DIGITAL - The ‘Digital’ in Architecture and Design

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The digital in architecture and design refers to the use of computational design processes and their manifest effect on the architectural outcome, rendered or built. Due to the continuous progress in digital design tools and methods ‘the digital in architecture’ is a moving target that can only be pinned down temporarily. My approach here is therefore at once historical and future oriented.
The digital is of course part and parcel of the technological transformations that sweep through all aspects of our civilisation impacting and indeed upgrading our lives via the digitalisation of all products, services and professional disciplines. The digital in architecture is thus inevitable, must be understood, embraced and push forward. That this has to be explicitly emphasized in the year 2019 is rather sad and alarming. Where is the architectural equivalent of the thriving research plus business eco-systems of FinTech, HealthTech, and LawTech in terms of the integration of Big Data and AI? Perhaps BIM comes closest, but concerns construction rather than design. Where is ArchTech? The movement of Parametricism comes closest, but the uptake of its insights, values and methodologies remains marginal within our field.

My focus will here be on the discipline’s acquisition of new, sui generis design capacities in distinction to the mere automation of prior ways of design, i.e. mere digital drafting or mere visualisation is not of interest here. A truly transformative ambition has been the hallmark of the avant-garde’s investment into the digital from its beginnings 25 years ago. The new digitally empowered design capacities and repertoires that have since been elaborated imply indeed a new characteristic architectural language, and have manifested a new style with epochal ambitions: Parametricsim[i].
However, an ambitious concept of style involves more than a new architectural language; it implies a whole new paradigm for the design disciplines, with new purposes, values and related design methodologies that are congenial both to the societal challenges posed and to the technological opportunities offered by the new digital civilisation.

Societal and Technological Context

The built environment must progress in step with the progress of society. It is therefore the task of the avant-garde segment of the academic discipline and profession of architecture to theorize and explore how best to guide the development of the built environment in ways that are congenial to the opportunities and challenges of societal development at the frontier of progress, largely induced by the convergence of computation and tele-communication we summarize here under the heading of 'the digital'. What characterizes the related current socio-economic transformation is the shift from an economy based on mechanical mass production to an economy of scope based on robotic fabrication and web-based services that can afford incomparably higher rates of innovations. This calls for and engenders a new level of urban concentration in knowledge-based creative industry hubs with a much higher degree of complexity and dynamism in the societal life process and thus also in the urban and architectural development. In this new era all work becomes communication-dependent creative work, as the new technologies of production and service provision have a nearly infinite and instant capacity to utilize innovations, in stark contrast to the previous era of fixed assembly line production. This socio-economic shift from 'Fordism' to 'Postfordism' finds it congenial architectural response in the paradigm shift from Modernism to Parametricism as the prospective epochal style for the 21st century. Modernism was congenial to mechanical repetition while Parametricism delivers digital responsiveness. Postmodernism and Deconstructivism were transitional styles and their interests in variety and complexity have been absorbed and enhanced within Parametricism. The intensity, complexity and dynamism of the social interaction and societal reproduction process can now be addressed via the new adaptive organisational and communicative capacities of a digitally empowered design process in which all elements of architecture have become parametrically malleable and responsive and subject to computationally empowered ordering processes. This digital upgrading is by no means automatic or trivial, but a hard won capacity that requires the continuous investment of analytic as well as creative intelligence from the whole discipline. The as yet untapped potentials on the horizon make this investment a very well worth effort.

Fordism Postfordism

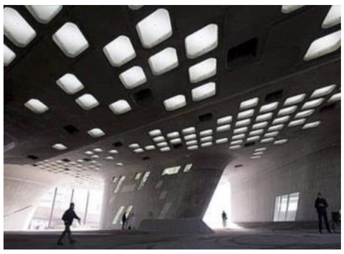
A Brief History of the Digital in Architecture

Although there have been earlier precursors, the use of digital design media took off and became impactful in architecture in the early 1990s, albeit at first only within the avant-garde segment of the discipline. Columbia University introduced its "paperless studio" in 1994/1995, promoting a full on switch to the digital. In 1993, when the seminal AD 'Folding in Architecture'[ii] was published, most work at Columbia was still hand crafted. A year later, the whole top floor at Columbia was equipped with brand new Silicon Graphics machines (that were exceptionally powerful at that time) running Silicon Graphics' visual simulation software 'Alias/Wavefront' ('Maya' since 1998) that had been developed for the animation industry. Greg Lynn was the most prominent protagonist, theorist and design teacher at Columbia. This was mirrored at the AA by Jeff Kipnis' Graduate Design Group which morphed into the AADRL in 1996 after Kipnis had left. The style of "Folding" was given a boost and became the first architectural style of the digital era. The influence of the newly acquired 'nurb' modellers was unmistakeable. Nurb surfaces and operations like 'lofting' allowed for coherent smooth transitions between sectional spatial profiles. The congeniality of these new formal possibilities with the prior formal explorations of Zaha Hadid[iii] led to a rapid and enthusiastic uptake of the digital at Zaha Hadid Architects, not least via the stream of digitally trained DRL students. The early days of Folding were playfully explorative, oriented towards new spatialities and morphologies. These were exuberant days of radical formal and conceptual innovation, inspired by the exciting conceptual universe of Deleuze and Guattari's 'A Thousand Plateaus'[iv] involving notions like the rhizome, multiplicities, assemblage, smooth space, line of flight, deterritorialization, becoming intense, and abstract machine. The denigration of the whole movement as "mere formalism" was due to ignorance and reductionism. While some protagonists were indeed just playing with forms, play can also be very productive of new possibilities. Especially in the context of design competitions where functional problem solving is inevitably posed, play can enhance the creative power to find new solutions.

The denigration of "formalism" forgets that formal repertoires are always also problem solving repertoires and that formal research and the expansion of formal repertoires is therefore empowering the problem solving capacity of the discipline.[v] The most important conceptual-formal-spatial innovations of Folding in Architecture were the concept of field conditions, continuous differentiation, iteration versus repetition, the slogans from part to particle and from typology to topology, and more concretely the concept of a single surface project. The movement also started to work through the implications of the new conceptions for structure, envelope, apertures etc. That the new style was both expanding and maturing rapidly became soon manifest in a series of important competition successes that also eventually got built: FOA's Yokohama Ferry Terminal (1995-2002) as well as ZHA's MAXXI (1998-2010) and Phaeno (1999-2005), and UNstudio's Arnhem Central Transfer Station (1996-2015).


Yokohama Terminal


MAXXI


Phaeno


Arnhem Central Station

The introduction of new, more generative computational methodologies and tools lead to the next stage within the development of digital design in architecture. Robert Aish's Generative Components (GC) for Bentley, first introduced in 2003 within the context of the Smart Geometry Group, was a milestone that expanded the power of parametric modelling by allowing for the proliferation and adaptive differentiation of complex components. We instantly realized that these techniques, developed to proliferate and adapt façade panels to complex envelope surfaces could be generalized to the proliferation and adaptation of buildings across complex topographic land surfaces. 'Parametric Urbansim' was born at the AADRL[vi], an important generalisation that made the announcement of 'Parametricism', first at the Smart Geometry Conference in 2007 and then at the Venice Biennale in 2008 plausible. The adoption of Java based processing, developed by Casey Reas and Ben Fry at MIT, and grasshopper, a powerful visual programming language and environment developed by David Rutten, first released in 2007, gave digital design and Parametricism a further boost. Grasshopper is a pertinent tool for the set up parametric models, i.e. networks of interdependent elements. The network of relations is set up and visualized graphically so that the designer can keep track of and intervene in the relational network he is designing. Grasshopper has also become the preferred platform for scripted plug-ins and for a new powerful set of integrated tools that push architecture's design intelligence beyond the mere handling of geometry to include engineering logics and real time access to physics simulations that allow for sophisticated form-finding and optimization processes to be seamlessly folded into the design process. Technical performance is being folded into the design engine as constraint, nevertheless leaving the designer sufficient degrees of freedom to solve complex problems of architectural organisation and articulation. In recent years Parametricism has further evolved its computational sophistication and its tools are now more immediately performance oriented. The integration of engineering and fabrication logics via tools like Kangeroo, Karamba, Milipede and Rhino-vault has led to a new stage in the development of Parametricism: Tectonism.

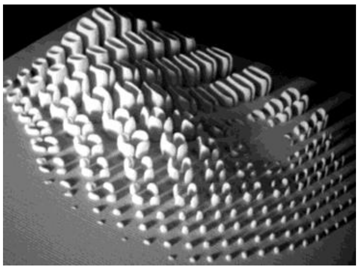
Tectonism as the latest Stage of Parametricism

Tectonism is the only style congenial to recent advances in structural and environmental engineering capacities based on computational analytics and optimization techniques. All other styles are incapable of working with the efficiencies of the adaptive structural and tectonic differentiations that issue from the new engineering intelligence, i.e. they force its adherents to waste this opportunity and thus to waste resources.

Tectonism implies the stylistic heightening of engineering- and fabrication-based form-finding and optimization processes. Tectonism is the currently most prevalent and promising subsidiary style (sub-style) within the overarching paradigm and epochal style of Parametricism. In retrospect we might distinguish tectonism from earlier phases of parmetricism like foldism and blobism.


Foldism


Blobism


Swarmism


Tectonism: Integration of Engineering Logics: Environmental, Structural, Material

In contrast to these earlier sub-styles tectonism is embedding a series of technical rationalities that secure both greater efficiency as well as greater morphological rigour, while maintaining sufficient degrees of design freedom to address programmatic and contextual contingencies.

While the overarching general design agenda remains Parametricism's pursuit of adaptive versatility and complexity, tectonism pursues these with a much richer set of parametric drivers and constraints than earlier versions of Parametricism. These drivers originate in sophisticated computationally empowered engineering logics that

are now available to architects at early design stages via structural form-finding tools like RhinoVAULT (for complex compression-only shells) and physics engines like

‘kangaroo’ to approximate shell or tensile structures (created by Daniel Piker), via analytic
tools like Principle Stress Lines analysis in ‘Karamba’ (Clemens Preisinger & Robert Vierlinger) that can also be turned generative, and via optimisation tools like structural topology optimisation in ‘millipede’ (Panagiotis Michalatos). Various fabrication- and materially based geometry constraints can also be embedded in generative design processes that are then set free to search the characteristic solution space delimited by the constraints. Tectonism therefore is intimately linked with explorations in digital or robotic fabrication.


Expressive Versatility of Tectonism

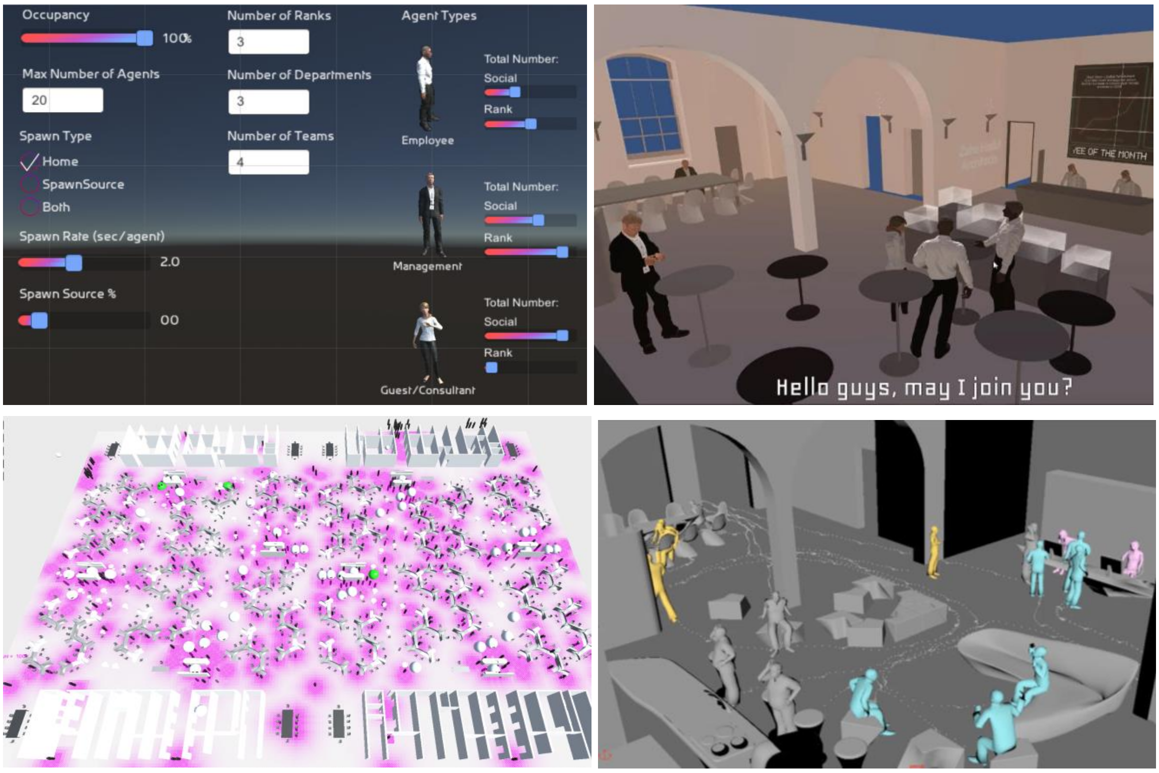
Design research groups like our ZHA CODE[vii] are developing custom tools to model the particular constraints of particular fabrication processes. The different building materials with their various related fabrication techniques, for instance curved folding of sheet material, tailored tensile fabrics, robotic hot-wire cutting of molds, or 3D concrete printing, each impose their characteristic morphological constraints that can be built into the digital form-finding engines, while each leaving plenty of freedom to the designer to find solutions to the complex organisational problems posed by the respective brief. So far, little computational empowerment has been delivered to this most fundamental of the architect’s design task, namely the social organisation by spatial and formal means that constitutes the societal function of the built environment. How can architecture’s social functionality become computationally tractable when the key competency of architecture is the innovative ordering of social interaction processes?

From Intuition to Simulation: Social Performance via Life-process Modelling

It is the author’s contention that Parametricism has to shift its focus from technical to social functionality, i.e. from foregrounding formal principles, design processes, and engineering logics to the foregrounding of social ordering principles and societal purposes. This shift poses new ambitious tasks while taking the versatile formal options, design processes, and technological advances of Parametricism for granted as tools. Design research continues and must become explicitly oriented towards social functionality. This is a necessary aspect of growing up and becoming serious about making an impact in the world. In short: Parametricism has to be re-launched as Parametricism 2.0[viii].

Due to its versatile formal and spatio-organisational repertoire Parametricism is the only contemporary style that can adequately address the new societal tasks posed to architecture by the complex social and urban dynamics of engendered by the information age. However, the way it is addressing these challenges so far still relies on the intuitive trial and error design browsing of experienced architects. The route to the computational empowerment of architects with respect to the crucial task of social performance can only be found via the development of a new simulation capacity, namely via agent-based life-process modelling.

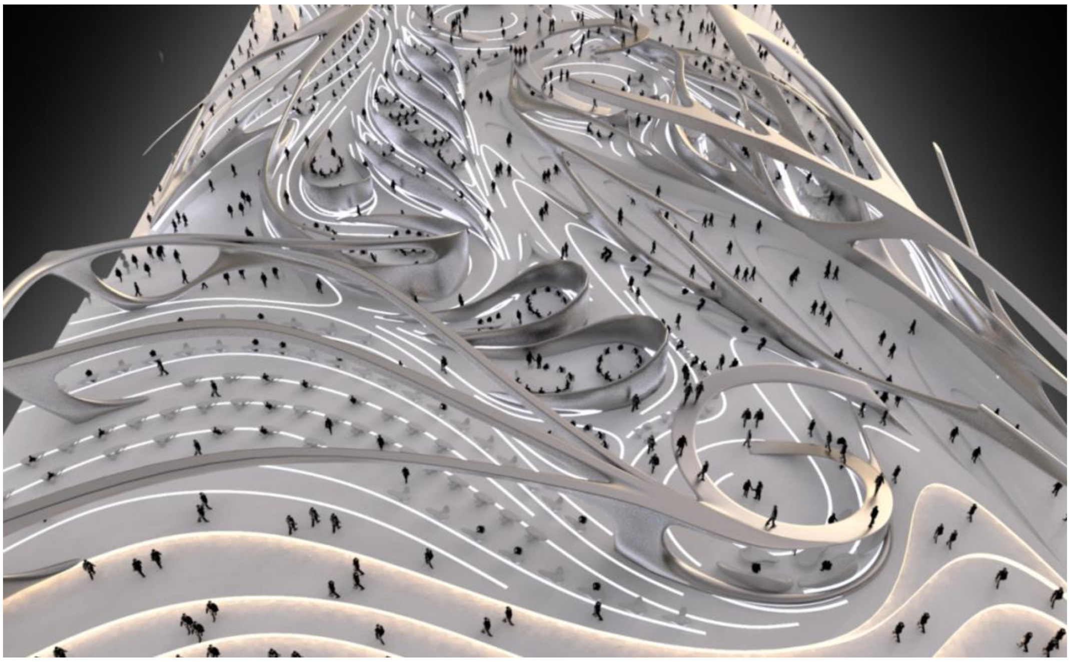
The simulation methodology developed by the author and his research team[ix] - under the research agenda 'Agent-based Parametric Semiology' - is conceived as a generalisation and corresponding upgrade of the kind of crowd simulations currently offered by traffic and engineering consultants concerned with evacuation, circulation and congestion. The simulations that must be developed to get a handle on the facilitation of various desired social interaction scenarios will have to be quite a bit more elaborate than the current crowd models testing circulation processes. The most obvious difference is the momentous expansion of the menu of action types that must be considered. The second major difference of these architectural simulations is that the agent population should be socially differentiated rather than homogenous, i.e. agent behaviours are varied in accordance with social status groups and roles. The third significant difference of architectural life-process simulations in comparison to the engineer's crowd simulation is the designation dependency of the agents' behaviours. Designed environments are always zoned and semantically encoded. For the agents this implies that they have a whole stack of behavioural rule sets and depending on where they are or which threshold they cross, a different rule set is activated and applies. Due to the semiological inscription of designations and behavioural rules, these agent-based models might be termed semiological simulations. Only within such a spatially differentiated and semiologically encoded order can specific social purposes be readily accomplished. The fourth aspect that distinguishes our agent populations from engineers' crowds is the following: Congenial with contemporary cultural conditions the underlying presumption of these models is that agents are largely self-directed, rather than running on pre-scheduled tracks. They self-select which interactions they participate in. These selections are guided by multi-dimensional, dynamic utility functions that are dependent on agent type and dynamic internal states. Agents utilise contingent opportunities that are encountered within the environment they browse. The fifth significant difference: the focus shifts from the aggregation of parallel individual actions to the simulation of integrated patterns of social interactions. The sixth important differentiating aspect of this new methodology is the fact that there can be no single generic agent model that could be transferred from project to project but models have to be tailored to each institutional type and indeed client.



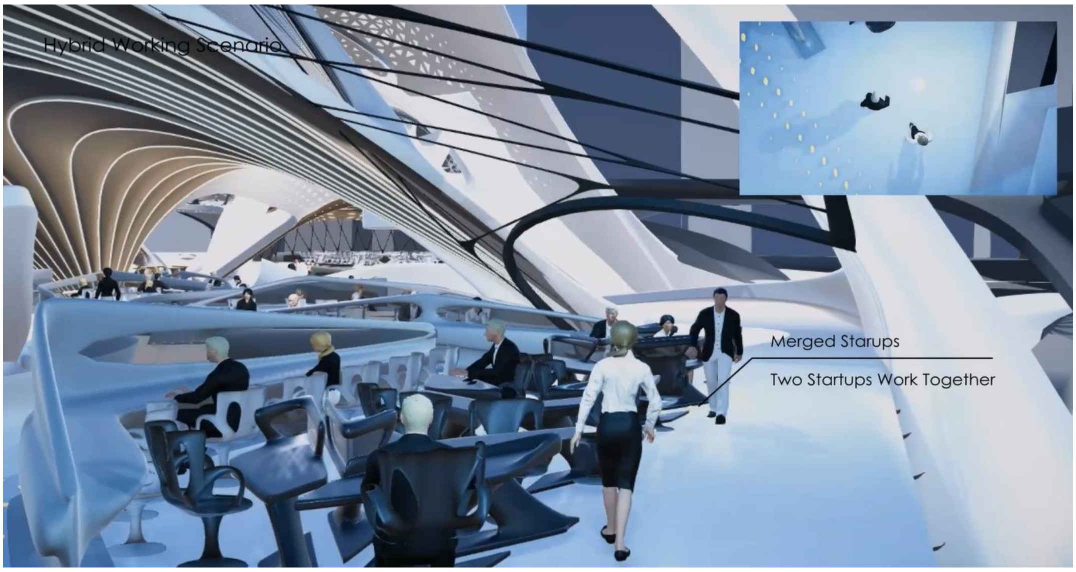
ZHA/Angewandte: Research project: Agent-based Parametric Semiology – Life Process Simulations. Research leader: Patrik Schumacher; ZHA Research Team: Tyson Hosmer (team leader), Soungmin Yu, Sobitha Ravichandran, Michael Fuchs; Angewandte Team: Robert Neumayr (team leader), Daniel Bolojan, Josip Bajcer, Bogdan Zaha.

All these differentiating features imply challenges and necessary complications, or positively phrased, necessary sophistications for this much more ambitious modelling

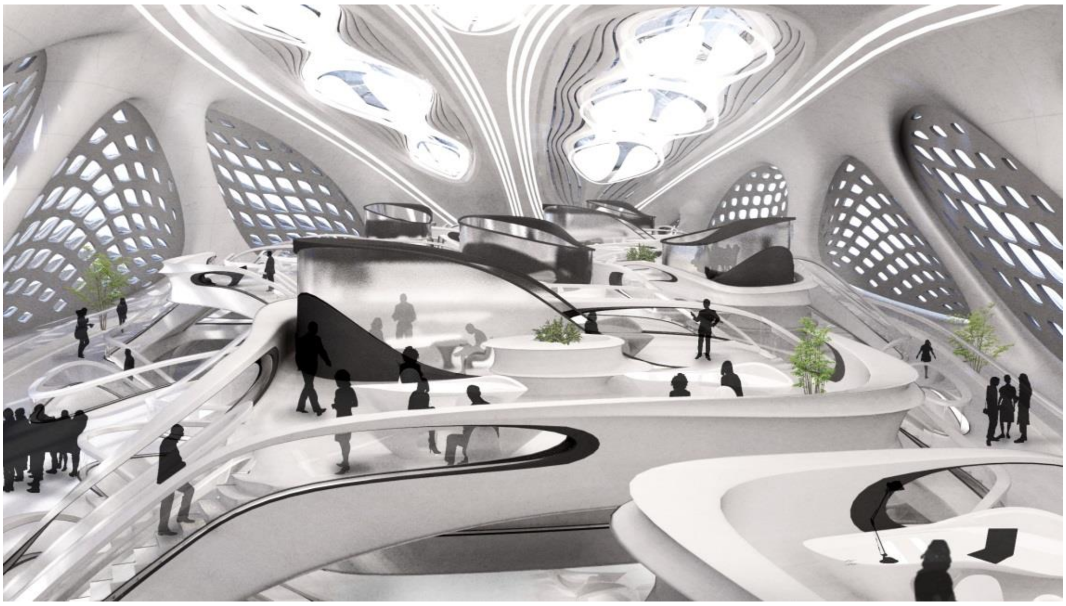
and simulation effort. The research team is currently building up increasingly large, differentiated and sophisticated agent populations using the Unity game development software as base system augmented with a lot of additional original coding. The development work concerning our agent populations benefits from a technology transfer from the game development industry.
The outlook and ambition here is to elaborate a scientific approach to architectural design via the simulation of a design's social functionality as key ingredient of optimisation via genuinely architectural, generative design processes, ultimately aiming at design processes using evolutionary algorithms that use agent-based life-process simulations with social communication and interaction frequencies as success measures to optimize social functionality, in line with the prerogatives of our postfordist network society.



AADRL 2017-2019, Constructing Agency – Studio Patrik Schumacher & Pierandrea Angius.
DRL Team Students : Suyang Li, Simon Perez, Irfan Bhakrani, Prabhat Arora;

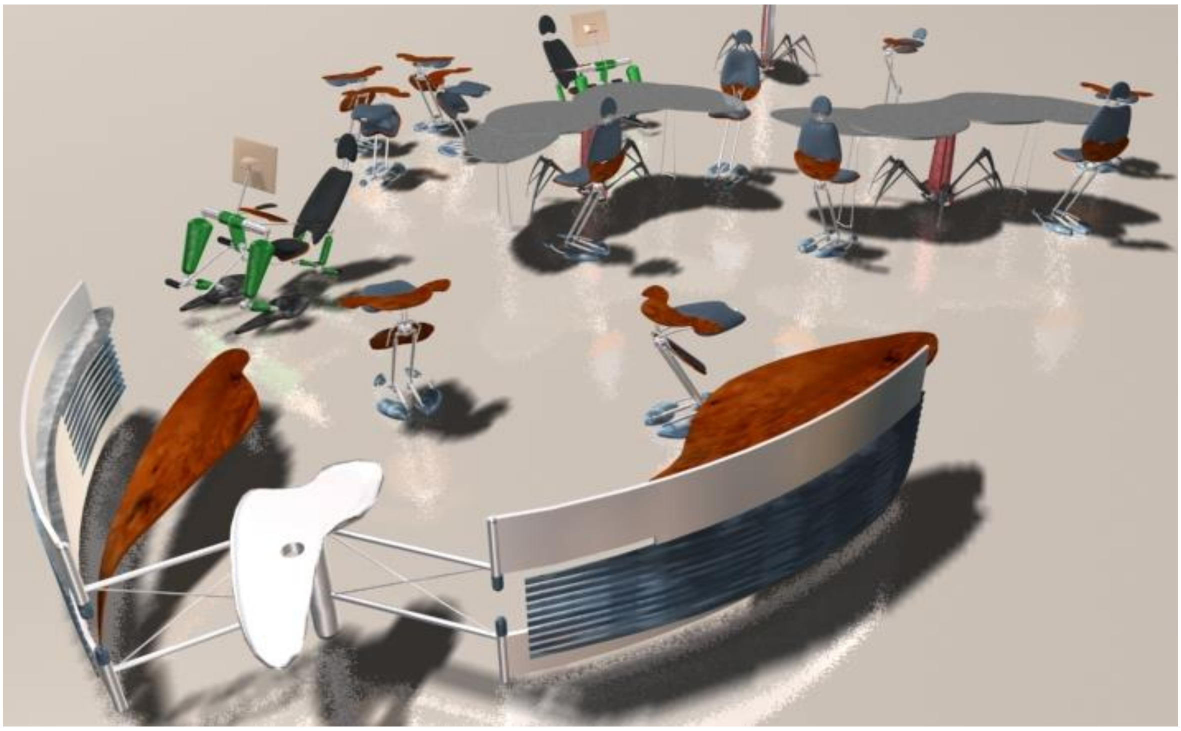


AADRL 2017-2019, Constructing Agency – Studio Patrik Schumacher & Pierandrea Angius.
DRL Team Students : Pendar Golfeshan, Alaa Ikbaieh, Omar Quaddoura, Otrebor Lavado


AADRL 2017-2019, Constructing Agency – Studio Patrik Schumacher & Pierandrea Angius.
DRL Team Students : Caleb Baldwin, Zhao Yuxuan, Xu Yuzhi, Cho-long Baek

Adaptive, Responsive, Creative – How AI can upgrade Architecture

The unprecedented level of dynamism in social interaction processes in contemporary creative industry work environments calls for adaptive, responsive and indeed creative built environments. The discourse of so called 'intelligent buildings' has to be radicalized and related to the core competency of architectural design, namely the ordering of social interactions. If these patterns of interaction become increasingly variable this implies the demand for an unprecedented level of real time spatial flexibility. This demand can be better met by responsive, or better still creative environments. The architectural elements that semiologically inform and order the social processes must themselves become active, intelligent agents. These artificial agents can technically be modelled in the same way we are modelling the various human agents in our population. The next step here are thus truly intelligent, creative, learning environments that operate in a self-directed fashion rather than merely responding in routine ways or waiting for instructions. The architectural elements that are meant to facilitate increasingly complex and dynamic pattern of interaction must become congenial participants in the collective life process. Just as we like our human colleagues and partners to be spontaneous, creative and self-directed, in accordance with shared success criteria, we want to our architectural robots to be self-directed companions and collaborators. This is an old AADRL dream, we are once more working on this year in my DRL studio.



Interactive Robotic Fields, Marcel Ortmans, Ivan Subanovic, Markus Ruuskanen, I Yu, AADRL 1999/00

End.

Notes:

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[i] See: Patrik Schumacher, Parametricism - A New Global Style for Architecture and Urban Design, AD Architectural Design - Digital Cities, Vol 79, No 4, July/August 2009, also: Parametricism – The Parametric Paradigm and the Formation of a New Style, part 11 in: Patrik Schumacher, The Autopoiesis of Architecture, Vol.2, Wiley & Sons, Lonsdon 2012

[ii] Folding in Architecture, AD Profile 102, March-April 1993

[iii] See: Patrik Schumacher, *Digital Hadid - Landscapes in Motion*, Birkhaeuser, 2003

[iv] Gilles Deleuze & Felix Guattari, A Thousand Plateaus – Capitalism and Schizophrenia, University of Minnesota Press, Minneapolis 1987

[v] Patrik Schumacher, Formalism and Formal Research, in: ARKETIPO – International Review of Architecture and Building Engineering - Rivista Internazionale di Architettura e di Ingegneria delle Costruzioni, #104, 2016

[vi] The Design Research Lab (AADRL) is a MARCH programme at the AA, directed by Theodore Spyropoulos, that was founded by the author and Brett Stele in 1996 with the mission to advance digital design methodologies and, crucially, to apply them to pertinent real world urban and architectural challenges, in order to demonstrate the superior performative power of the new formal strategies and methodologies.

[vii] ZHA CODE is the Computational Design Group at Zaha Hadid Architects led by Shajay Bhooshan.

[viii] AD Parametricism 2.0 - Rethinking Architecture's Agenda for the 21st Century, Guest-edited by Patrik Schumacher, AD Profile #240, March/April 2016

[ix] This research team has two sub-teams, one located at ZHA with team leader Tyson Hosmer and another one located at the University of Applied Arts in Vienna with team leader Robert Neumayr.