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Structuralism: Patterns of Interaction Computational Design Thinking across Scales

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Abstract: Digital design is driven by a thinking in structures that emphasizes patterns of order and their interaction. The paper presents an introduction into such design thinking and emphasizes the exploration of organizational pattern in various level of abstraction and scale through the integration of computational methods and workflows. Using a speculative design studio, held at Aalto University as a case study, the paper introduces novel ways of integrating patterns as relational frameworks, in order to formulate future-oriented answer to complex design challenges focused on landscape and urban questions. Special focus is set on the discussion of the integration of theory based computational methods within a teaching environment.

Keywords: Systems thinking, DataScapes, Data-driven design strategies, robotic interaction, responsive systems

1 Introduction

The current criticism towards computational design, in particular towards parametrism, can be summarized in the slogan "The digital turn is over!". A statement, which has grown louder within the last years in academic discussion, especially in the field of architecture. Heather Roberge reflects on this tendency "After over a decade of exuberant technophilia, a new generation of academics is arguing to a return to history as a reaction to architectural pedagogy`s long, and some would claim undertheorized, embrace of technology" (ROBERGE 2017). On a similar line, Michael Jacobs reflects on this topic by posing questions like: "Can we speak today of the rise of a new generic in Landscape architecture and urbanism – are we phased to an ongoing standardization with a more uniform landscape? Jacobs concludes, that we are confronted with a strong and negative impact of a new generic that fabricates an increased number of similar designed landscapes (JACOBS 2017).

The heated discussion about the conflict between tradition in opposition to technology is on the other hand opening up interesting new starting points for an integrative, extended computational design thinking in order to close the gap between the so far rather separated fields.

The presented case study is part of an ongoing research project, which aims to experiment with new ways of computational design thinking based on a structuralistic approach that shares similarities with the pattern-based logics discussed by M'CLOSKY & VANDERSYS (2017). By stressing traditional binary pairs of discourse like natural/artificial, soft/hard or dynamic/static the research project explores complex challenges we are facing today in the field of landscape architecture and urbanism at the interface to material, territorial questions and dynamic processes.

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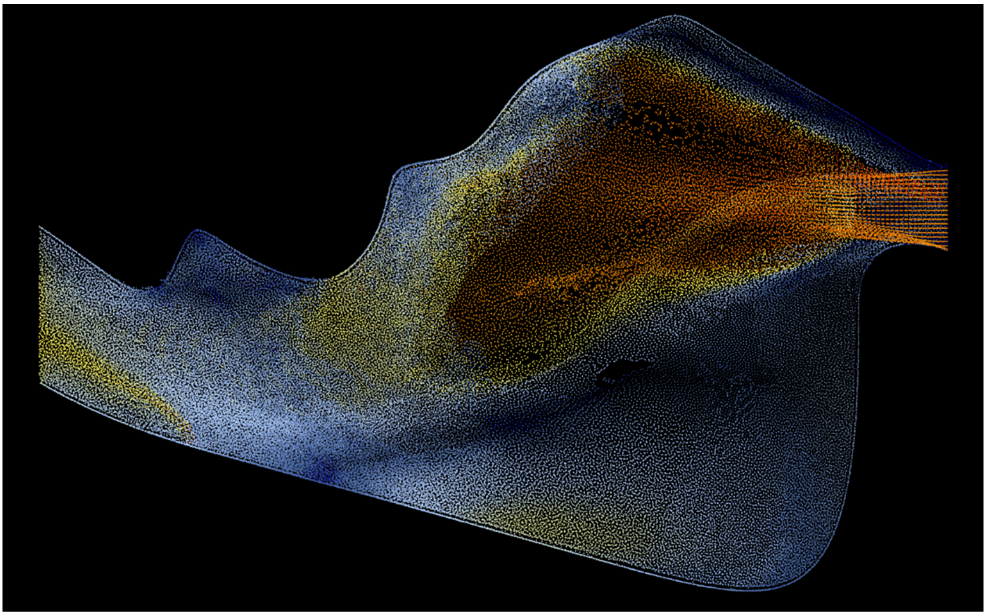

Fig. 1: Vector field of flood particles. Experimenting by translating behavioural water flow patterns (velocity and pressure) into a design strategy. Student project by Janne Keskinen and Yinan Xiao

2 Theoretical Background: Structuralism

As a discipline, landscape architecture has actively been involved in the exploration of digital technologies and applications from the very beginning. Already in 1965, the Laboratory of Computer Graphics was established at Harvard University, an institution influential in the advancement of mapping technologies, which eventually evolved into spatial analysis and the ubiquitous and indispensible Geographical Information Systems (GIS). But despite this early engagement in the digital, landscape architecture has not been able to fully utilize digital technologies as a creative medium for design up to now, due to a "weak theoretical discourse of making, which contributes to difficulties in conceptualizing a role for technology, theoretically and culturally, within design processes" (WALLISS & RAHMANN 2012).

With respect to the use of the digital in architecture and landscape design, current discourse is often hindered by a blurring of the notions of computerization and computation (TERZIDIS 2006). Something that Karen M'Closky has also pointed out with her observation that "if digital media are believed to be deficient, this is only because they are used to replicate hand-drawn techniques, rather than explored for the medium's inherent capabilities" (M'CLOSKY 2016). Computation is an approach to design that consciously explores the potential of the defining elements of a computable function as design tools: the formal relationship between sets of entities, the quantifiable properties of these sets of entities, and the algorithmic transformations and interaction of different quantifiable properties (KOTNIK 2010).

This implies that computational design is not about the formalization of design processes or the automatization of decision making but about the interaction of formal processes with architectural thinking. It is about describing relationships between data, geometry and space by means of parametric modeling and scripting resulting in a flexible network of associated dependencies. This network of formalized dependencies constitutes the rules of interaction that govern design development. Consequently, computational design is essentially topological by nature; it is not focused on form but rather on the underlying process of formation.

As a design approach, computational design primarily is about the detection of patterns as "the 'how' or the means by which we come to know, understand, or express these relationships" (M'CLOSKY & VANDERSYS 2017). Such thinking in patterns places computational design in conceptual proximity to mathematics understood as the science of patterns (DEVLIN 1994). Most of the basic patterns, thereby, are the result of direct formalization of human perception or as Martin Heidegger has formulated it: "*Ta mathemata*, the mathematical, is that 'about' things which we already know. Therefore we do not first get it out of things, but, in a certain way, we bring it with us." (HEIDEGGER 1992, 293). Hence, despite the seemingly abstract notation, computational design should be perceived not so much as technical calculation but as phenomenological exploration.

The notion of patterns as identifier of relations between or among things is predominantly used in design related discourse. Within the realm of science and technology, traditionally the notion of structures as "any set of objects (also called elements) along with certain relations among those objects" has been used instead (RICKART 1995). Accordingly, from a theoretical point of view, computational design is grounded in structuralism. Not in the sense of an anthropological structuralism based on the linguistic studies of Ferdinand de Saussure but rather a structuralism of the natural and technical sciences that has its grounding in Norbert Wiener's studies on cybernetics and the work of Ludwig von Bertalanffy on general system theory (SCHÄFFNER 2016, KOTNIK 2011).

With this, the structuralistic perspective onto computational design provides a common ground for an interdisciplinary exchange among the natural and technical sciences, well-established for centuries, and opens up a way of linking scientific and artistic ways of thinking by means of computation. Computational design is designing with structures, visualized as patterns and the opportunity to merge the necessity of physics with the freedom of design. Due to the ubiquity of structures on all levels of exploration, computational design is able to act over various scales in a seamless way, thereby questioning the traditional boundaries of architecture, urban design, landscape architecture and regional planning.

It is exactly this questioning of disciplinary boundaries, especially between urban design and landscape design that has been a major driver in the set-up of the Speculative Design Studio.

3 Case Study: Speculative Design Studio

The setup of an experimental design studio intends to create a framework for didactical research in computational design teaching. This set-up experiments with architecture- and landscape architecture MSc-Level students with different set of computational competences. The design studio framework actes as a starting point for currently on-going research in this field.

3.1 Process

The framework of the research is structured around three key elements:

pattern generation > pattern transformation > speculative interpretation

3.1.1 Pattern Generation

Taking the structuralistic perspective as a framework, the project researches into the local parameters of the site (urban growth, flow, sedimentation, water dynamics, human factors) in order to formulate an underlying systematic approach for translating these findings into abstract patterns. Special focus is set on the generation of patterns for process and performance (CANTREL & HOLZMAN 2016).

3.1.2 Pattern Transformation

Within the second part, abstract design patterns will be transformed, juxtaposing the theoretical inputs from landscape architecture and urbanism and computational input of the course. In designing an artificial manmade urban landscape with natural elements, we will examine and manipulate topological mechanisms (LEACH 2009). In understanding and adjusting these mechanisms, we will provoke physical reactions that will structure the site and provide the basis for a new urban pattern (MENGES 2008). Design scenarios will be organized along both physical and temporal lines. Strategic design and system thinking must enable variability in form, shape and scale.

3.1.3 Speculative Interpretation

In the final step, students are asked to formulate their own speculative design hypotheses by formulating a future-oriented approach towards the challenges of the site based on their pattern exploration. The aim of the speculative design hypotheses is to structure and prepare the site for future developments through an integrated design approach (FRICKER 2016). The speculative design hypotheses will support sustainable urban growth and the intensification of urban areas as well as encourage a dynamic interaction with underlying potentials or parameters of the site (WALDHEIM 2016).

3.2 Methodology

Reflecting on 'Structuralism' and 'Systems Thinking' as a powerful conceptual framework, the interdisciplinary research team looks into a new reading of large-scale landscape architecture and urban phenomena (ANDERSON & SALOMON 2010). The intention of this research project is to blur the traditional boundaries between static/built and dynamic/landscape environments in order. According to Gregory Bateson and György Kepes, pattern recognition can be regarded as the central mode by which to engage environmental relations (Contin et. al. 2013). The overall goal is to research computational design methods to reveal the important frameworks of patterns relative to organisation, process and relationship across scales and functions over time. Within a theoretical discourse, the power of the direct interaction between pattern and design is expanded towards a new definition of complex design strategies (SCHÄFFNER 2016). Computational explorations, thereby, are complemented by physical explorations through the integration of robotic fabrication, as well as theoretical grounding (OXMAN 2014).

3.3 Site of Intervention

Project area: City of Concepción in Chile, with special focus on the urban edge to the river Andalién.

Scale: working across scales: from S to XL (1:50 – 1:2000).

Task: We are looking for experimental explorations at the interplay between the city Concepción and the Andalién River at various scales. The joint studio allows students to either explore and or formulate small or large-scale design speculations providing urbanistic answers to the specific dialogue between natural systems and urban areas in Concepción.

Challenges: In Chile, as in the rest of the world, urban rivers have been severely modified, due to dynamic morphological and sedimentation processes coupled with a reckless urbanization and exploitation of the land. These disturbances create natural hazards derived from, amongst others, positioning human settlements in floodplains and thus, fluvial territory. In a context of climate change, the consequences of these conflicts will inevitably become more severe.

4 Computational Design Methods

To address the challenges of the site, three different types of computational approaches were presented in the skill building phase titled field, growth, agent. Students investigated these themes through hands-on scripting tutorials in Python as well as mini-assignments using a Rhino Grasshopper environment. The three types of computational approaches enable students to react in various ways to questions of topography, system interaction or environmental change and combine topics of landscape architecture with a formal framework for further investigation (WALLISS & RAHMANN 2016).

4.1 Field

The topic of field deals with computational design algorithms inspired by classical physical systems, especially force flows and resulting vector fields along surfaces. Fields act as mediators of forces that influence the path of particles or elements that make up the design (DAS 2016). Fields can be combined together, they are ephemeral and can act through and even be subtracted from each other. This makes them quite versatile for many design tasks, for example water flow and accumulation analysis on a steep terrain.

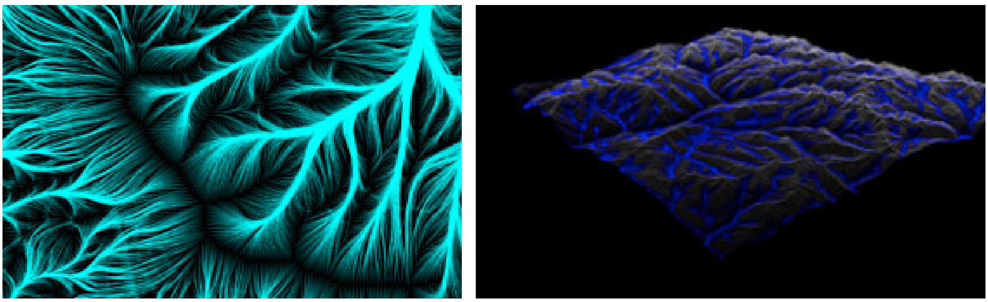

Fig. 2: Downhill direction mapping based on the height curves (left) and cellular-automata simulation of rainwater accumulation on the terrain (right). Both models were scripted in Rhino Python during the skill build-up sessions of the studio. In contrary to ready-made GIS applications, the students were able to manipulate the graphical output in order to draw conclusions for their design speculations.

4.2 Growth

The topic of growth deals with computational design algorithms inspired by biological systems of branching and propagation. Growth enables the exploration of time-based development processes inherent to the explored system (KELLEHER & TIERNEY 2018). Using an object-oriented approach, our data objects can approximate living entities, each with their own attributes (internally stored data) and methods (internally stored functions). Creating a system with simple but well-defined rules can exhibit emergent behaviors found in nature. Many of the forms generated in this way, for example organic city growth, exhibit very natural aesthetics that the students could explore and employ in their designs.

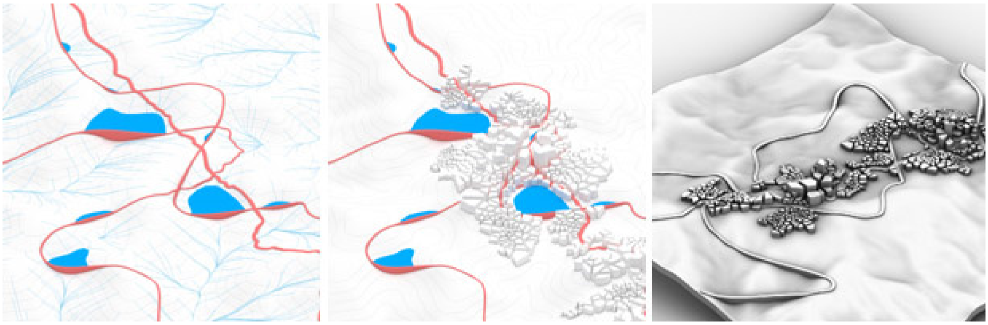

Fig. 3: HUT – High Urban Terrain, project by Solveig Døskeland and Joonas Saarinen. The project concentrated on generating a road network on the hilly terrain, which provided an opportunity to create dams and artificial lakes around which the city could grow.

4.3 Agent

The topic of agent deals with computational design algorithms inspired by social and behavioral systems. Agents possess two key features: independent behavior governed by internal rule-sets and a sensory capacity to perceive its immediate environment. Combined, these two features enable the agent to act seemingly independently in the unpredictable environment and to coordinate its behavior with other agents. This apparent prototypical built-up enables agents to accomplish complex tasks. Students explored the use of agent modeling in simulating pedestrian movements, traffic, animal flocking and complex fluid dynamics.

4 Conclusion and Outlook

All projects were motivated by rethinking traditional flood protection within an urban environment characterized by concepts of division and containment. Computational design methods were used to explore the dynamics of water flow, annual cycles and extremes, sedimentation, saturation as well as urban growth, infrastructure development or socio-economic sustainability. Focus in the exploration was on temporal patterns and opportunities for interaction in order to detect opportunities for symbiosis between the urban and the landscape.

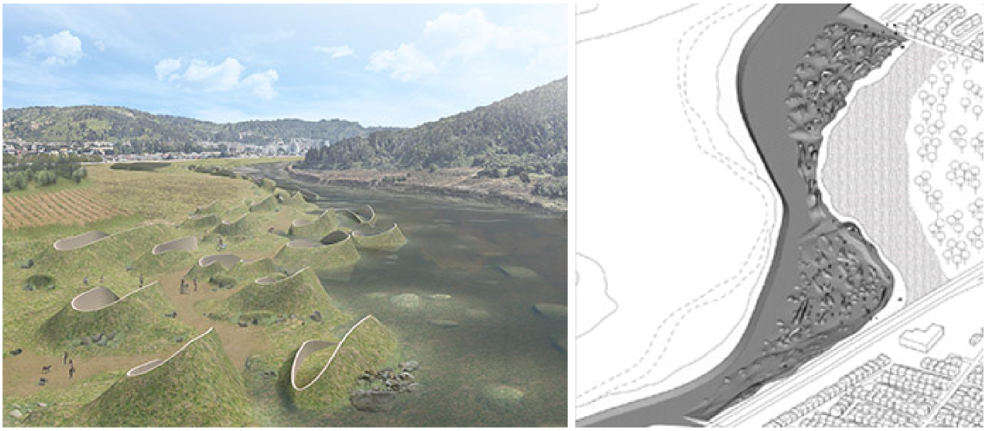

Fig. 4: Hyper Gills – River interference system, project by Janne Keskinen and Yinan Xiao. Hydrodynamic concrete barriers placed in the riverbed could accumulate sediment and create an artificial landscape with fertile soil over time. Plausibility of this scenario was directly tested using RealFlow software for fluid simulations with a custom-written Python data streamer to the Rhino environment.

This research-oriented exploration into theoretically grounded computational design methods aims at overcoming the disciplinary boundaries. The outcome of the speculative design studio demonstrates the potential of interacting with abstract theoretical thinking and concrete design visions. Computational methods, based on relational patterns for temporal and relational qualities are opening up new avenues for design (M'CLOSKY & VANDERSYS 2017). A thorough analysis of the site and its unique patterns forms the foundation to future-oriented solutions to complex urban issues. Contrary to traditional historical and site analysis, we propose that the reading and understanding of site-specific systems, which often occur in distinctive patterns reflecting complex synergies and relationships, can be represented in a more differentiated manner. The results of the studio demonstrate that the use of adapted computational tools does not necessarily lead to generic solutions but individual expressions grounded in site-specific conditions. The presented approach led to fully controlled design articulations, being able to take the temporal and dynamic conditions fully into account in order to articulate responsive designs across scales (FRICKER 2015).

Since early 2000, algorithms are uncovering urban and landscape relationships and predict possible use cases. Already during this time several research groups (MIT Media Lab, ETH Zurich) developed and used function-driven "deep-learning" systems, to generate designs with AI. Self-constructing, automized 3D printers are construction on site by adjusting the design according to real site parameters (environmental conditions, usability, safety).

McLuhan considered all forms of technology as a medium, which are interacting with each other and with the user (MCLUHAN 1964). As we are living in an enormous revolution in technology we can observe an interesting trend for the development of AI-driven design tools for the non-professional market. This will clearly have an impact on our profession if we are not able to bring in a new level of theoretical discourse within the computational design thinking and methodology (VRACHLIOTIS 2011). Integrating the potential of computational design thinking into our way of working enables us to create a vast spectrum of iterations of our concepts. We will be able to evaluate and optimize our designs with real-time feedback of site-specific data (time, seasons including ecological aspects), design data and user related data. This will lead to knowledge based decision-making tools fully in the control by the architect/landscape architect.

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