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Rereading Aggregates, Digital Design for Design 1

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Abstract

Representation in Architecture can function in two different ways: to explain or to generate. Using a representation as a generative starting point, representation does not function to represent but to construct a reality that is yet to come, a new type of reality. [1] This generative use of representation is generally understood as an invitation for interpretation. [2] The described studio is replacing the process of interpretation with a process of application. The studio used sequence that moves from representation that functions as explanation to representation as application, which differentiates it from a design sequence that moves from explanation to interpretation as described by Stan Allen.

The discussed educational design methodology for undergraduate architecture studio instruction uses a systematic and research based design approach originally developed by Lars Spuybroek as a one-year graduate and postgraduate studio. Within this method students first analyze processes of systems that generate patterns. In this state the representation is used to explain an already existing process as a set of essential rules. It is then applying these rules universally to different architectural aspects such as program, envelop and structure. The paper will discuss the methodology for the graduate and postgraduate program developed by Lars Spuybroek, and explain its adaption for undergraduate studio instruction.

Keyword: Methodology of CAAD, Education in CAAD, Generative Design, Parametric Modeling.

1. Introduction

Conventional architectural studios may start with research of site, program or specific building technologies as drivers for a design process, using digital tools as a means of presentation. In recent years we witnessed a larger number of digital studios that have been taught with the emphasis on digital tools. Foregrounding the tool these investigations often focused on the investigation of formal novelties for architecture. Greg Lynn, Zaha Hadid and Patrick Schumacher are leading this method in the studios they taught in Europe as well as in the United States (Terzidis, 2004).

The studio that will be discussed in this paper is an attempt to move the focus from the tool to methodology, as a constructive generic framework. The discussed method is based on Lars Spuybroek's approach to teaching digital design, which he developed at Columbia University, University of Kassel and the Georgia Institute of Technology. Certainly, similar approaches to digital design can be observed at the Architectural Association in London, the University for Applied Sciences in Vienna, at MIT, at University of Pennsylvania and at other universities. Instead of analyzing the similarities and differences between the different programs this paper will specifically focus on Lars Spuybroek's approach to digital design.

2. Research and Design

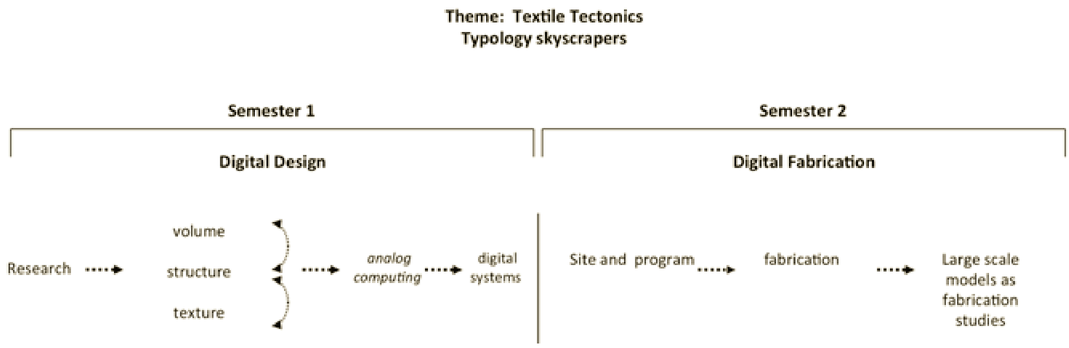

Figure 1. Structure Ventulett Studio, L. Spuybroek.

In the foreword of R&D Lars Spuybroek (2009, p.7) states:

> Information was text; form was architecture. Today, things have changed. Tools aren't fixed anymore, type isn't fixed anymore, demographic maps have been changed completely, products are being replaced by half-products and everything seems to be fluid and vague. Design requires more research, since the transfer into architecture is without prefixed codes, without prefixed forms and

> procedures. It is no longer enough that we do research before entering a design phase: we now have to research design itself.

In that context he postulates that our methods of teaching and designing must become more rigorous and clear.

Lars Spuybroek’s work at the Georgia Institute of Technology is the best documented of the three schools mentioned above. Georgia Tech’s Ventulett Program allows him to publish the work from each year in the Research and Design series (R&D). So far R&D I that presents work from 2007 and R&D II that presents work from 2008 have been published. The teaching methodology presented in these books is based on a two-semester program with two subsequent design studios, two theory seminars and a symposium that is linked to the topic of the specific year. In R&D I the topic was Uniformity and Variation, in R&D II the topic was Textile Tectonics. In 2009 the topic was Seeing and Feeling, 2010 Digital Craft and 2011 Beauty. The program is open to students at the end of the graduate program and postgraduate students. The studio takes place over two semesters: The first semester is structured into a research part and a design part. The second semester is structured into a site investigation and a second part that investigates fabrication.

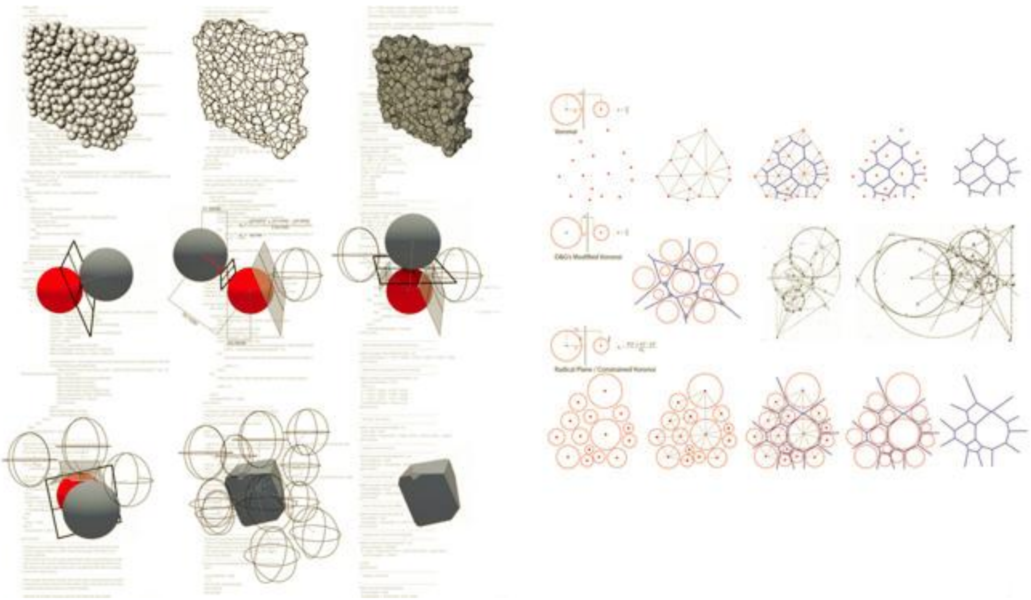

Figure 2 - Foam Tower (R&D2). Students: G. Braiman and D. Beil. Instructors Lars Spuybroek, Daniel Baerlecken.

For example the studio Textile Tectonics taught in 2008 and published in R&D II focused on the structure of vertical building types.

In the first part of the first semester students were asked to investigate in textile techniques. Topics within this research included gothic figures, braiding, foam, radiolarian and minimal path systems based on Frei Otto’s form finding experiments with wool threads (Kolodziejczyk, 1992). For each topic students were asked to diagram patterns as systems with varying figures and their configurations. These systems were understood by the students through analogue computing - Gaudi and Frei Otto - and through rigorous diagramming and subsequent translation into digital systems. The diagrams were parametric and were still able to vary within a certain defined range. During this phase students worked in pairs, which helped to foster a dialog-based approach.

In a second part of the first semester students were challenged to use the pattern systems analyzed in the first part of the semester to inform architecture in one or more of three interconnected systems. For example different façade systems might have been a result from relating a structural with an ornamental system or the relationship between a structural system with a volume or massing system. A pattern for instance might have been first used to inform a structural system that further informed the distribution of program elements, the positioning of floor slabs, the composition of the façade, the formation of apertures and possible relationships to a specific site. Students in this approach were challenged to develop a wide range of different prototypes for building components and elements and their possible relationships. Tectonic systems were developed as rule based systems that were flexible enough to potentially respond to different external and internal forces such as site and program without being tailored to a specific context.

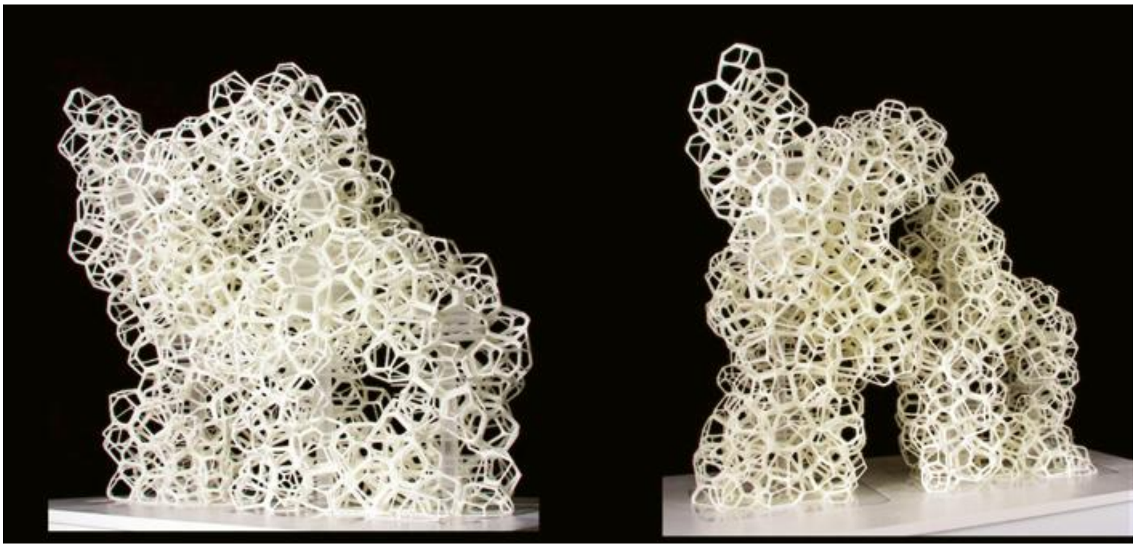

Figure 3. Spuybroek's Borgesian "zoo": Foam Tower (R&D2). Students: G. Braiman and D. Beil. Instructors: Lars Spuybroek, Daniel Baerlecken.

In the first part of the second semester students used the architectural systems that they developed in the first semester to respond to parametric forces of a specific site and program. The projects actualized themselves in this process as consequences. The students selected their own site and the program based on the potential that the previous developed system would have for a certain site and a certain program. The second part of the second semester focused on the exploration of tectonic properties through digital fabrication with an aim to produce large models. All models heavily involved computer numeric control, which would eventually add up to a potentially infinite Borgesian "zoo," a Wunderkammer of variations and studie (Spuybroek, 2009, p.7). These models included 2m high structures as well as mock-ups of full-scale façade structures.

3. Studio Methodology for Design 1

In summer 2011 Lars Spuybroek and we were asked to develop a new teaching method for a second year undergraduate studio at the School of Architecture at the Georgia Institute of Technology. Adapting a pedagogical framework that is based on the exploration of specific architectural concepts was challenging but provided a series of advantages for the specific situation of the curriculum of our Architecture School. After the Common First Year, Design 1 is the first design studio in the undergraduate architecture curriculum. The second year is followed by option studios that are offered in a vertical studio format that combine third and fourth year students.

The common first year introduces students to a wide range of different methods of perceiving the world and methods to help them to engage it. A studio similar to the Lars Spuybroek studio as elaborated above might provide the students with more time and feedback to develop one specific method much further and show how a specific understanding of the world might inform the design of a building. Such a sequence in the second year will also equip students for the following third year with an understanding of the fundamentals of design research, an architectural design process of a building of a certain complexity and the conventions of presentation in architecture. A very precise structure of the semester as well as a single research and design project also allowed building on the learning objectives from the first year. When in the first year the focus was on a large variety of media and tools this semester allows students to expand their knowledge and skills by developing a single method and specific set of tools much further. Developing a semester in 2 parts, one focused on research and one on design further allows for a clear structure of learning objectives.

In the research part learning objectives might be as follows: In focusing on one research topic for longer period of time students will be able to elaborate more on a specific topic and method and be able to present a research in a very precise and detailed manner. The analysis of systems outside the discipline of architecture allows the introduction of a methodic design process without favoring a certain type of architecture or a certain style. Since the research might be applied formal, structural or even decorative. The guidance trough a very rigid framework of research might support a parallel building of skills in using digital tools methodical. In using a rigid design process students will learn how a design process can be structured in a very methodical way. Developing a very precise framework further allows formulating equally precise learning objectives.

In the design part learning objectives will expand the previous objectives with the goal to apply a specific analytical understanding through the development of architectural ideas. It will provide a framework that allows students to manage and respond to a complex set of parameters that include site and program. The learning objectives in the second part of the studio also included the convention of architectural representation. Using one project that is not too complex in terms of site and program allows developing the project in further detail. This further allows touching on aspects such as material or structure. The studio that introduces an architectural program for the first time will in that way serve as a transition to more comprehensive design studios in the following years.

Adapting a graduate research studio to a second year undergraduate studio is of course not without organizational changes. Different to Lars Spuybroek's graduate option studio that is usually co-taught with about 15 students we had 60 students and instead of one year we were challenged to compress the sequence within one semester.

In order to manage the large group of students we split them in 4 groups of 15 students each. The 4 parts of the graduate studio were: A research part and a design part in the first semester and a site investigation and focus on fabrication in the second semester were altered into 4 slightly different parts, all within one semester. 1) Aggregation Techniques: Analysis, 2) Aggregation Techniques: Digital diagramming. 3) Differentiation and Integration: Programming and Siting the Aggregation. 4) New skills: Drawing, modeling and rendering. In order to maximize the consistency in approach, structure and outcome all sections shared a very detailed schedule and reviewed at the same times. The four sections were taught by Marcelo Bernal, Jihan Stanford, Sarah Soh and Alice Vialard. This allowed us to move between different sections with the goal to achieve consistent learning objectives. This format was choses to introduce this specific methodology to the instructors.

Beside the challenge of compressing a studio that Lars Spuybroek usually teaches over a period or two semesters into one semester one of the main challenges was to transform an upper level option studio into a beginning design core studio. This change raised a series of questions regarding "representation" with the studio's overall agenda, how do we respond to the core curriculum agenda and cover aspects such as program and program site relationships, and how do we integrate the teaching of software with the studio.

3.1. Representation

The Studio differentiates between two types of representation:

1) Representation with a backward vector: knowledge of an object presides the representation and representation is a passive act of documenting existing knowledge.

2) Representation with a forward vector: representation is an active process that allows us to gather knowledge through that process.

One always encounters both types of representation in a design process, of course. But within the presented studio format the forward representation is explored by a process that continuously adds new sets of architectural aspects to the original system of aggregation: While students diagram a flock of birds, a herd running away from a predator, people on a beach or the process of crystallization they understand that there is architecture embedded within these patterns. Since the methodology introduces architectural aspects in a stepwise procedure, each representation – diagrams, models, 3d depictions etc. - is informed by the knowledge gathered before (representation type 1) and by knowledge gathered during the execution of the representation, that responds to the aspects currently studied (which could be structure, texture, massing, fenestration, program etc.). This process is obviously bi-directional, when we look at the cracking of ice for example, that informs the cracking the program elements. The original diagram of cracked ice is re-visited with the pre-knowledge of how architectural program parts interact. So information is sent from the program diagram to the original diagram of the aggregate, but the same time the aggregation system sends information to the program, that creates moments of novelty. The resulting representation and knowledge is formed by both entities as a negotiation.

The program and site was introduced mid semester. This allowed students to develop systems independent from site and program constrains. Hiding the site and program for the first half of the semester also supported the idea to analyze and site and program through a previously developed framework. This helped students to develop a security and comfort to respond to program and site in unconventional ways. The introduction of conventions of architectural representation, such as plans, sections and elevations took place at the very end of the semester. A sensibility of 2d and 3d drawing and modeling techniques were developed in the research part of the semester. Depending on different research topics each student developed a language available at the end of the semester to present the systems that they analyzed. In the second half of the semester students were asked to use their modeling and drawing language within the convention of architectural presentation such as plans, sections and elevations.

3.2. Curriculum Integration

The challenge was to introduce a large volume of material to the students simultaneously within a very short time frame. This wasn't so much an issue in upper level option studios, where it can be assumed that students already have the right software skills, are familiar with the convention of architectural representation and have already exercised architectural problems that deal with a certain complexity of program and site. The challenge to introduce software, representation techniques and complex architectural issues in one course opened the opportunity to redevelop the way digital tools are introduced in the undergraduate curriculum.

In the previous schools curriculum software courses were taught separately from design studios and framed around different applications. In many cases these tools informed renderings of final projects, but not the design process itself. In this studio we focused on building digital skills more integral to an architectural design process. Rather than introducing technical knowledge separate from design, digital skills are introduced to become the instrument for design. Talking about digital skills does therefore not mean the tool itself, but the method that drives design. The techniques and tools of design are linked to the design through method. Similar to this analogy students in our studio were asked to develop methods, digital methods in our case, before introducing an architectural program and a site. Our goal was to walk students through a process were "digital" methods are used to define internal relations within the program and relations between the program and the site. Software introduced included Adobe Photoshop and Illustrator, Rhino, V-Ray and the basics of Grasshopper.

4. Structure

The studio that was first taught in the Fall semester of 2011. An investigation and unpacking of existing non-architectural systems was used to develop digital methods, which were used to develop an architectural project at a specific site. Students were asked to diagram and unpack aggregates as rule based systems, collections of items that are gathered together to form a total quantity. (Middle English aggregat, from Latin aggregatus, past participle of aggregare to add to, from ad- + greg-, grex flock, join together, attach) Climate for example is the aggregation of all local weather formations over longer periods of a season or year – with its local variations.

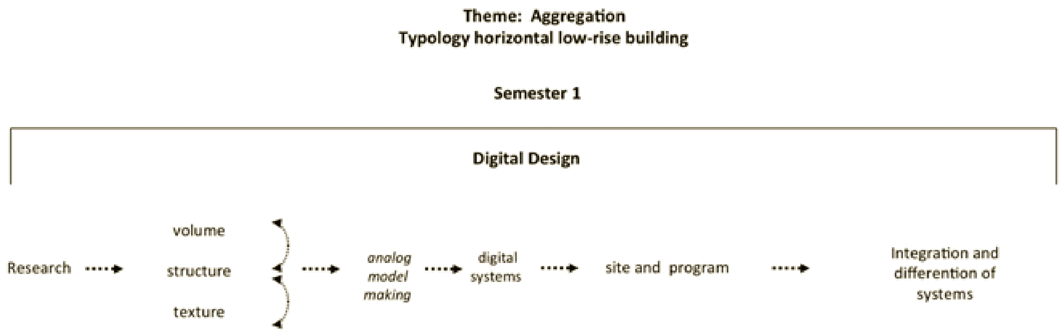

Figure 4. Structure undergraduate studio aggregates

4.1. Aggregation Techniques: Analysis (Week 1-2)

The studio did not investigate a material aggregate as a construction material (Dierichs, Menges, 2010), but as a system or architecture embedded within aggregational systems, that can be used to inform texture, structure, volume, program and any other architectural system. The aggregational parts are understood as varying parts, parametric parts with flexible properties that respond to different vectors or forces within their systemacy. This method followed an evolutionary process, which allowed for differentiation and integration of different systems with increasing complexity:

> Complexity increases when the variety and dependency of parts increases. The process of increasing variety is called differentiation and the process of increasing the number or strength of connections is called integration. Biological and cultural evolution produce both differentiation and integration at many scales and levels…(Weinstock, 2010, p.30).

This development of architectural complexity through differentiation and integration was developed in successive order in different layers and scales and not all at the same.

The types of aggregations researched were: cracking and nesting of different floating sea ice types such as drift ice or pancake ice, aggregation of people in a park, patchwork in self-organized African markets, complete and incomplete states of mud cracking, radial and linear types of glass cracking, diffuse-porous and ring-porous hardwoods, log driving, slime mold, igneous rocks, metal alloys, flocking of herds such as sheep, patterns of angelfish, sand formations and crocodile skin.

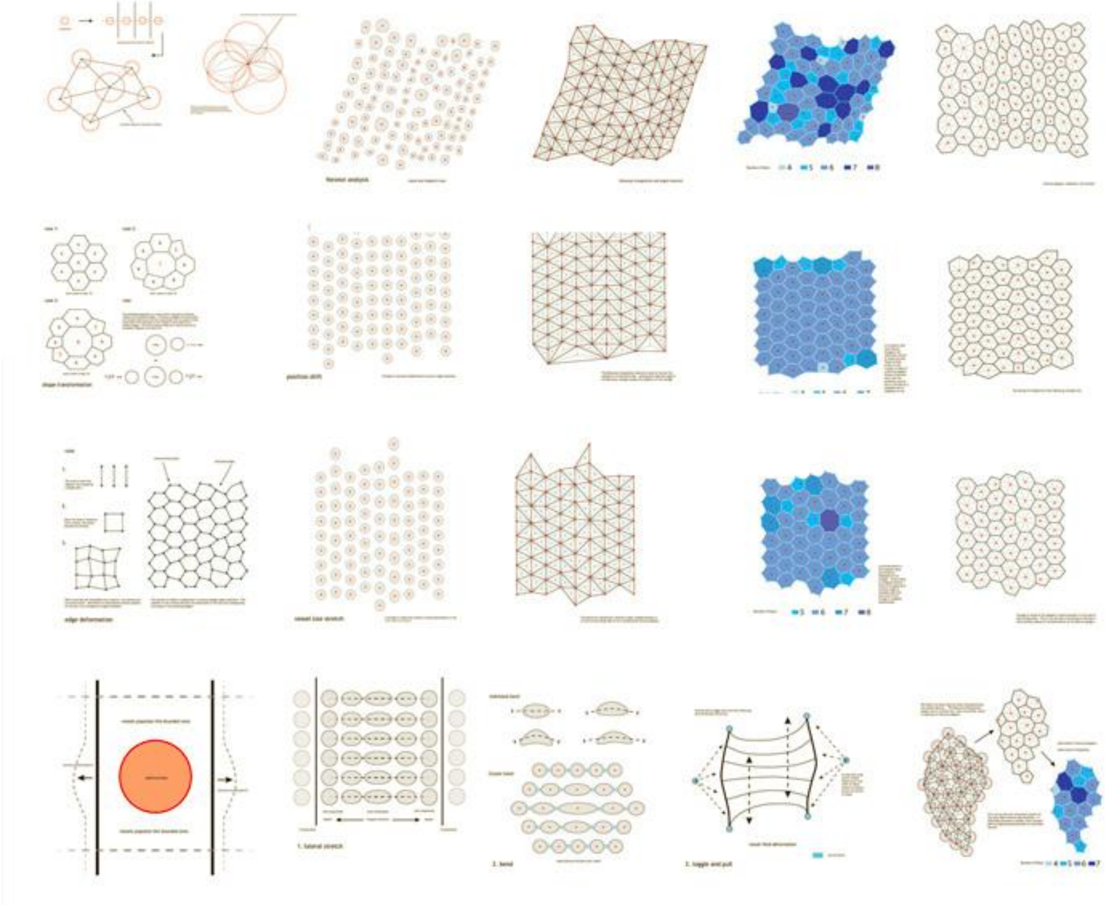

Figure 5. Diagrams. Students: O. Taylor and A. Wang. Instructor: J. Stanford. Coordinators: L. Spuybroek, D. Baerlecken

For the first five weeks the students worked in pairs and choose an aggregational structure from the given list of topics. Students learned how to transform images into diagrams in order to explain and gather a fundamental understanding about their aggregational system. The tools used were Photoshop, Illustrator and Rhinoceros. Students were asked to trace the images with typical diagram tools such as lines, dashed and dotted lines, arrows, colors and texts in different sizes in order to learn how to represent their analysis as a set of rules and pseudo-scripts.

4.2. Aggregation Techniques: Digital diagramming (Week 3-5)

In this phase students transformed the analyzed material into more architectural issues using specific architectural software applications such as Rhinoceros. They started by re- working the analytical diagrams into 2D patterns first and later into 3D patterns and morphologies. At the end of this phase the students had a broad range of aggregational structures, forms or patterns with parametric variation. This work was explored through large fields/carpets of configuring parts illustrating the variability of these parts and the rules of configuration. At this point parametric history editors with real time feedback were introduced to explore variability.

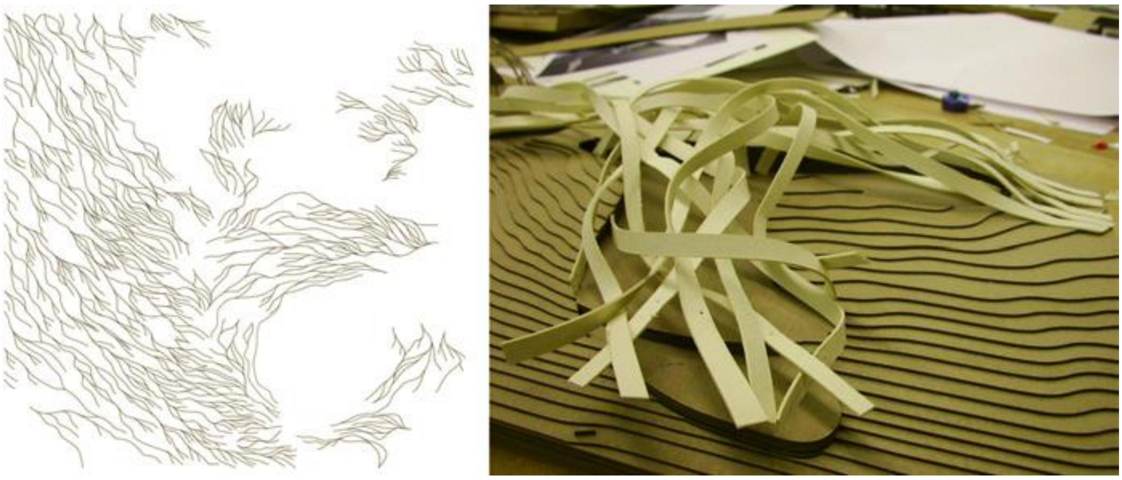

Figure 6. 3d system based on a 2d system of herds movements. Student: L. Kvasnicka Instructor: A. Vialard. Coordinators: L. Spuybroek, G.Riether.

4.3. Differentiation and Integration: Programming and Siting the Aggregation (Week 6-10)

The teams split up in this phase and the students worked individually from this point. They were asked to explore how aggregated systems can respond to the typology of the architectural program and to the site. The program for this particular studio was a cultural center with exhibition areas, a multipurpose area, a small indoor-theater, an outdoor- theater, a cafeteria, a space for administration and back of house facilities. The students could suggest additions to the program in order to accommodate for site or program specifics. The site, a larger area in a local park suggested a multitude of local qualities and potentials resulting from topography, vegetation, vistas, accessibility and the existing program within the park. The site was selected intentionally as an anti-urban setting to better respond to the student's selected aggregation types which all operated on a surface through horizontal extension. The students needed to select a specific site within a larger site area. They were further asked to develop a rationale and narrative for that choice through diagramming techniques.

The design process in this phase comprised the development of the related sub-systems of program, circulation and navigation. Each of these categories is developed in accordance with a specific spatial logic of the aggregation and a sophisticated spatial distribution of the program domains. Boundary conditions between program parts had to be studied to integrate or unify the different domains. A system of navigation and circulation was developed as a mean of orientation through the aggregational structure, which is especially challenging for non-hierarchical structures.

The students used the set of rules that they used in the research phase to explain their aggregational systems to now organize architectural systems such as program or site. For example: programmatic bubble diagrams, which reflect social relations and hierarchies transform into spatial or tectonic systems, which followed the systemacy as previously developed in the research phase. Site diagramming involved traffic flows, sight lines, sun and shadow behavior, but also experiential factors such as light or sound which now become part of the aggregational system.

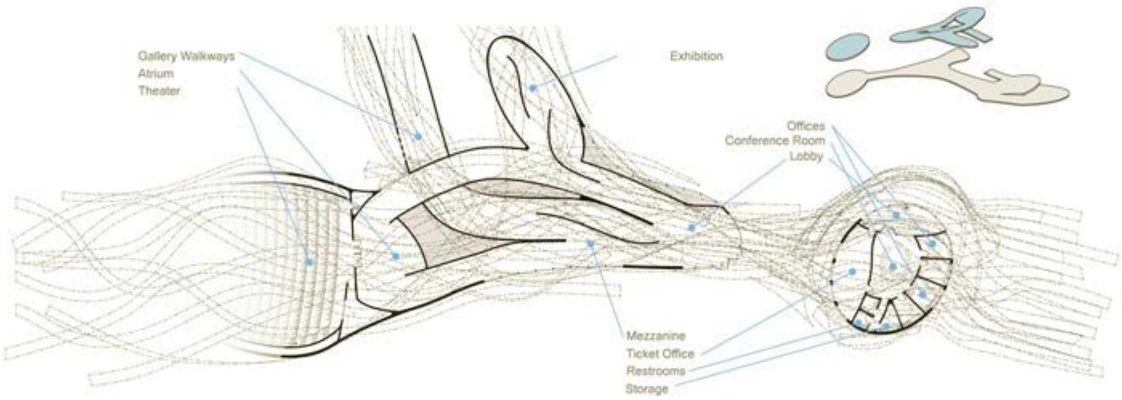

Figure 7. Plan developed from a 3d systemic model. Student: L. Kvasnicka. Instructor: A. Vialard Coordinators: L. Spuybroek, G. Riether.

The analytical research that first let to diagrams has now become a potential start of a project, which allows to further-develop ideas for stairs, entries, apertures etc. as part of the systemacy. In this phase the students learn additional modeling techniques in Rhinoceros, extracting digital information from the 3d file for physical model making, 2d drawing with AutoCAD and additional techniques in Grasshopper. A strong emphasis lied on the bi-directional feedback between digital model and physical to question both realms.

4.4. New Skills: Drawing, modeling and rendering (Week 11-16)

In the final phase the studio focused on production for the final presentation that included drawings, renderings, diagrams as well as physical and digital 3D models.

5. Case studies:

In this paragraph we want to discuss three projects, which exemplify different approaches within the methodology. The first two projects follow closely the methodology, whereas the last one deviates from the approach by using a method of analogue computing.

5.1 Metal Alloys:

The research of this project started with studying the structure of metal alloys with special focus on the Cahn-Hilliard equation that explains phase separation of a binary alloy at a fixed temperature. Principles of that microstructure, in which two materials interact with each other, were extracted to inform social interaction of spaces. Later the researched system was also used to inform a structural system of the proposed project (floor slabs, façade and column system).

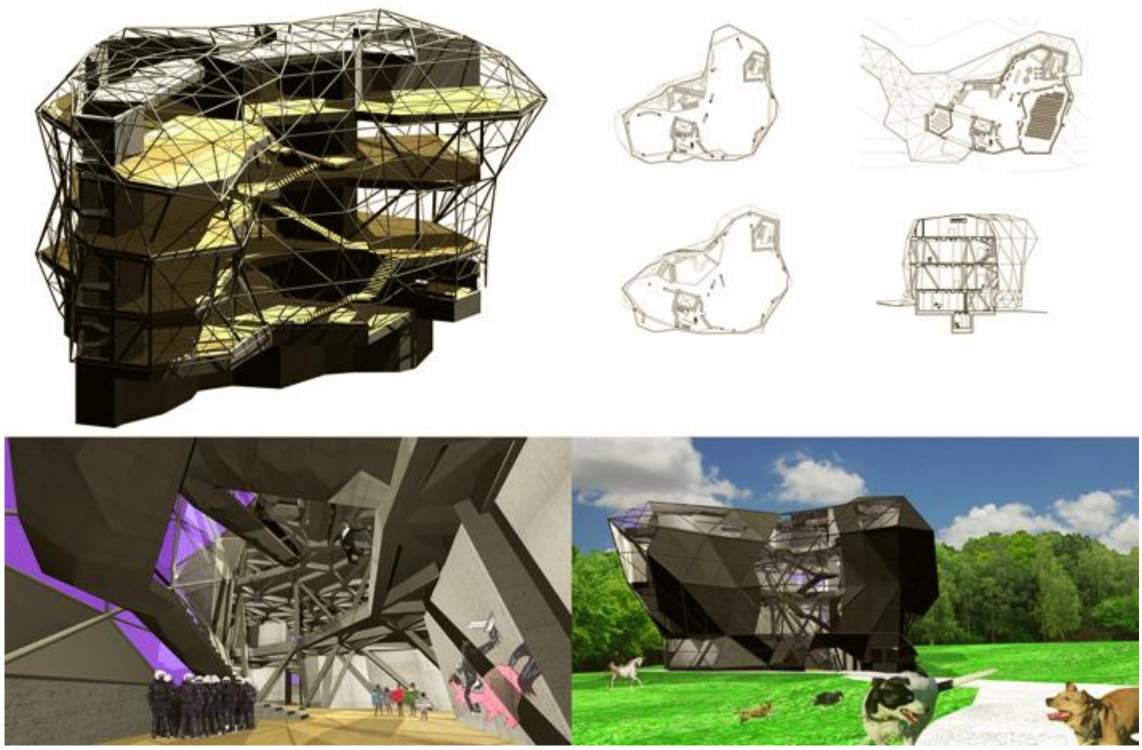

Figure 8. Metal alloys. Student: J. MacDaniels. Instructor: M. Bernal. Coordinators: L. Spuybroek, D. Baerlecken

5.2 Igneous rocks:

The second case study looks at igneous rocks and the crystallization process. The analysis of the cooling and solidification of magma was captured through diagramming forces, which create boundaries of crystals. The system of boundaries was first transferred to the program of the project by creating enclosures and connectivity for different programs and then further developed into a system of pyramidal roofs, which channel daylight in different ways.

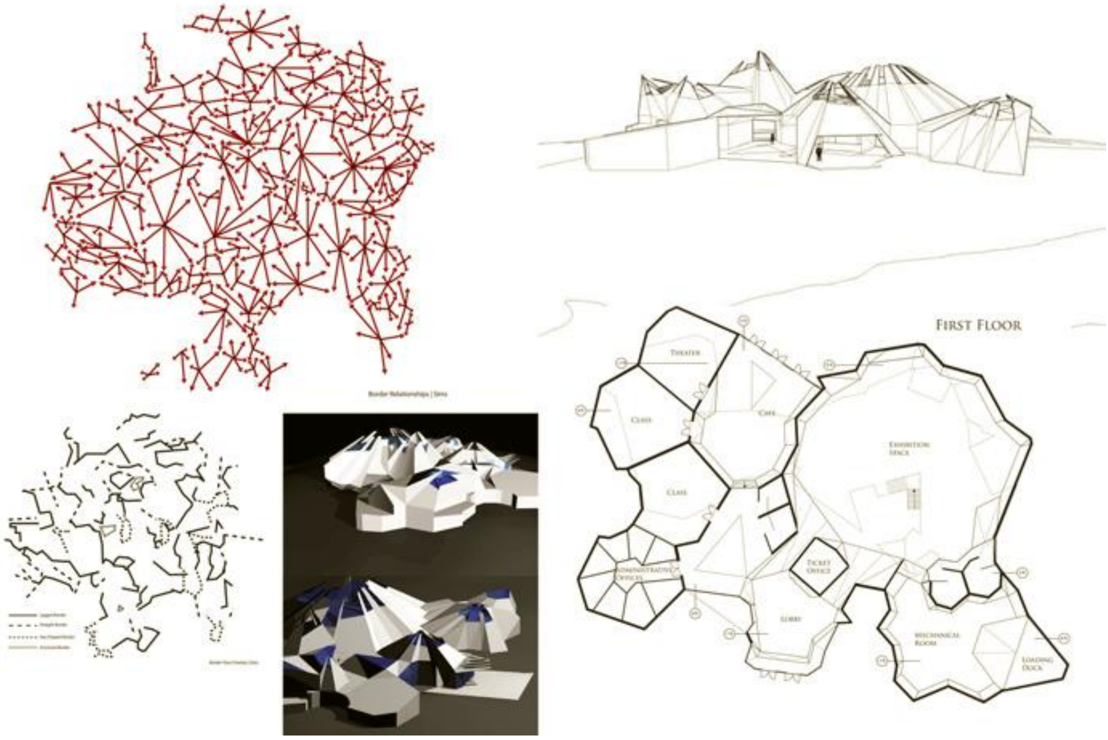

Figure 9. Igneous rocks. Student: S. Sims. Instructor: M. Bernal. Coordinators: L. Spuybroek, D. Baerlecken

5.3 Logs in a river:

The third case study is a project that analyzed the formation of logs in a river. In lack of visual material the project deviated from the studio methodology slightly by setting up an analog experiment: in a large model the different parameters such as flow direction, log sizes, amount of logs and boundaries were tested and diagrammed. The diagrams revealed the formation of groups and linking spaces, which were transferred to the design of roof system. The project was mainly developed through analogue model making. The project follows the same methodology, but deviated gravely in the tools used.

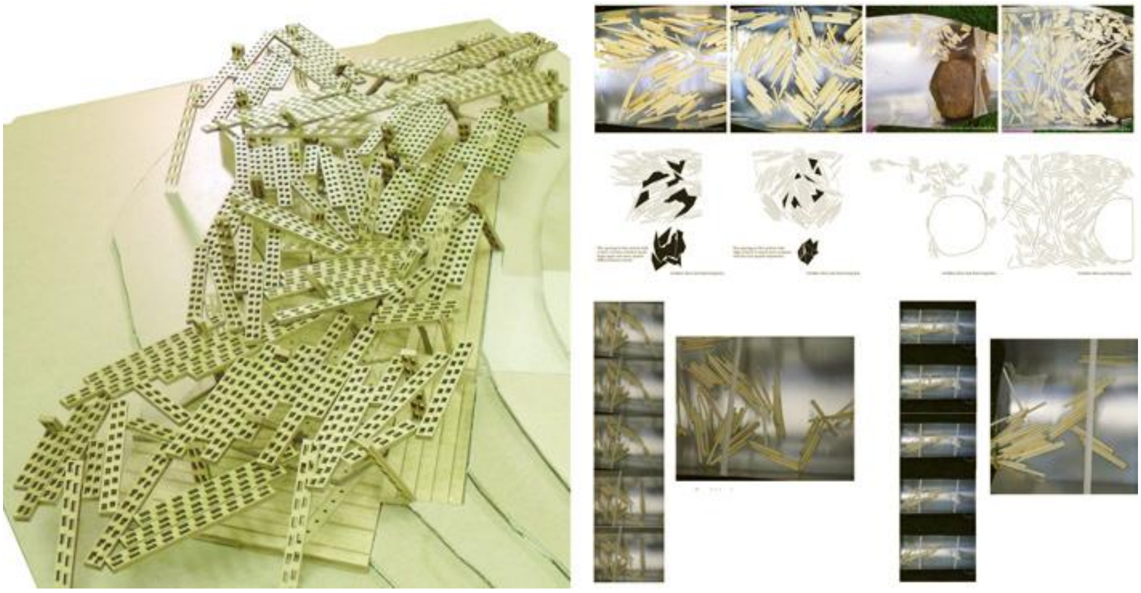

Figure 10. Logs in a river. Student: G. Rees. Instructor: M. Bernal. Coordinators: L. Spuybroek, D. Baerlecken

6. Conclusion

It is, of course, difficult to quantify improvements in architectural design, but it can be observed that the student's skills in drawing and digital representation show a deeper understanding of space and structure and that the methodology has fostered a conceptual understanding of tools and techniques within a design process.

The students also learned how to use representation in different ways: From representation that functions to explain something that already exists to the use of an existing representation that can generate something new. Students also learned how to edit and develop representations to communicate in a very precise and clear manner. Finally they learned about the architectural conventions of representation such as plan, section and elevation.

During the midterm review and the final review external reviewers commented on the methodology of the studio. Most comments were concerned with the scope and complexity of the project. One group of critics was recommending a more research driven agenda without any site or program, whereas the second group criticized the lack of a deeper understanding of the site and program. Both positions have merit, but the lightness of site and program was intentionally selected for the second year students: Students in the second year and first year in architecture after the Common First Year are generally longing to design their first building, but needed the guidance of the research phase to be able to develop a scheme.

From the student's point of view the studio was a large success. Although one constructive critique in the evaluations of the course was that the methodology came per surprise. We are therefore planning to offer more theoretical background or more lectures that would situate this methodology in a larger context if thought for a second time.

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