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Data-driven architectural production and operation

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Abstract: Data-driven architectural production and operation as explored within Hyperbody rely heavily on system thinking implying that all parts of a system are to be understood in relation to each other. These relations are increasingly established bi-directionally so that data-driven architecture is not only produced (created or designed and fabricated) by digital means but also is incorporating digital, sensing-actuating mechanisms that enable real-time interaction with (natural and artificial) environments and users. Data-driven architectural production and operation exploit, in this context, the generative potential of process-oriented approaches wherein interactions between (human and non-human) agents and their (virtual and physical) environments have emergent properties that enable proliferation of hybrid architectural ecologies.

Keywords: Data-driven Design, Generative Systems, Design Information Modeling, and Emergent Design Processes

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1. Introduction

Benjamin[1] stated 1936 that mechanical reproduction has freed the work of art from its dependence on ritual, which implied inter al. a move from drawing towards photography and film. In an even more extreme process of emancipation, digital production implies inter al. that the work of art and architecture become digital addressing, therefore, principles[2] such as data-driven or computer numerically controlled representation, generation, production, and operation. Thus, as more recently convincingly argued by Carpo[3], the historical understanding of buildings as physically built identical replicas of architectural intent (formalized in design) which eventually in the 20th century became serially, mass produced identical copies, is challenged by the contemporary data-driven parametric multiplicity and variation. Such multiplicity and variation allowing versions of architectural intent to be virtually or physically implemented and experienced through inter al. spatial reconfiguration has been explored within Hyperbody (fig. 1) with the understanding that multiple versions of the built space may be achieved through kinetic transformation.

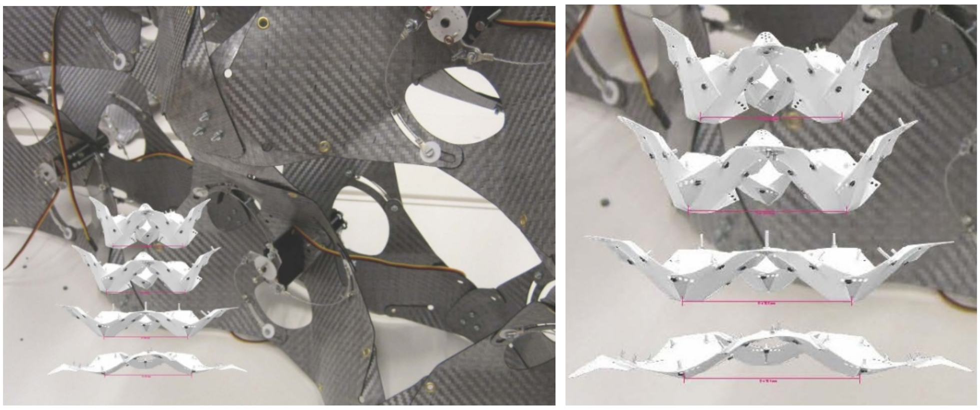

Figure 1: Physical change and variation explored within Hyperbody (2010)

Furthermore, experimentation with parametric multiplicity and variation has been addressed with focus on generative design and data-driven production, which were explored as tools to not only investigate an array of digital techniques but also critically reveal what these techniques may offer architectural production as well as outline what challenges remain in their application. The relationship between generative processes and data-driven production has been focus of current architectural research and practice largely due to the phenomenon of emergence explored inter al. within self-organization, which is defined as a process, in which the organization of a system emerges bottom-up[4] from the interaction of its components. Self-organizing swarms[5] for instance, are employed in generative design processes, which deal with ample amounts of data featuring sometime conflicting attributes and characteristics. Those attributes and characteristics are incorporated in behaviors according to which design components such as programmatic units swarm towards targeted

[1] W. Benjamin, The Work Of Art In The Age Of Mechanical Reproduction.

[2] L. Manovich, The Language of New Media. Cambridge: MIT Press.

[3] M. Carpo, The Alphabet and the Algorithm. Cambridge: MIT Press.

[4] M. De Landa, Deleuze and the Use of the Genetic Algorithm in Architecture, Rahim, A. (ed.), Architectural Design - Contemporary Techniques in Architecture, Academy Press.

[5] H. Bier, Building Relations, ed. by Bekkering (Rotterdam; Architectural Annual 2005-06: 010-Publishers), pp. 64-67.

spatial configurations[6]. In this context, architectural design becomes procedural instead of object-oriented and architectural form emerges in a process in which the interaction between all parts of the system generate the result. Thus, the architect becomes the designer of the process and only indirectly of the result.

2. Discussion

Swarms operate as multi-agent systems[7] consisting of simple agents that interact locally with one another and their environment based on simple rules leading to the emergence of complex, global behavior. Their use in design is of relevance because of their ability to embody both natural (human) and artificial (design related) aspects. Swarms are, basically, set up as parametric models incorporating characteristics and behaviors representing the natural and artificial systems themselves, whereas simulations of behaviors[8] show operation of such systems in time.
Intelligent (artificial) agents are conceived (in computer science) similarly to natural agents as autonomous entities able to perceive through sensors and act upon an environment using actuators[9]. Interactions between human and artificial agents may follow principles as described in the Actor–Network Theory (ANT) implying that material–semiotic networks are acting as a whole9 whereas the clusters of actors or agents involved in creating meaning are both material and semiotic. ANT, therefore, implies agency of both humans and non-humans, whereas agency is not located in one or the other, but in the heterogeneous associations between them.

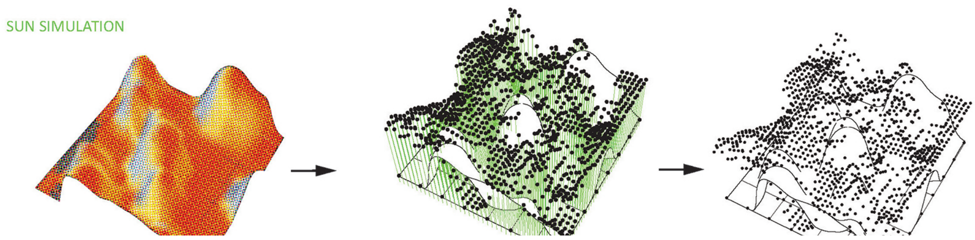

Figure 2: Generative design explorations developed with MSc 3 students by informing the point cloud with multiple simulations (in this case solar radiation for different seasons)

Such heterogeneous generative processes implemented in simulations are extensively discussed by De Landa[10] in relation to his interpretation of Deleuze's idea that form emerges from within matter itself, hence philosophy of immanence (not transcendence) in which matter itself has the capacity to generate form through immanent, material, morphogenetic processes. Simulations based on cellular automata and multi-agent systems are defined, in this context, as forms of knowledge visualization and means to conceptualize spaces emerging from local, bottom-up interactions.

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[6] H. Bier and T. Knight, Digitally-driven Architecture in H. Bier and T. Knight (eds.) 6th Footprint, Delft.

[7] Ibd.

[8] M. De Landa, ibd.

[9] B. Latour, Reassembling the Social: An Introduction to Actor-Network-Theory. Oxford University Press

[10] M. De Landa, Philosophy and Simulation: The Emergence of Synthetic Reason, Continuum Publishing Corporation.

Simulation in relationship to architecture has been addressed within the Hyperbody studio with respect to its ability to support the generative development of architectural production: Data-driven production processes and their intrinsic connection to physical, mathematical, biological, etc. sciences increasingly enable architecture to surpass mere technological application in order to address, as argued by De Landa, system, population and topological thinking. While, system thinking implies that all parts of a system are to be understood in relation to each other[11], population[12] replaces typological thinking as it rejects the focus on representative types in order to emphasize individual variation, and topology[13] studies space and transformation.

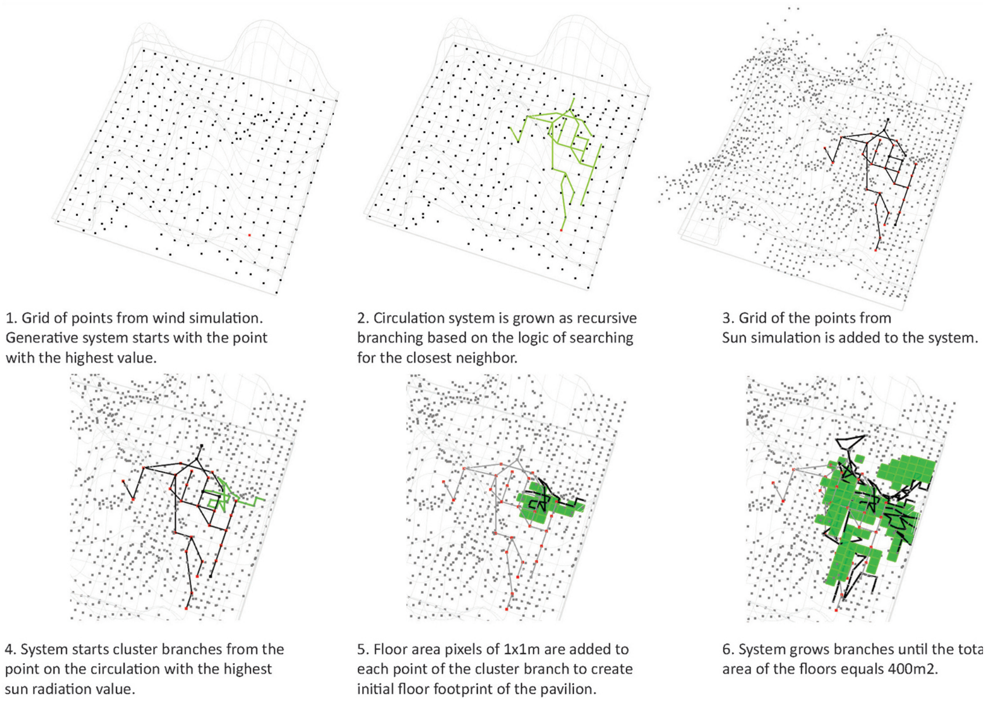

Figure 3: Diagrammatic snapshots illustrating generative systems within the informed point cloud

In this context, the architect employs agents that produce architectural artifacts, thus architectural production becomes the result of multiple interacting natural (human) and artificial agents. Such agent-based processes imply that same or similar (virtual and physical) agent systems may produce under similar conditions multiple (or endless) variations of architectural artifacts due to the emergent properties of the system.

Such emergent design processes have been focus of MSc experimentation at Hyperbody with the aim to develop complex generative systems and incorporate them in performance-based design processes. These processes address two main aspects: Generative systems are based on and derived from different types of complex systems[14] and second a chained and holistic algorithm that would ease the processes of design information exchange[15] between different stages of parameterization, generation and simulation for performance measurement and evaluation. Different types of complex system are explored and

[11] B. Wilson, Systems - Concepts, Methodologies and Applications, 2nd ed., Wiley.

[12] E. Mayr, E.: Darwin's Influence on Modern Thought, 1999 (retrieved 18-02-2013 from http://www.biologie.uni-hamburg.de/b-online/e36_2/darwin_influence.htm

[13] W. Sierpinski, General Topology, Dover Publications.

[14] J. Holland, Studying Complex Adaptive Systems, Jrl Syst Sci & Complexity 19: 1-8.

[15] S. Mostafavi, Performance Driven Design and Design Information Exchange. Computation and Performance, Faculty of Architecture, Delft University of Technology, Delft: eCAADe

customized based on the distinct design objectives and requirements considered in each of the projects. In other words, in these projects generative systems are defined as design mechanisms in which both synthesis and analysis sub-routines can be embedded and applied for a multidisciplinary performance-driven design. With this target, for the first step, initial studies were conducted exploring different complex systems[16] such as fractals, recursive systems, cellular automata, L-systems, and agent-based systems. By analyzing the behavior of each of these systems, on one hand the design teams were able to control the bottom-up emergence processes of complex systems and on the other hand change the behavior of these systems by introducing more conditionals or if-then structures in the scripts.

One project is representative and aims to integrate the data gathered from the site analysis from macro to micro scale in order to generate the design of a pavilion with emphasis on ecological and environmental aspects. At detail level, the focus was to achieve material and resource efficient design solutions through, informing the complex systems and integrating environmental and structural simulations in either chained sets of algorithms or holistic computational design systems.

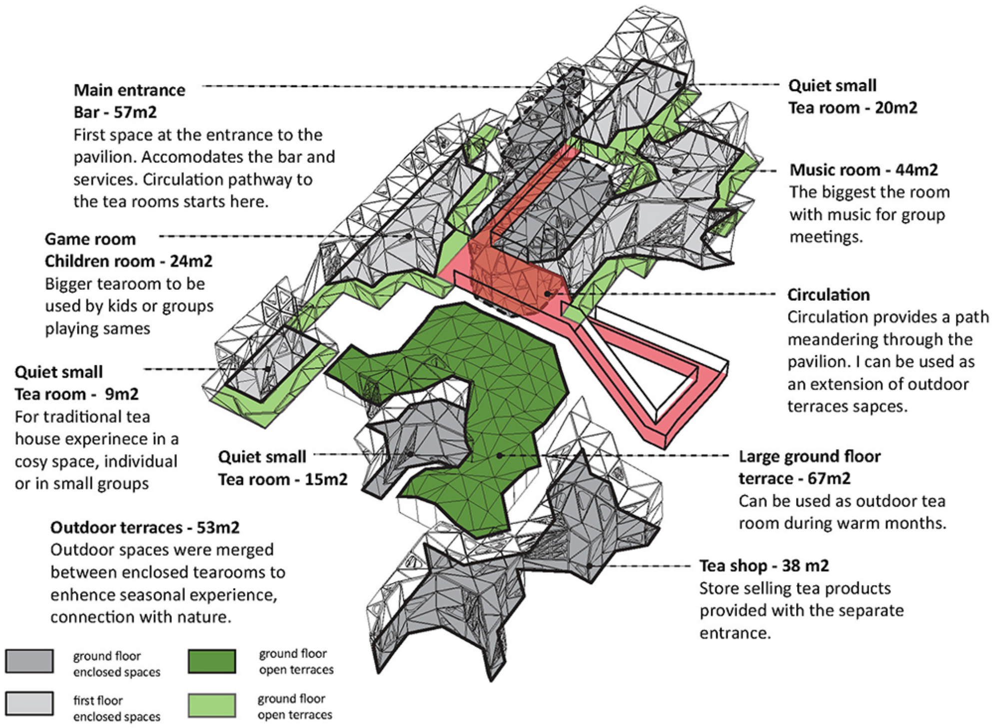

Figure 4: Diagram presenting one of the selected configurations of the Eco-locator pavilion

Eco-Locator (fig. 2-5) has developed a twofold climatic strategy focused on Computational Fluid Dynamics (CFD) for airflow simulation and solar radiation including daylight access simulations on site. The goal was to provide data sets that would inform the generative system. In this case, the generative system implies a recursive search evaluating site condition and generating rough configurations for the pavilion, its structure as well as its circulation system that will shape clusters for hosting the program.

The geometric logic of the recursive generative systems utilizes branching in order to allocate and search for the optimum floor plan arrangements considering wind and sunlight

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16 A. B. Downey, Think Complexity, Needham, Massachusetts: Green Tea Press.

qualities of the site. Since CFD simulations are dynamic, a strategy was established to transfer relevant data, from Autodesk Project Vasari, to Rhino through Grasshopper. The strategy consisted of implementing multiple simulations as for instance simulations for dominant seasonal conditions and employ color-coded mapping to inform the point-cloud. At the same time, solar-radiation evaluation was conducted and the results were associated with the grid of points populating the site, giving each point within the point-cloud, a multi-dimensional data-structure comprising different environmental values.

The first implementation of the branching system on the informed point-cloud produced the circulation scheme of the pavilion and secondary branches are then grown as well as required floor area and enclosures creating clusters of spaces.

In parallel to the initial parameterization phases and generative procedures, optimization routines are integrated in the process in order to improve structural and environmental efficiency at micro level. This implies that in addition to environmental conditions internal geometrical constraints are embedded in the recursive systems. These internal conditions are defined based on spatial and programmatic requirements. Eventually, the cyclic nature of the designed computational flow allowed the team to explore and test the performances of alternative designs for different seasons. This resulted in the development of meaningful designer interventions into the optimization process.

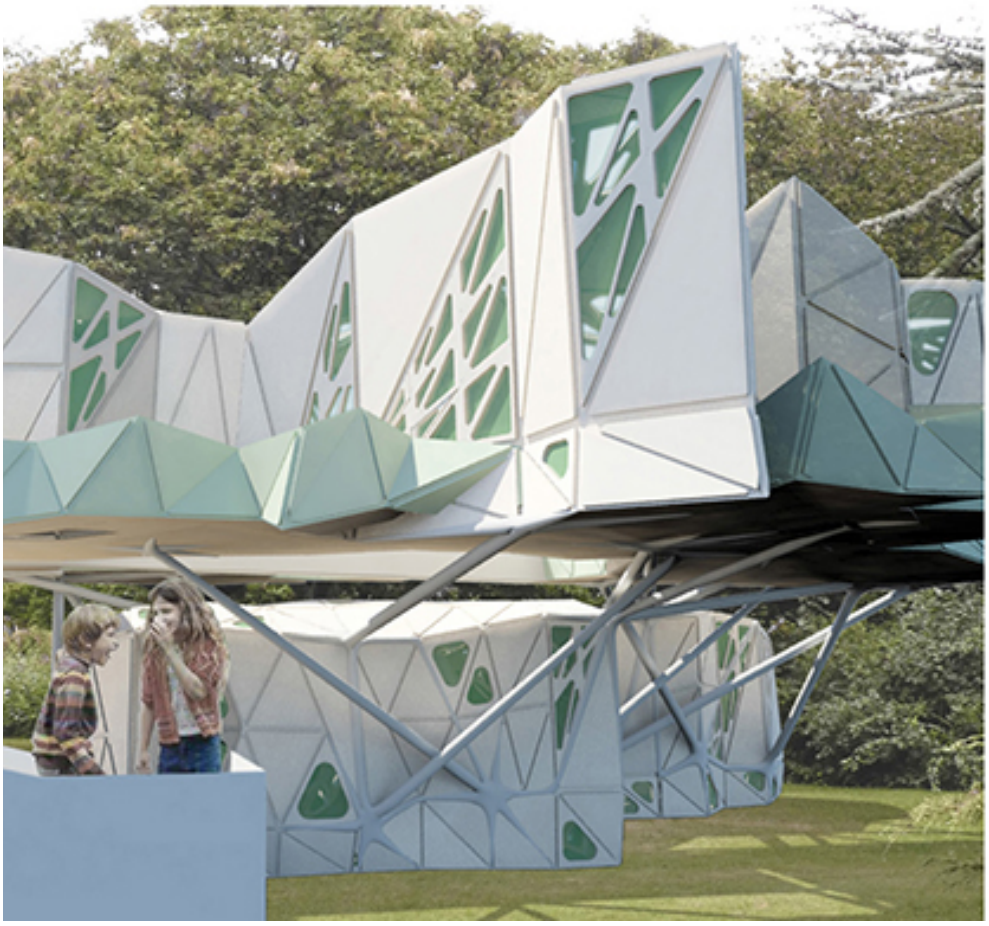

Figure 5: Renders illustrating spatial and morphological quality of the eco-locator project

This experimentation has proven that integrating complex generative system within a holistic design information model for data exchange between different stages of computational design processes, not only makes the complex systems more applicable and informed, but also establishes a balance between top-down decisions and bottom-up emergence processes.

3. Conclusion

In generative design processes natural and artificial agents operate as actors involved in creating meaning at both material and semiotic level and humans represent only one of many possible agential embodiments. This understanding relies on De Landa's neo-materialist cultural theory that rejects the dualism between nature and culture, matter and mind, natural and artificial, wherein reality is revealed in material, self-organized processes. In this context and in opposition to Alberti's (1452) formalization of (notational and authorial) architectural representation[17] consisting of plans, elevations and sections from which materialization is implemented, multiple and various architectural materializations emerge today from interactions between (natural and artificial) agents while authorship becomes hybrid, collective, and diffuse.

Thus notions such as original, copy, production and reproduction are subject of redefinition: If the apparatus used to create (pen) was in the age of mechanical reproduction different from the apparatus used to make copies (printing machine), today, these apparatuses conflate (into one computer-numerically controlled system) blurring not only the distinction between original and reproduction but also between representation and generation[18] due to the processes through which physically built space is produced and utilized. Multiplicity and variation imply, therefore, not only that design emerge from local interactions between non-human and human agents but also physically built space incorporating computer-numerically controlled (non-human) agents adapts and reconfigures in response to human needs.

While architecture are increasingly incorporating aspects of non-human agency employing information and knowledge contained within the (worldwide) network connecting electronic devices, the relevant question is not whether interactive, reconfigurable environments may be built, but how (artificial) intelligence may be embedded into environments in order to serve everyday life. In this context, data-driven architecture are not only produced (created or designed and fabricated) by digital means but are, actually, incorporating digital, sensing-actuating mechanisms[19] that enable them real-time operation and interaction with environments and users.

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[17] M. Carpo, ibid.

[18] W. J. T. Mitchell, Picture Theory - Essays on Verbal and Visual Representation, University of Chicago Press.

[19] H. Bier and T. Knight, ibid.

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About the Authors

Henriette Bier

After graduating in architecture (1998) from the University of Karlsruhe in Germany, Henriette Bier has worked with Morphosis (1999-2001) on internationally relevant projects in the US and Europe. She has taught computer-based architectural design (2002-2003) at universities in Austria, Germany and the Netherlands and since 2004 she teaches and researches at Technical University Delft (TUD) with focus on applications of digital technologies in architectural design and architecture. She initiated and coordinated (2005-06) the workshop and lecture series on Digital Design and Fabrication with invited guests from MIT and ETHZ and finalized (2008) her PhD on System-embedded Intelligence in Architecture. Results of her research are internationally published in books, journals and conference proceedings.

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After graduating (2010) from University of Tehran in Iran, Seyedsina Mostafavi joined Hyperbody (2011) to undertake research on computational design methodologies. His research focuses on Performative Morphogenetic Computational Design Methodologies with the objective to investigate optimized information management and modeling systems inspired by morphogenetic processes and fields. As an initial goal, he is trying to explore capabilities and limitations of Building Information Modeling (BIM) for performative design aiming to bridge the existing gap between Design Information Modeling (DIM) and BIM.