REPOSITIONING MOVING IMAGE IN COMPUTATIONAL DESIGN EDUCATION

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ABSTRACT

REPOSITIONING MOVING IMAGE IN COMPUTATIONAL DESIGN EDUCATION

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The boundaries between science, art and design have begun to disappear with the developments in computational technologies particularly in the 21st century. Along with this convergence via computational technologies, architecture and design adapt new design tools and methods, which affected the design process at the first glance. The circumstances of these adaptations influenced both theory and praxis in architecture and design by resulting in paradigmatic shifts in which the meaning of design tools evolved into design mediums eventually. In addition, the integration of these technologies into design education has become a challenge especially since 1980s.

This study proposes an approach to the problem of the integration of computational design technologies in early design education. The proposed approach arises from the examination of the intersection of the computational design process and moving image studies within the scope of the design education research field. The major shift in design with the developed computational design technologies requires new means to help designers to achieve designing the process and requires new means to facilitate this change. Therefore, the moving image idea can be reflected back and has the potential to be reinterpreted as an early intermediate computational design model helping a designer to understand her forthcoming design process. Model, moving image model, computational model, parametric and dynamic representation model are essential terms to comprehend during this investigation.

The contributions of moving image to design education are examined through its potential for improving the computational thinking process, easing the relational thinking both in conventional and computational design processes and acting as a trigger for the creativity in design education. In order to investigate these contributions, a case study called *Cubehocholic* workshop is designed. During the design of the workshop, Bloom's revised taxonomy is taken as a reference while constructing the workshop learning objectives and in order to assess the design process. Repositioning moving image model in computational design education has been examined throughout these assessments. As a result, it has been observed that moving image model integration to computational thinking cycle has helped the students in understanding their creative design process.

Keywords: moving image, computational design education, computational thinking, moving image model, computational model, parametric model, dynamic representation model, algorithmic model

ÖZ

HAREKETLİ İMGEYİ HESAPLAMALI TASARIM EĞİTİMİNDE YENİDEN KONUMLANDIRMAK

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Bilim, sanat ve tasarım arasındaki sınırlar, bilgisayar teknolojilerinin[1] gelişimi ile birlikte özellikle 21. yüzyılda yok olmaya başlamıştır. Bilgisayar teknolojilerinin getirdiği bu yakınlaşma en başta tasarım sürecini etkileyerek mimarlık ve tasarım alanlarında yeni tasarım araçlarının ve yöntemlerinin adaptasyonunu getirmiştir. Bu adaptasyonlar mimarlık ve tasarım teorisini ve pratiğini etkileyerek paradigmatik değişim ve dönüşümlere yol açmış, sonuçta tasarım araçları anlamsal olarak tasarım ortamlarına evirilmiştir. Ek olarak bu teknolojilerin tasarım eğitimine entegrasyonu özellikle 1980'lerden başlayarak bir problem olarak ön plana çıkmaktadır.

Bu çalışma bilgisayarla tasarım teknolojilerinin[2] erken tasarım eğitimine entegrasyonu problemi üzerine bir yaklaşım önermektedir. Önerilen yaklaşım bilgisayarla/hesaplamalı tasarım süreci[3] ve hareketli imge çalışmalarının kesiştiği

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[1] Bu çalışmada "Computational technologies" türkçeye "bilgisayar teknolojileri" olarak çevirilmiştir.
[2] Bu çalışmada "Computational design technologies" türkçeye "bilgisayarla tasarım teknolojileri" olarak çevrilmiştir.

noktaları tasarım eğitimi araştırma alanı çatısı altında incelemektedir. Bilgisayarla tasarım teknolojilerin gelişmesi ile tasarımda meydana gelen başlıca değişim, tasarımcıların tasarım sürecini tasarlamaları ve bu değişimin kolaylaştıralabilmesi için yeni araçlar ve yollar gerektirmektedir. Bu nedenle hareketli imge fikri tasarımcının ilerideki tasarım sürecini anlamasına yardımcı olabilecek ve geri besleme yapabilecek potansiyel bir erken ara hesaplamalı tasarım modeli olarak yorumlanabilir. Bu araştırma boyunca model, hareketli imge modeli, hesaplamalı model, parametrik ve dinamik temsil model terimlerinin tanımları önerilen potansiyeli anlamak için önemlidir.

Hareketli imgenin tasarım eğitimine olan katkısı, hesaplamalı tasarım sürecini geliştirme, hem geleneksel hem de hesaplamalı tasarım sürecinde ilişkisel düşünceyi kolaylaştırma ve tasarım boyunca yaratıcılığı tetikleme potansiyeli üzerinden irdelenmiştir. Bu potansiyel katkıları inceleyebilmek için *Cubehocholic* adında bir çalıştay durum çalışması olarak tasarlanmıştır. Çalıştayın tasarımı boyunca çalıştay öğrenme amaçlarını belirleyebilmek ve sonrasında öğrencilerin tasarım sürecini değerlendirebilmek için Bloom'un yenilenmiş taksonomisi kaynak olarak kullanılmıştır. Hareketli imge modelinin hesaplamalı tasarım eğitiminde yeniden konumlandırılması bu değerlendirmeler üzerinden gerçekleştirilmiştir. Sonuç olarak hareketli imge modelinin hesaplamalı tasarım düşünme sürecinde tasarımcının kendi tasarım sürecini yaratıcı bir şekilde tanımlayabilmesine yardım ettiği gözlemlenmiştir.

Anahtar Kelimeler: hareketli imge, hesaplamalı tasarım eğitimi, hesaplamalı düşünme, hareketli imge modeli, hesaplamalı model, parametrik model, dinamik temsil modeli, algoritmik model

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[3] "Computational design process" ingilizce anlamında hem bilgisayarla tasarım süreci hem de hesaplamalı tasarım süreci anlamına gelmektedir. Bu yüzden anlam kaymasını önlemek için çeviri her iki şekilde de kullanılmıştır. Bu çalışma boyunca "computational thinking process" hesaplamalı tasarım süreci olarak çevrilmiştir. Computation kelimesi kökeninde herşeyi yerli yerine oturtmak ve hesaba katmak anlamına gelmektedir (Cinici, 2012). Bu yüzden bu çalışma boyunca tasarım süreci ile birlikte kullanımı bilgisayar ortamında tasarım ile direkt olarak ilişkilendirilmemelidir.

To my parents and my dear husband with love

Meliha Akçay, Mehmet Akçay and Cem Kavakoğlu

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CHAPTER 1

INTRODUCTION

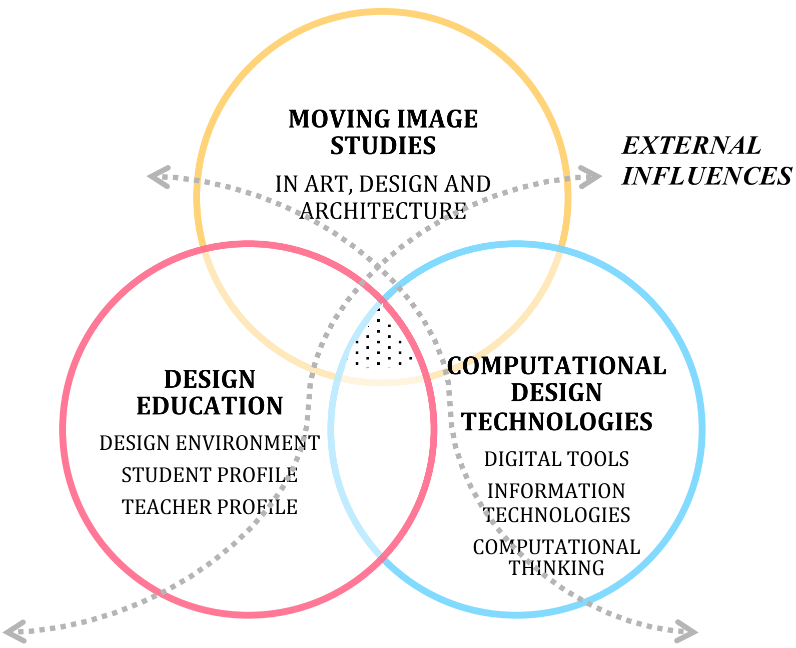
“It was a sunny day.” (Gönenç,2015)

This chapter describes the main scope and structure of the dissertation. The main research field of this study emerges from the intersection of design education in architecture, computational design technologies and moving image studies in general. Table 1

It can be said that the boundaries between science, art and design have started to vanish with the advances in computational technologies especially in the 21st century. There is a tendency to re-consider the foremost definitions that define the main scope and their implications in almost every field in general. There are ongoing discussions where design and architecture are the disciplines most affected by these advances, which have been feeding from the achievements in engineering and arts over the decades. However, design and architecture face new challenges not only related to developments in computational technologies but also the integration of these into design education.

It is known that computational design technologies, which is the broad name defining the union of digital tools, information technologies and computational thinking, have been changing design education considerably starting from the 1980s where the advent of these technologies forced students and teachers to use this medium and to deal with more complex problems. Complexity began to become something tangible in this context. Especially new generations are very familiar with all these technologies even though they may have some technophobia they are very good at adapting themselves to use them in general. Marc Prensky's metaphor of students as "Digital Natives" and teachers as "Digital Immigrants" clarifies the differences between the teachers and the students in this era so perfectly. In this metaphor students are introduced as native speakers communicating through their own language that is digital language and teachers are compared to immigrants that try to adapt to this new environment. While there is a flow of tremendous amount of information within this environment, there is also a danger of being a junk if the students do not know how to reach the proper information. In relation to this expanding information pool and the shift in students and teacher profiles, the researchers' and teachers' common effort is to maximize the potentials of these technologies and to integrate these advances into practice and education in best possible way. They can be called as moderators who direct this whole process by trying to prepare appropriate environment for design and design education. In addition, the uses of this information have much potential to help students as a mean of visual communication especially in architecture and design while dealing with complex design problems, which are called multidimensional in the context of this thesis.

Table 1 The research area of the study



Consequently, the integration of computational design technologies to design education especially starting from the first year, initiates a research field similar to the one in this thesis for many researchers. Many researchers question the integration of these technologies, from the logic behind them accurately to design education. This is a general problem that may not be solved simply by conventional teaching methods and it has been a particular debate since the 1980s.

This study tries to propose an approach to the problem of the integration of computational design technologies in early design education. The proposed approach arises from the examination of the intersection of the design process and moving image studies within the scope of the design education research field.

Many architects and researchers have studied the epistemological approaches towards the understanding of moving image and its relation to design and architecture rather than its implementations easing the design process. On the other hand, starting from the beginning of the 90s there has been an interest in this relationship within the design process itself while the moving image and design process definitions started to evolve with technological advances. Many researchers started to integrate this relationship and contents to their design process such as an analysis, representation or evaluation tool generally. In addition, these researchers mostly concentrated on the concepts of space, time and continuity linked to framing, camera movement, montage and cutting acts rather than focusing on moving image's own design process or methodology. It can be said that since this integration has been studied and developed with new technological developments, the study of moving image and its impacts on the design process started to be more explicit both theoretically and practically. Accordingly, these impacts started to have a reflection on design education especially in the design studio environment mostly as an analysis and generation tool for design and design experiences.

On the other hand there was research in architecture and design revealing out and using the concepts of moving image such as key framing, duration, etc. without referring directly to its essence and design process, solely though computer software which is designed especially for engineering and film studies (Lynn, 1999; 1999;

More, 2001; Rahim, 2001; 2005; Sevaldson, 2004; Picon, 2010). These pieces of research opened up a new door to the use of novel terms in design such as animate[4], time-based design, etc. However these studies did not point out these concepts in the scope of moving image, they concentrated on them as being just a new design tool for architecture and design.

While these tools had been integrated to design process, the discussions started to be conducted upon computational design mostly perceived as a form finding methodology in the beginning of the 90s. This methodology is mostly driven by the capacity of the computer software-produced for the animation production-and the algorithms generated in that era, which results in many debates about the role of computation and computational technologies in architectural design. There are still controversial discussions on this issue as like computational design technologies vs. creativity (Aish, 2005 ; Ahlquist & Menges, 2011; Brennan, 2011; Kilian, 2012). In this sense, the ongoing role of moving image idea in design should also be questioned in the realm of design education and the paradigmatic shift resulting from computational design technologies in the twenty first century.

The immediate expansion of terms related to the computational design technology advances also caused confusion on the re-interpretation of the moving image definition in general. Although it is commonly understood as and confused with the word "cinema" that is a visual art form having deep interrelations with architecture and design, the "moving image" term addresses three meanings; (a) The engagement between the static media and time notion. This engagement can be (b) a sequential ordering of the static media within time or it can refer to (c) an experience of motion within time. Therefore the meanings of the term related to visual art forms are excluded in this study because of their ambiguous nature that can blur the scope of this study, which is conducted on the relation of design education and moving image studies in general. The moving image term in this study can imply animation, video, motion graphics, flipbooks, etc.

[4] Animate is a term coming from Greg Lynn's seminal work "Animate Form" published in 1996. The author will examine this work in the context of this study in the literature review section.

Also it has to be mentioned that although computational design has been considered as a new paradigm in architectural design education, computational thinking has always been a part of design and design education either explicitly or implicitly. Today's complex design problems need to respond to the demand for high performance, responsiveness, etc. and force architecture not only think more and more computationally but also compel designers to parameterize the design problem which eventually makes design more interdisciplinary then ever. Parameterization of design problems should be differentiated from the computerization act but requires a deep understanding of the design to be developed and design the design process rather than the end product only (Terzidis, 2003; 2006; Sorguç & Selçuk, 2013). This major shift in design requires new means to help designers to achieve designing the process and requires new means to facilitate this shift. Therefore the moving image idea can be reflected back and has potential to be reinterpreted as early intermediate design models helping a designer to understand her own forthcoming design process.

The main reason for proposing moving image as a design representation model lies in the mutual relation of both moving image generation and computational design, that will be illuminated and explored at the forthcoming chapters of this study. During this investigation, model, moving image model, computational model, parametric and dynamic representation model terms are essential to comprehend in order to interrogate the aforementioned contribution of moving image as a design representation model to design education.

1.1. Problem Statement

Design representations are the essential elements, which define and transform ideas from one to another serving as an interactive interface for design and the designer during and after the design process. There is a mutual relationship between design and design representations, which has been evolving with the technological developments over five decades. These technological developments have influenced not only design and its representations, but also the design process and design thinking. The design tools started to transform into design thinking media where teaching, learning, application and generation can emerge (Sorguç, Selçuk, & Çakıcı, 2011; Senske, 2014). The conventional meaning of design representations such as sketch, model, plan, section, and elevation also started to change coherently this transformation. Especially the model term have begun to have a more substantial position in design process. The broad meaning of the model being a scaled physical entity of conception in design has shifted with its diversities and started to include a range of novel model definitions in the design process such as design models, digital models or computational models. The designer explores situations that she was never aware of and interprets her design process through the experience of these models. They are very helpful for the designer to re-explore, re-experience and re-interpret the design so that the design cognition of the designer may occur or may be improved interactively during or at the end of the design process. Moreover the hitherto static representation modes like plan, section and elevations become inadequate for some design problems, where the spatial and formal contexts cannot be free from multi dimensionality of internal and external forces shaping the design. In addition, time and inherent motion notions come forefront for some design problems by directing the designer into experience and exploration of the design process itself.

Students started to have a new level of recognition with the help of computational design technologies in design education. They have a new mind set so that design education started to evolve together with these technologies. These evolvements have begun to raise the crucial and coherent role of computational thinking in design and design education. In addition this transformation forces educators to propose new curricula, assignments and design studios in design education. The researchers and educators have started to question the evolvement of these computational technologies in the scope of teaching and learning activities. Consequently there is a rise of motivation and need in design education research field in order to find new means to experience learning and teaching with these technologies.

Visual thinking, which is based on both perceptions and relational thinking, becomes solidified by the advent of computational technologies where relations evolve into a derivative tool for perceptions of design in most of the design software. In this context, computational technology forces students to solidify their both visual and

relational thinking. Early design education aims initially to improve these thinking capabilities without any computer use.
Starting from the basic design course in the first year of design education, students try to figure out the primary relationship between the elements and the design itself. The main difference between basic design and further design studio courses is about design and its representations. Where the generated models are already the design end product in basic design, they are solely representations of design in the following design studios. For this reason, it can be said that design and its representations overlap through the final design also called the “model” in basic design course in design education. Students generate multiple models in order to solve the given design problem and ends up with a sole solution at the end of her/his design process in the basic design course.

Hence students try to relate the design end product and its representation that they develop and often this attempt fails in terms of the perception of their own design process. They have difficulties to understand and cognize their own process. Therefore their process stays intuitive especially in this first year. In education there are always many attempts to overcome this difficulty to help students to understand their own design process. So that in this thesis, moving image is to be used as a catalyzer to help students to understand their own design process and to improve their cognition.

Although students are producing different means of representations like sketches, plans, sections and physical models to communicate with their own design problem it is a very common observation that students have difficulty to relate and create these design representations in their mind as a part of the design act.

It is common knowledge that even for experienced designers, the early design process is a very vague and mostly ill-defined phase in which designers should define and frame the design problem, recognize the internal and external forces of the design and its multi-dimensionality. The designer metaphorically puts the first dot onto the paper in this early design process. It is also the case for the early phases of design education that the new rule sets and novel perceptions are imposed on design students in order for them to put that first meaningful dot.

During this process, student tries to communicate and convey through the generated models both by herself and with the teacher. Therefore the definition of the problem and the construction of the related vocabulary of the design problem is the most essential part. Since the student forces herself to understand the design process this leads, from an ill-defined design problem to a well-defined one for the designer so that she can recognize the parameters and forces shaping the design. In this study the transformation from an ill-defined problem to a well-defined one, signifies the self-awareness of student / designer about her design problem or design process. Mostly designer uses her intuition to tackle the problem in the very beginning. This is the creative phase then this creative phase is turned into a well-defined process through recognition. In general the design act begins with intuition, as the designer recognize internal and external forces on the design and the parameters. This act turns out to be a cognitive act in which the designer determines the process through her experience. Then this experience turns out to be knowledge and that knowledge results in a new cognition for the design process.

It can be seen that the shift from intuition to cognition in the design process happens more easily in experienced designers. This essential shift catalyzing the recognition of the design act should be thought about starting from the early years of design education. In addition, when computational technologies and various media merge with the design, the complexity of the process arises. Hence in order to articulate the role of computational thinking processes in the design act students should be able to establish a dialog between the design process and the computational technologies. In this context the role of moving image should be re-explored in terms of its potentials as a mediator. In this context the role of moving image which may have different forms but still represents the dynamism and the adaptability of the design process, provides potential to overcome the drawbacks of using only static representation modes like sketches, plans, elevations etc.

1.2. Hypothesis

There are two statements in this research; (1) Moving image, which is relatively complex yet explanatory and experiential in nature, works as a mediator and a feedback mechanism for the design process and its end product in design education, (2) the integration of moving image in the design process whether computationally or not drives the designer into computational thinking process in a spiral structure by triggering the creative act.

1.3. Research Questions

The main aim of this study is to make a contribution to literature on the conception of moving image and its relationship with design process -either computational or not- especially in early design education. Moving image models used as mediators in order to conduct a dialog for designer between the models and their representations also can be interpreted as intermediate computational models. The three-fold potential of moving image will be examined. These potentials are (1) improving the computational thinking process; (2) easing the relational thinking -both in conventional and computational design education-; (3) acting as a trigger for creativity in design education. In order to investigate these potentials the following questions are to be explored:

- How are moving image and computational design models similar? What are the common similarities between these two models?
- In which phases of the design process has moving image been used as a design representation?
- How can computational thinking be interpreted in the design process whether computationally or not when using moving images?
- How are the moving image model and computational models related in terms of their components/concepts?
- What kind of additional information can be gained by the use of moving image during the design process?

- How can the moving image model serve as a feedback mechanism in the design process?
- How can the moving image model and computational design relationship be integrated into design education?
- Can designers also benefit from this transformation during their design process? (For further studies)

1.4. Significance of the study

As a result of this integration this research can contribute to the architectural design education field in tandem with new technology and interdisciplinary fields by developing a proposed approach for early design education. The re-positioning of another discipline's accumulation in the early design education can also contribute to both computational design and design education research areas' literature and this can provide another perspective for both the theoretical and practical framework in general.

1.5. Assumptions and Limitations

> Students, although without previous experience in design per-se, do not come to the studio as a ''tabula rasa''. The pre-understandings students bring to their academic work come from their personal life experience (Kowaltowski, Bianchi, & Teixeira de Paiva, 2010).

Since the students of the 21^{st} century are digital natives then the integration of these technologies is not a challenge for them to learn. The issue at hand is to use these technologies in a well-structured way depending on the designer's objective. Therefore, in this thesis it is assumed that students, in this era, are digital natives therefore the problem is not to teach computer software mechanically, rather create computer design literacy.

The study is limited to the integration of moving image into the design process within a workshop, which is an informal teaching methodology. There were two workshops, therefore the conclusions derived from this study cannot be generalized in the scope of design pedagogy, but rather they can be considered as an attempt to integrate this proposal and discuss its implications in design education in general. The pedagogical debates on that manner are excluded from this study.

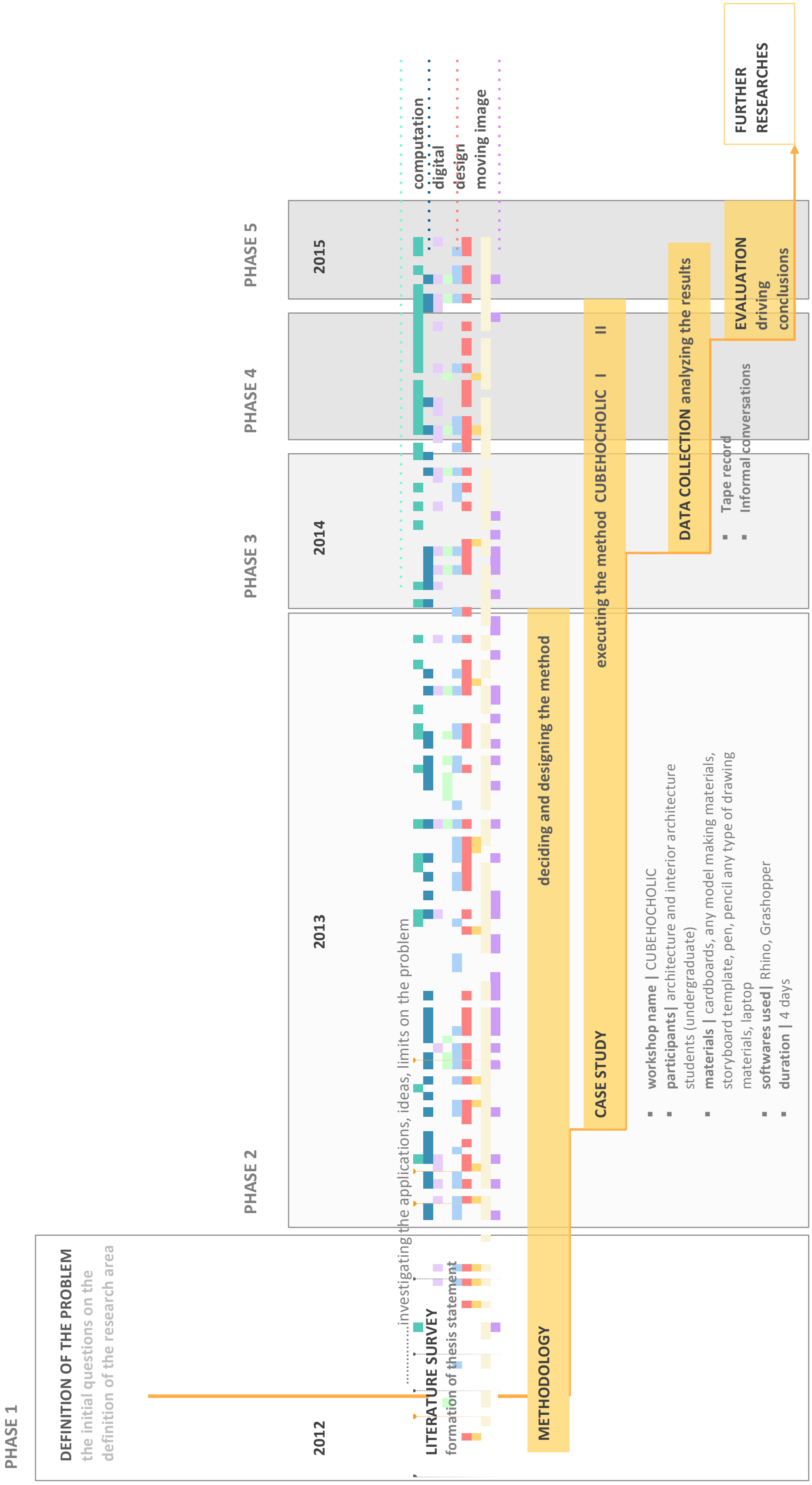
1.6. Methodology

> I could not hope to survey all the pertinent material nor even be sure that I would discover the most telling evidence in any one area. Fortunately, since the problem had attracted me darkly for several decades, I had by now accumulated boxes filled with references, from which a start could be made. With a bit of beginner's luck I could hope to establish my case sufficiently (Arnheim, 1969).

This research has been conducted in five distinct phases that are, (1) literature survey, (2) deciding and designing the method, (3) executing the method, (4) analyzing the results and (5) driving the conclusions. Table 2

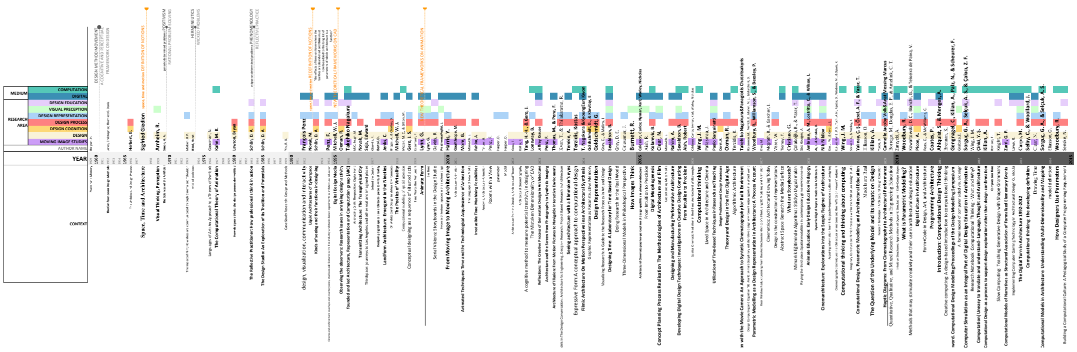
The literature survey as the first phase in this study has a reflection on the cross relationships in this multi disciplined research area and has derived via a frame through timeline based mapping -produced by the author in order to outline the previous research and their methodologies. Table 3 As a result of this literature survey-mapping, it was observed that starting from the beginning of the 90s the research focusing on the relationship with design and technological developments started to concentrate on more computational design technologies that include both information and digital technologies in general. It has been observed that mostly qualitative methods have been used; particularly descriptive and interpretive case studies have been conducted between the 90s and 2000s. The research under the umbrella of the design cognition field has adopted mixed research methods both regulating the qualitative data and turning in some cases to quantitative ones through protocol studies. This approach is explorative due to its nature of giving priority to qualitative research and then informing the quantitative one (Borrego, Douglas, & Amelink, 2009).

Table 2 The flow diagram of research phases



In the second phase in order to decide and design the method three significant methods that could be dealt with under this research process were initially examined. The first one is the protocol study method, which examines design activity by studying designers' behaviors. However this method does not seem to be very appropriate for this research since the research focuses on the implementation of a proposed model to design process and tries to understand how these models function in the design process rather than to understand the designer's behavior or creative level. The second method is thinking aloud method in order to analyze the designer's moves during the design process but this method also seemed not to be relevant regarding the scope of the thesis which tries to figure out how the proposed model can be integrated and work for design education. Since in this study the important thing is to identify the role of moving image in the design process, the third method, the case study research method, seems more appropriate in this study regarding the nature of the research questions concentrating on the relationships and starting the inquiry by asking how and why questions.

Table 3 The Mapping Scheme of the Literature Survey (for detailed information on this table see Table 9 at pg. 45)



As it is generally known, in a qualitative research method case study has been defined as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 1989)." Case studies, then, explore subjects and issues where relationships may be ambiguous or uncertain. But, in contrast to methods such as descriptive surveys, case studies are also trying to attribute causal relationships and are not just describing a situation. The approach is particularly useful when the researcher is trying to uncover a relationship between a phenomenon and the context in which it is occurring (Gray D. E., 2004). Because of the properties given according to Yin's exploration a qualitative case study method has been employed due to the futures summarized below:

- Handles the technically distinctive situation in which there will be various interests other than solely data points, and as one result
- Rely on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
- Benefits from the earlier development of theoretical propositions to guide data collection and analysis (Yin, 1989).

In the coming chapters the details of how these data are employed in preparing the case study for this thesis are explained.

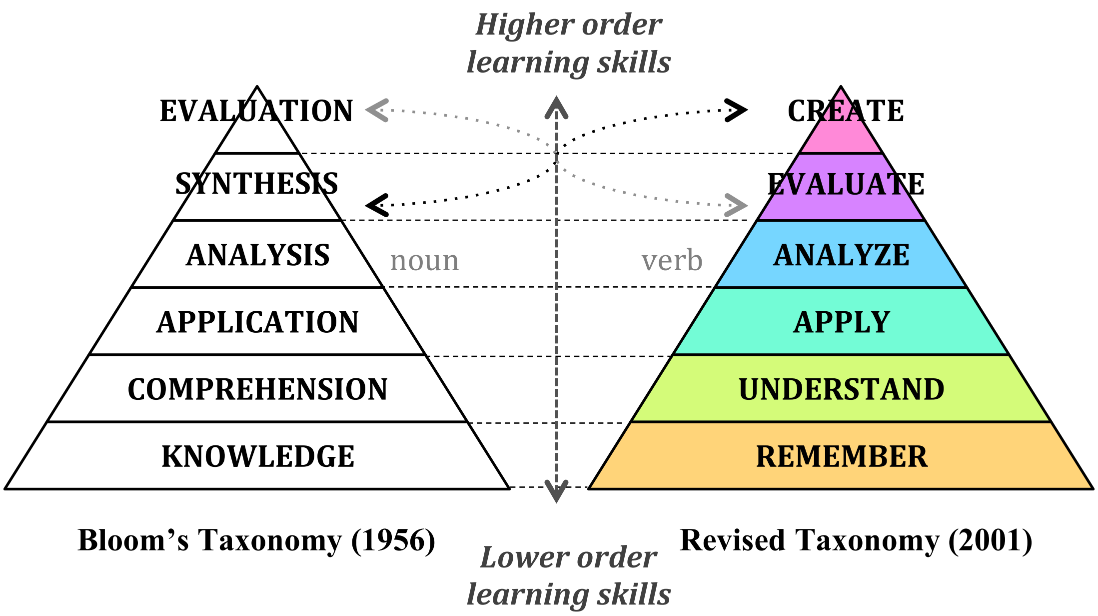
The inquiry process can be descriptive or explorative or both in the case study method. The context of the case can be that "a complex something/someone/situation needs to be studied qualitatively, intensively, in-depth and comprehensively. Similarly, in Art and Design research where the case may be a practitioner, an environment, for example a studio/workshop, a project, a commission, a consultancy, a learning setting, and so on" (Gray & Malins, 2004). The establishment of the case study method relies on variable tools like audio/video recording, visuals, interviews, transcripts, field notes, diary entries, letters, objects of material culture, physical artifacts, direct observations and physical observations (Yin, 1989; Gray & Malins, 2004).

Among these investigations the case study is organized according to the research questions and taking into account the related literature in this study's research field. Firstly, the type of case has been questioned during the design of the case study. There were initially three ideas on the case environments in order to implement moving image in the design process and observe and attain data whether from a design studio, an assignment or a workshop. The author decided to design a workshop as the case, because the design studio and assignments would bring limitations to the types of the students as being solely first year. Therefore rather than examining the sole first year students, author wanted to gather also information from the second year architecture and interior architecture design students who still fit the scope of early design education. As a result, the case study as a workshop named *Cubehocholic* consisted of three main phases that are (1) lecture, (2) tutorials and (3) work sessions.

The main idea of designing and executing the workshop is to observe and evaluate the design process. In order to generalize the case study, the design of the workshop has an important role in this study. Therefore in designing the case study Bloom's taxonomy played a crucial role, which was proposed so as to deal with circular and evaluation problems both in education and research fields among the improvement of communication between educators in 1956 (Bloom, 1956). Although Bloom's taxonomy originally was proposed for assessment, the revised version is to be used as a guide in this study.

Benjamin S. Bloom who is an educational psychologist, made a classification for thinking behaviors in the processes of learning. He classified three domains as cognitive, affective and psychomotor. The original cognitive domain taxonomy was classified in six major levels, which are (1) knowledge, (2) comprehension, (3) application, (4) analysis, (5) synthesis and (6) evaluation. Anderson & Krathwol revised this classification in 2001 and they redefined the cognitive domain linked to both cognitive and knowledge dimension (Anderson & Krathwohl, 2001). They highlighted learning as an activity in which the student mobilizes through her thinking skills, and proposed using verbs instead of nouns in Bloom's Taxonomy. The revised cognitive processes dimension consists again six major thinking skills classified from lower to higher as follow: (1) remember, (2) understand, (3) apply, (4) analyze, (5) evaluate and (6) create. Table 4

Table 4 Bloom's Taxonomy and Anderson & Krathwol's revised version comparison



Anderson & Krathwol's revised version of Bloom's taxonomy constructs a framework for assessing the learning objectives and outcomes. The cognitive process is linked to four type of knowledge dimension from concrete to abstract, which are (1) factual, (2) conceptual, (3) procedural and (4) metacognitive. The determination of learning objectives rely on a matrix identifying the relationship between cognitive dimension as an intention for an action and knowledge dimension as the needed/ expected level of knowledge to carry on the learning activity. Table 5 The revised taxonomy is used while designing the educational objectives and timetable of the workshop and assessing the observations of the design process in this study.

Table 5 The cognitive process and knowledge dimension of the revised taxonomy according to the intended actions

KNOWLEDGE \ COGNITIVE	REMEMBER	UNDERSTAND	APPLY	ANALYZE	EVALUATE	CREATE
FACTUAL	DEFINE	SUMMARIZE	RESPOND	SELECT	CHECK	GENERATE
CONCEPTUAL	RECOGNIZE	CLASSIFY	PROVIDE	DIFFERENTIATE	DETERMINE	ASSEMBLE
PROCEDURAL	RECALL	CLARIFY	CARRY OUT	INTEGRATE	JUDGE	PLAN
METACOGNITITVE	IDENTIFY	PREDICT	USE	DECONSTRUCT	REFLECT	RECONSTRUCT

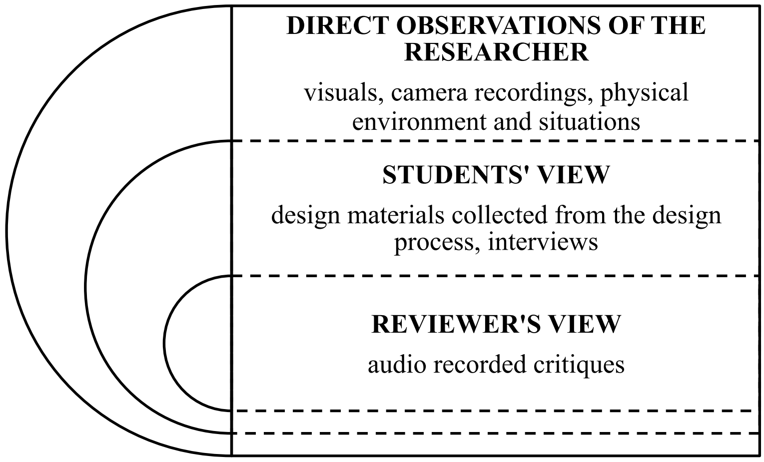
In the third phase the author executed the workshop in order to fullfill the objectives given in Table 4 through a designed timetable. While executing it, tools such as camera recording, visuals and interviews were used in order to evaluate the gathered materials from the direct observations at the next phase. After completing the workshop the author started to question the observations and wanted to see how the proposed model would work for more experienced design students. Therefore she designed a second workshop in order to compare and understand the relevance of design experience in this process, this time third and fourth year architecture students were included.

During the fourth phase the gathered information from the case study was analyzed through the materials collected during the execution of the workshops. The analysis part acted upon the data gathered from the design process of students, the direct observations of the researcher and the reviewer's view about the workshop. Table 6

As a result of this analysis the author produced design model diagrams that constructs upon spiral design models in order to understand the transitions and transformations between various generated models during the design process. In addition the learning outcomes of the workshop is discussed in regard to the Bloom's taxonomy and mapped on the developed design models according to the learning skills of the student.

The fifth phase has been employed to distill the gathered data and results of analysis for this thesis. In addition this phase will propose suggestions on further studies that can be conducted upon this intersectional research field.

Table 6 The gathered information for the analysis part



CHAPTER 2

LITERATURE REVIEW

This literature survey aims to clarify how moving image can act as a mediator for design and design process in design education in the age of computation. In this context this literature survey has three major sections dedicated to show studies on moving image and how these studies are employed in (1) architectural design, (2) modeling and (3) (architecture) design education in order to further discuss the potentials of moving image in design education in this thesis. In addition, the evolving role of representation modes is questioned in the realm of the new paradigm with the advent of computational design technologies in design and design education. The studies included in this study focused on the integration of moving image (in broad meaning) in the design process especially in a design studio environment as an analysis tool, as a representation tool or generation tool in general. The source documents are books, thesis and research papers on design studio assignments and workshops conducted in design studio environments.

2.1. Moving Image in Relation to Architecture

The idea of moving image that dates back to the motion studies of Ettienne Jules Marey and Edward Muybridge orienting the invention of cinematography, has been evolved by two main revolutions; first with the industrial revolution and second with the technological one, since then it has many indications in different areas beside cinema, visual arts etc. as in the case of architecture. As a result of these indications in design and architecture the crucial triology of space, time and motion phenomenon building up the structure of moving image definition has been being re-examined and redefined within the paradigmatic shifts led through these revolutions for almost over a century. Although the act of questioning these terms has started especially in art, firstly through cubist paintings, the advents in science such as Marey's motion studies led the debates of the 19th century to a common ground arena, especially for architecture (Lynn, 1999; Harris, 2000). Since then the representation modes in science and arts have started to be questioned depending on space, time and motion notions and the search for other dimensions that would be experienced through these notions began to effect architecture and design more than ever.

The effects of the industrial revolution growing in society opened up a new era for moving image such as cinema and its relation with architecture and design especially starting from the 1920s. Architecture and design started to become a tool for moving image in order to criticize the mechanical age and its influences on society and additionally every day life. While this relation seemed to be unidirectional at that era, it started to become mostly bidirectional with the technological advances where architecture started to consequently use moving image as a tool, either as a representation tool to make critiques of the modern era or as a presentation tool for design at the end of a project. The emergence of this mutual relationship brings out the pre-discussions on space, time and motion trio, and this time in the scope of architecture and design where the initial theoretical studies focused on the representation of space.

Sigfried Giedion defines space as a conception from relative moving point of reference rather than absolute and static entity of Newtonian physics (Giedion, 1967). According to this definition in order to understand spatial context and formal context the representation of space cannot be free from notions of motion and time. This argument has been grasped by many architects and influenced their design process in which space, time and motion association started to work as a novel way of seeing and perceiving both the built environment and their design process. In addition the interest in the moving image studies concentrating on both the representation and production of multi spatial aspects of time and timeless situations achieved through cinematographic techniques turn to be more explicit in the field of architecture.

The moving image tools and techniques such as cameras, framing, editing/montage and cutting as a novel tool in order to experience space and its constructions started to influence the representation modes of design and by such the designing act especially starting from the 1970s. The design of space occasionally turns into design of the event where the notion of movement became the initial driver of design representations like plans, sections, elevations and diagrams in which the narrative notion also began to be added to the aforementioned integration of moving image characteristics in design and architecture. Bernard Tschumi as one of the pioneers that led this integration both theoretically and practically outlined the architectural space as a “stage set,” which “indicates the movements of the different protagonists” in his profoundly inspiring works “Screenplays” and “Manhattan Transcripts.” This attitude offered a novel relationship between spaces, events and functions where the meaning of architectural representation started to have a complexity through an analogical relationship of space and time notions in moving image. Tschumi directed this analogical relationship as an architectural program generator by using the film image sequences, which inform the architectural program through fictional events composed by the horizontal and vertical montage techniques of Sergei Eisenstein.

While the integration of moving image techniques in architecture stands out as a novel representation approach for architectural programs and context, some studies started to express interest in the formal relationship of these techniques with the advances in technology that drive a digital revolution both in architectural theory and praxis beginning in the early 90s. The attitude towards adapting the essence of moving image as a design and representation strategy in architecture of the 80s started to transform into adapting solely the computer software tools as a form finding tool in the early 90s. This situation allowed new arguments towards a paradigm shift to emerge in which the moving image based terminology started to evolve and settle within the context of architecture and design. A broad range of digital tools related to film studies; including key frame animation, and kinematics, morphing, force fields and particle systems started to reshape the representational nature of form and form generation in architecture and design (Lynn, 1999; Kolarevic, 2005; Oxman, 2006).

Many of these modes depend on time-oriented parameters and are related directly to motion concept in design process. Sigfried Giedion's statement on the representation of space that cannot be free from motion and time notions in order to understand spatial context and formal context in the 70s (Giedion, 1967), is still relevant and more evident with the integration of these tools in the design process. While time has been a popular theme that has been questioned in art and science from the beginning of the 20th century, it started to be at the core of the discussions in architecture, design for form generation in architecture in the 21th century.

While time has become the primary famous parameter of the 90s leading the animation as a tool for form finding, duration and continuity notions started to gain relevance in architecture as a concept driver. In addition the static entity of form started to be questioned in terms of physics and mathematics, which introduce the effect of forces to form, and obtains a variation of it with parameterization. Greg Lynn's argument of "Animation implies evolution of a form and its shaping forces" endorsed a new perspective for form finding in architecture in 1999 (Lynn, 1999). The consideration of form "as a still frame produced by freezing the moving geometry" and "as an occurrence or event" has been turned into "a deformation and parametric variation" of a geometric motion which is generated through the act of field of forces over time. This argument's bases go back to Marey's motion studies in which the captured movement of the subject has fluidity in terms of its visual elements. Lynn interpreted Marey's studies as "an intimate connection between form and flow" where the captured images throughout the motion generate a cinematic section of form of motion (Lynn, 1999; Picon, 2010). Cinematic sectioning has emerged as a way of analyzing a "large land-mass by making many cuts through it" (Carpo, 2013; Jenks, 1997). This technique allowed architects to explore the continuity and disjunction of the form through a movement sequence of various situations, topography and circulation.

While the use of animation as a design methodology for form finding became more relevant, the discussions started to focus more and more on the effects of these integrations in the design process in the early 2000s. Lynn's attitude towards the static entity of form becoming into dynamic through the visitor's motion, internalized into the question of using time as a design parameter and its divergent new meanings in architecture (Lynn, 1999; More, 2001; Rahim, 2001). The studies started to examine the architectural use of time-based tools in the scope of parametric design and associative geometry modeling in which the alternative reading of time in architectural representation, form, and technology is presented in contrast to "cinematic modulation" (More, 2001). Gregory More has pointed out the divergence of parametric design from the cinematic treatment of time, and he claimed that architecture has to be reconsidered in terms of this divergence, which is the formal trigger of paradigmatic shift in both architecture and design (More, 2001).

In addition to the effects on architecture and design, the multiplicity of situations of design and their impacts on the perception of designer started to be effective by the use of time also as a mean of exploring both events and the design process which maximizes the potential design outcomes. Hence the spatialization of time started to differentiate into the temporal exploration of design and design process as in which the designer experience the architectural design as "mixtures of different programs creating new events, differentiated spaces and composite materials to organize the experiences" (Rahim, 2001; 2005). Meanwhile the arguments and discussions started to include the effects of this integration on design creativity in which designer can see and perceive multiple variations over time and compare them with each other (Rahim, 2005).

The dynamic time control with the integration of this computer software tools revealed the ideas of responsiveness, kinematics and movement in design and architecture that require changes in the model, which literally becomes moving in its essence. Therefore the understanding of moving image started to evolve additionally where the moving image is not merely an image anymore, rather it started to become a computational model.

Besides the effects of animation on form via computer software, the effects of having moving image's ultimate tool "the camera" in this virtual environment has changed the status of architectural representation from static to dynamic in terms of its projections since late the 90s. Adding the camera as a component to the experiential canvas of the computer software where the designer can observe the orthographic and three dimensional projections of design at the same time, reshaped the designers' perception in terms of form, program, event, material and light that can be experienced dynamically and recursively over and over. Meanwhile many studies considered this novel role of moving image as a tool for informing both the architecture and design process through its experiential and explorational nature (Penz F. , 2003; Davids, 1999; Nagakura & Chatzitsakyris, 2006; Pallasmaa, 2006; Temkin, 2003; Thomas & Penz, 2003). Consequently some of the studies began to focus on the potentials of moving image as a design representation rather than the effects of it in architecture with the advances in digital design technologies and information technologies.

2.2. The New Role of Moving Image in Design and Architecture

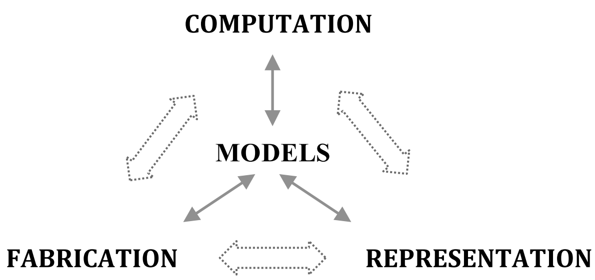
Many researchers have emphasized the significance of design representation during the design process by both analytical and empirical studies. These studies have been focused on different representation modes; conventional methods (sketching, drawing, and modeling) and computer aided design tools (digital models, diagrams and animations) especially after the 1990s. However the main focus of these researches is mostly on the static representation modes of design, whereas architecture as product especially depends on movement. Therefore among all representation modes -perspectives, schemas, plans, sections- moving image concept could not get enough attention until the digital revolution for design research area as a design representation. Conversely, as aforementioned, moving image has had its constructive and creative reflections in architecture since 1920s as a representation mode and as a critiquing tool for architecture and everyday life. Diana Agrest, François Penz, Juhanna Pallasma, Thomas Maureen, Donald Albrecht, Nezar AlSayyad, Mark Lamster and Mitchell Schwarzer are among the architects and researchers who have enlightened the relationship between architecture and moving image studies. These studies have covered the architectural theory and criticism of architectural styles within a qualitative approach; these are excluded from the scope of this study.

However the role of moving image has been redefined in a much broader sense with the advent of computational technologies and thus the moving image definition has been transformed from a simple representation, to a more advanced design model. There is a common commentary, critique on static representational modes as lacking understanding of the design process and its end product in terms of experience based relationships between space, time and motion notion. In addition, the evolving role of digital tools from being solely design representation generators to turning into a design thinking medium -where the design problems started to rely on its design medium more than ever with the developments in computational design technologies since the 1980s- opens a door toward the discussions on paradigmatic shifts in which the definition of representation modes especially the model term has been shifted and started to be reconsidered and reinterpreted in both design and architecture. These paradigmatic shifts are especially constructed upon the transformation of the static representation models to dynamic design models that generate a variety of design solutions in design and architecture.

The simple digital representation models began to turn into computational design models in which the whole design process started to be experienced through parameterization, and with the use of time and motion notions rather than the still situations. Computational models started to have a huge impact on both design and design process where the arguments started to focus on the shift from static representation models to dynamic design processes. Consequently moving image also started to be reconsidered implicitly and explicitly through the evolving definition of the model in design studies within different perspectives. Boran Kolarevic summarizes this shift by saying that “the plan no longer generates the design and sections attain a purely analytical role ” (Kolarevic, 2005). He states that the shift from conventional to dynamic design processes develops new territories for “conceptual, formal and tectonic exploration” in which the concepts of “variability, singularity and multiplicity” started to be emphasized within this situation.

Therefore the new role of representation and model depending on these concepts demands new approaches towards the design process, where the main aim turns out to be the situation instead of the solution itself (Ambrose, Lostritto, & Wilson, 2008). That is the adoption of the new representation modes and new models into design process where in this case, rather than being just a form generation, which act as an informing tool for design thinking during the design process. In other words beyond form generation these new representational modes and models articulate form and reintroduce new concepts and new morphological contents. The changing role and definition of the model with the aforementioned developments in computational design technologies can be remarked on as a cycle where the term deviates through its sub-contexts and meanings. What is meant here is that the understanding of the model does not have a singularity in this study rather it is seen as a continuous cycle where the designer jumps from one model to another in order to communicate with the design problem. The shift from the contradictory understanding of digital to computational and their mutual relation through advanced technologies, defines this era's zeitgeist under a loaded scope of multiple design styles such as parametric design, computational design, interactive design, performative design, design fabrication etc. The increased complexity of the nature of design problems needs multiple model generations in order to solve the problem or predict a situation within the design process. In addition the jumps between models in this cycle are bidirectional. This means that a representational model can become computational and at the same time then it can be again representational and it can become a fabrication model at a result of this cycle. Table 7

Table 7 The deviation between model types/definitions



Therefore it should be mentioned that the model definition and the investigation of the terms in related literature has been made due to this context where some of the model definitions have been excluded such as emergence, fabrication, optimization models. Rather the shifting meaning of model from representation to computation has been investigated due to the summarized shifts in design paradigms regarding the potentials of moving image models and the futures of computational models.
Architecture as a design discipline relies onto its representational models. As Gabriela Goldschmidt claims to design is to represent, and in no case is there design without representation (Goldschmidt, 2004). She explains the main aim of representation as the dialogue between the design team and an individual designer's dialogue with herself during the design process. This dialogue constructs representations at various phases of design. The representation mode depends on the task given to the designer. It can be a sketch, plan, section, diagram or animation. The main issue is to determine how the design problem, the task, is going to be introduced to the viewer or to the designer herself. This introduction and the representation of the design task are essential, especially in the early phases of the design process. How design is generated within a designer's view and how it is reviewed, reshapes design and creativity in this early design phase. In that manner, the external design representations (Oxman, 2006) like sketching, drawing and modeling have been the research focus within design cognition studies (Goldschmidt, 2004; Oxman, 2006; Oxman, 1995; Schön D. A., 1985; Schön & Wiggins, 1992; Visser, 2007). How designers think and reshape their design solutions have been the foremost questions in these researches.

Goldschmidt makes an epistemological framework of design representation in her *Design Representation* book through Leonardo da Vinci's "movable bridge design" in order to illuminate how sketches work at the conceptual phase of design. According to her nothing has changed much in design representation since Leonardo's era, the 15th century. She also remarks on Schön's "felt path" term, which describes the viewer's experiences of a building through the plans of building. "Felt path" is a virtual path that drives the viewer into a movement imagination inside or outside the building (Goldschmidt, 2004). According to Schön and Wiggins designing is an interaction of making and seeing, doing and discovering (Schön &

Wiggins, 1992). They explore kinds of seeing in designing and clarify what ‘seeing, moving, seeing’ actions contribute to design processes through drawings. Therefore the previously mentioned virtual path can be explained as an interactive interface constructed upon design drawings in which seeing, doing and seeing actions occur repeatedly. While highlighting the drawing action, they used the protocol analysis method in order to understand the designer’s behavior and acts due to the changing drawings. Schön and Wiggins’ research demonstrates that design is a process of making new representations and these representations generate new conditions, which drives designer to the solution of the problem. New representations generate new conditions and new insights towards the design process during this see-move-see cycle.

Regarding the views above, it can be stated that as the representation tool changes the design representation also changes and this change effects the construction of design in that manner. Therefore as the technology develops, new design tools and their adaptation to design process issue arise. Malcolm McCullough examines the adaption of digital tools into everyday life from the perspective of crafting in his book *Abstracting Craft: The practiced Digital Hand*. He remarks that this adaptation can take a long time where the invention and innovation cannot often occur contemporaneously (McCullough, 1996). In addition, during this adaptation there were ongoing debates on the digital evolution and its implications on design as being misunderstood in terms of concepts, tools and their applications on design in some cases (Lynn, 1999; McCullough, 1996; Mitchell, 1995; More, 2001; Oxman, 2006). These adaptations also mutually affected the designer’s behavior towards the design problems and situation. As a result of these affections, the new theoretical frameworks on design have been suggested and discussed intensely.

As one of the pioneers of these theoretical discussions, Rivka Oxman, tries to formulate digital design theory by proposing a series of structured models of digital design methodology in her research paper *Theory and Design in the first digital age* (Oxman, 2006). In order to structure these design models Oxman identifies and discusses the forms of change and transformation of these models by referring to Schön’s “reflection in action” model (Oxman, 2006). According to her, Schön’s conceptual terminology of design as the "interaction with a visual medium" for "informing further designing" has still relevance as a concept in models of digital design (Oxman, 2006). She emphasizes Mitchell's statement of "designing the process rather than product" in order to show how a computational model goes beyond the design representation. Oxman remarks that the role of interaction with design representations has broadly been recognized as a fundamental factor in design whereas interaction also constructs the distinctions between the digital models. She examines these interactions through a traditional design activity schema that constitutes upon four components of digital design: *representation, generation, performance* and *evaluation* (Oxman, 2006). She structures the digital design models according to this schema where these models are: (1) CAD models, (2) Formation models, (3) Generative models, (4) Performance models, (5) Integrated compound models. Table 8

Table 8 Digital design models scheme according to Oxman

CAD Models	Representation	
Formation Models	Topological Formation	Form finding
	Associative Formation	
	Motion based Formation	
Generative Models	Shape Grammars	Functional interactions Cultural interactions
	Evolutionary models	
Performance Models	Formation models	Interactive systems
	Generation models	Optimization
Compound Models		

However these distinct classifications of model terms under the umbrella of digital design start to be too strict when reconsidered in terms of the paradigmatic shifts with computational design technologies that do not include solely digital design in their essence. As these technologies were integrated into the design process more rapidly the models generated during the design process started to overlap more and more. Moreover, it can be said that the design process itself has been transformed into a model making action. In this overlapping system the key terms are abstraction and definition of models of thoughts that play crucial role in both design and computational design realm (Gengnagel, Kilian, Palz, & Scheurer, 2011). These abstractions for formal representations have moved from static to dynamic concepts that define a new role of the representation in design process by the emerging digital design theory since the 90s (Oxman 2006). In addition to the shift of model definitions the key concepts of design, form and function have evolved into multiple variations from one singular stable condition (Kolarevic 2005). The term "making of form" turned into the "finding of form" (Kolarevic 2005) and now it is turning into the "process of form" in which the concept of form has been transformed into formations (Oxman 2006). Hence the hitherto static representation models like plan, section and elevations become inadequate for some design problems, where the spatial and formal contexts cannot be free from the multi dimensionality of time and motion notions and in addition internal and external forces that direct the designer into experience and exploration of the design process itself.

Therefore the changing role of design representations and their effect on design and design education should also be elaborated in literature in order to grasp the role of moving image as a model in design and architecture regarding the paradigmatic shifts that occur through the developments of computational design technologies. In addition, the research included in this literature review generally looks from the side of the design process rather than the moving image studies in general.

In the forthcoming section the moving image in relation to design education will be examined in order to understand the role of moving image in design education within these paradigmatic shifts. While the term model has been redefined as both being a design representation and thinking medium, the selected studies will be linked to several circumstances of this situation in design education in the scope of moving image integration to design.

2.3. Moving Image in Relation to Design Education in Architecture

Moving image is also related with architectural design education by several academics and researchers in different ways in architecture design. These studies focused on the integration of moving image to design education and elaborated its role in the design process through research projects, design studios and workshops in general. One of the pioneer studies, how moving image can be integrated to architecture design education, was achieved by CUMIS (Cambridge University Moving Image Studio) in the late 90s (Penz, 2003; Stickells& Mosley, 2008). CUMIS has underpinned the Department of Architecture's Digital Studios for Practice-Based Research in design, visualization, communication and interactivity (Thomas & Penz, 2003) so that they are more directly related to design education. This group contributed to design education in different ways by exploring the potentials of moving image as a tool for narration, as a tool for spatial exploration and as a tool for time exploration (Penz F. , 1994; Penz F. , 2003; Thomas & Penz, 2003). Penz has stated another important contribution of moving image integration to design education as being an experiential design tool, which elicits the designer's thoughts in a novel way during the design process. He emphasizes that moving image as the experiential apparatus suits for the early stages of the design process where the main representational elements like drawings and models are few (Penz F. , 2003). In addition, he proposed 'Cinematic Aided Design' in order to communicate a future architectural design situation by using Computer Aided Design (CAD), blue screen and cinematic language. Figure 1

Another important contribution on how moving image can be integrated to design education has been provided by Takehiko Nagakura who is an architect and professor from Massachusetts Institute of Technology (MIT), working on the relation of representation and computation of architectural space. He founded and has led the Architecture, Representation and Computation group (ARC) since 1996. ARC includes a wide range of research projects on architecture in motion graphics, interactive spaces and computer graphics visualization of unbuilt architecture. KyoungEun Kwon, a master student of Nagakura's at MIT, has examined the influence of camera movements on architectural experience in architectural design process in his master thesis (Kwon, 2004). Kwon and Nagakura associated the type of spaces with camera movements in order to emphasize the spatial qualities like "private/public", "viewing/being viewed", "single/ clusters", "landmark and various activities." This study shows the relation between moving image and computation through the classification of spaces and associated camera views as an analysis and synthesis tool in architectural design.

Figure 1 "Rooms with a View" as an example for Penz's Cinematic Aided Design (Penz F. , 2001)

Another research, which was conducted at ARC group, is about spatial cinematic mediation in order to improve the quality of architectural presentations. Nagakura and Panagiotis Chatzitsakyris queried the potentials of moving image as a representation tool in their paper *Man with the Movie Camera* at 2006 (Nagakura & Chatzitsakyris, 2006). According to them there is a lack of animation software toward the construction of a cinematic spatial representation. For this reason they introduced a new tool for architects that helps architects to construct a quick cinematic representation of their designs (Nagakura & Chatzitsakyris, 2006). Figure

2 Different representations of same event have been explored with the use of their tool. Nagakura and Chatzitsakyris also criticized using hitherto static representation modes and they outlined the beneficial aspects of moving image during spatial exploration.

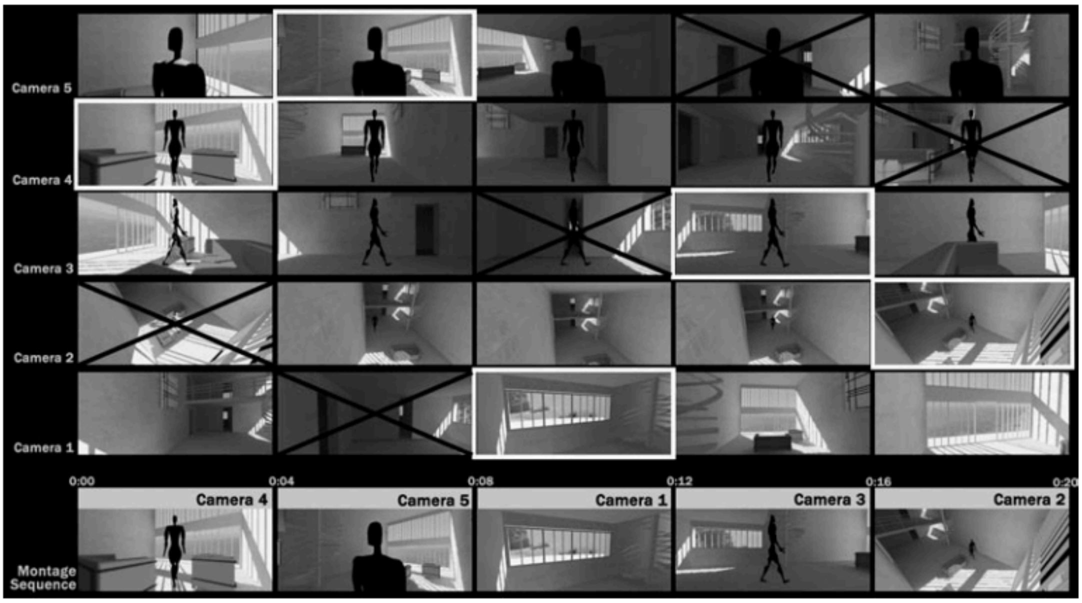


Figure 2 The quick representation of the movement in space enhancing a feedback for designer (Nagakura&Chatzitsakyris, 2006).

Another study that approaches to moving image in animations as a design creativity tool is Jeffrey Krause' *Reflections: The Creative Process of Generative Design in Architecture*. Krause investigates the mapping of instructor-based feedback into an iterative generative design process in his paper. He uses studio environment in order to explore creativity, aesthetics and creative process. During this exploration animation works as an evaluation tool in order to enlighten the generative design process that is described by the author as a conversation, a sketching tool, and a working relationship similar to a professor and a student (Krause, 2003).

In addition to the moving image as a feedback and a design creativity tool during the design process, another studied aspect is on the informative and constructivist role of moving image in the architectural design process. There is a mutual relationship between architecture and moving image, linked to experience of space and motion notions in which neither of them exists without the other. Nik Nikilov emphasizes this reciprocal relationship through the design studio environment in his paper *Cinemarchitecture.* He examines the role of architecture in the construction of vision and the perception of built environment (Nikolov, 2008). Figure 3 As one of the major issues is to qualitatively understand the spatial relations in a virtual medium that is moving image. Nikolov's study has a special importance in considering moving image as a thinking medium rather than a simple representation. He is influenced by Brian Mcgrath's and Jean Gardner's *Cinemetrics*, a multi-dimensional method to measure spatial relationships, movement and time. Macgrath and Gardner propose a new model for drawing and imaging during the design process via digital tools. Moreover another importance of this study is their statement of how architecture drawings are transformed into a thinking medium where the pre-assumptions on time and movement terms should also be re-considered through constructivist aspects of moving image tools. In their words:

> Today's architectural drawing is a way of thinking, working and being in the world, not merely a servo-mechanistic process of simulating objects and illusionary scenes in service of what has become standard building production (Mcgrath & Gardner, 2007).

He adapts this argument and methodology in his design studio and then he examines the projects of students via case study methodology. His research is conducted from two perspectives, (1) architecture and vision (2) memory and perception. He emphasizes that the terms such as movement, space, speed, and duration are cinematic constructions of both the mind and the physical body and they extend "the scopic regime of architecture" throughout the periphery of design practice (Nikolov, 2008). Nikolov's study results demonstrate that rather than enabling the novelty in design, the students' drawing techniques were more successful as exercises in analysis and seeing (Nikolov, 2008). As it is accepted in computational design thinking, the way of drawing as design representation affects the way of seeing and the *Cinemetric* (Mcgrath & Gardner, 2007) methodology affects architecture two fold; first as a representation mode and second as perceptive apparatus that architects can benefit from while manipulating space and time in order to “embody the inert materials of buildings” (Nikolov, 2008). Figure 4

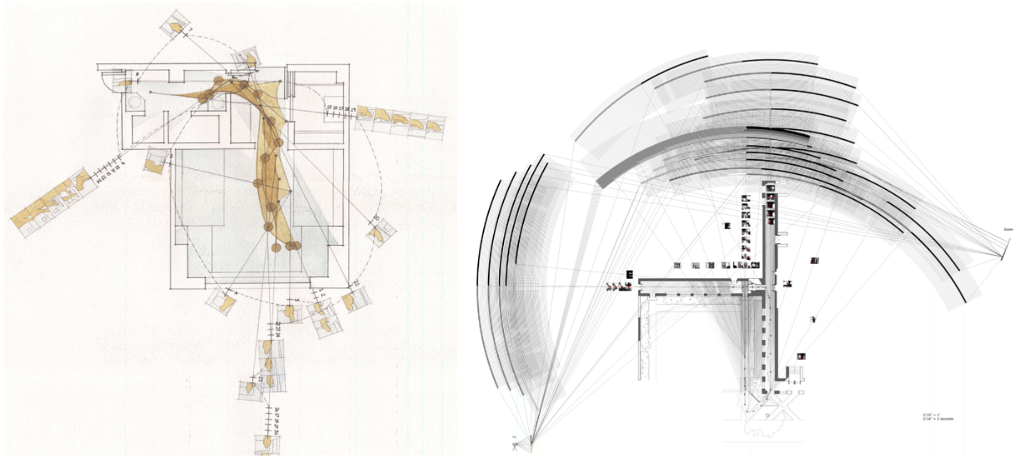


Figure 3 The camera sets as the cinematic apparatus directing the subject’s actions and boundaries (Nikolov, 2008).

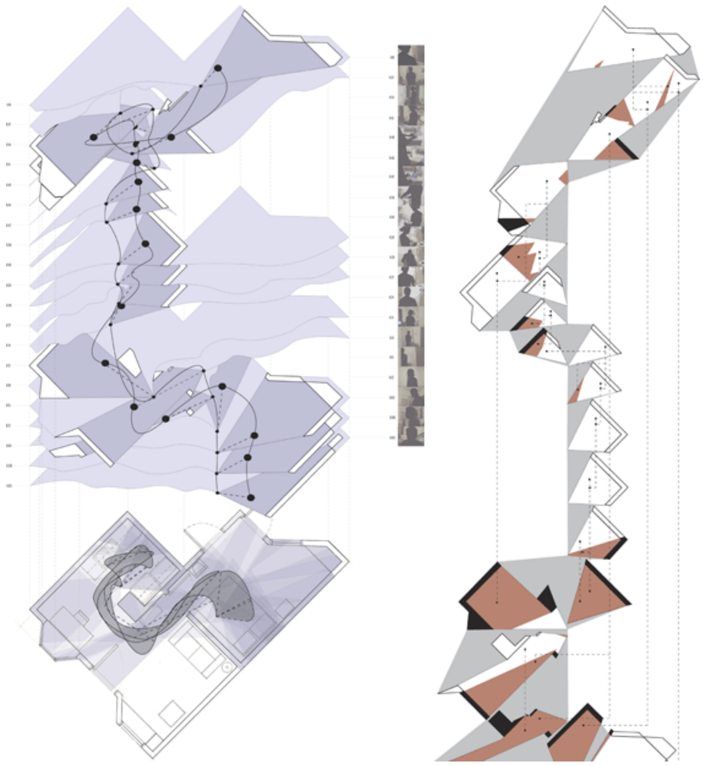


Figure 4 The continuum of memory and time as “sheets” and the measurement of time through recognition (Nikolov, 2008).

As like Nikolov, Carmella Jacoby Volk and Anat Messing Marcus have achieved another important example similar to Nikolov's study called *Haptic Diagrams* (Volk & Marcus, 2009). They introduced a model based on the formal translations of diagrams into architectural forms so that moving image becomes a generative tool for design process in their methodological approach. This model is conducted through diagrams called *Haptic Diagrams* in order to generate a set of three possible procedures (1) from cinematography to diagram, (2) matter-surface-figure, (3) haptic diagrams as program generators (Volk & Marcus, 2009). They examined these procedures through a workshop conducted with interior architecture students. Students use film footage as "a material in order to generate an abstract machine, a conceptual diagram" at the first stage of the workshop. Figure 5

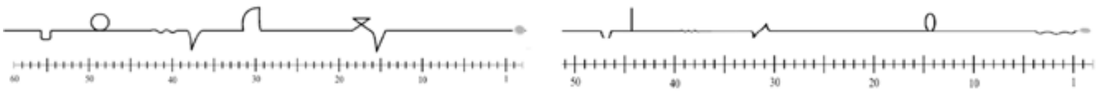


Figure 5 Conceptual Movement Diagram from film footage (Volk & Marcus, 2009)

They use moving image as a generator for "spatial temporal scenarios" by transforming and mapping the film footage's cinematic language, camera movement, points of view, composition, sound or narrative, into dynamic parametric data via digital media in the second stage of the workshop (Volk & Marcus, 2009). Figure 6

Figure 6 Mapping of the paths (Volk & Marcus, 2009)

According to Volk and Marcus, this dynamic parametric data as a model makes the additional flows, forces and contexts available during the data organization of the design program. They point out that this model generates a multiplicity of solutions rather than a singular architectural form and keep its relations to the 'event' and 'program' open (Volk & Marcus, 2009). Figure 7 In fact this model structures the design process as like an experiment. During this procedure moving image acts like a visual translational apparatus between the diagram and form in design process. On the other hand in this study how moving image acts as a design tool in early design education has not been completely clarified.

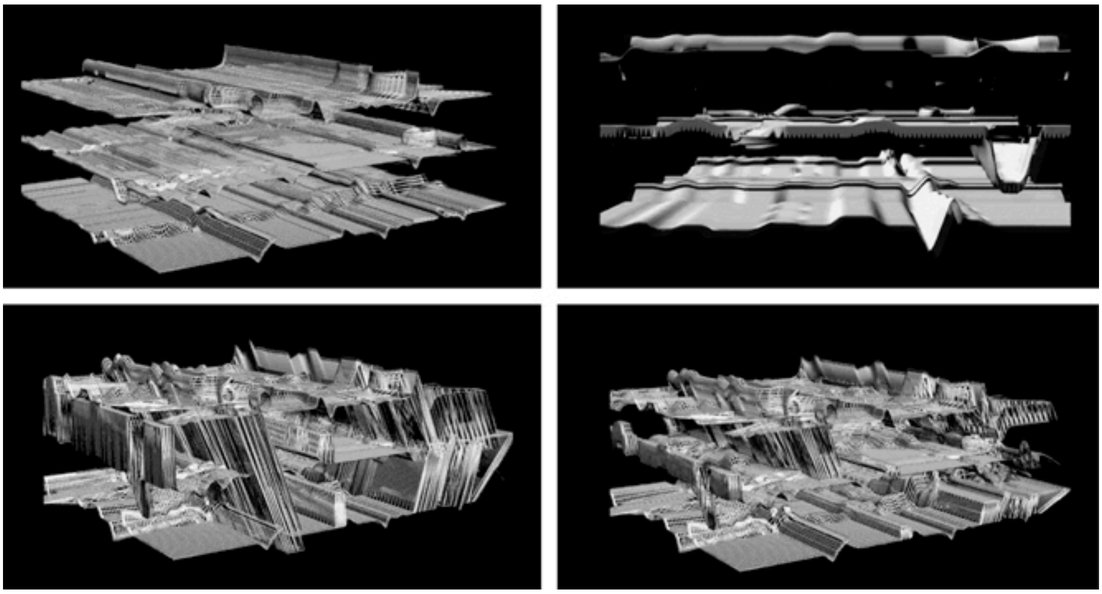


Figure 7 The multilayered view of the unfolded conditions of difference and sameness (Volk & Marcus, 2009)

As it is seen, both Marcus and Volks and Nikolov's approach to moving image is similar in terms of the integration of moving image into design process. In this respect these studies constitute an important potential feedback for the understanding of the term model in computational design and today's technology by highlighting the role of moving image as a way of thinking. While Nikolov's approach have a more explicit reasoning Marcus and Volk's study shows that the students' design process remains intuitive and relies on implicit reasoning.

Another research illustrating the reciprocal relation between architecture and moving image is *Utilization of Time-Based Techniques in Research and Teaching* by Paolo Sanguinetti. Sanguinetti explores the relationship between architecture and moving image as a teaching and research tool in architecture (Sanguinetti, 2006). During this exploration computer animations combined with moving image techniques has been used for form tectonic analysis and for the conceptualization of space through the study of film. Her method is conducted in the early stages of design through four steps, (1) cinematic structure, (2) film as site, (3) transcoding[5] transparency and (4) mapping the urban fabric and combining various time-based media (Sanguinetti, 2006). Figure 8**,** Figure 9 Sanguinetti's study shows that computer animation as a design representation works in the conceptual phase of design expanding the understanding of design in four dimensions and also in cultural meanings (Sanguinetti, 2006).

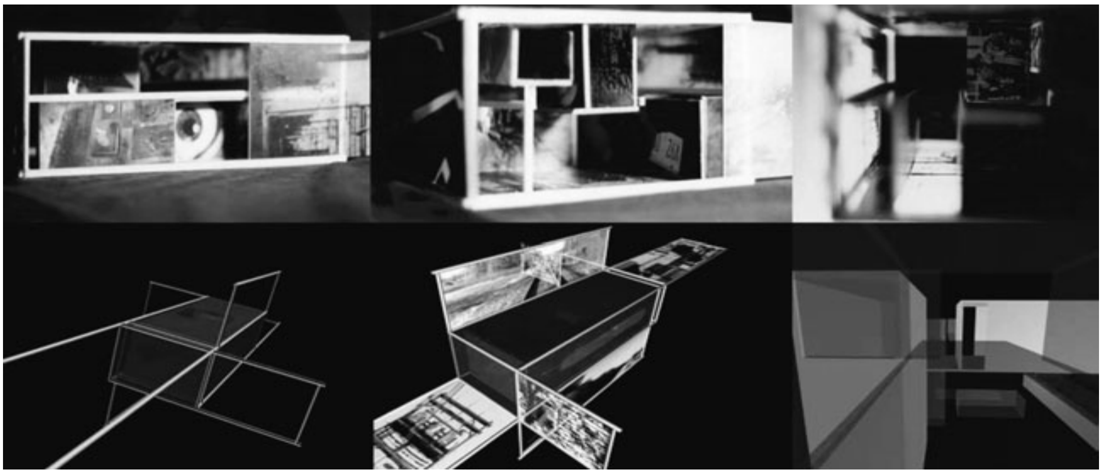


Figure 8 Physical model and still images from the cinematic structure of animation

[5] According to Sanguinetti "transcoding transparency" is a more open-ended approach to film as a medium. The main aim of this approach is to experience the transparency as a phenomenon manifested in film at many levels, ranging from physical to psychological, from the condition of looking through reflective glass. Students chose a film and a scene that conveys an experience of transparency. They analyze and map the patterns of light, the movement of the camera, and other cinematic techniques from their chosen scene onto their physical models (Sanguinetti, 2006). In addition Sanguinetti refers to Lev Manovich's definition of transcoding which is the interpretation of cultural layers into computer layers and vice versa. According to Monavich these two layer become insepareble within the digital era. For further reading see Lev Monavich, *The Language of New Media*, Cambridge: MIT Press, 2002.

Another important study focused on time, space and motion tiriology is Mathew Knox's research based on animation, *Rear Window Redux: Learning From the Architecture in Hitchcock's Film Using 3D Modeling and Animation*. Knox uses Alfred Hitchcock's film, "Rear Window", to analyze the films' unique architectural sensibility through 3D modeling and animation and then apply that knowledge in student's work (Knox, 2007). Knox's study has a common ground with Sanguinetti's approach in which the mutual relationship between architecture and moving image are explored. This relationship is symbiotic where architecture feeds from moving image. In his course students construct the main scene and space at the film and they analyze it in digital media. Then they evaluate the spatial concepts such as space, light and meaning through analysis of architecture and the moving image (Knox, 2007).

Figure 9 Still images of the Film as Site phase: New York documentary animation

As like Sanguinetti's design studio, Birger Sevaldson has examined time as a design parameter in an experimental design studio called 'Designing Time' at the Oslo School of Architecture. In this studio the students are engaged in time-based issues in order to develop and test strategies and techniques relevant to time based design. According to Sevaldson working with time helps students to develop the ability to investigate relations and systems and to understand these through time based analyses and abstraction, which is analogous to similar to exploring different instances of multidimensional parametric models. Figure 10 Sevaldson's study shows that the students start with observations of real life phenomena. He points out that the observation of these changes in time has lead to rediscovering the opportunities for interventions and in some cases innovation (Sevaldson, 2004).

Sevaldson's and Marcus and Volk's approach links design with a thinking process that is very similar to the cyclic learning model proposed by David Kolb. Kolb's cycle has a four-stage categorization: (1) concrete experience, (2) reflective observation, (3) abstract conceptualization and (4) active experimentation (Kolb, 2014). Sevaldson's study focuses on change with time in moving image, in that sense it could be considered different from the aforementioned studies. On the other hand since Sevaldson and Volk's approach links design by learning cycles, they are similar.

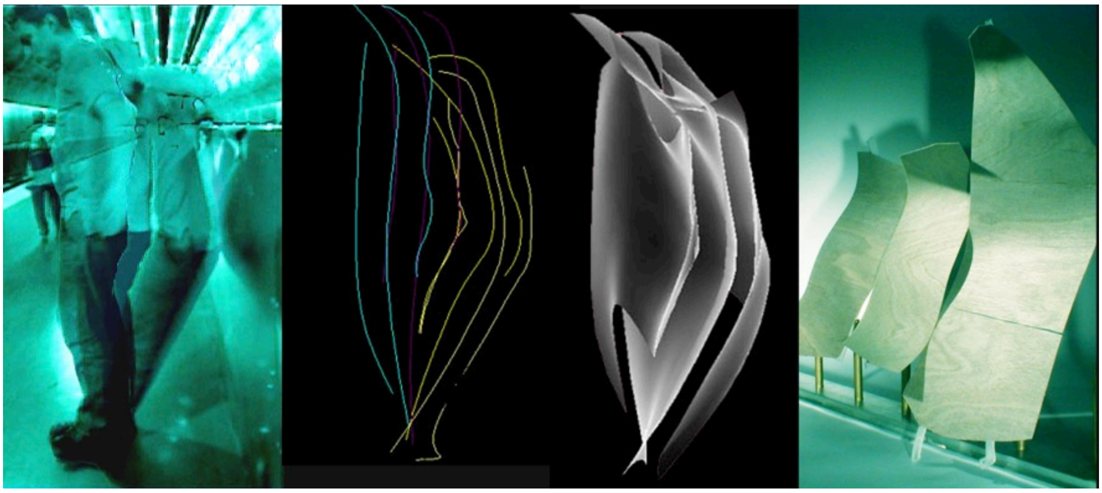


Figure 10 A smooth process (analysis, abstraction and materialization) moving from observation of the body-related use of a train station waiting area towards furniture for waiting. (Jens Pettersen and Lars Bjerke)

Michael A. Ambrose, Carl Lostritto and Luc Wilson presented a new approach towards the design studio at CAADRIA[6] 2008 by introducing the use of animation and motion graphics in the foundation of design education (Ambrose, Lostritto, & Wilson, 2008). Unlike the research above, according to Ambrose et al. animation becomes a design methodology especially in the first weeks of the architectural education. Similar to Sanguinetti, Ambrose et al. examines animation as a process whereas the movement is the key concept. Where Sanguinetti analyzes tectonics in architecture from a different perspective by using moving image, Ambrose et al. focuses on the design process rather than its end product. But they intersect in the

[6] Conference on Computer Aided Architectural Design Research in Asia

scope of using moving image as an analysis tool either through animation or film. In these studies they conceived animation and motion graphics as drivers for students' design process where the main aim is to find an "attitude about solution" rather than a solution to the design project (Ambrose, Lostritto, & Wilson, 2008), which is an essential subject matter in design education.

Ambrose et al.'s study's main aim is to see the direct relationship between the camera, movement of objects, and time. They observe that setting up two sets of distinct parameters, time and camera movement, allows students to design with respect to each and compare the result of the decisions made (Ambrose, Lostritto, & Wilson, 2008). In this respect their research demonstrates that the integration of moving image is very beneficial for achieving feedback during the design process. Regarding this context this study can be enlightening for the development of the design tasks in order to construct a clear description of the introductory relationships between space, time and movement terms in architectural design studios. In addition, the course syllabus can help students to understand the integration of time, camera and motion terms as parameters of the design tasks.

Another interesting design studio using moving image both as an analysis and generation tool and in addition as a representation model is Unit 15 at Bartlett School of Architecture, managed by Nic Clear for eleven years between 2000 and 2011. It has been a long running design studio exploring the role of moving image in design education in different learner profiles. Nic Clear wrote the first course description of the design studio, Unit 15, as below:

> Unit 15 will explore through the use of animated computer generated environments new forms of spatial organization in relation to ideas such as cognitive mapping, cartography, landscape design, film theory and film criticism and theories of everyday life. [7]

The initial approach which emerged from this description oriented the studio over a decade and is constructed upon the idea of integration of computer-generated

[7] The M.Arch. Unit 15 course explanations are taken from the official web site of Bartlett School of Architecture. The additional information on the course description between 2000 and 2011 can be found on this web site: http://www.bartlett.ucl.ac.uk/architecture/programmes/postgraduate/units-and-showcases/march-architecture/unit15/2000-2001, last accsessed on February, 02, 2015.

animation to design process both as a drawing apparatus and narrative generator. In Clear’s words:

> Our approach to animation is to challenge the conventions of traditional orthography and to counter act the growing formalism of generative models of virtual architecture seen in many American schools.

This attitude started to include motion graphics, video and interactive media generation through the developments in digital design technologies while the arguments on the terms like augmented, real and virtual in architecture have been going on. However Clear’s approach of seeing moving image as a way of thinking remained the same. He states that the ideas of duration and movement can never be expressed through conventional representation models. He uses film and animation and calls them time-based media- in order to express these ideas in architectural design process.

The novelty of Clear’s study is to develop a drawing process based on time. Later this study has been published as “Drawing Time” in the Architectural Design journal (AD) under the guest editorship of Neil Spiller. Clear discusses and proposes moving image integration to architecture and design process as a methodology for producing novel representative sets that unite the traditional, conventional and digital media representations under a united umbrella (Clear, 2005; 2013). He emphasizes the duality of time-based techniques as being not merely a drawing tool but at the same time becoming an imaging medium for the designer that can be adapted as a model in architectural production “for mapping out the formal, narrative, experiential and spatial possibilities of the project alongside the processes of production” (Clear, 2013).

Towards redefining moving image as a model

Throughout this literature survey it has been observed that the moving image relationship with architecture and design is based on the trilogy of space, time and motion. As it is seen while many researchers are generally concentrating on moving image as an analysis, representation and generation tool which has a grand impact on both perception of form and event generation (Ambrose, Lostritto, & Wilson, 2008;

As & Schodek, 2008; Clear, 2005; Eui-Jee Hah 1, Tuch, Agotai, Wiedmer, & Opwis, 2008; Knox, 2007; Nagakura & Chatzitsakyris, 2006; Pallasmaa, 2006; Penz F. , 2003), there are a few studies that see moving image as a way of thinking during the design process (Clear, 2005; 2013; Nikolov, 2008). While some of the studies see moving image as a communication mode for architectural and urban issues and try to reveal its practical side in the scope of the visual communication field (Penz F. , 2001; 1994; 2003; Pallasmaa, 2006), others concentrate on the use of moving image as an experience apparatus that reveals the various sides of the design problem during the design process (Sevaldson, 2004; Ambrose, Lostritto, & Wilson, 2008; Clear, 2005; Clear, 2013) and feeds the designer eventually in order to experience either the process or the un built environments (Nagakura & Chatzitsakyris, 2006; Kwon, 2004). Table 9

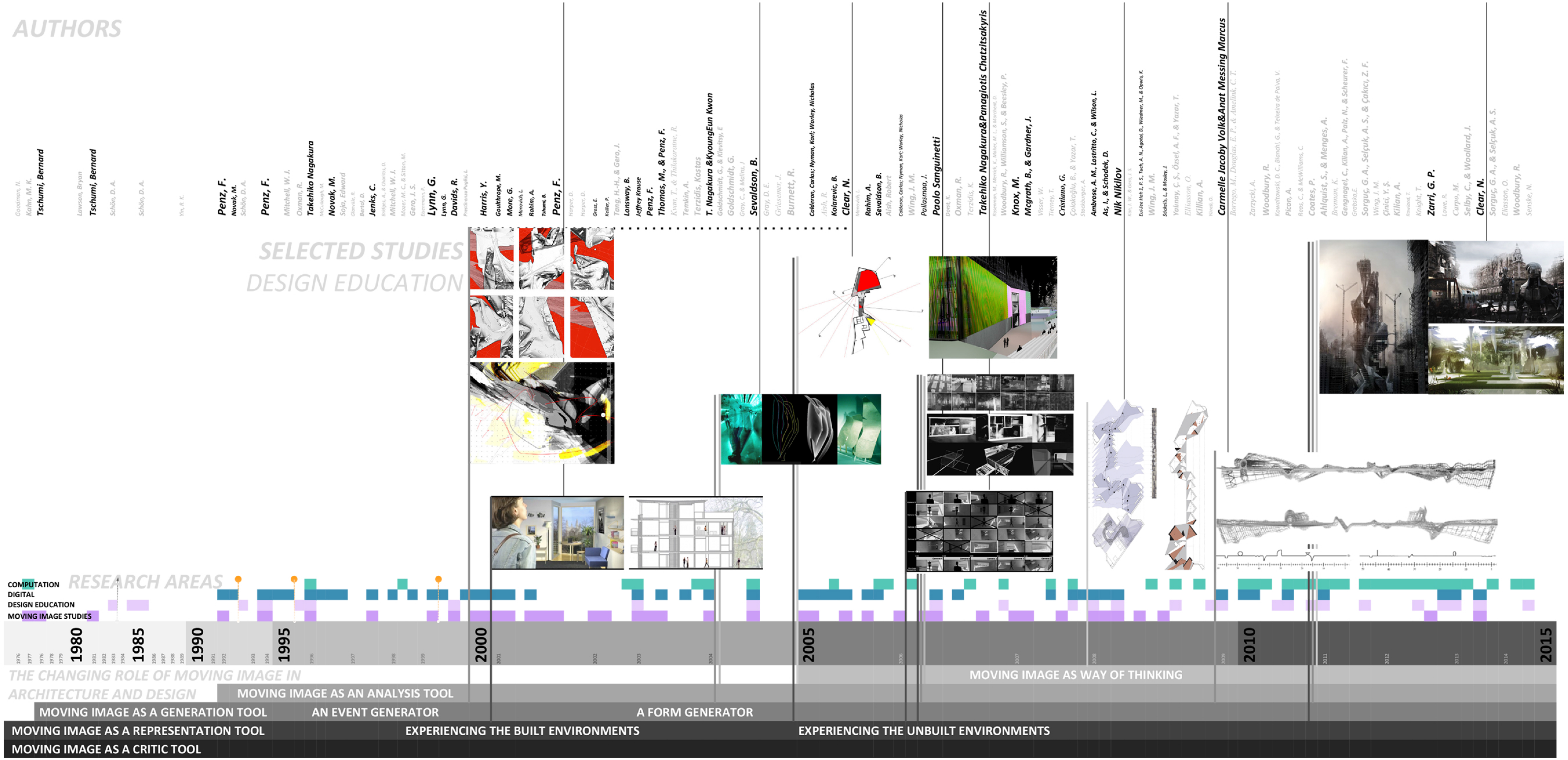
Afterwards these studies conducted dually, from moving image to architecture and from architecture/design to moving image in general. When some of the studies produced architectural project as an end product, they used moving image types such as animation or motion graphics as an analysis, representation or generation tool. When some of them use moving images as a way of thinking, some of them focuses on moving image's perceptive notions such as motion and time and uses its techniques such as montage, framing and camera for drawing, for form finding and event generation. It is observed that the integrated digital tools for film studies as key frame animation, morphing and time based tools have been used as form generation and design evaluation tool during the design process (Ambrose, Lostritto, & Wilson, 2008; As & Schodek, 2008; Calderon, Nyman, & Worley, 2005; Goulthrope, 2001; Kolarevic, 2005; Krause, 2003; Lynn, 1999; Rahim, 2005; Rahim, 2001; Sevaldson, 2004; Sevaldson, 2005; Volk & Marcus, 2009).

Although several studies have indicated the beneficial aspects of relating moving image with architecture and design, there are some studies that also pay attention to the deficiencies of this union especially when it is integrated into the design process. All moving image studies require techno skills either to use moving image production tool or digital modeling tools in recent era. This has an impact in design education field where the moving image studies in general have been introduced to students late in the curriculum because of their complicated abstract nature (Ambrose, Lostritto, & Wilson, 2008). However there are studies emphasizing the enabling force of moving image in early design education for exploratory experiences which introduces a level of abstract thinking and achieves a strong grasp of space, time and motion concepts (Ambrose, Lostritto, & Wilson, 2008). Table 10

As it is seen in these studies the use of moving image has always been a subject of exploration and many researchers have studied its reciprocal use in design and architecture. Yet how moving image and computational design technologies in a broad sense can be integrated is a subject to be explored.

Table 9 Literature review mapping timeline showing the changing definitions, paradigms in design studies and moving image in order to understand the changing role of moving image in architecture and design

Table 10 Literature review mapping timeline according to moving image in relation to design education in architecture



CHAPTER 3

MOVING IMAGE IN RELATION TO COMPUTATIONAL DESIGN MODEL

It is observed that moving image has been used in design process especially at the conceptualization, abstraction and analysis phases of design as a representation, generator and thinking medium throughout the reviewed literature prior to this section. Therefore regarding these studies it can be stated that the early phases of the design process, where the initial design ideas are constructed, moving image with its informative nature, turns into a medium and drives the designer into another perceptual realm. It can be assumed that this perceptual realm can also serve as a base for design creativity whereas the designer interprets with more visual and relational information through moving image compared to static representation modes such as plan, section, elevation etc. Furthermore the changing role of design representations and the role of moving image in design education was elaborated through the related literature regarding the paradigmatic shifts that occur through the developments of computational design technologies.

Consequently the developed literature during the last decade on design representation and design process shows a variety of approaches that investigate what model means within the computational realm. These studies tried to devise a taxonomy by examining the redefinition of the model via both design representation (Goldschmidt, 2004) and computational design research areas (Kolarevic, 2005; Oxman, 2006). While Oxman evaluated the model from a taxonomic point of view, Mitchell explored the model as a design-thinking medium. With the redefinition of model in computational design medium, the motto of "designing the process rather than the product" has become much more vivid. With this motto, the computational model started to get ahead of representational model. However, representation is still very important when it comes to expressing the complexity of the design problem.

Today it is seen that design representation tools and complex computational design models cannot be separated from each other. Designers should deal with a high level of complexities and all these technologies allow and motivate the tackling of these complexities that can be defined as a multidimensionality (Sorguç & Selçuk, 2013) including internal and external forces, and various parameters such as time, motion, etc. The model generation related to form finding turned into a process finding where moving image can have a potential role for the exploration of this process. In this respect moving image should be reconsidered through the understanding of the model term in relation to computational design process.

Outlining moving image as a model and binding it with computational design research area requires an explicit definition of the term "model" and in addition the interpretations of the term in this study. Starting from the very first year of design education students met with design representation modes such as the aforementioned plans, sections, elevations, animations, physical models etc. But most effectively, in the first year of architecture design education (or early design education) the main issue focuses solely on the "design of the model" in which the "model" term goes beyond just a representation and becomes the product, the design itself and the design medium in addition. Therefore in this chapter the manifold definitions of the term model are interrogated in order to structure the proposed relationship between the moving image model and computational design model.

3.1. Definition of The Model Term

Model has been defined in various ways throughout the history and it has its manifold metaphorical reflections not just on design but also on daily life in general. The definition of the term "model" scatters at science, art and architecture. Therefore in order to grasp the definition of the term, firstly looking from a broad picture and then defining the "model" term related within this study is more comprehensive.

Rather than pointing to a uniform definition of the model looking into the term as model in science, model in art and model in design can be more comprehensive in order to structure the role of the “model” term in this study.
Olafur Elliasson who is an artist, interested in perception, movement and embodied experiences, aims to transform thinking into doing in his seminal art works especially films, sculpture and installations (Eliasson, 2014). This transformation of thinking to doing emerges through a model that he defines as an image, a representation of reality without being real itself (Elliasson, 2008). According to him every model depicts various degrees of representation. Here the dilemma of the model, being itself and representing an alternative reality argument arises. And this has been at the core of the arguments and discussions especially in design studies since “there can be no design activity without representations” (Goldschmidt, 2004).

James Griesemer remarks that, the model as the representation itself, replaced neither the ancient meaning that is being the subject of imitation nor the transitional eighteenth-century one, which is acting like a tool for presentation of projects (Griesemer, 2004). He elucidates this ambiguity by quoting directly from Nelson Goodman’s *Language of Art* that indicates a clear image on the model. In his words:

> A model is something to be admired or emulated, a pattern, a case in point, a type, a prototype, a specimen, a mock-up, a mathematical description-almost anything from a naked blonde to a quadratic equation- and may bear to what it models almost any relation of symbolization (Goodman, 1976; Griesemer, 2004).

Goodman sees a model as a symbolization of an instance of the modeled and he defines it also being an exemplar. This symbolization act relies on initially observation of the object or the subject. In the opinion of Axel Killian, models are the abstraction of this observation, endeavoring to replicate an object or something in reality in an abstract way, which can serve as the basis for a precise and relevant simulation (Killian, 2008). This abstraction as a conceptual process acts as a reduction of significant information about the observed object or content. In addition an abstraction does not have to be linked to the actuality of the modeled phenomenon. Reducing the entities and focusing on the various crucial information gathered through the observation reflects an aspect towards the modeled. Therefore these various aspects constitute a set of assumptions about the simplified perceptions linked and limited to the use of the model and the modeler (Kvan & Thilakaratne, 2003). In Kvan et al.'s words:

> Models are abstract representations, not replications of realities. Therefore architectural models do not represent properties of materials, true colors, textures etc. just as weather models do not represent the precise properties of the atmosphere (Kvan & Thilakaratne, 2003).

Thus model is an entity in which the real and the interpretation of the real are the main subject of the debate. It is also a heuristic tool that works as like a conductor for design, designer and user. This heuristic tool can work in a dual way; it can be categorized as descriptive and process models (Mozer & Sitton, 1998). It can describe a unity of the observed objects or it can describe a data set obtained from experiments via mathematical equations. In other words this description can be qualitative or quantitative according to the purpose of the model. The second category is explained as "process models vary in their abstractness, from qualitative verbal descriptions to quantitative computer simulations that embody the cognitive process " (Mozer & Sitton, 1998). According to Mozer & Sitton process models work as an explanatory cognitive mechanism focusing especially on the performance of the model.

Another aspect of the model is being the process itself where the initial aim fits the etymological definition of the modeling act defined as "action of bringing into desired condition," from the 1650s (Harper, 2001). During this action the determination of the desired conditions yields the whole establishment of model. What happens when the modeler does not know what she desires?

This question suits for design activity in which the initial act is the problem definition. Representations including models direct design into different situations and solutions. Throughout this definition it is appropriate to say that design is constructed on its representations; plans, sections, schemes, physical models, thinking models, animations, diagrams and etc. Therefore model can be also defined as a communicative bridge between mind and user of the model. It can be physical, virtual, graphical, mathematical or verbal. Besides being a communicative bridge, or a representation tool, model becomes a medium where the new experiences, explorations and learning activities occur in many dimensions and phases of the design (Sorguç & Selçuk, 2013). In Sorguç & Selçuk's words:

> Model is process, a thinking procedure that becomes a new medium of experience, exploration and learning revealing different level of complexities and dimensions within the new technological developments (Sorguç & Selçuk, 2013).

This process determines the mediums where the design is generated. From this point of view modeling is also a thinking process starting with observation of the phenomenon and then transferred through the generation of the problem definition. In this cycle there is a passage through different type of models. Therefore the elaborated definition of the term model related to the object and subject of the model turns into an explanation and exploration of the relationship between models, where novel relationships emerge from "model to model". This transformation also yields the design process in which the designer shifts from one model to another in order to solve the design problem.

Consequently regarding these model definitions from different point of views, the excepted model definition in this study will be two fold (1) as object/subject (phenomena[8]) (2) as a thinking process. Therefore model term in this study is defined as a communicative bridge between the design and the designer constructed on an assumption set based on the abstraction of an observed phenomenon (Sorguç & Selçuk, 2013; Killian, 2008). Regarding this definition in the next section the model as a computational thinking procedure will be interrogated in order to clarify how this procedure works as an exploration and learning environment for designer.

[8] Phenomena is defined as "any object, fact, or occurrence perceived or observed" in philosophy. http://global.britannica.com/EBchecked/topic/455614/phenomenon

3.2. Modeling as Computational Thinking

> Computation is about the exploration of indeterminate, vague, unclear, and often ill-defined processes; because of its exploratory nature, computation aims at emulating or extending the human intellect. It is about rationalization, reasoning, logic, algorithm, deduction, induction, extrapolation, exploration, and estimation. In its manifold implications, it involves problem solving, mental structures, cognition, simulation and rule-based intelligence, to name a few (Terzidis, 2006).

Kostas Terzidis defines computation through this loaded keyword pool working as a set for the definition of computation. According to him computation is briefly a procedure in which logical or mathematical methods take place. Throughout these definitions computational thinking definition can be defined as a procedure in which the mathematical or logical methods take place in order to solve an ill-defined problem.

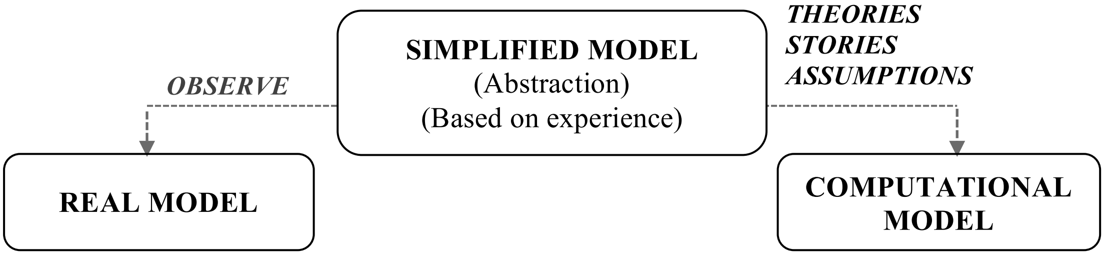
Jeannette Wing, Head of the Department of Computer Science at Carnegie Mellon University (CMU) and Corporate Vice President of Microsoft Research, defines computational thinking as an analytical approach towards solving problems, designing systems and perceiving the cognitive aspects of human behaviors (Wing J. , 2008). In her words:

> Computational Thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent (CunySnyderWing10) (Wing J. , 2011).

According to her computational thinking unites mathematical thinking when solving problems, engineering thinking when evaluating a complex system and scientific thinking when trying to understand the human mind, intelligence and computability in general (Wing J. , 2008). Wing's approach constructs a common ground on thinking, learning and education through computational thinking in general in that manner. Wing questions the level of the integration of computational thinking methods to the education system in her article "Computational thinking and thinking about computing." According to her computational thinking is for everyone and this started to be an educational challenge. This challenge is also reflected in the design education curriculums. As Nick Senske states rather than developing fluency about design tools and software, design education curriculums started to develop around the core idea of "computational thinking" that will foster novel mindsets and design skills. In addition these new mindsets can help to improve the adaptation and participation in the new technological developments (Senske, 2014). As aforementioned, computational thinking acts as a modeling medium in which the translations occur from one model to another and this medium works as an experience and exploration environment including various complexities and dimensions within the new technological developments (Sorguç & Selçuk, 2013). Moreover through these experiences and explorations, teaching and learning processes occur, within different cognition of the models depending on the designer of the model and the user of the model (Sorguç & Selçuk, 2013).

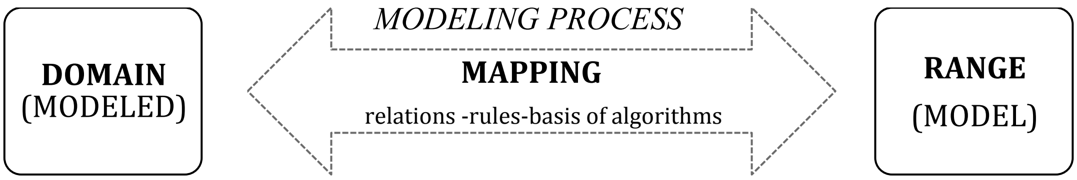
Sorguç & Selçuk define computational thinking as a learning cycle that has steps starting from the observation of phenomena depending on the real model and then evolving into the computational model through experiences, theories, stories, assumptions and abstractions (Sorguç & Selçuk, 2013). Table 11

Table 11 Partial computational thinking cycle generated through Arzu Gönenç Sorguç's critiques during this study



Sorguç, Selçuk & Çakıcı expresses that this computational thinking cycle has its relative point with Kolb's learning cycle that is constructed upon four main phases that are "experiencing, processing (reflective observations), generalizing (abstract conceptualizing), and applying (active experimenters)" (Sorguç, Selçuk, & Çakıcı, 2011). According to Sorguç et al. this cycle indicates the synthesis of diverse information and knowledge based upon the simulation models that are considered as the knowledge literacy. The observation of the phenomena directs the perception of the real model and the initial step of this cycle is the determination of the related vocabulary of the model through a reference system that can be constructed upon the dimension of the real model, precision of model, relations between the modeled (domain) and the model (range). According to this vocabulary the designer identifies the parameters and through the mapping of these parameters based on relations/rules or based on an algorithm she constructs the computational model. Table 12

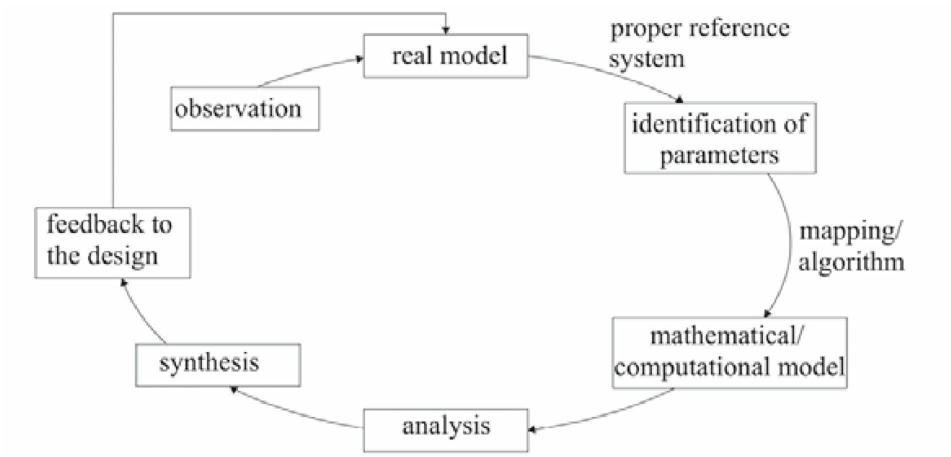
Table 12 The mapping of the relations and rules based on the identified parameters and acting as a basis of algorithm



The designer can explore various reinterpretations on the modeled (domain) and the model (range) and the relationship between each through analyzation and synthesis steps. An interaction occurs through this information flow from domain to range. According to Sean Ahlquist and Archim Menges these interactions and information flows called data sets constitute the definition of computation related to the design act. They emphasize that this “computational process start with elemental properties and generate rules to end with information” (Ahlquist & Menges, 2011). When the mapping of these generated rules become dynamic the system turns into a cycle in which the interaction between design and designer becomes evident. And this interaction directs the designer into a feedback phase which can be considered the new medium of exploration and experience where the learning occurs in two levels (1) learning through the modeling process (2) learning by testing the end product (the end model) (Sorguç & Selçuk, 2013). Table 13

This cycle works as a thought process for problem solving and learning by utilizing observation, abstraction, decomposition, algorithmic thinking, generation, evaluation, generalization and transition (Selby & Woollard, 2013; Wing J. , 2008; Sorguç & Selçuk, 2013; Sorguç, Selçuk, & Çakıcı, 2011; Wing J. , 2011). It can also be said that when the designing act is defined as computation, it is linked to a model of thought in which the abstraction becomes the protagonist of this whole process (Gengnagel, Kilian, Palz, & Scheurer, 2011).

Table 13 Computational thinking process cycle by Arzu Gönenç Sorguç and Selma Arslan Selçuk (Sorguç & Selçuk, 2013).



Regarding the related literature above Sorguç & Selçuk's "computational thinking process cycle" is adopted in order to interrogate the transitions and transformations of the models during the design process. Therefore henceforward the definitions of the included models in this cycle are clarified as: computational model, parametric model, algorithmic model and dynamic model.

3.3. Computational (Design) Model

> Computational thinking and the resulting computational models are not only the substitutes of "phenomena, things, forces and more," but also that new interface between different domains and the role of mathematics in this mind shift plays a crucial role (Sorguç & Selçuk, 2013).

The computational model definition in science and design differ from each other regarding the essence of their problem definition, which should be well defined in the scientific one, and in the other it ill defined in its nature. However it is accurate to define computational model as a process (model) from both perspectives. Figure 11

While the scientific model directs this process toward the quantitative end of the spectrum (Mozer & Sitton, 1998), the design models uses this process based upon relational thinking, in order to clarify the design called a black box and tries to turn it into a white one. However, while the designer generates design outcomes through this computational model based on actual relationships the main difference from the scientific model emerges as the intuition. Killian states that this major difference called intuition directs the designer's decisions and the computational model cannot substitute these human designer cognitive powers (Killian, 2008). On the other hand he points out that the transformation of a design problem from ill defined to a well defined one assist designer as a control mechanism on the design and "manipulation of the computational relationships can reduce complex problems in the real world to intuitively manageable design problems, which can be imaginatively explored and searched (Killian, 2008)." In fact this control mechanism relies on the abilities of designers to "formulate, represent, implement and interact with explicit, well-formulated representations of knowledge" (Oxman, 2006). And these abilities require algorithmic thinking and comprehension of the parameterization, multidimensionality and reference systems in order to transform a ill-defined design problem (black box) into a well-defined one (white box) (Sorguç & Selçuk, 2013).

The essence of the physical model that is solely conceptual and metaphorical starts to change through computational models that generate novel possibilities during the transformation of the design problem (Killian, 2008). According to Killian "these possibilities can be obtained neither by introspection nor abstraction through an analog environment" (Killian, 2008). However, the translation of the analog process into a computational one can obstruct the creative aspects of design exploration because there can be a loss of information during this transformation or the information transformed would not work in the novel medium. Sorguç et al. also outline this case as a translational gap, a transformational issue of the domain and the range, where the modeled and the model indicate deficient data sets. Therefore the initial act of the definition of the parameters in other words constructing the related vocabulary of design plays a very crucial role in computational modeling.

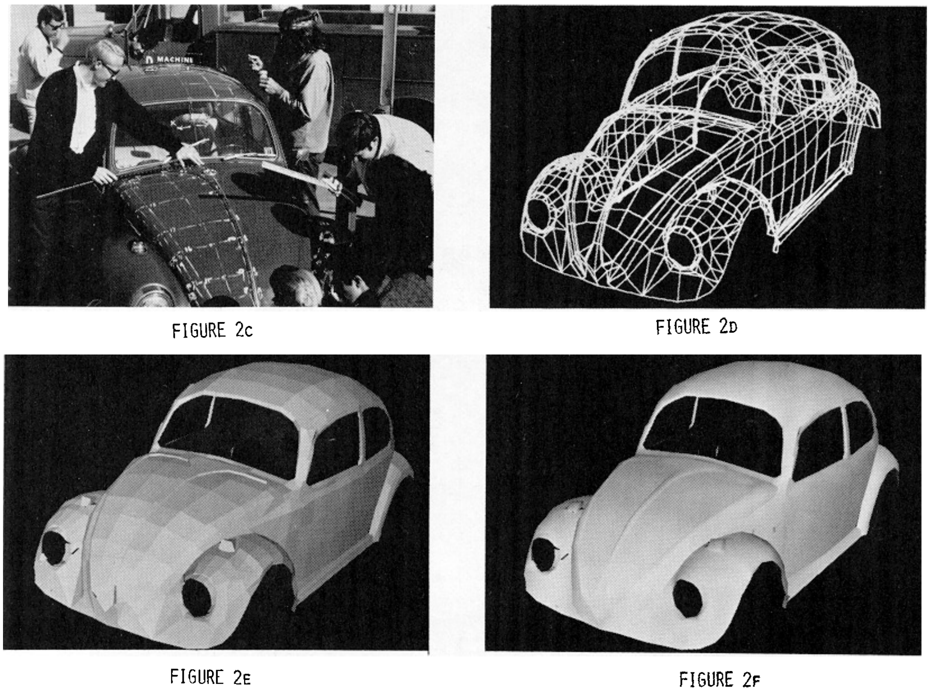


Figure 11 The real model, observation and computational model generation from the article *A Characterization of Ten Hidden-Surface Algorithms*, Robert A. Schumacker

3.4. Parametric Model

The etymological meaning of parameter comes from Modern Latin in the 1630s, and geometry in the 1650s and from Greek as “para- "beside, subsidiary" plus metron "measure". It was solely related to geometry until the 20s and in 1927 the meaning turned into "measurable factor, which helps to define a particular system." Thirty years later the meaning of the term transformed to (influenced by perimeter) "boundary, limit, and characteristic factor" in the 1950s (Harper, 2001). Parameter defined as “a numerical or other measurable factor forming one of a set that defines a system or sets the conditions of its operation” from a technical aspect and it is defined as “a quantity whose value is selected for the particular circumstances and in relation to which other variable quantities may be expressed” from a mathematical aspect in the Oxford Dictionary, 2015. Its definition has been evolving within paradigm shifts and with technological developments for almost four centuries.

In this study, the parameter term can be defined briefly as the related vocabulary of the design problem regarding the computational thinking process and computational model definitions. It constitutes the range (the model) in that manner. Hence parametric model is the model that operates through the parameters of a defined range in order to assemble a unity in the design problem. In addition parametric model defines the relationships and constraints of the design. Therefore from a geometrical aspect the dimension of an object can be a parameter but from visual aspect the texture or color of the object also can be a parameter related to the design problem. Furthermore it refers to broad meanings, where it means solely a dimension value, which effects the size of the geometry in solid 3D modeling software, and it can refer to more dynamic concepts where the change of one parameter can effect the whole design and its process just in one move in dynamic modeling software. Figure 12, Figure 13

The parametric model becomes dynamic when the relationships construct and control the whole design process. Therefore the definition of these relationships plays a crucial role for design and the designer. Robert Woodbury points out that these relationships direct design in a coordinated way and they change parts of the design. He states; "The act of relating requires explicit thinking about the kind of relation; is this point on the line or near to it?" (Woodbury, 2010). This dynamic parameter control of these relations transforms design process into an exploration process. Figure 14 Figure 15 Every design move and variable can be controlled, and every conjunction of the design process linked together in this computational thinking process through an algorithm. Figure 16 While the values of the parameters change, the defined relations remain the same within the "updated" parametric model (Yalınay, Özsel, & Yazar, 2008). This updated model implies families of designs or variations of a design in that manner (Woodbury, Williamson, & Beesley, 2006; Yalınay, Özsel, & Yazar, 2008). In Woodbury et al.'s words: "By varying the inputs to a model, different specific designs are produced." Consequently the process itself turns into a dynamic iterative process in which multiple iterations and feedback between these designs (models) occurs (Tierney, 2007).

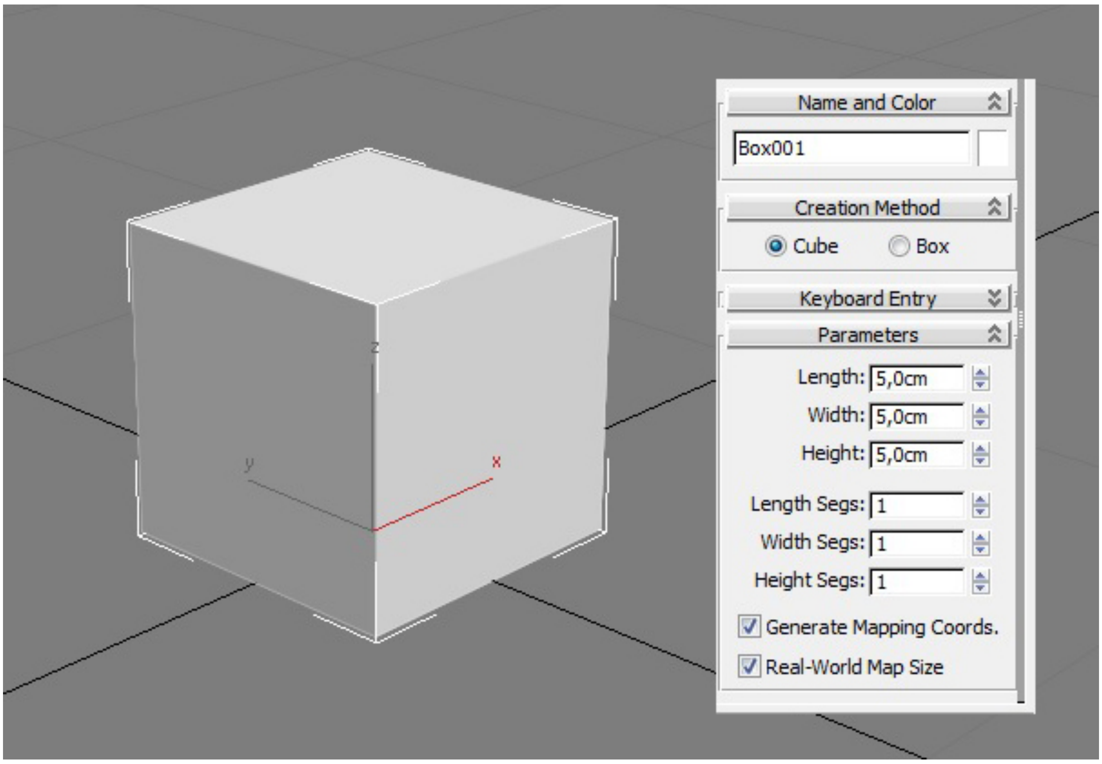


Figure 12 Dimension parameters at 3dsmax Software (Produced by the author)

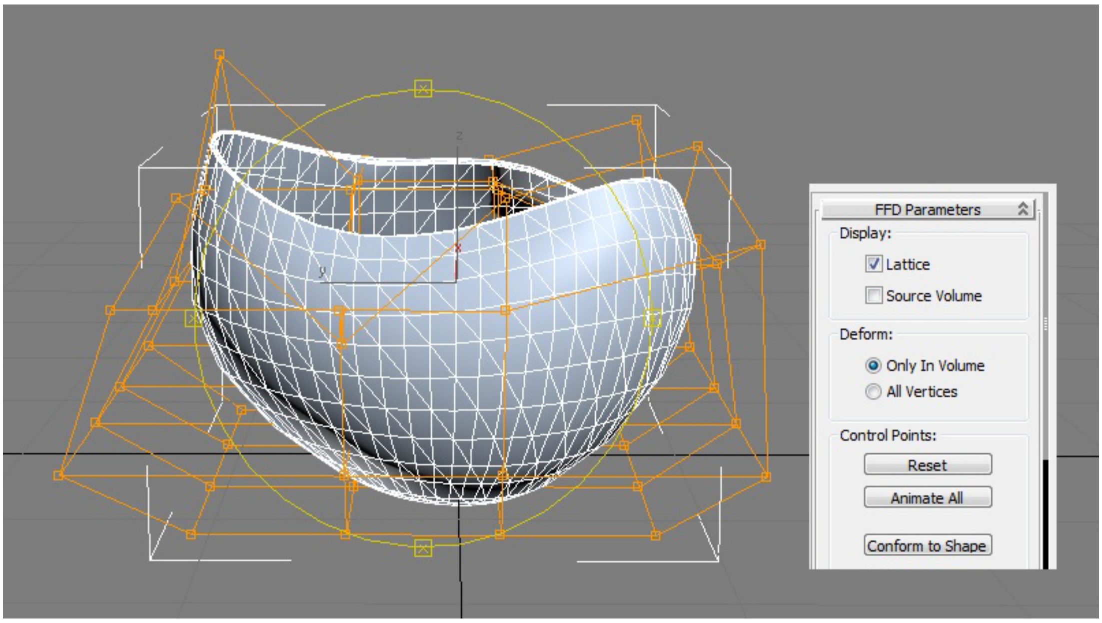


Figure 13 Free Form Deformation (FFD) Parameters in 3dsmax (Produced by the author)

Design called as a black box turns into a white box within this iterative process. There are no more greys and blurs in this process (Sorguç and Selçuk 2013). When a point changes, designer can see the whole picture, how it affects design, form and functions all together. However this white box results in unexpected outcomes that even the designer of the model could not predict within the thinking process.

These unexpected outcomes, which can be called the creative shifts, feed the designer every time and turn the process into a learning loop in which the novel situations are generated. Killian also emphasizes these unexpected outcomes as a consequence of a robust model harboring uncontrollable complexity. According to him when this situation affects the robustness of the scientific model, it offers novel design potentials to the designer (Killian, 2008). In addition these novel situations can emerge novel thinking ways for designers and they can redirect the designer into another path of solution like using a different algorithm to solve the same math problem.

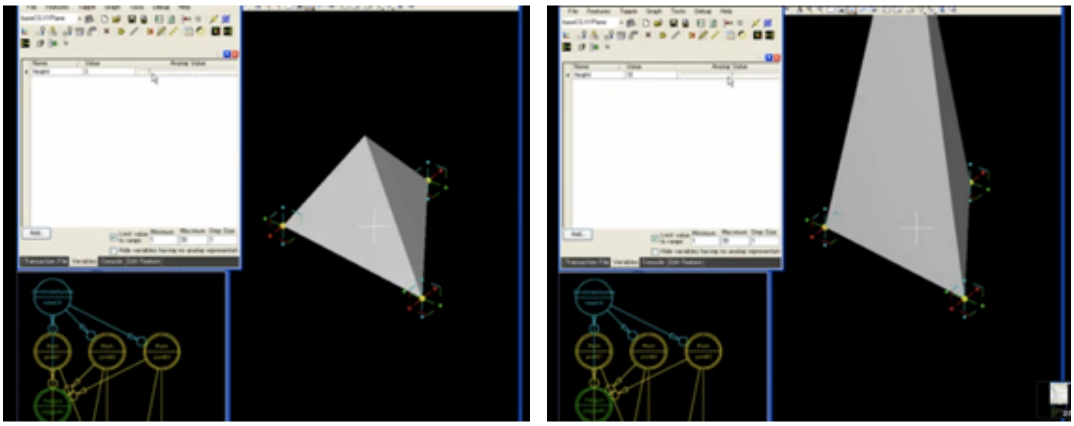


Figure 14 Dynamic height dimension control of tetrahedron in Generative Components

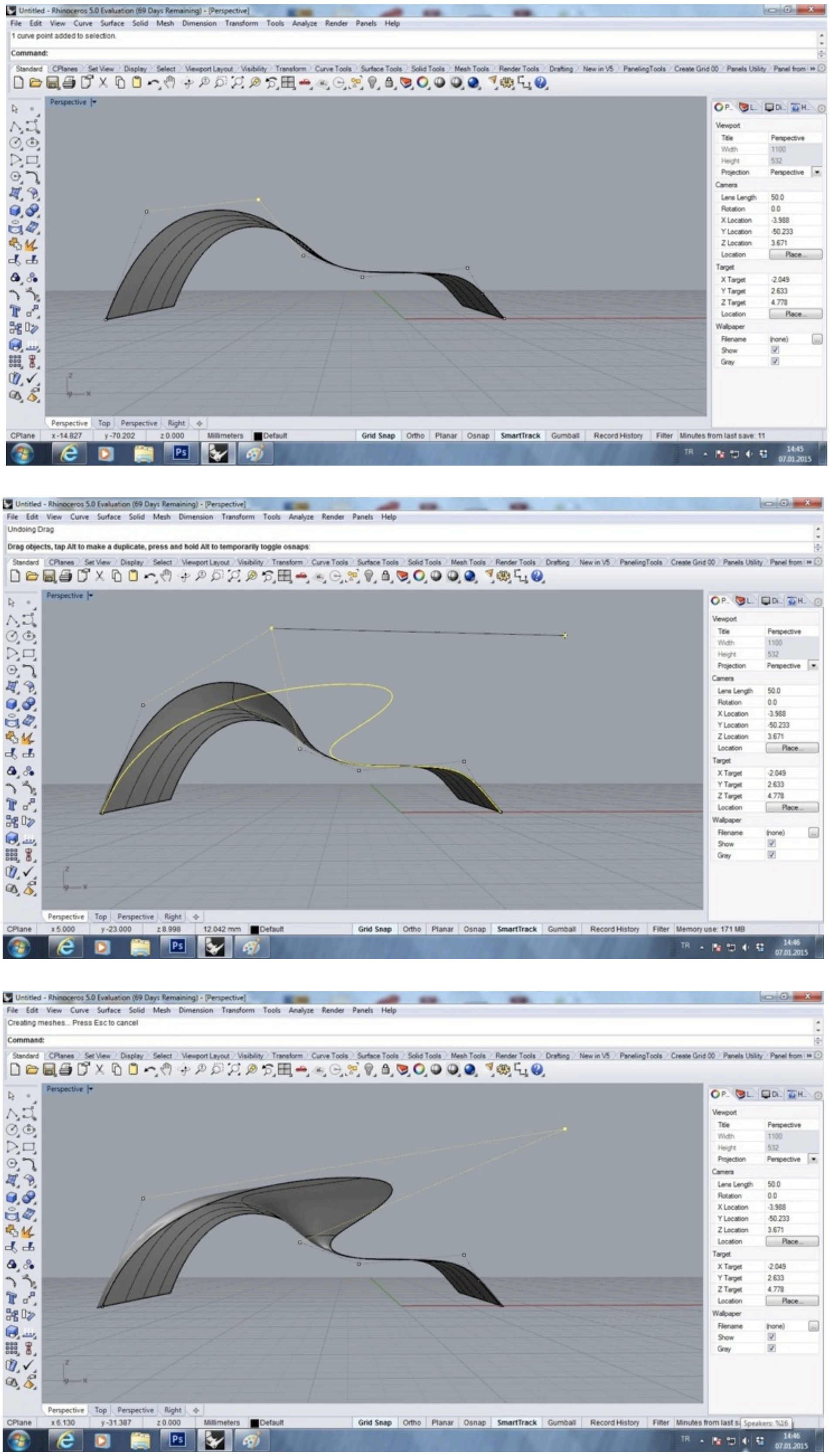


Figure 15 The dynamic shape, curve control with record history tool in order to manipulate the lofted surface in Rhino (Produced by the author)

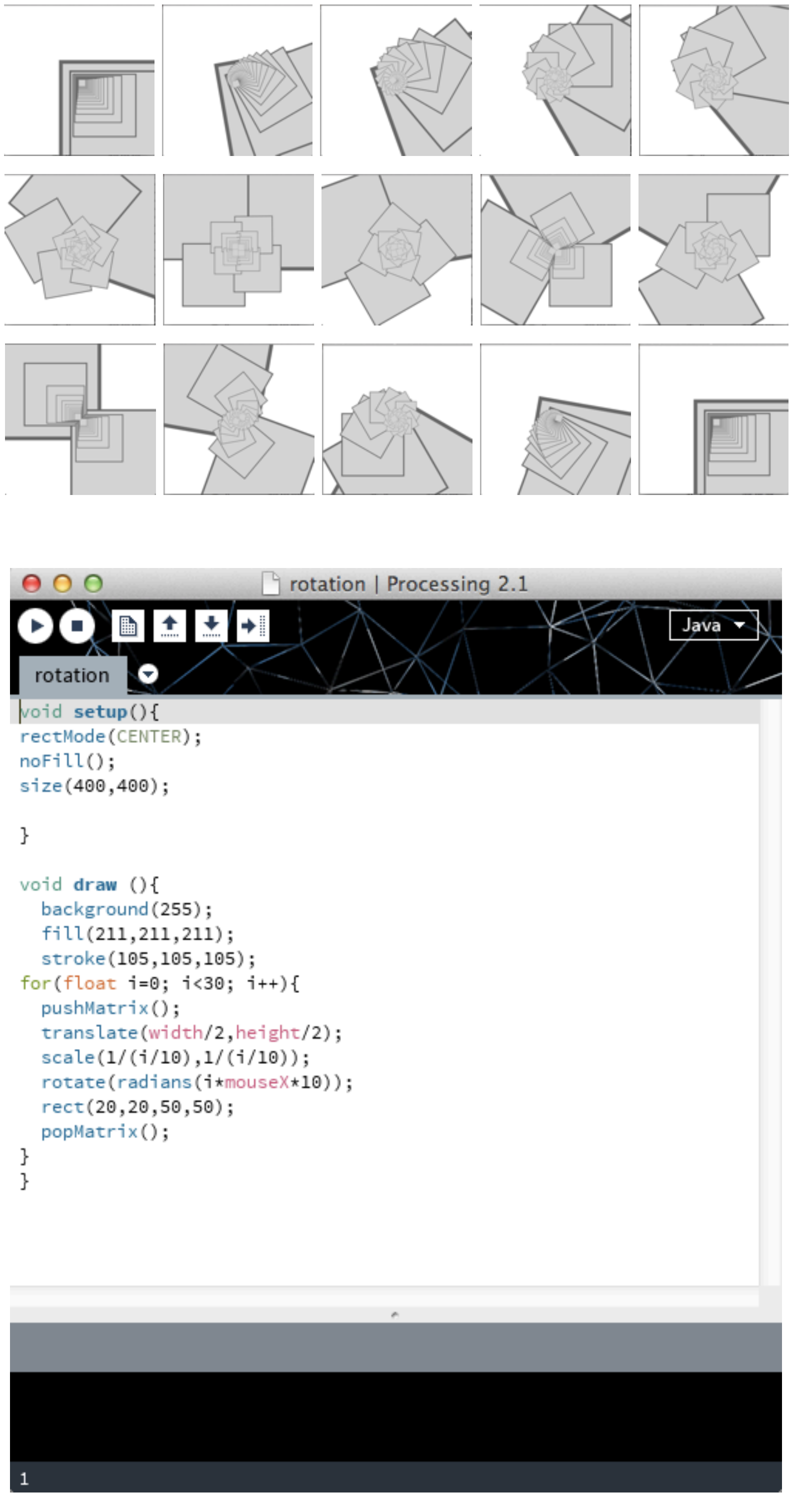


Figure 16 Interactive and dynamic shape generation by (rotate) function Every time the rotation angle changes with the interactive use of mouse in X direction (Produced by the author)

3.5. Algorithmic Model

An algorithm is a precise instruction. It is a procedural technique for solving (design) problems through a finite number of steps "using logical if-then-else operation" (Terzidis, 2006). This step-by-step procedure is an abstraction for taking input and producing some desired output (Wing J. , 2008). It articulates also the ill-defined problems in order to create an exploration of possible paths that may stimulate the solution of the problem (Terzidis, 2006).

There is no need to use a computer for algorithmic thinking. It can be executed by human or by a computer. For instance, a recipe for cooking is also an algorithm, which directs the cook step-by-step to the final result or dish. An address description can also be an example of algorithm "go ahead, turn at the first right, then after ten meters you will see the building on your left." These are the algorithms of everyday life. An algorithm does not solve a problem by itself; rather it just opens a door in order to solve it if the steps are precisely executed. If you turn at the first left instead of right at the second step, you execute the algorithm wrongly and then you cannot reach the destination in other words you cannot solve the problem. Figure 17

```
to repel
ask turtles
[
  set closest-turtle min-one-of other
       turtles [distance myself]
  set heading towards closest-turtle
  back 1
]
end
```

The turtles are being told:

'Dear turtles, I would like to ask you to look through all the other turtles to find the one whose distance away is at a minimum.'

Then they must remember which turtle this is by storing its reference in the name *'closest-turtle'.*

Now the turtles are told:

'Set your heading so that you are pointing towards this "closest-turtle", and back off one step.'

Figure 17 Algorithm as script and a semantic analysis of the algorithm (Coates, 2010)

Casey Reas and Chandler McWilliams define the four qualities of algorithms in "Form+Code" as: (1) "There are many ways to write an algorithm"; (2) "An Algortihm requires assumptions"; (3) "An algorithm includes decisions"; (4) "A complex algorithm should be broken into modular pieces" (Reas & McWilliams, 2010). The first quality points out that there can be multiple ways to address a direction, to get from point A to point B. In other words, when the designer changes the whole algorithm changes and different set of directions emerge accordingly. The second one states that assumptions are at the core of the algorithms, for instance, how do you describe how to cross the road to a person? You would say: look right and then left and then if you see the road is clear of any cars moving, cross the road by walking. But what happens if the person that you are describing does not know what a car is, what left is, what right is and even what walking is? (Sorguç, 2012)[9] Therefore there should be an assumption set, a -predefined-knowledge set in order to execute the algorithm in a right way, in order to protect the person from death. The third quality addresses that a person who reads the instructions also needs to choose a starting point, and then implement the instruction (Reas & McWilliams, 2010). The forth quality refers to the different path instructions that should be divided into small and familiar pieces in order to be executed like passing from Europe to Asia in İstanbul (from one side to another), there are multiple ways, vehicles to use and multiple starting points and locations. These qualities define algorithm and algorithmic thinking in which the explicit descriptions, introductions and knowledge are the protagonists of these procedures that construct the transformations between steps.

Algorithmic thinking as a characteristic of computational design -thinking and also model- (Aish, 2005 ; Wing J. , 2008; 2011; Sorguç & Selçuk, 2013) is essential in order to transform an ill-defined design problem into a well-defined one in design. In other words it works like a key while turning the black box into a white box in that manner (Sorguç & Selçuk, 2013). The mapping of the related vocabulary, parameters, relations or rules requires an algorithm in order to construct the range in the computational thinking cycle. In addition an exploration occurs through this mapping procedure. This exploration also works in some cases as instant feedbacks where the designer explores the outcomes of the algorithm when executed on her design problem. Paul Coates defines this as "a habit of algorithmic thinking" in which the designer gets a feel for how minor changes in her algorithm affect the

[9] This example is rephrased from the initial discussions on this dissertation with Arzu Gönenç Sorguç in 2012.

design outcome while dealing with a complex system (Coates, 2010). According to him algorithmic thinking gives a designer an advantage towards an understanding of the design problem itself and considering the possible solutions. In his words:

> This is a very different approach from the gradual build up of design moves; or rather it is the same kind of process but with the added advantage of instant feedback on the consequences of the rule changes (Coates, 2010).

This instant feedback directs the designer into various models in which the translation of the mapping procedure becomes more explicit. Killian addresses this explicit translation as the externalization of the process that also translates the range (the modeled) into other representative models, those addressing novel design problems. He states that:

> The externalization helps formalize the components and allows new problems to be addressed while adding more aesthetic qualifications to enter into the design problem, further broadening and strengthening the application of the cognitive role in the computational process and ushering the built model into an autonomous existence in relationship to the computational digital model (Killian, 2008).

This cognitive process informs the designer's internal and external representations through the relationship sets where the model becomes the most crucial element of the design in this computational cycle. Beyond its cognitive aspect the algorithmic model also works as a design generation tool that describes, illustrates and also operates the design's embodiment in the world (Coates, 2010). Figure 18 It is not solely a measurement or analysis tool. When it is executed through the computer software as a design script it can also act as an exploration toward the design software that limits the designer's imagination with the pre-determined objects. Hence the designer metaphorically bypasses the design software and she exceeds the limitations of the established objects, components introduced through the user interface. She generates her own interface through this process. In "Algorithmic Architecture" Terzidis claims "Algorithmic design does not eradicate differences but incorporates both computational complexity and creative use of computers." According to him this incorporation drives architectural design from formalism and rationalism to an "intelligent form and traceable creativity." In addition a corporation between the designer and computer arises where the designing process turns into a mutual relationship “from intuition to precision” (Aish, 2005).

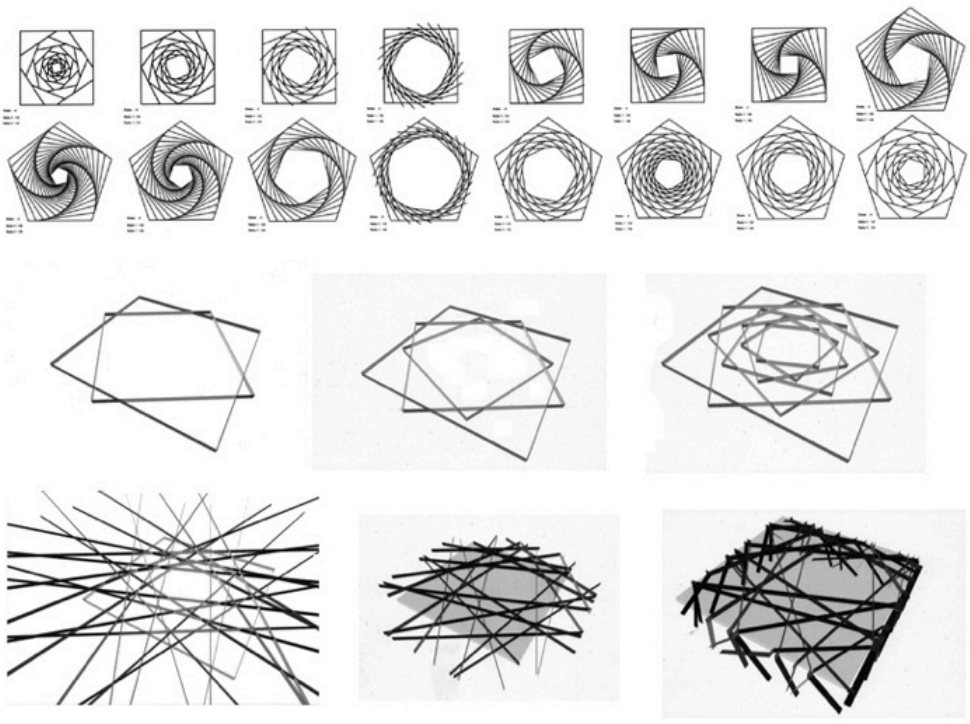


Figure 18 Sepentine Pavillion, Toyo Ito, London, 2002. “The rhythmic lines of Ito’s pavilion resulted from a recursive system of rotated concentric squares. Arup helped to create a pattern of beams” (Reas & McWilliams, 2010).

3.6. The Potential Role of Moving Image as a Model

As aforementioned in this study, moving image is defined as the engagement between the static media and time notion. This engagement can be a sequential ordering of the static media within time or it can refer to an experience of motion within time.

Starting from the 19th century moving image has been used within broad areas for inquiry, generation, development and representation (Clear, 2005). Moving image in this study does not solely refer to cinema rather it refers to its essence that started with Etienne Jules Marey's revolutionary scientific motion research. Figure 19 Therefore moving image in this study can also address the sequentially layered frames gathered on one or multiple frames such as a flipbook or an animation. Figure 20

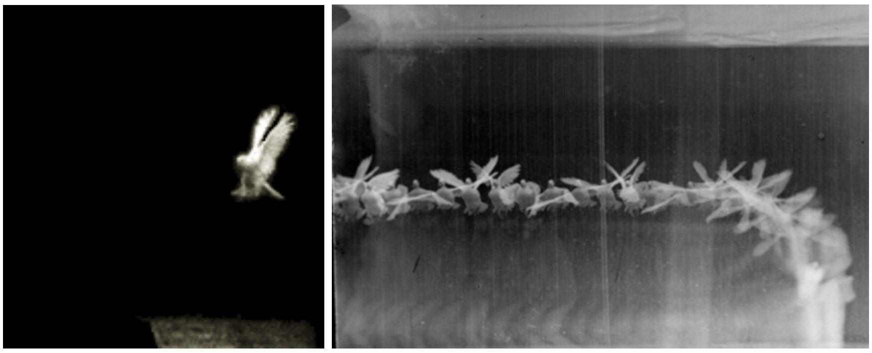


Figure 19 Étienne-Jules Marey, Bird Flight, Pigeon Landing, 1894 and Étienne-Jules Marey, 'Flight of gull', 1886

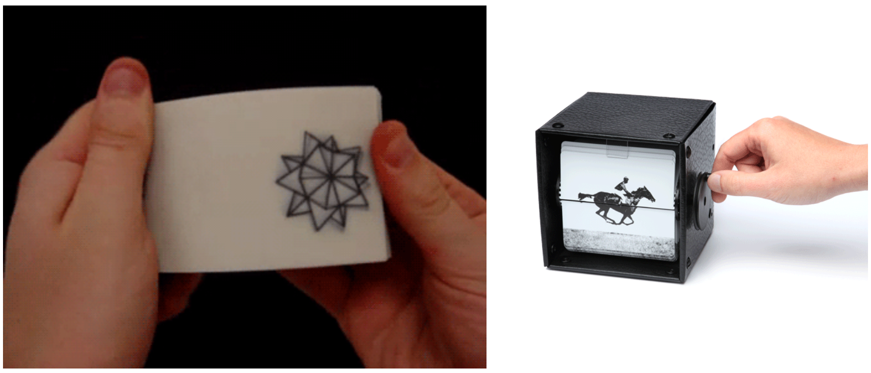


Figure 20 A handmade flipbook and a flipbook machine

So other than this definition, “the experience of motion within time” explanation involves the time-based media and designs such as film, video, animation and projection mapping, etc. These types of moving images are primarily attached to a screen, which has also evolved in definition through centuries. Moving image can be projected onto a flat screen as in film or can be displaced onto a 3D object, which can also be in motion. This displacement is called projection mapping, which is also defined as “spatial augmented reality” and “video mapping” in related literature. Therefore, the moving image in this study can also refer to installations, screenings and projections on objects such as models, buildings, spaces etc. Figure 21, Figure 22

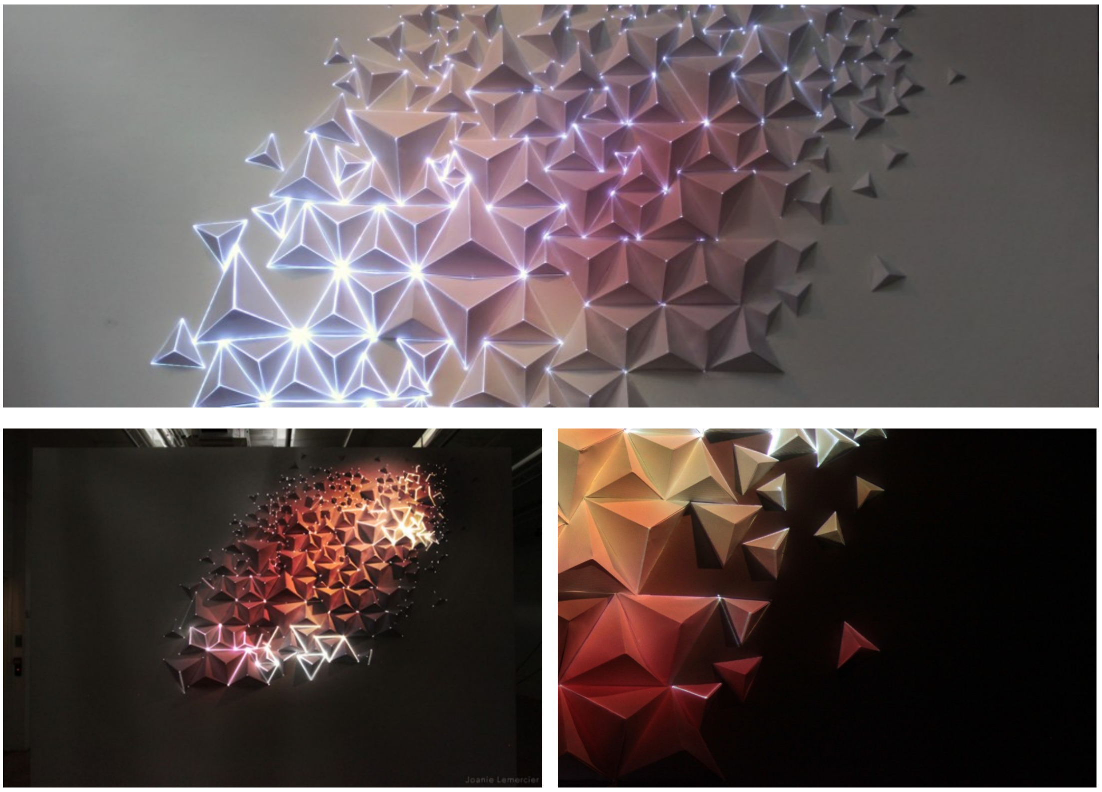


Figure 21 “Paper and Light” projection mapping installation by Joanie Lemercier, 2012.

Sergei Eisenstein’s famous quote “If it moves, it is alive” summarizes the effect of the moving image in art, design, and architecture. This impact is a new understanding of what is real and what is possible through the manipulation of time notion. In that manner, the experiences through moving image act as a new understanding of the reality. However moving image should not be thought merely as an end product; instead it relies on a design procedure that has a potential role as being a model for the real and the imagined.

Figure 22 "Paleodictyon" project by AntiVJ, projection mapping on Sheigaru Ban's Centre Pompodiou Metz in France and its design process

The design process of moving image exposes and suggests a set of situations, in other words, a multiplicity of states conducted upon various conditions that unites a model of another reality, another case. Therefore as generated models in order to solve a design problem, moving image can have a potential as being a model of its design process rather than being solely an end product in that manner. From this point of view, a sequential drawing can also be defined as a moving image model in which the drawing steps can be articulated in detail in order to identify or solve a design problem. Figure 23 In this study "moving image model" term will be utilized, and it will grasp the definitions and types mentioned above. In order to understand the potential role of moving image as a model, the design of moving image will be elaborated in the next section.

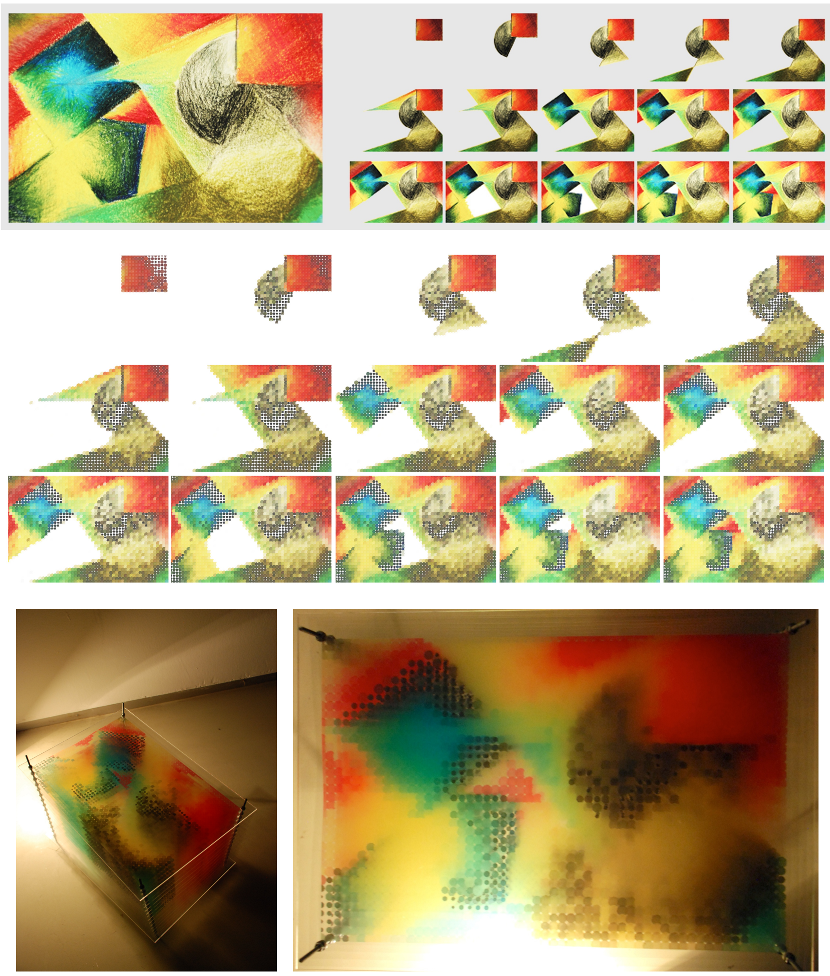


Figure 23 The sequential drawing session, computationally generated images and final model of the project "Response", which was designed by Gökhan Ongun, Burcu Bilgiç, Ezgi Balkanay and Ayşegül Akçay during See Pixel workshop[10].

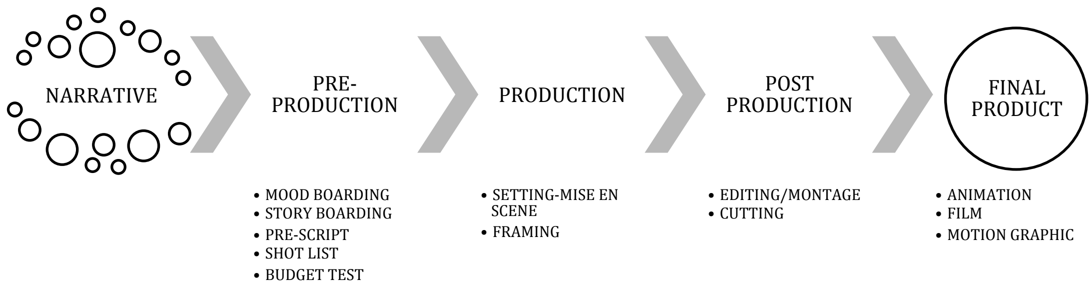
[10] See Pixel: Computational+Visual Processsing for Design Drawing Workshop was held between 21-24 january 2013 at İstanbul Bilgi University, Department of Architecture, Turkey. Workshop

3.6.1. Designing the moving image model

In its essence-moving image is also a model that gathers different kinds of information and synthesizes a number of different components into a single piece that articulates complex ideas (Clear, 2005). Furthermore time and motion terms have their relative points that cannot be implied, they can only be experienced within the designed model.

Designing the moving image requires five phases (1) narrative as the initial input, (2) pre-production, (3) production, (4) post-production and (5) the final product as an output. This process involves sub-processes and contexts that depend on the final product type that can be video, animation or film. Table 14

Table 14 The moving image design process



According to the type of the moving image after the narrative the most crucial part that constructs metaphorically the skeleton of the moving image is the pre-production phase. This phase is again conducted in five stages: (1) mood boarding, (2) storyboarding, (3) pre-script, (4) shot list and (5) budget test to estimate the cost of the production. Table 15

executives and organizers are Onur Yüce Gün, Şebnem Yalınay Çinici, Benay Gürsoy, Mete Tüneri, Emre Erkal.

Table 15 The pre-production phases

Regarding the scope of this study, which aims to understand the contribution of moving image to design education in architecture, the forward sections focus on the examination of pre-production phases of moving image generation and its relation to computational thinking process. The main reason for taking the pre-production phase into account is because of its essence, being the early design phase of the moving image model generation. Therefore the phases after pre-production including budget test, shot list and pre-script are not included in the investigation in this study.

3.6.2. The initial trio of the moving image model: Narrative, Mood Boarding and Storyboarding

Narrative

Narrative is the first step of the moving image generation, which also can be defined as the initial idea. According to the Oxford Dictionary narrative's definition is three fold (1) "A spoken or written account of connected events; a story", (2) "The practice or art of telling stories", (3) "A representation of a particular situation or process in such a way as to reflect or conform to an overarching set of aims or values." The first and the third definition are relevant for this study.

Mood Boarding

Mood boarding is an idea, concept wall in which the related elements are stored. A mood-board gives the overall idea of the design idea, the ambience, literally the mood of the design.

Storyboarding

A storyboard is a means of describing and planning the continuity or shot-by shot flow of a film using sequential illustrations (Cristiano, 2007). It defines the settings, framings and point of views. It is a preliminary design tool working also as a process model of the films and animations in which all the related information is mapped through factors like scene locations, lighting, camera positions are determined and executed.

3.7. What is in between Moving Image Model And Computational Model?

Computational thinking process and moving image generation (film-making/video/animation) have their relative points in their procedural essence. They both intersect on the subject of the programming of the process. The initial states of observation and the idea part construct a bridge between these two processes. Moving image as film, video or animation has the development and pre-production phases where the skeleton of the image as a model is generated. These phases are conducted on the stages -as aforementioned- that are narrative, mood boarding and storyboarding that have their analogy over computational thinking procedure. Narrative is associated with defining the overall object or situation, events and moves, mood boarding is associated with definition of characteristics of elements and parameters, storyboarding is associated with defining the relationships and rules therefore mapping as a basis of algorithm defined in the previous section by referencing the computational thinking process cycle. Table 16

Table 16 The Association of Moving Image Model with Computational Thinking Process Terminology

NARRATIVE	EVENTS, MOVES, SITUATIONS
MOOD BOARDING	CHARACTERISTICS OF ELEMENTS
STORYBOARDING	RELATIONSHIPS, RULES, ALGORITHMS

3.7.1. Narrative: Scripting the events and relationships

Narrative is generally known as a written or verbal story constructed basically on events and situations. Therefore in order to understand the whole story, both the overall and detailed meaning of events and situations should be clear in descriptions. As a generic term it refers to a logically ordered sequence of elementary events or solely an event. These events as fundamentals of the narrative address the specific actions, moves, behaviors, states, situations etc. (Zarri, 2012).

On the other hand, in design narrative works as an unorganized information pool that unites an ill-defined design problem. The processing of this information needs classification, decomposition, re-composition, grouping or clustering in some instances in order to be clearer even though the problem is a well-defined one in order to transform it into a design. Kenneth Kahn's "A Computational Theory of Animation" is a logical example from the 70s basically enlightening the description phase of the narrative for a well-defined one. He simplifies the very well known tale "Cinderella" in order to introduce it as a computationally modeled animation. The generated system does not know about the appearance of any real-world objects. Instead of using trees, faces, eyes, etc. he limits the system with geometrical objects such as circles, blobs, triangles, spirals and etc. in order to reduce the complexity of the design problem. In his words:

> This limitation is to avoid the need to imbed in the system tremendous amounts of knowledge. For example, if the system were to use eyes then it would need to know how they move, vary, express emotions, and are combined with the rest of a face (Kahn, 1977).

Thus he abstracts the narrative, simplifies it and transforms it into information clusters conducted upon (1) characters and (2) relationships. For instance he uses a categorization system based upon physical description, personality and role/part in the story in order to define the characters. For relationship descriptions he uses a mutual system in order to define how the characters treat each other. Figure 24 In this example, narrative acts as a real model, which is observed and then simplified step-by-step according to identified characters and relations. Table 17

```
(CREATE CINDERELLA
        (PHYSICAL-DESCRIPTION (AND BEAUTIFUL SHABBY))
        (PERSONALITY (AND GOOD FRIENDLY HARD-WORKING SHY))
        (ROLE-IN-STORY MOST-IMPORTANT)).

(CREATE STEP-MOTHER
        (PHYSICAL-DESCRIPTION UGLY)
        (PERSONALITY (AND MEAN SELFISH STRONG EVIL)))
```

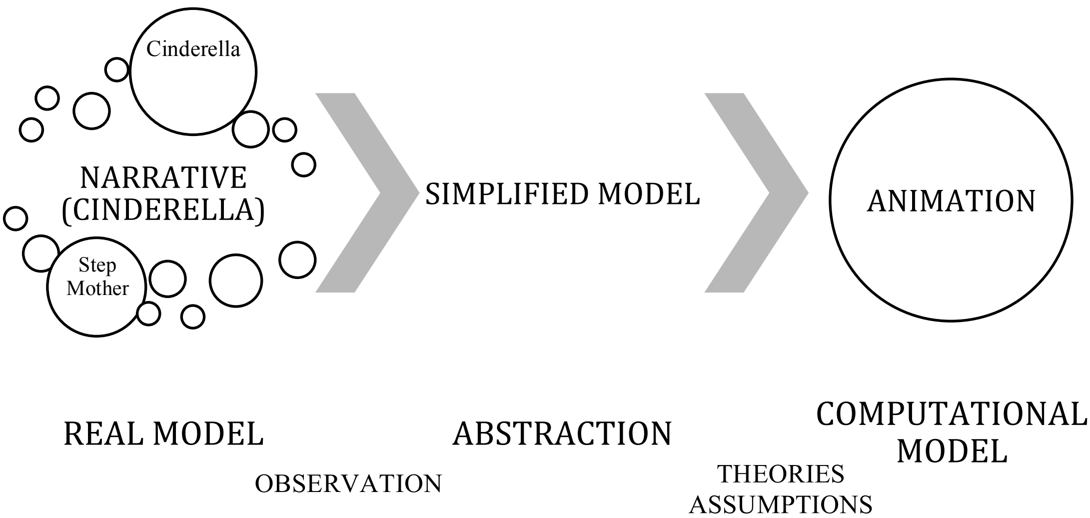
Next we will define the relationship between Cinderella and her step mother and then continue defining the other characters.

```
(CREATE (RELATIONSHIP STEP-MOTHER CINDERELLA)
        (AND DOMINATES HATES))

(CREATE (RELATIONSHIP CINDERELLA STEP-MOTHER)
        (AND OBEDIENT TOLERANT))
```

Figure 24 Descriptions and Relationships of characters in "Cinderella" in Kenneth Kahn's A Computational Theory of Animation, 1977.

Table 17 The Simplified Process Model of Kahn's "Cinderella" version



What happens when the narrative is unknown or ill-defined in a design situation? This is the secondary case that suits for design in general. The narrative defines the events and directs the whole process regarding the design problem. In this situation the narrative can be attached to a single object or a subject. Therefore the observation and abstraction part conducts upon the object and maybe sometimes the designer does not articulate a narrative of the design and she just moves according to the information gathered from the design problem questions that can give directions to the design moves and events eventually. In this case narrative emerges for situations and goes beyond being the whole and becomes part of the design evolving within the emerged novel situations. Coates semantic analysis can be an example for this kind of narrative definition that starts and end within a sole event. Again he defines the characters, this time points are resigned to be turtles[11]. There is a point cluster that turns into a turtle group and the first basic event is defined as the finding the closest turtle and second event is defined as setting the head toward it. But the initial main aim, the wanted situation is the repelling of the turtles from each other in Coates' words this is the setting of "How to repel?" Figure 25 Therefore two basic events are generated in order to reach to the desired situation. And Coates articulates these events as moves and rules and makes a semantic analysis of it. He summarizes this situation as "ASKing" questions and "SPELL IT OUT" actions in order to computerize it, in other words translate it to the computer (Coates, 2010). Figure 26

```
to repel
   do something
end
```

Figure 25 The simple question "How to Repel?"

The turtles are being told:

'Dear turtles, I would like to ask you to look through all the other turtles to find the one whose distance away is at a minimum.'

Then they must remember which turtle this is by storing its reference in the name *'closest-turtle'.*

Now the turtles are told:

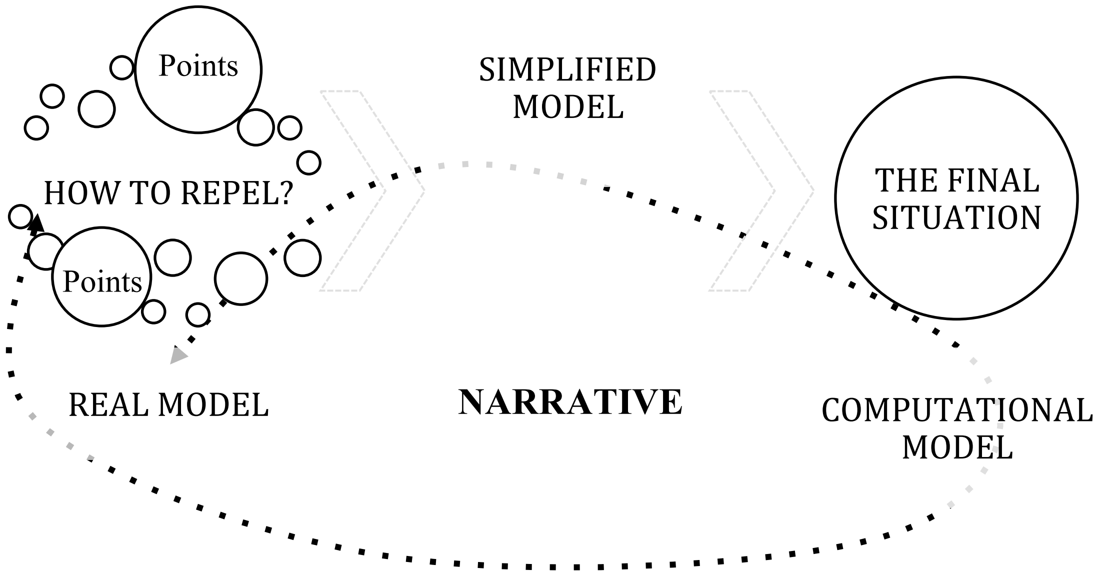
'Set your heading so that you are pointing towards this "closest-turtle", and back off one step.'

```
to repel
ask turtles
[
  set closest-turtle min-one-of other
      turtles [distance myself]
  set heading towards closest-turtle
  back 1
]
end
```

Figure 26 An example for the narrated and the semantic analysis of the script as algorithm from Paul Coates, Programming Architecture, 2010.

[11] Coates adapts turtles from NetLogo language. Logo is an educational programming language, designed in 1967 by Daniel G. Bobrow, Wally Feurzeig, Seymour Papert and Cynthia Solomon. Today the language is remembered mainly for its use of "turtle graphics", in which commands for movement and drawing produced line graphics either on screen or with a small robot called a "turtle". http://en.wikipedia.org/wiki/Logo_%28programming_language%29#cite_note-cslsPreface-1

Table 18 The simplified process model of Coates' "Repelling" Event



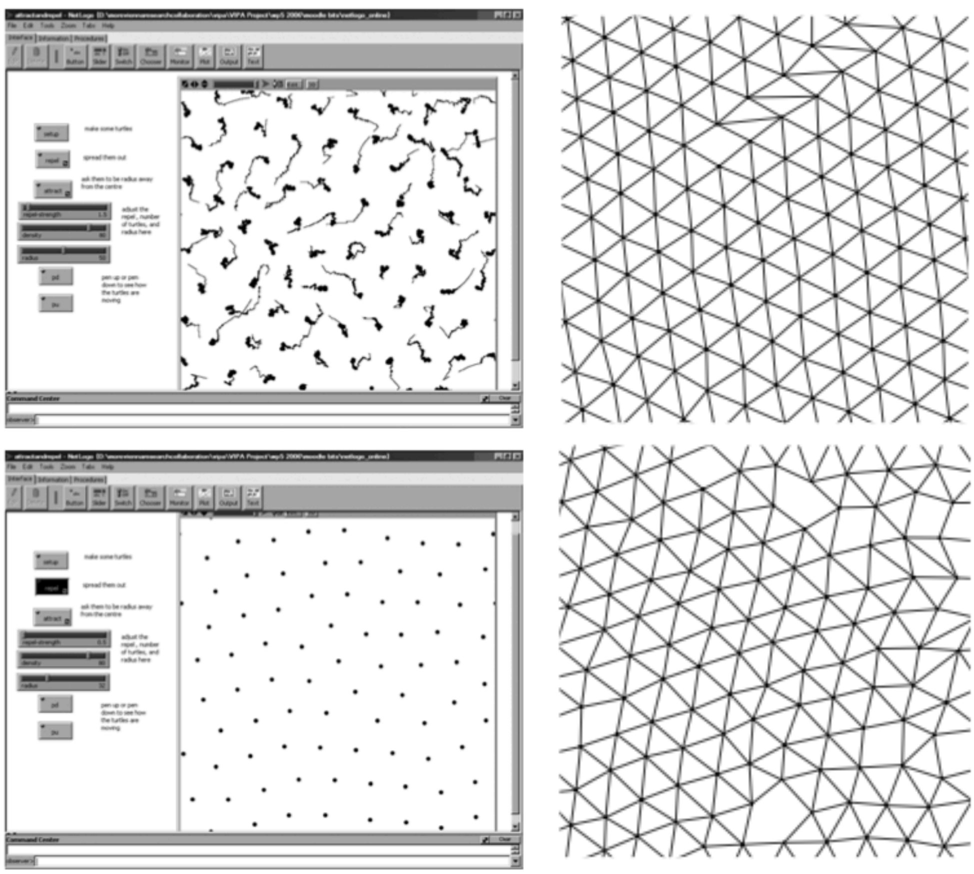


Figure 27 The characters, points as turtles and the final situation

3.7.2. Mood Boarding: Defining the characteristics of elements and parameters

Mood boards are the visual communication engagements between the designer and the overall concept of the design in which related themes, ambience, mood of the characters, elements and parameters are assembled all together. They can contain, texts, visuals, samples of objects and textures. Therefore a mood board is like an information package about the upcoming design. Figure 28 Figure 29 From that point it resembles the concept maps and mind maps that rely on textual contents where the main aim is also gathering the needed conceptual data in order to organize and represent the knowledge. They include definitions, prepositions, events, and objects and in addition the hierarchical relationships that are related or will related with design problem. Table 19

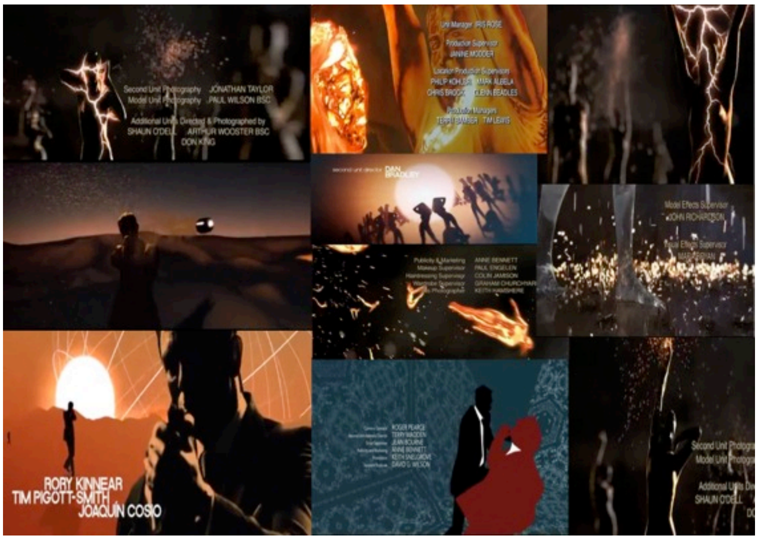


Figure 28 A mood board from Skyfall film focusing on contrast and fire themes.

Table 19 The Characteristics of Elements of the Skyfall movie depending on the mood Board

ELEMENTS	COLOR	PATTERN	POSITION	*CHARACTERISTICS*
AMBIENCE	Dark Brown	Natural	Background	*Scary-Mysterious*
MOOD *(OF THE PROTAGONIST)*	Yellow-Orange	Artificial-Detailed	Foreground	*Brave-Dangerous*

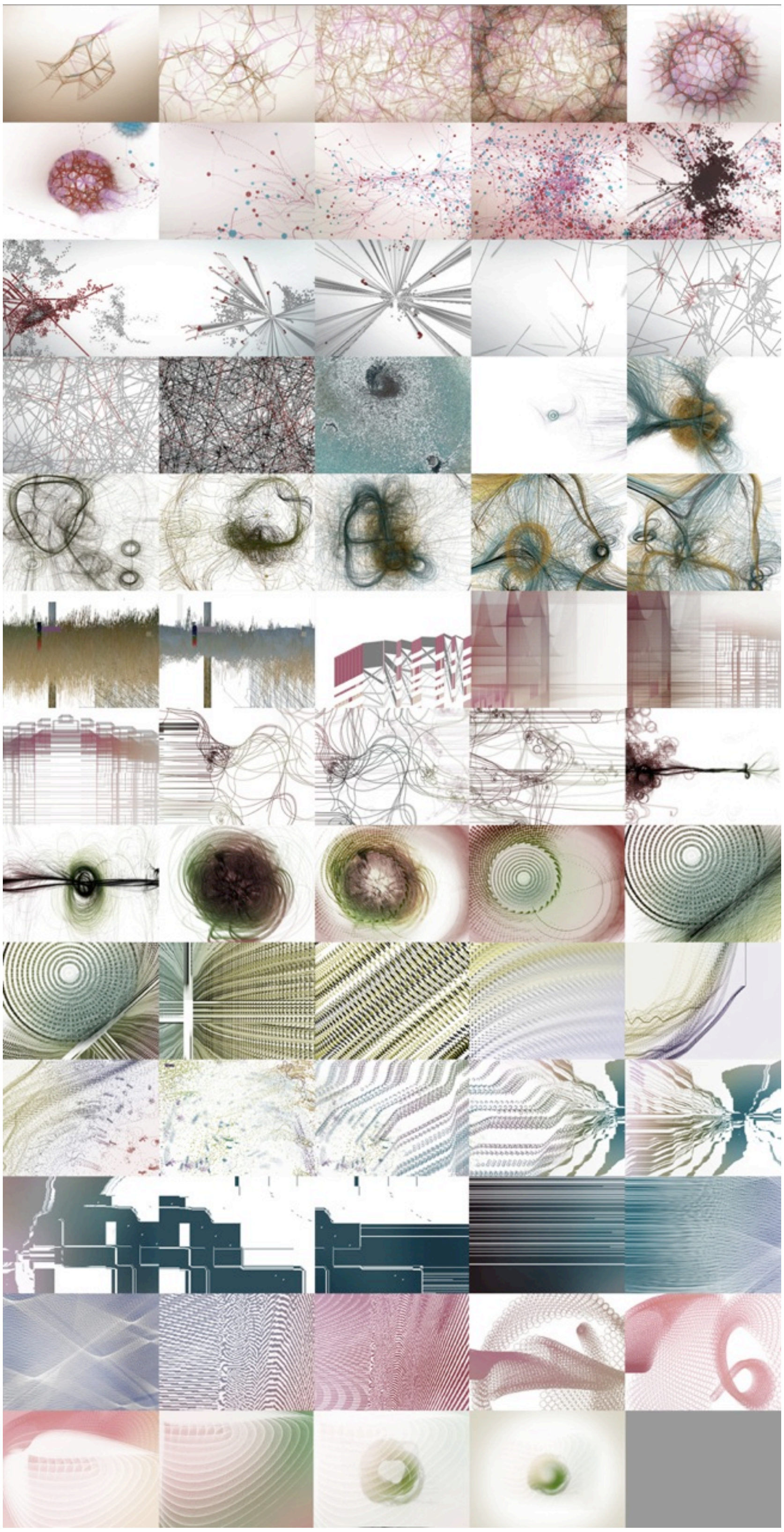


Figure 29 Mood board for an abstract short TV commercial for Dupont by Logo.

3.7.3. Storyboarding as mapping the parameters, rules as a basis of algorithm

A storyboard is composed of sequentially framed images structured by a narrative. Figure 30 It is an “ordered strategy” (Temkin, 2003) like an algorithm in which the rules and relations are outlined through a time-based composition. It works as a documentation of the project in which all the variable elements of content are mapped scene-by-scene, step-by-step. The mapping has a narrative that engages the acts, moves as sequences of first, next, then and last steps. Table 20

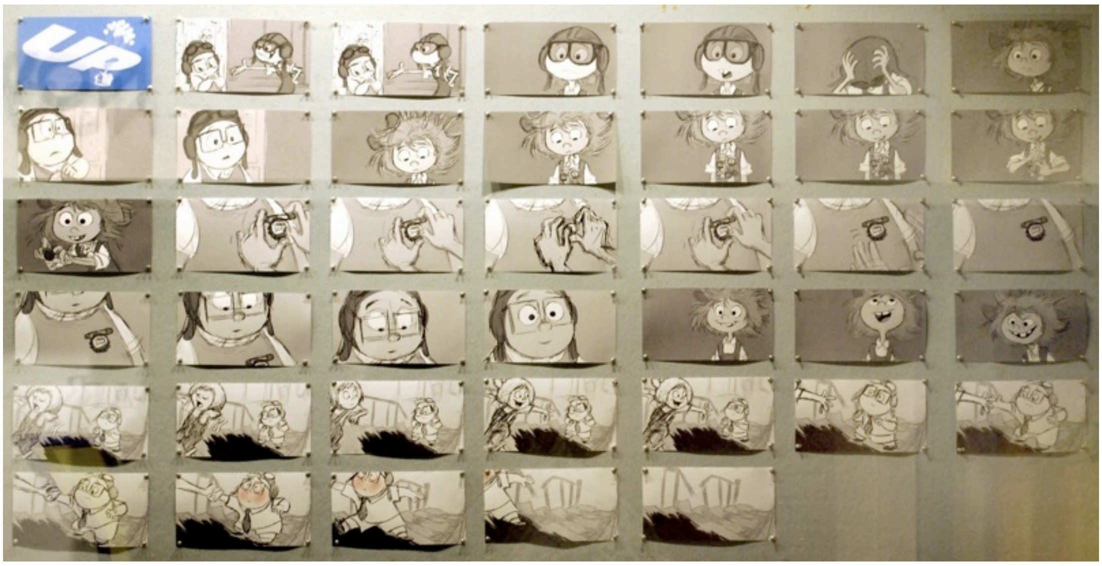


Figure 30 Storyboarding of *Up,* animation, 2009.

Table 20 The Sequences of the steps in storyboard

FIRST	NEXT	THEN	LAST

The defined elements and parameters gained from narrative script and mood board are mapped to storyboards in order to construct the image as the model. It is essential to gather the defined parameters through a unified time based pool where it can frame the relationship between events, elements and parameters within the model. This time based pool can refer to a single frame or multiple as called as scenes.

Scenes and frames can be associated with (recorded) design moves in the model. Figure 31

The model here is not just solely an image; on the contrary it is combined through many. Storyboarding highlights the model variations and helps the designer to analyze the design moves scene-by-scene, step-by-step. Throughout this phase the designer can return to the intermediate phases in order to synthesize in addition.

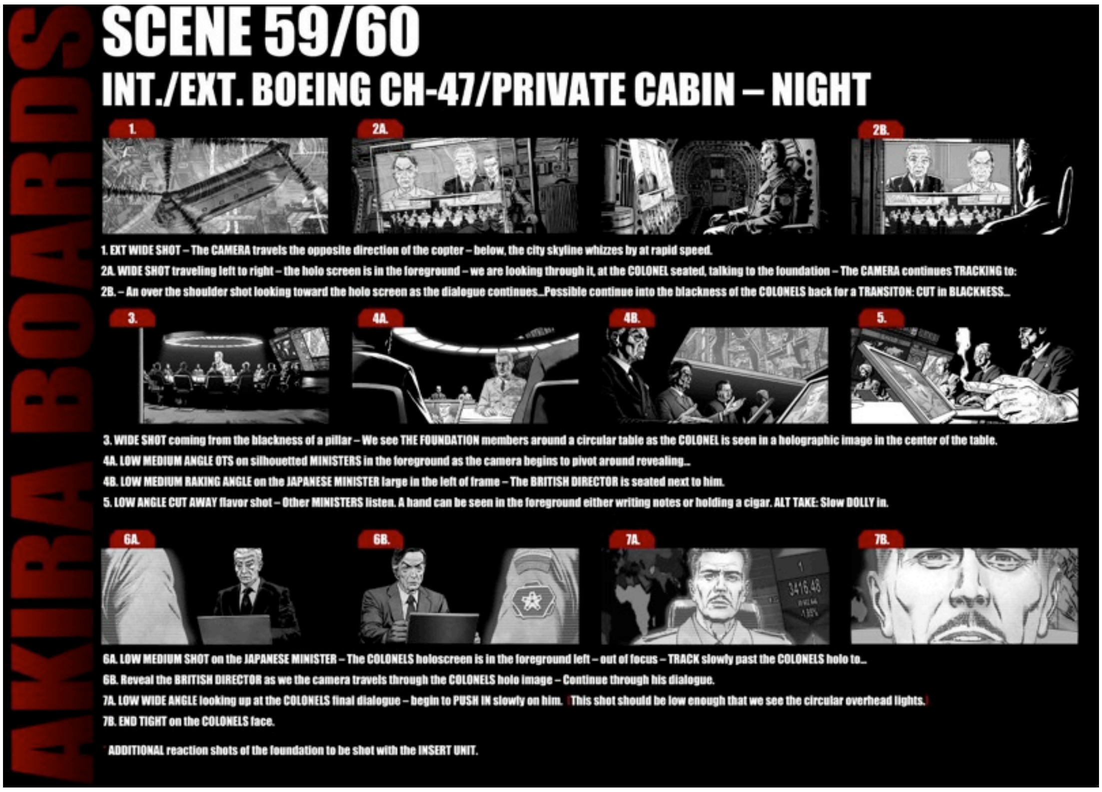


Figure 31 Storyboarding and the narrative script below the frames of unreleased Akira Movie by Chris Weston

According to René Davids "the relationship of one framed image to another can be a story in itself (Davids, 1999)." Therefore it is also relevant to say that every frame can generate its own vocabulary, elements and event that can be called as information set. The designer transmits this set from one frame to another. As a result of this, translation occurs between the model, modeler and user of the model in which the moves and relationships are explained through the narrative. In addition this sequential act diverts attention from the single image, from part to the whole without neglecting the design steps. Therefore it automatically and un-intentionally records shifts for the perception of the process itself. Consequently it becomes a way of thinking for arranging relationships in which the sequential directions can be changed. Figure 32 Table 21

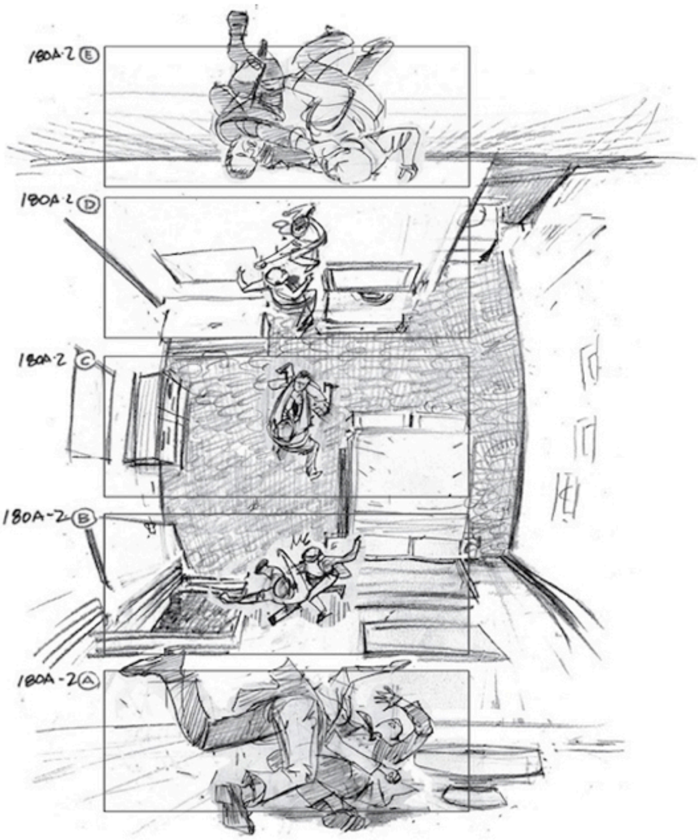
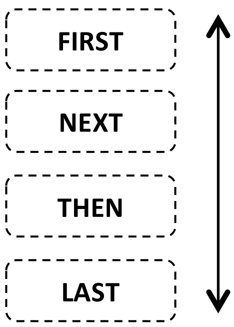


Figure 32 Storyboarding of Inception (2010) by Gabriel Hardman, in vertical direction. When a frame is subtracted, the whole process changes, the continuity fails

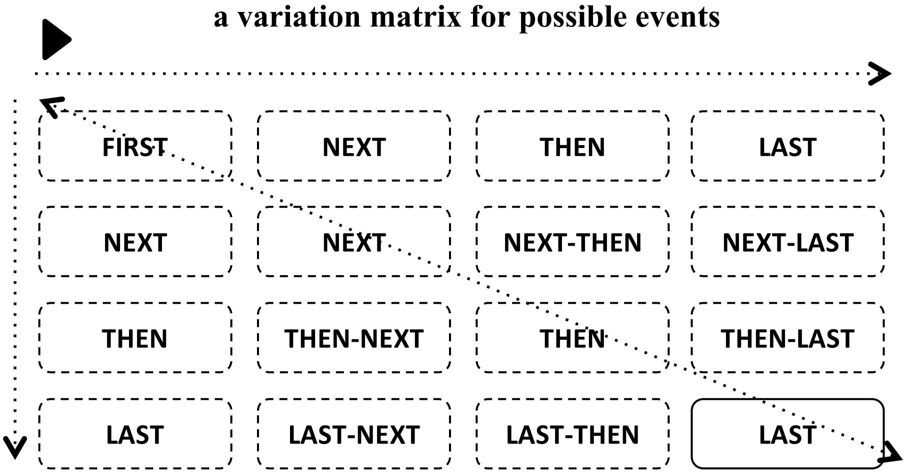
Table 21 The Sequences of the steps in storyboard, vertical direction



In its essence it resembles a solution matrix of a computational model defining variations of the possible design solutions. Table 22 Every step, every variation is connected to each other. Therefore storyboarding is also a dynamic act where frames are linked together. When one of them changes, the whole sequence and the overall design deviate accordingly.

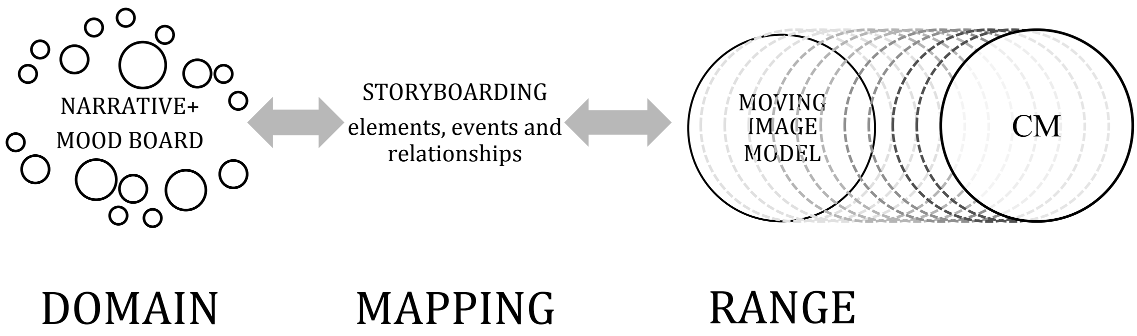
After mapping the defined elements, parameters and relationships through storyboard a translation starts from the developed moving image model to the computational model consequently. Table 23 This act is linked to the nature of the design problem, where two type of translation emerge, as called in this study (1) direct/fluent and (2) paused.

Table 22 Storyboard resembling a solution matrix for possible design solutions: a variation matrix for possible events



The narrative can be translated directly to storyboard as an algorithm or it can be translated within pauses caused by the unexpected outcomes originated through the translation of the design problem from one medium to another. As a result of these pauses or unexpected results, the designer can change and define the design problem again or directs the model into another solution path intuitively. This situation produces novel perception of the models that are called creative shifts in this study.

Table 23 The storyboard associated with mapping process from domain to range and the translation from moving image model to computational model

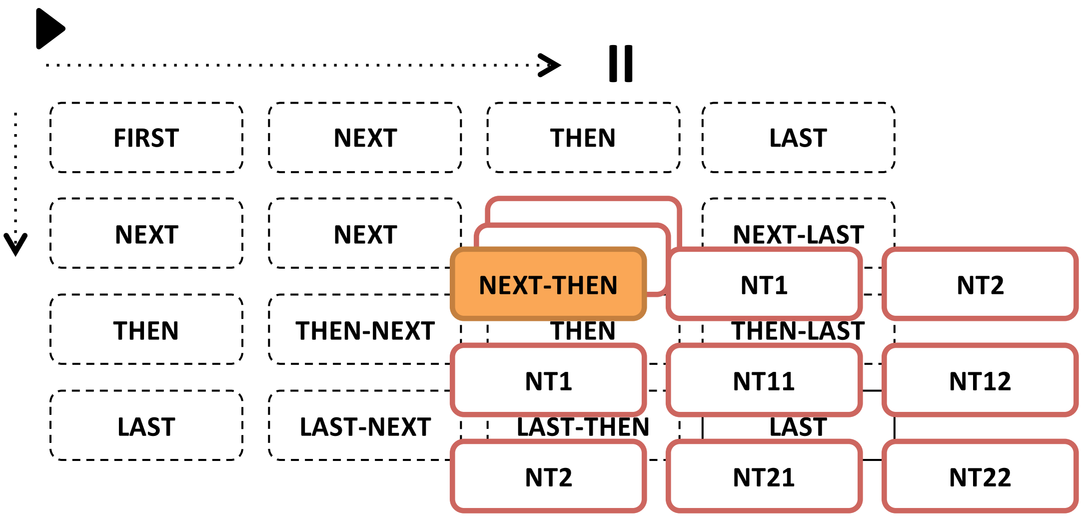


When an ill-defined design problem yields into a well defined one then the storyboard can be translated, transformed into another medium directly where there is no more ambiguity. Willemien Visser, a cognitive psychologist and cognitive design researcher defines design as a multifaceted activity with its ill definition, complexity, ambiguity, and the incomplete and conflicting constraints (Visser, 2007). According to her design as construction of representations, as activity functions with knowledge and recognition. From Visser's point of view the translation of design problem can be explained as below:

> Indeed, if a design task is no longer open-ended, ill-defined, ambiguous, if its constraints are the object of agreement, a 'design problem' can become a 'transformation problem' or even no longer constitute a problem (Visser, 2007).

Therefore the second situation where the translation is metaphorically paused opens a gate for the creative shifts in which the designer restructures the frames through her recognition and combines different series even different components. A novel variety of design solution set develops correspondingly. Table 24

Table 24 The unexpected outcome and the novel design solution set developed through the translation of the model



3.8. Integrating the Moving Image Model to Computational Thinking Process Cycle

Regarding the main aim of the research that is to understand the contribution of moving image to design education in architecture, the related definition of model terms are questioned in the preceding sections. As aforementioned considering these model definitions from different point of views, the accepted model definition in this study is two fold (1) as object/subject (phenomena) (2) as a thinking process. In addition to that design process is associated with modeling process in this study. During this process the designer communicates with herself through various model representations. She jumps between these generated models and tries to understand and translate them within each other in order to solve the design problem.

Modeling as a process is constructed on an assumption set based on the abstraction of an observed phenomenon (Sorguç & Selçuk, 2013; Kilian, 2012). This process functions as like a bridge between the design and the designer and generates a dialog within its ingredients. Regarding these definitions and by referencing the Sorguç & Selçuk's computational thinking cycle diagram, the models and their abbreviations included in this study are as below:

REAL MODEL	**RM**
PHYSICAL MODEL	**PM**
COMPUTATIONAL MODEL	**CM**
MOVING IMAGE MODEL	**MIM**
DIGITAL MODEL	**DM**

These models emerge during the computational thinking cycle both as input and output depending on the nature of the defined design problem. Accordingly a feedback loop occurs through this process that is also called the learning loop in this study.

PROCESS

INPUT ⟷ OUTPUT

FEEDBACK

The related terminology and sub-models are also discussed in the previous sections such as: parametric model, dynamic model and algorithmic model. These discussions concentrated on the consensus understanding of these terms and their role in the computational thinking cycle. Computational thinking is defined in related literature as an approach to problem solving, including a learning process by utilizing observation, abstraction, decomposition, algorithmic thinking, generation, evaluation, generalization and transition constructed on various model generations (Selby & Woollard, 2013; Wing J. , 2008; Sorguç & Selçuk, 2013; Sorguç, Selçuk, & Çakıcı, 2011; Wing J. , 2011).

Additionally, it has to be mentioned that there is a general confusion about the understanding of the terms computation, computerization and digital. The computation is directly related to the process, and digital model is an outcome, an end product in this study. To generate a computational model, the designer does not need a computer. The inclusion of computer in the process is a computerization act allowing designer to crunch number of data and thus to explore many instances of its computational model. Also, it should be pointed out that it is hard to separate these models from each other because of their similar essence. MIM can be associated with CM, but at the same time its pre-production phases can associate with parametric and algorithmic model. This does not mean that their definitions are same. They can substitute each other, according to the design problem nature. Table 25

Table 25 The substitutional relationship between MIM and CM

MIM		CM
MOOD BOARD	⇔	PARAMETRIC MODEL
STORYBOARD		ALGORITHMIC MODEL

Killian's view of understanding the outcomes of computational models as starting points for design rather than a simple transfer of computational results into literal form also affects the unified definition of the model term in the computational thinking cycle in this study. Killian remarks that when a model produces novel opportunities for the designer, the model becomes generative and the depth of the model is linked to these novel opportunities that digs an exploration hole within the "unforeseen variations" (Killian, 2008). These novel opportunities and "unforeseen variations" are also called as "unexpected results" and "creative shifts" in this study.

As in Ambrose et al.'s approach to the design process, where the main aim turns out to be the situation instead of the solution itself (Ambrose, Lostritto, & Wilson, 2008), Kilian points out that design should not be solely about the execution of established processes but about querying the understanding of the factors involved in the design situation. This is a much more complex task and it goes far beyond the traditional geometric and numerical representation of current computational practices but it happens in designers minds regardless of the involvement of computation (Kilian, 2012). The question is whether by externalizing such processes more can be learned and explorations can be pushed further for improving the downstream design processes (Kilian, 2012). In addition Kilian states that computational design in architecture and engineering has largely been limited to the definition of form and performative evaluation of such geometries (Kilian, 2012). In his words:

> Computation is still an obstacle in many cases in translating design intent; it lacks the fluidity of human thoughts and the emergence of ideas so common in successful brainstorming sessions. A human brain seems to constantly

> reconstruct its knowledge in filling the gaps and missing pieces and fluidly shifting from recalling things to creating new thoughts (Kilian, 2012)."

This externalization issue is pointing out metaphorically a relational thinking barrier rather than a visual one in design process. The reconstruction of the knowledge and embedding them into relation sets direct the designer into various solutions in which the novel creative thought could emerge intuitively or computationally. Robert Woodbury remarks that the designer has to step back from the direct design activity of design and concentrate on the logic that binds the design together in order to define these relation sets. He also points out that there is a formal representation requirement in order to create this relational process and during this process novel concepts can be introduced which may have seem to be unrelated with design thinking (Woodbury, 2010; 2014). According to Woodbury the representation of this relational thinking is a complex act of thinking constructed upon these novel representation modes and in addition the designer has to gain new skill sets and new strategies (Woodbury, 2014). Therefore gaining these new skill sets and strategies brings the questions how will these novel skills and strategies be adapted to design and education? Beyond integrating the shifting design representation modes and techniques solely through software usage into design education curricula, the adaptation to these cross-disciplinary world, needs a novel way of thinking that is computational design thinking. The design software updates itself or vanishes rapidly and new ones takes the place of the other, therefore the designer tries to adapt the interface and different execution of these design tools every time over and over. When the logic of the system is familiar to the designer, transferring between the different design software is more efficient.

Aish emphasizes the major role of the development of algorithmic thinking as a novel key design skill while questioning the progression from intuition to precision (Aish, 2005). According to him the transformation from intuition to precision occurs through dynamic representation modes that the designer figures out the whole process through the medium. The integration of these novel skill sets needs a base knowledge as like Sorguç's "crossing the road" example given in the algorithmic model section. This base is necessary especially for early design education that resembles the question of "how do you describe how to cross the road to a person if she does not know what a car is, what road is and even what walking is?" Therefore in order to integrate the related terminology to gather a base knowledge for the computational thinking process, the moving image model is integrated in this computational thinking cycle as a base medium for gaining a designer new skill sets.

The integration of moving image knowledge accumulation of pre-production phases into the computational design process and re-functionalism of this accumulation in early architecture design education will be discussed through a case study conducted as a workshop named *Cubehocholic* in the next chapter.

Nic Clear states that moving image by outlining the immediate relationship between the input system and output system produces a feedback loop in which "an output system may itself become a part of another input systems" (Nic Clear, Notes on drawing video). This is a spiral way of thinking that the process is redirected through this feedback loop in which the learning activity occurs. According to hypothesis of this research moving image captures and articulates the in-between states at the feedback stage of computational thinking process. It can open a manipulation gate between the model and the varieties of the model through a mapping procedure. This process can lead the designer into different perceptions of the model and the modeled. Therefore the student can understand the problem, problem states and the solutions through this process more precisely and in a more creative way. It can widen the field of vision of the students in that manner.

CHAPTER 4

CASE STUDY

> We communicate in a circle. This is the form of communication between the simple Black Box and the observer, appearing to be a "Black Box" to the Black Box. Black Boxes do not have to be simplistic systems. For instance, I really have no idea what is happening in your head and I can see none of your ideas, nor (therefore) can I share them. If you represent them in some way, it is still not your ideas I see, but my interpretation (building my understanding) of your representation (Glanville, 1997).

As Ranulph Glanville points out, the understanding of the one's ideas is impossible in its essence without interpretation of the observer, this claim has its relative point on the exploration of design activity also. Since the designer communicates with design by externalized representations of her thoughts, it is also relevant to assume that these externalizations are not the designer's real thoughts. Here there is a dilemma, which the investigation of the design activity fails from the beginning because the information gained from observations always depends on interpretations. On the other hand this view can also be an enlightening point for exploration of the design activity as an input during the perception of the design representation where the designer also interprets what she sees. A designer always communicates with her design through representations and constructs her thoughts depending on her perceptions of the pre-defined representations (Goldschmidt, 2004). In addition to perception concept, the designer experience her designs through these representations therefore the medium and the type of the representation gain a substantial importance in order to achieve her design goal.

Since the main aim of this study is to understand the contribution of moving image to design, it is essential to observe and then explore the design activity in order to generate knowledge on the subject. Therefore foremost the primary step is to construct the research within the convenient domain of design. According to Şebnem Yalınay Çinici this kind of approach fits especially in design education domain in which the design act goes beyond being the object of the inquiry and becomes an approach by itself (Cinici, 2012; Yüncü, 2008). Design education is a representational domain where design takes place and is transformed into potential research areas, which is methodologically called as research by design in order to generate architectural knowledge (Yüncü, 2008; Cinici, 2012). In addition, Çinici points out that educational environments offer not only environments for research and investigating and developing knowledge, but also they provide opportunities for every individual to contribute to the generation of knowledge within the simultaneous learning-teaching dynamic, especially in design education (Cinici, 2012). Therefore in this study research by design or design research approach will be adopted within the educational domain in order to investigate the moving image contribution to design education.

Early design process is a very fuzzy phase in which the designer should define the design problem and metaphorically puts the first dot onto the paper. Axel Kilian defines the early design stage as the most innovative and creative phase of the design process in which transformations occur continuously between the design concepts and formal representations (Kilian, 2012) He states that it is this continuous design state that is hardest to capture with current computational approaches. This is because of tentative essence of the early design stage relying onto the design problem definitions. In fact the potential of the design problems also lay beneath in their tentative essence (Kilian, 2012). Therefore many designers define the design problem again and again and they create a new problem definition beyond the previous definitions in which they should jump between the different design scenarios (Kilian, 2012). Thus these jumps can be within the dynamic models in which the model itself turns into a moving image where the designer can have a feedback loop with herself. This is the case also for early phases of design education that the new rule sets and novel perceptions are imposed on design students in order them to put that first meaningful dot.

4.1. Searching for Creative Switches

According to John S. Gero, designing is a mixture of activities and tasks involving distinguishable processes which occur over time. In the characteristic of conceptual designing part of the design process involves finding and determining what is needed. Through this process a designer reinterprets the design representations and she carries on a conversation during the process that Schön describes as "reflection in action" which also directs the designer to the emergence of new ideas (Gero, 1998).

Gero describes the situatedness and constructive memory concepts constructed over these definitions. He claims that constructive memory is not a static imprint of a sensory experience that is available for later recalls (Gero, 1998). From Gero's perspective situatedness is an important notion that provides insight into why conceptual designing often leads in unexpected directions with the constructive memory of the designer, which maybe also explains the unpredictable nature of design acts (Gero, 1998). These design acts reflect creative moments in their essence. According to Gero, creativity being one of the main concerns of design can be called as novelty, unpredictability, and value (Tang & Gero, 2002) relying on constructive memory and situated acts, is relatively a mysterious zone for designers and design researchers.

In the opinion of Kees Dorst creative design seems more to be a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis, and evaluation process between the two notional design spaces that are problem space and solution space (Dorst, 2006). He remarks that a designer seeks to generate a matching problem solution pair in design process as a coevolution. He questions the design definition in terms of a problem solving and creative design theories. According to him if design is a problem solving theory/action, instead of a definable problem there should be a problem construction phase. The modeling of this phase seems to be fuzzy in terms of rational problem-solving paradigm (Dorst, 2006). He constructs a new model of design in which a design problem is taken as a paradox, "made up out of the clash of conflicting discourses." He points out that the nature of creative design is the connections between these discourses (Dorst, 2006).

Another view is about the nature of creativity as building upon the experience of external representations that generate the variations through design process. From this point of view creative process is continuous and it has neither constraints nor specialized vocabularies (Özkar, 2004). According to Mine Özkar creativity is a thought process in which the uncertainties and the redefined constraints are explored during the design process (Özkar, 2004). She proposes an early integration of a computational perspective to design education with the dynamic use of rules, recording, seeing and doing (Özkar, 2004). This is an analogical approach towards design thinking as it is a computational procedure.

In addition to these views from cognitive and educational realms, it is also relevant to address the understanding of the creative act from the computational design realm. Therese Tierney points out that the creative tension arises between the apparent reductionism inherent within computational methods and the new complexities possible though dynamic modeling and form-generating software (Tierney, 2007). According to her first generation design research focused on rationalization of the architectural design product, second generation focused on the social aspects and since the 1990s the focus has been driven onto the architectural design processes itself, where the unpredictable, novel and the unimagined started to be more critical. She defines design as a dynamic iterative process in which multiple iterations and feedback between agents, parts, and systems occurs (Tierney, 2007). An interaction occurs through the flat screen and the user interfaces of the design software. Every step can be controlled, and every conjunction of the design process linked together.

As aforementioned in previous section while discussing the dynamic parametric model definition, design as a black box turns into white box within this iterative process. There are no more greys and blurs in this process (Sorguç & Selçuk, 2013). When a point changes, designer can see the whole big picture, how it affects design, form and functions all together. Therefore the perception of the designer evolves into an intuition and goes beyond just being represented by a digital image and turns into an algorithm that supports the designer during the design process (Çolakoğlu & Yazar, 2007). This is the procedure where the intuition turns into precision in order to have reasoning for design cases (Aish, 2005).

According to Robert Aish design is about exploration of new materials, new forms, speculations with an intuition and spontaneity. Therefore during these explorations the main aim is to find the new ones, the creative ones. The abstraction, externalization of ideas, concepts, augmenting the cognitive processes and arriving to the satisfied point even if it is not optimized lies beneath the computational tools, which are dynamic in their essence (Aish, 2005). Therefore the definitions of the design process have been evolved in the computational realm and within the enlightenment of computational studies extending the imagination and testing the ideas over and over again; the traditional relationship of "function-form-structure" has turned into an array of "information-field-interaction" (Tierney, 2007). This array redefines the design process where the initial act is the imagination within the designer's mind with internal representations. This act directs the design process into a grand feedback loop where the internal and external representations bound together through dynamic representations in the virtual canvas that can be constructed as a set of codes or as a digital image.

The classic scheme of design process and the creative process explorations are still working in design education and practice fields. Nevertheless the design process and the creative switches occurring during this process started to be redefined within the collaboration of software programs and designers. This is the main concern where the designer steps back or in while designing and aiming to find solutions during the design act. There are instances where the unexpected shifts occur during the design process. These instances can be called unpredictable situations relying on the designer's perceptions through representations during the design process. If these unpredictable situations turn into novel conceptions then the designer's act seems to become creative. However according to some researchers novelty is not enough in order to call something creative. Margaret Boden defines creativity as a process of becoming sensitive to a question, to a flow or a missing link in an area of knowledge (Kowaltowski, Bianchi, & Teixeira de Paiva, 2010). It is the capacity to produce new and original ideas, which have to have a specific purpose and solve a determined problem (Kowaltowski, Bianchi, & Teixeira de Paiva, 2010).

Another point of view on this creative shift is about the liberation of a designer's imagination by the computational realm, which is free from material qualities and constraints (Terzidis, 2003). Terzidis emphasizes the evolvement of a designer's behaviors through this shift where intuition and perception are bound together. The dynamic control of the design process constitutes a new way of thinking, a creative thinking method through, image, mathematics, mappings and relational clusters of design as algorithmic processes aiming at the exploration of unpredictable, uncharted formal properties and behaviors in order to extend human thinking (Terzidis, 2003). In his own words:

> Computational formal explorations do not eradicate human imagination but rather extend its potential limitations. Computation is not a substitute for human creativity and therefore cannot be antagonistic. Rather it provides the means for exploration, experimentation, and investigation in an alternative realm. For the first time perhaps, form might be aligned with neither arbitrary creativity nor computational determinism but with creative computation and computational creativity (Terzidis, 2003).

Regarding this quote it can be said that the creativity norms and definitions also evolved with the developments in computational design technologies and hence the assessment of creativity of a design and its process also has changed in these circumstances. Therefore in order to design a case for understanding the potential role of moving image in computational design education needs a novel methodological approach rather than the previous research conducted on designer's behaviors by using protocol study.

4.2. *Cubehocholic* Workshop as a Case Study

4.2.1. Introduction

This study focuses on the integration of moving image knowledge accumulation of pre-production phases into the computational design process and tries to re-function this accumulation in early architecture design education. As a result of this integration this research can contribute to the architectural design education field in tandem with new technology and interdisciplinary fields by proposing a new position of moving image in early design education. The re-functionalism of another discipline's accumulation at the early architecture design education will be discussed through a case study conducted as a workshop named *Cubehocholic*, which was executed by the author.

While generating the case study Ambrose et al.'s study had an effect because of its pedagogical context. In this pedagogical context the main problem of animation in its static representations has been pointed out. In this part of the study it is stated that animation, "albeit imbued" with motion, thus becomes a shockingly static tool; simply a fly by, or walk through of an already completed project (Ambrose, Lostritto, & Wilson, 2008). Another view that has an impact on this case study generation is about the integration of storyboarding into architectural design education. According to René Davids the storyboards can introduce the concept of movement through space and time without complex computer technology and the critical and technical challenges it presents (Davids, 1999). In addition to these views Nic Clear's studies had a huge influence during the design of this case study and his views on the construction of the moving image is employed as a reference while developing the case study in this thesis. The primary stages of constructing the moving image are:

> (1) Setting out the narrative and tell the story of the project, (2) describing processes involved in the production of the project, (3) communicating style by using the graphic language of the project and (4) developing and communicating the spatial ideas of the project (Clear, 2013).

4.2.2. *Cubehocholic* as an experimental learning environment

The main aim of the workshop is to integrate the moving image as a model, which directs the designer into the computational thinking process by triggering the creative act during the design process. The reason for overlapping these two mediums lies beneath their dynamic essence where the design process can be experienced in terms of time and motion notions. Therefore in this study moving image is introduced as a model that gathers and synthesizes different kinds of information and components within a single unity by articulating the complexity through variations of the multi-dimensional model. During this integration there were initially three model generations (1) moving image model (MIM) (2) physical model (PM) and (3) computational model (CM). The aim was to achieve an overlapped hybrid model by projecting the moving image and computational model onto the physical model at the end of the workshop.

Bloom's revised taxonomy was used while designing the workshop in order to assess the final results, and the learning objectives was determined linked to the cognition level and knowledge dimension matrix as below:

- The students will generate/construct different design representation models such as moving image model, computational model, digital model and physical model and express their design through these models.
- The students will learn to combine multiple design representation models during their design process.
- The students start to learn the basics of 3D modeling and computational modeling terms and will be able to use 3D modelling and computational modelling tools in beginner level.
- The students will start to identify the relationships between the modeled (domain) and the model (range) .
- The students begin to evaluate the design process as combinations of variable situations and evaluate the relationship between these variables.
- The students will learn to define the design problem from an intuitive or ill-defined to a well-defined one.
- The students will explore and define the related vocabulary of the design problem.
- The students will define the parameters of the design problem.
- The students will organize the design process.
- The students will develop a thinking way/behavior through setting the relations between the first, the next and the last step of the design process.

Therefore, they will set a dynamic design procedure in which the steps are connected and related to each other.

4.2.2.1.Description

Cubehocholic I workshop was held at İstanbul Kemerburgaz University in the Department of Architecture on 02-05 June 2014 at Turkey. It was a four-day workshop established as a summer event after the official spring semester 2013-2014. The participants included six-first year and eight-second year architecture and interior architecture students in addition to one graphic designer who is also a graduate student. There was one tutor for fifteen students. Table 26

Table 26 Participants' list according to their department and education year

Participants	1st year	2nd year	Graduate
Architecture	3	8	
Interior architecture	3		
Graphic design			1

The workshop explored a design process through different model types, tools and concepts. *Cubehocholic* tried to open a dialogue on new ways of looking at the real object and its transformation into different types of models as aforementioned (1) moving image model, (2) physical model and (3) computational model. During this model exploration the analogue sketching techniques engaged with computational design tools with the use of Rhino and Grasshopper software. None of the participants had used geometric and parametric modeling software before, however some of them were familiar with 2D drawing with AutoCAD software and Photoshop (especially the second-year architecture students). In addition to that except the architecture and interior architecture students the graphic designer had never worked on a 3D design task and model. The design of the workshop was grounded in Sorguç and Selçuk's "Computational thinking process cycle" (Sorguç & Selçuk, 2013). Figure 33 Instead of giving a design problem just a sole little wooden cube was given as the real model at the beginning of the workshop in order to investigate the model transformations and the creative shifts. Figure 34 In addition to the wooden cube the workshop poster has been given as a clue to start on. All the students commented on what they see and what they perceive through the poster and what they understand from the main phrase of the poster "the story of the cube between moving image and computational design." Hence the design goal was self-defined by the students after a brief introduction. Figure 35

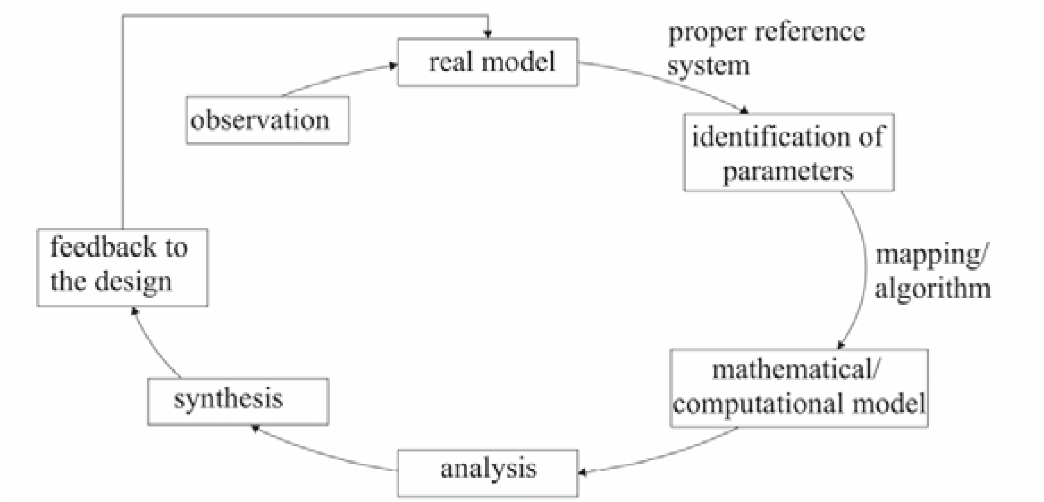


Figure 33 Computational thinking process cycle by Arzu Gönenç Sorguç and Selma Arslan Selçuk (Sorguç & Selçuk, Computational Models in Architecture: Understanding Multi-Dimensionality and Mapping, 2013).

Figure 34 Wooden cube as the real model

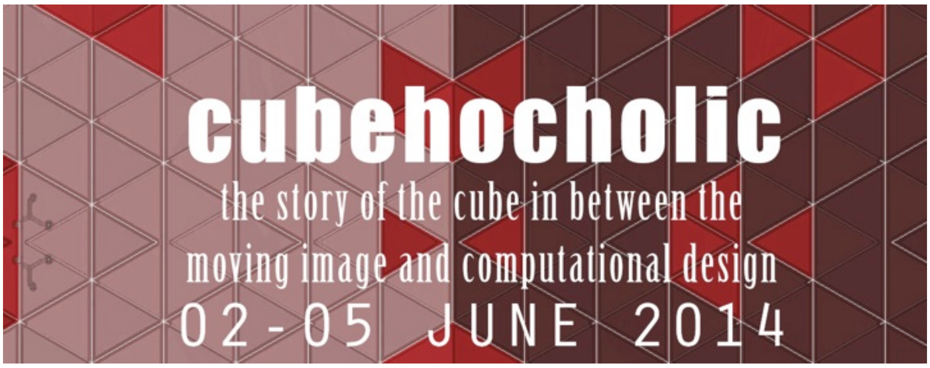


Figure 35 The main phrase of the *Cubehocholic* workshop cropped from the poster

4.2.2.2.Materials

The main materials of the workshop were: cardboard, model making materials, storyboard template (drawn by the executer of the workshop), pen, pencil, drawing materials, laptop and as software Rhino software and Grasshopper plugin.

4.2.2.3.Components

The timeline of the workshop was designed on a schedule of 8 hours per day structured upon three acts called components; (1) lectures (2) tutorials and (3) work sessions. The components of the workshop are linked the integrated scheme of the wooden cube to the computational thinking process cycle. Figure 36

Lectures are constructed on the model definitions, brief instructions and screenings. Tutorials were organized in three parts (1) 3D Modeling (Tutorial: Rhino 01, Rhino 02) (2) Computational Model Generation (Tutorial: Grasshopper 01, Grasshopper 02) and (3) Projection Mapping. The initial basic terms, interfaces, basic geometry, editing commands, components, definitions and functions are introduced during tutorials (1), (2) and (3). Following the lectures and tutorials work sessions were organized in order to develop the self-defined design tasks. Table 27

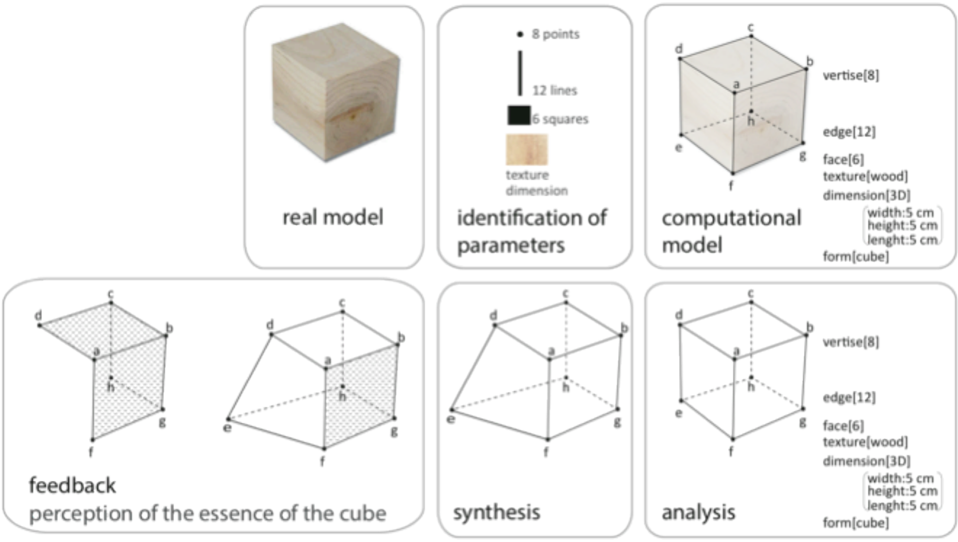
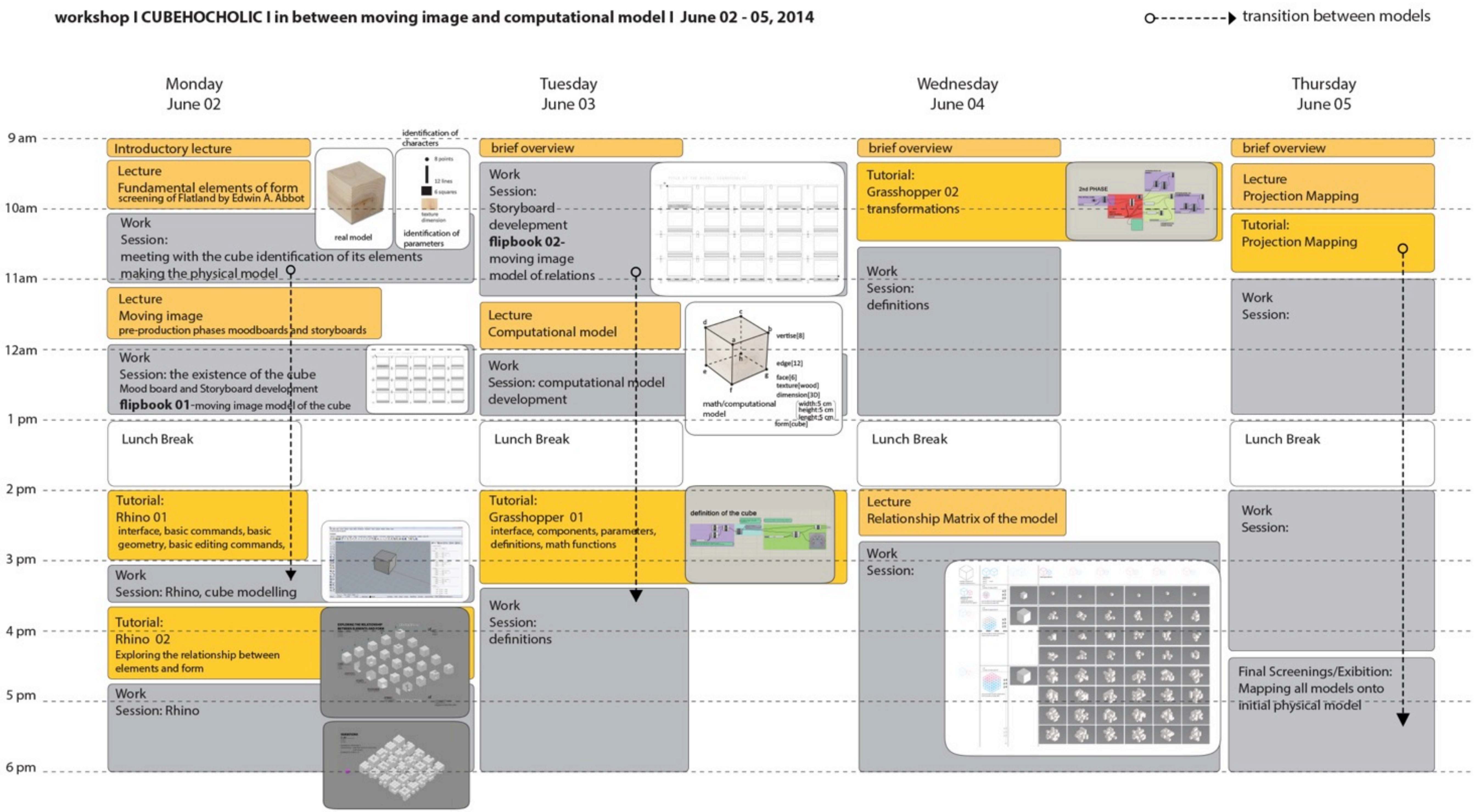


Figure 36 The integration of the wooden cube into Sorguç's & Selçuk' Computational Thinking Process Cycle

Table 27 Timetable of the workshop



Day 1:

The lecture part started with the discussion on the workshop poster. What is seen on it and what is perceived were the main questions. After the discussion the fundamental elements of form and dimensions were discussed through the screening of “Flatland”, an animated movie based on the novel of Edwin A. Abbot. Figure 37 “Flatland” is about living in a two-dimensional world named “Flatland” in which the characters are geometric shapes such as squares, circles, lines, hexagons, pentagons and the protagonist of the movie is a square.

Figure 37 Edwin A. Abbot’s book cover and Flatland’s movie poster

Physical Model

Afterwards the students met with the wooden cube and they made a representative physical model of the cube in different scales with the materials that they had chosen in the first work session. Figure 38

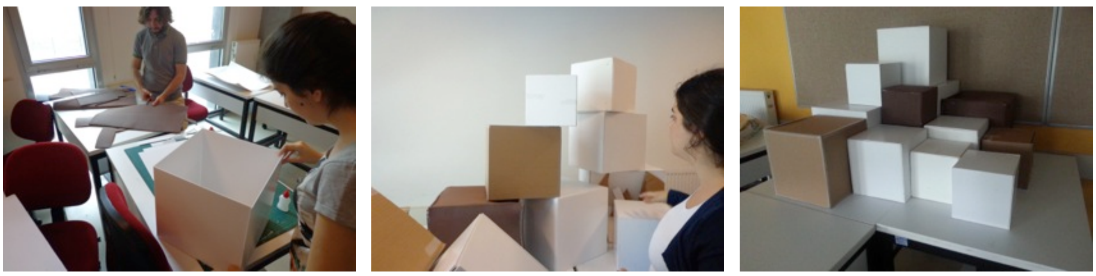
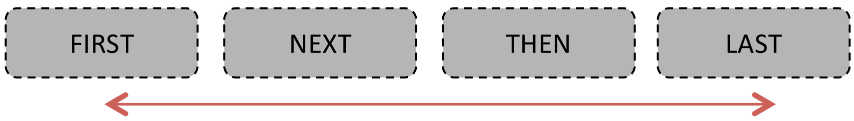


Figure 38 Physical cube models with different scales

Moving Image Model

Later on, a brief lecture on moving image preproduction phases was conducted. Following this lecture the second work session aimed to develop mood board and storyboard of the existence of the cube. The students were given a storyboard template and at the end of this session some of the students developed their first flipbook (01). Figure 39**,** Figure 40**,** Figure 41

As aforementioned in Chapter 3, moving image as film, video or animation has the development and preproduction phases where the skeleton of the image as a model is generated. These phases are conducted in the stages that are scripting, mood boarding and storyboarding, which have their references a prior to computational thinking procedure. Mood boarding is like a mind map that gathers the necessary parameters and elements all together. Storyboard is an "ordered strategy" (Temkin, 2003) like an algorithm in which the rules and relations are outlined through a time-based composition. It is a documentation of the project in which all the variable elements of content are mapped scene-by-scene, step-by-step. The mapping has a narrative that engages the acts, moves as sequences of first, next, then and last steps.



Therefore storyboards in this session worked as an information package about the cube's story in terms of characters/elements/parameters, translations/transformations and relationships/events/moves/actions. While developing the storyboards students were asked to identify this information as showed through the frames below.

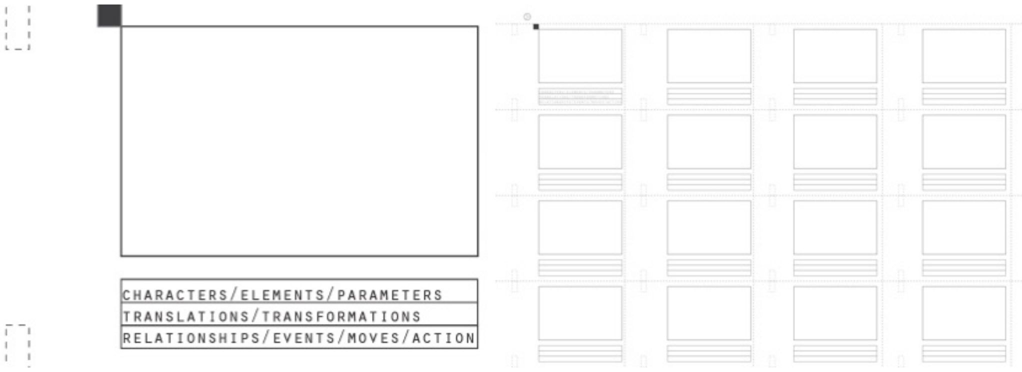


Figure 39 Storyboard template (drawn by the author)

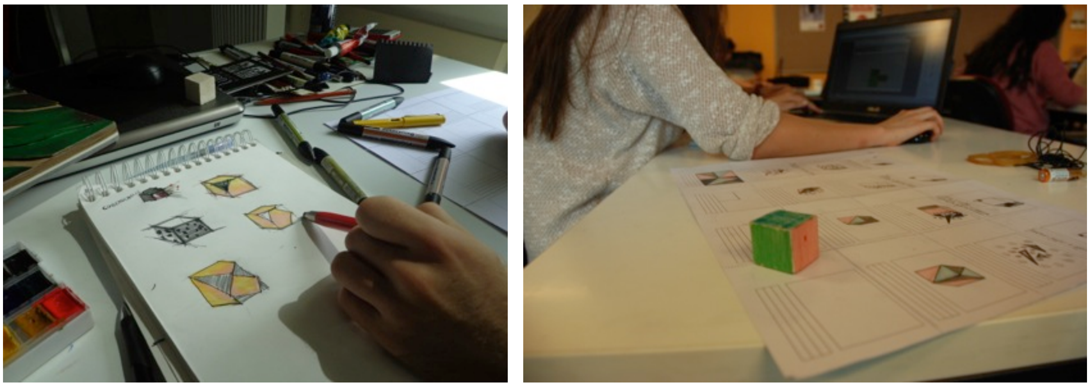


Figure 40 Students are working on their storyboards

Figure 41 The first flipbook (01) at the end of the session

Throughout this session the identification of parameters, characters and elements started to appear. After developing the initial storyboards, the tutorial session for geometric modeling in Rhino was started. The tutorial was conducted on the basics and interface of the software as aforementioned. During the work session the students tried to get used to the experiential viewports of software and the dynamic perceptions of orthogonal and perspective viewports. “Flatland” was very beneficial in terms of the perception of these viewports and how they relate to each other. In addition to the basic commands and editing tools students also explored the relationships between elements and forms in the second tutorial (Rhino 02).

Day 2:

Moving Image Model

MIM generation via storyboards kept going in the morning and students developed more frames and more details on the relationships and transformations.

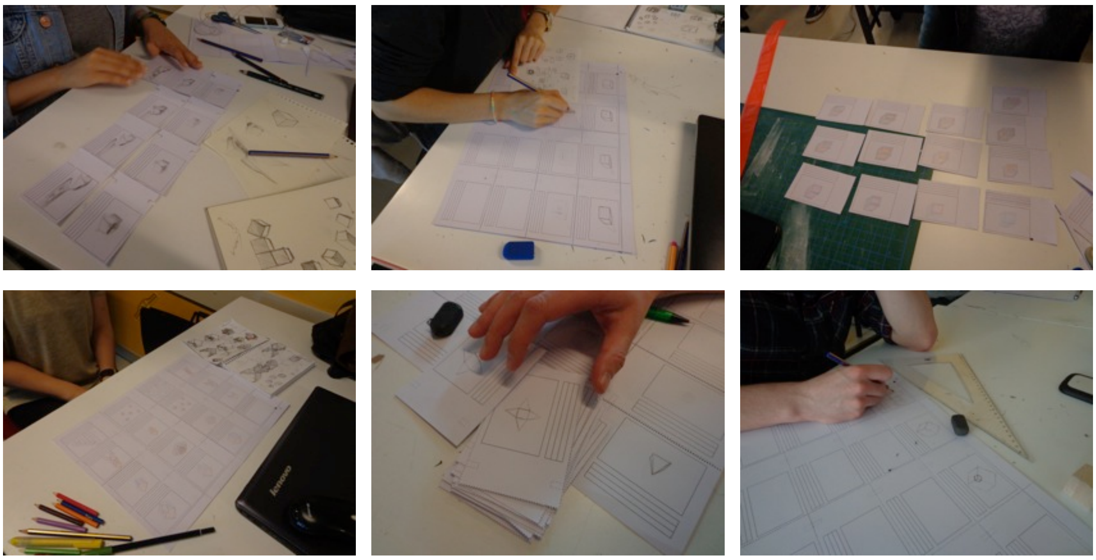


Figure 42 Storyboards of students from second day of the workshop

Computational Model

Regarding the definition of computational model as process models based on actual relationships requiring a comprehension of algorithmic thinking, parameterization, multidimensionality and reference systems (Mozer & Sitton, 1998; Killian, 2008; Sorguç & Selçuk, 2013), a lecture on computational models was conducted as an introduction. Afterwards students tried to redefine and redevelop their storyboards. The whole afternoon was dedicated to a tutorial on Grasshopper (01) focusing on its interface, components, parameters, definitions and math functions. Figure 43 Students tried to make a cube definition by using Grasshopper plugin during the work session hours. They tried to define the cube through variable components and parameters.

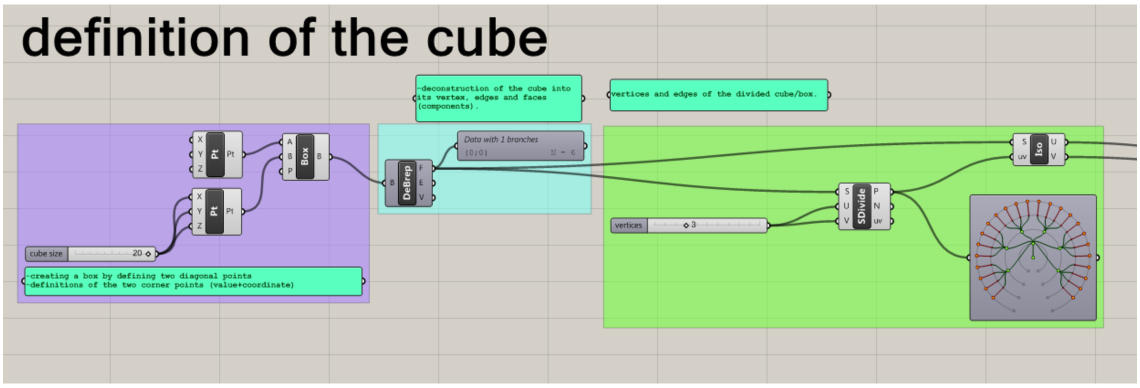


Figure 43 Tutorial, Grasshopper 01: The definition of the cube

Day 3:

On the third day of the workshop the Grasshopper (02) tutorial focused on the transformations of the shapes and forms and their relations with components and parameters. Afterwards students started to develop their own cubes by using their storyboards, in which they identified the parameters and transformations sequentially. Throughout this work session it was observed that many of the students protected their initial ideas and concepts but they changed or manipulated the sequential acts of the storyboards according to their definitions. Figure 44 Some of them revised their initial ideas according to their definitions in Grasshopper in which unexpected outcomes occurred occasionally through the definitions. They unintentionally started to develop a relationship matrix of their cube models. Table 28 Following this transformation of MIM into CM, a lecture on Relationship Matrix of the Model was conducted. Table 28 During the lecture part the variations of the cube and its relations to its parameters and transformations of these relations were discussed.

Figure 44 The storyboard of a second year architecture student

Table 28 Relationship Matrix of the Model

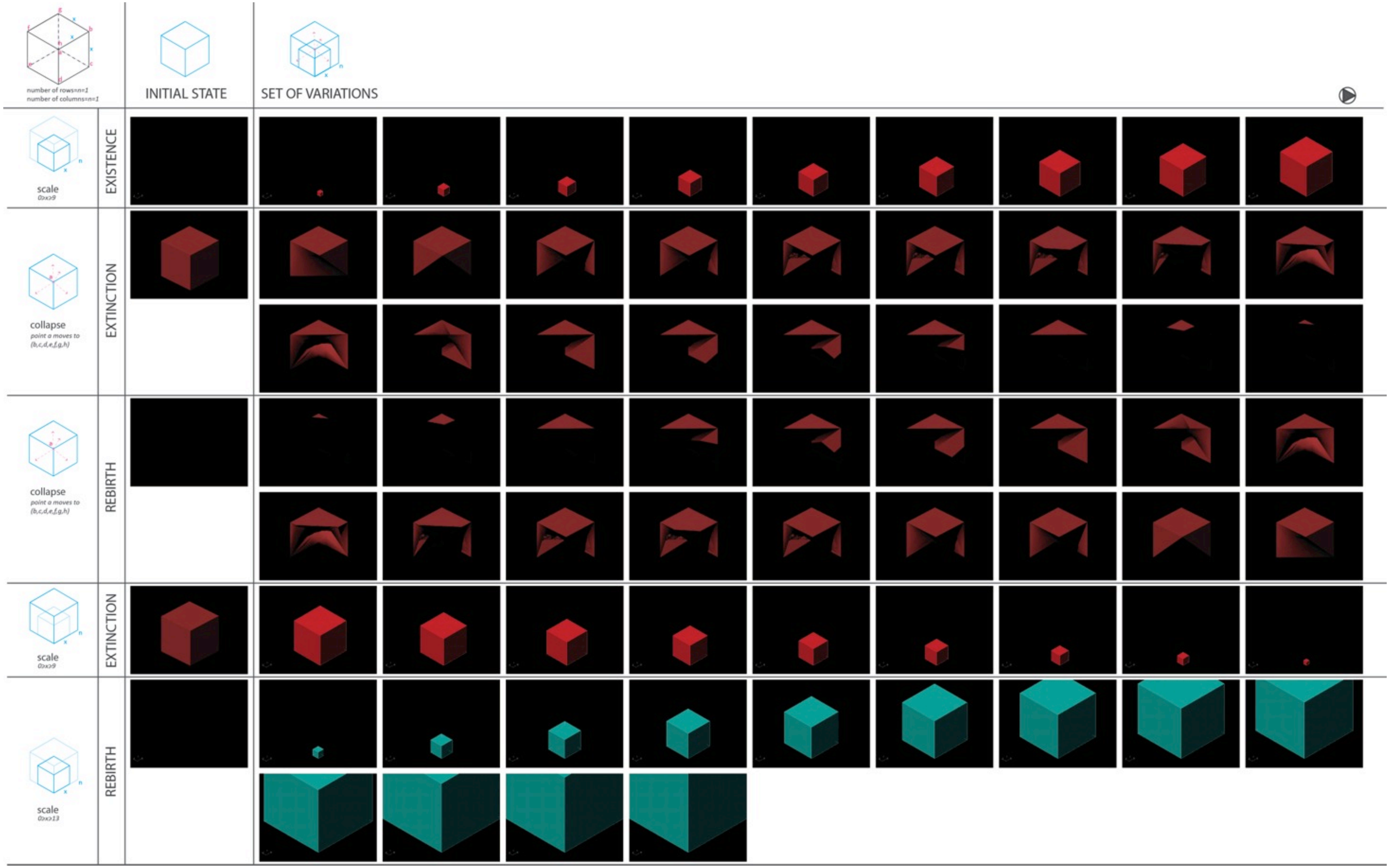
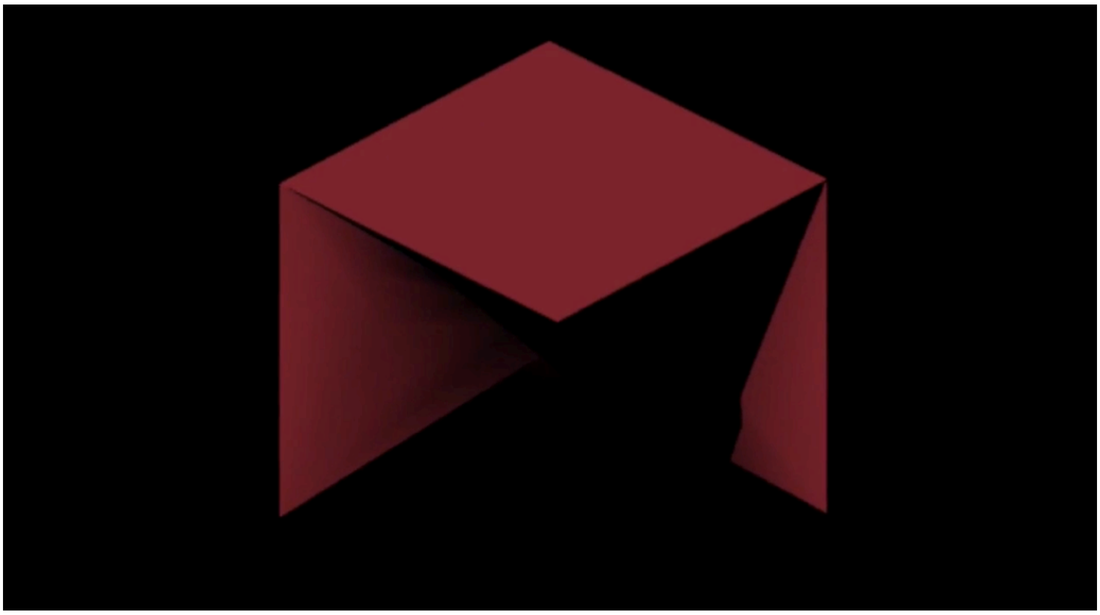


Table 29 The Relation Matrix of MIM and CM

	MIM (STORYBOARD)	CM	MIM	CM
CHARACTERS/ELEMENTS/PARAMETERS	POINTS OF THE CUBE		COLOR OF THE CUBE (RED)	COLOR OF THE CUBE (RED)
TRANSLATIONS/TRANSFORMATIONS	EXTINCTION	EXTINCTION	-	-
	REBIRTH	REBIRTH	-	-
	REBIRTH DIFFERENTIATION	REBIRTH DIFFERENTIATION	RED BECOMES BLUE	RED BECOMES BLUE
RELATIONSHIPS/EVENTS/MOVES/ACTIONS	COLLAPSING THE POINTS	REPLACEMENT OF POINTS	-	-
	REDUCING THE NUMBER OF POINTS	REDUCING THE NUMBER OF POINTS	-	-
	MELTING THE POINTS	-	-	-

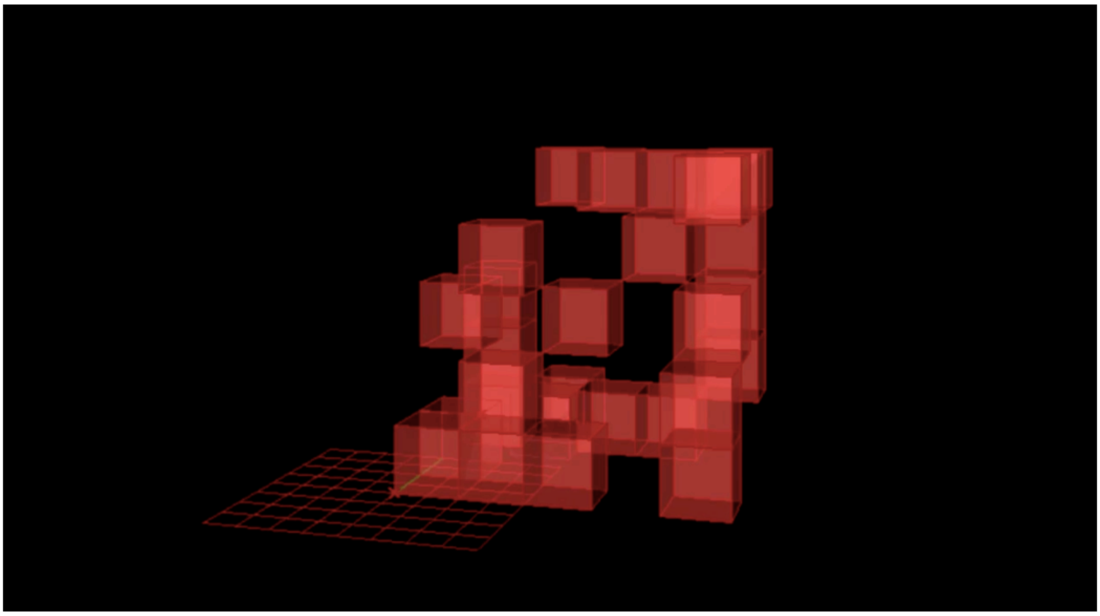
Day 4:

The lecture part on this day was on projection mapping and several projection mapping examples were shown to students. The tutorial on projection mapping was canceled because the students needed more time to work on their cube's CM. Students continued to developed their CM and they produced multiple frames as final situations of their cubes up to the afternoon of the fourth day. They produced a moving image sequence of their designs in order to project onto the physical models. Figure 45 At the end all the models were projected on screen as a final exhibition and due to the timeline schedule the executor of the workshop directed the mapping session; the projection mapping tutorial part has been postponed to be a one-day workshop together with exhibition.



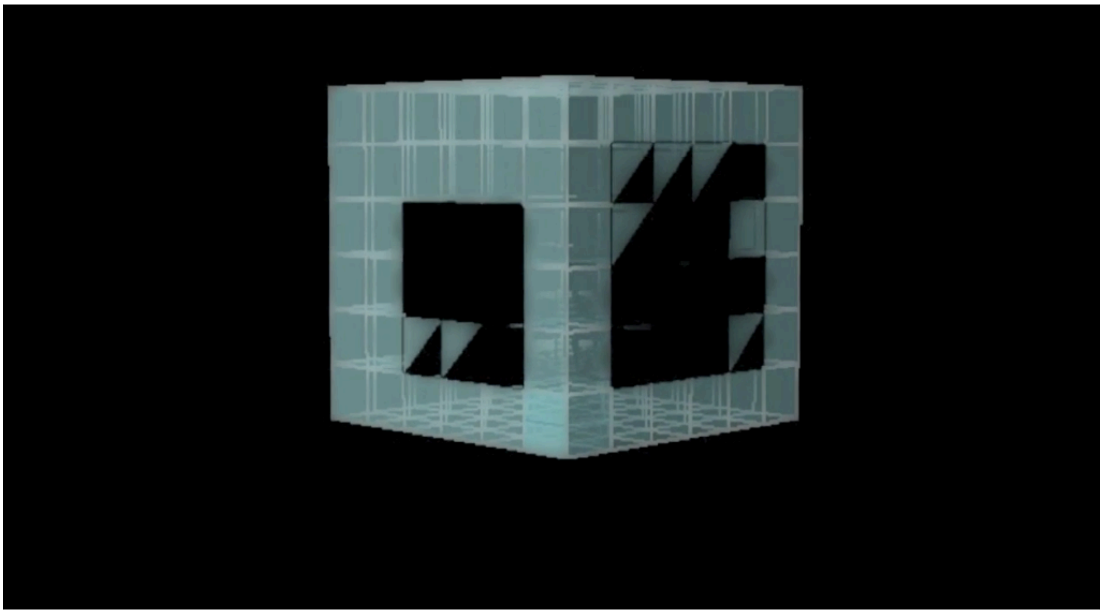
2nd year architecture student's moving image sequence
https://drive.google.com/file/d/0BzF9GD5Up4EpUE9oX21CUFdiTFk/edit?pli=1

Figure 45 Final moving image sequences



Graphic designer's moving image sequence

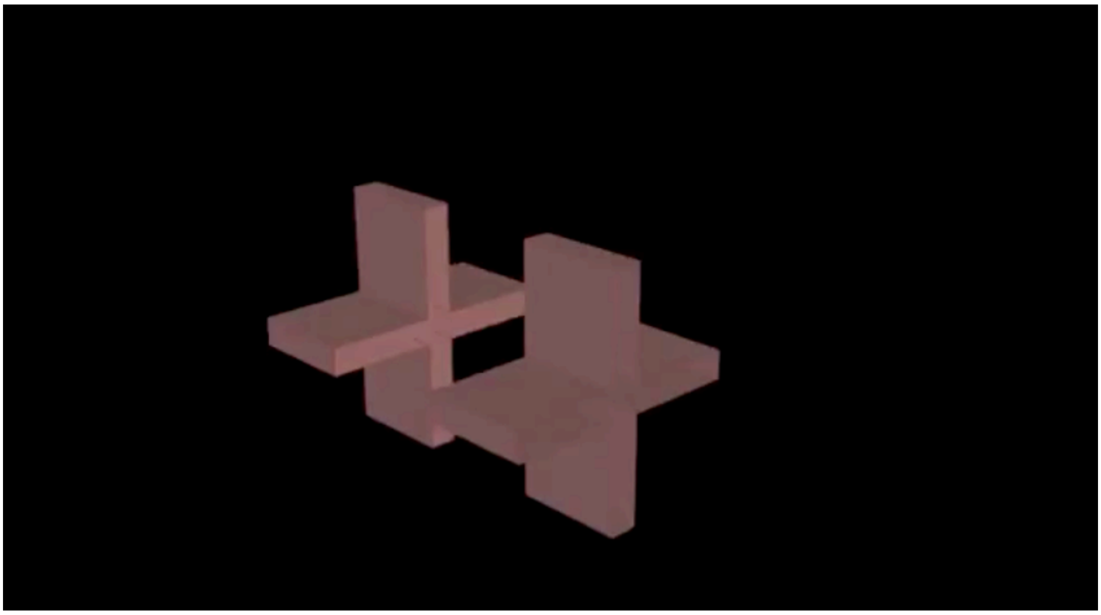
https://www.drive.google.com/file/d/0BzF9GD5Up4EpV0toZjQ2VkhxcWM/edit ?pli=1



1st year architecture student's moving image sequence

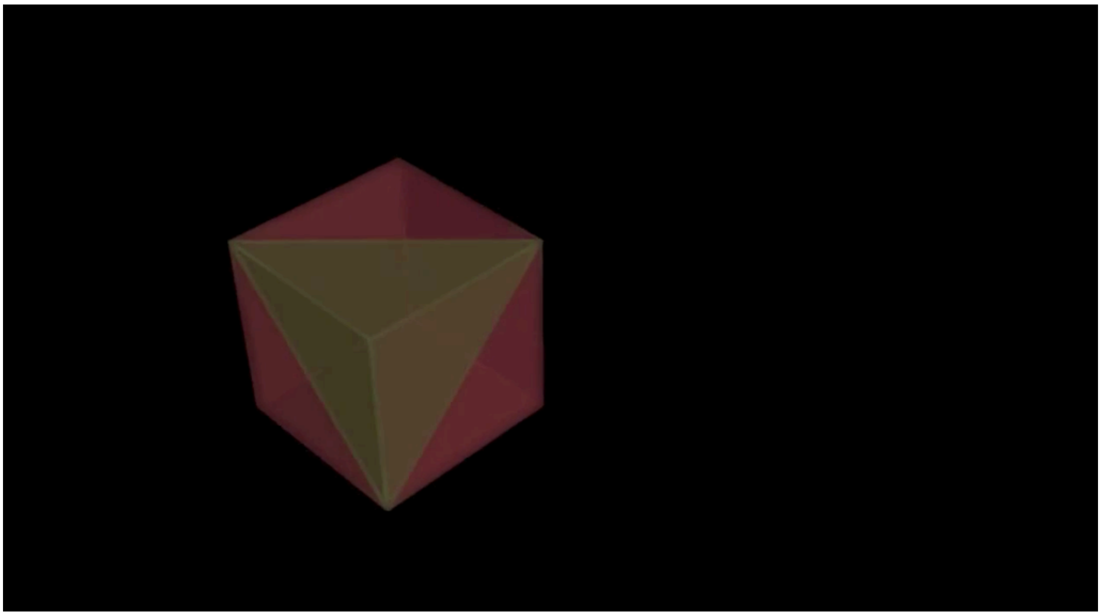
https://drive.google.com/drive/folders/0BzF9GD5Up4EpVl9OMGpxRFdaUms

Figure 45 (Continued)



1st year interior architecture student's moving image sequence

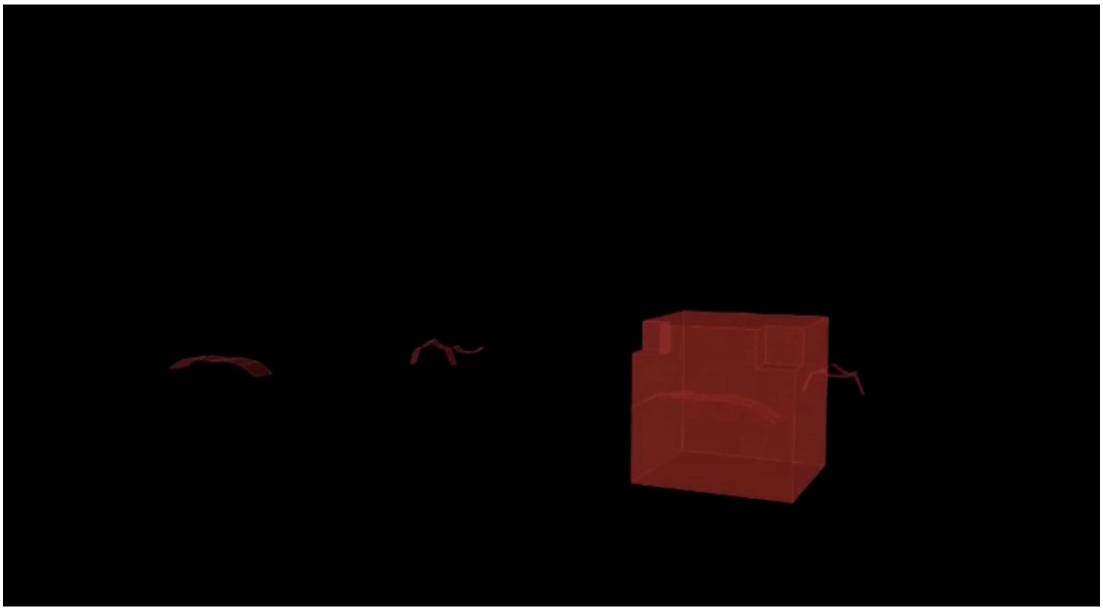
https://drive.google.com/file/d/0BzF9GD5Up4EpTG9xS094ZWZaRjg/edit?pli=1



2nd year architecture student's moving image sequence

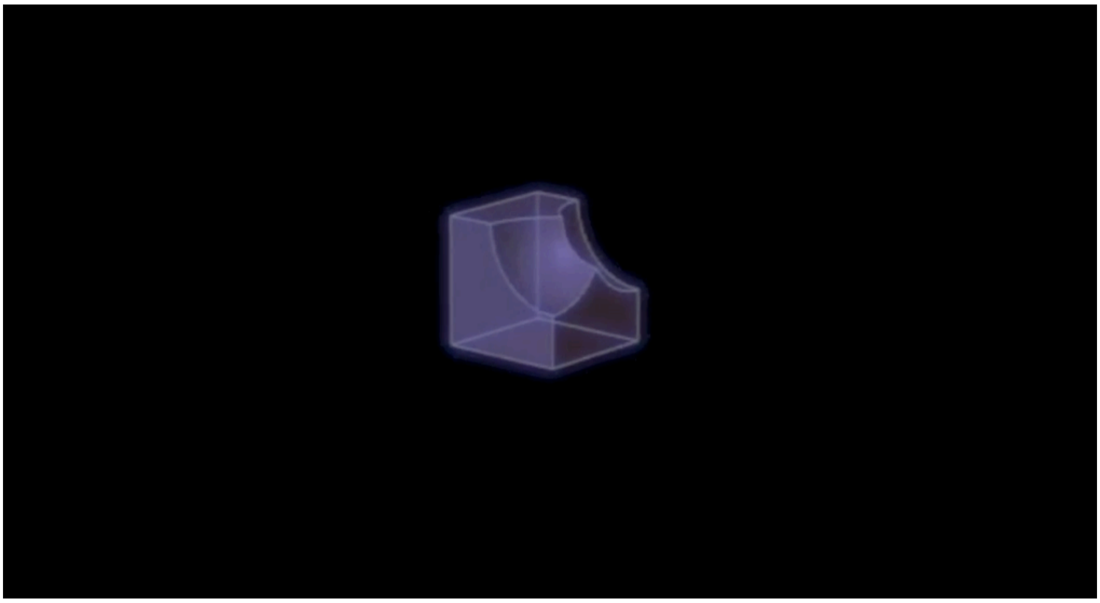
https://drive.google.com/file/d/0BzF9GD5Up4EpUTd2OWVFdDhwWEk/edit?pli=1

Figure 45 (Continued)



2nd year architecture student's moving image sequence

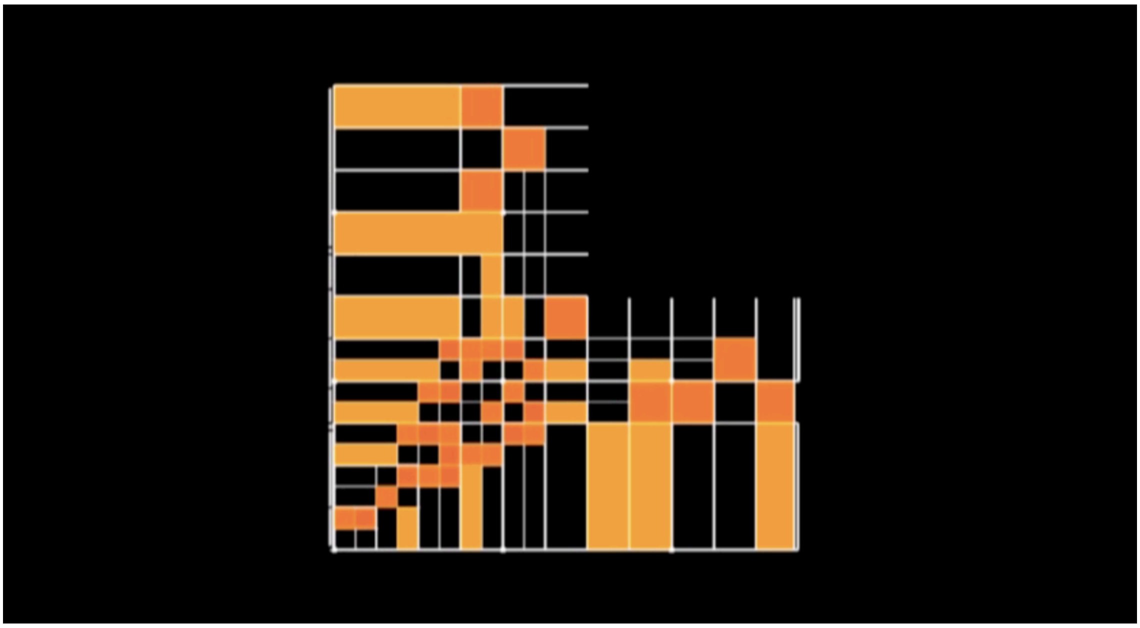
https://drive.google.com/file/d/0BzF9GD5Up4EpVzVYMVd4ZDJzdXM/edit?pli=1



1st year interior architecture student's moving image sequence

https://drive.google.com/file/d/0BzF9GD5Up4EpZkNxMDVTOW1aREE/edit?pli=1

Figure 45 (Continued)



2nd year architecture student's moving image sequence
https://drive.google.com/file/d/0BzF9GD5Up4EpN0w1cV81Q1RCTWc/edit?pli=1

Figure 45 (Continued)

4.2.2.4.Discussion

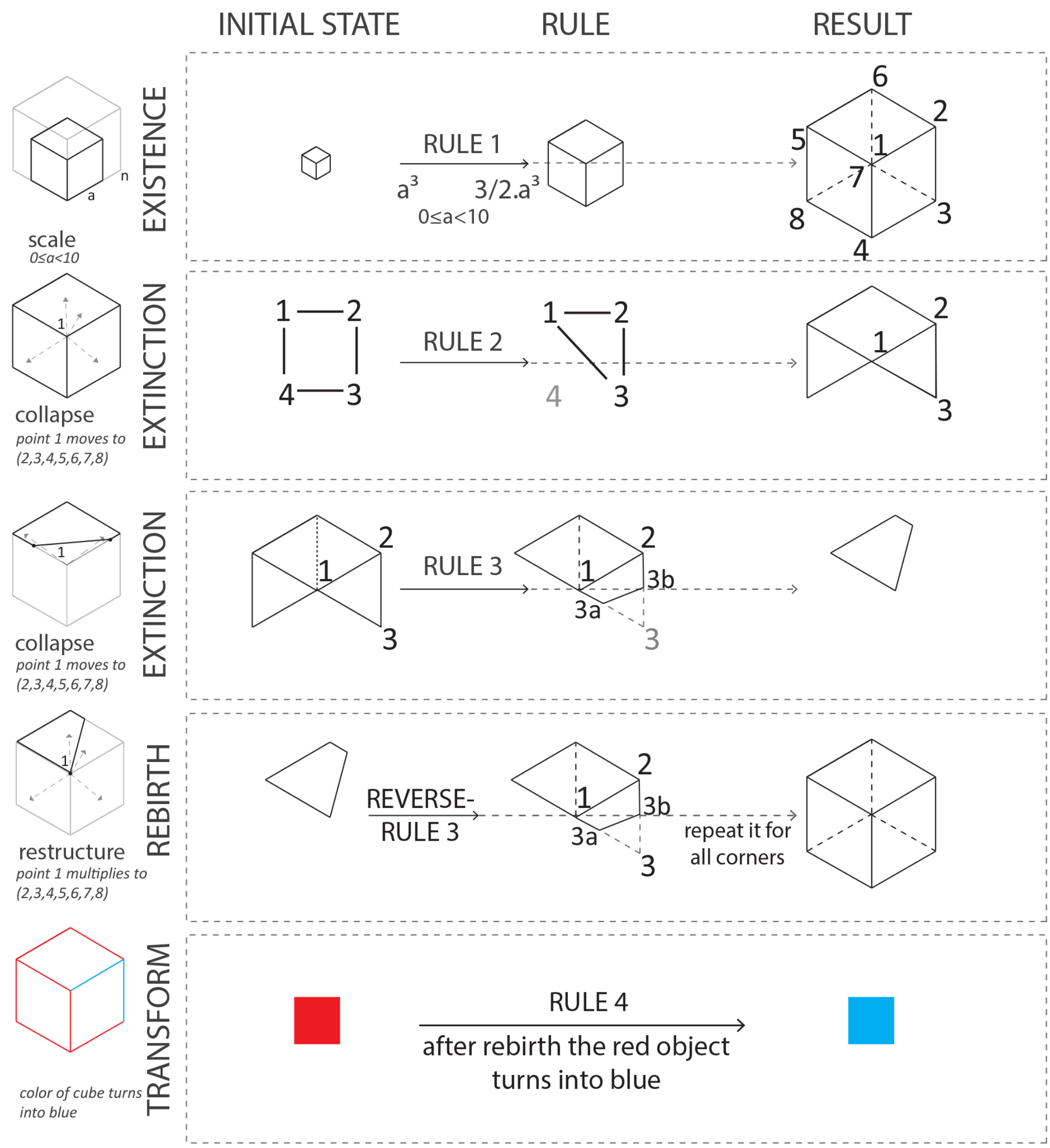
The students produced the design of probabilities throughout a computational thinking process at the end of the workshop session. It has been observed that while designing these probabilities the complexity of the design arises due to the translation from storyboard to moving image model. These can be seen from the frame numbers that generally increase during the computational model generation after the storyboarding phase. This can be interpreted as a better grasping of relationships, interrelations and transformation of the factors during the design process.

Another observation was about the transition between multiple model generations and how they differ from each other. The initial differences between the physical and computational model are a realization of the probabilities and the ability of construction of the variations in this immaterial medium where the designer can see and explore the complete instances. That is, the designer sees "if and elses" in the computational model and she just explores the "if" conditions with physical models. This situation is also relevant to storyboards in which the designer can see various states of design. While experiencing these if and else states, some of the students realized that they had generated a rule-based design during the workshop. They started to have a new level understanding of their own design process. And they started to have a new level understanding of their design. The generated variation matrixes directed them to see their own design as a set of generated situations. Terry Knight defines this situation as giving insight into the object that is generated. She claims that computational design can be two fold, fast and slow, where slow computing does not require any computer in its essence. Still, it directs the designers to the generation of a set of designs instead of designing a single design (Knight, 2012). The variety of different set of designs strengthens both visual and relational thinking. Although shape grammars are not specifically examined in this study, it has to be mentioned that some of the studies generated their own shape grammar that is constructed upon the if-then statement. Knight define this statement as below:

> The *If* part specifies the condition for doing something to a design, the *Then* part is what happens if the condition is satisfied. And a shape rule is a visual thinking and reasoning way-applying applying rules in a step-by - step computation to generate a design. (Knight, 2012)

This definition suits the definition of the storyboard in this study that is a documentation of the project in which all the variable elements of content are mapped scene-by-scene, step-by-step by engaging the acts, moves as sequences of first, next, then and last steps. During this mapping procedure the redefinitions and the reinterpretations of the wooden cube as design, constructed as "a range of rules that correspond to familiar design moves" (Knight, 2012). The main moves generally included adding, subtracting, moving and multiplying the components and elements that were defined during mood boarding. Besides being a generative tool for setting the rule sets linking to the solution sets, the defined vocabulary and generated grammar during storyboarding work as an analysis phase binding the visual thinking to relational thinking. In other words, it works for the transition from the static to the dynamic design model. There are also non-parametric rules such as camera angles used for positioning the object in the frame in spatial context.

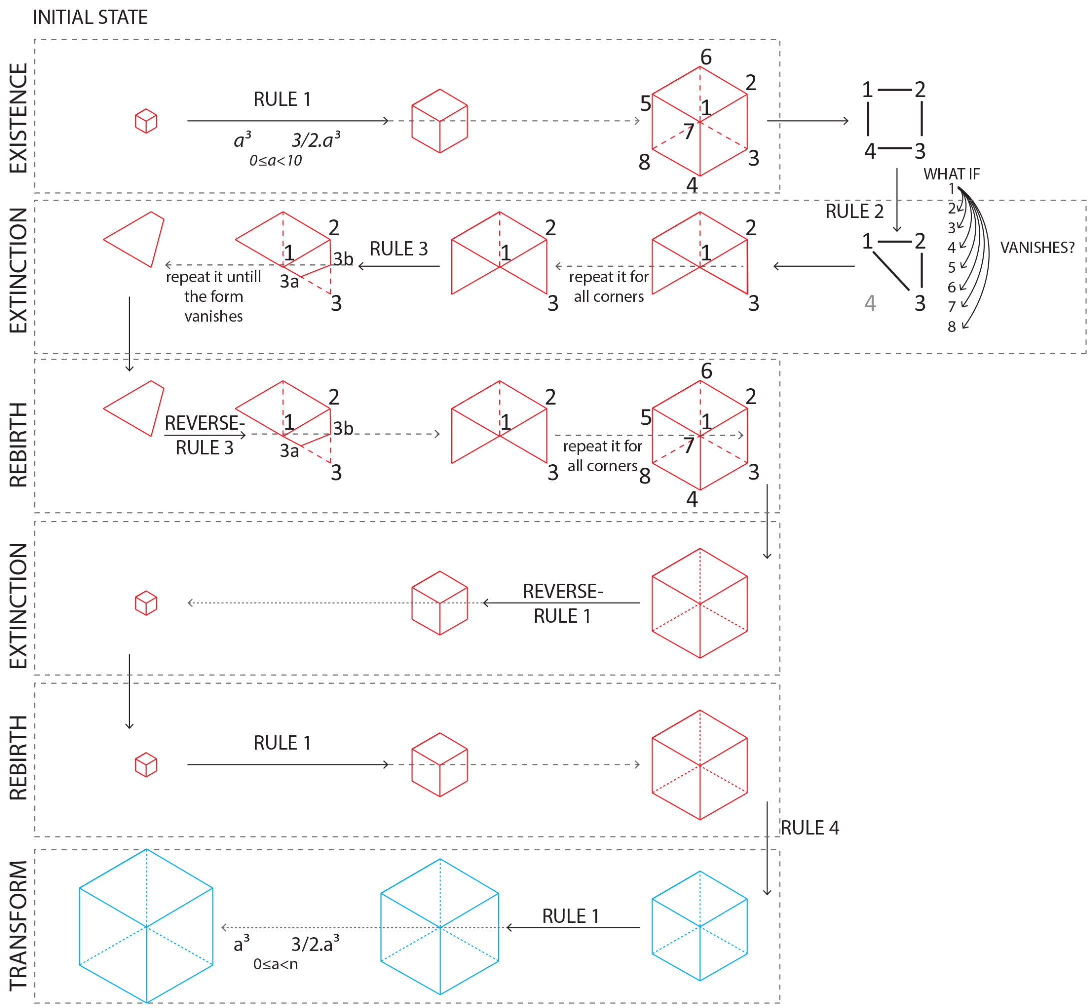
Table 30 The rule set for the generation of the story of the cube



The transitions and translations can also be called in Knight's terminology a flow from "slow computing" to "fast computing" in which the students intuitively created their own problems from the observation of the wooden cube and then constructed a set of rules that defines the set of solutions by redefining and reinterpreting the cube definition through both moving image and computational models. However some of the students did not realize this rule based configuration throughout their design and they just concentrated on the sequential frame generation for the final moving image model.

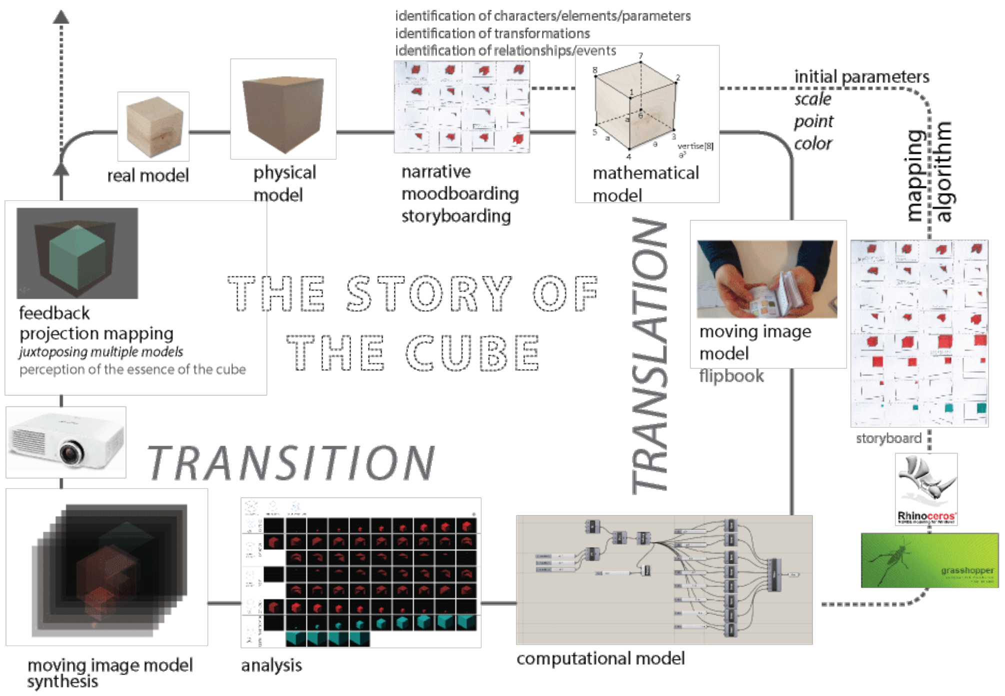
While some of the students changed their storyboards and their initial ideas during the translation to the computational model, some of them translated their storyboards as they were.

Table 31 The translation of storyboard to a rule based design generation



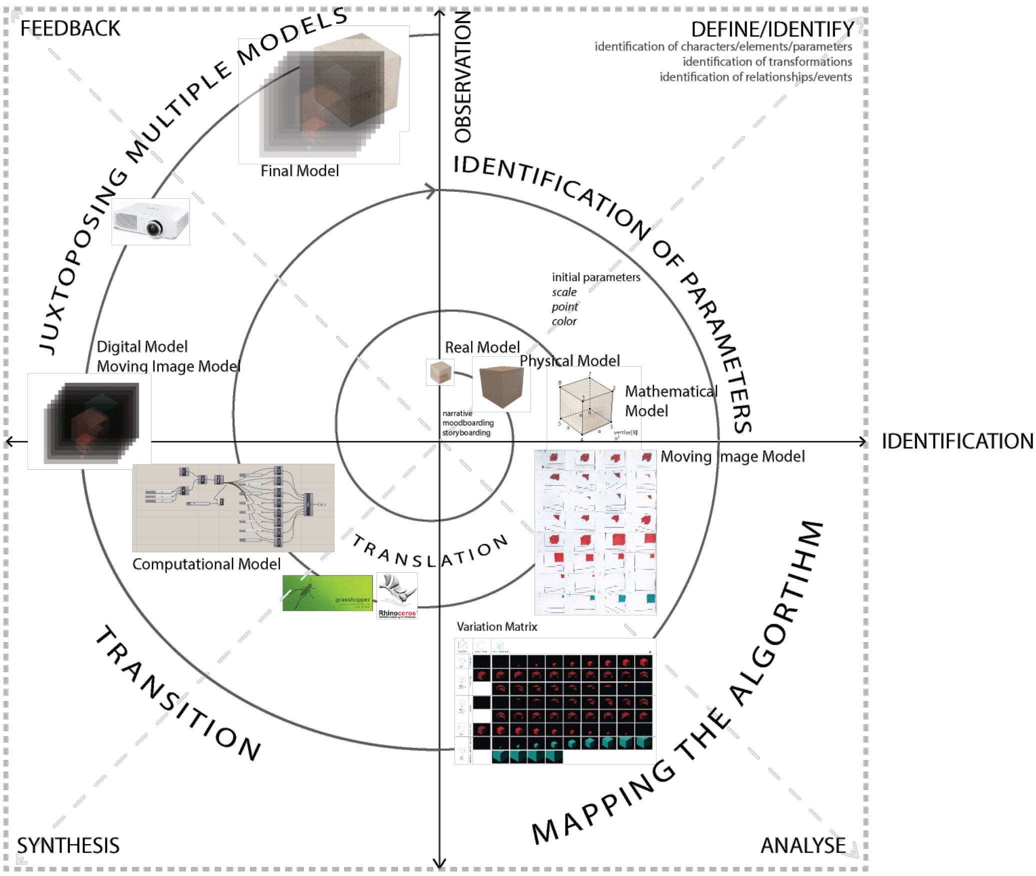
Another substantial observation is about the students' way of thinking during the design process. The workshop was conducted upon Sorguç & Selçuk's computational thinking cycle as aforementioned. Therefore the design processes of the students yield through this cycle. However the feedback mechanism and its relevance has changed for every student. While second year students have translated their storyboard to computational model directly, the first year students have manipulated their storyboards during this translation. Thus it can be said that the feedback mechanism worked at different phases for first year and second year students. Also some of the students realized unexpected results through their computational models and they have generated their moving image model according to these unexpected results called creative shifts in this study. The students started to configure and realize the transition of from one model to another and they started to comprehend that the output of one model transforms into another model's input eventually. This situation directs the students into a spiral way of thinking where the learning activity occurs through the feedbacks gained from the model generations.

Table 32 The story of the cube embedded into the computational thinking cycle



Definition of the cube is one of the most essential parts of the study. The whole process started from the essence of the cube and its visual representation. When the process carried forward, the representational mediums started to differ and initial visual thought started to transform into a relational one. At the end this transformation resulted in many cube definitions that were constructed on the discovered relationships. And the dialog between the designed and the designer started to evolve according to this transformation. This dialog does not lie just on the geometry or shapes; it also starts to lie in the relationships. It has been observed that as the design experience increases, this dialog turns into a much more relational way of thinking rather than visual.

Table 33 The spiral way of thinking during the generation of the various cube models



The juxtaposition of all models (PM, MIM and CM) releases a new understanding towards reality notion through the projection-mapping phase of the workshop. Reading the juxtaposed models together directs the students into a new reality, where the medium is no more solely physical, digital or virtual rather it is also multidimensional because of its manifolds that can be seen at the same time. The reading of the juxtaposed model, or seeing the design solution as a whole at this new reality, opens a gate towards also new interpretations of the designed models and also the design solution/ designed object itself. Neither of the models dominates each other they act together as a different representation where the different meanings can emerge through its perception.

4.3.*Cubehocholic* II Workshop

4.3.1. Description

Cubehocholic II workshop was held at Middle East Technical University in the Department of Architecture, Ankara, Turkey, on 09 December 2014. It was a three-hour workshop integrated to the ARCH 333 *"Mathematics in Architecture*[12]" course. Nine forth year architecture students participated to the workshop and there were three tutors, Assos. Prof. Dr. Arzu Gönenç Sorguç, Müge Krusa (architect), the author. The main idea of the workshop is grounded in (as like the first workshop *Cubehocholic*) Sorguç and Selçuk's "computational thinking process cycle". The moving image model is also integrated into this computational thinking cycle. Figure 46 There were initially two model generations (1) moving image model (MIM) and (2) computational model (CM) during the workshop.

The components of the workshop were (1) lecture (2) tutorials and (3) work session. Due to the students' experience the lecture part and discussion part of the workshop had been revised. As in *Cubehocholic*, the workshop started with a brief lecture on moving image and its preproduction phases focusing especially on mood boards and storyboards and elements of form and their relationships to the whole. In addition the

[12] *ARCH 333 "Mathematics in Architecture"* is an elective undergraduate course that has been being executed by Assos. Prof. Dr. Arzu Gönenç Sorguç for eight years. The course started in Department of Architecture at Middle East Techical University (METU) in 2006. Unlike the classic attitude towards mathematics in architecture education Sorguç has adapted the course to architecture design education as a way of merging mathematical thinking with the design process. This merging directs the students into an exploration process where they can evaluate their process and product as a whole through mathematical thinking (Sorguç ve Selçuk, 2009).

lecture part tried to open a gate towards the design through the title of the workshop "*Cubehocholic* II: The story of the cube between moving image and computational design." The initial discussions concentrated on the definitions of the terms included in this title through the questions (1) What is moving image? (2) What is a cube? and (3) How can a cube be computed?

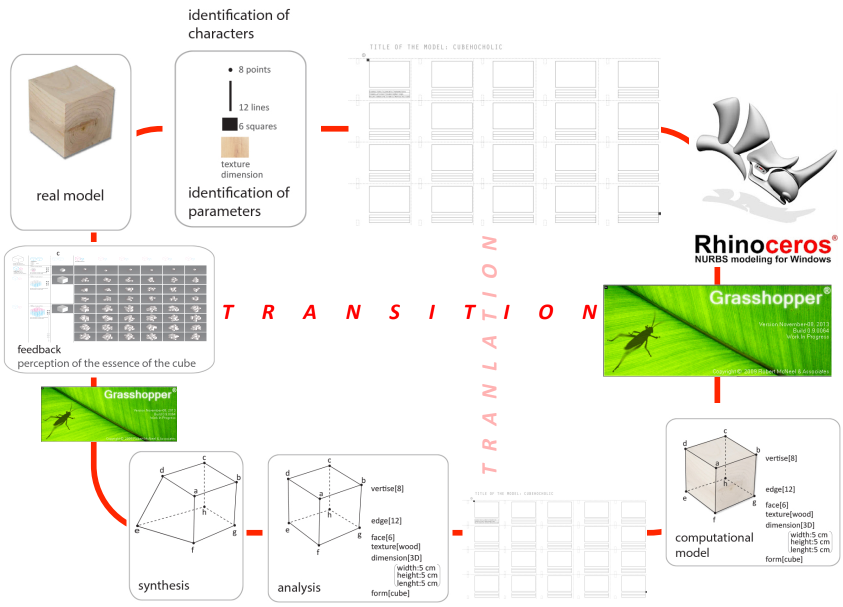


Figure 46 The moving image model integration to the Computational thinking process cycle of Arzu Gönenç Sorguç and Selma Arslan Selçuk

After the lecture part students had started to observe and examine initially the given wooden cubes as the real models at the beginning of the work session and they defined their own design problem according to this observation. The students were given a storyboard template and at the end of this first work session all of the students developed their first flipbook. Figure 47 They identified the characters/ elements/ parameters, translations/ transformations and relationships/ events/ moves/ actions that appear in their design below the frames of the storyboard templates. Figure 48

Figure 47 The observation and then transition of the cube to the storyboard templates

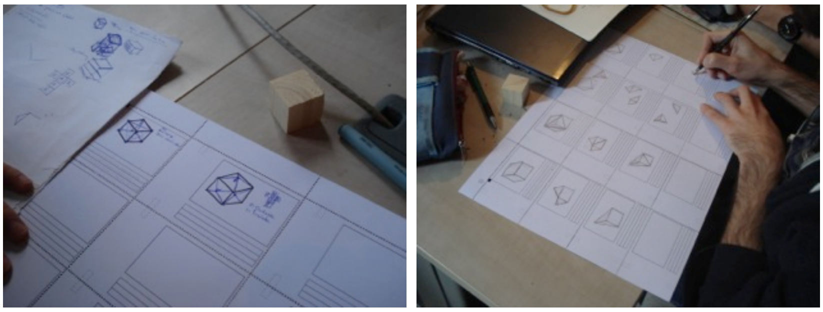


Figure 48 The identification of characters, translations and relationships on the storyboards

Following this work session the tutorial part was realized focusing on the definition of the cube and its formal deconstruction and reconstruction by using Grasshopper plugin. After the tutorial the students started to define their own cubes according to their exploration in the storyboards. Figure 49

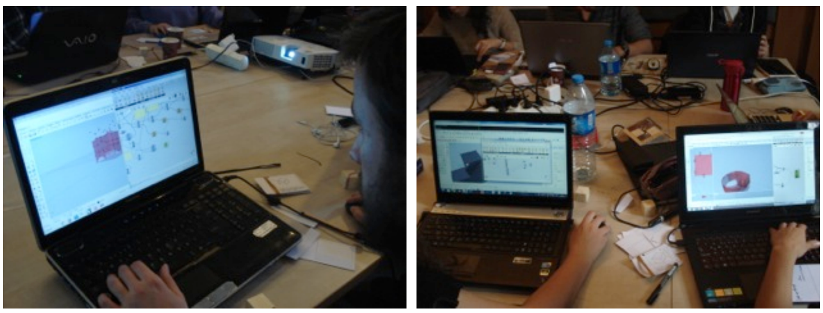
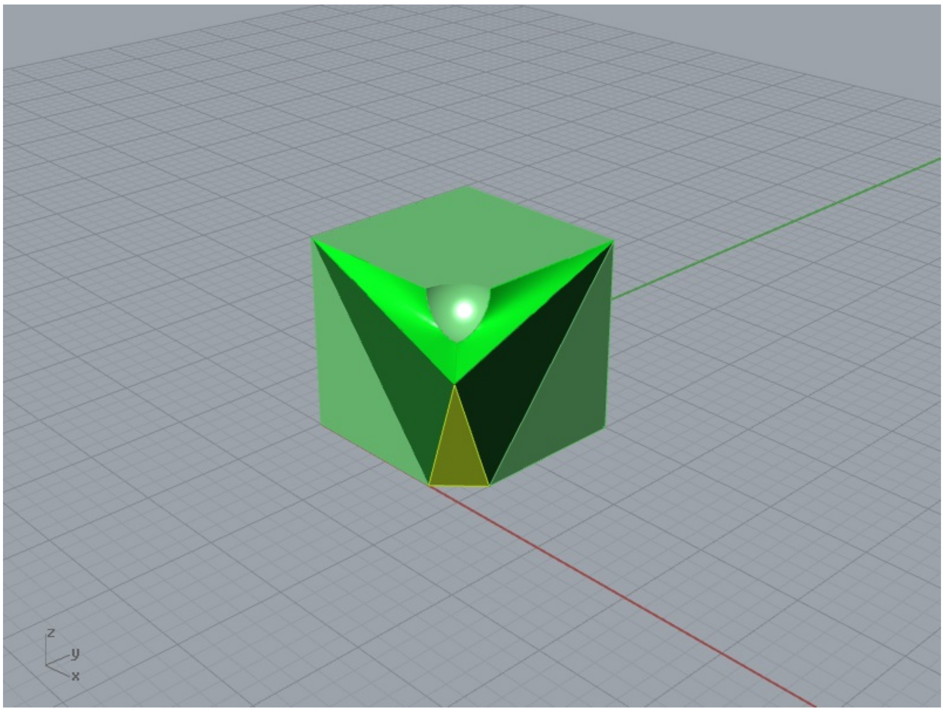
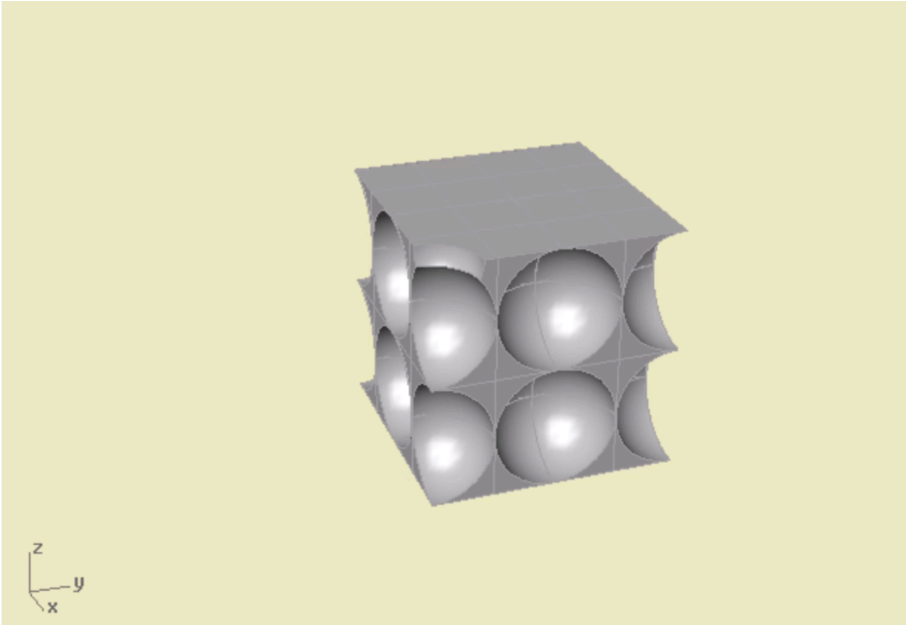


Figure 49 The translation of the storyboards and definitions of the cubes at digital medium

Afterwards they were asked to generate both a moving image model and a variation matrix showing the initial parameters and their relationships. The students sent their work one week after the workshop and it has been observed that some of them has changed their initial idea and revised their design according to the feedbacks that he gained from the transition of storyboard to computational model. Unlike the first Cubehocholic workshop, there was no physical model generation and projection mapping session in this workshop.



4th year architecture student's moving image sequence
https://docs.google.com/file/d/0BzF9GD5Up4EpWnhIY0hyemlHa3c/edit?pli=1
Figure 50 Final moving image sequences



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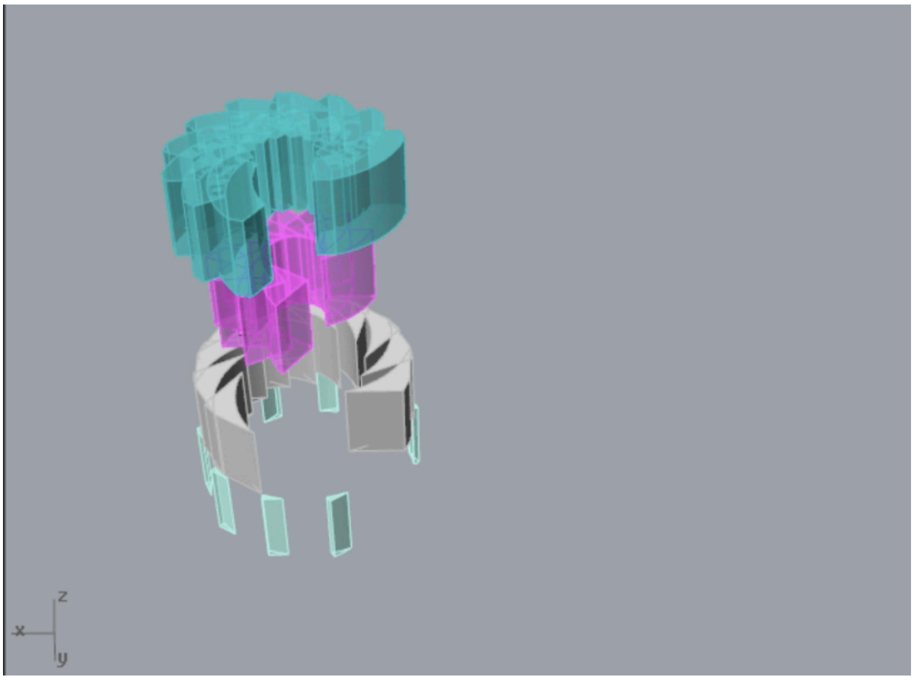
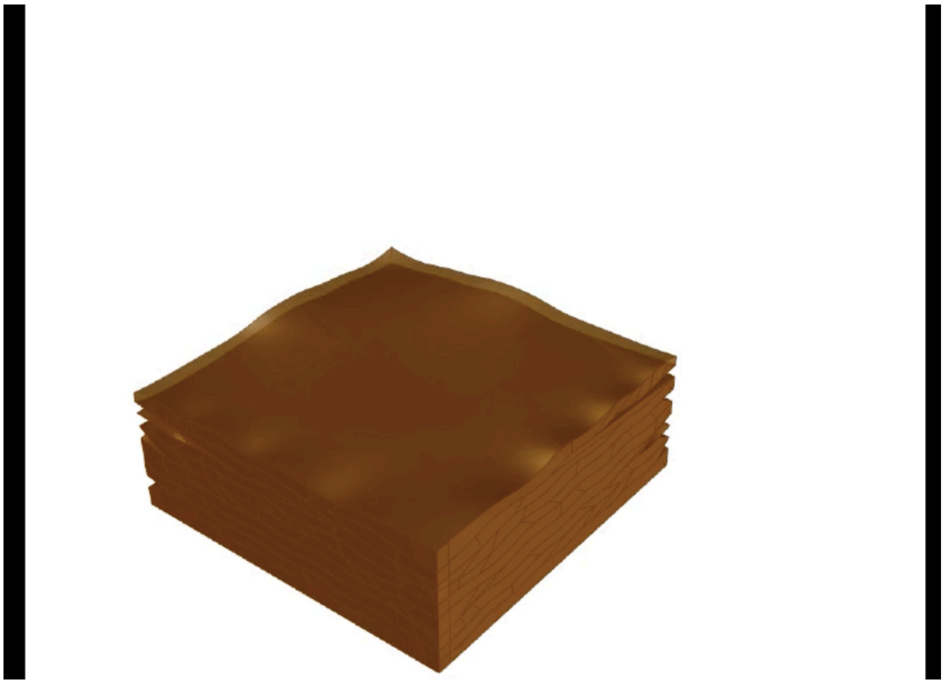


4th year architecture students' moving image sequence
https://docs.google.com/file/d/0BzF9GD5Up4EpaUdMN21RUEFMVjg/edit?pli=1

Figure 50 (Continued)



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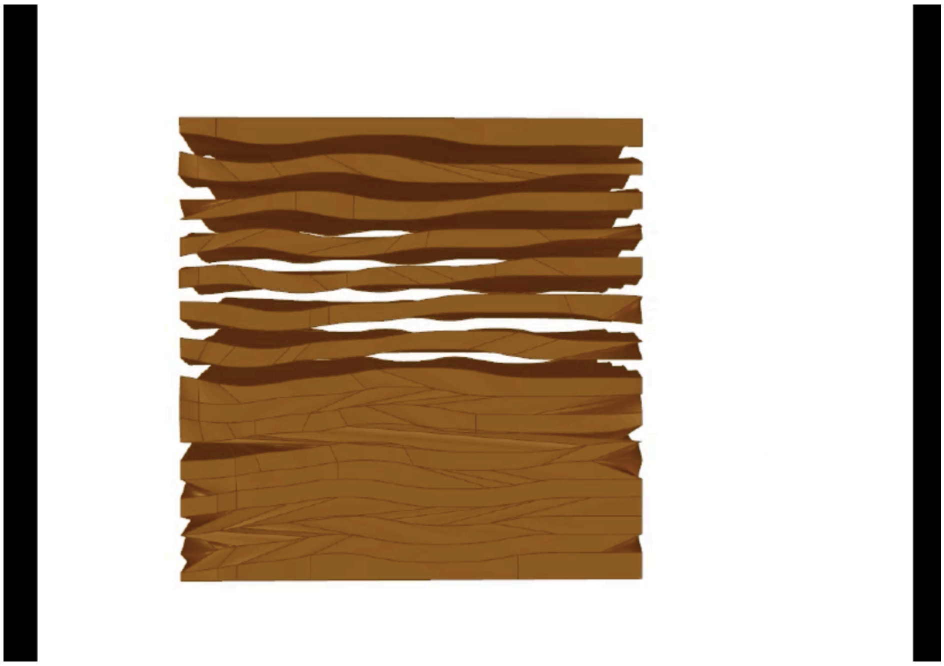
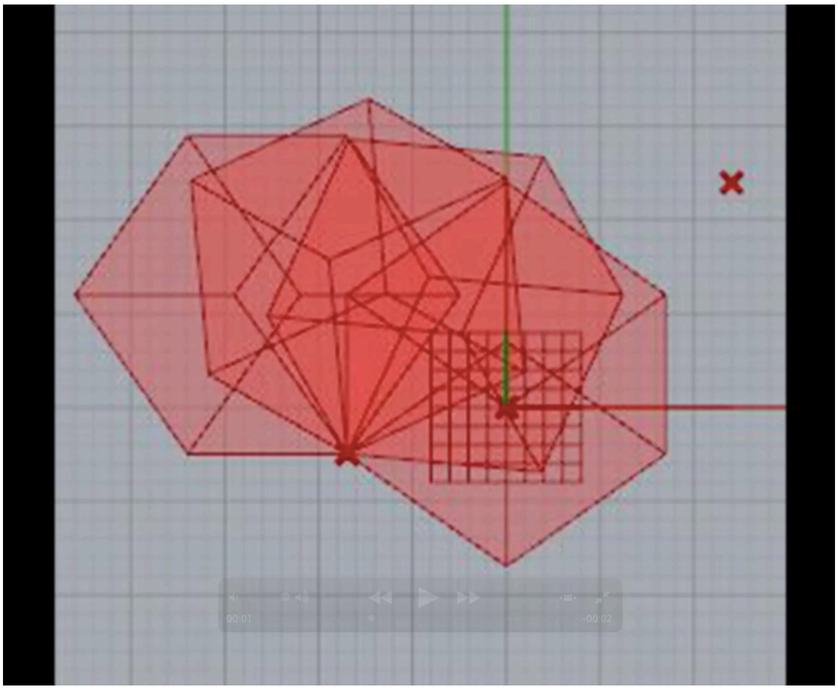


4th year architecture student's moving image sequence

https://docs.google.com/file/d/0BzF9GD5Up4EpSUhQN2x0cDgxV3M/edit?pli=1

Figure 50 (Continued)



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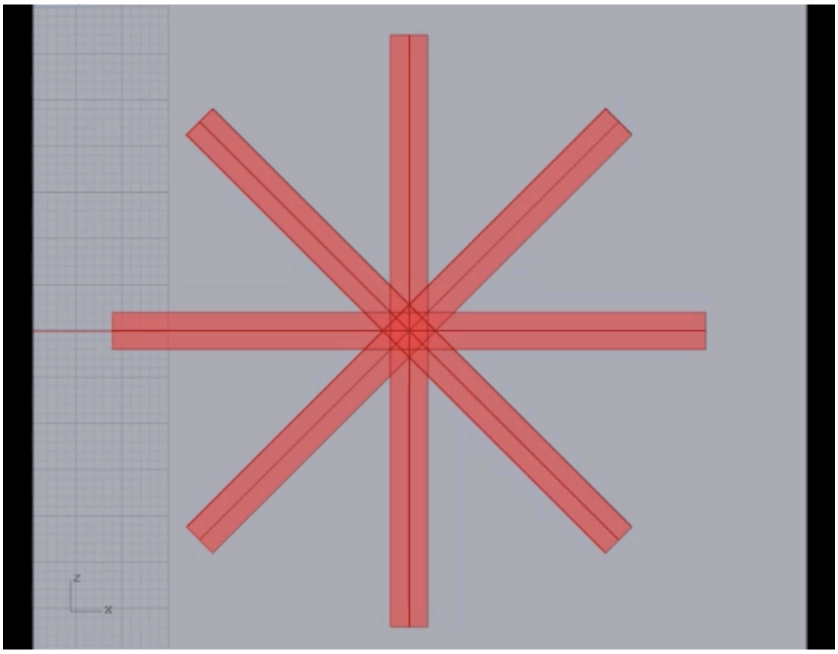
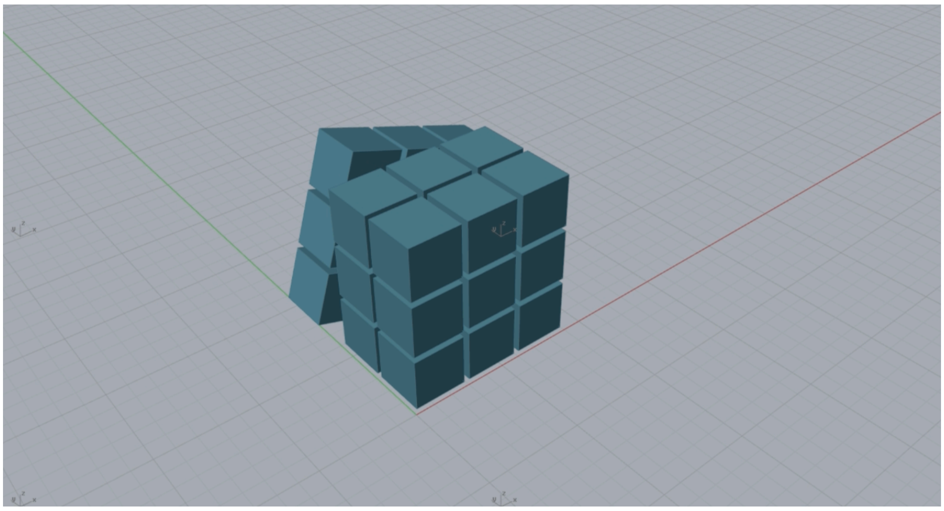


4th year architecture students' moving image sequence

https://docs.google.com/file/d/0BzF9GD5Up4EpUU9GWWRWQ0k3TWM/edit?pli=1

Figure 50 (Continued)

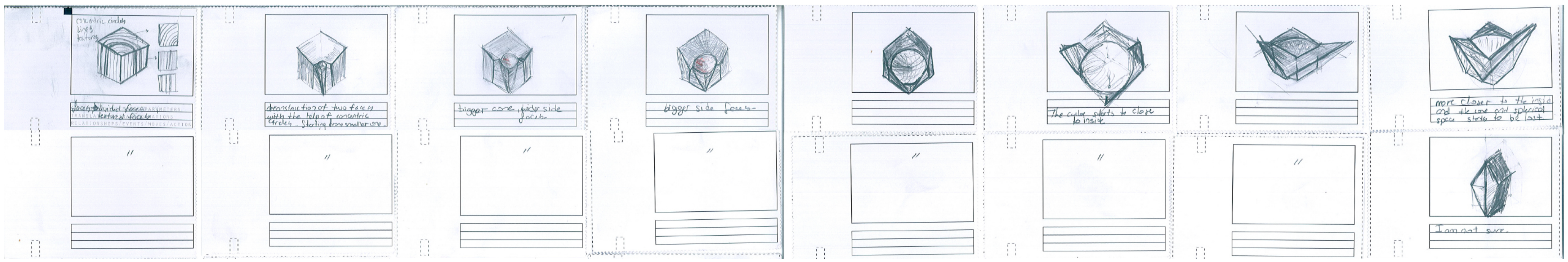


4th year architecture student's moving image sequence
https://docs.google.com/file/d/0BzF9GD5Up4EpYTdDRFp6eUdGQnM/edit?pli=1
Figure 50 (Continued)

The translation of storyboards to computational models resulted in many unexpected outcomes. While some of the students interpreted this transition as a novel way to look at the design problem some of them perceived it as a translation difficulty related to their software knowledge. However, even though they struggled during this translation they tried to reconfigure and reconstruct their computational model over and over. This can be interpreted as an outcome of the direct translation, which orients the student into a practice field where she can gain more experience on using the computational design tools.

Another observation is about the variation matrixes and storyboards, which show that students are more capable of relating the parameters and elements because of their design experience. However there were still some students who could not relate their design with the variation matrix.

Table 34 The variation matrix and storyboard of 4th year architecture student



4.3.2. Discussion

As mentioned above, moving image as a representation model gathers and synthesizes the variable information about the design and its process like its elements, parameters, components and their relationship to the whole. In addition to the articulation of this information, moving image model generates variations of a single unity where the relational thinking stands out because of the (sequential) essence of the procedure. This sequence reflects the design moves by exploring the acts and rules that developed during the process. Therefore a moving image model acts also as a thinking model in which these moves are recorded.

Cubehocholic workshops (I&II) differ from each other according to their program timeline and participant characteristics/profiles. In the first one the participants were less experienced in terms of design when they are compared to the second workshop participants. In addition to that, the participants in the first workshop did not have much experience with digital design mediums. In *Cubehocholic II* the students have had the experience of using the digital and computational design tools, like 3dsmax, Sketch up, Rhino and Grasshopper plugin generally for one or two year.

Although the participants differ from each other in terms of design, medium and tool experience, they were given the same problem. In other words the workshops revisited the same problem through different student groups within same mediums. The main differences of the workshops are the durations, which were designed according to the design and tool experience of the participants. The differences coming to the foreground are as below:

- The duration of the exploration process of the second workshop was lesser than the first workshop because of the design and tool experience level of the participants. The participants finished their storyboards in almost two hours and they started to explore and redefine the model in the computational medium faster than the first group.

- The computation of the cube through moving image model and its translation to the computational and digital medium reflected its feedback on the students very quickly in the second workshop that they started to ask if they can start doing the moving image model over and over. This situation highlights that the learning cycle within the computational thinking model appears rapidly as a feedback and the students, once they get this feedback, want to restart the process again. On the other hand in the first workshop this feedback appeared on the last day where the students finished all the model generations.
- The fastened feedback loop, which occurred in the second workshop, highlights and substantiates the spiral way of thinking during the computational thinking cycle.

Regarding these outcomes it can be said that the participants' will to repeat the storyboard session depends on the experience in design and design tools in education. The experienced group defined their design problem, produced, learned and wanted to redo it again. During this process the will for repeating this procedure points out that the feedback phase at the computational thinking cycle emerges faster than in the first group. And in addition to that the translation and transition of the models (from MIM to CM) also appears to be faster and merged more precisely when compared to the first group. This enlightens the major role of experience on the design process itself and how it effects the duration of learning.

Another thing that has been observed through the workshop is how the participants discovered the transitions between models and how they explored their dialog through this process. Especially the first year architecture, interior architecture students and the graphic designer from the first workshop and some of the fourth year architecture students from the second year workshop explored a dialog between themselves and models and they tried to rephrase and redirect their process according to the unexpected outcomes called creative shifts in this study that appeared through the computational design model. Therefore they did not make an exact replication of their moving image models (MIM) during the translation into the CM. When some of them reinterpreted the instances of the events and actions, some of them figured out this translation open a gate towards new meanings in their design process and they restructured and redefined their design problem as it can be seen through the storyboards and variation matrix tables in Appendices A and B.

On the other hand the groups interpreted these unexpected outcomes differently. The first group mentioned above interpreted these unexpected outcomes as their fault, as an error and they tried to make their MIM exactly as it is and they failed again and again because of their lack of knowledge using Grasshopper (the computational design tool). At the end they figured out the difference of these two mediums and models and after they finished their CM they wanted to replicate their CM onto their MIM. The intuitive process turned out to be a well-defined procedure at the end of their session. However the second group at METU interpreted these unexpected outcomes as an exploration of their process and they redefined their design problem again. They did not change their MIM according to their CM.

Table 35 The 4th year architecture student's computational thinking cycle

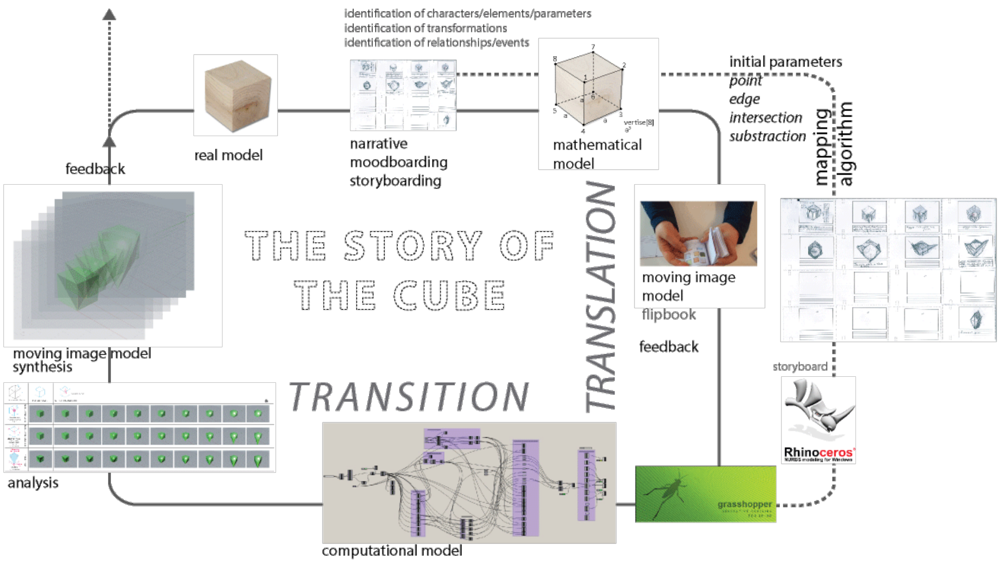
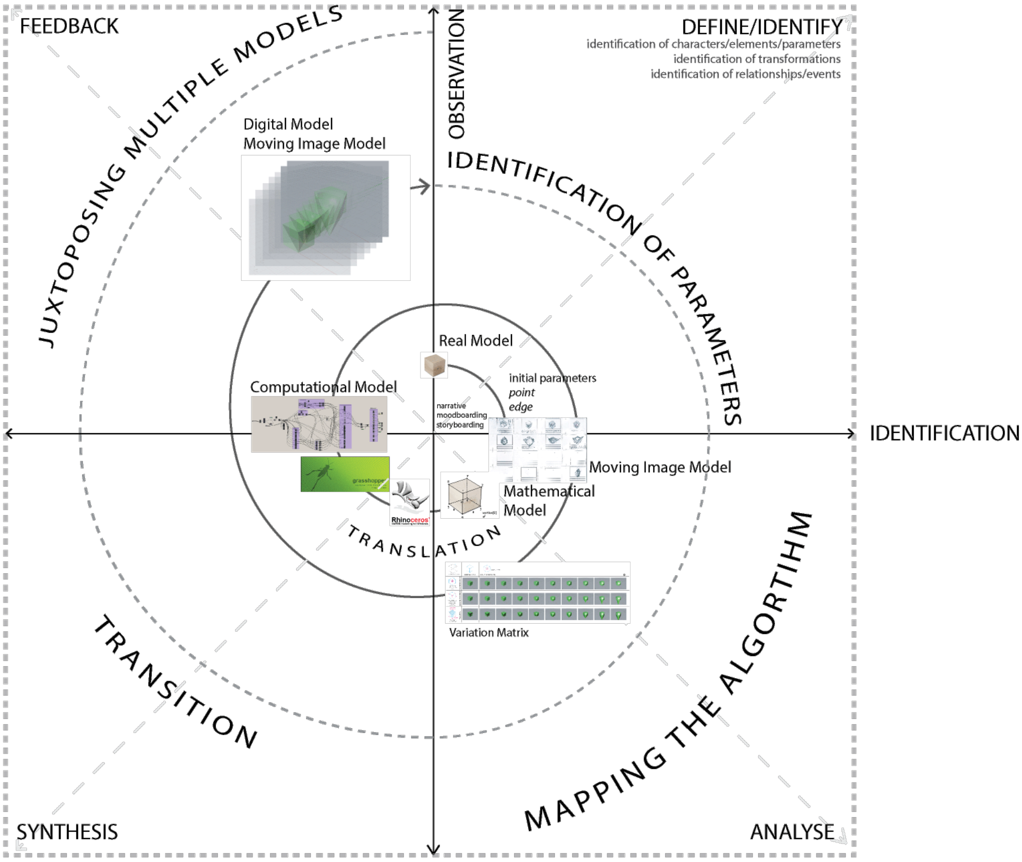


Table 36 The 4th year students' spiral way of thinking showing the transformation from one model to another



CHAPTER 5

CONCLUSION

This study contributes to literature on the research field emerging from the junction of design education, computational design technologies and moving image studies in general by suggesting an approach to the difficulty of the integration of computational design technologies in design education. This suggested approach is about the conception of moving image as an intermediate computational model and its relationship with design process in design education. The research is structured upon two statements, mentioned in the hypothesis part in Chapter 1, as below:

1. Moving image, which is relatively complex yet explanatory and experiential in nature, works as a mediator and a feedback mechanism for the design process and its end product in design education.

2. The integration of moving image in design process whether computationally or not, drives the designer into a spiral computational thinking process by triggering the creative act.

Regarding these statements, the contributions of moving image to design education are examined through its potential for improving the computational thinking process, easing the relational thinking both in conventional and computational design processes and acting as a trigger for the creativity in design education. In order to investigate these contributions, the following questions were explored through a literature survey and a case study called as *Cubehocholic* workshop that was designed within the scope of this study.

- In what ways are moving image and computational design models similar? What are common denominators between these two models?
- In which phases of the design process, has moving image been used as a design representation?
- How can computational thinking be interpreted to design process whether computationally or not/otherwise when using moving images?
- How are moving image model and computational models related in terms of their components/concepts?
- What kind of additional information can be gained by the use of moving image during the design process?
- How can a moving image model serve as a feedback mechanism in the design process?
- How can moving image model and computational design relationship be integrated to design education?
- Can designers also benefit from this transformation during their design process? (For further studies)

Consequently, in this chapter the conclusions driven from examination of these questions are elaborated through the contribution of moving image to design process in the context of design education.

5.1. General Conclusions

The aim of this study is to provide a conceptual framework on the reinterpretation of moving image definition as well as its contribution to design education. The initial examinations are based on the implications of moving image in design education and its relationship with design process. Firstly, in Chapter 2, the relation of moving image with architecture and design is discussed starting from a broader context regarding the paradigmatic shifts in design caused by computational technologies and then the author narrowed down this investigation in the scope of design education through the related literature. After the examination of various integrations of moving image to design education, in order to reconsider the moving image definition as a design representation, the model term and its evolving definition is overviewed in relation to the changing paradigms with computational design technologies in Chapter 3. These two chapters constitute a conceptual framework for also designing the case study of this research, which is discussed in Chapter 4 particularly.

Throughout Chapter 2, it is observed that the relationships between moving image, architecture and design are linked through shared concepts, which are the trilogy of space, time and motion. Many researchers examined this trilogy in a contextual manner and used moving image especially for concept, event and form analysis, representation and generation during and after the design process. While some of the studies concentrated on the moving image from this respect as a facilitator and as an apparatus affecting the experience of the design and the end product, few of them offered moving image as a way of thinking in order to solve a design problem. The role of moving image as a communication mode for architecture and design in visual terms, firstly turned into an experience apparatus for design and the end product through the use of camera, cutting, editing and framing and then its role started to be questioned by few studies linked to its production process phases such as narrative and storyboarding.

On the other hand, the role of moving image in architecture and design has been evolved with the development in computational design technologies and studies started to concentrate on the integration of moving image to design process as a facilitator. In addition, as the complexity of design problems increase with the development of computational design technologies, the pros and cons of these developments and their impact on both design and design education oriented researchers and designers to question the multidisciplinary junctions that can help to understand how to ease the comprehension of these integrations. Furthermore, it can be said that the boundaries between disciplines in science, art and architecture have been vanishing rapidly more than ever in that manner. These vanishing boundaries opened up a gate for architecture and design by integrating the digital tools, which were designed mostly for engineering and film studies such as key framing, animation, morphing etc. These integrations resulted in many theoretical and practical studies on form finding and triggered a paradigm shift in architecture. Time, as one of the main protagonists of the trilogy, has stepped further and started to drive the design as being the initial parameter within this paradigm shift. Meanwhile, the hitherto static representation models started to be questioned in parallel to this paradigm shift. The integration of digital tools in design and their changing impact on design process, from being a tool to transforming into a medium, started to effect the design process reciprocally. As a result, the studies began to reconsider the design representations and especially models in these novel design mediums.

Overviewing the effects of the reciprocal use of moving image in architecture, design and design education parallel to these paradigmatic shifts concludes Chapter 2. This chapter clarifies that the integration of moving image with computational design technologies in design education has not been much explored yet. This was a starting point in order to discuss the new role of moving image as a model in design process in that manner.

In Chapter 3, moving image is reconsidered and reinterpreted as a model that directs a designer to a computational thinking cycle. Therefore the changing role of design representations and the role of moving image in design education were elaborated through the paradigmatic shifts occurred with the developments of computational design technologies and the changing definition of model term was examined regarding the studies in both computational design and the design studies area.

During this investigation, Sorguç & Selçuk's computational thinking cycle has been taken as a reference and as a core for further examination. Throughout this examination, model, computational model, parametric model, dynamic model, algorithmic model and computational thinking model are elaborated in order to integrate the moving image as a model into this thinking cycle. It is observed that while some of the studies concentrate on model from taxonomic point of view, some of them redefine it as a design-thinking medium, where the whole design process can be explored dynamically.

As the complexity of the design problems rose, the problems started to be multidimensional and unsolvable without computational model generations. From this respect, the integration of the computational design technologies into the design started to be a challenge also for design education. In order to ease this integration, the moving image model was proposed as a mediator in this study, in which the pre-production phases such as narrative, mood boarding and storyboarding constitutes a substantial communication channel for the exploration of the design process.

The relationship of these pre-production phases with the computational thinking cycle is associated with various models regarding the phases of the computational thinking cycle that starts initially with observation. Narrative refers to definition of the overall object or situation, events and moves, mood boarding clarifies the characteristics of elements and parameters, storyboarding defines the relationships and rules and functions as an algorithm mapper in the computational thinking process cycle. These associations led Chapter 3 as a base for the design of the case study in which the proposed approach was elaborated according to the reviewed literature, also enlightening the redefinition of model and moving image.

Regarding the literature in Chapter 3, the model term is defined as a process, which is constructed on an assumption set based on the abstraction of an observed phenomenon, by generating a dialog between the design and designer in this study. The substantial models that will be included in the case study are remarked as real model, physical model, computational model, moving image model and digital model, which emerge during the computational thinking cycle both as an input and an output depending on the design problem. In order to understand the mutual relation between these models, the arguments on computational, relational, visual and algorithmic thinking are examined. It has been observed that many studies point out these model transformations as new design skill sets of designers. Hence, the improvements of these new skill sets have broadened the arguments in the design education field.

The general framework developed from the related literature in Chapter 2 and Chapter 3, bases the design of the case study called *Cubehocholic* workshop in this study. The subject matter was kept simple as a sole wooden cube. The reason for picking single and simple subject matter is about the major priority and concerns of this study, which is achieving an objective assessment of the case study. The consistency of the process of the workshop was more important than the subject matter.

The case study was designed according to the revised Bloom's taxonomy and the workshop timeline was mapped linked to the objectives of the proposed case. Table 38 The learning objectives and outcomes of the workshop are evaluated according to the cognitive and knowledge dimension matrix. Table 37 The cognitive processes dimension consists six major thinking skills as, (1) remember, (2) understand, (3) apply, (4) analyze, (5) evaluate and (6) create. These thinking skills are associated to four type of knowledge that is (1) factual, (2) conceptual, (3) procedural and (4) metacognitive.

The integration of the moving image model into the computational thinking cycle was examined through the executed workshops and the results are elaborated from three aspects, which are students' work, researcher's observations and critics' reviews during this study. As a result of the workshop, it has been observed that the integration of the moving image model into the computational thinking cycle has helped the students in various procedures such as:

- Defining the design problem from an intuitive or ill-defined to a well-defined one
- Exploring and defining the related vocabulary of the design problem
- Defining the parameters of the design problem
- Organizing the design process

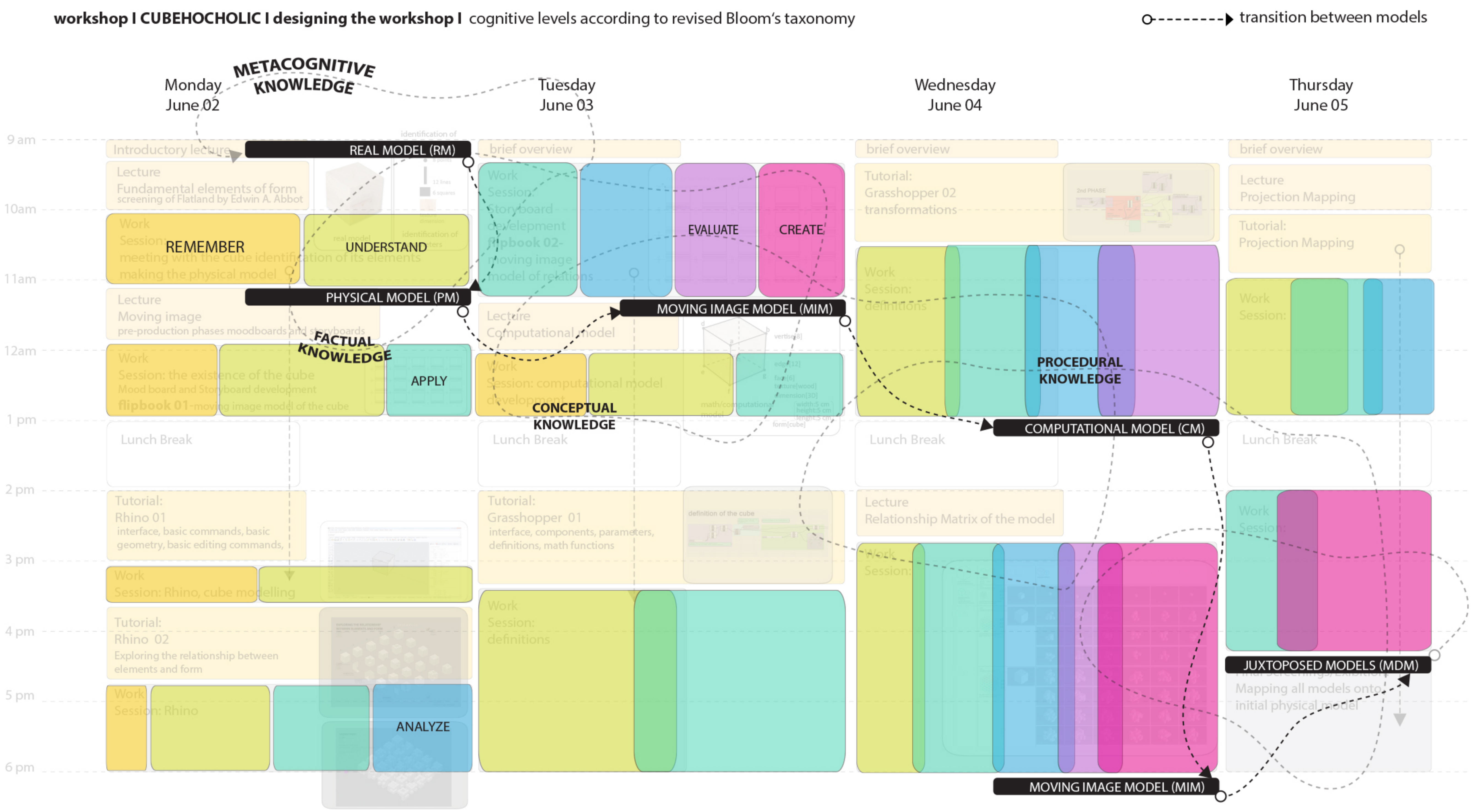
- Developing a way of thinking /behavior through setting the relations between the first, the next and the last step of the design process, therefore designing a dynamic design procedure in which the steps are connected and related to each other.

The meaning of “well defined” interpreted as self-awareness of designer’s own design process in this study. Also, the transformation of design problem from black box to white box refers to this self-awareness. The designer does not define the design problem in a better way. In fact, she constitutes a better understanding of the process while trying to define it over and over. The outcome of this trial can be a surprise even for the designer, herself because of two main reasons. First it is hard to read, understand multiplicity during the design process according to the problem nature. Secondly, even if the process is well defined through storyboarding session, which starts to clarify the relations, the outcome is often another model generation that can also be another design problem itself or an unexpected outcome that can drive the designer’s interpretation into another way during the design process.

Table 37 The juxtaposition of cognitive and knowledge dimension of Bloom's taxonomy with the objectives of *Cubehocholic* workshop

OBJECTIVES OF CUBEHOCHOLIC WORKSHOP	KNOWLEDGE (KNOWLEDGE \ COGNITIVE)	REMEMBER	UNDERSTAND	APPLY	ANALYZE	EVALUATE	CREATE
The students will generate/construct different design representation models such as moving image model, computational model, digital model and physical model and express their design through these models.	FACTUAL						
	CONCEPTUAL		■				
	PROCEDURAL		■	■			■
	METACOGNITITVE						
The students will learn to combine multiple design representation models during their design process.	FACTUAL						
	CONCEPTUAL		■				
	PROCEDURAL			■			
	METACOGNITITVE						
The students start to learn the basics of 3D modeling and computational modeling terms and will be able to use 3D modelling and computational modelling tools in beginner level.	FACTUAL						
	CONCEPTUAL		■				
	PROCEDURAL		■	■			
	METACOGNITITVE						
The students will start to identify the relationships between the modeled (domain) and the model (range) .	FACTUAL	■					
	CONCEPTUAL	■	■				
	PROCEDURAL						
	METACOGNITITVE						
The students begin to evaluate the design process as combinations of variable situations and evaluate the relationship between these variables.	FACTUAL						
	CONCEPTUAL		■				
	PROCEDURAL			■	■	■	
	METACOGNITITVE						
The students will learn to define the design problem from an intuitive or ill-defined to a well-defined one.	FACTUAL	■	■				
	CONCEPTUAL		■				
	PROCEDURAL						
	METACOGNITITVE						
The students will explore and define the related vocabulary of the design problem.	FACTUAL	■	■				
	CONCEPTUAL						
	PROCEDURAL						
	METACOGNITITVE						
The students will define the parameters of the design problem.	FACTUAL	■	■				
	CONCEPTUAL		■				
	PROCEDURAL						
	METACOGNITITVE						
The students will organize the design process.	FACTUAL		■		■		
	CONCEPTUAL			■	■		
	PROCEDURAL				■		
	METACOGNITITVE						
The students will develop a thinking way/behavior through setting the relations between the first, the next and the last step of design process. Therefore, they will set a dynamic design procedure in which the steps are connected and related to each other.	FACTUAL						
	CONCEPTUAL	■	■	■			
	PROCEDURAL			■	■	■	■
	METACOGNITITVE	■					

Table 38 The mapping of the cognitive levels according to revised Bloom's Taxonomy onto the timeline program of the workshop



Constructing a thinking process, where all the representation models are connected and in a relationship with each other, initiates a creative shift and turns into a mind shift, where the designer can explore the computational thinking process and direct the process through the feedbacks over and over. Rather than a linear way of thinking, this procedure has continuity during the design process, which is called a spiral way of thinking in this study. Besides, computational and spiral way of thinking also implies to the self-awareness of designers' design process.

The spiral way of thinking is constructed on four main acts initiated with observation, which are definition, analysis, synthesis and feedback. These four acts are constructed through identification of parameters, mapping the algorithms, transition and juxtaposing multiple models by referencing Sorguç & Selçuk's computational thinking cycle.

The spiral way of thinking suits the computational thinking process in which the generated models, in other words the solutions, regenerate novel real models that restart the process. The key phase here is feedback, where the continuous observation, analysis and synthesis loops are generated in this process. As a result of the feedback, the learning occurs and the next model generation becomes more advanced than the last one because of the regenerated knowledge included in the process. For example, in the *Cubehocholic* workshop the real model is a wooden cube. The designer observes this real model and redefines it by using its materiality, gravity, geometry, etc. The complexity of the new cube lies beneath this initial definition, which is attached to the designer herself. Therefore the knowledge of the designer, what she wants to see, what she needs, what she wants to explore or experience effects the definition of the problem and the vocabulary that is included in the definition. Regarding this definition the creativity, experience, knowledge and the defined problem itself, structures the model in this computational thinking process. The exploration of this model is linked directly to the generation of the model. Therefore, it is also linked to the tools and the mediums used in this process. During the spiral way of thinking, the designer's perception of the design problem and solution is also linked to the design experience. It has been observed that the design experience effects the feedback mechanism through this cycle. In addition, the exploration of the design depends on the generated model, in other words the generated model limits the design. When the design experience increases, the model generation exhibits more complexity because of the learning act.

The first year, second year and fourth year students' behavior differs from each other in terms of the feedback phase. While the feedback occurred at the end of the workshop on the fourth day for first year and second year students, some of the fourth year students got feedback instantly right after the storyboard session. Although the effects of design experience were expected, the instant occurrence of feedback was interesting due to time limitation in the second workshop. In addition to design experience, the background of the designer is also important in order to discuss the creativity term, especially in the storyboarding phase.

Another important observation is about the translation of storyboards to computational models. Sometimes students imitated or mimicked the storyboards, sometimes they explored something in the flipbook and others discovered, saw an unexpected outcome that could change even the design problem and process itself. Therefore, it can be said that the moving image model and computational model do not have many limitations within their definitions during the design process, and the boundary between them vanishes because of their similar essence. However, it can be said that storyboarding and the computational model have a major difference between each other where the designer can see the probabilities at the same time in the computational model. The storyboarding phase of a moving image model includes the rules at a level of complexity as probabilities in individual or pairs (Sorguç, 2014). Sorguç explains this complexity through a chess game. In her words:

> There are sixteen chess pieces for a player. There are certain rules for how the player can move these pieces and every move results in a bad or good consequence. An experienced chess player can imagine the whole chessboard, including the state and the probabilities that can happen or exist on the board. The storyboarding is like seeing these states that the player can imagine at a time with her number crunching capacity but on the other hand computational design is like seeing the whole chessboard at the same time,

seeing all the probabilities through the board that it helps the player to explore and experience every move within the same time.

Therefore, in order to explore this complexity, firstly the definition of the vocabulary in the storyboarding is essential in terms of the transition to computational model. Storyboarding is the intuitive and creative act that includes also the articulation of the main idea of the design and its vocabulary in advance. The transition and translation of the storyboard into a computational model is essential because the final result, the solution or the output, can still be a mystery to the designer. Sometimes this translation causes some unexpected outputs that can direct the designer to creativity in the computational model and sometimes it protects its essence.

The thinking process is a linear one at the storyboarding phase because of its sequential substance. However, the computational design process is an agile way of thinking, where it drives the designer into feedback loops as aforementioned, and in this process the design, as output, can turn into an input in another cycle. During this spiral thinking cycle while the occurrence of the unexpected outcomes has been called creativity, it can be said that the main creativity lies beneath the construction of the vocabulary of the problem in the narrative, mood boarding and storyboarding phases where designers create their own thinking boxes and since the designers differ from each other, all these thinking boxes are unique in that manner.

The generated models are juxtaposed during the workshop process and the juxtaposition of these models generates a novel perception towards the definition of the cube in terms of form and relations. And in addition to that, the students reconsider and reinterpret the essence of the cube and its variations through a computational thinking process. They discover new meanings, relationships, and a novel way to look at and define it through the relations. Therefore, they start to question what a cube is and what it looks like, how it can be computed, its formal and relational potential during this process, which evolves from visual into relational and at the end computational.

In this spiral thinking cycle moving image model initiates a creative instant, which is constructed upon "unforeseen variations" (Kilian, 2008) by revealing a new insight through possibilities that cannot be achieved through conventional modeling approaches. The possibility of exploring such variations can trigger design creativity and improve the self-awareness of the designer about her design process. Moreover moving image model provides an interface between different means of model generations (computational, physical etc.) and design process itself.

As the spiral diverges, the complexity of the model increases parallel to the knowledge generation. Therefore, the effects of design experience can be seen directly through the duration of problem solving act throughout the design process. During this process, as aforementioned, after observation of the real phenomenon there are four main stages called identification or definition, analysis, synthesis and feedback that are linked through identification of parameters, mapping of the algorithm, transition and juxtaposition of multiple models which led the designer into a feedback loop at the end. This model has been generated through Sorguç & Selçuk's computational thinking cycle. In order to understand the effects of moving image model integration to this cycle and its relationship with the learning activity and creativity, Sorguç & Selçuk's computational thinking cycle is juxtaposed with Edward S. Ebert's Cognitive Spiral principles by using the students' design process during the *Cubehocholic* workshop.

According to Ebert, among the researches on creativity, there is no consensus on creativity assessments (Ebert & Ebert, 1998). While some of the studies are interested in the creativity of the product, until late 90s the relationship between the process and creativity did not get enough attention. His "cognitive spiral model conceptualizes creative thinking as an integral component of all cognitive processing" (Ebert & Ebert, 1998) where the initial comment on creativity is also about its essence as a part of the cognitive process differing form one person to another rather than its assessment through the concepts of novelty, value or unpredictability studied by many pieces of research in the design cognition field that were constructed on Boden's creativity theory.

In this study, creativity is linked to the creation of the designer's thinking boxes, which is based on computation. Every designer creates their own thinking boxes and it is the real creativity, that they cannot be identical in that manner. In addition, the construction of the design problem and its vocabulary are the most essential and creative phases, in which the identification and mapping acts can occur continuously. The flow of this spiral thinking is bidirectional, where there is a flow of different kinds of information that unites the cognition of the designer. Ebert constructs this cognition on five thoughts, which are (1) perceptual thought, (2) creative thought, (3) inventive thought, (4) metacognitive thought and (5) performance thought. Regarding these modes of thoughts he states "The same five components recur over and again, but never return to the exact spot from which they began: a spiral, not a circle."

The juxtaposition of these models through the *Cubehocholic* workshops shows that the generated thoughts do not belong exactly to a phase, but rather intertwine throughout the information flow through models. The perceptual thought begins with observation and also has been gathered during the mapping process, where the designer analyzes the initial problem definition, vocabularies and relations. The mapping of algorithms of relations with storyboards and the transition of these storyboards to computational models, result in creative thoughts, in which the designer can reinterpret, remap or redefine the related vocabulary or design problem. This situation was observed as the unexpected outcomes occurred while translating the storyboards to computational models during the workshop. The inventive thought acts as overall evaluation of the results of the creative thought, in which the variations of situations and new possibilities has been synthesized for the possible design solution. Ebert associates the inventive thought phase as building with materials or assembled information. According to him these materials are gathered as information through the creative process. He emphasizes that the combination of information acts as a new way of inventing a unique experience.

After building up the computational model, the juxtaposition of models resulted in reinterpretations on cube's definition in both workshops. In *Cubehocholic I*, students also started to realize the difference between the materiality and immateriality of the object and its actualization. The juxtaposition of physical, moving image and computational model led to emergence of a new understanding on the comprehension of the cube definition. As a result, they reconsidered and started to think about their process and some of them wanted to restart. This process can also be called as evaluation of the process where the feedback has occurred at the end. This feedback can result with an abstract type of knowledge that is defined as metacognitive in Bloom's taxonomy. In addition, according to Ebert's cognitive spiral this feedback constructs a metacognition in which the students start to think critically towards their solution. This state orients whether the design problem is solved or the final situation satisfies the designer or not. Until to this phase, the spiral way of thinking suits with Elbert's cognitive spiral juxtaposed with Sorguç & Selçuk's computational thinking cycle. However, the fifth phase, performance thought, could not be observed through the workshops due to the time limitations. Performance thought is "where the results of cognitive processing find their expression." It is the state where the information gained from all phases are stored and may be translated and expressed in various ways. In other words, the knowledge transfer occurs within this phase, where the designer executes the gathered information for different purposes and can carry this knowledge in order to develop new procedures. Therefore, it is accurate to say that this phase may occur if this study can be executed as a long-term assignment in a design studio.

Table 39 The spiral thinking model of 2nd year architecture students at *Cubehocholic I*

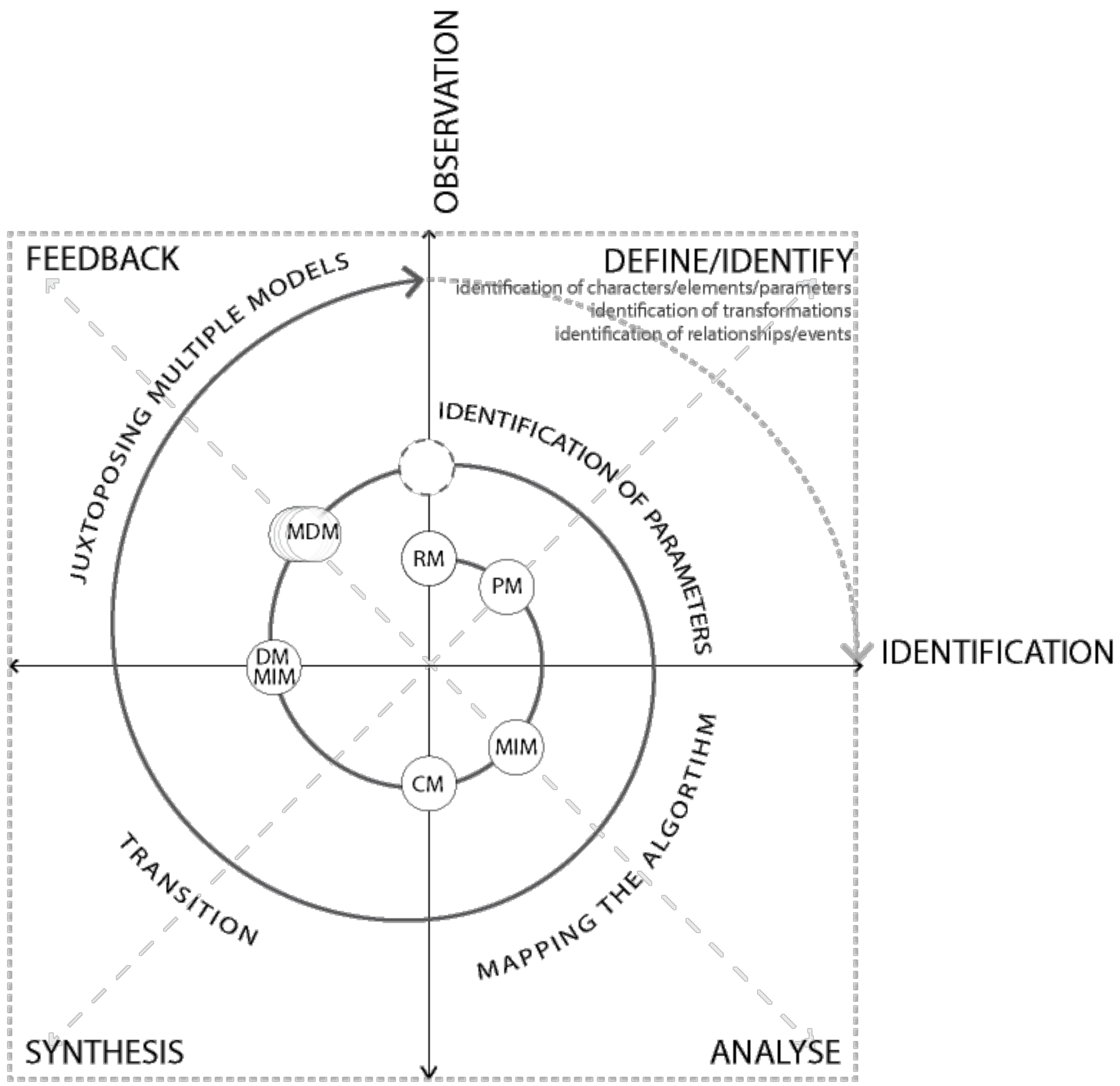


Table 40 The spiral thinking model of 4th year architecture students at *Cubehocholic II*

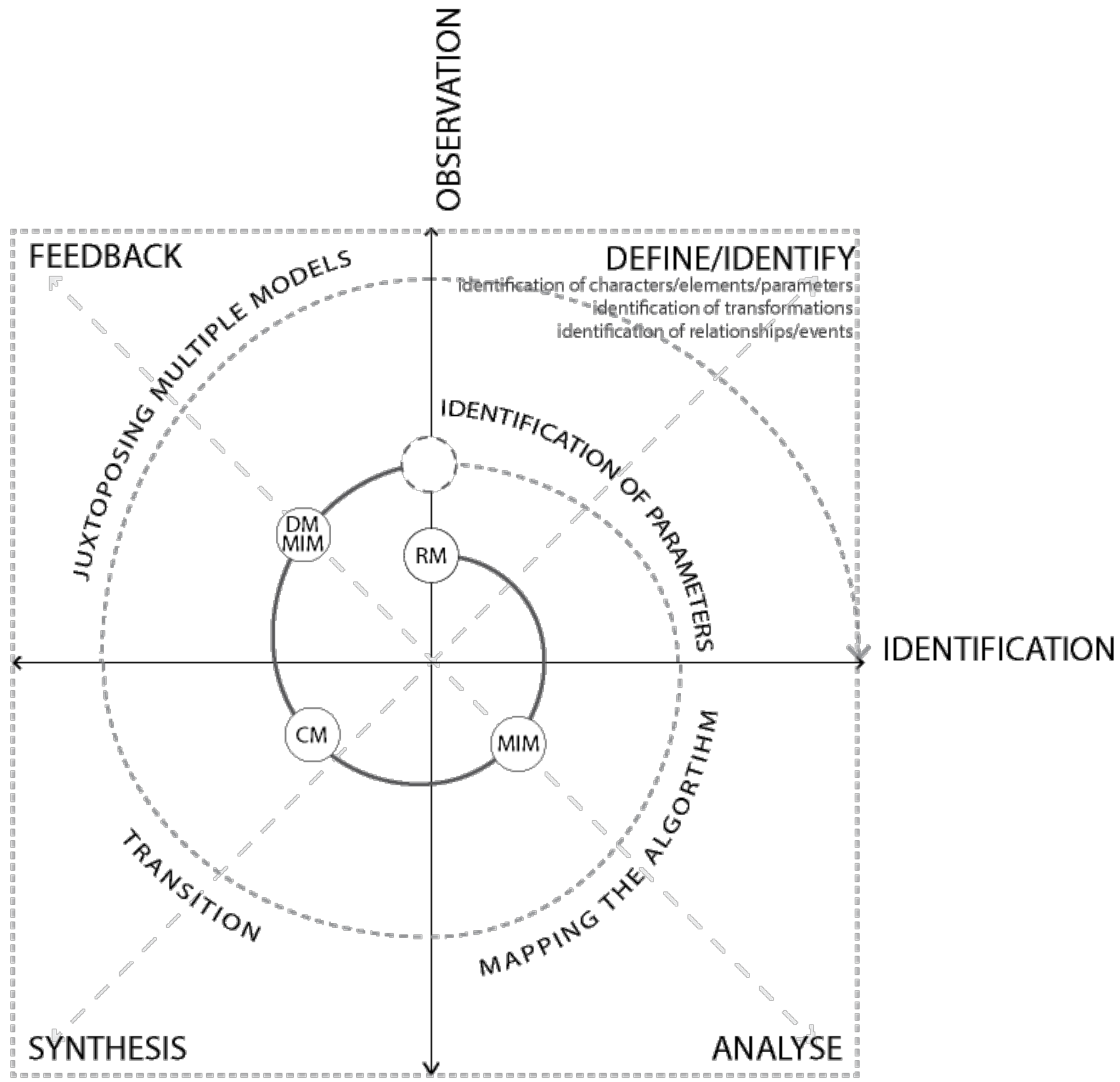


Table 40 The juxtaposition of 2nd year architecture student's spiral computational thinking model in *Cubehocholic II* with cognitive spiral model

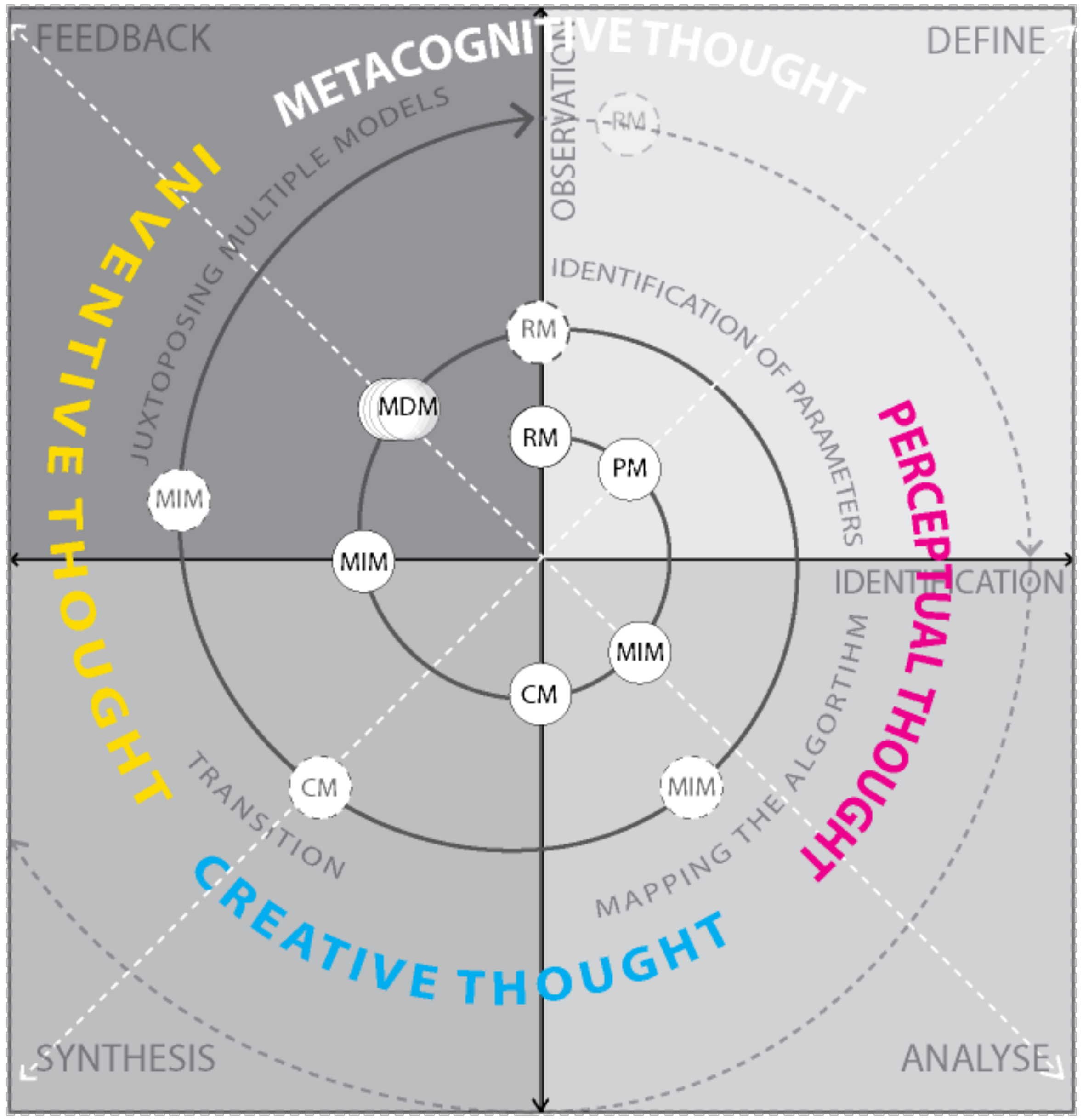
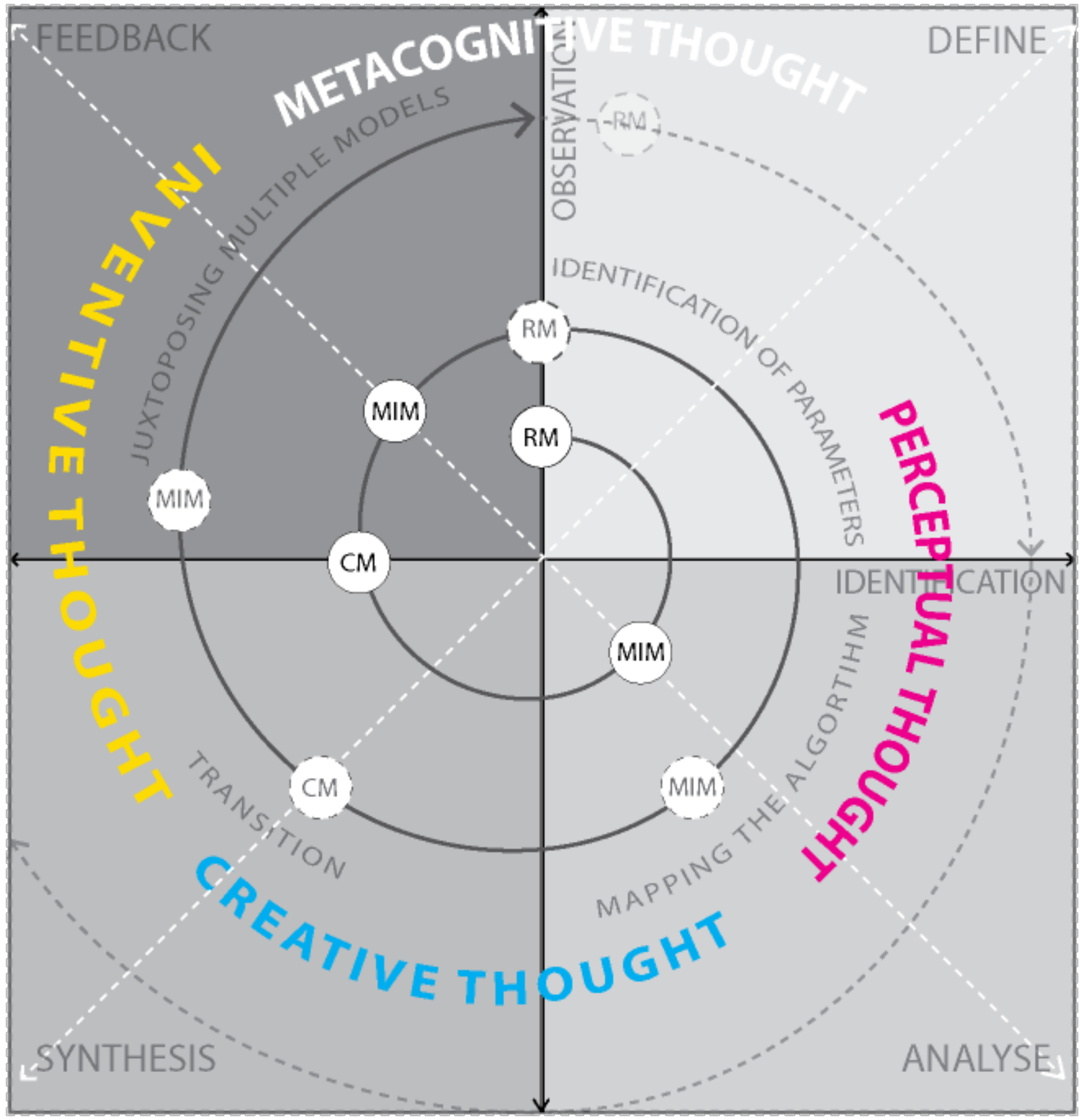


Table 41 The juxtapositon of 4th year architecture students spiral computational thinking model in *Cubehocholic II* with cognitive spiral model



5.2. Implications for Further Studies

This study questioned just the interpretations of the computational thinking model and it was not interested if the model was good or not. Every student and designer generates his or her own computational thinking model. The evolving relationship of models in the design process has been discussed according to the impacts of computational design technologies to design and design education. The suggested use and adaptation of moving image model in computational design thinking process was elaborated through case studies designed as workshops. The discussions concentrated on the views of the evolving role of design tools into design mediums and their transformation into thinking mediums consequently with technological advances. The arguments embody the learning activities and the mind shifts that occur through these new mediums as a result of the impacts of computational design technologies in design education.

However, this study focuses solely on the impacts in early design education through a workshop. Therefore, the transformation of the generated knowledge to the other areas of design and design education is also another aspect that can be studied in detail in future. In addition the designed workshop, *Cubehocholic*, has a potential to be executed in a design studio as a long-term assignment.

The metacognitive knowledge level can be replaced by constitutive perception since the observation of metacognition was not possible due to the workshop durations. Therefore, the replacement of constitutive knowledge level can also gain another perspective for this study and also for further studies in the scope of design education.

The experienced designers and how an experienced designer can benefit from moving image models in their design practice can be constructed in further studies. In every step of the design process experienced designers can use the moving image model and computational model as well as in their practice. The name of the models can change but the essence still remains. In addition the impacts of this model integration in architectural design can also be another study to reveal out the possible use of this model as a mediator in professional manner.

Furthermore, the fourth phase of the *Cubehocholic* workshop, which is projection mapping can also be a further research implication in the scope of design education. Projection mapping as a moving image model and its implications on design that can change the perception of both designer and students has a potential to articulate its applications.

Moreover, the moving image pre-production phases, narrative, mood boarding and storyboarding and their relationship with computational medium through the use of other software except Grasshopper can also be interesting in order to understand the tool and medium dominance in design education as a further study.

Lastly studying the analogical fundamentals of moving image and computational thinking concepts would be interesting especially in order to expose the transition phase in particular. There was a translation and transformation between representation models that were generated during the workshop processes. These translations and transformations from MIM to CM have overlapping concepts that can be linked to computational thinking fundamentals. Wing defines computational thinking as taking an approach to solving problems, designing systems and understanding human behavior that draws on concepts fundamental to computing (Wing J. , 2006; Wing J. , 2008). According to her computational thinking uses abstraction and decomposition when attacking a large complex task or designing a large complex system (Wing J. , 2006). Therefore the articulation of the information and selecting the appropriate representative medium of this information drives both problem definition and the problem solving actions. Terzidis points out that computation involves these problem solving actions, mental structures, cognition, simulation and rule based intelligence structured upon an exploration process of the indeterminate, vague, unclear and ill-defined processes by aiming to extend the human intellect (Terzidis, 2006). Hence in order to understand this fuzzy process it is essential to enlighten the fundamentals of its thought procedure.

Karen Brennan defines these concepts as follows, sequence, conditionals, loops, operators, parallelism, variables, events, and lists (Brennan, 2011). Therefore a mapping study can be conducted in order to comprehend the subordinate relations between moving image model and computational model through these shared concepts. A descriptive study may help to construct an interface or plugin for designers in order to translate their initial narrative on the design problem. The following association scheme of MIM and CM concepts can be taken as a starting point for this further research. Table 41

Table 41 The associated concepts of MIM and CM according to Brennan's computational model descriptions

MODELS	MIM	CM	DESCRIPTION		COLOR CODING
CONCEPTS	SEQUENCE	ALGORITHM	SERIES OF STEPS FOR A TASK		
	REPETITION	LOOPS	PLAYING/RUNNING THE SAME ALGORITHM/SEQUENCE		
	EVENTS	PARALLELISM	THINGS HAPPENING AT THE SAME TIME		
	EVENTS/MOVES/ACTIONS	EVENTS	ONE THING CAUSING ANOTHER THING TO HAPPEN		
	RELATIONS ?	CONTIONALS	MAKING DECISIONS BASED ON CONDITIONS		
	CHARACTERS/ELEMENTS	DATA/VARIABLES	VALUES STORED, RETRIEVED, UPDATED		
	RELATIONSHIP	OPERATORS	SUPPORT FOR MATHEMATICAL AND LOGICAL EXPRESSIONS		

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APPENDIX A

STUDENTS' STORYBOARDS FROM *CUBEHOCHOLIC* WORKSHOP

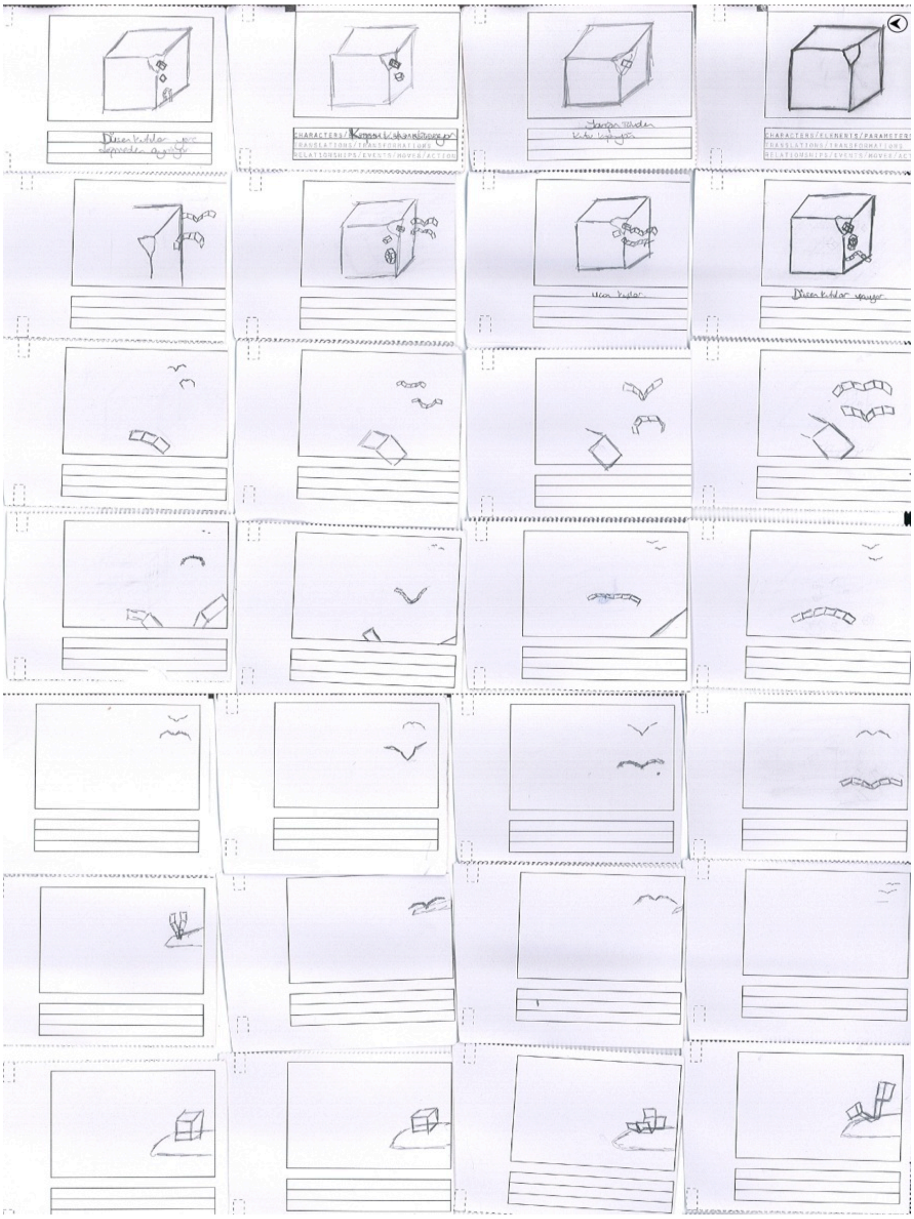


Figure 51 2^{nd} year architecture student's storyboard

Figure 52 1st year interior architecture student's storyboard

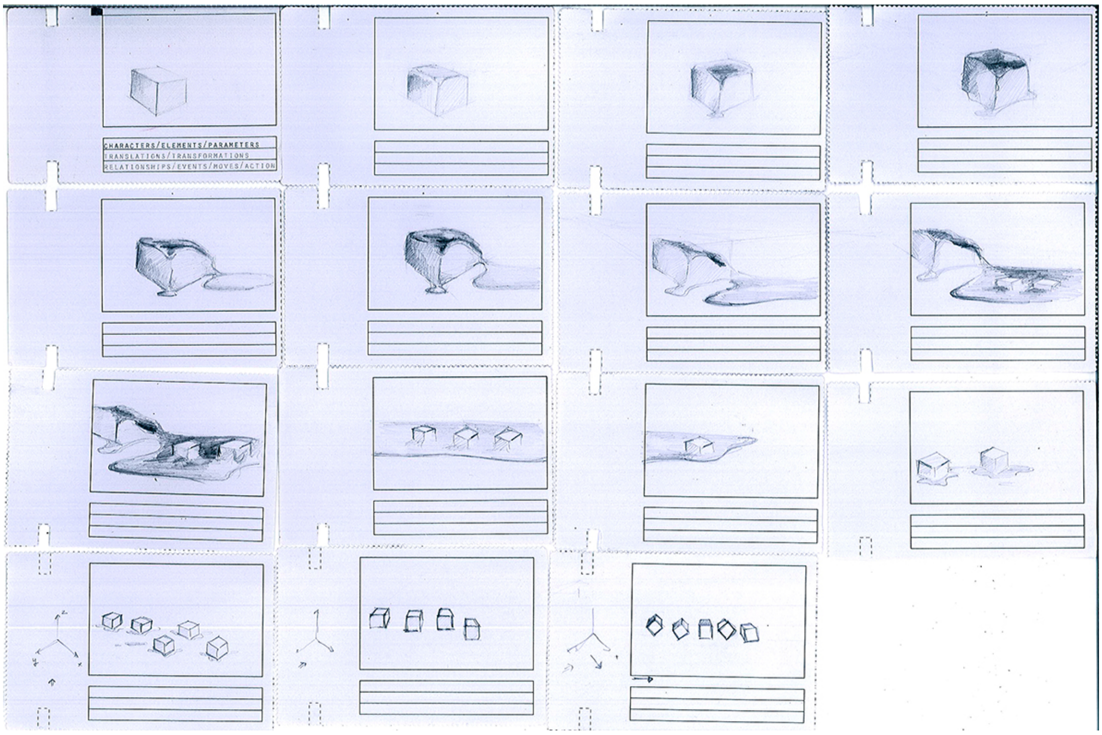


Figure 53 1st year architecture student's storyboard

Figure 54 1st year interior architecture student's storyboard

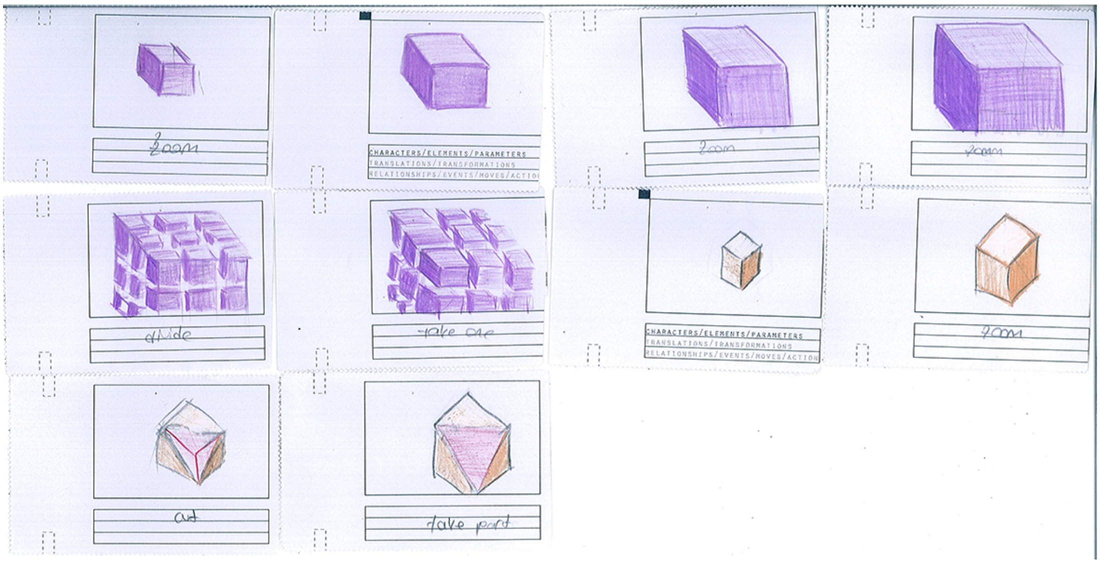


Figure 55 2nd year architecture student's storyboard

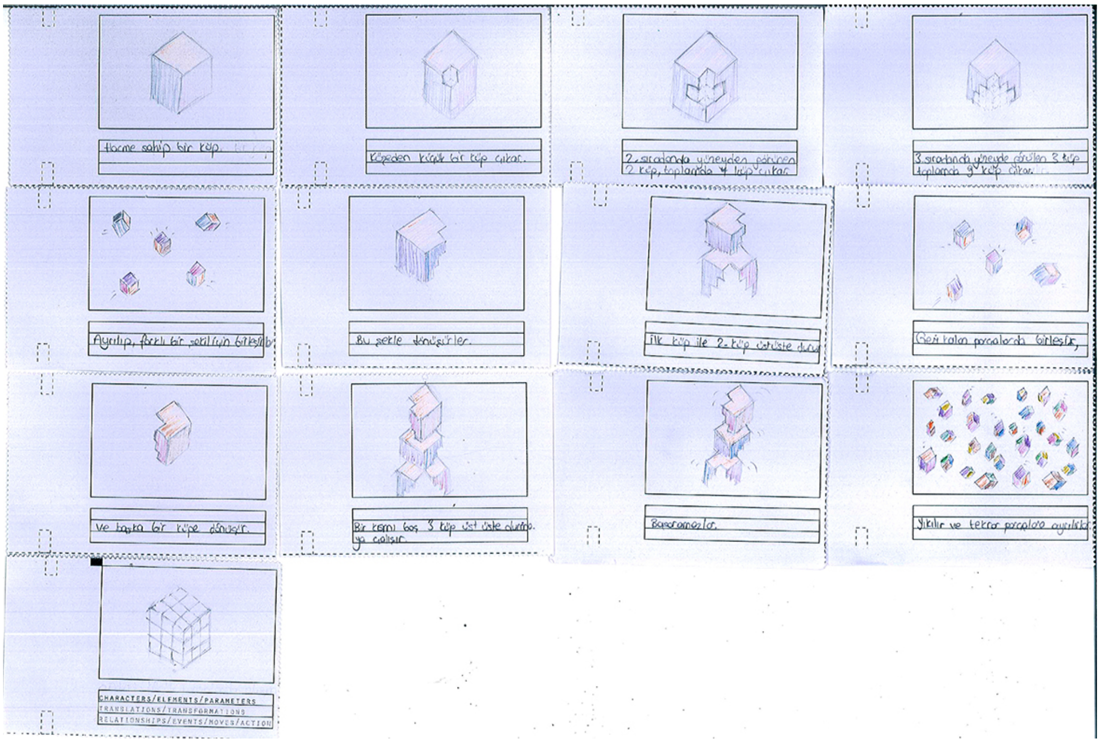


Figure 56 1st year architecture student's storyboard

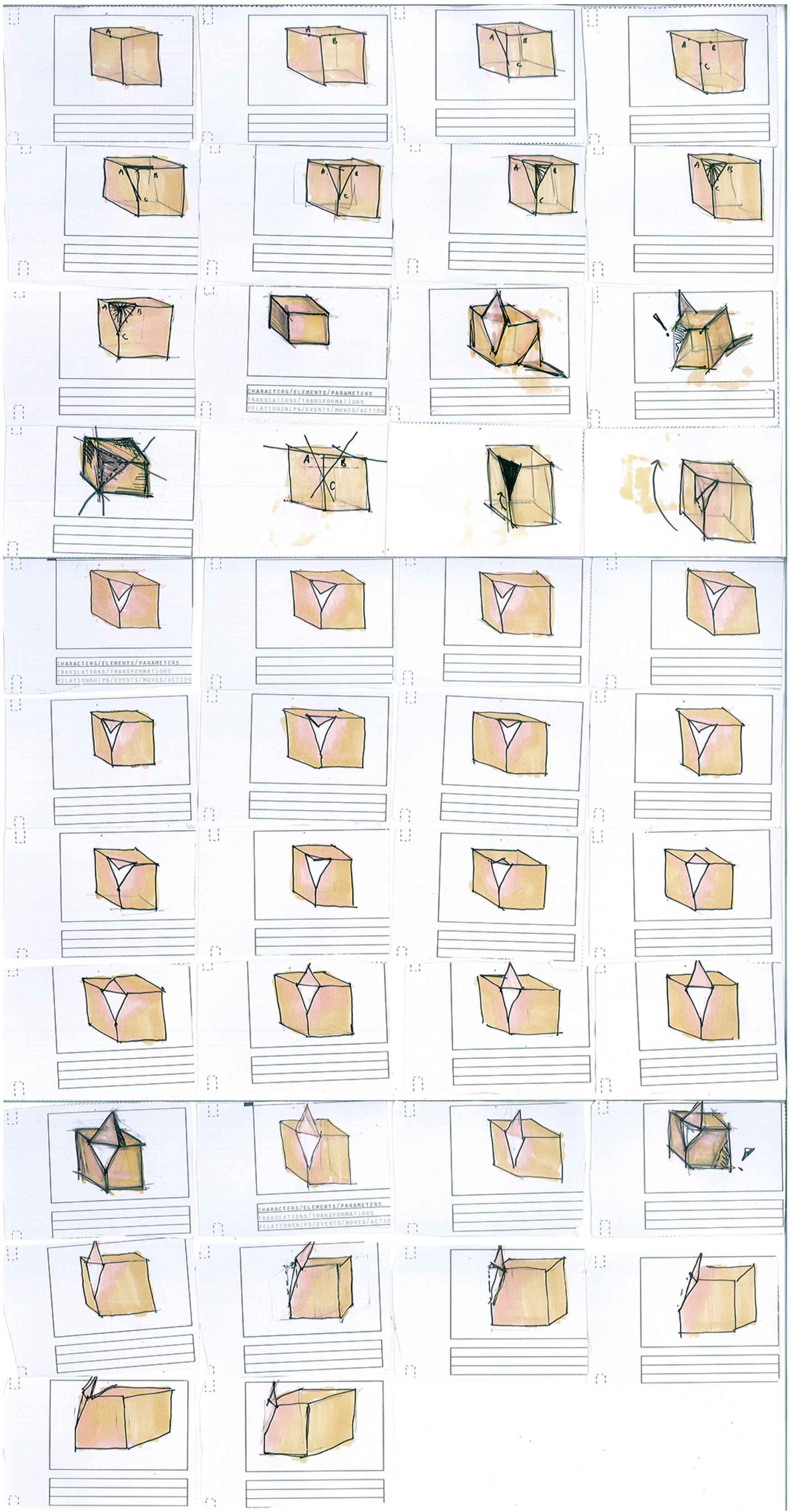


Figure 57 2nd year architecture student's storyboard

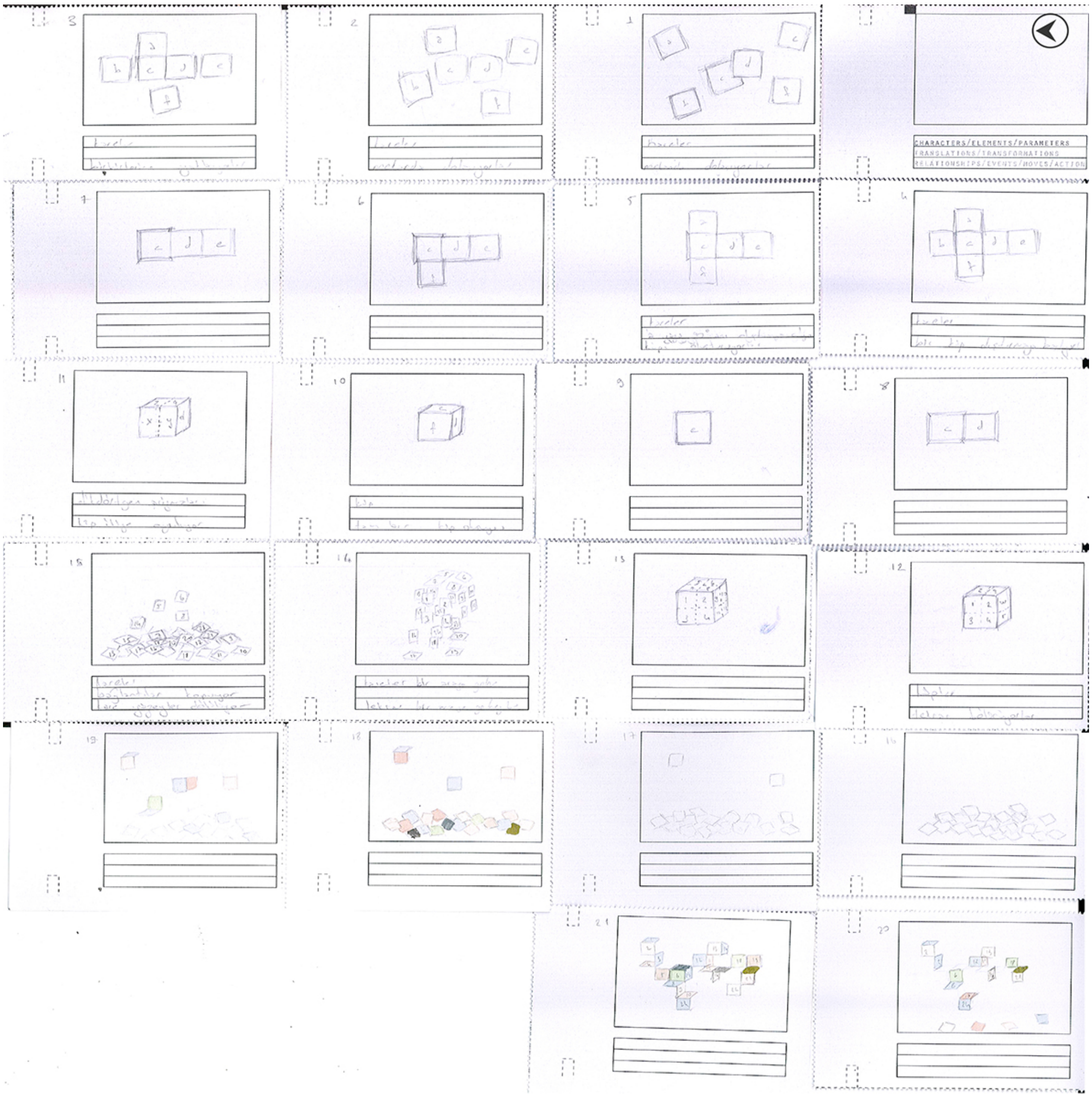


Figure 58 Graphic Designer's storyboard

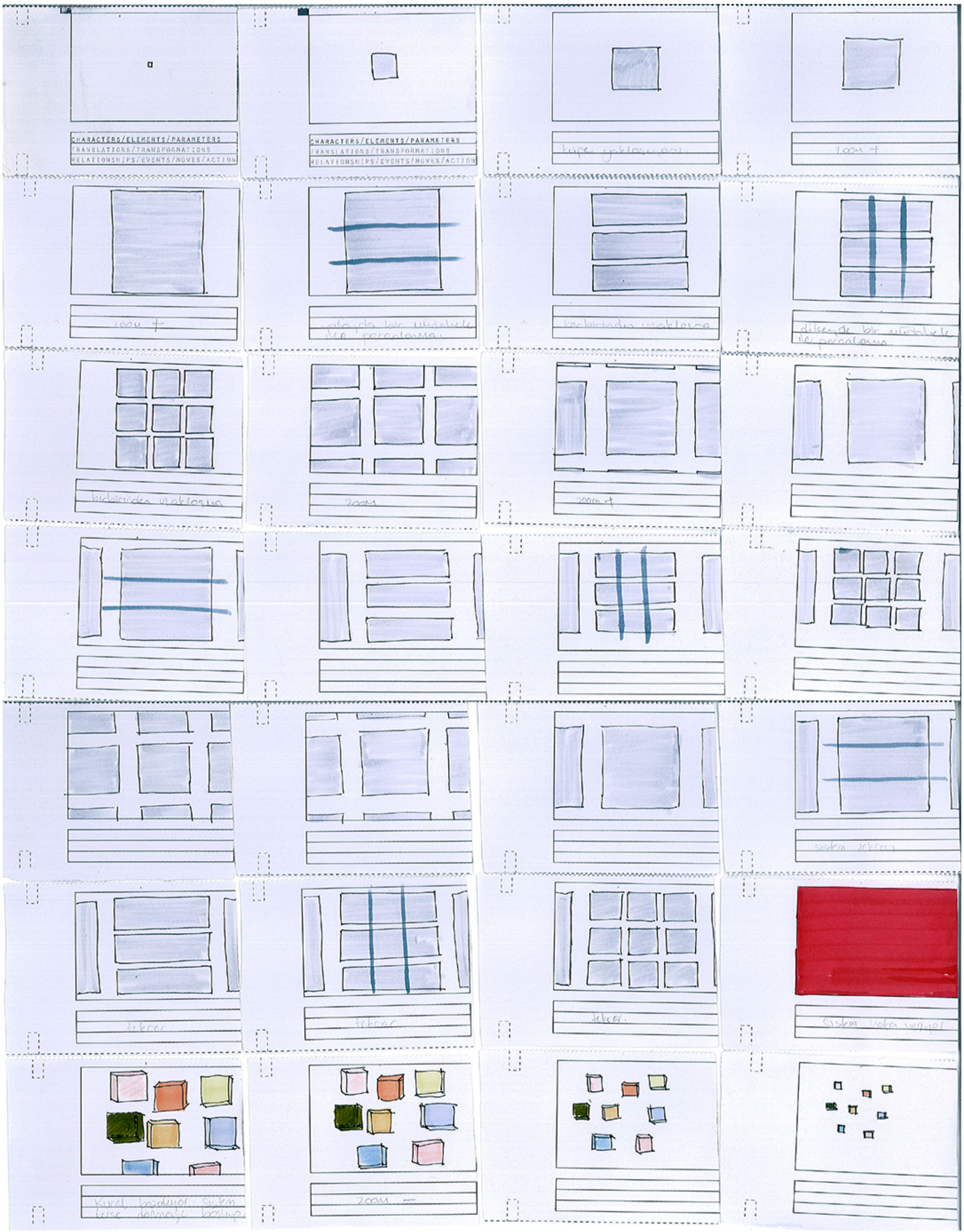
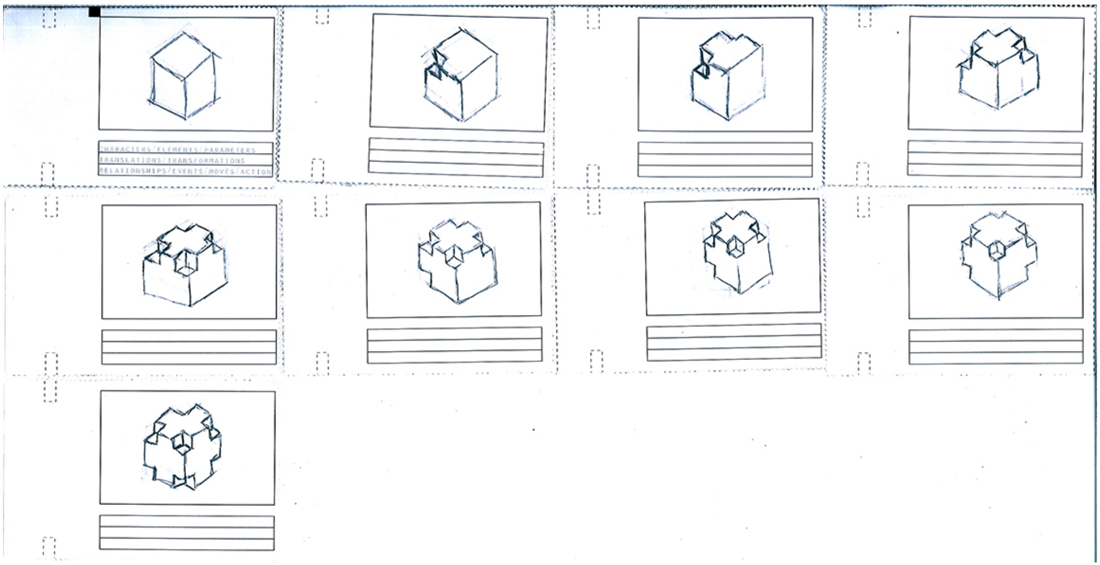


Figure 59 2nd year architecture students storyboard

STUDENTS' STORYBOARDS FROM *CUBEHOCHOLIC II* WORKSHOP



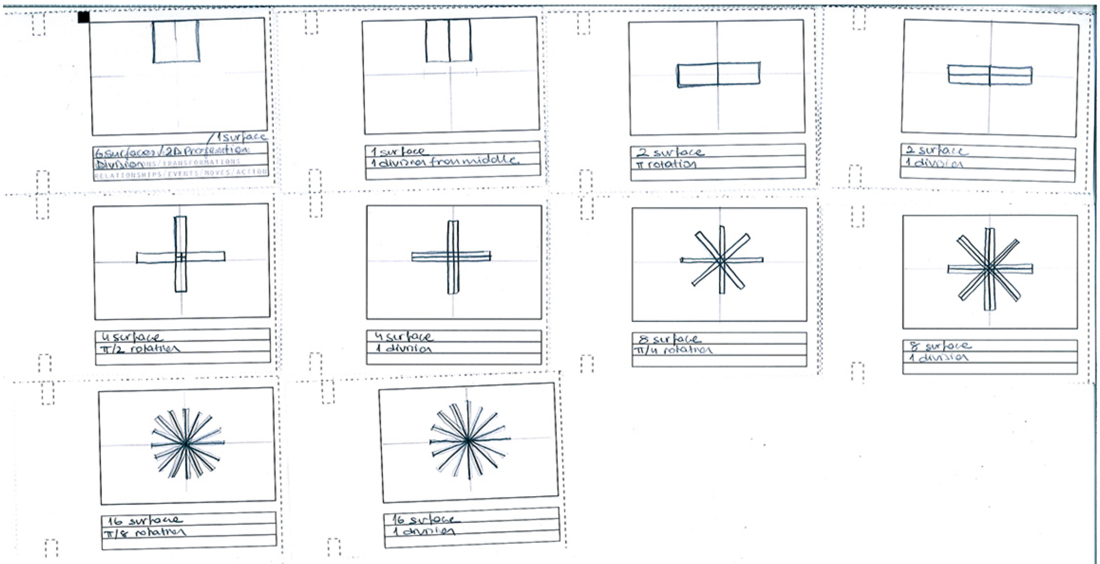
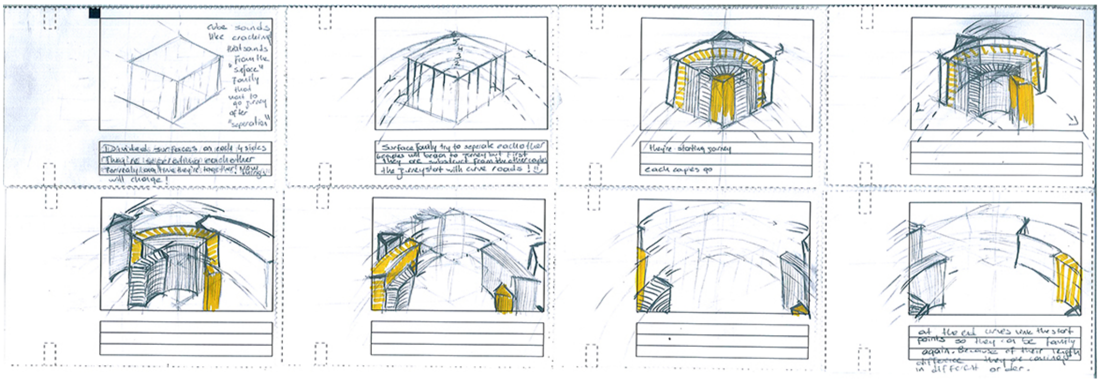


Figure 60 3rd and 4th year architecture students' storyboard



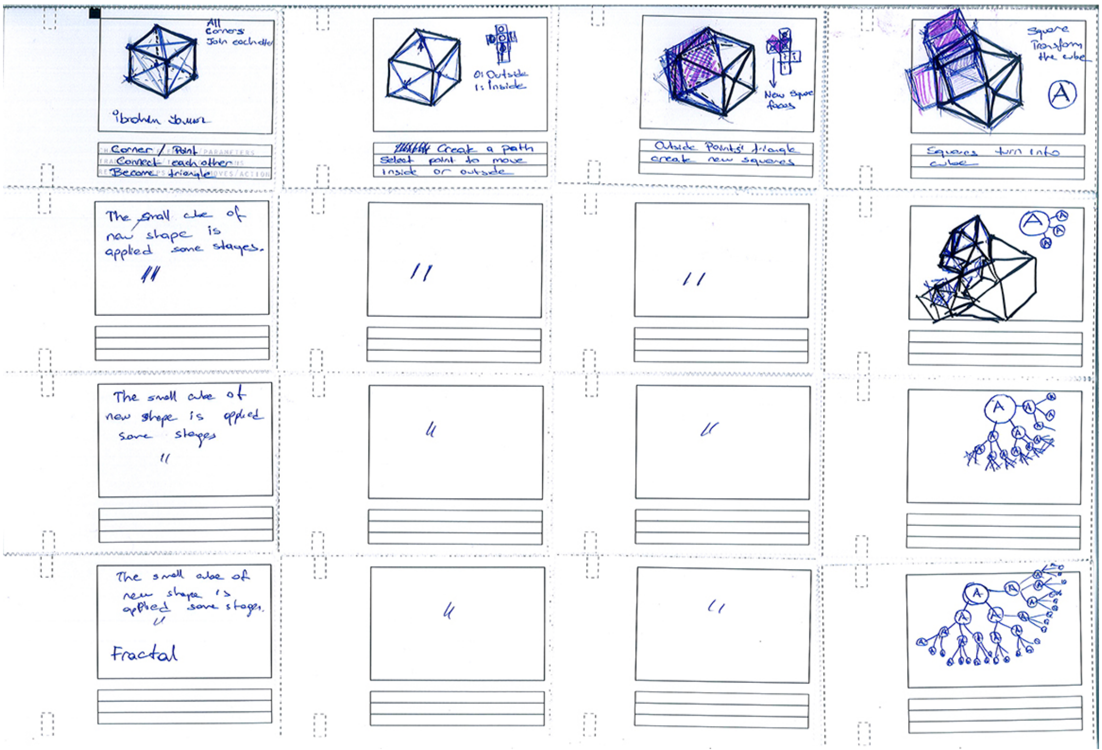
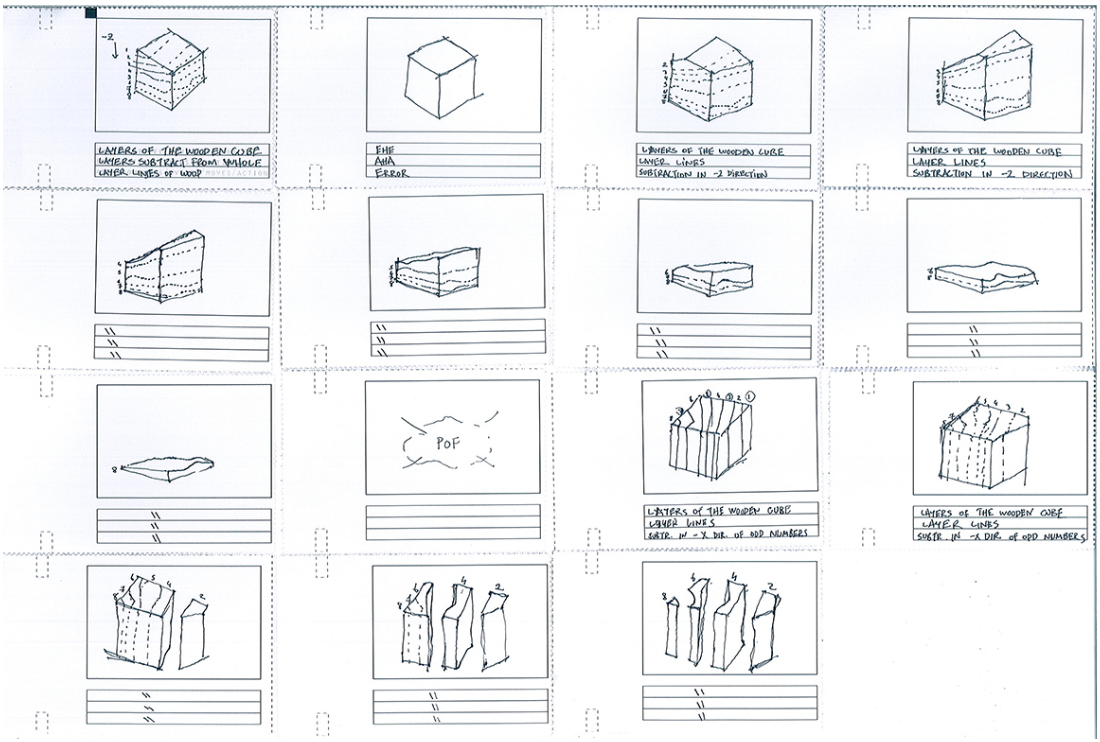


Figure 60 (Continued)



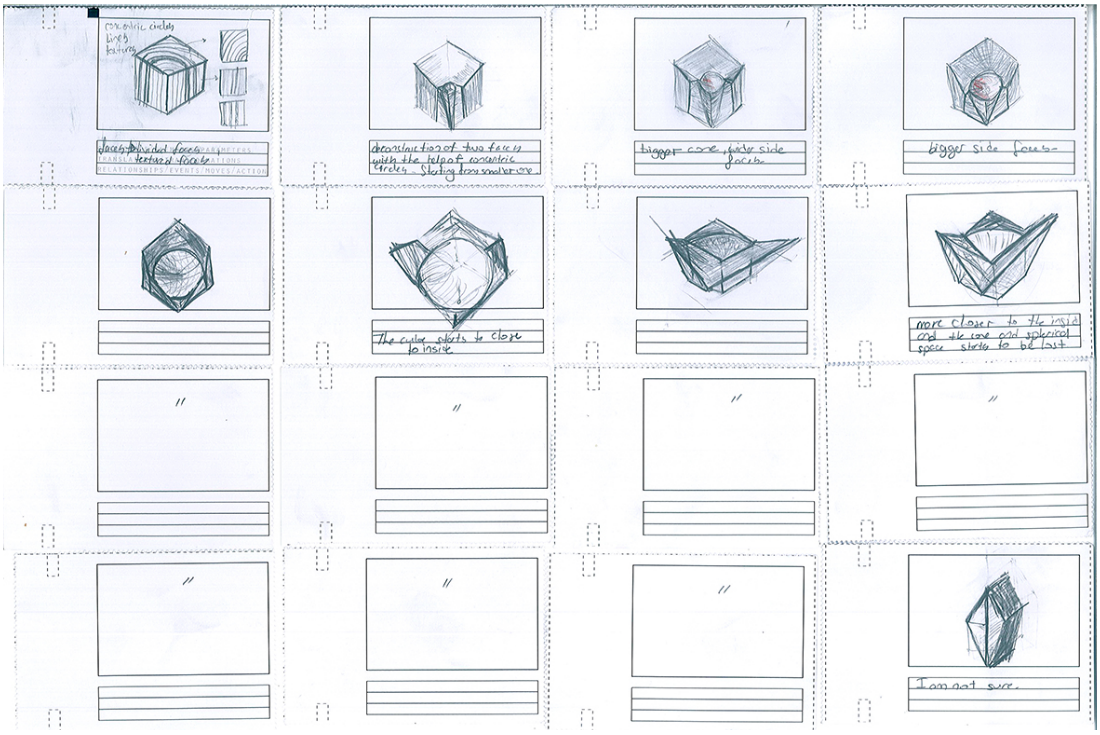


Figure 60 (Continued)

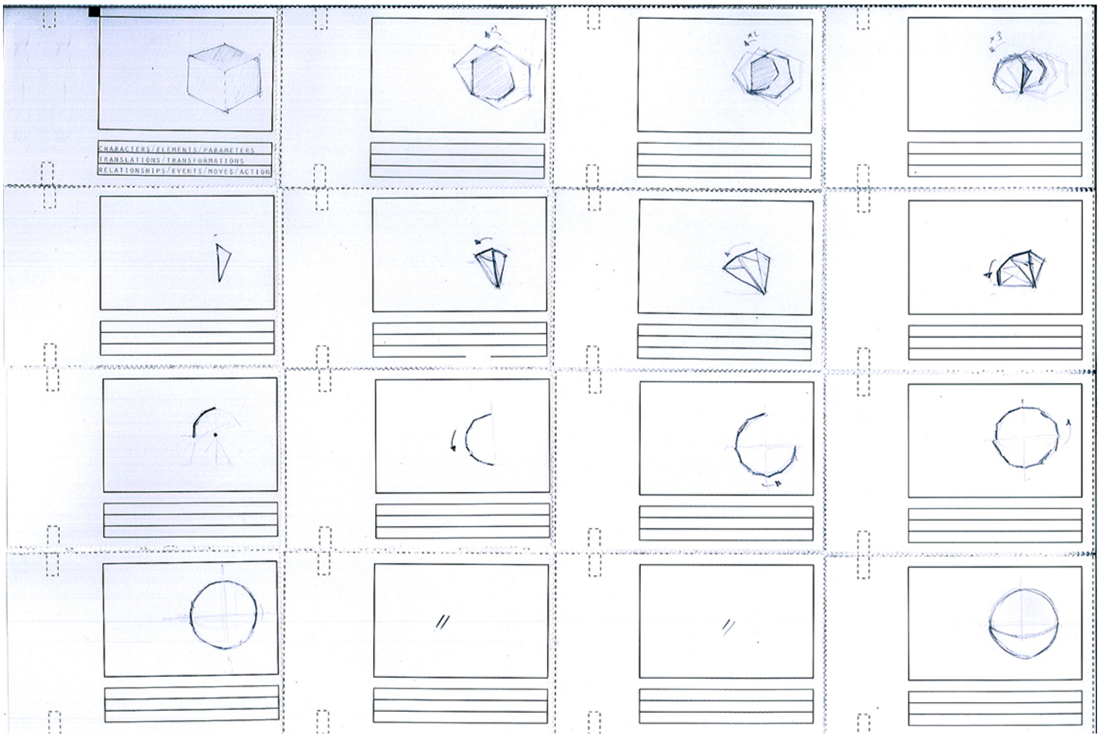


Figure 60 (Continued)

APPENDIX B

STUDENTS' VARIATION MATRICES

Table 42 One of 2nd year architecture student's cube variation matrix is an example to one to one translation from storyboard to computational model

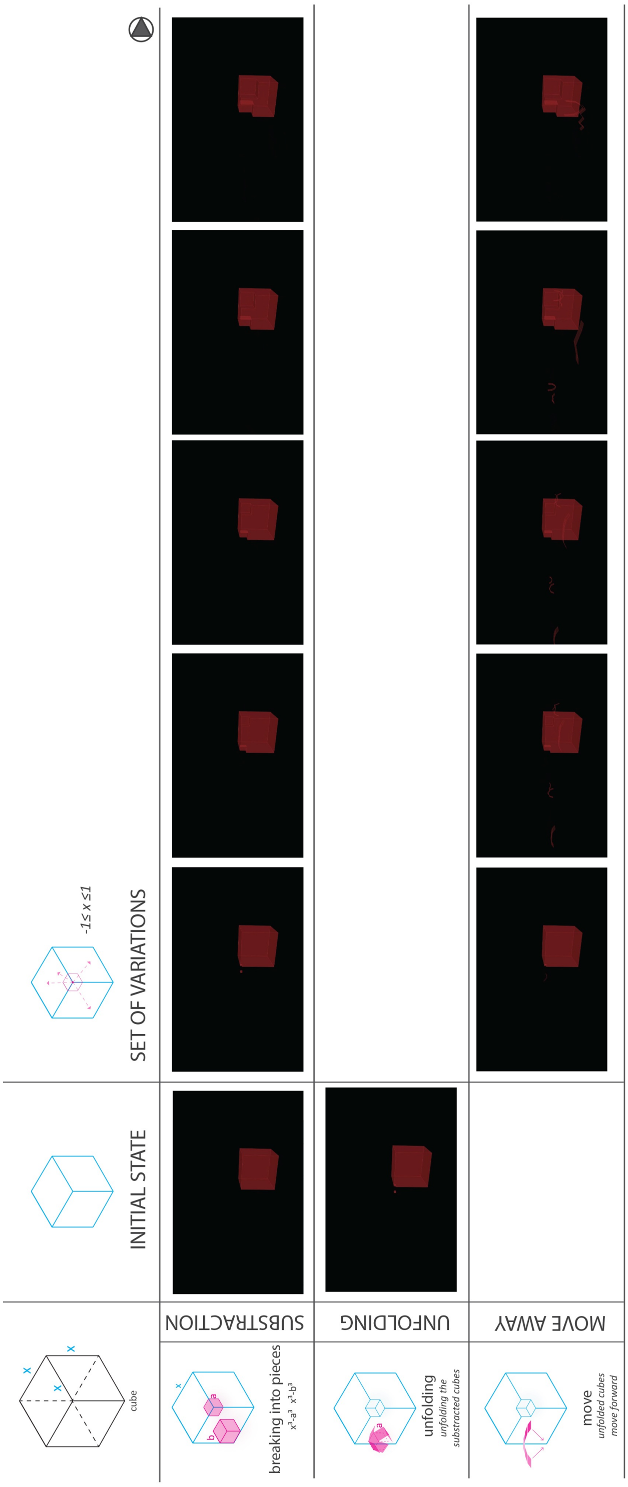


Table 43 1st year architecture student's cube variation matrix and the unexpected result while translating the storyboard to computational model

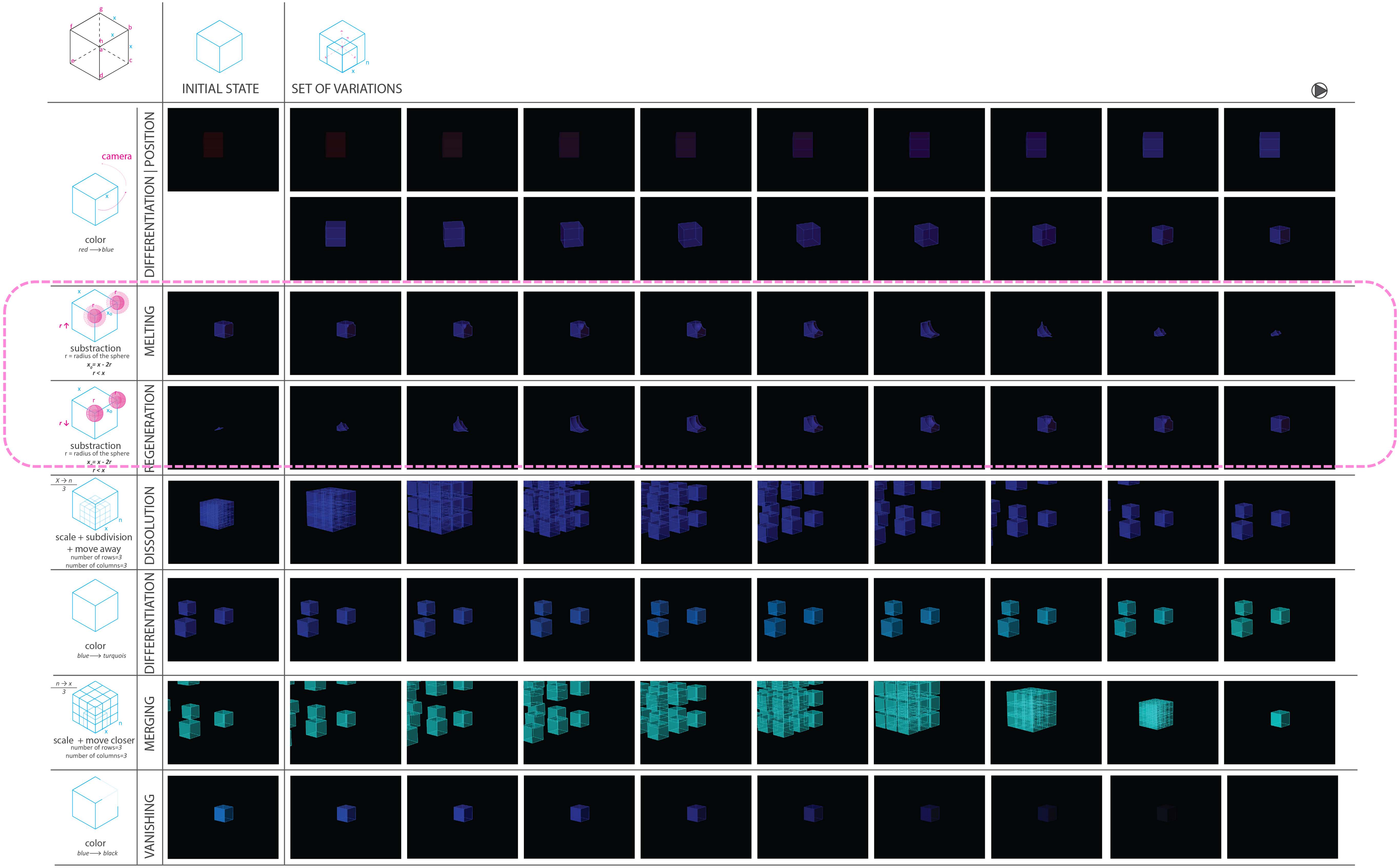
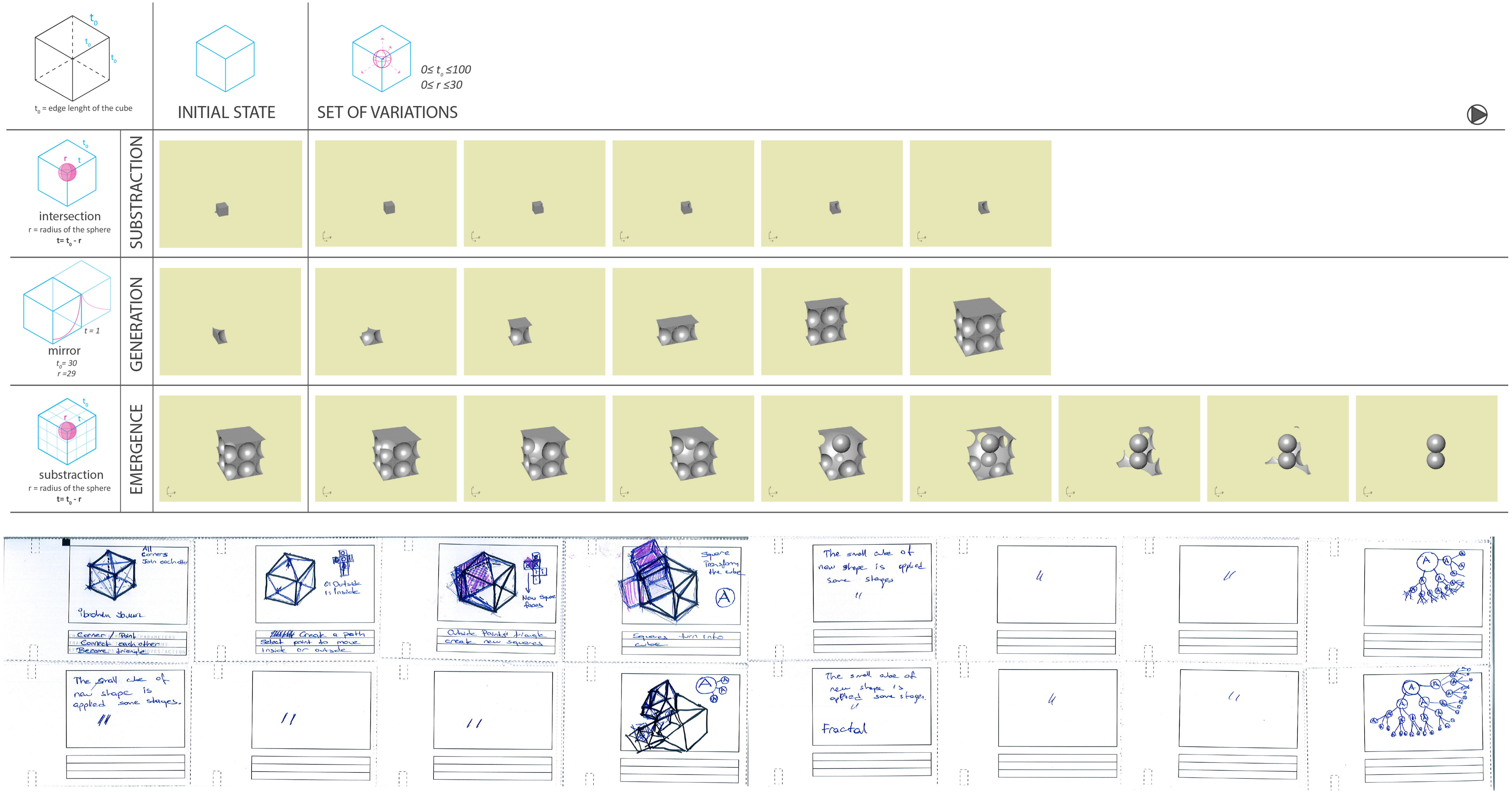


Table 44 4th year architecture student's variation matrix and storyboard; a new design problem is defined after the storyboard session during computational model generation.



CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Kavakoğlu Akçay, Ayşegül
Nationality: Turkish (TC)
Date and Place of Birth: 26 June 1981, Ankara
Marital Status: Married
Phone: +90 535 393 45 82
E-mail: akcaysegul@gmail.com

EDUCATION

Degree	Institution		Year of Graduation
M.ARCH	METU	Architecture	2008
	ENSA-Paris-Belleville (6 months)	Architecture	2007
B.ARCH	DEU	Architecture	2006
High School	TED Ankara College		1998

WORK EXPERIENCE

Year	Place	Enrollment
2015-Present	İstanbul Kemerburgaz University Department of Architecture	Lecturer
2011-2015	İstanbul Kemerburgaz University Department of Architecture	Teaching Assistant
2010 2012	Eskişehir Osmangazi University Department of Architecture	Studio Instructor
2008-2010	CAG Architectural Workshop	Architect
2008 May-June	Uygur Architects	Architect
2005 2006	Oran Architects	Architect
2005 June-August	Agora Restoration Project	Architect

FOREIGN LANGUAGES

English, French

PUBLICATIONS

Kavakoğlu Akçay, A. "The cinematic image as an architectural conductor: a mediated hint from the future architecture" in *Filming the City–urban documents, design practices & social criticism through the lens*, Intellect Books. (Will be published as a book chapter in April 2016)

Kavakoğlu Akçay, A. "From Moving Image to Computational Design Model ", Nexus Conference: Relationship Between Architecture and Mathematics, Proceedings of PhD Day Session, (2014)

CONFERENCE PRESENTATIONS

Kavakoğlu Akçay, A. "From Moving Image to Computational Design Model ", Nexus Conference: Relationship Between Architecture and Mathematics, PhD Day Session, (2014)

Akçay, A. "The cinematic image as an architectural conductor: a mediated hint from the future architecture", The Mediated City Conference: Los Angeles, (2014)

Akçay, A. " Captured Ideologies in Cinematic Spaces: Jacques Tati's Les Vacances de M. Hulot, Mon Oncle and Playtime as Case Studies", Urban Popcultures 3, Inter-Disciplinary.Net, Prag, (2013) (will be published)

Yorgancıoğlu, D., Soyöz, U., Çetin D., Akçay, A. "Revitalization of the Seafront Strip around Old Galata Bridge", 2nd Biennial of Architectural and Urban Restoration: Migration and Multiculturalism. The Conversation of Small Scale Architecytural Structures against Fading Away and Natural Hazards, İstanbul, (2013)

Akçay, A. "The Representation of City Images in Cinema: The Case of Renaissance", Atmosphere 2011 Conference: Mediated Cities, Winnipeg, (2011)

EXHIBITIONS

Akçay, A., Hacıömeroğlu, T.N. "Formal Montage" Photography Exhibition, 3rd International Çanakkale Biennial, (2012)

Akçay A., Işır Ö. "Bigger and Bigger" Workshop Exhibition, My Friend Biennial, International Children Biennial, Çanakkale, (2012)

NATIONAL AND INTERNATIONAL ORGANIZATIONS

"Mimarlık Eğitiminde Pedagoji ve Pratik Arasında Var Olmak" Symposioum, Organizing Committee Member, İstanbul Kemerburgaz University, İstanbul, (2014),

3mm Project Exhibition, Tokyo Designers Week, Academic contributor, Tokyo, (2013), (International)

3mm Exhibition, İstanbul Design Biennial, Academic Program, Project Team Member, METU, Ankara, (International)

Fabric Form: C.A.S.T. Workshop at METU, Organizing Committee Member, METU, Ankara (International) www.fabricform.wordpress.com

DEU Faculty of Architecture, National Architecture Student Meetings: Meeting 7,5, Organizing Committee Member, İzmir, (2003)

WORKSHOPS

Cubehocholic II, METU , Ankara, (2015)

Cubehocholic, İstanbul Kemerburgaz Universitesi, İstanbul, (2014)

Formistila, Bademlik Design Festival, ESOGU, Eskişehir, with T. Nihan Hacıömeroğlu (2014)

Molding with Textile, METU Department of Architecture, Ankara, with T. Nihan Hacıömeroğlu, (2012)

Bigger and Bigger Workshop, İstanbul Kemerburgaz University, with Öznur Işır İstanbul, (2012)

AWARDS

National Architectural Design Competition for Daily Child Care Facilities in Organized Industrial Zones, 3rd Prize, (2013)

MEMBERSHIPS

Registered architect at TMMOB Chamber of Architects

DEU Faculty of Engineering Theater Club, performance player, (2000-2003)

HOBBIES

Movies, Photography, Paper Folding, Carpentry