircle shape. At this point was newly created main street located connecting the station with SungAn Road on the south. Main Street soon grew to be the new center of commercial and economic activities anchored by the station, gaining a new name 'Hon Machi (본정

통 本町通)'. Also, at the west of the Main Street the central market was created in large scale. As a permanent market, the central market competed with the traditional HanJoo market near HanJoo Gate.

Japanese Government executed a city development program creating a new city centered on the railroad station. Named as 'North HanJoo,' the new city matched HanJoo in its size. This city expansion was accelerated by 'JoSeon City Plan Act (조선 시가지계획령)' issued by Japanese Government-General of Korea in 1934. Based on Japanese mainland law 'City Plan Act', the new law intended to rearrange lands and roads, and initiate redevelopment of HanJoo inside of the former Town wall.

For the expansion of old HanJoo, a set of grid blocks were formed near HanJoo Railroad Station. Soon, large-scaled textile, dye, fertilizer, and canned foods factories were constructed at the riverbank on the west and inland on the east next to the railroad. Especially the eastern blocks of old Town Wall was cleared to provide space for new cart-way road connected up to the train station.

As a result, HanJoo grew into a large city with twin centers in HanJoo (now called Ancient Town) and North HanJoo (Old City). North HanJoo differed from HanJoo on the south by its 120 × 100 m grid blocks. On the other hand, HanJoo maintained a few historical square blocks that originated from Shilla Dynasty, most of which lost its shape and alleys inside the blocks.

While HanJoo decayed as HanJoo Market lost its competitiveness, Hon Machi in North HanJoo soon grew as a city center of economic activities as Japanese and Koreans from the countryside flooded in. Especially large amount of capitals and goods that flowed from Japanese cities drove Hon Machi to replace HanJoo Market's function. City hall, court, and police stations were gradually constructed south of HanJoo Station Plaza, forming administrative district of Japanese government. Following the Main Street, post office, banks, and tax offices were established. Also, on the northern part of the Main Street, theater and bakeries were created near the central market collectively serving floating population. On the east of the station to hills inns and brothels were formed.

On the hills of the eastern side of the station Japanese Shrine (신사 神社) was established, and a Japanese community was formed around the shrine. Also, large reservoir was formed behind the shrine which established city water supply and drainage system. Japanese community grew into large-scaled residential area with a group of apartments for the station workers being constructed on the site nearby. Near the main road central elementary school was created, and central middle, high, and girl's high school were created in time.

Near the bus station on the northern railroad, inns and Chinese immigrant community were formed. Chinese community in HanJoo comprised of Chinese laborers from Shandong Peninsula (山東半島) who were brought for the construction of the railroad and new roads. Restaurants, Chinese pharmacy, and silk shops were opened for Chinese immigrants. Large number of Chinese laborers formed separate market in HanJoo.

Representative Korean community was Gyo Dong Neighborhood which functioned closely with Korean merchants. King's residence which located in the center

Fig. 9.2 HanJoo, Model Korean City: Urban Grid and Railroad Station (1890–1945) (image taken from [1])

of old Town Wall was shut down, where HanJoo Elementary School was first formed and in 1916 HanJoo County Hall was installed. Near the Hall was constructed HanJoo People's Hospital, and the site of former barrack was replaced by a modern 'HanJoo Park.'

As old Town wall was demolished, large institutions such as hospitals, churches, cathedrals, and schools replaced the walls and its nearby sites. Especially on the southeastern and southwestern corners of the Wall rotaries were formed. HanJoo Cathedral and HanJoo Central Church built by Catholic and Presbyterian missionaries from France and America, respectively, operated BaeSung School and HanHwa School providing job trainings and primary education to Korean youth. Such Institutions many of which are now designated as modern architectural heritage were built by brick-makers from Shanghai (Fig. 9.2).

9.3.4 Industrial Complex and National Route Network (1946–1994)

From the mid 1940s and early 1950s, Korean Peninsula underwent highly chaotic transition as the Independence (1945) and Korean War (1950–1953). More than 80 % of the central HanJoo was destroyed by bombing in war, and city function was paralyzed. An immediate recovery of HanJoo was impossible after the period, and the reconstruction effort led by the central government started as late as in the late 1960s due to political chaos and budget shortage.

It is in 1962 that the central government passed 'City Plan Act' which aimed to set up a set of plans for major cities including HanJoo. Subsequently, HanJoo Comprehensive Plan, enabled by 'Act on the Use and Management of the National Territory (국토이용관리법, 1972)' was prepared modeled after Euclidian Zoning Ordinance which is a local government's regulatory tool for controlling the type and scale of private developments. However, the plan was not adapted right away due to political strife and lack of budget. It was until 1970s when parts of plans were put into action.

In such process, many of city administration and major city institutions during Japanese colonial era evolved into HanJoo's modern city functions without major changes. First, city hall located at the center of HanJoo expanded its function. Meanwhile at the central crossroad in front of HanJoo Railroad Station twelve-story corporate buildings were constructed by companies such as HanGook Phone, DaeMin Insurance, and JinSung Products, forming a center of HanJoo business district.

HanJoo was the representative city where migrants from all corner of Korean Peninsula settled in after the Korean War ended. The migrants temporarily settled on the hills of WooAm Mountain on the east of HanJoo Railroad Station, which later developed into permanent settlement. Most of the communities in fact reused the brothels which were built in Japanese colonial era. In addition, many unauthorized residential structures were built without infrastructure of water supply and drainage.

It is noteworthy that HanJoo's full-scaled redevelopment of downtown area began not upon the end of Korean War, but upon worst flooding of HanJoo River in the early summer of 1970. Overflow of HanJoo River caused serious damage as most of residential areas from NamSeok Bridge to HanJoo Market were submerged under water. The central government dispatched 'Special Disaster Relief Team' under prime minister's office, rebuilding dyke on the riverbank.

In such effort a set of riverside ways were built on the riverbank. In addition, a series of bridges including HanJoo Wooden Bridge were rebuilt. Especially HanJoo Wooden Bridge was the first wooden bridge across HanJoo River starting from GoRye Dynasty era which allowed HanJoo to trade with western regions. Next to the wooden bridge, HanJoo Bridge was newly constructed, over which, HanJoo started to expand westward from the late 1970s.

The central government implanted a set of massive industrial facilities and the associated company towns for workers mostly on farmlands outside of cities, accessed by the newly developed national highways and railroads. It is in 1975 that the HanJoo IC from National Highway 777 was laid out 10 km west of HanJoo. Also, National Highway 44 which branched from HanJoo IC connected HanJoo directly with other cities by providing horizontal passage across Korean Peninsula. National Highway 44 is laid out parallel to ancient road which once connected HanJoo with western coast and Chinese cities. Greenbelts were designated as well around HanJoo with limited development area.

Subsequently in the early 1980s, a large-scaled HanJoo Industrial Complex was developed in West HanJoo, which accommodates 30,000 men in an area of

Fig. 9.3 HanJoo, Model Korean City: Industrial Complex and Inter-city Highway (1946–1994) (image taken from [1])

990,000 m^2 that stretched from HanJoo IC to HanJoo National University. In proximity with the complex, a group of company apartments were built to accommodate complex workers. HanJoo Industrial Complex expanded gradually, and continues to lead industrial production of HanJoo region. In fact, HanJoo Products and HanJoo Chemical, which operated major factories inside the complex, are now HanJoo Semiconductor and HanJoo Biomedical, respectively, and continue to be in charge of state-of-art technology of HanJoo region (Fig. 9.3).

In the south of National Highway 44, HanJoo National University relocated into the area of 496,000 m^2 from its downtown buildings driven by 'Restructuring of National Universities Act' of the central government. In proximity to the campus were created HanJoo National Medical School and HanJoo National Hospital. In addition, near the campus HanJoo Educational College opened as it expanded its border to southwestern parts of HanJoo River. This resulted in formation of a campus district with population up to 40,000.

HanJoo succeeded in hosting the national athlete's in 1986. The central government and Korea Land Development Corporation acquired farmlands south of the railroad, constructing sports complex, swimming pool and other athletic facilities. Also, the express bus terminal was opened at a point where National Highway 44 and the sports complex met, in order to accommodate the express bus terminal function separated from the existing intercity bus terminal. Next to the newly created express bus terminal in West HanJoo, New World Hotel was built in association with the New World Department Store, along with wedding complex. Private apartment complex developed by HanJoo Construction and lease apartments for low incomers were built as well.

In previous city centers of HanJoo (Ancient Town) and North HanJoo (Old City), multiple small-scaled redevelopment projects were implemented by HanJoo City and Korea Housing Corporation from the 1980s. Old factories located near the railroad station in North HanJoo was relocated to outskirts of the city, and a series of housings were developed for low incomer's community. Motels and brothels on the east side of the station were also remodeled into lease apartment for low incomers as well.

9.3.5 Development of New Town (1995–Present)

From the mid 1990s, HanJoo as municipality led large-scaled city expansion, transforming the city structure from previous Ancient Town and Old City. These changes were initiated by '9th Municipality and Local Parliament Election Act' in the early 1990s which aimed to activate autonomous municipality system with a pair of local counsel and mayor elections held in 1991 and 1995, respectively.

In 1995, 'city-county administrative system (도농통합체 都農統合市)' was authorized which bound local cities with nearby farmlands. However, this law was used as a legal basis for administrative and public institutions to be relocated to city outskirts from downtown. As a result, the law unexpectedly resulted in emptied city center.

HanJoo followed the administrative change by unifying with nearby farmlands in 1996, completing a gigantic city-county state of HanJoo City. Right after the unification, HanJoo established HanJoo Land Development Company (HJ Company) to execute a series of land development and construction projects within newly expanded HanJoo City jurisdictional boundary. In addition, an array of large-scaled acquisitions of land and developments of housing complexes were led by Korea Land Development Corporation along with HanJoo-based HanJoo Construction and Jingo Construction.

Land development of HanJoo was largely initiated as the central government released the greenbelt regulation that previously prohibited development of lands. HJ Company purchased individual farmlands from farmers nearby Highway Interchange and consolidated the lands into a larger tract with city infrastructure installed. The tract was subdivided into several blocks which then were sold to individual private construction companies. To make such land development on the city outskirts feasible, HanJoo relocated major public institutions such as city hall, court, broadcasting company headquarters, and schools that established stable consuming market and floating population to the newly developed tract.

West HanJoo and its high-rise apartments in the 1990s were formed centered on Korea Electro Power Corporation, which were relocated from Seoul as a result of balanced development of region program. Large parks, public library, and hospitals were installed in the large-scaled residential developments laid out on a typical Korean-styled superblock of up to 500 × 600 m with car-dependent transportation system.

Subsequently in the early 2000s, a series of mixed-use complexes anchored by three to five residential towers with 40–60-story was developed on 500 × 600 m superblock. Such mixed-use residential development was proceeded to modernize outdated residential neighborhood of HanJoo with an aim of creation of city landmark. However, negative evaluation is dominant as such large block developments often failed to create pedestrianized environment with socially mixed residential community.

Meanwhile, in order to continue to accelerate large land development on the outskirts, HanJoo has built 'O' shaped HanJoo Ring that connects HanJoo Railroad Station on northeast and HanJoo River on Southwest. Furthermore, HanJoo Ring ties HanJoo City Soccer Field, HanJoo City Baseball Field, and HanJoo City Gym which are created on expanded border at southern riverbank with HanJoo Citizen's Park, functioning as central spine of New HanJoo. In addition HanJoo is now connected to HanJoo International Airport which was built on the previous U.S. Army airfield 10 km southwest of HanJoo through HanJoo Ring.

As the central government planned the construction of new high-speed railroad home with the birth of KTX, HanJoo Railroad Station was relocated from North HanJoo to northwestern outskirts of New HanJoo, renamed as KTX HanJoo Station. Problem arose as previous HanJoo Station area was left empty, and local market began to crumble HanJoo City responded by hosting 'HanJoo Movie Festival' to use as international show with the construction of convention center with international hotel and shopping complex. However, the redevelopment of HanJoo Railroad Station area is yet to be implemented due to its accessibility from KTX HanJoo Station and express bus terminal.

As HanJoo concentrated on development of city outskirts, city downtown decayed fast. The reasons behind such decay can be understood as a result of diminished residential community and office workers as well as youth population in central market and Main Street due to relocation of administrative institutions and railroad station along with the relocation of schools. Starting from 1980, the decay of HanJoo downtown reached its peak in early 2010, which caused some parts of the downtown to be declared as dangerous in night time. The population of city center diminished from 150,000 in 1970 to 50,000 in 2010 (Fig. 9.4).

Markets at downtown are not a match for large-sized modern markets located at New HanJoo's express bus terminal, KTX HanJoo Station, and large apartment blocks. HanJoo citizen's preference of using car also proved to be fatal to downtown markets as they lack enough parking lots. Fire at central market in 1991 consumed two-third of the market. While the building being reconstructed, the market had already lost a large number of consumers.

It can be said that the central market is hard to recover by itself. Recent news that city hall will be relocated to city outskirts further hinders the possible regeneration of city downtown. On the other hand, lands near HanJoo National University in North HanJoo had been developed into multi-single family housing to accommodate university students. This full-grown university community in West HanJoo, have already outgrown the downtown with no economic contribution to its decayed retail and commercial districts.

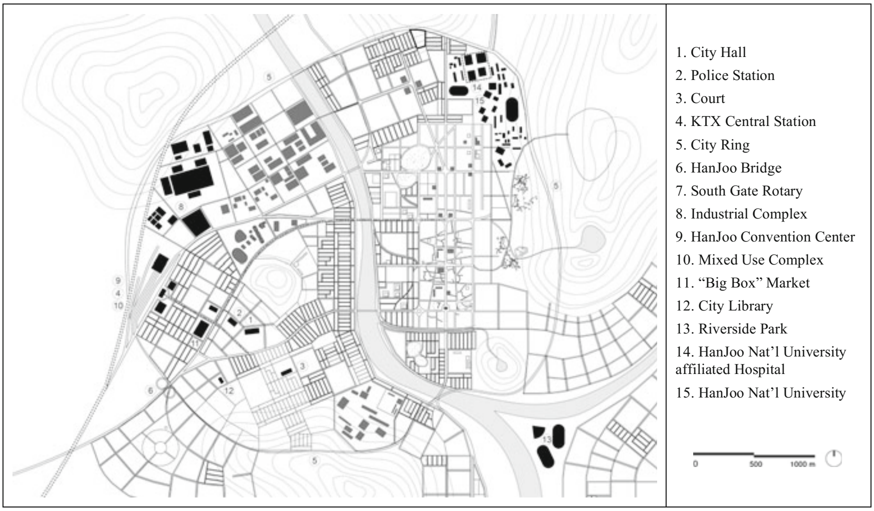

Fig. 9.4 HanJoo, Model Korean City: Suburban Growth and Beltway (1995–Present) (image taken from [1])

Recently, HanJoo has initiated a series of downtown revitalization projects including pedestrianized SungAn Road, remodeling of the central market, restoration of BookJoo Stream and NamJoo Stream, and creation of HanJoo Cultural Center responding to the central government's revitalization initiatives. However, it is doubtable that whether downtown area possesses an edge to compete with large business district on the city outskirts. Especially outdated residential environment proves that without qualitative residential environment it is impossible to attract youth and stable residential population while competing against the outskirts.

9.4 An Interpretive Portrait of Korean City

Among the cases that feature the aforementioned characteristics of HanJoo—Model Korean City, are SunChun, YeoSu, GuRye and NamWon all of which have collectively formed a regional sphere along SeomJinGang River (섬진강 蟾津江). SeomJinGang River, originating from inlands of Korean Peninsula and flowing out onto the South Sea, gave birth to a group of Paleolithic and neolith settlements in the region. However, this geographical condition also provided a medieval entryway for Japanese armies to pass through YeoSu and GwangYang (광양 光陽) from the South Sea to the inlands.

First of all, NamWon (남원 南原) on upper SeomJinGang River was an ancient strategic battleground between east and west powers of Korean Peninsula as Shilla and Baekje dynasties clashed. It was also a cross-road point where Avatamsaka

Buddhism (화엄불교사상 華嚴佛敎思想) and Confuciansm (유학사상 儒學思想) passed by neighboring UnBong (운봉 雲峰) along the national Arterial Road 24. NamWon was built as an 850 × 720 m walled town on inundated land at YoChun Stream, one of major tributaries to SeomJinGang River, to function as a regional administrative center by Shilla Dynasty. Around 992, NamWon began to grow into a regional market town as a transportation node on land routes (currently national Arterial Road 17 and 19) to both east and south coastal regions (Fig. 9.5).

Fig. 9.5 NamWon, GuRye, SunChun and YeoSu in the Regional Context (image taken from [9])

GuRye (구례 求禮) served as a starting point of larger SeomJinGang River as it provided JanSooJin Port (잔수진 潺水津) near ByungBangSan Mountain (병방산 丙方山) which was the last river port from the South Sea. GuRye was established as a 350 × 350 m squared wall town near BongSungSan Mountain (봉성산 鳳城山) to function as a regional administrative point for neighboring southern areas. In the neighboring areas along the river, a set of markets formed: YulJang Market (율장 栗場) on chestnut forest near YoChun Stream; GuRye Market (구례장 求禮場) on SeoSi Stream; and HwaGae Market (화개장 花開場) on lower SeomJinGang River. Eventually NamWon and GuRye dismantled their city walls during Japanese Colonial period, and expanded on modern grid block system with railroad stations built in the center.

SunChun (순천 順天), on the other hand, was rather unique in its growth history as it remained outside of Seoul's influence until modern era. As an administrative and military center, SunChun was a crossroad market where a variety of products from neighboring fields, mountains, hills, and seas collected together. During GoRyo and JoSeon dynasties, SunChun functioned as a circular walled town in the sand valley. However, as GyeongJeon Railroad Line for GunSan on the West Sea and Jeolla Railroad Line for YeoSu on the South Sea were connected via SunChun in the 1930s, SunChun accelerated its growth as a regional hub by siphoning the neighboring farmland population. In the mid 2000s, SunChun has again evolved into an eco-friendly city upon transforming SunChun Bay Reed Bed into a widely acclaimed preserved natural park and hosting an International Garden Expo (Fig. 9.6).

SunChun YeoSu GuRye NamWon

Fig. 9.6 Cartographic Portrait of Phased Growth of NamWon, GuRye, SunChun and YeoSu (image taken from [9])

YeoSu (여수 麗水) was first developed as an ancient maritime stop-over of cultural transmission and commercial trade in the 4th century B.C., as it connected eastern coast of China and Kita Kyushu (北九州市) and Honshu (本州) of Japan by Kuroshio Current. Later, JoSeon Dynasty established a naval base on the southern hillside of JongGoSan Mountain (종고산 鐘鼓山) which functioned as a defensive point up to modern era. The modern old port and new port were developed through a series of large-scaled land reclamation projects during the Japanese Colonial era. Such development of YeoSu as an international trading port destined for Fukuoka and Osaka, was intensified as it was connected to the southern regional railroad system in Korean Peninsula. Later, the construction of YeoSu Industrial Complex and GwangYang Industrial Complex on reclaimed land in GwangYang Bay continues to transform YeoSu into a national petrochemical and steel manufacturing hub.

9.5 Conclusion

This narrative model of Korean City addresses the geographical and historical traits embedded in their region that have directed the growth path of the Korea cities while differentiated themselves from other cities. Understanding of cities through such growth model, despite its limited applicability, suggests the two useful policy implications for better city planning actions focusing on 'how to relate a city with other cities within larger region and how to relate a new town with the old town within larger city context.'

First, a group of Korean cities share in common regional cultures which stretch from deep inland streams to coast area, with integrated waterway of both river and sea at the center. Such regional attributes call for the necessity of regional governance and collaborative planning practice within a regional watershed. Thus, cities must be planned and managed together under mutual influence in region whose spatial and cultural dynamics often go beyond the jurisdiction of a city and a town.

Second, the spatial development pattern of features a sequenced mosaic of agricultural ancient town, rail station-anchored old town, and highway-based new town each of which has been developed exclusively for its functional purpose. In particular, the overall growth path of Korean city, particularly during the past century, is a product of, rather than organic growth, but 'intended transformation', significantly driven by a set of deliberate governmental policies. In such process, the development of old town was causally contributed to the decline of ancient, and so has been the development of new town. Thus, both functional and physical connection between them must be critically repaired for mutual benefit by sharing a same vision that will allow both redevelopment and regeneration within a larger city.

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Chapter 10
A Rule-Based Generative Analysis Approach for Urban Planning

Rudi Stouffs and Patrick Janssen

Abstract Urban plans are difficult to comprehensively analyze quantitatively because they lack sufficiently detailed information. They tend to emphasize land-use, possibly suggesting general building typologies. Nevertheless, they are generally conceived with respect to objective criteria, such as population targets, plot ratios, gross floor areas, etc. This research suggests a rule-based approach to generate relevant building data that can serve to analyze and assess such urban plans with respect to these and other relevant criteria, requirements and targets. Such generation must necessarily take into account local conditions, building typologies, codes and regulations.

10.1 Introduction

Use of computational support for urban planning and design is mostly limited to modeling. Its use for performance analysis, either to inform the design process or to assess design solutions, though available, is still sparse. Part of the problem may be the absence of, or the difficulty in retrieving, sufficient amounts of data to support performance analysis. Certainly, this issue is dependent on the location; if not site-specific, it will differ at least from country to country. Nevertheless, there is always a limitation to the data that is readily available and any specific design queries may necessitate data that cannot be obtained by regular means. To assist in overcoming this hurdle, we distinguish three complementary approaches: extracting data, synthesizing data and mining data. Extracting data refers to data that can be found online however not in a readily downloadable or applicable format and requires manual processing or the development of dedicated scripts to extract the data from the source. Synthesizing data refers to data that is generated from existing

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_10

(design or analysis) data based on assumptions, heuristics and/or typologies. Mining data refers to the application of data mining techniques in order to understand relationships between data.

Another part of the problem may be the lack of simple and flexible workflows that support performance analyses and can easily be integrated into design and planning processes. Especially when such processes are characterized as dynamic, collaborative and constrained by time, skills and the availability of tools. While various systems exist to support performance analysis within urban planning and design processes, these tend to be neither simple to use, nor flexible in their ways of usage, nor can they be easily integrated with other tools that may serve other parts of the workflow. Modular workflows that can easily be adapted by the user to apply within a particular design context or process are of special interest. Such workflows often rely on various software tools that must be seamlessly connected in order to allow the user to switch back and forth between modeling and analysis.

In this paper, we focus on synthesizing data and demonstrate how data synthesis approaches can be used to support performance analysis at early planning and design stages when urban visions have been defined only conceptually and still need to be elaborated in terms of a plan or model. Specifically, we present a rule-based approach to generate relevant building data that can serve to analyze and assess urban plans with respect to relevant criteria, requirements and targets. Such generation must necessarily take into account local conditions, building typologies, codes and regulations. We also address the integration of data synthesis and performance analysis and identify some obstacles for developing integrative workflows on the fly in response to specific questions that may arise in the planning and design process. We draw upon examples observed and investigated within the context of various studios, addressing urban planning, urban design and architecture, including an international, collaborative design studio (Winter School) involving over 170 students and 30 design tutors, organized by the International Forum on Urbanism (IFoU). Finally, we critically review our endeavors and draw some ideas for developing improved support for urban planning and design.

10.2 Related Work

Various systems for parametric urban design already exist. Beirão et al. [1] present a parametric urban design system that provides automatic feedback on a number of urban indicators and density measures. König [2] presents an open source library for computational analysis and synthesis, denoted CPlan, which supports the optimization of spatial configurations. However, both systems only consider buildings as rectangular blocks and do not support a differentiation in building typologies. Knecht and König [3] present a tool that, given a street network, generates building lots and buildings, the latter in one of four types: row buildings, courtyard buildings, ribbon buildings and free-standing blocks. However, the tool supports only one building type at a time and treats other parameters, such as building depth, similarly. As such, it mainly focuses on small developments.

Esri CityEngine [4] considers a procedural modeling approach for generating 3D city models. Specifically, it adopts a rule-based approach inspired by shape grammars but using procedural rules. While CityEngine is very comprehensive in terms of modeling different building typologies, including their facades, it primarily targets 3D visualization over analysis and assessment. Additionally, much of the work in using CityEngine to generate 3D cityscapes is manual in nature, developing or selecting rules that apply to specific plots in order to generate the relevant buildings. Finally, though CityEngine supports some analysis, this is fairly limited and the data generated within CityEngine cannot easily be exported back into a 2D GIS environment (besides Esri ArcGIS) for detailed analysis and assessment.

In this paper, we target the semi-automatic generation of information that is explicitly relevant for the analysis and assessment of an urban plan. For example, the identification of the number of floors and service cores may lead to a measure of useable floor space that can serve to calculate approximate returns on investments. Other than the 3D building shape, it is possible to export such data for further analysis into a 2D GIS environment. We also emphasize workflows that simplify or (semi-)automate the process of rule selection and support the integration of data synthesis and performance analysis.

10.3 Background

This work was initially developed for an international, collaborative design studio and, subsequently, further developed alongside an M.A. Urban Design studio and a Master of Urban Planning studio.

10.3.1 The IFoU Winter School

The motivation for this work stems from an international, collaborative design studio (Winter School) involving over 170 students and 30 design tutors, organized by the International Forum on Urbanism (IFoU), in which the authors participated as tutors. Participants from all over the world came together to work for 12 days on proposals for Jurong Industrial Estate (JIE), a 5000 ha industrial area in the west of Singapore. The brief was to develop proposals for the transformation of JIE from an almost mono-functional, segregated and fragmented, polluted industrial area into a major catchment area for future population growth that integrates clean(ed) industrial plants with green lungs, attractive housing and vibrant urbanity for one million people.

During the IFoU winter school, students were divided into teams of 8–10 students, who then worked intensively together to develop visions and proposals.

The grouping of the students was organized in such a way so as to ensure that each group included a mix of students from different institutions and regions in the world. While this rich mix of students created great opportunities for cross-cultural interaction and design, it also presented some significant challenges. One of these challenges was the dynamic and at times even chaotic nature of the design process. The design process that emerged from within these groups of students was highly non-linear, and combined sketching and drawing with digital methods and tools. Typically, groups would meet intermittently to discuss overall strategies and goals, and would then break into smaller sub-clusters to work in parallel on specific topics. Often, these sub-clusters would then start exploring completely new ideas, which would later have to be reconciled within the larger group. In many cases, conflicts emerged which then had to be resolved through heated discussion. In general, this reflects the fact that urban planning and design is fundamentally an unstructured or 'wicked' process characterized by (1) multiple actors with differing, legitimate values and opinions; (2) high uncertainty; (3) aspects of irreversibility; (4) no clear solutions; (5) being fraught with contradictions; (6) being persistent and unsolvable [5].

At the start of the winter school, students were provided with extensive data on the existing conditions of JIE. The students were then encouraged to use this data as a starting point for their design process, and to use digital methods and tools to develop proposals. However, this proved difficult due to the fact that the software tools that they tended to use were very diverse. Students had to be able to use the tools they were familiar with and to exchange data in a variety of formats. Although some students had experience in using Geographic Information System (GIS) software, most were only able to use simpler types of tools such as Autodesk AutoCAD and Trimble SketchUp. These issues may seem to be secondary, but in reality they had a significant impact on the types of proposals that were developed and on the arguments made to support those proposals. One key challenge in all groups was the difficulty they had in backing-up claims about their proposals with quantitative data.

Figures 10.1 and 10.2 show two slides from the final presentation from Group 9, the winning group. They highlight two key issues with data synthesis: one relating to the generation of urban proposals and the other to the evaluation of urban proposals.

Figure 10.1 shows one of the waterfront typologies developed by this group that integrates industrial with residential functions. The overall target for the winter school was to create housing and other amenities for one million people, while still maintaining a significant portion of industrial clean-tech industry. The target resulted in some quite well defined requirements of floor areas for different functions. However, models such as those shown in Fig. 10.1 are purely visual and cannot be used to quantify the total floor area that would result. With all groups, it was difficult to understand whether the proposed typologies and urban massing were appropriate for one million people or not. In some cases, the floor areas may have fallen far short. This type of quantification is important since proposals that work well at lower densities may be fundamentally flawed at these higher densities.

Fig. 10.1 Group 9: proposal for waterfront typologies. *Credits* Marco Berger, Geraldine De Neuville, Fei Bo, Goh Jia Li, Meng Jing, Ravish Kumar, Peter Lie, Delon Leonard, Jasmin Mok, Josef Odvarka, Made Perwira, Jaume Pla, Tanzir Taher, Xia Mengjia, Zhao Danyu (tutors: Erik l'Heureux, Patrick Janssen, Eui-Young Chun)

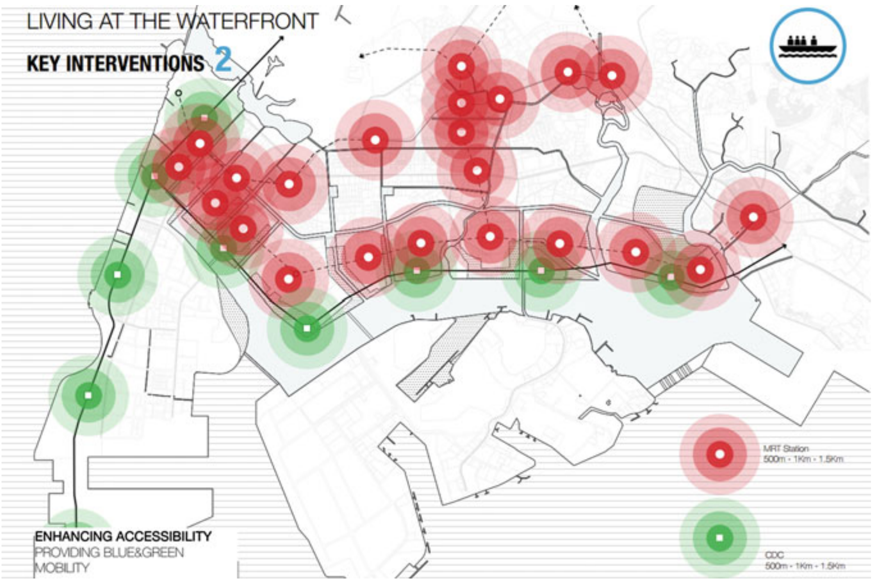

Fig. 10.2 Group 9: enhancing accessibility. *Credits*: idem

Figure 10.2 highlights a different type of data synthesis issue, related to the evaluation of urban proposals. The figure shows how accessibility in JIE would be enhanced by adding various new transport nodes and systems, including additional train stations and interchanges, and also a boat transport system. In this case, the development of the proposals was based on GIS data. However, there was no quantification of actual improvements in accessibility, and as a result it was hard to understand whether the proposed configuration of transport nodes and systems was better than other alternative configurations. GIS systems have tools that could be used to quantify the improvements in accessibility, such as proximity analysis and network analysis. For example, this would allow for the calculation of indicators such as the percentage of people who live within five minutes of a transport node. This would then allow for direct comparison of alternative options. From the point of view of the workflow, the problem however is the disconnect between the 2D GIS model and the 3D urban/building model. The calculation of accessibility requires data on the number of people living and working in each building, which in turn requires floor area data from the 3D model.

10.3.2 Urban Planning Studio

Some of the results of the IFoU Winter School were further developed in an urban planning studio within the Master of Urban Planning program at the Department of Architecture, National University of Singapore. Figures 10.3 and 10.4 show two excerpts from the presentation of the "Ecotopia" project, one of the projects selected from the urban planning studio to demonstrate the data synthesis approach.

Ecotopia stands for a carbon-neutral city amidst lush mid-rise livability. Addressing future resource needs for a projected 2050 Singaporean population increase of over 2 million, the project includes a model of self-sufficiency with respect to five urban metabolism elements: water, energy, food, waste and greenery.

Fig. 10.3 Ecotopia: land use master plan. The site is divided into three different mixed-use belts, from *top* to *bottom* mainly residential, mainly industrial and mainly commercial. *Credits* Andrea Meinarti Rachmat, Tey Hui Ping Serene, Delon Leonard, Wu Xin Peng, Loh Sze Sian (tutor: Oscar Carracedo)

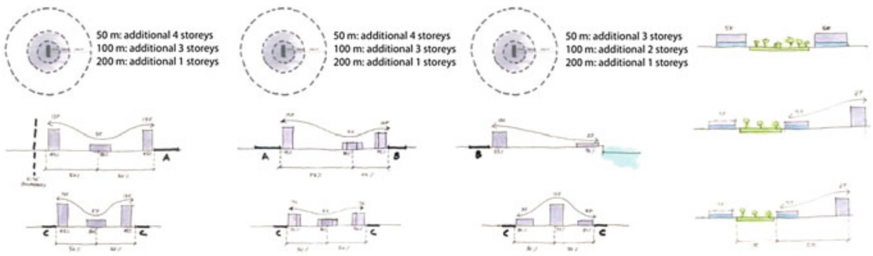

Fig. 10.4 Ecotopia sketched rules for building coverage, distribution and height, in relationship to roads (classes A, B and C), parks and other boundaries, from *left* to *right* within the residential belt, within the industrial belt, within the commercial belt, and with respect to parks. *Credits* idem

The overall site is divided into three different, horizontal, mixed-use belts: mainly residential in the North, mainly industrial in the middle, and mainly commercial around the waterfront. Each belt is divided into a number of eco-cells, such that three different mixed-use cells make up a self-sustainable eco-strip. Each eco-strip joins together industrial clusters around each of the metabolism elements of waste, energy, food and water, in a closed loop to ensure self-sufficiency. Using projected numbers of future demands on resources, a 'per person area requirement' is calculated, which is taken into consideration in calculating the maximum possible population.

Figure 10.4 presents the Ecotopia sketched rules for building coverage, distribution and height, for the different mixed-use belts and in relationship to roads (classes A, B and C), parks and other boundaries. These sketched rules formed the basis for the data synthesis approach.

10.4 Synthesizing Data

Prior to the start of the winter school, a semi-automated data synthesis method was developed to generate building models based on a set of simple rules. As the main purpose of these building models is to quantify the overall massing and floor areas that can be achieved, these building models only needed to consist of simple massing with floor plates and did not need to be highly detailed in their visual appearance. In order to support fast iterative generation of large-scale urban models, a parametric modeling method was conceived that generates building models based on parameter fields encoded as images. This method consists of three main stages. First, the proposed urban typologies need to be encoded as parametric models with a small number of general parameters, such as maximum building height, site coverage, plot ratio, and ratio of functions (e.g., residential, commercial and industrial). Second, for each parameter, a grey scale image is overlaid over the site and used to create a parameter field. Figure 10.5 shows an example of four images applying to five parameter fields. These images can either be created by hand in an

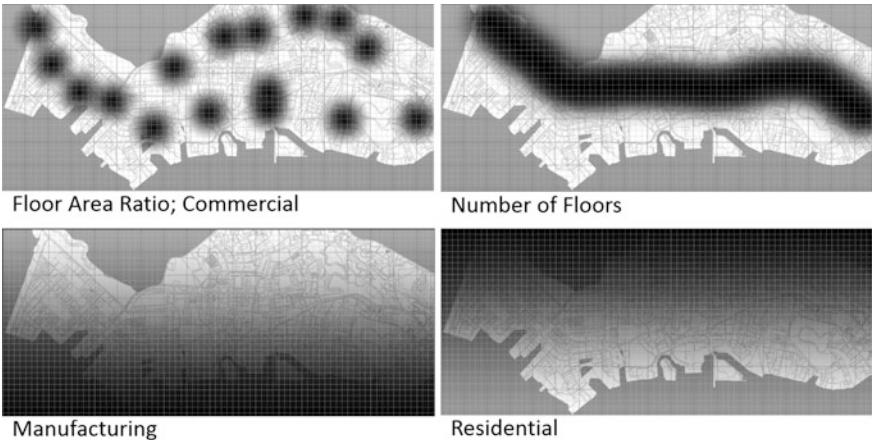

Fig. 10.5 Four grey scale images defining five parameter fields overlaid over the site. *Credits* Ibrahim Nazim

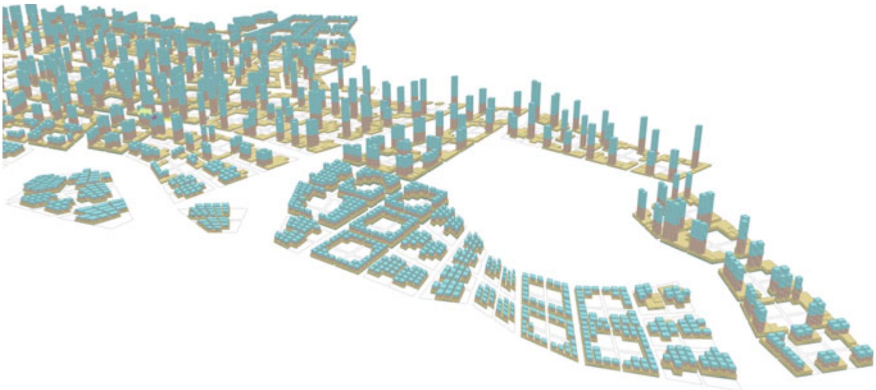

Fig. 10.6 Resulting model generated from the parameter fields shown in Fig. 10.5. *Credits* idem

image-editing tool, or in a GIS system based on certain proximity rules. By default, dark areas of the image correspond to high parameter values, light areas to low parameter values.

Third, large parcels on the site are subdivided into smaller plots according to various subdivision rules, and the parametric models are then used to generate varying building models for each plot, reducing the need to manually detail the road network and plot distribution. The resulting model generated from the images in Fig. 10.5 is shown in Fig. 10.6. This model includes floor plates for each floor, which makes it straightforward to calculate floor areas, such as the total floor area for each function.

SideFX Houdini was used to implement the data synthesis method. The parametric models that serve to generate the building models were actually encoded as procedural rules taking as input the respective values from the different parameter fields. Additionally, a number of workflows were developed to support both generating and evaluating urban models. Exporting the Houdini model to Unity Technologies Unity allowed for advanced visualization. Transferring the data within Houdini from the 3D building model on each plot back to the base polygon for that plot, these base polygons with the attribute data attached could then be exported as a Shape file and imported back into a GIS system.

However, having developed these workflows, it quickly became apparent during the winter school that there was not enough time for groups to apply these types of workflows. Despite having overcome various hurdles, the workflow still proved too challenging for use in the timeframe of the winter school. This was mainly due to the fact that the students had limited knowledge of both GIS and parametric modeling, and learning these methods in such a short timeframe was not feasible. Hence, after the winter school was completed, the workflow was adapted and used to further develop a number of proposals from the urban planning studio to demonstrate the applicability of the method in the context of a design studio. Specifically, rather than relying on parameter field images, the rules were adapted to consider proximity to roads of different categories, MRT lines, parks, waterfront and, possibly, other boundaries, all elements that would have been previously identified in the 2D model. Additionally, the workflows were further relaxed to allow the import of the 2D model as a drawing (e.g., from AutoCAD).

Figure 10.4 illustrates the "Ecotopia" sketched rules for building coverage, distribution and height in relationship to roads, parks, waterfront and other boundaries, for the different mixed-use belts. These sketched rules were disambiguated and encoded as procedural rules. Figure 10.7 shows the model resulting from the data synthesis method. The model was developed in collaboration with one of the students responsible for the "Ecotopia" project in order to ensure a proper interpretation of the project specifics (including the sketched rules) and in order to assess the applicability to the design studio context. The data synthesis results of this and one other project were also presented in an exhibition "Rethinking Urban Practices For Jurong Vision 2050" held at the National Library Building and at the URA (Urban Redevelopment Authority) Centre in Singapore.

10.5 Localization

The data synthesis method firstly developed for the winter school only considered a podium and towers typology for mixed-use functionalities (industrial and commercial in the podium and office and residential in the towers). The variation in the resulting model in Fig. 10.6 is due to an automatic division of plots into smaller entities, such that the podium does not have to fill the entire plot but may be concentrated near the roadside. In the Ecotopia model, the building typologies were

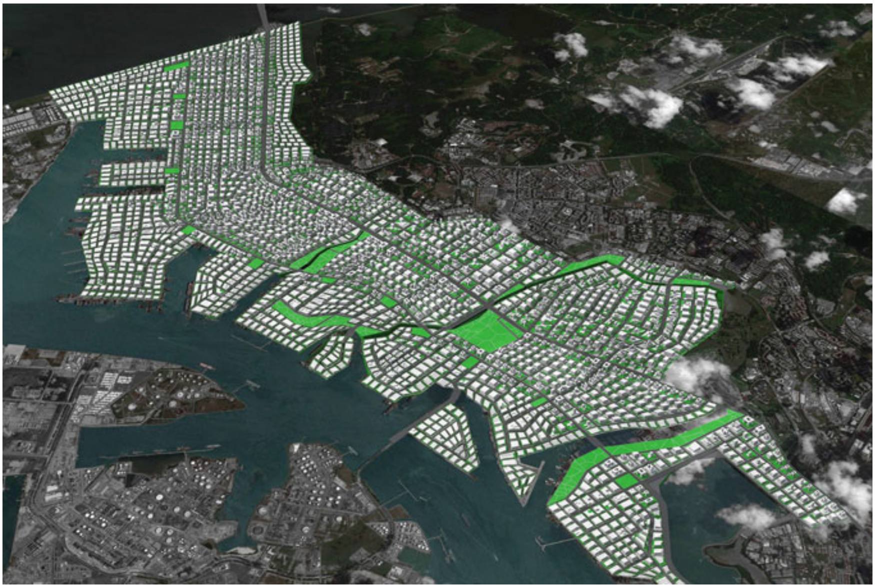

Fig. 10.7 Generated model of Ecotopia, corresponding the rules shown in Fig. 10.4 and the building typologies as considered in the "Ecotopia" project. *Credits* Lin Xiong and Andrea Meinarti Rachmat

adapted from the project specifics and consider, among others, also an elevated platform with a central light well supported by four corner towers. While urban planners and designers might specify and develop their own typologies, for the purpose of using the data synthesis method and workflows in a design studio setting, taking into accounts constraints of time and effort, it would be important to provide a number of predefined typologies that, while offering sufficient variability, also reflect on the geographical and cultural context of the project. For example, public housing developments in Singapore consider a limited number of apartment types as prescribed by the Housing Development Board (HDB) and arrange these apartments mostly in a point block configuration of either 4 or 6 apartments. Also, JTC Corporation, as the main developer of industrial and business parks in Singapore, considers a number of standard building typologies, such as *flatted factories*, which are high-rise, multi-tenanted developments with common facilities such as passenger and cargo lifts, loading/unloading bays and car parks. JTC's flatted factories are designed for clean and light businesses that require functionality, production flexibility and space utility. The development of such typologies for the data synthesis method is the topic of future research. Other localized information to be taken into account are building codes and regulations, including setbacks from roads, maximal building heights, etc.

10.6 Conclusion and Future Work

We presented a rule-based approach to generate relevant building data from 2D urban plans that can serve to analyze and assess such urban plans with respect to different criteria, requirements and targets, and can be applied within a design studio context. We have emphasized the need for such generation to take into account local conditions and building typologies.

Future research will explore both computational methods and interactive workflows. The former investigation will include a grammar-based data synthesis approach. This approach will require the conception of a relevant representational and description model for the generation and analysis of building information from urban plans. The model will draw on existing research and development on shape grammars, description grammars, *sortal* grammars and structures [6], and GIS, and be driven by relevant analysis requirements. The model will be assessed in the exploration and development of an exemplary grammar within the Singaporean context and its application to one or more urban plans. This will include an investigation of the encoding of some relevant building typologies and, possibly, of relevant building codes and regulations.

The research into interactive workflows will include the development of methods and tools that make these approaches more accessible to urban planners and designers. The current ecosystem of GIS and modeling systems are overly complex and therefore make these approaches very challenging. As a result, most students (and many practitioners) simply revert to guesswork and rules-of-thumb. The new methods and tools need to be intuitive and enjoyable to use while at the same time enabling design options to be systematically explored with respect to specific constrains and performance criteria.

Acknowledgments The IFoU Winter School and the M.U.P. urban planning studio were supported financially by NUS-JTC i^3 Centre and in kind by JTC Corporation. The exhibition "Rethinking Urban Practices For Jurong Vision 2050" was realized in association with "Rethinking Our City for Singapore's Next 50 Years," a series of nine concurrent and successive exhibitions held throughout Singapore from July until the end of 2015, organized and funded by the School of Design and Environment, National University of Singapore. We thank Ibrahim Nazim and Lin Xiong for implementing the data synthesis method and workflows.

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Part IV
Analysis of Other Cultural Artifacts

Chapter 11
Player Segmentation Strategies Based on the Types of Self-recognition in Online Game World

Young Yim Doh

Abstract This research was conducted in an attempt to suggest player segmentation strategies based on the types of self-recognition in online game world. Using the framework based on six types of self-recognition in online game world by Young Yim Do (2009) (Self-enhancer, Trend-expressionist, Relation-oriented, Isolated-antisocial, Social contributor, and Self-interest), I reinterpret the major game behaviors, core values, and psycho-socio-cultural characteristics of the six types. Finally, I suggest new strategic points to improve the player satisfaction for each type of game service design.

11.1 Introduction

In the online game world, people are given opportunities to create characters that reflect who they are, what they want, what they dream of, and what they fear. Individuals engaging in game activities express their needs and values in the cyber world. They also learn how to form a community and interact with others in a virtual setting [1]. This supports the claim that people perceive online games as another living space that both reflects their real lives [2] and embodies lives that are different from their offline lives [3].

Just like individuals who live in the same area in the real life do not have the same self-recognition, the lives of online game players in the virtual world are not the same, although they sign on to the same game. Different players attribute different meanings and values to different behaviors. As a result, the game world can illustrate the emergence of diverse cultural codes in the digital world.

This paper is an extension of a part of the author's doctoral dissertation. Because of a pronunciation problem, her family name 'Doh' has been changed to 'Doh' after writing doctoral dissertation.

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_11

When we segment the players' types of self-recognition in the online game world properly, we can understand the varying needs of different groups. A better understanding means we can focus on the things that really matter to players. Therefore, from the perspective of service design, useful segmentation strategies can give us a chance to deal with the five design problems below in more efficient ways. First, through understanding precisely the players' deep desire and satisfaction, service providers are able to provide better experiences for players [4]. Second, by using tools from the scientific segmentation method, players and service providers can become aware and communicate with different perspectives. Third, through ascertaining which groups can be properly targeted to achieve a desired outcome, service providers can easily set strategic priorities. Forth, understanding the tailoring service element for different segments can increase the usage and satisfaction. In addition, better personalized service design strategies can be implemented. Finally, in the pre-design phase, which can be done with minimum negative impact on players, service providers can develop more effective preventive intervention strategies.

The purpose of this study is to suggest player segmentation strategies based on the types of self-recognition in online game world. Using the framework based on six types of self-recognition in online game world [1], I reinterpret the characteristics of six types and suggest new strategic points to improve the player satisfaction for each type.

11.2 Player Segmentation Strategies Based on the Types of Self-recognition in Online Game World

11.2.1 Six Types of Self-recognition in Online Game World

In 2009, I discovered the six types of self-recognition in Mabinogi, which is one of the MMORPG (Massive Multiplayer Online Role-playing Game) Genre services in Korea: Self-enhancer, Trend-expressionist, Relation-oriented, Isolated-antisocial, Social contributor, and Self-interest.

I used Q methodology to investigate the types of self-recognition in online game world. Invented by Stephenson, Q methodology examines subjective attitudes, beliefs, and values objectively. Both inner experience and outer behavior are matters for objective, operational, definitions and study [5]. Subjectivity refers to a person's communication of his or her point-of-view on any matter of personal and/or social importance. This methodology provides a foundation for the systematic study of subjectivity [6]. Individuals state something meaningful about their personal experience, and the Q methodology provides a systematic means to examine and reach an understanding about such experiences [7]. Subjectivities are empirically available in the sense that people do have attitudes, behaviors, and stylized self-expressions [8].

Instead of providing scales that are predetermined by the researcher, the meanings are dependent on the participant's subjectivity or "map of mind". The holistic perspective "total person in action" becomes the central focus and the term "self-referent" is the key [5]. I am not interested in how many people hold certain views, which is a task more suited for survey research, but rather, my goal is to accurately discover the nature of diverse viewpoints.

Q methodology is well-suited for investigating a specific phenomenon from the player's viewpoints (and not the researcher's perspective) and for extracting meaningful experiences, understanding these experiences, and evaluating them systematically [7]. In contrast to the "R method," which involves finding correlations between traits (such as ratings of behavior statements) across a set of persons, the "Q method" computes correlations between people across a set of statements. The Q factor analysis reduces the many viewpoints of individuals down to a few shared perspectives [9].

This approach usually uses small group observation and I selected and guided 20 players (male $N = 13$, female $N = 7$, age range 16–37) to assign 82 online game behavior statements according to a quasi-normal distribution in a forced-choice format. The instruction was to sort the statements based on their behaviors in the game world from 1-point ("I do not behave this way at all") to 9-points ("I typically behave in this way"). The collected Q data were analyzed using the QUANL program.

As a result, I discovered a three factor structure of self-recognition in online game world and each factor has two contrasting behavioral modes showing normative ("I typically behave in this way") and de-normative ("I do not behave this way at all") behavior repertoires. Usually, in the interpretation process of Q subtypes, researchers describe one factor as one subtype. However, in the online game world as cyberspace, players have a more malleable attitude toward keeping social norms compared with real space. Therefore I interpreted each behavior mode as one independent type of self-recognition (Table 11.1).

11.2.2 The Self-Enhancer

The self-enhancers are highly goal-oriented. They set goals in the game world and strive to achieve these goals. In the process, they feel a sense of accomplishment

Table 11.1 Psychological criterion for the types of self-recognition in online games [1: p. 66],

Criterion for the types of self-recognition in online game world	Factor 1 ($N = 10$)	Factor 2 ($N = 6$)	Factor 3 ($N = 4$)
Psychological reference point	Self	Relation	System
Function of online game world	The stage of self-identification	The field of forming relationships	The system of gaining utility values
Upper-lower contrast criterion of behavior repertoires			
Normative	Self-enhancer	Relation-oriented	Social contributor
De-normative	Trend-expressionist	Isolated-antisocial	Self-interest

Table 11.2 Characteristics of self-enhancers and strategic points for improving game service satisfaction

Motto	I have accomplishments
Major game behaviors	Single play tendencies Do not bother others
Core values	Achievement, growth, mastery
Psycho-socio-cultural characteristics	Setting goals are important Game has a meaning of tasks that needs to be done Have strict standards to evaluate self Easily feel inferior Often feel guilty because they believe in strictly following social norms
Strategic points for improving game service satisfaction	Clear goal setting Visualization and feedback system for skill mastery process Independent game space Standardized social norms in community

and satisfaction. Because they are uncomfortable with receiving help from others for the fear that they may cause a burden to others, they tend to play alone in game settings. Self-enhancers wish to feel self-achievement. Thus if they feel they are not skilled enough, they seldom participate in team play.

Their primary values are effort, achievement, growth, mastery, and self-enhancement. From the perspective of social standards, the desire to accomplish is usually formulated extrinsically rather than intrinsically, so it can be inferred that people in this group are compelled to believe they are trying hard and that following the normal standards is the correct way of life. Due to such characteristics, they feel guilty if they do not follow the social rules and often feel a sense of inferiority if they do not achieve the high standards that they set for themselves. Once they become part of a group or organization, they contribute to the maintenance of the rules and standards of the group. People in this group are highly motivated once goals are set, so it is very important for them to find goals that are in accordance with their values. This would provide them an opportunity to self-enhance.

In order to improve the satisfaction of this group, the game space should allow behavior affordances such as clear goal setting, visualization, and a feedback system for skill mastery process, independent game space, and standardized social norms in the community (Table 11.2).

11.2.3 The Trend-Expressionist

Trend-expressionists desire to create a stylish and chic self-image. Because they are seeking attention, they do not care if they cause problems on others. The reason for playing online games is for pleasure and enjoyment. In addition, they are interested

Table 11.3 Characteristics of trend-expressionists and strategic points for improving game service satisfaction

Motto	I am different
Major game behaviors	Engage not only in game activities, but also fan art and other creative activities to pursue their own images
Core values	Belongingness, trend, brand, fun
Psycho-socio-cultural characteristics	Try hard to look cool Become a trendsetter Struggle for other's recognitions Pursue self-satisfaction, therefore sometimes overlook social norms or rules
Strategic points for improving game service satisfaction	Opportunity to realign themselves with target group or trend Express their creativity and show their entertainer's trait Diverse tools to express their style Fashion-conscious behavior be applauded In order to avoid conflict with others, need to keep social order and promises

in creating new trends. Ironically, though, it is important to note that the baseline for determining whether they are unique is in the others' perspective. Thus, trend-expressionists are very conscious of what others think of them and the others' views on them act as a powerful source for determining who they are.

In the game world, people in this group express themselves through purchasing expensive clothes and tools and flaunting their appearances. They believe they are the main actors (actresses) on the stage called the online game and behave as they own the world. Although they claim to value uniqueness, they tend to just follow the trend in reality. Trend-expressionists seldom have the capacity to create new self-images, but they act as key players in "booming up" certain images and turning them into trends. Self-satisfaction is one of the most important values for people in this group. As a result, they do not hesitate to cross the lines when they see it necessary and tend to act whimsically depending on situations. Having consistency and following the norms are of little importance to them. People in this group like to get attention from others. When the relationships are formed in the online game world, these relationships can have more impact and power on them than their offline relationships.

In order to improve the satisfaction of this group, the game space should allow behavior affordances such as opportunities to realign themselves with trends, and express their creativity and entertaining traits. They should also, have diverse tools to show their style, and their fashion-conscious behavior should be applauded. However, in order to avoid conflict with other players, this group needs to keep social order and promises (Table 11.3).

11.2.4 The Relation-Oriented

The relation-oriented group is interested in forming new relationships and finding other aspects of one's identity in the process of meeting new people. People in this group are comfortable with asking for help when needed and often help others as well. When they face problems and obstacles while playing games, they usually confide in their friends and acquaintances rather than looking at guide books. Although these people do not consciously try to make new friends, they feel comfortable in social settings where they meet diverse people and possess an extraverted personality.

The members of the relation-oriented group often talk with friends, start a conversation with newcomers, easily open up to others, and share worries with others in online game settings. They do not care so much about how they are viewed by others and thus act freely and comfortably in the game world. However, the relation-oriented easily "disappear" once they are burdened with a strong responsibility, so those who wish to form exclusive or extraordinary relationships with the relation-oriented people may feel disappointment or even a sense of betrayal. People in this group participate in guild or community activities, but they are not bounded by the group rules. Within the community, they either act as nurturing leaders or play a significant role in channeling communication. This group consists of highly influential people who are amiable, but individuals in the group do not like to be at the center of attention or be given much responsibility. They do not like hierarchical systems but they have an ability to capture the dynamics within the system and act as a mediator.

In order to improve the satisfaction of this group, the game space should allow behavior affordances such as opportunities to form their identity and relationships, chatting and conversation services, guild system and social gathering events in small groups to build intimate relationships, and an atmosphere to talk privately (Table 11.4).

Table 11.4 Characteristics of the relation-oriented and strategic points for improving game service satisfaction

Motto	Enjoy our life freely
Major game behaviors	Chatting with others and sharing their thoughts
Core values	Sympathy, communication, intimacy
Psycho-socio-cultural characteristics	Form relationships with diverse people Freely act without caring about other's perceptions When overwhelmed with much responsibility, just leave
Strategic points for improving game service satisfaction	Opportunity to form their identity and relationship Chatting, Conversation Service Guild, Social Gathering Self-acceptance and intimate relationships are their reward Atmosphere to talk privately

11.2.5 The Isolated-Antisocial

The isolated-antisocial group is maladapted and engages in negative behaviors such as showing hostility or ignorance towards others. Because they pay little attention to others' feelings, people in this group either throw disdainful remarks to newcomers or ignore others. Problems in the real life may cause them to choose isolation in the game world and they may play the game as a means to get rid of their frustration and escape from the reality. In certain cases, they may even perceive negative feedback from others as a sign of receiving attention. When they first play the game, they may think that such behaviors are acceptable since the game world is different from the real world. However, when such negative behaviors ensue, others will show aversion, and people in this group will become even more isolated and antisocial.

In some cases, a relation-oriented person may turn into this type if he is too overwhelmed by real life worries and responsibilities and is hurt. Because he is hurt and drained of energy, he chooses to be isolated and left alone. On the other hand, he may engage in aggressive behaviors and show hostility towards others to let his frustration and anger surface. People who show characteristics of high self-control and discipline may act aggressively in order to feel a sense of catharsis. The isolated-antisocial group has low self-esteem and, feel that they lack control of their surroundings, and as a result, feel frustrated. So, if people in this group do not engage in game activities, they are likely to show problematic behaviors. In a way, playing online games may be a safer way to console and protect them.

In order to improve the satisfaction of this group, the game space should allow behavior affordances such as discovering ways to increase self-esteem, forming positive and healthy relationships with others, feeling catharsis through frustration and anger dissolution, and setting up new life goals (Table 11.5).

Table 11.5 Characteristics of the isolate-antisocial group and strategic points for improving game service satisfaction

Motto	Just leave me alone
Major game behaviors	Interact with only the game Do not interact with other players Sometime engage in negative interactions with others to receive attention
Core values	Escape from boredom Manipulation of self and others
Psycho-socio-cultural characteristics	Repressed, isolated Afraid of revealing themselves Sometimes act antisocially as a result of frustration or anger from relationships
Strategic points for improving game service satisfaction	Recovering from the scars of relationships Need to build trust with others Give warm attention to overcome frustration Frustration and anger dissolution

Table 11.6 Characteristics of social-contributors and strategic points for improving game service satisfaction

Motto	Together, we can change the world
Major game behaviors	Possess affluent social capital in the online game world
Core values	Social values, community fidelity social responsibility
Psycho-socio-cultural characteristics	Contribute to the community Affectionate towards newcomers Like to help beginners
Strategic points for improving game service satisfaction	Community building service Feel leadership and compassion Proud of their ability and diligence

11.2.6 The Social-Contributor

The social contributors are advanced players who know how to play the game effectively and stably. They are affectionate about life in the game world and are very caring of other players. People in this group use much energy, time, and money in the game world, so it is unlikely for them to quit easily. They believe that their game world is a place where all players contribute to make it a better place to live, and thus should strive to maintain social order together. People in this group are altruistic and pursue social values.

The social contributors understand the mechanism and culture of the game world, so they view social responsibility and contributions as tasks they need to carry out for self-development. They are very responsible in the game world; they actively participate in community services and help others, including beginners. Through partaking in such behaviors, they pursue both self-enhancement and social contributions. People in this group are comfortable with their surroundings and are wise. They usually have positive attitudes and are extraverted. Because of these characteristics, they usually are leaders of the community that they are in, such as guilds. They also actively participate in monthly online and offline meetings with other game players.

In order to improve the satisfaction of this group, the game space should allow behavior affordances such as community building service, opportunities to demonstrate leadership and compassion, and being able to show pride in their abilities and diligence (Table 11.6).

11.2.7 The Self-Interested

The self-interested group feels a sense of achievement when they utilize social relationships, social systems, and information for egocentric reasons. When people

Table 11.7 Characteristics of the self-interested and strategic points for improving game service satisfaction

Motto	Solely focus on my desires
Major game behaviors	Pursue personal profit through game systems and social relationships Do not spend much time or money
Core values	Profit, competition, power, money social recognition
Psycho-socio-cultural characteristics	Use game world for gaining profits Strongly desire social recognition Diligent and active, but are not socially responsible Ignore rules and social standards for self-interest
Strategic points for improving game service satisfaction	Item trading system Competitive activity for monetary rewards Market, event, challenge

in this group need to make decisions, they value practicality and live a competitive life. They do not like to lose and stop themselves from spending much time and money on games.

This group actively uses the game world for personal gains only and rejects social responsibility. In the game world, they are energetic and fervently carry out their business. When something or someone stops them from making profits, they post objections on the board and loudly express their complaints. Because the behaviors of the self-interest group are egocentric in nature, they are not very respected by others. People in this group participate in game activities because they feel such behaviors would benefit them in one way or another. They are keen in grasping the resources in the game world and effectively utilize those resources for self-centered purposes. They do not like to lose or give up anything and belittle those who need their help. The self-interest group does not feel much guilt in deceiving others and breaking the rules if they can get what they want.

In order to improve the satisfaction of this group, the game space should allow behavior affordances such as an item trading system to get profits from the game, competitive activities for monetary rewards, and events with big deals (Table 11.7).

11.3 Conclusion

The game environment provides a setting for psychological projection and game players have the opportunity to improve self-awareness through reflecting on their online game characteristics. In addition, they gain understandings and insights about their ideal selves and feared selves. As a result, the act of constructing self-recognition and expressing them is meaningful in that it allows game players to recognize their life value in cyber space. The process of creating self in the game world demonstrates how the life of individuals evolve in a digital ecological environment. In this aspect, the online game world is not a virtual world. Rather, it serves as another ecological environment where an individual can express their self and form a new social culture [1].

Differentiating users by types of self-recognition provides a more accurate and specific psychological model in analyzing the behavioral patterns of game players than differentiating by age, gender, socioeconomic status, or other demographic standards. Compared to surface level data, a deep understanding of players enables service designers to find common drivers of behavior, thoughts and feelings across segments [4]. The concept of self-recognition encompasses the values of individuals and the community that these individuals constitute. In addition, these differences in values amongst groups help us understand how these values are manifested in the game players' behaviors [10]. The culture code of the online game world may vary depending on the types of self-recognition that dominates it. Based on different types of self-recognition, players have opportunities to remember different things, in different ways and for different reasons [4]. Understanding these differences provides service designers with chances for nudging players into creating personally relevant gaming experiences.

The findings from this study will help us understand the psychological meanings and values of online game players. Such knowledge would allow us to draw more clear and accurate predictions of future online game worlds and ultimately assist in providing new service insights and making an effective personalized marketing strategy when necessary.

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Chapter 12
Style Synthesis Based on Strategic Styling Decision

Kyung Hoon Hyun and Ji-Hyun Lee

Abstract This research proposes a method to synthesize car designs based on strategic styling positioning (product appearance similarities among product generations, portfolios and competitors). Automobile manufacturers strategically upgrade new designs similarly or differently from the designs of previous generations, both those within product portfolio, and those from competitors. Design similarity is a critical element of the design upgrading process, and design upgrade strategies vary depending on the automobile manufacturer. Some car brands maintain high similarities with their previous car designs, while others change the designs of new cars. Thus, this paper investigates ways of implementing design similarity to synthesize styles that reflect the particular styling strategy. The implementation of design similarity for generating design alternatives will help to derive two major contributions: first, to provide better understanding of the function of visual reference, and second, designers can strategically upgrade new generations of car designs while maintaining (or changing) a specific style.

12.1 Introduction

Design upgrades are an important element of product upgrades that influence the purchase intent of potential customers [1]. Strategic product upgrades over generations are important to fulfill customers' needs to purchase [2]. For instance, automobile manufacturers strategically upgrade new designs similarly or differently from the designs of previous generations, designs within product portfolio, and

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_12

designs of competitors. This process is called facelift and full model change. Facelift is when the car manufacturers marginally change the style of car model generations, and full model change is when the car design goes through a complete design change [3]. The exact period of design upgrades varies depending on the car manufacturers, but facelift is conducted approximately every one or two years while full model change is conducted roughly every five years [3]. The design upgrade strategy varies depending on the automobile manufacturer as well. There are car brands that maintain high similarities with their previous car designs, and there are car brands that change when designing new cars [4]. According to Hyun et al. [4], Hyundai drastically changes car designs over generations, while Jaguar maintains car designs over generations. Thus, design similarity is a critical element of the design upgrading process. The implementation of design similarity to computational design synthesis can contribute to automatically generate design alternatives that best fit the design strategy of the product. Thus, this paper investigates ways of implementing design similarity to synthesize styles that reflect the style strategy. The implementation of design similarity for generating design alternatives will help to derive two major contributions: first, better understanding of the function of the visual reference can be provided; second, designers can strategically upgrade new generations of car designs while maintaining (or changing) a specific style. To reach our research objective, we have conducted six major tasks: (1) collecting data for design similarity calculation, (2) decomposing car designs elements from the data; (3) calculating design similarities among car design elements; (4) identifying visual significance on car design elements; (5) generating a weighted sum of design similarities with task and; (6) generating design alternatives based on the strategic styling decision.

12.2 Related Works

12.2.1 Visual References

According to Crilly et al. [5], there are four different types of visual references: (1) similar products (from within the same category); (2) dissimilar products (from other categories); (3) historic products (cultural artefacts); (4) non-products (natural objects). The visual references help express whether the product form is familiar or unique. Hekkert et al. [6] found out that the familiarity (typicality) and uniqueness (novelty) were important qualities in formation of aesthetic preferences. The concept of typicality and novelty works relatively due to its nature of comparison. In other words, the typicality and novelty of the product form is perceived relatively; therefore, it is defined depending on the product pool. In other words, the design that had been considered unique can be reconsidered as familiar when new designs are introduced.

12.2.2 Design Similarity and Visual Significance

The similarity calculation was based on Fourier decomposition as used by design style literature [7]. Fourier decomposition represents repetitive periodic functions. The design elements were represented as sets of points on closed curves. The similarity values were represented as a total of 100 %, where a higher similarity index value represents similar shapes of the design elements. The similarity values were then organized into adjacency matrices in order to evaluate the relationships among design elements based on the distribution of the similarity index. According to Chan [8], visual impact influences visual significance of design elements. A design element with a more stimulating shape will be more memorable and recognizable. Therefore, eye tracker was used to identify the visual significance of car design elements. Looking probability was used to measure probabilities of fixation duration of specific design elements. Rupp and Wallen [9] proposed a method to compute looking probability. Looking probability is calculated by dividing fixation duration in an area of interest by total picture area covered by the area of interest. Thus, the design similarity of car designs was calculated based on the style quantification method proposed by Hyun et al. [4].

12.2.3 Strategic Styling Decision

Automobile manufacturers actively applied their styling strategy by either following the styling trend or leading the trend. According to Person et al. [10], styling strategy based on the product appearance similarity can be envisioned through the “Strategic Styling Decision” (Fig. 12.1). The strategic styling decision consists of three major components to analyze styling strategy based on product appearance similarities: present product portfolio, succession of product generations, and products of competitors. The present product portfolio indicates the degree of similarity of product appearances among every product among one manufacturer. In terms of car design, a good example would be different classes of cars, such as small-sized sedan, mid-sized sedan and large-sized sedan. The succession of product generations indicates the degree of similarities among generations of a specific product. For instance, analyzing 6 different generations of BMW 5-Series fits within this category. Lastly, products of competitors indicate the degree of similarities among specific products and competing products. For instance, analyzing BMW 5-Series against Hyundai Sonata, Audi A4 and Mercedes E-Class applies to this category. The 3 axis of Strategic Styling Decision is used for Styling Strategy Positioning.

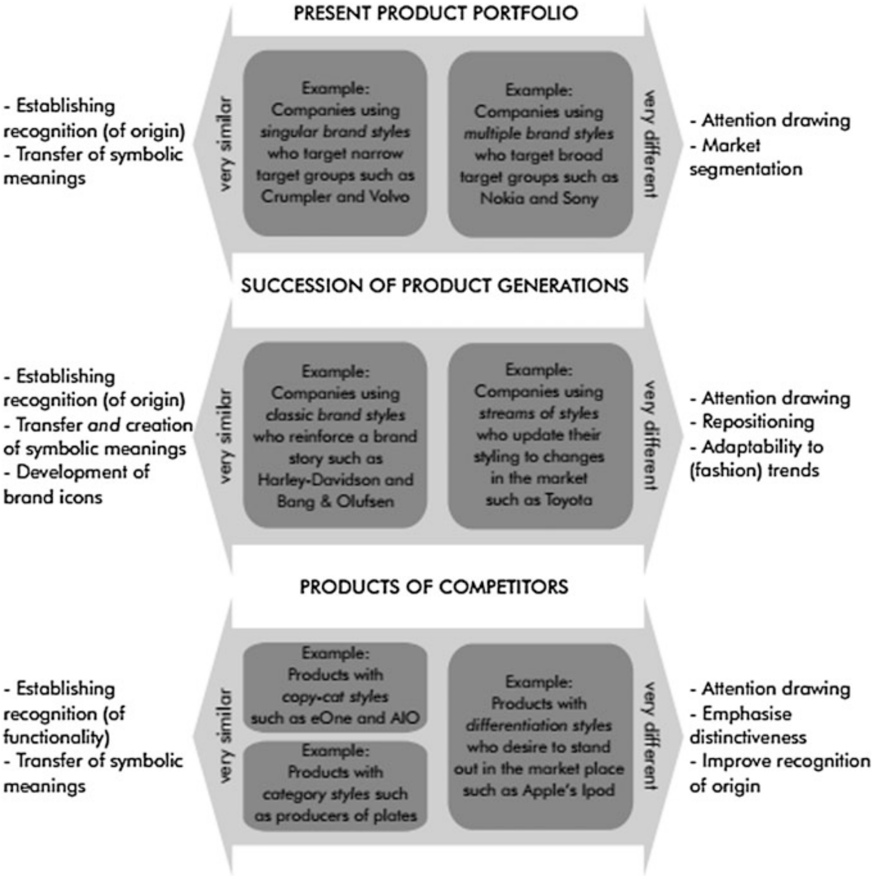

Fig. 12.1 Strategic styling decisions taken from Person et al. [10]

12.3 Methods and Implementations

12.3.1 Data

24 car designs from 22 brands were collected from an online car photograph database. 19 car design elements were decomposed from the photographs. The front, side and rear views of the car photographs were collected to extract the car design elements. Then the 19 design elements were represented as sets of points. A total of 465 design elements were used for the synthesis. The 19 design elements are illustrated in Fig. 12.2.

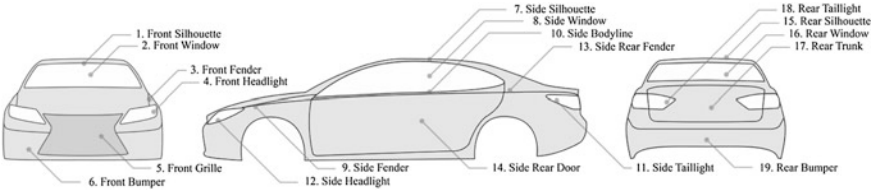

Fig. 12.2 19 stylistically important design elements that are used in the research taken from Hyun et al. [11]

12.3.2 Design Similarity and Visual Reference

The design similarity of 19 design elements of the 24 car designs from 22 brands was calculated based on the style quantification methodology proposed by Hyun et al. [11]. Design elements were compared within the same category of design elements. For instance, front window was compared only with front windows, and side taillight was compared only with side taillights. The 19 similarity values were then combined into a single value to compare the similarity between car designs. To aggregate 19 similarity values, we used visual significance values as a weight. As shown in Fig. 12.3, the visual significance on each design element was identified through the eye tracking experiment. The experiment participants were asked to correctly guess the name of the brand that corresponds to the displayed car design image. While subjects were identifying the brand of the car design, eye tracker collected the subjects' eye fixation data.

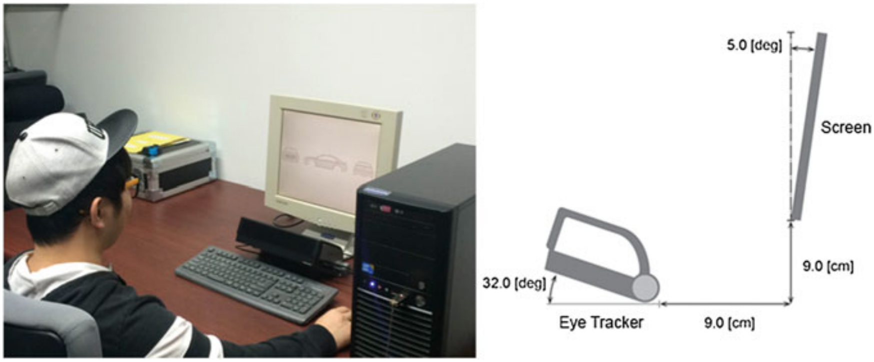

Fig. 12.3 Image of eye tracking experimentation setting taken from Hyun et al. [11]

12.3.3 Styling Strategy Positioning

The positioning of styling strategy is calculated based on the conceptual elements of strategic styling decision proposed by Person et al. [10]: (1) present product portfolio; (2) succession of product generations; (3) products of competitors. However, unlike Person et al. [10], who proposed elements of strategic styling decision conceptually, we empirically calculated the three elements through the degree of design similarities. For instance, the positioning of present product portfolio was defined by calculating the product appearance similarity of a brand. Therefore, by evaluating how similar or different the product appearance is within the brand, we were able to locate the styling strategy positioning of the brand. The positioning of succession of product generation is defined based on the product appearance similarities among product generations. The history of a car's models was evaluated through calculating the degree of similarities within product generations of a specific car design. Lastly, positioning of products of competitors was calculated through the product appearance similarities among competing car designs. Therefore, relatively unique or common car designs were identified. Figure 12.4 is a re-interpreted graph of a 3-dimensional representation of Strategic Styling Decision.

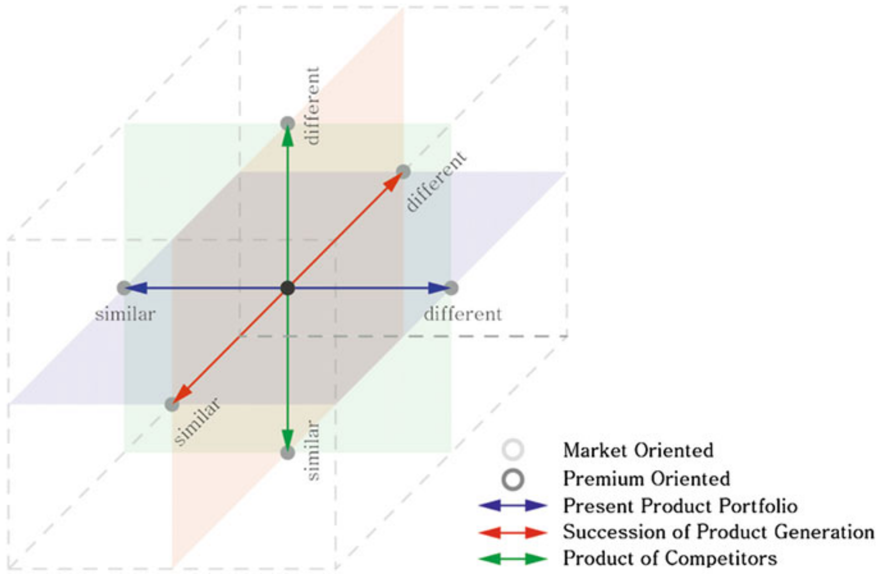

Fig. 12.4 3-dimensional representation of strategic styling decision re-interpreted based on Person et al. [10]

12.3.4 Style Synthesis

Style is synthesized based on the target similarity value. To give a brief example for the style synthesis based on the product appearance similarity, Fig. 12.5 shows the brand style synthesis of the BMW 2010 5-Series. The target product appearance similarity to the original design in this case is 80 %—the target similarity value can change depending on the desired degree of similarity to the original style. The target similarity signifying input similarity percentages is placed right next to the arrow. Similarity measurements among the BMW 5-Series 2010 and other car brands were calculated to meet the target similarity value. Ultimately, numerous design alternatives were generated.

According to the style synthesis process, a new BMW 5-Series was generated. In this case, the three design similarities of the strategic styling positioning were used as a target similarity instead of one. Thus, a new design alternative that fulfills the target similarity of product generation, product portfolio and products of competitors was synthesized. Figure 12.6 shows that the target similarity value was 55 % for product generation and 70 % for products of competitors. Thus, the BMW 5-Series with 55 % similar to previous 5-Series generations and 70 % similar to current competitors is created.

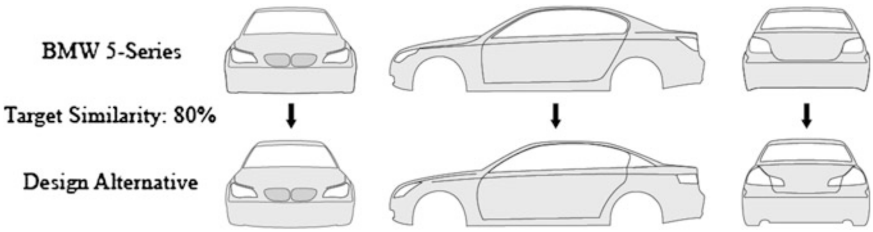

Fig. 12.5 Style synthesis process

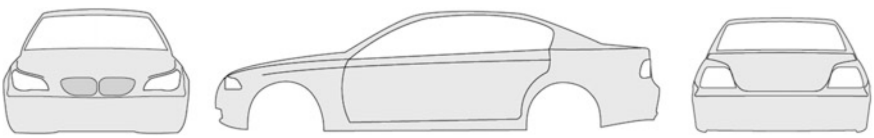

Fig. 12.6 New BMW 5 Series in accordance with strategic styling positioning

12.4 Conclusion and Future Works

This research proposed a method to synthesize product appearance based on styling strategy positioning. Instead of getting help from designer subjectivity, empirical analysis and synthesis provides objective insights on car designs as a new source of information for designers. However, the process of recombining car design elements to meet the target styling strategy produces numerous alternate designs. Thus, it is important to optimize the computational cost of synthesizing the target designs. The optimization of product appearances based on the target styling strategy will be included in future work. Also, the proposed method currently synthesizes car designs by combining existing design elements from actual car designs. Thus, design flexibility is limited since it is not capable of creating "new" design elements. Therefore, future works on generating new design elements that do not yet exist is important for style synthesis.

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Chapter 13
Phylogenetic Analysis of Korean Traditional Rhythm

Hyungjoong Kim and Ji-Hyun Lee

Abstract Phylogenetic analysis approach of musical rhythm is first introduced by Godfried T. Toussaint. In his research, he analyzed rhythmic similarity of Flamenco and found the ancestral rhythm. We will briefly review what he had done in his work, and apply his theory and method to Korean traditional rhythm, '*Jangdan*'. To fill a gap between Spanish and Korean traditional rhythm, we mapped each rhythmic source into four bases of DNA and use neighbor joining clustering method for visualization. Our final goal is to measure a similarity between Korean traditional rhythms and find the ancestral rhythm.

13.1 Introduction

When we find a regular pattern of the sound on a time sequence, we call it as a rhythm. Then where is this musical rhythm come from? Howard Goodall presents a theory that human rhythm recalls the regularity with which we walk and the heartbeat [1]. Okay, it sounds reasonable. But if so, why musical rhythms from different culture have their own characteristics? Other researchers suggest that since certain features of human music are widespread, it is reasonable to suspect that beat-based rhythmic processing has ancient evolutionary roots [2]. In short, musical rhythm might be started from a heartbeat and evolved into various types of styles. But it is not an easy work to prove this because we cannot just sit on the table and listen every rhythm from all over the world and trace back to the ancient rhythm. To avoid this, simple logic for normalizing musical rhythms is needed. This research starts at this point.

Phylogenetic analysis approach of musical rhythm is first introduced by Godfried T. Toussaint. In his research, he analyzed rhythmic similarity of

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_13

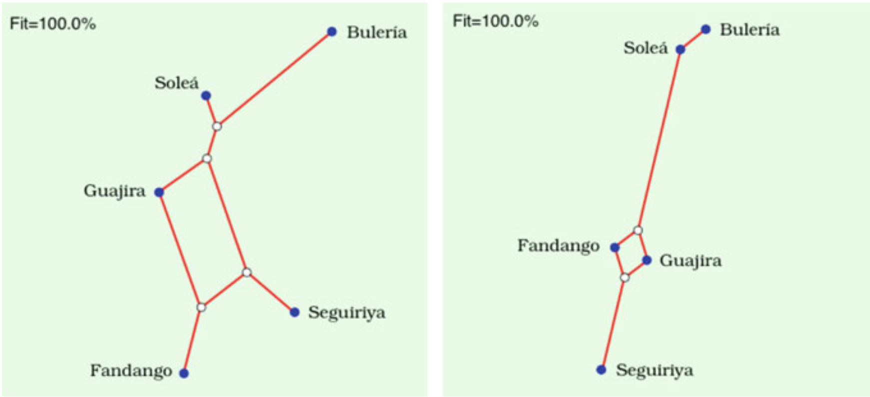

Fig. 13.1 *Left* Phylogenetic analysis of Flamenco using 'the chronotonic distance', *Right* Phylogenetic analysis of Flamenco using 'the directed-swap distance'

Flamenco, musical genre of southern Spanish regions of Andalusia. He suggested that phylogenetic approach might analogize "ancestral rhythm" of flamenco. I will briefly review what he had done on his work, and apply his theory and method to Korean traditional rhythm, '*Jangdan*'. Our final goal is to measure a similarity between Korean traditional rhythms and find an ancestral rhythm.

13.2 Related Work

13.2.1 Phylogenetic Analysis of Musical Rhythm

Toussaint converted basic flamenco rhythms into five 12/8 time metric timelines in simple way [3]. For example, rhythm of seguiriya can be represented as [1 2 3 4 5 6 7 8 9 10 11 12]. When you clap harder on bold face number, it is the basic rhythm of seguiriya. We can represent the rhythm as binary strings, put 1 on the bold onset, 0 on the rest, such as [1 0 1 0 1 0 0 1 0 0 1 0]. Following this method, four other rhythms of flamenco can be analyzed in this way. (Fandango: [1 0 0 1 0 0 1 0 0 1 0 0], Soleá: [0 0 1 0 0 1 0 1 0 1 0 1], Bulería: [0 0 1 0 0 0 1 1 0 1 0 1], Guajira: [1 0 0 1 0 0 1 0 1 0 1 0]) Toussaint considers this as a DNA of the rhythm.

To analyze these rhythms, it is necessary to measure the relative distance between each other. A wide variety of methods for measuring similarity between two rhythms are existed [4]. Among them, he found out that two methods are the most accurate way of measuring the similarity: the chronotonic distance and the directed-swap distance.

13.2.1.1 Finding an Ancestral Rhythm

Using these methods, he calculated a distance matrix and visualized relative distances of five rhythms (Fig. 13.1). During this process, empty nodes had to be drawn in order to raise the fitness values; these nodes can be considered as rhythms that are not existed. Toussaint focused on the node that is drawn at the center, and considered it as the rhythm that we have not known or the assumed ancestral rhythm. The reason why phylogenetic analysis is widely using in biology is that it determines evolutionary relationships across large groups of organisms throughout the history of life of each species. Therefore, Toussaint said it could be possible to think these rhythms are derived from this particular center-located musical rhythm.

13.2.2 Phylogenetic Analysis of Traditional Korean Musical Rhythm

We analyzed similarities between Korean traditional rhythms using following method. Thanks to our ancestor's wisdom, we already have our own way of recording musical score called '*Jeongganbo*'.

The *Jeongganbo* notation system is the earliest Asian mensural notation with pitch and duration. We selected ten *janggu* (Korean traditional percussion) rhythms: *gueteori*, *jungmori*, *jungjungmori*, *jajinmori*, *namdogutgeori*, *namdojajinmori*, *namdojajingutgeori*, *namdosalpuri*, *kyeongkidosaalpuri*, *kyeongkigutgeori*, *kyeongkijajingutgeori* and converted all musical notations into '1' to make simple binary strings, and put '0' into the empty onset (Fig. 13.2). Also, we extended number of squares to 24 rather than 12, because this way makes much easier to compare two, three and eight time metric rhythm. Number 24 is the lowest common multiple (LCM).

However the analyzed result was quite disappointed than we had expected. We could not find any accurate and worth information from it. We thought that it is because Korean traditional rhythm includes not only score information but also temporal information. Moreover, the composition of musical note is not as simple as *flamenco,* which has only two sounds (clap harder and softer) rather it has various sound dynamics such as '*deong*, *kung*, *deok*, *kideok*'.

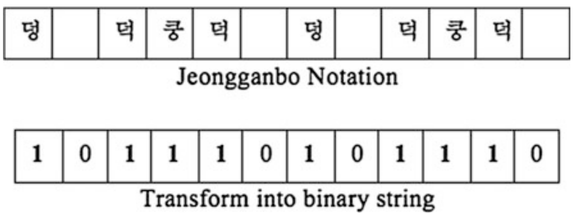

Fig. 13.2 Gutgeori rhythm

13.3 Rhythm as a DNA

13.3.1 DNA Sequence

When we analyzed Korean traditional rhythm in Sect. 13.2.2, there was a significant problem. In *flamenco* rhythm's case, only one of two sounds can be chosen in one onset, clap harder and softer. However, in *janggu* rhythm's case, there are several different sounds that can be put into each onset so that it is quite hard to be analyzed as binary string like *flamenco*. Actually, five different types of onset are needed to get a proper result, '*deong*, *kung*, *deok*, *kideok*' and onset for empty space. Therefore we decided to put different characters in a rhythm for measuring distance. Let's assume that one rhythmic cycle is like a DNA sequence of the rhythm, and sound of each *janggu* can be mapped into four bases of the DNA such as adenine(A), guanine(G), cytosine(C), thymine(T). Since *SplitsTree* is specialized in analyzing biological information, we thought it could be possible to find similarities between rhythms using this software. For this, we used 'neighbor joining' clustering method to create a phylogenetic tree. This software is usually used for creating phylogenetic trees based on DNA or protein sequence data, the algorithm requires knowledge of the distance between each pair of taxes (e.g., species or sequences) to form the tree [5]. Our first experiment was just randomly mapping sounds of *janggu* rhythm into four bases of DNA, *deong* as T, *deok* as C, *kung* as A, and *kideok* as G, and put '-' on empty onset.

However, the result of this was also not satisfied. It somehow clustered '*namdo*' into same phylogenetic area but still was not enough to get ideal classified information. We supposed the reason of this is that the relationship between A-T-C-G might not be a good representation of rhythmic sources (*deong*, *kung*, *deok*, *kideok*). According to Watson-Crick base pairs, adenine and thymine, guanine and cytosine are paired. In *janggu* rhythm, *deong* and *kung* are the basic sound like a bass drum, and *deok* and *kideok* are like a snare. Since each sound can be grouped as a pair, we modified *deong* and *kung* as T, *deok* and *kideok* as G.

In this process (Fig. 13.3), we got the result that seemed to be quite improved than before. From *jajinmori* and *gutgeori*, *namdogutgeori* and *namdojajingutgeori* are derived, *kyeongkijajingutgeori* and *kyeongkigutgeori* as well. It also classified two *salpuri* rhythms in the same area so that they can be considered as another genre. The LSfit index (how accurate the correspondence between the distances in the graph and the distances in the set of objects is) of this graph is 94.5 %, which is pretty high. To get more accurate result, we took one more experiment. When we dealt with the empty onset in previous experiment, we put '-'. This hyphen character is used in real DNA sequencing when they are not sure which base it is, so using hyphen actually decreases the fitness. So rather than using '-', we put 'C' to increase fitness value. Moreover, we divided T into T (*deong*) and A (*kung*), leave G as *deok* and *kideok*, and the result was much more satisfied (Fig. 13.4).

The result showed that every rhythm we had analyzed starts from the point near by the *gutgeori* rhythm as the name implied. In fact, *gutgeori* is the most famous

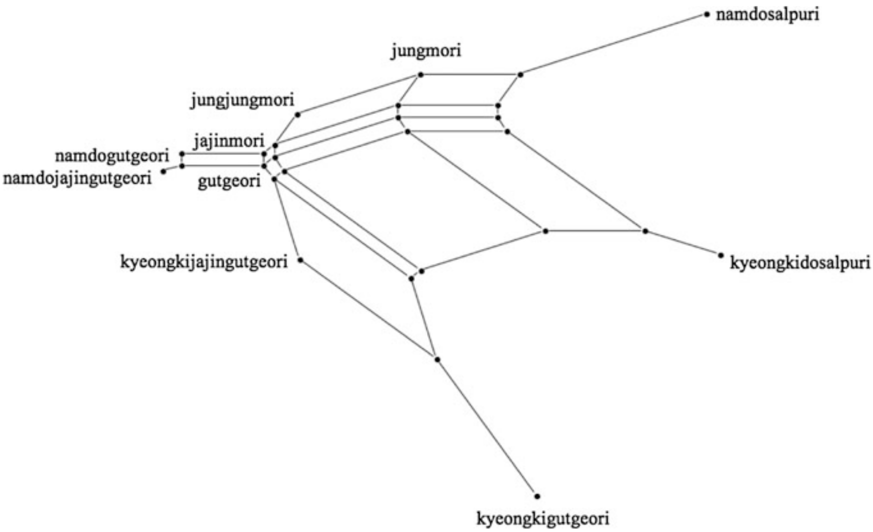

Fig. 13.3 Phylogenetic analysis of Korean traditional rhythm

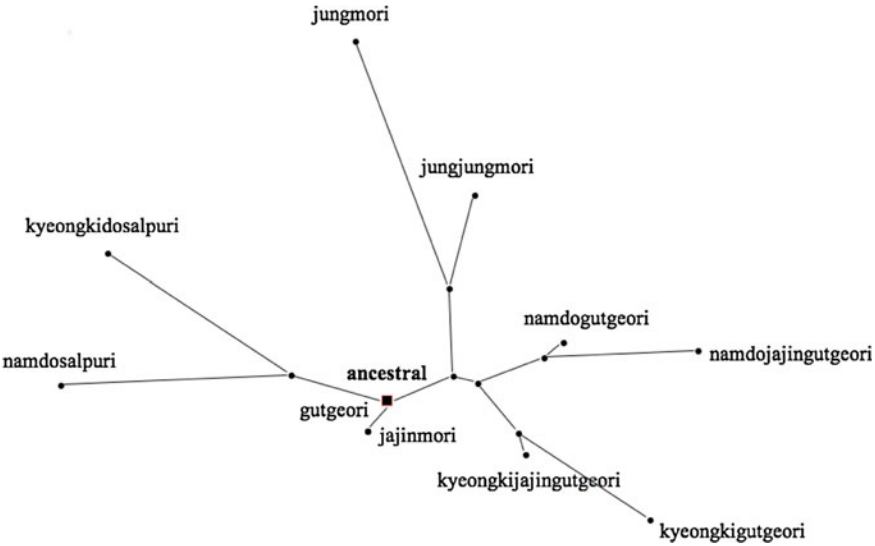

Fig. 13.4 Position of Ancestral rhythm

using rhythm in a wide range of Korean traditional music. Rhythm of *kyeongki* and *namdo (these are name of two different region in Korea)* are clearly clustered into one group, also *jungmori* and *jungjungmori* as well. In *salpuri* case, it is somehow classified into different category. *Salpuri* is actually classified as one specific genre in Korean traditional music. When you listen this rhythm, *salpuri* sounds the most disparate from others.

13.3.2 Ancestral Rhythm of Korean Traditional Music

Throughout our experiment, we started to wonder how this ancestral rhythm sounds like. Sadly, it was not easy to represent the exact musical note of ancestral rhythm only by using *SplitsTree*. Rather, it can be inferred that our ancestral rhythm sounds most similar to *gutgeori* rhythm and also has close relationship to *jungjungmori*. We represented the ancestral rhythm by hand. We compared two rhythms *gutgeori* and *jungjungmori* and changed different onsets as 'A'. The result is [TCCCGCAC GCCCTCCCGCACCCCC].

13.4 Conclusion

In this paper, we introduced phylogenetic analysis approach of musical rhythm. Moreover, we transform Korean traditional percussion instrument sound into four bases of DNA to calculate the distances between traditional rhythms, and find the ancestral rhythm of Korean traditional music. The result of this phylogenetic analysis is somehow well fitted because it found the *gutgeori* rhythm as an origin, which is correct. In addition, it clusters certain rhythms that are evolved in the same region. We have not reproduce the exact ancestral sound yet, but we expect that this approach can find the ancient musical rhythms that we have never heard of. Also, this way of analysis can be used in ethnomusicology field, tracing back to the history of human rhythm.

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Part V
Tools

Chapter 14
Implementing Shape Grammars for Designers

Andrew I-kang Li

Abstract For the computational understanding of visual artifacts, shape grammar provides an important theoretical framework. In addition to the theory, there have been numerous computer implementations; these have tended to be proofs of concept. As such, they are essential steps in development, but do not directly help researchers do the kind of analyses seen in the literature, which were done by hand. That is to say, we have a theory but not yet a sturdy tool. We present a prototype implementation to help designers and design researchers work with shape grammars. This implementation allows users to focus on domain tasks—editing and testing grammars—by shielding them from sub-domain tasks—mechanical tasks like matching shapes and applying rules. A grammar is displayed as a collection of shapes in 3D space that users can manipulate directly; a commercial 3D modeling application is used for this purpose. The components of the implementation are designed to make it easy for users to switch between editing and testing their grammars. The implementation handles emergence and is general. We report on users' experiences with the implementation in workshops on grammatical design and analysis.

14.1 Introduction

For the computational understanding of visual artifacts, shape grammar [1, 2] provides an important theoretical framework. It has been used on subjects ranging from patterns on classical Greek pottery [3] to a twelfth-century Chinese text on buildings [4] to twentieth-century paintings [3].

In addition to the theory, there have been numerous computer implementations (see Chase [5] for a thorough overview); these have tended to be proofs of concept. As such, they are essential steps in development, but do not directly help

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_14

researchers do the kind of analyses above, which were done by hand. That is to say, we have a theory but not yet a sturdy tool.

As an analogy to this situation, consider the financial spreadsheet. The idea is straightforward. There is a matrix of cells, and in each cell the financial analyst can enter either a number (an independent variable) or a formula that operates on numbers in other cells to produce a new number (a dependent variable). If he changes one or more of the independent variables, the dependent variables change accordingly.

There are two levels of work here. One involves formulating the independent variables and the formulas. This is the stuff of financial analysis, the domain level. The other level is the calculation of the dependent variables. This is straightforward execution of domain-level decisions and occurs at the sub-domain level.

In an implementation of a spreadsheet, the work is divided cleanly: the financial analyst works with the numbers and formulas, and the implementation takes care of the arithmetic. He is relieved of sub-domain work and can focus on domain work.

If there were no spreadsheet application, and the financial analyst had only grid paper, pencil, eraser, and perhaps a calculator, he could still do his work, but it would be slow and he would make many mistakes. Worse, he would be spending time and effort on arithmetic that he could be spending on financial analysis.

This is roughly the situation of design analysts who use shape grammars. Their domain work is creating grammars and evaluating the designs generated. [See Computing style [6]] The sub-domain work involves applying rules to existing shapes to produce new shapes; this is shape arithmetic. In studies like those mentioned above, the analysts worked by hand, doing large amounts of shape arithmetic while trying to remember the big picture.

In response, we have developed a prototype implementation for shape grammars in which design analysts draw shapes and rules directly, just as financial analysts enter numbers and formulas directly into the cells of a spreadsheet. The implementation then takes care of the shape arithmetic, just as a spreadsheet application takes care of the financial arithmetic.

14.2 The Implementation

The implementation has three components. The first is the commercial modeling application, **Rhinoceros3D**; users use it to create, edit, and save grammars.

The second component is a free-standing **shape grammar interpreter**.[1] With this, users run grammars and generate new shapes. It is general, which means that

[1]The interpreter is based on an engine by Chau et al. [7]. This engine transforms shapes, finds subshapes, applies rules, and displays the current shape (in 3D). It handles emergence and labeled points. We wrapped this engine in an interface that displays rules visually; displays next shapes; and imports and exports shapes, rules, grammars, and derivations [8].

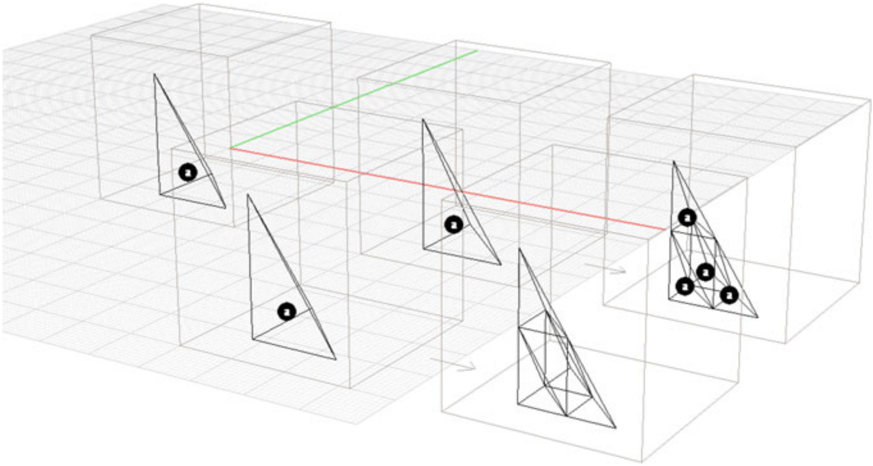

Fig. 14.1 A grammar for creating three-dimensional Sierpiński gaskets. It consists of an initial shape (*left*) and two rules (*right*)

users can make and use their own grammars. It also handles emergence, which, as Krishnamurti ([9]: 940, n. 9) says, is what makes an implementation "worthwhile".

The third component is a set of **scripts**, written in Python and RhinoScript. Users use these to transfer grammars and shapes between Rhino and the interpreter.

To demonstrate how a user would use the implementation, we show how to create and run a grammar that generates the fractal designs known as Sierpiński gaskets. The grammar consists of one initial shape (the labeled tetrahedron) and two rules. Each rule consists of a left shape, an arrow, and a right shape. Each shape is contained in a frame (Fig. 14.1).

To generate a new design, the user starts with the initial shape, applies one of the rules, and transforms the initial shape into a new shape.[2] She continues applying a rule, each time transforming the current shape into a new shape, until she is satisfied with the shape or until a rule cannot be applied (Fig. 14.2).

14.3 Using the Implementation

Using the implementation involves these steps:

1. Creating the grammar.
2. Testing the grammar; i.e., generating and evaluating designs.

[2]For the technical explanation of rule application, see Stiny [1].

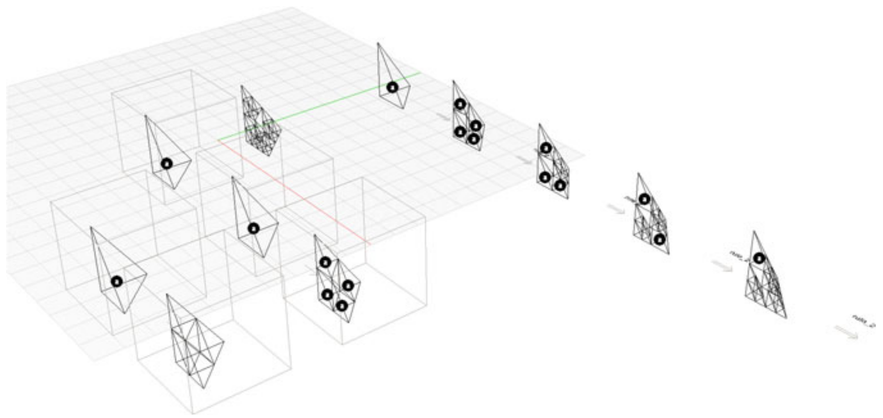

Fig. 14.2 The derivation of a new Sierpiński gasket, behind the original grammar. It consists of 6 shapes: the initial shape (at the back), 4 intermediate shapes (to the right of the initial shape), and the final shape (in front of the initial shape)

3. Revising and retesting the grammar until the results are satisfying; i.e., moving repeatedly through the edit–test cycle.
4. Using the results for some further purpose, i.e., converting the shapes from representations to more concrete artifacts like images for publication or 3D-printed objects.

14.4 Creating the Grammar

The user's first step is to set up an empty grammar document in a Rhino document; she does this with the *new grammar* script. The script creates two layers, one each for an initial shape and a rule, and draws three frames. Each frame delineates the volume inside which she can draw a shape (Fig. 14.3).

Now she can draw shapes with lines and annotation text dots.[3] Each shape should lie within the appropriate frame and on the appropriate layer. She can edit the grammar in any way at any time: she can add initial shapes and rules with the *new initial shape* and *new rule* scripts; she can delete initial shapes and rules; and she can revise initial shapes and rules. In this way, she can draw the two-rule grammar for generating three-dimensional Sierpiński gaskets (Fig. 14.1).

[3]Because the labeled points are implemented as annotation text dots, the labels can consist only of text. These are not as appealing as graphic labels, which are frequently seen in the literature, but they are functionally equivalent.

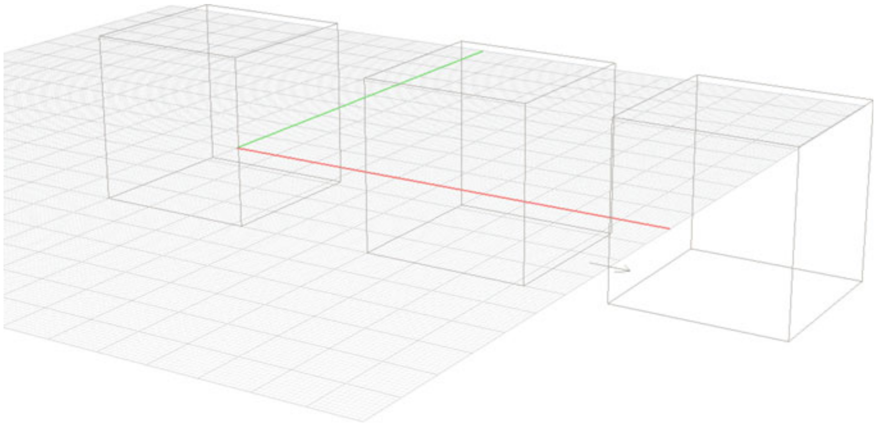

Fig. 14.3 The Rhino document, set up as an empty grammar document. The user draws an initial shape inside the *left frame*, and *left* and *right* shapes in the *middle* and *right frames*

The user can arrange the initial shapes and rules in any way she finds congenial, just as she can arrange icons on her computer desktop. This contributes to the sense that the grammar is an object for her to work with, to manipulate directly.

When she has finished drawing the grammar, she exports it with the *export grammar* script, which generates a file. This is a text file and is easy to understand, but in most cases she need not look at it.

14.5 Testing the Grammar

Now that the user has exported the grammar, she moves to the interpreter to generate shapes. The interpreter has three windows: the main window, in which the grammar and the current shape are displayed; the preview window, in which the possible next shapes are displayed; and a console window, for diagnostic purposes.

She opens the grammar file. The initial shape and rules are displayed in plan view on the left; the main canvas, on the right, is empty at first (Fig. 14.4).

To start generating shapes, the user selects the initial shape[4]; it then appears in the main canvas as the (first) current shape; it can be displayed in isometric, perspective, or orthographic views, and can be rotated in space (Fig. 14.5).

To see what next shapes can be obtained by applying any of the rules, the user clicks *show distinct (all rules)*. To see those resulting from a single selected rule, she clicks *show distinct (1 rule)*. The next shapes, if any, appear in plan view as a scrollable list in the preview window (Fig. 14.6). Calculating these next shapes is shape arithmetic, and it is done by the implementation, not by the user.

[4]It is necessary to select the first current shape because there may be more than one initial shape.

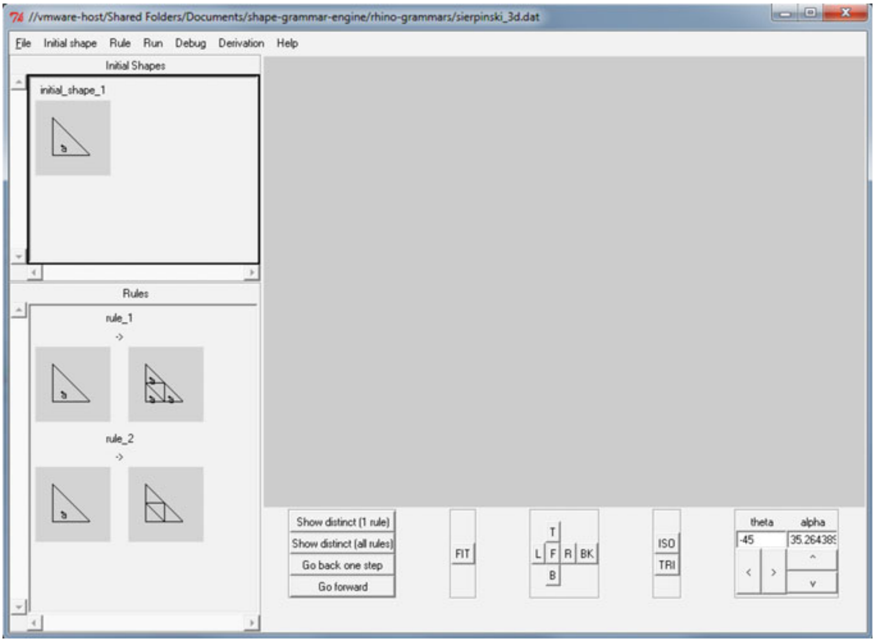

Fig. 14.4 The main window of the interpreter after importing the grammar. The initial shape is on the *upper left*. The rules are on the *lower left*. They are shown in plan view. No current shape has been selected, so the main canvas, on the *right*, is empty

In this case, there are two next shapes. The user can inspect either of these by selecting it; it then replaces the initial shape in the main canvas, becoming the new current shape (Fig. 14.7). She can continue applying rules and transforming the current shape until she is satisfied with the result. The interpreter retains a record of this history, known as a derivation.

If the user wants to undo or redo a rule application, she can step backward and forward through the derivation, as in a browser. It also may happen that she decides that she will not get a satisfactory result with the grammar as it is. In this case, she can simply return to the grammar document in Rhino, revise it, and run the revised version in the interpreter.

Let us assume that the user does not need to modify the grammar and has now finished a satisfactory Sierpiński gasket (Fig. 14.8).

She can save her results by selecting *Save derivation.* The interpreter generates a file which, like the grammar file, is an easily understood but ignorable text file. It includes the grammar, the initial shape, the final shape, all intermediate shapes, and the rule applied at each iteration.

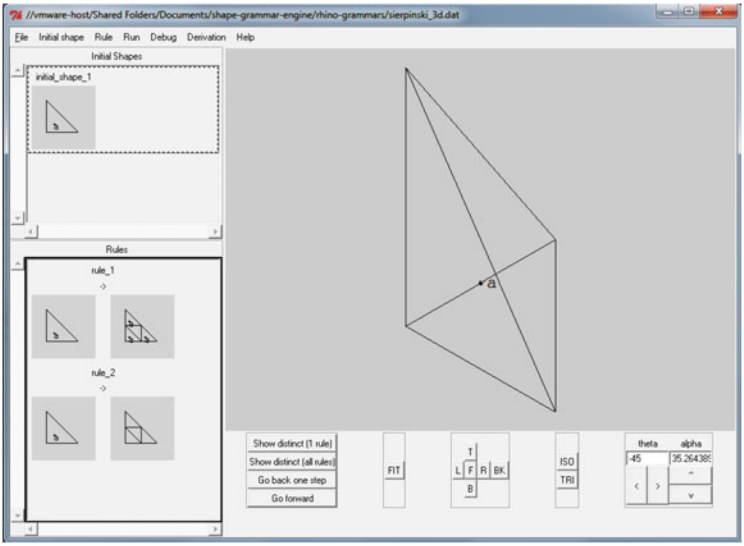

Fig. 14.5 The main window of the interpreter after selecting the initial shape as the (first) current shape. Since no rules have been applied yet, it is still the initial shape. It is shown here in isometric view

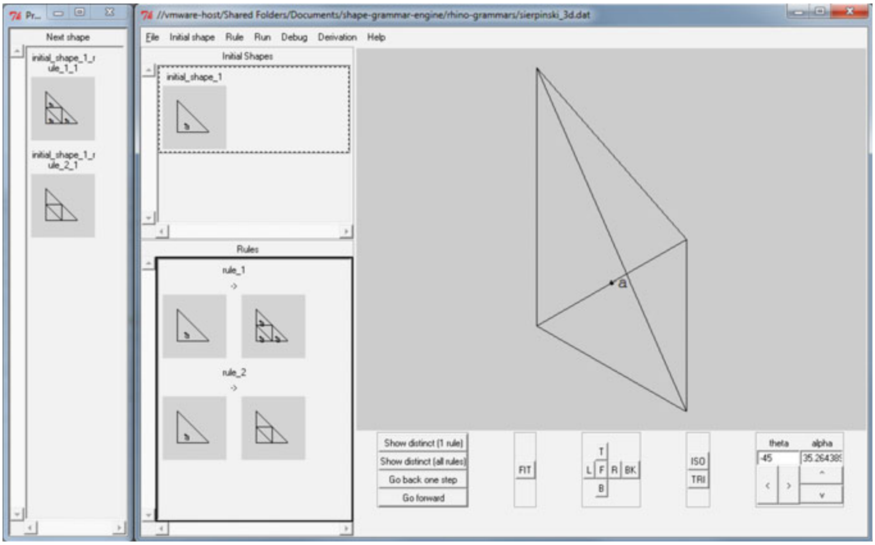

Fig. 14.6 Given the current shape and the rules, there are two possible next shapes. They are shown in plan view in the scrollable preview window on the *left*

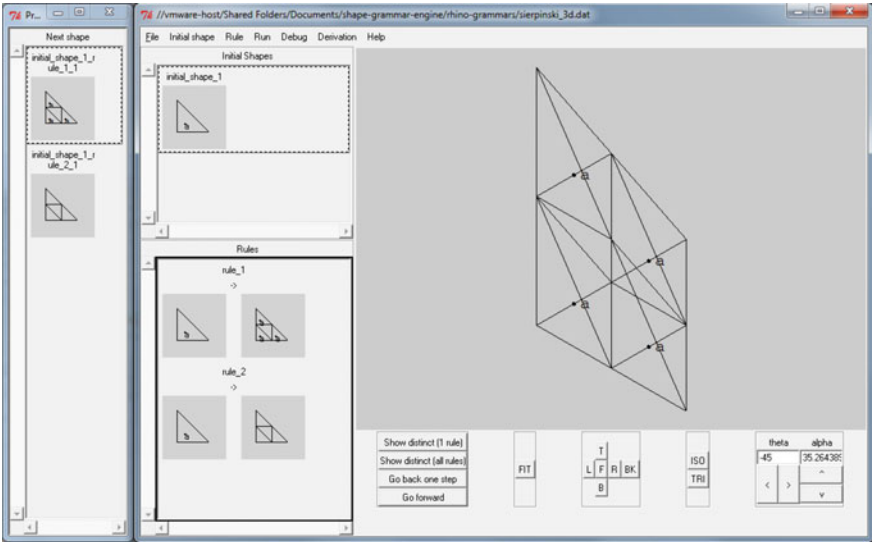

Fig. 14.7 The user selects one of the two possible next shapes (*left window*); it becomes the new current shape (*right window*, main canvas)

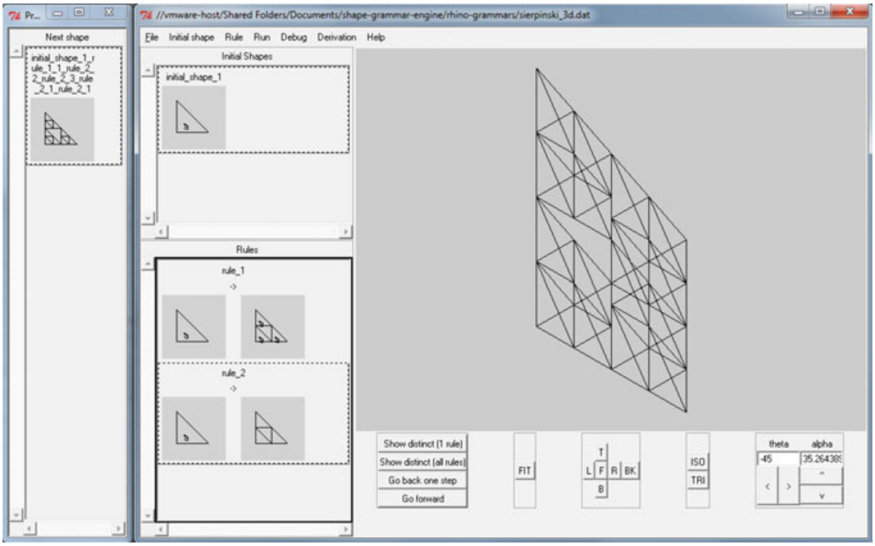

Fig. 14.8 The finished Sierpiński gasket

14.6 Using the Results

The user's work is not done: she has created new shapes, but now she needs to use them. That is, she needs to transform these representations into physical artifacts, whether fabricated objects or simply drawings on a page [10]. To begin this transformation, she uses the *import derivation* script, which uses the derivation file to draw the derivation in the Rhino document (Fig. 14.2). Now all the shapes in the derivation, from the initial shape to the final shape, appear in Rhino as wire frame models, which she can use like any others created in Rhino. She can convert them to surface and solid models; she can render and fabricate them.

14.7 Observations and Discussion

We have used our implementation in several workshops on mass customized design, ranging from one to five days in length. In the longer workshops, participants not only created designs with the implementation; they also converted those designs into physical objects through laser cutting and 3D printing. Some participants had a basic familiarity with Rhino or similar modeling application, and all were new to shape grammar. They were learning both shape grammar and the implementation at the same time.

The goal of the workshops was not to test the implementation per se; it was to give the participants the experience of accomplishing design tasks with shape grammars and the implementation. Thus, we were interested to see whether the implementation generally helped or hindered them, and in what ways.

14.8 Users Were Able to Focus on Domain-Level Work

We observed that participants learned the basics of both shape grammar and the implementation quickly, and were then doing design work easily, including downstream fabrication. For example, in the two-day workshop, participants were introduced to shape grammar on the first day, and to the implementation on the morning of the second day. By the end of the second day they had created and revised grammars, created designs, and fabricated some of those designs.

Once the participants had become familiar with the implementation, they focused on domain-level questions: What if I change this rule? How do I get that shape? In other words, they were successfully shielded from sub-domain-level tasks. We attribute this to several factors.

One is that the domain objects—the shapes and rules of the grammar—are presented in a domain-appropriate way, i.e., visually, and are directly manipulable. Most domain operations, such as 'find next shapes', are single commands, initiated by the user but executed by the implementation.

Another is that the implementation is general. Given the basic elements of lines and labeled points in three-dimensional space (using the U_{13} and V_{03} algebras, in grammar speak), users can create any shapes and rules. They can create grammars for their own purposes.

Finally, we suspect that being able to manipulate shapes directly and getting feedback quickly create a virtuous cycle that motivates users.

14.9 Users Were More Interested in Product Than Process

The derivation of a design is unique to that design, and specifies it within the design space. Grammars in the literature regularly include derivations. Given this significance, we provided the capability to move an entire derivation—not just the final shape—from the interpreter back into Rhino, and we expected users to use this capability. However, we observed that users showed little interest in the derivation. Instead, they were interested in accumulating new designs: product over process.

This discrepancy between theory and practise is, on reflection, not really surprising. As Woodbury [11, p. 17] has noted, designers tend to be pragmatic and indifferent to theory. 'Amateurs program because they have a task to complete for which programming is a good tool'. This applies to shape grammars too.

14.10 The Implementation Made Users Aware of the Conventions of Shape Grammar

The interpreter executes—and thereby enforces—the conventions of shape grammar, just as, say, an interpreter of the Python programming language executes and enforces those of Python. As a result, users who have not yet assimilated those conventions may be surprised by the results that the interpreter produces.

One case is when users could not visualize the results. This type of surprise is to be expected in shape grammar, because of emergence. (Recall [9].) The interpreter is doing what it should do.

Other cases, however, merit some thought. Sometimes users drew shapes imprecisely. For example, they drew rectangles with slightly different proportions and expected the interpreter to see them as similar. Or they drew shapes containing overlapping or abutting lines, which are invalid. In shape grammar theory, such shapes are reduced to their maximal form by replacing the overlapping and abutting lines with single lines. When the interpreter received non-maximal shapes, it sometimes produced incorrect results.

In such cases, we may wonder how to distinguish precise and imprecise, correct and incorrect. On the one hand, a formalism like shape grammar is a formalism, and therefore requires precision, including precision about imprecision. By requiring precision, the interpreter helps users acquire the habit of precision. On the other hand, Woodbury's [11] remark about the pragmatism of designers suggests that we consider whether we can get by with less precision. This is a question addressed by Jowers et al. [12] with their 'fuzzy' implementation.

For our part, we will continue to implement shape grammars as they are defined formally, even as we are aware of the tension with designerly pragmatism.

14.11 Conclusion

Our experiences tend to confirm our basic approach: shield users from sub-domain tasks, support the edit–test cycle, and use a modeling application as an editing platform.

This approach has two general benefits. The first is that the sub-domain work is performed more accurately. The second is that the user can now concentrate her attention on domain tasks: editing and testing grammars.

There is additionally a third benefit, that three-dimensional grammars are usable. These have always been theoretically possible, but they are difficult to draw on paper and even more difficult to execute mechanically. It is probably for this reason that there is little three-dimensional work to be seen in the literature (Koning and Eizenberg [13] is one of the few examples). Now, with Rhino as the platform for viewing and editing grammars, it is easy to do three-dimensional work.

Needless to say, much remains to do, to ask, and to try before designers and design analysts have a robust tool for working with shape grammars. With respect to our implementation, the next step is to tighten the edit–test cycle by reduce the distance between the grammar-editing platform (Rhino) and the grammar-running platform (the interpreter). In the current version, switching between editing and testing requires exporting a file from one platform and importing it into the other. These steps can be eliminated by relocating the interpreter inside Rhino.

Other steps are less obvious. Having seen that users can be more interested in products than process, how should we develop the implementation so it best supports users? At the same time, the users that we observed were doing design work. Do users doing analysis work the same way? What about the many technical features of shape grammar that are still to be implemented: schemas, weights, parallel grammars, description, and so on? How will users want to interact with these features?

There is still much to learn about how designers and analysts work with grammars.

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Chapter 15
Designing for Culture: The Development of a Cultural Design Tool for Service Design

Yu-Hsiu Hung and Wei-Ting Lee

Abstract In Service Design (SD), there have been various tools being developed to help designers create ideas and innovative ideas. However, currently most tools do not particularly address an intended culture when it comes to design, which is believed to influence the user experience and the quality of a service. In this study, we introduced the development of a cultural design tool, i.e., a culturally oriented persona, to help designers consciously integrate culture elements in SD. We also demonstrated a case study that made use of the tool to enhance the services of traditional tea houses in Taiwan. The results of the study provide evidence of a culturally oriented persona as an innovative design tool supporting design activities in the SD process.

15.1 Introduction

Culture shapes who we are today. In creative industries, culture is a key. Without culture, a design is soulless. Every design, be it a product or service, requires an endeavor to take into account the target's culture. A design that truly embraces a culture will generate warm hearted feelings appreciated by the consumers and thus may enhance purchase probability. Furthermore, a design that fits with the user's cultural profile will enhance usability and product performance [1]. On the other hand, from designers' perspectives, culture is a great resource to generate ideas. Designers can obtain inspiration from a culture through in-depth understanding of that culture. Well-known designs such as fashion designer brand Shiatzy Chen is a good example of integrating traditional Chinese aesthetics into product design.

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_15

Along with the growth of creative industries, there is evidence of strong growth of the service economy around the world in recent years. To be successful in the marketplace one can no longer merely rely on product innovations. Rather, innovations in services are also important in creating consumer value that can stimulate consumption and generate revenue to a business [2].

Tools and methodologies are being studied in an attempt to develop effective SD. Among them, the use of persona has been considered an effective approach in the early phase of the SD process. Persona is a description of a person which includes idiosyncratic details and things that s/he desires to achieve [3]. Persona also delineates a person's behaviors and lifestyle [4]. The use of persona can help designers to be cognizant of the users and to switch between a user's perspective and a designer's perspective during SD development [5]. Despite its high popularity in the academia as well as in the design industry, there is no consistent way of creating personas. Furthermore, personas have been criticized for being "too flat" and not carrying rich personalities enough to represent a real person [6]. Personas do not specifically address cultural and social information about an interested culture in supporting design activities [7]. Therefore, we proposed a cultural design tool—Culturally Oriented Persona—that carries information on the characteristics of a culture, and complements typical personas in the SD process.

15.2 Literature Reviews

15.2.1 Designing for Culture

There is a growing interest in designing for culture. In SD, although little work is done on accommodation of culture in the design process, studies on products and interfaces have indicated that interfaces showing characteristics relevant to culture increase product usability and performance [1]. For instance, Smith and Chang [8] incorporated cultural fingerprints as a diagrammatic means to improving the acceptability of website design. Smith et al. [9] presented a process model for developing usable cross-cultural websites. They introduced the concept of cultural attractors (e.g., color combinations, trust signs, use of metaphor, etc.) to define the interface design elements of a website that reflect the signs and their meanings to match the expectations of a local culture. Moreover, Moalosi et al. [10] integrated socio-cultural factors (including social practice factors, material factors, emotional factors, and technology/design factors) into the conceptual design phase to generate culturally oriented products.

The above studies demonstrated the potential for using cultural dimensions/attributes/characteristics for designing innovative SD. In fact, the concept of culture can go from broad to specific and may change overtime by events. Therefore, culture is viewed and defined differently by scholars. It is associated with people, and its content involves a wide range of phenomena, such as norms, values, shared meanings and patterned ways of behaving [11]. In a broad sense, "culture is communication, and communication is culture" [12]. It "includes race and ethnicity as well as other variables and is manifested in customary behaviors, assumptions and values, patterns of thinking and communication style" [13]. More specifically, culture is the socially transmitted knowledge and behavior shared by some groups of people [11]. It is a "system of meaning that underlies routine and behavior in everyday working life" [14]. It is also "a system of inherited conceptions expressed in symbolic forms by means of which men communicate, perpetuate, and develop their knowledge about attitudes toward life" [15].

To summarize, culture is considered a system of collective values and patterns of behaviors and thinking that are meaningful to/shared among individuals in supporting social communications and interactions. For the purpose of this paper, this working definition is used to analyze and decompose culture.

15.2.2 Symbolic Interactionism

Symbolic Interactionism, originated in sociology, refers to the way we (learn to) interpret and give meaning to the world though our interactions with other people [16]. Blumer contended that reality is composed of objects (or symbols), each of which carries a meaning. Meaning evolves from social interactions with objects/symbols in the environment and with people. Simply put, people interact by interpreting another's act based on the meanings produced by their interpretations. The focus of Symbolic Interactionism is on the interpretation/production of meaning through existing symbols/symbolic construction; understanding symbols is important in understanding human behavior that is constrained by social norms and values [16, 17]. Blumer argued that symbolic interaction is a communicative process involving five elements: the self, the act, social interaction, objects, and joint action. He explained that: the self (the way that one person acts in relation to the attitudes of others) can become an object/symbol of self-indication ("a moving communicative process in which the individual note things, assesses them, gives them a meaning, and decides to act on the basis of that meaning") [16]; individual action is yielded from the process of self-indication; joint action (e.g., rites and norms) consists of aligning individual actions through a process of interpretation of others' actions; social interaction means people interact by interpreting another's act based on the meanings produced by their interpretation.

Blumer's explanations of the five interrelated elements of symbolic interaction are in accordance with our working definition of culture. In fact, the idea of culture can be developed from the perspective of Symbolic Interactionism [18], because culture is constructed, learned, interpreted, and transmitted among a group of people where meanings are given/shared in supporting social interactions.

15.3 Framework for Analyzing Culture and Developing a Culturally Oriented Persona

A typical persona is a model of a fictional user that shows patterns of behavior, goals, skills, likes/dislikes, attitudes and demographics of an intended user population. The aim of this study is to develop a culturally oriented persona to assist designers in using culture as a catalyst for developing innovative SD. In this study, a culturally oriented persona resembles a typical persona but with the focus on modeling a culture (rather than a user population). The premise of this study is that people interpret, convey meanings to each other, and adjust meanings based on what they have been informed in the social context [19] and such a communicative process of meaning assignment and generation could have been influenced by an existing culture or could have created a culture.

Therefore, the analytic framework to analyze a culture and to develop a culturally oriented persona can be constructed from the perspective of Symbolic Interactionism. To this end, our framework integrates Blumer's five elements of the communicative process with the constructs of our working definition of culture. It consists of the following four components:

- **Symbols/objects** represent things in the culture that are assigned meanings by individuals. They reflect "the self" and "objects" in Symbolic Interactionism.
- **Behavior** is the actions of an individual in response to stimuli or others. It reflects "act" in Symbolic Interactionism.
- **Ritual/Rite** is a set of actions/behaviors performed by individuals to express the symbolic values. It represents a planned set of activities that combine various forms of cultural expressions and that often have both practical and expressive consequences [20]. According to Hartley [18], rites allow for social interactions on different levels, and have multiple consequences; rites can serve as an entry point for new comers. It reflects "act", "joint action," and "social interaction" in Symbolic Interactionism.
- **Values** are a synthesis of shared meanings, assumptions, and ideals among people that reflect traditions and are worth striving for [21].

Personas are design tools [4]. The four components in the proposed analytic framework can be used in a SD project to guide the investigation of a culture of interest. Results can be easily transformed to model a culture and to create a culturally oriented persona—which includes the definition of an intended culture, the descriptions of symbols/objects, behavior, rituals/rites, and values of a culture. Our proposed culturally oriented Persona offers a brief sketch of an intended culture. The format and pieces of information contain cultural scenes (resembling the photo in a conventional persona), and the cultural elements—symbols/objects, behavior, rituals/rites, and values—(equivalent to the biographical information, behavioral patterns, and environmental information in a conventional persona).

A culturally oriented persona brings in additional insight for designers in designing a service. For instance, it uncovers hidden variables that could have reduced the quality of a service. Such variables can be translated into a visible set of requirements for the definition of a future service.

Our proposed framework for developing a culturally oriented persona is effective in enhancing the outcome of SD in several ways: (1) there are benefits of gaining insight of social aspects through persona design [22]; (2) theories in Symbolic Interactionism and cultural dimensions enable designers to hypothesize user actions and behavior in experiencing technologies [23]; (3) symbolic-interactionism-informed content (i.e., the design of the proposed culturally oriented persona) facilitate the communications among project members [24]. The following demonstrates a case study in developing a service touch point for traditional Taiwanese tea houses using the proposed analytic framework and the culturally oriented persona.

15.4 Case Study: Enhancing the Services of Traditional Tea Houses in Taiwan

A tea house (as shown in Fig. 15.1) in Taiwan is an establishment that focuses on serving tea, demonstrating traditional tea ceremonies, and selling tea and tea ware items. The tea house industry is losing its market share in the tea-drinking business because of the increasing number of convenient tea shops. Enhancing the services of traditional tea houses in Taiwan was the main goal of the case study.

Fig. 15.1 Snapshot of a tea house in Taiwan

15.4.1 Semi-structured Contextual Interview

To help resuscitate this industry, we conducted contextual interviews with five tea house owners (male, mean age = 43) in the Tainan city, Taiwan. For every interview question, we adopted the laddering technique [25] to elicit higher/lower level abstractions of the cultural elements in the tea culture. Based on their responses, the interviewees were asked to explain "why" their articulated abstractions were associated with the tea culture. As such, the interviewees could be guided to describe/indicate the values that are appreciated in Taiwanese tea culture, and the ritual/rite, symbols, objects, as well as the behavior that prevail in the tea culture. The following shows the interview questions used in this study:

- What does Taiwanese tea culture mean to you?
- What are the examples of Taiwanese tea culture?
- How could cultural things be different if there is a lack of Taiwanese tea culture?
- What makes for better Taiwanese tea culture?

In addition, during the interview, we also asked the interviewees how they maintained their business and what could be done to improve it.

15.4.2 Findings

Results of the interview were converted into conventional and culturally oriented personas.

The *Persona* generated from this study is shown in the following.

- First time user: Jeff, (Male, 40 years old, construction supervisors)
- Personality: Enjoy family life, may hang out with friends on weekends, like exercise, emphasize healthy lifestyle, and like to do things quickly.

Below is a description of the *Culturally Oriented Persona* (Fig. 15.2) and the cultural components identified from our case study.

- **Values**—calm; natural; down-to-earth; health; sharing
- **Ritual/rite**—behave politely; follow etiquette; respect elders; hand down to next generation
- **Behavior**—savor tea through the scent of the tea set, tea, teacup, and tea leaves with gentle movement; appreciate the tea leaves, and savor the aftertaste of the tea in the mouth and throat
- **Symbol/object**—tea set (including brewing teapot, pouring teapot, aroma cups, drinking cups, saucer, preparation tray), pewter tea container; tea packaging; tea table.

From the interview, we found that a tea house gets new customers primarily through word of mouth. One of the challenges most interviewees had was to make

Fig. 15.2 A culturally oriented persona generated from the case study (photos obtained from Microsoft Clipart)

those who did not know the tea culture appreciate the behavior/ritual of savoring tea and return to their tea houses after their first visit. Results of the interview also suggested that providing novices (or new customers) with a comfortable environment where customers can easily experience the tea culture without hassle is important. In other words, providing a service that quickly and seamlessly immerses customers in the tea ceremony is critical to the business.

15.4.3 Design Activities and Design Outcomes

We recruited four junior year Industrial Design students (as designers) at a major university in Taiwan to perform design activities for the SD project. Before participants performed design activities, they were instructed the purpose of the project. Participants were then presented with (1) results of the interview, and (2) traditional personas, and (3) the culturally oriented personas. They were told to use the given information to conduct idea sketching. Additionally, participants were allowed to ask any questions about the interview results and the information on the personas. The SD proposals were evaluated based on how much they addressed (1) the cultural components shown in the culturally oriented personas; (2) the interview results. The following explains how the cultural components of the culturally oriented personas were integrated into differing idea proposals.

Design outcome #1 (Fig. 15.3): This is a gift design focusing on the value of "sharing". It emphasizes the ease of sharing tea. The gift set includes six teacup-like

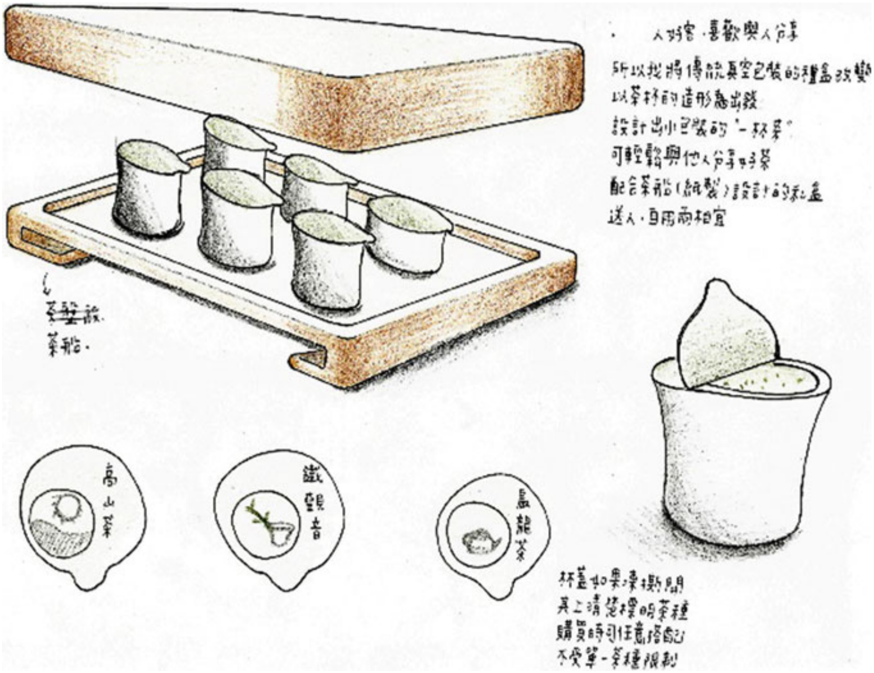

Fig. 15.3 Design outcome #1: gift design—the ease of sharing tea

packages. Each package contains one serving of tea leaves. Information about the tea leaves contained in each package is printed on the seal (top) of the package. Gift donors can customize the tea combination for each set. The design of the gift box resembles the traditional tea preparation tray.

Although this design incorporates the value of sharing in the traditional tea culture and the cups resembled the traditional teacup shape, it is simply a touch-point design and it does not convey any other cultural components that are important to the traditional Taiwanese tea culture. Therefore, we evaluated this proposal as having insufficient depth of the culturally oriented persona to be considered good SD.

Design outcome #2 (Fig. 15.4): This is a tea set design that focuses on the "close to nature" value of the traditional tea culture in Taiwan. The idea is to incorporate the nature (plant) into the behavior of tea savoring. By designing a compartment in the preparation tray for plants, the participants proposed that the users can recycle the unused tea or water to water the plants.

"Close to nature" is the only cultural component addressed in this design. The design of the tea set could have improved by integrating other important cultural components such as ritual/rite and behavior as this product will interact directly with the users and thus could provide a better service through a more thoughtful

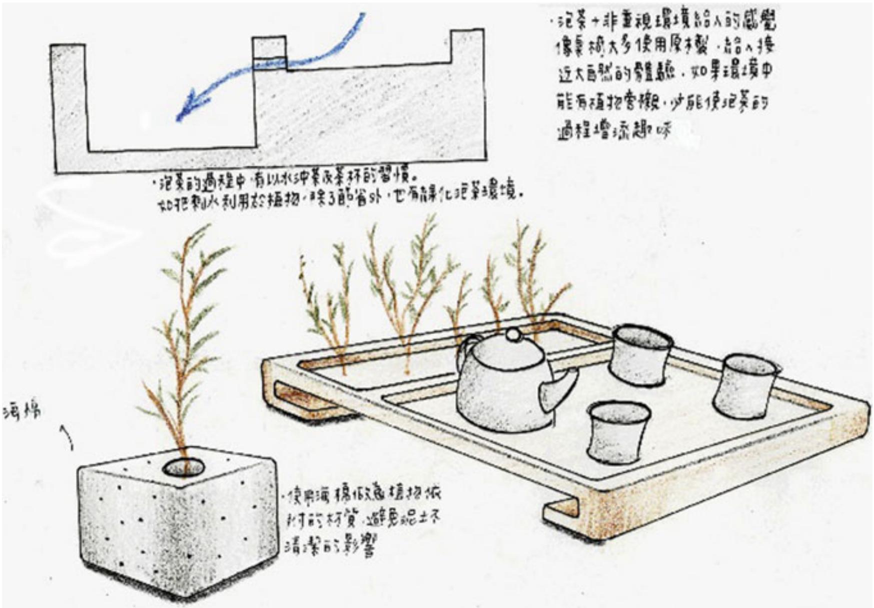

Fig. 15.4 Design outcome #2: incorporating the nature (plant) into the behavior of tea savoring

design. This design is simply a touch point design as well. Therefore, we did not consider this design a qualified candidate for the final selection.

Design outcome #3 (Fig. 15.5): This is a drinking cup design that focuses on the behavior of tea savoring, the value of sharing, and the ritual/rite of etiquette conformation. There are two graduations on the interior of the teacup which divide the teacup into three portions. According to conventional tea drinking etiquette, there are three steps in drinking a cup of tea. The first step is to sip and savor the tea when it first touches your mouth and tongue. Next, sip a second time and hold the tea in your mouth to feel the scent and taste of the tea. Lastly, by the third sip, feel the scent of the tea in your nasal, oral, and the entire body.

This design has turned the tea savoring rituals and behavior into an integrated service that can convey and educate the traditional tea savoring culture to the users. This design also emphasizes the value of sharing by creating a conversation and interaction between the person who serves the tea and the person who is being served. Furthermore, this design quickly guides new customers (especially those who do not appreciate savoring tea) into the tea ceremony through the three text labels.

Therefore, among the three design outcomes described above, the third design can be deemed as the closest to the desired outcome from the culturally oriented persona framework that we proposed.

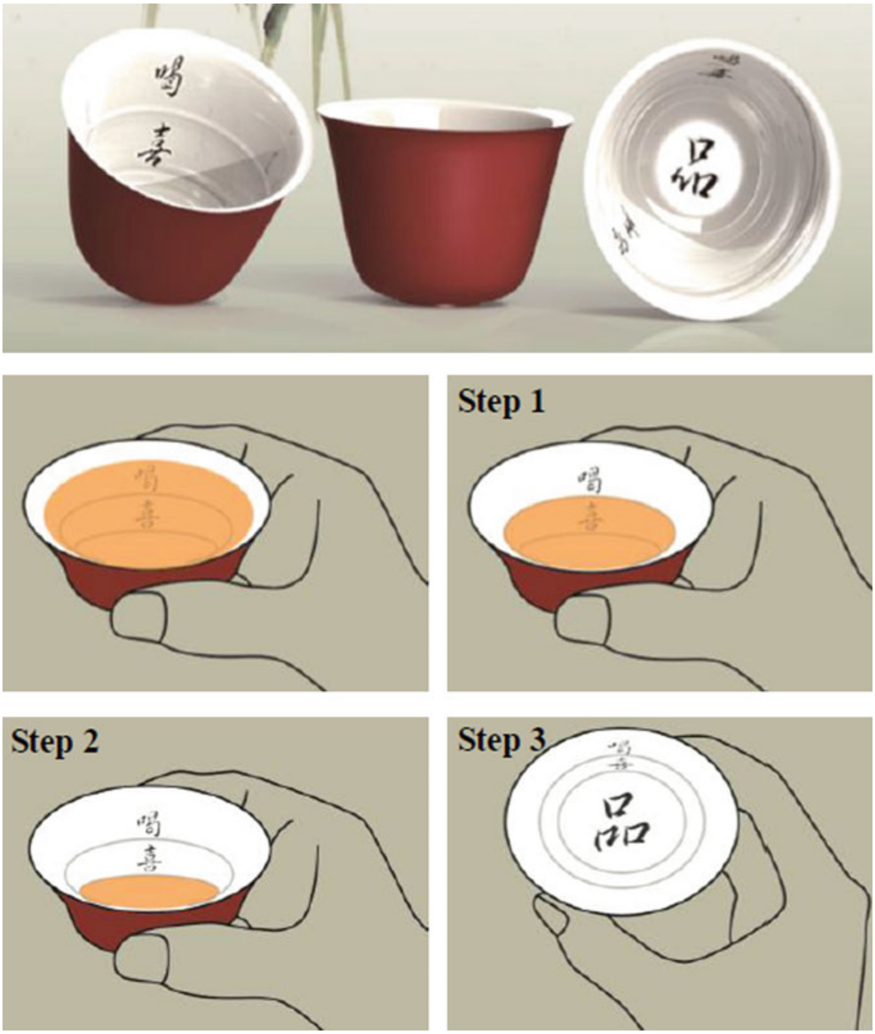

Fig. 15.5 Design outcome #3: conveying and educating the traditional tea savoring culture to the users

15.5 Conclusions

Personas are a powerful complement to aid SD and they amplify the effectiveness of quantitative, qualitative, and usability methods. However, traditional personas have shortcomings (e.g., lack of cultural and social aspects of information in design). Therefore, we developed a culturally oriented persona through an analytic framework of a culture to supplement the existing personas in the SD process. The analytic framework is developed from the theoretical components of Symbolic

Interactionism and our working definition of culture. The framework that we proposed contains four components: symbols/objects, behavior, ritual/rite, and values. The efficacy of the proposed culturally oriented persona was demonstrated by a case study of a service touch point design for traditional Taiwanese teahouses. The results showed that a culturally oriented persona was able to guide the design and evaluation of a service touchpoint reflecting traditional Taiwanese tea culture.

We do not contend that a design idea has to address all cultural components identified in the culturally oriented persona, meaning that the number of cultural components used in a design cannot be used to determine the quality of a design. We suggest using culturally oriented personas to provide guidelines to the designers. Specifically, culturally oriented personas help reveal implicit information, such as ritual and values that are otherwise hidden and cannot be recognized or detected easily. The outcome of our study is limited with the number of participants in demonstrating the efficacy of the culturally oriented persona in enhancing SD. Future studies are needed to address the limitations. It is our hope that through this study, the methods and tools for developing SD can be advanced.

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Chapter 16
A Method for Measuring Qualitative Building Circulation Factors—A BIM-Enabled Approach Using Quantities

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Abstract This research aims to develop a BIM-enabled approach to evaluating the qualitative factors of building circulation. Building circulation should be strategically planned with consideration for efficiency, privacy, safety, and additional binding-forced factors such as fire-egress. As these building circulation factors impact overall spatial planning and building organization, a well-defined circulation plan is critical, especially in the early phases of design. In order to establish an optimal circulation plan, architects and related specialists manually conduct iterative analysis tasks to improve the design based on their knowledge and expertise. With the advent of Building Information Modeling (BIM), building design and analysis can be automated by BIM-enabled assessment tools applied to given models. BIM-enabled analysis is based on a series of explicit quantitative data computed from building components and their properties, such as metric distance and number of turns. This enables us to measure explicit egress distances between specific spaces and exits in accordance with the regulations of the national Fire Code. However, even more intrinsic building circulation factors such as 'convenient access' have generally been ignored in the development of such BIM applications. This paper proposes an answer to the question of how to measure qualitative building circulation factors using BIM-enabled quantities. Two key categorical elements are suggested as a potential solution: BIM-enabled circulation quantity and a weighted function. In order to measure qualitative factors, building circulation quantities are classified and applied to a weighted function that can assign a relative importance to each factor. The applicability of the evaluation approach was checked by a circulation analysis application on a test case.

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_16

16.1 Introduction

Building design accommodates various objectives such as specific requests, building uses and aesthetic expression [1]. Since building design influences building performance and functionality, a well-defined design is highly significant considering its objectives. In establishing a circulation plan, building circulation should be planned with an emphasis on efficient metric path distance, security and pedestrian amenities, among other considerations, depending on its distinctive design purpose [2]. Therefore, diverse requirements should be checked and analyzed for design feedback during the design process. Conventionally, multiple domain-specific experts manually perform iterative design analysis checks based on design references such as building regulations, requests for proposals (RFP), literature materials and their own empirical knowledge [3]. Manual analysis is time consuming and the results cannot be independent from arbitrary judgement [4, 5]. Today, computing technologies offer objective methods of analysis and support existing methods for reducing iterative burden [6]. Furthermore, the process of design and analysis is increasingly automated by various BIM-enabled assessment tools [7]. BIM-enabled design analysis is regarded as a rapid, explicit and standardized method featuring an object-oriented approach. Although the benefits of using BIM for building design analysis have been proven by several key projects such as the GSA courthouse project [7, 8], some issues remain unresolved, such as the extent of design checking objects. For circulation design review, intrinsic factors of building circulation such as ‘convenient access’ are typically excluded as targets of design checking in the BIM-enabled assessment environment. In this context, we focus on qualitative evaluation factors of building circulation as they pertain to issues of BIM-enabled building design analysis. This research aims to develop BIM-enabled circulation analysis and the evaluation approach to assist architects and related experts with the design of efficient and appropriate building circulation.

16.2 Background and Objective

16.2.1 BIM-Enabled Circulation Analysis Issue

In the building information modeling (BIM) environment, design analysis and checking use an explicit and logical approach to utilizing objectified building data, including objects and their attributes [2]. Today, automated rule checking is a cutting-edge subject for BIM application pertaining to design analysis and assessment [11]. A well-recognized case of successful utilization of automated rule checking is the GSA courthouse planning project which was conducted by the U.S. federal government. The project carried out circulation checking and space program validation, preliminary energy and cost estimation based on federal courthouse design guidelines [3, 7, 8, 9]. For circulation, over 180 rules were checked and thousands of paths were evaluated where problematic or valid paths could be identified. The automated evaluation of circulation options shorten the conventional design process and improved design quality by giving feedback even in the preliminary design phase [3, 7, 8, 14].

In general, circulation-related requirements are stated officially both with (a) quantitative and (b) qualitative contents. For example, (a) "Attorney/witness rooms must be directly accessible from public circulation." (b) "Judge's chambers are accessed from restricted circulation with convenient access to the courtrooms." [9] BIM-enabled rule checking places targets on explicitly-described requirements such as in the example above [10]. Contrary to explicit and quantitative factors, qualitative circulation factors found in implicit statements of rules, like example (b) above, can typically have more than one solution. The source of the solution is captured in the base design knowledge [11]. Because a solutions are difficult to define computationally, qualitative and implicit building circulation factors are thus far ignored and excluded from rule checking targets [10]. In the case of the GSA project, implicitly-described statements were also excluded from the checking process. In this paper, we discuss one strategy for BIM-enabled circulation analysis and evaluation by handling qualitative issues through quantification of information.

16.2.2 Research Approach

In general, BIM-enabled design review tasks are based on software-driven methods. Because they are dependent on pre-defined rule sets that handle specific regulations, it is difficult to apply extended rules beyond the scope of pre-defined rule sets and parameters [14]. As an alternative to this method, the Building Environment Rule and Analysis (BERA) Language was developed as a BIM domain-specific programming language targeting spatial program and building circulation analysis [12, 13]. It enables users to define customized rules. As an its application, Hyunsoo Lee et al. defined Numeric Data of Building Circulation (NDBC) that organizes numeric data derived from path objects for the purpose of quantitatively analyzing building circulation, which is illustrated in Fig. 16.1 [14]. This research showed that

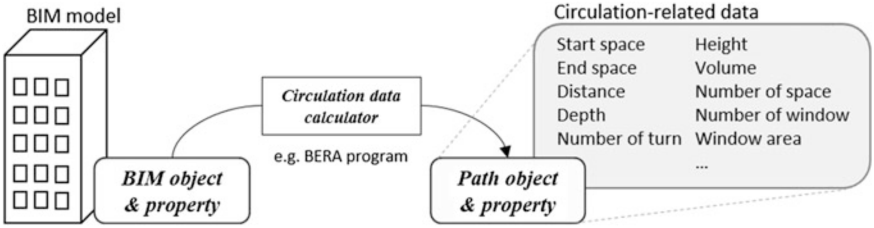

Fig. 16.1 Circulation-related data

BIM-enabled quantities are enough to be applied as fundamental information for the evaluation of building circulation [15]. In this paper, the approach to circulation analysis of the previous research is further developed focusing on circulation-related quantitative data derived from BIM models.

16.2.3 Research Scope

This paper introduces approaches to the analysis and evaluation of qualitative circulation factors in the BIM environment. The scope and sequence of research are as follows:

1. Classification of the evaluation factors relevant to building circulation
   This step is the process of classifying circulation quality-associated factors. These factors are categorized according to various criteria, including building type-specific design guides, RFPs, and previous research, which is then specified according to corresponding BIM data.
2. Development of BIM-enabled circulation evaluation
   An approach to circulation evaluation is proposed that considers quantitative and qualitative requirements in accordance with building type or design purpose. Weighted values expose differences among the classified factors. A path instance is then quantified by distinct calculated values.
3. Implementation of circulation analysis-application and demonstration
   The application of circulation analysis is implemented with the purpose of demonstrating the validity of the suggested evaluation approach. Circulation analysis is demonstrated by using an actual building model and applying a specific scenario.

16.3 BIM-Enabled Evaluation Approach to Qualitative Circulation

16.3.1 Classification of Circulation Evaluation Factors Using BIM Data

16.3.1.1 Metric Distance

Generally, a metric distance, indicating total distance, is considered primarily for design and analysis of building circulation. However, there may be varying path values with the same total distances but different horizontal and vertical distances. From the pedestrian perspective, horizontal paths are preferable to vertical paths of the same distance [2]. In addition, vertical paths should be minimized when planning facilities for the handicapped. Therefore, physical distance needs to be subdivided into horizontal and vertical distances and evaluated according to degree of importance. In this regard, the first type of circulation factors and its related BIM quantities are defined as:

$$\text{Metric Distance} = \{\text{Vertical Distance, Horizontal Distance}\} \tag{16.1}$$

16.3.1.2 Complexity of Circulation Path

Influences of circulation pattern variations is acknowledged throughout multiple research results. Among path properties, turning conditions, which is derived from the change of turning direction, determines circulation pattern especially in terms of circulation complexity. There are related studies in the domain of space syntax such as the representation of weighing graphs and estimations of space syntax factors that are relevant to turning conditions [16, 17]. Borrowing the space syntax model, the second type of circulation factors and its related BIM quantities are defined as:

$$\text{Complexity} = \{\text{The number of turns, The angle of turns}\} \tag{16.2}$$

16.3.1.3 Accessibility of Circulation Path

Building circulation can be interpreted by systems of spatial relation [2, 15, 18, 19]. Spatial relation means relationships between connected spaces. There may be variables, such as depth, that influence integration and connectivity of spaces [15, 18]. As one of the important concepts in space syntax, connectivity can be defined with a mathematical definition as the number of directly connected spaces to a specific unit of space [20]. For circulation accessibility of circulation, interspatial connectivity is considered. The third type of circulation factor and its related BIM quantities are defined as:

$$\begin{aligned}\text{Accessibility} = \{&\text{The number of Inter-spaces, The number of directly}\\ &\text{accessible spaces the inter-spaces}\}\end{aligned} \tag{16.3}$$

16.3.1.4 Amenity of Path Environment

Extensive research has been conducted regarding various influences of path environment on pedestrian circulation such as daylight, spatial scale, surrounding scenery, and safety [21–23]. For example, in hospital circulation an emphasis is placed on daylighting because of its positive effects on patients both physically and mentally. From an architectural perspective, openings like windows are building components that regulates indoor lighting by determining the amount of daylighting allowed into the interior spaces. Here, our research focuses on space-associated path environments and, thus, the last type of circulation factor and its related BIM quantities are defined as:

$$\text{Amenity} = \{\text{Window Area, Spatial Volume}\} \tag{16.4}$$

16.3.2 Development of Evaluation Approach Applying Circulation-Related Data

Building circulation diversity reflects to the many architectural variations in building shape and building type, among others [2, 9, 10]. For instance, circulation in shopping malls tends to be linearly extended in order to increase the length of time that visitors stay. However, circulation in office buildings emphasizes path efficiency through short travel distances. Preferably circulation-related qualitative factors are weighted according to the situation in order to comprehensively evaluate circulation design. This paper classifies the factors into four types—metric distance, complexity, accessibility and amenity of circulation path-as illustrated in the previous section. Based on this classification, the concept of circulation evaluation using a weighted system will be introduced. A weighted system is intended to quantitatively reflect degrees of importance among factors and types.

Figure 16.2 represents the proposed approach to circulation evaluation, which can be summarized from a computational view as: (1) input data: quantities of the classified circulation and user-defined weights of corresponding circulation data,

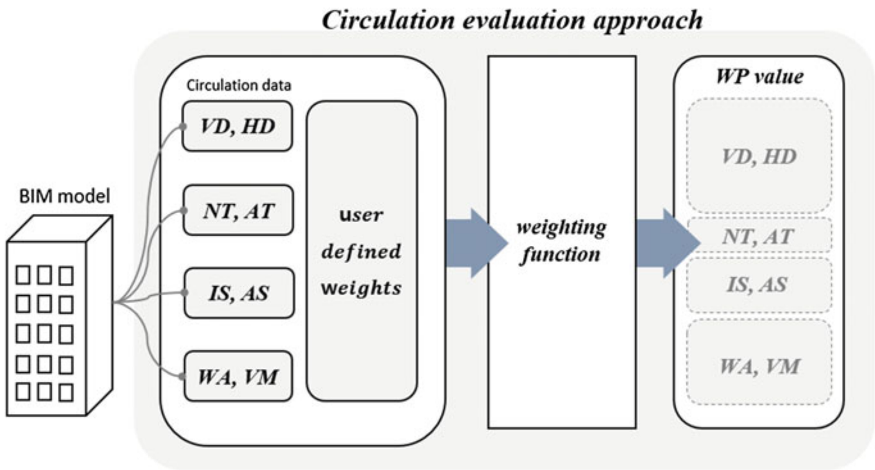

Fig. 16.2 An approach to evaluation of circulation in the research

(2) weighted function: an algorithmic definition of weighted values on various factors, (3) output data: a result value calculated from the weighted function. The result value is named 'Weighted Path' (WP) which denotes a quantitative concept in terms of a scored-path. This value is expected to be an objective platform for the evaluation of circulation design.

16.4 Demonstration of Circulation Analysis Using Circulation Data

16.4.1 Implementation of a Circulation Analysis Tool

Based on the concept of the suggested evaluation approach, a circulation analysis software is implemented to support the analysis and evaluation of circulation paths by generating useful circulation data and WP value. This software tool has two types of functionalities. One is searching for spatial information of a target building and the other is reporting weighted circulation path and related values based on numeric circulation data.

Through several interfaces that support the two functionalities, users can select the start and the end spaces that define a circulation path. Users can also identify various types of information of specialized paths (path instances) such as circulation evaluation factors and corresponding data. After generating path instances, users are asked to apply weighted values on the classified circulation types and the factors in each type. With user-defined weighted values added to the circulation data, mathematical calculation for WP value is done in the back end side of the software. The results of the calculations are represented as basic visual information such as a pie or linear graph that represents the weighted values and path values of both before and after weighted values are applied, as shown in Fig. 16.3.

16.4.2 Demonstration of Circulation Analysis and Results

In order to test applicability of the evaluation approach, circulation analysis and evaluation is demonstrated with an actual college building model by applying a specific path design scenario. This scenario deals with which path among, several alternatives, would be suitable in terms of efficiency, distance, and simplicity. It can be depicted in detail as follows:

- Start space: all lecture or work rooms from a specific department are selected as a collection of start spaces. In total nine spaces are designated as start spaces.
- End space: all graduate student laboratory rooms of a specific department are selected as a collection of end spaces. In total four spaces are designated as end spaces.

Fig. 16.3 Graphic representation of a weighted path in a related software

With nine start spaces and four end spaces, thirty-six path instances are generated and corresponding numeric data of given paths are weighted according to the weighted input values by the users (authors). The result of the weighted values on path data implies path values that are approximated within the specified criteria of metric distance, complexity, accessibility and path amenity. In this case, an adjustment to the ranking order was made after applying weighted values as described in Fig. 16.3 (the gray line and the red line indicate the results before and after the weighted value adjustment in the ranking order). If there are no weighted values applied to circulation evaluation factors, the resulting value for a specific path is the same in every instance.

16.5 Conclusion

This paper introduces a method of conceptual analysis as fundamental research for evaluating circulation with consideration not only for quantitative but also for qualitative factors. The methodology features and highlights the application of BIM data and a system of weighted values. In the initial step, qualitative factors need to be quantitatively defined. Circulation evaluation factors are classified into four types: metric distance, complexity, accessibility and path amenity. Each type is defined by quantitative circulation data from BIM objects.

Building circulation may have different conditions and priorities that reflect the objectives of the building design. In this context, design analysis and the evaluation process establish value among the various design objects factors. Here, weighted value function is suggested as a solution. Finally, based on this approach to circulation evaluation, a software program is implemented and demonstrated with an actual BIM model that displays the viability and effectiveness of this method of analysis.

With further development of this research, advanced and more elaborate methods are expected to emerge that can assist architects with automated methods of checking circulation design iterations that consider specific objectives within much broader evaluation criteria. Several directions for further research are as follows: (1) expansion of types for circulation evaluation that may entail theoretical and empirical study regarding building circulation, (2) expansion of circulation evaluation factors within each type that is needed to generate and extract meaningful building information from BIM models as a part of the quantification of design knowledge, (3) further development of a weighting function with algorithmic definitions that respond to expanded factors.

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Chapter 17
The Grammar Lens: How Spatial Grammar Channels Interface Design

Robert Woodbury

Abstract The human information processing (HIPS) model predicts that people design by searching in a problem space, but the HIPS model alone provides insufficient guidance for system design. The eight generic tasks presented here elaborate the overall search task into sub-tasks that may be recombined in many different overall design processes. Supporting any such tasks and processes requires a notational system, for which the cognitive dimensions framework provides an analytic structure. Cognitive dimensions analysis requires descriptions of the activity undertaken, the notation used and the environment providing the notation and supporting the activity. We split the notation into two parts, one for design states and one for the design space. In addition we posit the notion of an interaction metaphor or lens that channels system (environment) designs in specific channels. We describe 25 grammar-based systems in cognitive dimensions terms, analyze them for their support of the eight generic exploration tasks and present a cognitive dimensions analysis for one conventional grammar-based system. The grammar lens for design exploration system appears to strongly channel system designs.

17.1 Introduction

> Every idea that is a true idea has a form, and is capable of many forms. The variety of forms of which it is capable determines the value of the idea—Frank Lloyd Wright

As Wright implies, exploring a space of possibilities is central, indeed essential, to many kinds of complex work. Accounts of such exploration have occurred in the literature for a long time, with perhaps the first thorough systematic treatment being that of Newell and Simon's Human Information Processing System (HIPS) [111]. HIPS describes human problem-solving action as being search in a problem space, largely constrained by a task environment In turn, the task environment almost always include external media with which people store problem configurations.

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_17

In design, HIPS became a principal research concept, around which arose accounts; of designer action, [3, 29–31], the use of heuristic search as a computational strategy for solving design problems [44, 113, 120, 127], and direct use as a concept and object in systems that aim to support design work [20]. In visual analytics, the term "analysis of competing hypotheses" describes a key phase in analytic workflows. Introduced at length by Heuer [79], the term is becoming central in visual analytics. The first step in such an analysis is to identify all potential hypotheses, though this is one of the least specific aspects of the method. Relatively recently, the computer science community, and HCI in particular, has published a number of perspectives, system and evaluations. For example, Shneiderman et al.'s [124–126] argument for supporting exploratory research and providing rich history-keeping appears to have provided key direction in this area. Each field has its own terminology and authors such as Lunzer and Hornæk [101] have coined now-accepted terms such as *subjunctive interfaces.* In the face of a Tower-of-Babel-like profusion of terms, in this article we adopt the simple and, hopefully, neutral term *alternatives* to encompass the entire complex. When we write "alternatives" we refer to the general enterprise of exploring a space of possibilities.

Much work that illuminates searching for alternatives has extended the HIPS model since it was first published. Building directly on HIPS, researchers such as Eastman [41], Akin [3, 4, 112], Purcell and Gero [119], Eastman et al. [40] and Cross [31] have developed sophisticated accounts of designer action interpreted partly through the HIPS model. Suchman [152] widened the scope of the field with the publication of *Plans and Situated Action* to include detailed appraisal of context and the situations in which humans act. Despite considerable debate about the merits of HIPS versus situated action [151, 158], both perspectives persist and thrive. Indeed, the area of *distributed cognition* [81, 82] might be seen as a fusion of these (and other sources). Its contribution has been to include the physical environment as an essential part of the cognitive system itself. Accounts with it include external tools as embodying aspects of cognition in an overall system.

17.2 Activity Supported

The HIPS model claims that people use alternatives, but itself is silent on specific patterns of use. What do people do when they interact with alternatives? This depends, of course, on the task they are doing and the media they are using. For example, and informally, doing early design with pencil, eraser, tracing paper, tape, pins desks and wall space, people will make multiple sketches and arrange them in overlays and side-by-side on desks and walls. The on-desk arrangements will likely be more ephemeral, with lots of paper shuffling to put alternatives in close spatial proximity. Simply because of the time involved to place drawings on a vertical surface, on-wall displays are likely to be more considered and persistent. People will tend to erase relatively infrequently and only things that they are sure are "mistakes" in some way. Given that the media influences human action, we can expect a variety of interaction patterns across tasks and systems. We should also expect some constants: abstract actions that are present in nearly every situation. In this section we offer a sketch of generic tasks that involve alternatives. What do people do to work with alternatives? The following items overlap to some degree. They are meant more to describe and differentiate key acts than as a classification system.

They find alternatives from other sources. We include this act to point out that designs seldom arise ab initio: rather they use precedent in a variety of ways. Digital media have greatly increased the both availability of importable material and the modes of importation. Use of other sources may be vary from the literal “Let’s do something like this”, to the metaphorical “Our muse is the flow of waves and here are several paintings.” Finding occurs throughout design, but especially at the start of an exploratory design process.

They make alternatives. These can be from scratch, or more often, as a result of copying to make a modification. With digital media every action can, in principle, make a new alternative. In rough terms, an alternative may be mostly distinct from those “around” it, or mostly similar. The terms *breadth* applies when the former dominate, and *depth* when the latter are in the fore. *Ceteris parabis,* designers will prefer media in which an alternative can be made quickly and at low cost: design work needs to “flow” and time is an important commodity. They will also prefer media that leave decisions open, that “suggest and explore rather than confirm” and have “an appropriate degree of refinement” [16, p. 113]: alternatives gain value when they give easy access to other, yet undiscovered, alternatives. The process of making alternatives is far from prescribed, rather it is highly contingent on what has been done before (and often what has just been done) [14]. Alternatives are memory, made external and explicit.

They reflect on alternatives. Doing design changes how you do design. Schon’s term “reflective practice” is the most common label for such change [123]. Schon argues that designers create their own “design worlds” in which they both operate and learn about their present and future work. Archea [7] makes essentially the same argument in his account of design as “puzzle making”. The point here is that designers seem to play with their media as they seek a way of designing (Schon’s design worlds; Archea’s puzzles) that works to understand and act in the current design situation. Such work may not seem to be directly related to the problem at hand, but is essential to designing. Alternatives are a key part of both Schon’s and Archea’s accounts.

They scan visual collections of alternatives to find items of interest. People access organized collections by visually scanning for items of interest. In pre-digital days, walls covered with drawings and shelves and tables with models were perhaps the most common instance of design media that enable such scanning. With digital media, visually organizing and then scanning collections has become common in design offices that commonly use many alternatives, for example, see Gerber and Lin [63]. Indeed, since about 2010, visualizations of collections have become commonplace in both research and professional design publications. Abstract visualizations, such Pareto front diagrams, have long been reported in the research literature [120–122] and are now by CAD companies [8]. These render alternatives by a few of their properties often reducing an alternative visualization to a single point in a graph.

They compare alternatives. Comparing is scanning in depth. It involves visualizing (some aspects of) alternatives in a single display (typically side-by-side, superimposed or abstracted as in the scanning item above), and actively reflecting on their commonalities and differences. Comparing yields both choices (A is preferred to B) and combinations (part of A and part of B might work to make C).

They organize alternatives. Whenever more than a single alternative exists, the set of alternatives will be organized, perhaps in multiple ways. Sometimes the medium itself prescribes organization, for instance, a sketch book makes temporal sequencing easy and constrains other organizational forms. Organization is context-dependent. What works for a collection of developing sketches might be quite different from a narrative presentation to a client or from a project archive. Organization can be driven by metadata (time, place, author…), driven by a specific need or simply done ad hoc (indeed, the presentation software Prezi [117] is based on interactively moving from ad hoc to multiple structured organizations). Organization includes removing items from view, e.g., filtering and hiding. Digital media have increased the scope and variety of tools for organizing objects, often at the sometimes considerable cost of creating and maintaining metadata to support such organization.

They remember (they store into memory) key alternatives. A significant part of the value of an alternative is what it allows a person to recall. To recall something, you must have committed it to memory. Alternatives can be points of access to memory. Remembering requires both time and attention. With a manual sketchbook, people spend significant time and effort on sketches. The HIPS model tells us that some of such time is likely spend building the memory associations required for future recall. Thus an alternatives system that supports direct work with alternatives will likely help memory better than one that automatically generates alternatives.

They recall prior alternatives. Recall is the flip side of remembering. Finding yesterday's or last week's sketch of a specific part of a design is a frequent occurrence. Recall is more specific than search; it can be thought of as search in which prior direct personal experience of an artifact enables accessing that, or related, artifacts. Recall depends on memory. For example, in sketching, any sketch property (pen vs. pencil, paper type, the sketchbook used, the approximate date, the style of sketch (e.g., loose, hard-edged), the type of sketch (plan, elevation, section,…), even a coffee stain) can be a trigger for recalling ideas, events and other sketches that are relevant now. Search has augmented but not replaced such idiosyncratic devices for recall.

The above eight generic activities can shed light on recent work on supporting alternatives by providing eight tasks for which support might be expected. Several recent publications provide specific framing for interacting with alternatives. Shneiderman [124] presents a broad analysis of potential creativity support frameworks and tools and identifies both "what-if" tools and histories as strategies for supporting creativity. Shneiderman et al. [126] summarize issues and approaches to creativity support and provide guidelines comprising 12 principles, the first of which is to "support exploration." Terry and Mynatt [154] provide case studies in which sophisticated users undertake tasks with conventional software. They document people engaging workarounds to access alternatives, that is, use of software in idiosyncratic fashion or with secondary notation. Further, they use such workarounds as starting points for new interface designs and principles, naming the new strategies of *side views, parameter spectrums* and *design horizons.* Woodbury and Burrow [162] review the state of the art in alternatives in the design field and outline the structure of computational design spaces and implications for future interfaces. Lunzer and Hornæk [101] coin the term *subjunctive interfaces* to describe applications that support parallel setup, viewing and control of alternative scenarios. All of their three cases support simultaneous interaction with multiple alternatives. Bradner et al. [11] document designer practice using optimization software to explore solution spaces, making the key conclusion that professionals often use design optimization to understand the design space, not merely to find the "best" solution.

Looking at tools themselves, we observe that the HIPS model predicts that people will use external media to aid the fundamental action of search in a problem space, that is, they will want to access multiple states. In sharp contrast, almost all widely used computer tools represent (or provide user access to) a single state at a time, which in fact that and Mynatt [155] label as the *Single State Document Model.* This very large corpus of tools fails to enable a fundamental form of human behaviour: solving problems by search in a problem space.

Exploring possibilities in Newel and Simon's problem space is greatly hindered by humans' serial processing ability. This is further culled by most current computer-tools' document storage models, which are mostly *Single State* [154]; permitting the storage and recovery of only a single-state of data at a time. This model extends over to the Graphical User Interface (GUI) layer; enforcing a linear interaction model with data. In today's tools, a task as simple as comparing two states of a design requires devising workflows of various steps, which at times, impose additional cognitive overhead; overloading designer's short-term memory and reducing their ability to shift focus.

Some systems have made problem space search for alternatives a fundamental aspect of human action to be supported and amplified by computers. In this paper we focus on systems, interaction techniques and interfaces for alternatives, subordinating other research on alternatives to frame supporting arguments. This is a focus, not a value, choice. The general alternatives literature is large; from it we aim to sketch the past, present and possible future structure of interacting with alternatives.

Any external (to the human mind) system for working with alternatives can be productively viewed as an information artifact. The cognitive dimensions of notations framework is a vocabulary for designers to evaluate the usability of such artifacts. The framework, first put forward by [68, 69, 71], turns the knowledge of psychology of programming into a form that is usable for non-psychologists and gives names to concepts that may seem obvious, but significantly impact design decisions and trade-offs. The framework applies to specific notational systems described by the task supported, the notation used and the task environment. Tasks in the framework typically belong to one of six types: *incrementation, transcription, modification, exploratory design, searching* and *exploratory understanding* [10, 70]. There are fourteen dimensions, which we mark in this paper with special typography. (The description of the dimensions below are quoted from [9].

Viscosity(cd)	Resistance to change
Visibility(cd)	Ability to view new components easily
Premature commitment(cd)	Constraints on the order of doing things
Hidden dependencies(cd)	Important links between entities are not visible
Role-expressiveness(cd)	The purpose of an entity is readily inferred
Error-proneness(cd)	The notation invites mistakes and the system gives little protection
Abstraction(cd)	Types and availability of abstraction mechanisms
Secondary notation(cd)	Extra information means other than formal syntax
Closeness of mapping(cd)	Closeness of representation to domain
Consistency(cd)	Similar semantics are expressed in similar syntactic forms
Diffuseness(cd)	Verbosity of language
Hard mental operations(cd)	High demand on cognitive resources
Provisionality(cd)	Degree of commitment to actions or marks; and
Progressive evaluation(cd)	Work-to-date can be checked at any time

The cognitive dimensions of notations framework is used in formative evaluation of software systems during their design process, for example, [83] use the dimensions as guides in creating the Forms/3 spreadsheet system. The framework is also used to evaluate existing systems, such as Green and Petre's [71] evaluation of several visual programming languages and environments, including LabView and Prograph. Depending on system and the type of task it supports, some dimensions may be more important than others, and some may become irrelevant.

Working with alternatives falls into one of the four types of user activity typically used in cognitive dimensions: exploratory design. It also introduces a distinct kind of activity not anticipated in cognitive dimensions: *reflection*. which appears to be related to the relatively sparsely described generic task of exploratory understanding in cognitive dimensions Blackwell et al. [10].

Cognitive dimensions structure information artifacts as having three qualities [69, 71]: First, the *activity* being supported provides a process model that conditions (but does not define) the exploration a person may do. Second, the *notation* provides the representation available to support the activity. Third, the *environment* provides a system for editing the state and space notations. For our present purposes we make two changes to this structure. First, we split notation into two parts.

The *state notation* provides the representation of objects on which the activity focuses. It suggests or, more strongly, provides a collection of operators by which one state of the representation becomes another. The action of these operators trace out the space of possibilities that can be explored. The *space notation* provides a structure by which artifact representations are organized. It can be the same, or different, from the space of possibilities defined by the artifact representation operators. Second, the *interaction metaphor* provides a lens that strongly conditions the environment (the systems and interfaces that get built). This last quality is actually the perspective taken by the work's author(s): it is inferred rather than directly observed. Thus, its "true" value is hidden and the value used is our attribution. However, as Dennett argues in *The Intentional Stance* [35] attributing at a design or intentional stance is a near-necessity in understanding any system.

While a particular approach to alternatives has other qualities, these five qualities provide a useful space for comparison and for predicting new possibilities for supporting alternatives. For example, consider a simple 2D drawing system. In this system, the supported activity is creating and editing 2D line drawings. The state notation comprises lines along with operators for inserting, deleting and moving line endpoints. The space notation is defined by applying these operators to a blank drawing in all possible ways thus potentially producing a vast space of possibilities. One limited space notation would place line endpoints on a grid and provide operators for iterating through alternative placements and for transforming the underlying grid. The environment might be a visual programming node link diagram (a common device in computer-aided design at the time of writing) along with tools to store, mark and retrieve states. The environment might also be the prevalent drawing system design: an interactive canvas with a set of tool bars, menus, and widgets. The interaction lens might be *history,* that is, a view that meaningful exploring can be done by revisiting and branching from work that has already been done.

We use all five qualities when reviewing specific systems for alternatives. However, in reviewing many papers, we find the interaction lens to be a strong organizational principle in reviewing systems. Such lenses give a position from which interface design proceeds. The perspective of what an interface "should" do, seems to be the strongest principle for classifying interactive alternatives editors. Such a perspective tilts design features to cohere with the perspective and implicitly excludes or diminishes other features. We call such perspectives "lenses" as they bring features into selective focus. A minority of systems employ more than one lens. All systems though share (or can be explained through) a common background of cognition describing what people do with alternatives and why they do it.

Through our review many systems we find a relatively small number of interaction lenses: grammar, history, version, representation, task and optimization. In this paper, we focus on what we call the *grammar* lens, that is, the lens that seems to have been taken in almost all implementations of grammar systems. We describe and compare several grammar systems by the state-notation, space-notations they use and environments they provide; by the generic activities exploration and the grammar-specific activities they support; and present a cognitive dimensions analysis of three grammar-based systems.

17.3 The Grammar Lens

The grammar lens takes the intellectual structure of a generative grammar as a machine over which to build an interface. The interface typically supports rule creation and editing, rule application and derivations chains. An extension is to visualize (parts of) the language of the grammar. The grammar lens might also be called the *constructive lens* or the *state space lens* as its focus is on the generating operations for a space of states, each state created by applying an operator to a prior state.

17.3.1 Grammar Background

In the design disciplines, notably architecture, notions of exploring spaces of designs began in the early 1970s, with the first publication of shape grammars [144] followed by the definitive [131], a formalism by which languages (spaces) of designs could be compactly described. Clearly, Stiny's work was influenced by Noam Chomsky: the shape grammar formalism echoes both the concept and form of Chomsky's grammars [27]. Working independently and in two-dimensional layout, a specific class of design problems, Charles Eastman (CMU) analyzed extant approaches [42] and reported a "general" space planner [43, 44] while Ulrich Flemming (TUBerlin, then CMU) developed a representation for space planning based upon adjacency, and abstracting dimensional variation away from the generative mechanism itself. The notion of a state space accessed by operations and tracing out design derivation, that is, the notion of search, underlaid all of these efforts. This is hardly surprising given the salience of ideas of searching problem spaces in concurrent developments in the field of artificial intelligence [111]. Contemporary authors presented reviews and frameworks for search as a model for designing, notably [145, 165, 166]. Later, Coyne et al.'s [28] comprehensive book on knowledge based design gave many examples of search-based techniques, while Mitchell's extremely clear *Logic of Architecture* [106] presented a comprehensive account of design search and grammars within a logic framework. Research in this area took several directions. A large body of work grew up around specifying grammars to generate specific classes of designs, for example, Palladian floor plans [147, 148], Froebel blocks [132], Moghul gardens [149], ice-ray lattices [130], Taiwanese venacular dwellings [24, 26], traditional Chinese architecture [25], Frank Lloyd Wright houses [93], coffee makers [1], the Marrakech Medina [39], MEMS resonators [2], firestations [164], Queen Anne houses [53], Buffalo bungalows [36], high-design architecture [51], deStijl art [89], Greek pottery [92], paintings (Kirsch and Kirsch, [86], Harley-Davidson motorcycles [118] Japanese tea-rooms [87], temple cellas [33] and automobile design [102].

Another body of work focused on explicating the structure and properties of space-generating representations. Notable here are Stiny's multiple papers [128, 129, 131, 134–139, 142, 144] and book [143] arguing and demonstrating that representations of *shape* admit emergence of patterns and configurations not explicitly represented at the outset. These papers framed future research in design spaces precisely because they established emergence as a key property useful to designers. As argued below, though, it turned out that most systems and interfaces fall short of strong support for emergence. Other papers extended the shape grammar formalism by developing related devices by which shapes carry and compute on non-spatial information [88, 91, 133, 140, 141]. "Shape" in the sense meant by Stiny was far from the only design representation on which research focused. Little, if any, of this research admitted emergence in the sense meant by Stiny.

Stiny's definitive article [131] also defined *parametric shape grammars,* in which rules are defined over *shape schema* but apply to regular non-parameterized shapes. Most of the published shape grammars above employ parametric shape grammars. Apparently such admit more compact and direct rules for specifying languages of designs. Yet, until recently, no general parametric shape grammar implementation exists. Li et al. [100] and Woodbury [168, 169] generalize shape grammars as *shape schema grammars* to apply over *shape schema,* essentially parametric models. Shape schema grammars fully admit emergence and subsume parametric shape grammars, but, in the general case, have intractable matching algorithms.

Others did analogous work over representations other than shapes. Stiny himself distinguished shape grammars from *set grammars* [135], in which the objects over which grammars remain shapes, but the operations over which rules are constructed are simple set operations and do not involve shape arithmetic or reduction. Carlson et al. [18] specified the even simpler *structure grammars* defined over sets of arbitrary atomic symbols and elements from a transformation group. Both of these representations admit relatively simple algorithms and neither displays emergence. Prats et al. [116] introduced decompositions as an additional layer in generative design, particularly applicable to curved shapes.

Shapes by themselves carry only spatial information. Extensions to shape grammars that admit additional information (such as process data, and material and graphic properties) include *labels* [131], *colors* (a specific term standing for the more general notion of a quality [91] and *weights* (another specific term denoting a more general notion of a quality) [141].

Others followed grammatical threads apart from shape grammars. Graph grammars, which have been widely used in other areas, notably graph drawing, comprise sets of graph rewriting rules. They are a general and generally intractable formalism for expressing languages of graphs, which in turn can represent objects of interest in some domain. The extant work using graph grammars stops at the specification of grammars for particular domains, for example, solids modeling and physical part representation [47, 48, 161], figures composable as collages [37, 72] and, in an intellectually interesting twist, shape grammars [67]. Grabska [66] provides an introduction to so called *realization schemes* by which graphs can be mapped to objects in a domain. Woodbury [161] used plex grammars to build a declarative notation for solids modeling in constraint systems.

Orthogonal layouts, that is, arrangements of rectangles on a plane, are fundamental to architectural design. Flemming developed representations and systems based on them for tightly packed arrangements (rectangles tiling a larger rectangle) [49, 50] and loosely packed arrangements (rectangles do not overlap but they can be separated in space) [52, 55, 56, 58, 60]. Kundu [97] reported a simple tree structure that captured all but the key *pinwheel* case described by Flemming, and Harada [74] employed Kundu's structure to model discrete layout changes within a physically-based modeling loop. Harada's work is notable as the alternatives generating part of the system was invoked within rapid user interaction as a way of making discrete changes in physically-based models.

Several authors developed grammar systems over, sometimes specific, property-value schemes directly representing objects in a domain. Fenves and Baker [46] developed several such schemes for civil engineering problems. Friedell and Kochhar [62] describe *schema grammars,* specifically grammars operating over object comprising property-value pairs and directly representing objects in the domain. Weitzman and Wittenburg's *relational grammars* perform an essentially similar role in directly representing objects of interest. What such schemes gain through proximity to their domains they tend to lose through generalizability. Indeed Woodbury and Burrow [171] caution that such schemes can suffer what they call a *programmatic pitfall,* in which the domain obscures otherwise obvious computational approaches. Woodbury et al. [15, 163, 172] built a generative design mechanism on top of Carpenter's *typed feature structure* formalism and demonstrated it within Penn's ALE system. Woodbury and Burrow's keynote article [171] in a special issue of Artificial Intelligence in Engineering Design and Manufacturing (AI EDAM) in 2006 [150], built on this work to make a general argument for the necessary qualities of design space exploration systems. Several other authors contributed rejoinders [5, 32, 57, 65, 95, 114, 157, 170]; the overall collection presents a wide discussion of issues in design space exploration.

In addition to specific formalisms and systems, there exist a large number of articles offering explanations of formalisms and/or speculations on what grammar might, or might not, be able to accomplish. There have also been a number of limited reviews of the grammatical research in design [12, 22, 103]. In a technical vein, Mitchell included shape grammars as spaces of design alternatives in his early article [105] arguing the need for formal representations. Stiny and March [146] posit *languages of design* as a key component in abstract systems they call *design machines.* Mitchell et al. [107] show how to use *markers* (an informal label for standard shape grammar labels) to include information needed for functional analysis in grammars. They demonstrate an example of a simple hut in the Topdown grammar system [108]. Depending largely on grammar definitions from computer science and with little explicit relation to the issues introduced by geometry, Mullins and Rinderle [110] posit approaches to using grammars in engineering design. Duarte and Simondetti [38] demonstrate simple grammar mechanisms to aid in the process of using digital representations in CNC fabrication. Several authors focus on human-computer interaction issues in using grammars. Knight [90] describes exercises in the creative use of grammars in studio education (members of the language of a grammar were typically realized as physical models). Woodbury [167] relates processes using spatial grammars to the humanistic tradition of hermeneutics. Woodbury and Radford [174] argue for human-centred models for using grammar in design. Datta and Woodbury [34] and Datta [32] construct use cases for generative notations within mixed-initiative systems. Bruton's thesis [13] and Bruton and Radford's book [14] present an argument for contingency in conceiving and using grammars in artistic and design work.

17.3.2 Grammar-Based Interfaces for Alternatives

A thread in the larger grammar literature is designs and implementations of grammar-based interfaces for alternatives. In Table 17.1, we review 25 interactive grammar systems. Of these only one, GENESIS [76, 78] has had direct industrial impact. Another grammar-like system, CityEngine [160], has a large current industrial application. Likely owing to the research context when these systems were produced (largely relatively early in the history of computational design), the systems focused largely on making and, to some extent, organizing designs. With two exceptions, they focus making through the lens of rule application, and thus, in terms of the cognitive dimension abstraction$^{(cd)}$ are abstraction hungry. One system,

Table 17.1 Summary description of 25 interactive grammar systems

System	Activity supported	State notation	Space notation	Environment
Simple interpreter	Ma	Non-emergent shapes	Levels of rule execution	Rules and parallel rule applications in levels
SGI	Ma	2D emergent shapes	Derivation sequences of sentential form	Rules, derivations with undo stack and state display
Shape grammar interpreter	Fi, Ma, Rf	2D emergent shapes	Search tree of sentential forms	Rules and derivations
Prolog spatial grammar interpreter	Ma, Rf, Or	Non-emergent shapes	Search tree of sentential forms	Rule and state display, Prolog interpreter
Topdown	Ma, Rf	Symbols and their replacements	Inspecific	Explicit specification and refinement of abstract designs
Prolog shape grammar interpreter	Fi, Ma, Rf	2D emergent shapes	Search tree of sentential forms one derivation chain stored	Rule and state display, Prolog interpreter

(continued)

Table 17.1 (continued)

System	Activity supported	State notation	Space notation	Environment
discoverForm	Fi, Ma	Motif + single rule + level	None	Interactive rule editing superimposed on result
Tartan Worlds	Ma, Rf, Or	Tartan grids with symbols	Search tree of sentential forms	Rules, states and match choices
GENESIS	Ma, Rf, Or	Sets of boundary representation solids	Search tree of sentential forms	Rules, matches, states and explicit design space
GRAMMATICA	Ma, Rf, Or	Expressions and their compositions with a control algebra	Language of the grammar	Language of grammar display, Prolog interpreter
Harada et al.*	Ma	Parametric 2D and 3D layouts	No space maintained	Direct manipulation of layouts; grammars reorganize layouts as needed.
SEED-config	Ma, Rf, Or	Functional decompositions *and satisfying designs*	Branching explicit design space	Rule, state and explicit space display
SEED-layout	Ma, Rf, Or	*Functional decompositions* and hierarchical rectangular layouts	Branching explicit design space	Rule, state and explicit space display
3D shape grammar interpreter	Ma, Rf	Sets of instances of primitive solids	Decomposition into *deterministic* basic grammars	Vocabulary, rule and state views
GEDIT	Ma, Rf	2D shapes	None maintained	Select rule, view possible matches, select match to apply
SG-CLIPS	Ma, Rf, Or	2D objects	Branching explicit space	Select active state, enumerate immediate derivation steps
Simulated interpreter	Ma, Rf	Simplified, non-emergent shapes	Single derivations	View applicable rules, rule matches and rule applications
3D form synthesizer	Ma, Rf	3D objects	None specified	Define one or two rules, view pre-determined application sequence
SGMP	Ma, Rf	3D objects	Not specified	Automatic rule application

(continued)

Table 17.1 (continued)

System	Activity supported	State notation	Space notation	Environment
Shape grammar interpreter	Ma, Rf, Or	shapes in $\mathcal{U}_{0,3}, \mathcal{U}_{1,3}$ and $\mathcal{V}_{0,3}$	Derivations	Rules and various local navigators
McKay et al.*	Ma, Rf	Bitmap images	Not specified	Define rules and observe their matches
Jowers et al.*	Ma, Rf, Or	Curved shapes	Derivations only	Define initial shape, control rule application, define shape rules
spapper	Ma, Rf, Or	3D parametric primitives	Inspecific	Rule definition, display of elements of grammar language
SGI	Ma, Rf	Shapes in $\mathcal{U}_{1,2}$	Derivations	Review and edit shapes and rules, view sentential forms, view derivations
xploreForm	Ma, Rf, Sc, Co, Or	Line motif + single rule + start and end levels	User-defined sets of states	Edit state and collections, make selections of states

Table 17.1: Descriptive analysis of 25 shape grammar interpreters. References to publications in which interpreters are reported
*Interpreter has no reported name. *Simple interpreter* Gips [64]; *SGI* Krishnamurti [94]; *Shape grammar interpreter* Krishnamurti and Giraud [96]; *Prolog spatial grammar interpreter* [53, 54, 61]; *Topdown* Mitchell et al. [108]; *Prolog shape grammar interpreter* Chase [21]; *discoverForm* [18, 19]; *Tartan Worlds* Woodbury et al. [175]; *GENESIS* Heisserman and Woodbury [78]; Heisserman [76]; *GRAMMATICA* Carlson [17]; **Harada et al.* Harada et al. [74]; Harada [73]; *SEED-Config* Woodbury and Chang [173]; Akin et al. [6]; *SEED-Layout* Flemming and Chien [59]; Akin et al. [6]; *3D Shape Grammar Interpreter* Piazzalunga and Fitzhorn [115]; *GEDIT* Tapia [153]; *SG-CLIPS* Chien et al. [23]; *Simulated interpreter* Li [99]; *3D Form Synthesizer* Wang and Duarte [159]; *SGMP* Ertelt and Shea [45]; *Shape grammar interpreter* Li et al. [98]; **McKay et al.* McKay et al. [104]; Jowers et al. [85]; **Jowers et al.* Jowers and Earl [84]; *spapper* Hoisl and Shea [80]; *SGI* Trescak et al. [156]; *xploreForm* Mohiuddin and Woodbury [109]

GRAMMATICA [17], implements a control algebra (essentially a small programming language) over rules, making it even more abstraction hungry. The two exceptions are discoverForm [18, 19], which constantly rewrites its single grammar rule based on interactive input; and Harada et al.'s [73, 74] physically-based modeling system, which interactively applies sequences of rule applications within a physically-based modeling loop. As Carlson and Woodbury [19] argue-*Our emphasis is on the exploration of patterns, as contrasted to their generation.* xploreForm [109] is a contemporary version of discoverForm, with specific subjunctive functionality. These exceptions aside, the basic design is invariant: define rules; define an initial shape; observe matches of rules to the current shape; choose and apply a match and repeat. Thus a user can step through a grammatical derivation, typically not knowing what has yet to be derived. There is often an automatic mode, whereby the system produces one or more elements of the language of the design without user intervention. Highlighting of the location at which a rule may apply is a common interaction device. Some authors, such as Tapia [153] and Li et al. [98] propose detailed interactions to aid in the rule application process. As Table 17.2 shows, with respect to the alternatives tasks, the basic design of an interactive grammar system primarily supports "reflect," "make" and "organize". The abstraction(cd) introduced by rules almost guarantees that grammars will serve reflection well-it takes a lot of explicit thinking about designs to produce a set of rules! Indeed, the high level of abstraction(cd) in grammars and their systems may well explain why the primary use of grammars has been to analyse corpora of designs to produce explanations (typically as a form of narrative) of formal structure. The exceptions are precisely those systems that make rule application highly interactive, thus effectively suppressing time for reflection. In discoverForm reflection requires adhoc secondary notation, such as sketches or saving files. In Harada's system, rules are so visually suppressed that reflection essentially disappears. In contrast, xploreForm provides tools for reflection through supporting multiple simultaneous states, which can be edited in parallel.

We present a summary cognitive dimensions analysis of six grammar-based systems. Given the similarity across this class of systems, we selected two "standard" examples and four outliers for sketch cognitive dimensions analyses, shown in Table 17.3. The reason to choose more outliers is that such systems may best indicate new directions of development for grammar-based interactive systems. We include a detailed analysis for one "standard" system: GENESIS. While we believe that the GENESIS system is largely typical of its class, its highly abstract rule editing makes it perhaps more viscous(cd) and less role-expressive(cd) than other systems in the class. It is, however, vastly more expressive (in an informal sense). That it operates over collections of labeled solid models and their parts and has a wide range of query functions makes practical definition of a range of complex artifacts.

17.3.2.1 Cognitive Dimensions Analysis of the GENESIS System

The GENESIS system was part of Jeff Heisserman's PhD thesis at CMU [75, 78]. It was further developed by Heisserman and others at The Boeing Company [76, 77]. Figure 17.1 gives a screen shot of the major part of the GENESIS interface as it existed at CMU in 1991.

Viscosity(cd): GENESIS displays high viscosity due to rule interaction, the requirement to use the interpreter to determine how a rule applies, and the slow speed of the interpreter (approx 1 rule application per second).

Visibility(cd): Rules are locally very visible. Complex rules have internal predicate calls, reducing visibility. Rule sequences have very low visibility.

Table 17.2 The 25 grammar systems compared to the eight generic exploration tasks

System	Find	Make	Reflect	Scan	Compare	Organize	Remember	Recall
Simple interpreter	–	r	–	–	–	–	–	–
SGI	–	r	–	–	–	–	–	–
Shape grammar interpreter	–	r	✓	–	–	–	–	–
Prolog spatial grammar interpreter	v	r	✓	–	–	d	–	–
Topdown	–	r	✓	–	_	_	–	–
Prolog shape grammar interpreter	–	r	✓	–	–	–	–	–
discoverForm	v	r(i)	_	_	_	_	–	–
Tartan Worlds	v	r	✓	–	–	d	–	–
GENESIS	–	r	✓	–	–	d	–	–
GRAMMATICA	–	g	✓	–	–	dl	–	–
Harada et al.*	–	d(i)	–	–	–	–	–	–
SEED-config	–	r	✓	–	–	d	–	–
SEED-layout	–	r	✓	–	–	d	–	–
3D shape grammar interpreter	–	r	✓	–	–	–	–	–
GEDIT	–	r	✓	_	_	_	–	–
SG-CLIPS	–	r	✓	–	–	d	–	–
Simulated interpreter	–	r	✓	–	–	–	–	–
3D form synthesizer	–	r	✓	–	–	–	–	–
SGMP	–	r	✓	–	–	–	–	–
Shape grammar interpreter	–	r	✓	–	–	d	–	–
McKay et al.*	–	r	✓	_	_	_	–	–
Jowers et al.*	–	r	✓	–	–	l	–	–

(continued)

Table 17.2 (continued)

System	Find	Make	Reflect	Scan	Compare	Organize	Remember	Recall
spapper	–	r	✓	–	–	l	–	–
SGI	–	r	✓	–	–	–	–	–
xploreForm	–	r(i)	✓	✓	✓	✓	–	–

*no name given for system
r alternatives are made through applying rules
r(i) rule application is interactive
g rules combined with grammatical programming
d derivations
d(i) rules combined into derivation sequences
l elements of the language of a grammar

Table 17.3 Summary of cognitive dimensions analysis of six grammar-based systems

System	Viscosity(cd)	Visibility(cd)	Premature commitment(cd)	Hidden depenencies(cd)	Role-expressiveness(cd)	Abstraction(cd)
GEDIT	1	5	2	5	4	4U
GENESIS	5	2	5	5	1	4
GRAMMATICA	5	1	5	5	2	5
discoverForm	1	5	1	3	5	1
Harada et al.*	1	5	2	3	4	2

System	Secondary natation(cd)	Closeness of mapping(cd)	Consistency(cd)	Diffuseness(cd)	Hard mental operations(cd)	Provisionality(cd)	Progressive evaluation(cd)
GEDIT	4	3	4	4	5	2	3
GENESIS	5	3	1	4	5	5	2
GRAMMATICA	5	4	2	5	4	5	2
discoverForm	2	2	5	5	1	2	5
Harada et al.*	4	3	4	4	2	1	5

The numbers are a measure (from 1 to 5) of the degree to which a system exhibits a particular cognitive dimension. Values labeled with a number followed by a “U” are provisional: they were unable to be clearly evaluated given the information available. These numbers are not value rankings—the cognitive dimensions are neither good nor bad. Rather they raise issues for evaluation, some positive, some negative, and most affected by other dimensions. We present a detailed analysis of GENESIS in the next section

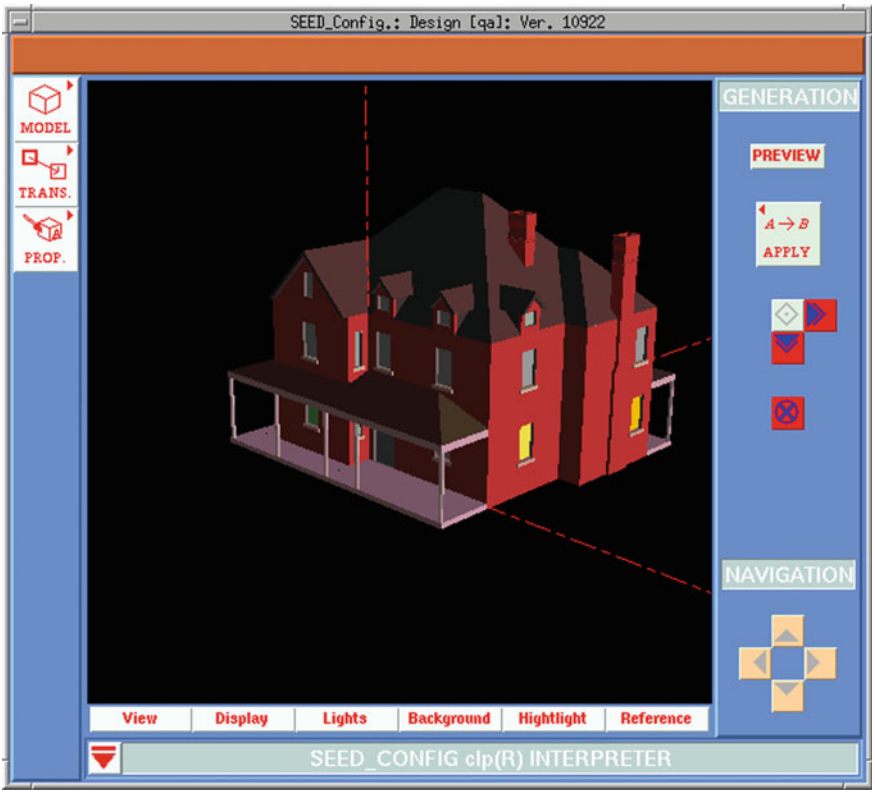

Fig. 17.1 The GENESIS interface circa 1991

Premature commitment(cd): Rules imply very high premature commitment. Grammars can address this with very fast rule application, thus creating a make-see-evaluate cycle that would reduce premature commitment. Genesis was too slow to achieve this.

Hidden dependencies(cd): Rules have hidden dependencies through their internal predicate calls. Effects can be very hard to trace. Like all grammar systems, GENESIS creates a hidden dependency between rules and designs. The purpose of an interpreter is to find where rules apply, thus revealing a dependency that is very hard to see without the interpreter. Role-expressiveness(cd): Rules, particularly those used for control, can be very obtuse. Error-proneness(cd): As Flemming [53] notes, a purpose of a grammar interpreter is to enable exploratory decision making, that is, making and correcting errors incrementally. That said, the logic notation, like most programming languages, creates many opportunities for making errors.

Abstraction(cd): All grammar systems are abstraction hungry. Rules abstract action so that it can be applied in contexts unknown at the time of rule writing. GENESIS is even more hungry than most. Rules are expressed in Prolog notation, in which internal predicates can create multiple layers of abstraction.

Secondary notation[cd]: GENESIS inherits the secondary notation conventions of Prolog (comments, pretty printing, mnemonic names, predicate ordering, easy test cases). It has little escape from formalism outside of these devices. In particular, there is no way to annotate a state interactively.

Closeness of mapping[cd]: All grammar systems have low closeness of mapping. Rules abstract from the domain. To write a rule is to pull away from the particulars of a design to general cases. GENESIS aggravates this with its symbolic, as compared to graphical, rules. If reflection is taken as the supported task, then an argument for high closeness of mapping can be made. Rules, that is, general cases map well to what is being learned in reflective practice.

Consistency[cd]: At one level, all grammar systems have high consistency: rules are a uniform mechanism for expressing action. At a lower level, consistency problems can be severe. There is much idiom in writing grammars, for example, the use of placeholder marks to control rule application. GENESIS adds to this with the consistency issues introduced by its use of a programming language (in this case, Prolog) to express rules.

Diffuseness[cd]: Grammars are notoriously diffuse. They tend to be written as sets of small rules that act sequentially and in concert to achieve an effect. These create hidden dependencies[cd] among the rules. GENESIS adds to this problem with its use of internal predicates in expressing rules. Hard mental operations[cd]: It is often very difficult to develop a rule in GENESIS, partly because rule action itself is hard to anticipate and partly because the Prolog notation shows low closeness of mapping[cd]. It is essentially impossible to develop GENESIS rules without a sketchbook. Provisionality[cd]: A highly interactive grammar interpreter should display low provisionality[cd]-make a rule and see what it does. However, many rules only come into play at advanced states in a derivation sequence, so being able to store states is essential. GENESIS' slow, sequential, single-state rule application greatly increases provisionality.

Progressive evaluation[cd]: In principle, rule action in a grammar can be checked at any time. In practice, barriers arise if a rule requires a certain design configuration, or is dependent on prior application of other rules. Then the interpreter must take the user to a suitable state. This can be partially overcome by using secondary notation to create test cases for the interpreter.

GENESIS decreases progressive evaluation[cd] through the symbolic form of rule expression. Rules must be expressed in proper syntax before they can even be tried.

17.4 Discussion and Conclusion

It seems clear that the grammar lens strongly channels the design of interactive systems. Existing grammar system are nearly silent on five generic exploration tasks (find, scan, compare, remember and recall), and some systems provide limited support, largely through derivations, for the organize task. The almost exclusive focus on making, that is step-wise construction of designs through grammar rule application, has, arguably, excluded other concerns. Grammar systems are naturally reflective as to devise a grammar requires formal explication of the class of designs being modeled. The exceptions to this narrow norm are those that, in some sense, treat the design space as an artifact in its own right. discoverForm [18, 19] enables rapid movement in the space, but provides no tools for holding more than one state in memory. It essentially defers this task to human memory. GRAMMATICA [17] provides explicit computation and management of design spaces, but has a highly symbolic interface. Harada's [73, 74] system submerges grammar rule application inside a physically-based modeling loop, giving rapid discrete changes but making the grammar rules and their application opaque. The recent xploreForm [109] points in a new direction—maintaining part of the explicit space directly in the interface. These "edge" systems (in the sense of being on or outside the general norm for grammar systems) show differences in cognitive dimensions, particularly premature commitment(cd), error-proneness(cd), diffuseness(cd), provisionality(cd), and progressive evaluation(cd). More importantly, they point out directions for refocusing the grammar lens more broadly, to other generic tasks and to use other interaction devices.

This paper is part of a larger project to understand the design space of design space explorers. We intend papers on each of the several interaction lens in the literature: history, version, representation, gallery, task and interactivity. Our overall goal is to both understand this new and large design space and to learn the principles and practices for designing and implementing more effective design space explorers.

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Chapter 18
Answering Questions with Questions: A Personal Take on Gödel's Incompleteness Theorem as It Relates to Architecture and Design

Andrzej Zarzycki

Abstract This paper discusses the role of prototyping as a vehicle to integrate electronic media technology, materiality, and physical computing into architectural design process and education. It connects a creating-making approach to a broader maker and hacker culture through adaptive and autonomous assemblies and embedded electronic systems. It recognizes the need for a new conceptual discourse on what constitutes effective design methodology that nurtures innovation and considers all design factors: social, cultural, and technological.

18.1 Introduction

The role of prototyping as a form of conceptual thinking and design methodology has been on the rise since the introduction of digital fabrication processes into architecture. It represents a cyclical phenomenon, since the discipline of architecture originated from the notion of the Master Builder and the close connection between the intent, the method, and the outcome. In more recent years, fabrication technologies not only provided designers with direct access to means of production and the ability to control design outcomes, but more importantly allowed a feedback loop characteristic of past craftsmen involved in creating-making. The current interest in and the implementation of prototyping technologies exemplify attitudes expressed by Louis Kahn in his famous inquiry of "what the brick wants to be" or Michelangelo's pursuit of embedded characteristics of materiality: "I saw the angel in the marble and carved until I set him free." Computation and electronic technologies combined with smart materials provide a new ingredient in the creating-making of a built environment. Understanding virtuality in the context of materiality and materiality in the broader intellectual, cultural, and social frame-

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J.-H. Lee (ed.), *Morphological Analysis of Cultural DNA*,
KAIST Research Series, DOI 10.1007/978-981-10-2329-3_18

work is critical for the integrity and future of the discipline. This creating-making tradition continues to redefine architecture as it is consistent with and representative of a broader current culture of makers and hackers: the culture that permeates all aspects of our daily lives with a shared DNA-like structure.

18.2 Culturally Conditioned Creativity

Philosophically, maker culture empowers individuals to redefine their own world. It is an alliance of a human with a machine (computer, robot, CNC, 3D printer). It shifts the conceptual position of a designer/creator from the rage against the machine (limited by technology) to joining with the machine against the arrogance of mass production, standardized thinking, and quasi-creativity—an assumption that one fits all and one thinks for all.

Consequently, the innovation of technology becomes as important as its creative use, defining the future of design not only by finding new ways of rearranging solutions within a current paradigm but also, or perhaps primarily, by tinkering with the very nature of creative processes and tools as a source of new ideas. This calls for constructing a proverbial typewriter each time we author a new text, to overcome Friedrich Nietzsche's tools-and-thoughts predicament: "our writing tools are also working on our thoughts" [1]. Out-of-the-box solutions no longer appeal to aspiring new designers, nor to their destined users-consumers. In the days of computational almost-perfect reproducibility marked by sophisticated tools, such as 3D printers, laser cutters, or CNCs, being original and creative involves reformulating tools and processes themselves. Modified programming scripts or unprecedented materials appropriated from other industrial applications become starting points for creative explorations and the separation from the known and the obvious.

18.3 From a Consumer to a Maker and Creator

While the Maker Movement empowers designers and architects by putting them in direct contact with the production of the built environment, more importantly it transforms the relationship between creators and users. The participants in the built environment expect a similar level of involvement in and authorship of the public domain as architects have. Being a silent and passive consumer of design and culture no longer is glorified or aspired to. Democratized environments allow users to customize these environments and make them adaptive to their personal and often esoteric needs. This significantly shifts the role of designers and the types of designs they produce. Open-source, open-ended, and crowdsourcing approaches are just some of the modifiers of cultural modes of production that define the new relationship between creativity, intellectual property ownership, and authorship.

A significant extension, or perhaps subversion, of this approach is the emergence of electronic networks that facilitate almost-instant knowledge and technology transfers as well as new forms of collaboration such as crowdsourcing. Collective wisdom and collective authoring (creativity) further redefine maker culture, shifting the center of gravity from an engaged artist or designer into enabled consumers and users. This shift provides opportunities for greater social appreciation of design. However, it also redefines the roles designers play from sole content creators to mentors and facilitators of socially and culturally driven creativity. This repositioning quantifies design as a resultant of collectively and individually made choices driven by value, image, and cultural relevance.

18.4 How to Blow Soap Bubbles?

A seemingly easy question often requires a sophisticated and complex answer. This was the case with the Digital Bubbles project (Fig. 18.1) developed by a student team for one of the interactivity courses. The soap bubble (machine) installation was designed to respond to ambient sound levels, or it could also be used for remote interactions with microphones as sound sensors to create elaborate soap bubble formations. The development process involved constructing multiple working prototypes and testing kinetic and electronic assemblies (Fig. 18.2). Each subsequent version focused on refining the prototype performance and soap flow and on fine-tuning sensors and actuators. The precision of connections, designing for tolerances, and material fatigue had to be considered and continuously addressed. Fine-tuning the latency of electronic systems with the physical behavior of materials required prototype testing and redesigning.

The process of making and remaking prototypes is analogous to retracing over previous sketches with a new layer of translucent paper. The iteration is what stirs imagination, and the iteration is what makes it perfect. The final design emerges through the process of human, material, and computational interactions that can

Fig. 18.1 Testing functionality of an early soap bubble installation prototype

Fig. 18.2 Refining prototypes and scaling up to create interconnected assemblies

only be addressed and solved through a close and hands-on understanding of a problem. However, there is a significant difference between sketching and building. Subsequent sketches may refine the design intent but do not significantly advance the level of design resolution; prototypes do. The conceptualization without a material grounding and performance feedback loop detaches design from effective actualization and greater social impact. For example, the increased reliance on drawings to define building design is commonly paralleled by reduced innovation in materiality and physical construction [2].

18.5 Why Build Bubble Machines, not Buildings?

While a bubble machine is not a replacement for a physical building, it is also not a nicely crafted drawing, rendering, or even conceptual model. We learn by abstractions and extrapolations when we cannot do the real thing. While drawings help designers with understanding compositions and layouts, nothing conveys design materiality (I am not considering color and texture selections here) and constructability unless we engage in the process of making it. It can be making it virtually or physically, but most likely it should involve both.

Having an opportunity to teach design students in various non-architecture disciplines, including industrial, furniture, and digital design, I have always appreciated their ability to deliver quasi-final products. This could be a working cart, door lock, safe and visually pleasing chair, or fully functional website, mobile app, or video game. Even if they were only in the proof-of-concept stage, they still worked and were real. My architecture students, with amazing conceptualization and communication skills, often had difficulty understanding why one would need to test design: why bring it into the realm of reality and understand it as an actualized idea. If it is drawn, it is resolved, they often seemed to think. The physical world is not that simple. It has many more variables that can make design difficult to realize and also has constraints that can stimulate design outcomes.

18.6 Should We Have More Biology Than Biomimicry in Architecture?

Biomimicry is an important line of research looking into ways to extend natural biological creativity into other sciences and disciplines of life. This means going beyond phenotypical similarities and diving deep into genotypes and fundamental building blocks of nature—introducing science into design.

The Algae Façade project (Fig. 18.3) combines building technology with physical computing (sensors, actuators, and microcontrollers) and biological living organisms—algae (Fig. 18.4). The project used a building façade as a harvesting surface for algae growth for subsequent conversion into biofuel or as a simple carbon-footprint offset. The algae façade serves as adaptive sharing device that is designed to both optimize sun exposure for algae panels and reduce the solar gains in the glass façade behind. This sophisticated and complex behavior is best solved by an adaptive system of microcontrollers with actuators and distributed sensors continuously monitoring building performance. This gave students an insight into new ways of design thinking: design can emerge out of an algorithmic and adaptive

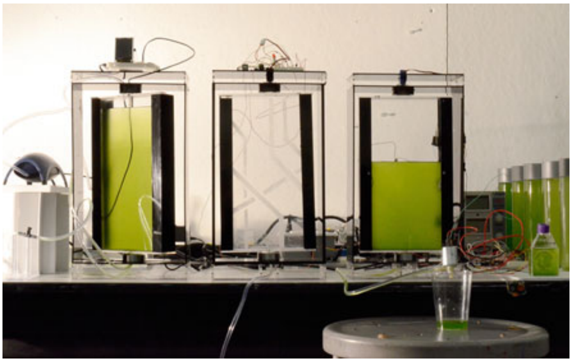

Fig. 18.3 Algae panel prototypes; each tests a different panel functionality

Fig. 18.4 Algae cultivation, showing 14-day cycle of growth from beginning to harvesting

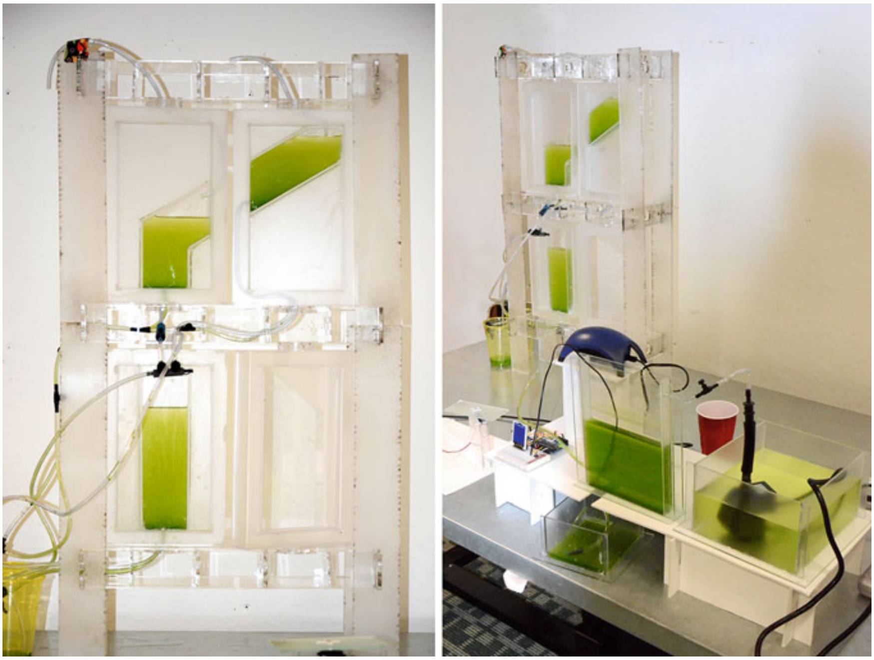

Fig. 18.5 Testing early prototypes

process driven by data rather than by an a priori set of assumptions. It also required students to engage the project not only physically, by understanding building performance and construction assemblies, but also biologically, by working with actual algae specimens obtained from a biology lab.

An important part of the prototyping process was not only to set up operating parameters for the design (Fig. 18.5) but also to develop a set of algorithms that would govern the algae cultivation process and panel behavior (Fig. 18.6). Defining adaptive and interactive designs as a collection of interdependent factors introduced system thinking into design. Students had to consider all possible scenarios that may impact design outcomes.

While this project is reflective of the bioreactive façade designed by Arup for the BIQ House in Hamburg, Germany, the focus of student work was on extending existing precedent into more adaptive and autonomous building skin. In student design, algae panels track sun location, aerate water inside the panels, and monitor temperature in several points of façade assembly, allowing for various functionality overrides to maintain optimal building skin performance. For example, in case the water temperature inside were to drop to 29 °F, the panel would drain to prevent the algae solution from freezing.

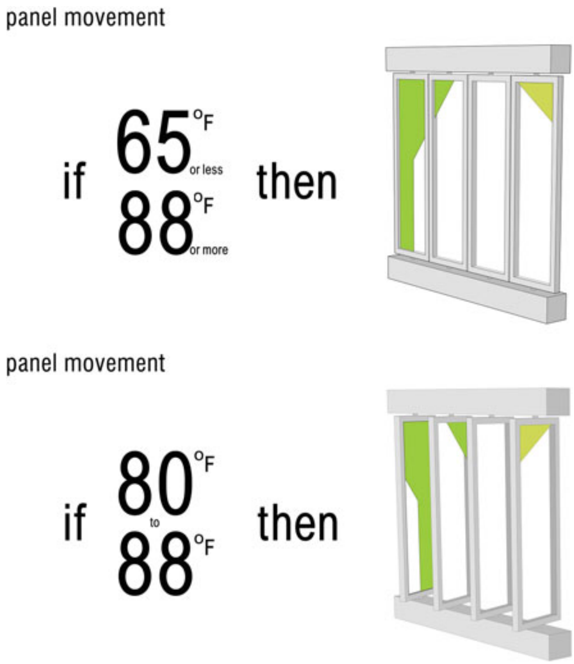

Fig. 18.6 Defining algorithmic operabilities of adaptive panels

An important part of design is using technology and architecture as a social and cultural statement. Buildings and cities are man-made habitats that can and should coexist with the natural environment. They can manifest societal stewardship of the environment and architecture's role in it. In some aspects, projects like the Algae Façade continue the tradition of the Centre Georges Pompidou in Paris, which treats a building's technological framework as yet another design and expressive factor. They liberate technology from its servitude role in architectural design into a primary and dominant expression. More importantly, they engage society in a dialog about the role of technology in everyday as well as cultural life. The Algae Façade project, like the BIQ House, becomes an agent of social and technological change by promoting new cultural and design standards. It effectively serves as a data visualization structure with physical adaptive panels as a display medium.

Furthermore, a design approach that starts with precedent as a holistic design solution (fully functional mechanism), not only as an inspiration (visual and metaphoric), provides a potent vehicle for bringing design resolution to a higher level—to precedent 2.0. Not unlike in evolution, new designs should build upon previous successful designs—not only phenotypically but also genetically. Using the BIQ House as a design springboard allowed students to dive directly into more sophisticated design issues and research work.

18.7 Is the Medium Indeed the Message?

When McLuhan and Fiore [3] coined the adage to title his seminal work, he could not have fully understood the possible range of application of synthesizing form with content. My personal take from reading McLuhan's works is not only that utility, materiality, and beauty (utilitas, firmitas, venustas) [4] cannot be separated but also that the media narrative component should be added into Vitruvius's list. The narrative and media dimension that seems to have been lost in architecture needs to be considered again. Media is an extension of the semantic value of form and function in architecture with significant "overwrite function" ability. While this was certainly evident in architecture in the past, present media establishes a new cultural dialogue by including temporal, user-specific, and user-defined experiences. It connects with a society as a whole and individually with its members.

In the Adaptive Media Façade project (Fig. 18.7), designers looked at media displays not only as visual communicators but also as opportunities for addressing glazing privacy, embedding photovoltaic frits, and merging media components with the adaptive daytime shading system (Fig. 18.8). In the current media-rich world, with personalized expressions openly shared in electronic social networks, it is time to explore the ways our electronic lives inform architecture. While this might seem to some like a design disaster—the antithesis of the architect's control over design characterized by Mies van der Rohe's concern for the position of window shades in his residential glass towers—it is the next step in democratization of creativity and artistic expressions. Crowdsourcing and collective intelligence are the game changers in other aspects of life. Why not in architecture?

The Internet of Things (IoT) platform, utilizing distributed sensing, actuators, and microcontrollers, allows for a direct integration between embedded objects or buildings and users via handheld devices such as smartphones. Used for security access and controls, building data monitoring, or content authoring, mobile devices effectively extend spatially and conceptually what is considered a building and its perimeter. A mobile interface connects directly to what is often hidden within and defined as a private realm. Smartphones also provide opportunities for greater public participation in authoring media contents, in a similar way as the D-Tower project by artist Q.S. Serafijn and architect Lars Spuybroek (NOX) does. However, the greater conceptual relevance lies in their similarity to artistic media projections

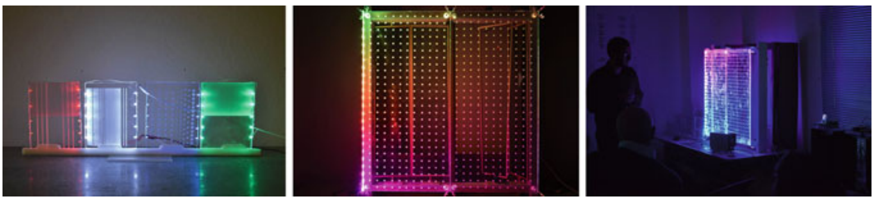

Fig. 18.7 Media façade: initial exploration of glazing treatment (*left*) and final design (*center* and *right*)

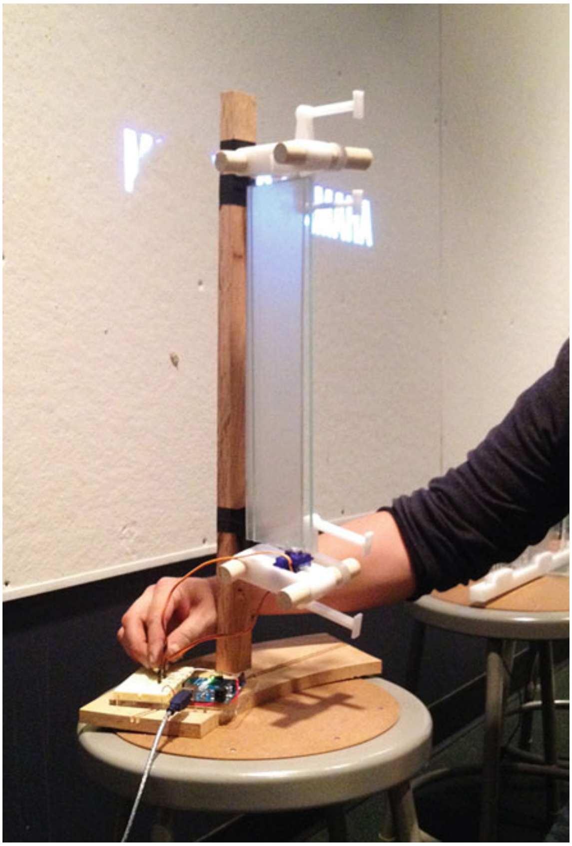

Fig. 18.8 Adaptive shading component

done by Krzysztof Wodiczko, projects in the Media Façade Festival such as a SMSlingshot installation by VR/Urban, or works by the NuFormer[1] studio that start redefining the boundary between ownership in public and private domains. Furthermore, virtual (augmented reality-based) and projection (projection-mapping) media creations escape the simple societal judgements that are directed at graffiti art or tagging. Since they do not deface or damage private property and often serve an important social role, virtual and augmented transgressions become socially acceptable and often a preferred form of communication.

An example of such a direct integration is the Tectonic Media Façade project (Fig. 18.9), which hacks a traditional LED display into façade tectonic expressions. A particularly interesting aspect is the approach to the project that reuses standard 8 × 8 LED matrixes with a MAX7219 chip in a participatory media interface. The media expressions and interactions are extended with the microcontroller (Arduino) and smartphone (Android) connectivity utilizing Bluetooth technology (Fig. 18.10).

[1]http://www.nuformer.com/.

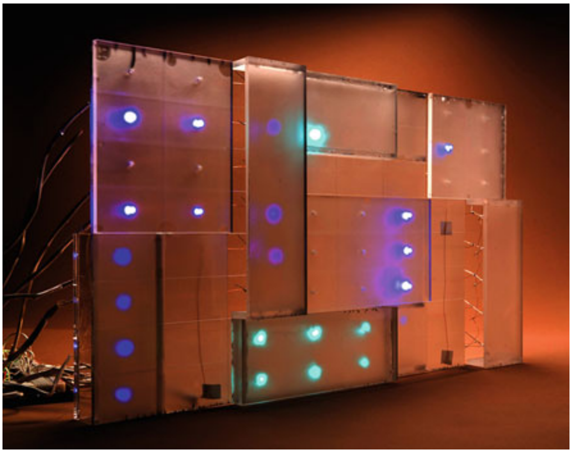

Fig. 18.9 Tectonic Media Façade as an 8 × 8 LED matrix

Fig. 18.10 Implementing Bluetooth connectivity between Android app and Arduino

While there are various ways to connect users with embedded building systems, Bluetooth provides an easy, on-location (10-meter range), and democratic (available in most smartphones) method of crowdsource participation. In this particular arrangement, users can pair their own device with the media façade and author its content. A highly appealing aspect of this project is its high "hack" value—achieving sophisticated functionalities with relatively easily reappropriated and off-the-shelf components and technologies.

18.8 Do You Trust Your Work?

While the self-watering green wall project (Fig. 18.11) is a simple exercise in urban farming and physical computing (microcontrollers, sensors, and actuators), it introduces two critical concepts into design, and more importantly into design

Fig. 18.11 The self-watering green wall installation

education. (1) It requires a student to develop an algorithm to define the system behavior, even if it is very simple. This means that the student needs to understand all contributing factors and constraints, and is able to quantify them. (2) It provides an immediate validation check about the design. It tells you "yea" or "nay" and ultimately provides the gravity to everything you do. In this particular project, perhaps the most difficult part for the student was to leave for the winter break with the faith that the system developed by her would function autonomously over the following four weeks with no harm to her plants.

Even this simple project required intellectual commitment and provided a real-life, almost real-time feedback that is missing from traditional paper-only or paperless-only design studios grounded in the assumption-and-no-validation world. This highlights an important role computation and technology should play in culture and society. It should not only open new horizons but also readdress an existing environment by providing an extra-skeletal support framework for the already-known physical world.

The design feedback is critical in the reiterative building development process as well as in the professional growth of an architect. The quantification of this feedback transforms design evaluation from verbal virtuosity to technical competency.

While we no longer ask architects or engineers to stand on a bridge designed by them when it is fully loaded with trucks of dirt as a guarantee of good design and workmanship, the sense of responsibility, ownership, instant validation, and consequences of one's work is important in student learning and professional practice. For the student, leaving a plant for an extended period of time and trusting in her own work became an informative experience and provided reassurance about her abilities. While this may sound like a rather naïve example, it was actually more meaningful than paper- or digital-based conjectures that often lack confidence in becoming real.

This example reflects another important question I often pose to my students: "Would you buy a product you are designing? Is it worth…?" The question makes many of my students and colleagues pause in a meaningful way and not answer it.

18.9 Should Architecture Expand Like the Universe?

The critical point that needs to be addressed here is whether expanding the discipline of architecture to creating-making, prototype development, and design/idea validation is still architecture, or perhaps part of engineering? Does the consideration of user experience (UX)—spatial and nonspatial—or architecture as user interface (UI) move architecture too far into the world of media or cause it to lose its identity? One could make an argument about master builders of the past, including Filippo Brunelleschi, with their all-inclusive design approach. However, this would be a simple argument, since no one would opt for removing these established names from the pantheon of architects.

A more meaningful argument is the need for the discipline (architecture) to maintain its solvency—to meet its long-term mission as a creative, problem-solving, and future-forming discipline: a discipline that goes beyond a self-referential and self-contained black hole or a cheerleader team for someone else's game and wins. Finally, an expanded field of architecture maintains cultural equilibrium in a technologically driven world, not by denying progress but by engaging it.

18.10 Why Do We Do This?

The combination of computational simulations achieved with the range of current software, with physical prototype validations driven by gathering actual data, provides a strong educational framework that the professional world is looking for. It is not about teaching vocational subjects or preparing for draftsmanship but rather about instilling the ethics of idea forming, design development, and ownership: coming up with the design that matters and makes the world a better place. Stepping away from a purely conceptual design thinking that detaches itself from physical, economic, social, ecological, or technological constraints is critical in maintaining the discipline's future relevance and cultural role.

Computation transforms not only what we do but also who we are. The digital machine makes us behave in particular ways that conform to its own logic, and we, as a society, do it consciously and willingly. Perhaps this is possible because the technology is seen as an extension of ourselves, not a replacement for who we are. The British anthropologist James Burke in *The Axemaker's Gift* [5] described our cultural history as a constant shaping of tools by people, and consequentially shaping people and the way they think by the tools they create. This dictum applies today as it did in the past, describing our cultural relationship with the electronic media. Digital design methodology and tools play a crucial role informing our perception of reality and consequently shaping expectations toward the future. James Burke's adage mirrors Steve Oles's observation: "The future, it could be argued, is the true medium of the designer," where he discusses the importance of visual media in forming a design proposition.

While some would argue that the best way to predict the future is to invent it [6], designers and architects ground inventions in research precedent and practical experience. They also need to base them on quantifiable and verifiable outcomes.

18.11 Should We Reconsider the Discipline?

What distinguishes these projects is not the use of fabrication techniques and a learning-by-doing approach but the emphasis on bringing the design resolution to the higher level of reality where students are responsible for defining an actual performance and the behavior of the designed system. In this scenario, design as conceptual proposition is followed by an increased design resolution through prototyping of actual building assemblies and seeing building as an active co-participant of human habitation. In this scenario, building becomes an active variable that quantifiably responds to continuously evolving design constraints (parameters) and escapes purely deductive design thinking. This approach extends the field of architectural design beyond form- and pattern-making, or designs based on hypothetical users, and focuses on data-driven building behavior. Design responds to outside and changing needs with the ability to supersede initial designer thinking. While it is certainly technology, including building technology, oriented, it ultimately positions design as an agent of habitation (living in the world), not a signature of a given aesthetical period or an architect's need to reassert her or his vision. While design can originate as a conceptual and aspirational conjuncture, it ultimately needs to reach the level of resolution that satisfies all social, cultural, and civilizational/technological constituencies.

18.12 What Is the Endgame?

The projects discussed above focused on several educational objectives: (1) grounding design in a higher level of physical and technical resolution by promoting the creating-making process, (2) emphasizing research that goes beyond inspirational visuals and addresses the whys and hows of architecture, (3) using design as a springboard to ask inquisitive questions—the adoption of Gary Rolfe's reflective model (Fig. 18.12): "What," "So what," and "Now what?" and (4) finally, using design to motivate and advance research.

While new computational technologies make us rethink established modes of creativity and address design concerns that were previously unsolvable (outside a designer consideration), they also open new territories that are both exciting and less familiar. Maker and hacker culture—expressed through commonly shared cultural DNA—reformulates traditional inert notions of architecture and design

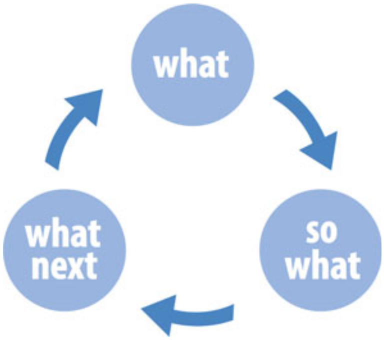

Fig. 18.12 Adaptation of the Terry Borton's reflective model [7] by Gary Rolfe

production. The built environment will no longer be designed from scratch but rather tweaked and re-appropriated from existing or mass-produced elements with a data-driven understanding of its context. This will become significantly more pronounced when the built environment is defined less by its physical form (hardware) and more by its software (embedded electronic and media functionalities).

Acknowledgments Digital Bubbles project was developed by Leland Greenfield and Edward Perez (Figs. 18.1 and 18.2).

The Algae Façade project was developed by Samantha Bard, Mary Lopreiato, and Libertad McLellan (Figs. 18.3, 18.4, 18.5 and 18.6).

The Adaptive Media Façade project was developed by Anthony Morrello and Anthony Samaha (Figs. 18.7 and 18.8).

The Green Wall project was developed by Milena Popow (Fig. 18.9).

The Tectonic Media Façade was developed by Kristen Schindler (Fig. 18.10).

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