Implicit Space

Christian Derix
Aedas R&D, UK
http://www.aedasresearch.com
christian.derix@aedas.com

Abstract. *Algorithmic design must start with the observation of physical behaviours. When applied to designing spatial configurations, correlations between occupation, experience and spatial properties as implicit performances require mapping that can be abstracted into notations for algorithmic encoding. The algorithmic descriptions of space are calibrated by physical models. Both algorithms and catalogues of physical models are weighted and compiled into a heuristic design system that enables the generation of spatial configurations based on behaviours of occupation observed in real spaces. The final designs of this Implicit Space course constitute diagrammatic building configurations designed from the inside-out through encoded occupant experiences.*
Keywords. *Spatial configuration; behavioural mapping; heuristic algorithms; design system.*

INTRODUCTION

Implicit Space refers to the invisible dynamics and properties of space that are inherent in the relationships between built environments and their occupation. Strands of spatial analysis develop descriptions of such implicit properties, while architectural design creates methods for the conception of the built spaces.

The aim of the visiting professorship of Emergent Technologies at the Technical University Munich (TUM) for the winter semester of 2011-2012 was to enable the students to create design systems synthesizing behavioural mapping, spatial analysis and algorithmic design in order to plan a behaviourally-driven spatial configuration. The curriculum assumed that no student had done observational and behavioural mappings or written algorithms before. As will be described later, the program was divided into three phases of 1 - mapping observations, 2 - encoding experiential syntax and 3 - developing a multi-modal design system. After the description of the curriculum, two projects will be described that illustrate the program and its intentions. But first, a short discussion about the theoretical context of the curriculum.

DIAGRAMS > NOTATIONS | HEURISTICS > ALGORITHMS

Caruso St John admonish the lack of architectural coherence when digital technology, especially computation or algorithms, is used: *"[...] It is cheating to muck around with algorithms and mapping programs to generate facade details [...]".* They believe that interpretation of social or cultural settings must be included when designing architectural spaces (Pearman 2005).

The general approach in architectural computing is to use algorithms like swarming or tools like Grasshopper and re-produce the provided representations as design expressions. The design studio Implicit Space reversed this approach by seeking to specify algorithmic representations encapsulating the syntax of a spatial experience that the designer can implement in new contexts.

Herbert Simon (1969) suggested that design is a search process with unknown outcome. The designer is influenced by his context and therefore a 'bounded rationality' that renders all design processes subjective. Meaning that algorithms are not objective and when contextualized become adapted heuristics. A designer always builds a heuristic for or from his experience and context, including spatial, social and cognitive. To design an algorithm for a spatial system means to start with a spatial experience that can be mapped subjectively into a 'bounded heuristic' before understanding what the generic patterns of that experience or space are that can be abstracted into an algorithm.

In the mid-90s to 00s, the paradigm of diagrammatic architecture cemented the 'buildings as algorithms' approach. According to Robert Somol (2007) diagrams are generative like an algorithm by producing emergent formations from sequential repetition of operations and serial differentiation. Eisenman's houses serve as examples of generative diagrams. This is appropriate for aspatial shapes but the algorithm as a weighted tool for formal outputs becomes an arbitrary 'black box'. The search process becomes entirely virtual during conception. Being spatial, must not start with some black-box but by understanding the phenomena and structure behind the differentiation from a situated point of view. The design of an algorithmic system must start with being physical, by being embedded within an analogue spatial system.

Stan Allen (2009) proposes 'notation' systems as a more appropriate concept for new digital architectural representations after drawing. Allen borrows the distinction into autographic and allographic arts from the philosopher Nelson Goodman [Allen 2009]. Sculpture or painting are autographic arts where the artist creates a work from direct personal actions giving it authenticity. Allographic arts like music or poetry *"depend upon notational practices as a consequence of the ephemeral nature of the work itself or the need to manage an intricate collaborative structure. […] Allographic arts do not imitate or reproduce something already existing, they produce new realities, imagined by means of abstract systems like notation"* (ibid.). He goes on to argue that notation represents time-based experiences while diagrams represent organizations like spaces. The interpretation of diagrams requires little convention and is produced by a designer with his own key. As heuristics they are personal approximations of perceived structures behind organization like a spatial configuration. They are generative in the sense that they allow for a free interpretation of the structural abstraction behind an organization. Notations on the other hand like algorithms are encoding conventions that enable contextualized re-interpretation of an experience.

If an algorithm is therefore meant to produce a contextualized interpretation of an architectural experience, the experience has to be mapped first into diagrams which can approximate its dynamics and properties before it can be generalized for designing. If we want to heed Caruso St John warning about losing architectural context, we must first understand the spatial context and its dynamics: *"The use of notation signals a shift away from the object and towards the syntactic, [...]. The use of notation marks a shift from demarcated object to extended field"* (ibid.). A physical experience comes before a virtual re-production, not the other way around.

GENERIC FUNCTION

A strong precedent for this type of correlation of space and occupation expressed through a notational syntax exists. The original Space Syntax theory by Bill Hillier and Adrian Leaman (Hillier et al., 1979) was not so much an analytical theory than a theory of design. Rules for the correction between spatial configurations and activity or occupation were sought. The axiom for Space Syntax and Hillier's later work Space is the Machine (1996) is that *"to occupy space means to be aware of the relationships of space to others, that to occupy a building means to move about in it, and to move about in a building depends on being able to retain an intelligible picture of it"* (Hillier 1996). All models are based on permeability structures, indicating potential for types of movement. 'End spaces' such as classrooms or offices are constrained to facilitate specific occupations. Their configurational value lies in their location docked onto movement spaces. A building has degrees of freedom in its movement areas that are mostly semi-private to public. The configuration of occupation spaces connected by movement spaces gives rise to 'generic functions'. Generic function represents the implicit performance afforded by the global configuration of a building. These functions are not meant to be specific functions but generic behaviours like standing in groups or sitting at certain locations, affording control over behaviours from vantage points etc. The correlation between generic behaviours and spatial configuration Hillier coined the 'Inverse Law'. They map each other.

A designer forms his design heuristics not only from schooling but also from being in space. In any social and cultural settings, certain generic functions and spatial structures exist that inform a designer's 'pre-structures'. The built environment providing spatial knowing and modes of production represent configurational genotypes. Design instances produced from some brief or context become phenotypes. The 'generic function' of a phenotype emerges from the designing process and its heuristics. It is however also the genotype that provides constraints within which the phenotypes converge towards a set of generic functions. Hillier calls this principle 'emergence-convergence' which proposes that generic functions arise from elementary design moves. Building typologies for architects should essentially be classifiable by their generic occupational patterns while categories from engineering for construction or development for sectors are used instead.

Like the Inverse Law and the convergence towards global permeability structures, it is the local moves either as designer or as occupant that produces or interprets locally spatial phenomena afforded by the configuration. The concept is neither global (top-down) nor local (bottom-up) but a hybrid as suggested by Hermann Haken (1971) in his Synergetics theory of self-organization.

Younger Space Syntax methodologies also provide syntactical notations for local phenomena like Benedikt's Isovist, axial maps or the j-graphs (Hillier and Hanson, 1984, Hillier 1996). These developments complement the global pattern notations by providing quasi-subjective measures that reveal implicit local performances of global configurations when moving through space.

Hillier et al. use observation techniques and mapping of general occupation as indicators of types of generic spatial performances and socio-cultural expressions of spatial configurations. As described above the mapped observations are initially diagrams of a spatial phenomenon. Generic patterns are distilled from the diagrammatic maps and encoded into notational systems. A crucial last step in the configurational theory of Space Syntax has always been missing: its validation by implementing the theory into design systems.

CURRICULUM

The curriculum attempts to concatenate the above described sequence of defining spatial dynamics into a design system through three phases. The intended outcome from phase 3 should be an instantiation of a spatial configuration based on the initially observed spatial phenomenon or experience of occupation. Another challenge was the spatial setting, as the design system has to be applied to design spatial configurations of a building interior rather than a building massing or urban tissue. The scale of the final design was meant to be small enough to reflect the initial observation but also engage a spatial configuration, that is not room or pavilion size only.

For the observation and mapping phase, the newly built and neighbouring School for Television and Film (HFF) designed and built by Peter Boehm architects was chosen for its contrast in spaces such as its complex volumetric foyer, distribution areas and workspaces, its arrays of small individual offices at the top and its eccentric circulation with 'stairwell to heaven' at its centre. The experience and spatial phenomena mapped and diagrammed in phase one did not specify the design brief for phase three. The students had to research building programs that reflect the phenomena or occupation patterns not necessarily match the program of the case study (in line with Hillier's notion of 'generic function' representing buildings rather than the other way around).

Each phase lasted 4 weeks with 2 weeks for the final design. At the end of each phase a crit with invited guests was held to discuss the work and allow the students to explain publicly their projects. The course was held in English and 24 students enrolled (with only 3 German students). For the first two phases all students had to conduct their own projects. In the last phase 6 project groups were formed based on common or complementary mappings and syntaxes. Theoretical literature debating the concepts and design approaches accompanied the phases.

The course structure consisted of four weekly modules: design studio, lectures, workshops and programming seminar. While coding was only to be used from phase two onwards, seminars began from week one to give students a head start.

Mapping spatial observations | autographic

The first mapping exercises consisted of choosing a route that had to be subdivided into intervals at which intensities had to be quantified. Intensities could be measured by any medium or metric available but had to be appropriate for representing change while moved along that route. Depending on the first measured observations, a mode of mapping had to be applied, selecting between

- Continuous: change along paths including intersecting routes forming a network (process-based)
- Discrete: field-base statistical sampling of correlating features (like elements in sight from locations, people's activities in view distances to walls etc)

Mapped features had to be subjective and localized, from an occupants point of view. Measurements should attempt to describe the experienced spatial or social impressions perceived, and map them into some kind of diagrammatic relationship to reveal their structure. Ideally, implicit associations between spatial features and behaviours, either individual or social, should be revealed. Observation therefore could be of oneself, others, others in relation to oneself, but always in relation to spatial properties.

Having mapped quantities, change, thresholds, associations into some autographic format to represent the experience, diagrams of potential sequences, i.e. of using the maps had to be produced. This type of analogue heuristic of 'using space' was to be accompanied by graphical key expressing conditional choices, actions and unit conventions, which represented a first stab at annotation or syntax.

A workshop was held by Lucy Helme of Aedas|R&D to teach the students behavioural mapping techniques used in practice such as Space Syntax ltd or Aedas|R&D. Behavioural mapping intends to capture generic activities in buildings resulting from spatial configurations but also from building operations. During the workshop techniques such as 'snapshot' mapping at time-intervals, 'gate-counting' at locations, 'trailing' occupants, 'observation' of activities and 'interviews' were introduced and conducted.

Encoding experiential syntax | allographic

The final diagrams of the last phase included actions and conditions. Some aspects of those mapped and structured observations had to be generalized and transposed into a notation convention like computer code. The integrated programming environment Processing based on the Java language was used as it is easily accessible but also limits the geometric functionality, focusing the student on some elementary representation.

The intention of this phase was not only to translate diagrams into notations but to find rules for the patterns observed in the HFF building. A generalization process takes place where a series of codes are designed that resulting in a rule set that syntactically correlates to a spatial or occupational pattern. A kind of 'inverse law' was established that allows the mapping between a 'generic function' and a spatial configuration. The allographic code notation enables designers to interpret these patterns in new contexts.

To demonstrate the encoding of the diagrams into time-based notations, a second workshop was held by Åsmund Gamlesaeter also of Aedas|R&D, to teach simulated actions based on Craig Reynolds (1999) steering behaviors and environmental feedback between some geometric environment and embedded agents. Students learned how to program agent systems, distributed representations like graph representations of discretized spaces and vector graphics. Additionally, professional software development and structuring of code and classes were demonstrated to further development by the students.

Defining multi-modal design system | syngraphic

The third phase had two stages: the design system specification and the instantiation of a spatial configuration. The students had to present their mappings and code patterns to the course and six groups of four students were assembled around spatial or behavioural patterns. This consolidation process mirrors Hillier's convergence principle where a series of generic functions could be identified from the observations and notation. The students had to research references projects of building designs where non-functional activities would drive or support the design of the spatial configuration. The programs of those reference projects were partially borrowed and adjusted to serve as design brief for the eventual instantiation.

The notation used in phase 2, i.e. computer code, represents as discussed above time-based experiences and unfolding associations but less so spatial expressions such as perception of scale or material. Hence, physical scale models of spatial situations had to be built investigating qualities of the generic patterns found that are difficult or impossible to represent via computational simulation (subject also to early coding skills). A series of development loops entailed, adapting codes and models towards the insights gained from the other medium. Additionally, the brief development also required further design aspects to be integrated through code and or models regarding planning issues beyond the patterns such as accessibility or room schedules.

Before starting to design an instance from brief, all groups had to assemble a workflow synthesizing the media. A syngraphic design strategy had to be established that rendered the idiosyncrasies of each medium evident. Ideally, each design decision represented a local choice in a hypothetical space. Modules of spatial conditions were developed that like languages could be assembled according to design syntaxes founded on physical investigation of both spatial observation and scale material models.

CONVERGENCE TOWARDS SPATIAL TYPES

The two projects below have been selected for description because they managed best integrate the initial behavioural patterns from observational mappings via coding abstractions into a design system, calibrated with physical models.

1) Floating room

[Jana Bäumker, Katariina Knuuti, Juan Carlos Venegas Del Valle, Anna Wojcieszek]

The Floating Room project is concerned with the fuzzy quality of a plan. The perception of space is not as delimited as it appears in graphic plans. How can this fuzziness be leveraged to design with?

The group's initial observational mappings in the HFF centered around visual properties of space like connectivity to other areas that inform choices but also levels of claustrophobia in relation to perceived spatial 'tightness' or seclusion, measured as depth of spatial hierarchy. The codes developed on this basis had mainly to do with exploring the visual accessibility of areas adjacent to a location. The approach was less based on visual fields then on visual graph analysis developed by Alasdair Turner (Turner et al., 2001). Therefore, the codes discretized space and gave them initial values from drawn plans that become synthesized into new location states by calculating what other locational values can be visually accessed, resulting in a percentages of perceived adjacent functions and exposure. The percentages indicated the *floatiness* value of a location, i.e. if the location is perceived as an isolated functional space or fuzzy space.

The residential cabin '4 corners' of Avanto architects from Finland was chosen as reference project because it embodies an intimate open plan with overlapping functional areas. Serving as case study, the codes were extended to take external connections into account and calculate total isovist areas per grid location. This results in 3 measures calculated that are weighted to give an overall floatines value per location.

The aim of the project focused on the planning of small layouts through open subdivisions to allow for private and semi-private functions to co-exist. Some spaces therefore need to dual in function depending on their proximity and visual exposure.
To that end, series of physical models were built that test relations of wall partitions and their effect on perceiving qualities such as narrowness, tightness, exposure, convexity for certain functions and thresholds between spaces. Here is was identified that light and views to the outside play a major role, which as integrated into the visual graph analysis described above.

Having compiled a catalogue of spatial effects resulting from relations and dimensions of partitions, and concluding development of 3 spatial analysis simulations, an integrated workflow was established that consisted of 6 steps: 1 define program, connectivity and target *floatiness*, 2 place a partition (wall), 3 analyze partition lines against physical effects, 4 determine area subdivisions, 5 perform spatial analysis with code, 6 adjust and fix areas. Loop (Figure 1).

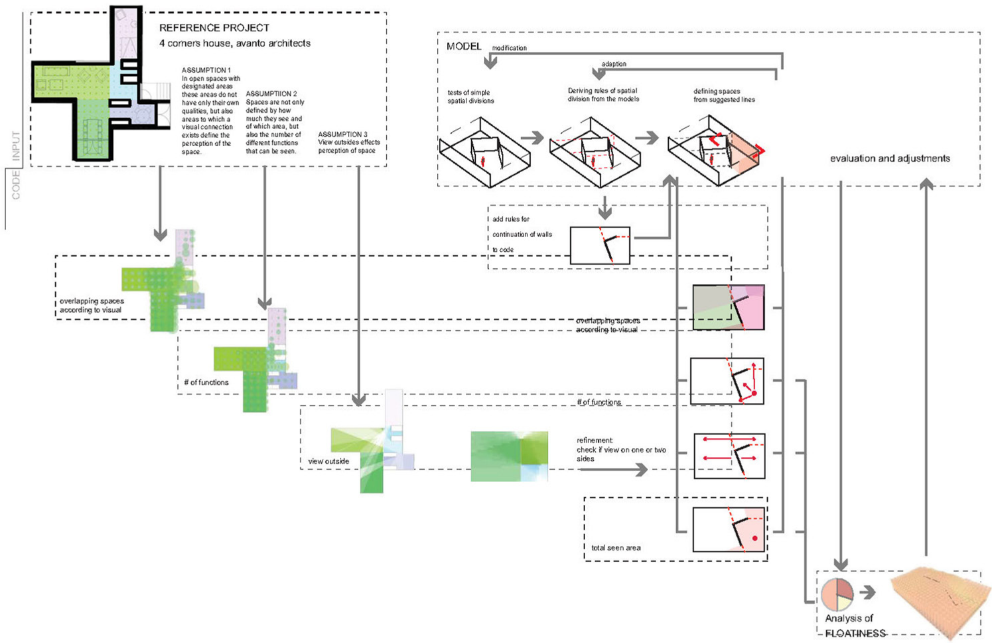

Figure1
Floating Room integrated design loop, starting top left with reference project.

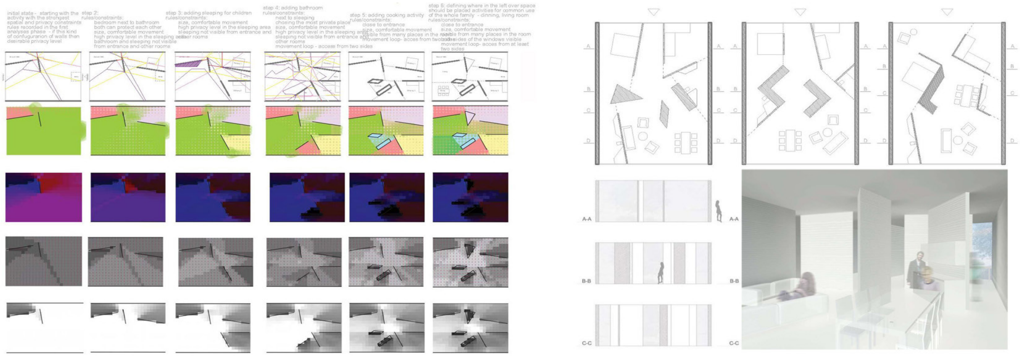

Figure 2
Left: sequence of partitioning and their spatial qualities analysis. Right: three plans developed from system.

The design system was applied to a multi-party apartment block test site in Helsinki. Three flats with slightly different context from the block were used to run the system on. The resulting open residential layouts were coherent with the stated area, adjacency and *floatiness* targets (Figure 2).

The process much resembles the 'barring process' used by Bill Hillier (1996) as an example of designing spatial configurations based on the 'inverse law' producing 'generic function'. The students were not aware that they had reached this level of research sophistication in just one semester and had programmed and defined the whole process to execute it.

2) Grammar of transitions

[Henry Zimmermann, Takahiro Ishihara, Matthew Deutrom, Miguel Izaguirre]

As the name suggests the project investigated rules of movement between and within spaces. During the observational mapping phase at the HFF, group members investigated the constancy of movement and how spatial features would impact on movement behavior. In architectural practice and research, movement is often abstracted to be unobstructed straight lines between visible corners as in visibility graph calculations. While many temporary events can deviate a route from its straightest unobstructed path connecting two locations, the mapping revealed two types of path that correlate: direct and median path. The median path being the center lines between edges as in the straightest skeleton proposed by Auerhammer (Auerhammer et al., 2000). Diagramming the paths and types of behaviours along them, it was found that where the two paths match, the spaces mostly represent transition spaces. Where the two deviated the spaces became used for generic activities such as standing and talking. In other words, the distance between the direct path to medial line correlates to probabilities of other generic occupations occurring. This assumes that both movement and generic activities occur in the same space. As Hillier (1996) pointed out, the relation between movement and specific occupation spaces is usually of adjacency rather than overlap.

The mapping revealed the spatial parameters in plan and section that give rise to those deviations and temporary areas of generic activities, including light conditions and ceiling heights. Two coding projects then separately simulated conditions of movement: the straightest skeleton approximating medial axes (Figure 3) and an agent-based hill-climber choosing routes of spatial openness with high ceilings and large visible areas. The former being a parametric configuration, the latter a generative self-organization. As with all projects, students were not aware that they approximated state-of-the-art research through contextual knowledge and heuristics of their own, i.e. they were not aware of the algorithms mentioned above.

The reference projects focused on circulation-based spaces such as galleries, where circulation

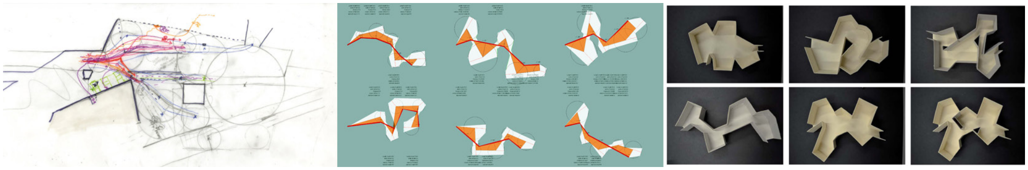

Figure 3
Three stages of the development of The Grammar of Transistion (from left): mapping deviation, encoding difference of movements into parametric simulation and model making of sequqnces.

and temporary occupation coexist, such as the Against Symmetry courthouse conversion project by Europe Studio or the Towada Arts Centre by Ryue Nishizawa. Like the latter, the project was meant to become a carefully crafted linear sequence of spaces where the balance between moving and standing is well calibrated. This required further investigation into the parametric set up of spatial correlations towards the movement routes, spatial thresholds and viewing rhythms.

Models of scale, proportion, wall types and numbers and roof conditions were created as modular catalogues (Figure 4). This allowed the students to perceptually investigate sensual qualities but also to align adjacent spaces, so they could be fitted according to intended spatial effects of the transitions. Further codes were developed that integrated that knowledge including parameters specifying rhythm of spaces by offsetting distances against the direct path, skewness of path, approach angel to exhibits (giving impressions of collocated artefacts), closeness of spaces and their overall density. The weighting of those parameters, constrained against each other, visualized the types of coexistence of activities and movement and evaluated the spatial sequence in a graph by intensity of difference between local transitions and global performance.

The modular catalogue of space units and parametrically weighted simulation were used to design a series of assembled instances on a topographic site with five galleries expressing five types of spatial experiences that could serve different types of exhibitions.

CONCLUSIONS

The two projects described, illustrated the transition from phase one to three. The projects were successful in the sense that they managed to integrate the early observations and experiences via a notational abstraction into a design system that designs spatial configuration not by quantitative dimensions only but by behavioural heuristics. The final design results should in a next stage be enriched by further design drivers and evaluated for the compliance with their targets. On the other hand, performances are generally already inherent in the design system,

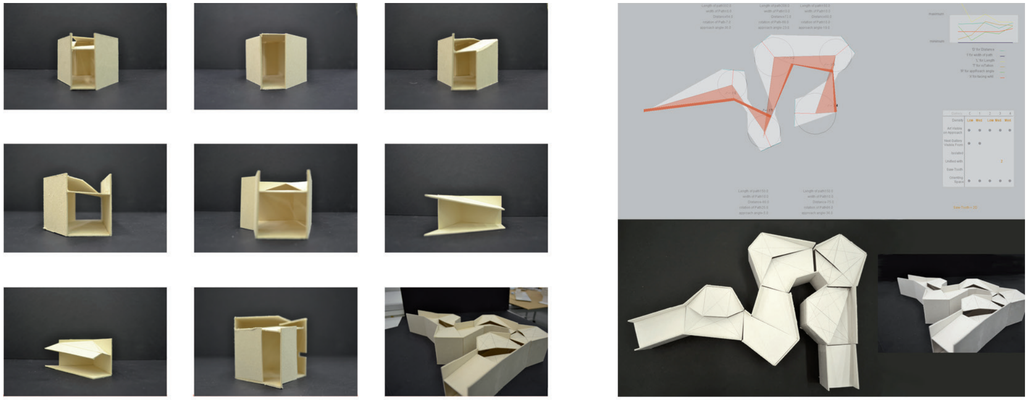

Figure 4
Catalogue of modular space units and assembled spatial configuration. Top right: evaluation graphs of configuration.

progressing further towards a phenomenological design system (Derix 2010).

Pedagogical
The chosen approach of arriving at an algorithm and a design system rather than using an established algorithm as design expression (and excuse for concept), has always produced better computational design students (in courses I taught) who were able to direct their own design projects as if designing in a 'normal' analogue way. They manage to create new epistemological realities that established algorithms don't offer automatically as these are based on knowledge for another purpose. Complexity served *a priori* usually leads to banalization. Complex patterns have to be arrived at through the understanding of the design space and its elementary relations.

Experiential typologies| disappearance of form
The design approach outlined is reminiscent of Hans Scharoun or Herbert Hertzberger's architectural design systems (to name but two). Both belonged to what was then called 'organic' architecture in the sense of defining a spatial organism from 'living' parts where the living refers to occupation and relations of actions. Like Frank Lloyd Wright they generally started from communal areas where activities and social functions were shared and worked outwards (or simultaneously on several areas). They used generalized notational systems to aggregate their spatial configurations.

The examples given illustrate how the product of shape and geometry disappear and only a field of potential activation exists that, of course, requires activation through occupation. Computational Design should be perceived like other design methods as a 'normal' sensitive design approach that doesn't inherently contain an aesthetic. Spaces should rather be conceived for facilitating types of occupation. Allen (2009) concisely concluded: *"Geometry is the invisible scaffold that at once controls the distribution of parts, but disappears in the final building."*

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