# Architectural Morphology
# Investigative modeling and spatial analysis

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**Abstract**

The development of new theorical and technical means, particularly in the field of computer science and its direct applications, leads more and more to a renewal of the approach on design and architecture. The increasing place of modeling and calculations in the architectural process confirms that Architecture lays on the interface, in this case ambiguous, between art and science.

# Speakers

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# Introduction

*This workshop was presented as follows :*

The Research Workshop Architectural Morphology: Investigative modeling and spatial analysis is meant as a beginning or a point of departure, in research and for coming events revolving around modeling and spatial analysis in architecture. With speakers of considerable repute within the field commonly referred to as Space Syntax, as well as in other Architectural fields, it is meant to communicate cutting edge analytical, configurative modeling as well as explore relations to other modeling and analytical traditions in architectural research. Furthermore, through the participation of AEDAS R&D and the experience of many of the speakers, the relation between modeling and analysis in research and practice will be highlighted and discussed.

## John Peponis, GeorgiaTech School of Architecture

## Concrete applications of Space Syntax

We unfortunately missed the begining of this first presentation.

That presented direct application of spatial integration calculations on Atlanta districts.

[explanation schema and formulas]

It is possible for example, by distinguishing pedestrian and car axial maps, to show evidences of "bad" designed district in the sense that they are not liveable for a pedestrian, what is no more possible nowadays. Such designs present a strong lack of flexibility.

Such errors could have been avoided by the use of analytic methods like spatial analysis, and we need today to switch from an exclusive descriptive approach of architecture to a normative point of view ; we need more normative, evidence-based practice. For example, back to the Atlanta districts, it can be showed through investigative modeling that a greater building flexibility could have been permitted thanks to a non equivalent distribution of block size ; that can be put in parallel with the need for local activity diversification.

Of course spatial analysis will never be the direct answer to the difficult question of what is an ideal city, but the motivation of space syntax has always been a normative aim through a better understanding of urban systems

Sophia Psarra, UCL

# The Venice variations : Interactions between generation and explanation

## 1 Role of spatial analysis considerations in Design and Architectural Knowledge

Architecture and its narrative approach are direct consequences of the geometric spatial configuration and an embodied experience, which can be approximated through a topological description of space. That's why geometry and topology play both key roles in architectural analysis ; they have in fact a strong relationship which form determine most aspects of the architectural experience.

As a consequence, a useful tool of investigative modeling can be the try of different geometric shapes associated with the same topology. In that case, whereas the spatial integration stays the same (since we define it in the classic way, with $N$ places and $d_{ij}$ the topological distance from place $i$ to $j$, the mean accessibility to other places : $I_S = \frac{2}{N\cdot(N-1)} \cdot \sum_{i<j} d_{ij}$ ) because it depends only of the topological configuration, the visual integration differs and is interesting to consider as a design criteria. The visual integration can be defined as follows : the architectural structure can be considered as a subset $A \subset P \subset \mathbb{R}^2$, where $P$ is the part of the space we work in. Then the visual integration of a point is the measure of the visually accessible subset taking into account the architectural obstacles (walls). For $M \in P$, it is defined as

$$I_v(M) = \int\limits_{M' \in P \setminus S} \mathbb{1}_{\{M+tM\vec{M}'|t\in[0,1]\}\cap S=\emptyset} dS$$

Such a criteria can also be generalised in 3 dimensions, by discrete superposition of floor layers, or by an analog continuous definition.

Its use can then play role in the development of architectural knowledge. In [3], Calvino explains that imagination can be in fact considered as *Ars combinatoria*, that means finding one good configuration among all possibles. In other words, creating is exploring the plurality of words. The knowledge can be classified in 4 types : dialectic knowledge (empirical), encyclopedic knowledge (to make predictions), analytic knowledge (calculations) and creative knowledge (imagination) ; and design is in particular the combination of the last two : it joins these two different types of knowledge through functionnal aspect and the use of imagination.

To go further in the role of computation in design, we can consider the work of Smithson in the 70s, and the concept of "Mat-building" developped particularly in [5]. The important ideas are that architecture and urbanism are closely linked to the notion of emergence, and that an only top-down approach is not sufficient, a bottom-up approach is also needed, by considerations of evolutionnary fields and local relations.

That importance of computers in design was later in the 90s confirmed by the apparition of evolutionnal design, e. g. design through genetic algorithm that use given rules of the genetic languages to compute new designs. That is again a bottom-up approach for which the unpredictability of the emerging properties is inherent to the system and its self-organisation.

## 2 Evolution and Urban form : case Venice

## 3 Comparison to the project of hospital by Le Corbusier

## 4 Consequences on design

Daniel Koch, KTH

# Architectural Interfaces & Resilience

## Introduction

Architecture can be seen as the interface between the one and other : it has a strong impact on the social relations. Whereas socio-cultural identification can explain differences in housings, on the opposite how is architecture communicating with these socio-cultural considerations?

## Characterization of interfaces

## Consequences for the resilience of the built environment

Pablo Miranda Carranza, KTH

## Tools used nowadays in advanced spatial analysis

### Generalities

### Analysis of bunker architecture through convex decomposition of space

# Meta Berghauser Pont, TU Delft
# Density, Architecture and the City

## Why study density?

Through history, density of cities has always have a great importance. As a concrete example, there is evidence of the link between a high density of population and health problems in Ansterdam, Jordean at the end of the 19th century. At the same time, regulations to constraint the height of buildings according to the street width were taken all over the world (see Paris of Haussman for example). The promoters of the Garden City took the aspect of a healthier city as a main argument. In the late 50s, Jacobs proposed ([4]) in opposition to these idealisms a return to a more natural and by consequence a more dense city.

Today, density can still be an issue. Back to the example of Amsterdam, the global density is too low, as a consequence of an explosion of the urban footprint, and of different relative growths of land uses (the proportion of dwellings went bigger).

We could try to give an answer to the question of arguments for or against densification, but there are very much pertinent arguments on both side, so the really important aspect that appears is the study of density in itself, the fact that it has good or bad consequences on some aspects of the urban system is in fact an other problem, depending most of the time on the particular concrete situation we are in.

## Measuring density

## Performance of density

**Ermal Shpuza, Southern Polytechnic State University**

# Interaction between boundary shape and circulation structure in the built environment

Recent research work has been oriented towards the study of the mutual effect of rules and constraints, in the sense of the relations between the building shape and the social organization occupying it. These two elements have totally different time longevity, so we can ask if it could lead to contradictions between the functionnal aim of an architecture and its effective use.

That lead to the study of two aspects and the links they have : the boudary shape of the building and the contained circulation. Circulation system is directly linked to a level of movement, and can be taken as a local description of floorplates, whereas the boundaries are more a global description. Such a study can also be done at the urban scale, by searching the impacts of an imposed shape on internal circulations.

We will see here first the pure shape aspect, then the influence of circulation on shape, and finally the inverse relation.

## 1 Unique shape approach

It can be useful to first describe the boundary shape in itself, since we will interest us later on clustering of shapes.

Given a boundary shape, it is possible to extract a polygonal approximation (which can be exact in the case of a polygonal shape, what is the most used case for the following studies), and then classify it through the classification of the polygon.

It has been shown ([Missing reference]) that a polygonal shape can be quite uniquely put in correspondance with 6 sets of reals numbers, that are, if we note, with $S$ summits of the polygons, $A_i(s)$ the set of depth $i$ adjacent summits to summit $s$, $S_i^j = \{d(k,a)^j | k \in S, a \in A_i(k)\}$, the particular sets $S_1^1$, $S_2^1$, $S_3^1$, $S_1^2$, $S_2^2$ and $S_3^2$.

Such a classification of polygonal shapes is the starting point of the following work, since we will work on unscaled polygonal shapes, i.e. with $\mathcal{P}$ set of polygonal shape and the equivalence relation on it : $\mathcal{R} : P_1 \mathcal{R} P_2 \iff (\exists \alpha \in \mathbb{R}^*, S_i^j(P_1) = \alpha S_i^j(P_2), i = 1,2,3, j = 1,2)$ , on the quotient set $\mathcal{P}/\mathcal{R}$. On the following, when we consider polygonal shapes, it will always be on that set.

## 2 From circulation to shape : the inside-out approach

This approach is a modular approach, in the sense that it goes from inside to outside. The internal space influences the boundary shape. A shape can be seen as the result of an equilibrium of constraints, external and internal forces. That approach is the consideration of the internal forces only, to understand the influence of internal constraints (for us the internal circulation) on the boundary

shapes. To do that, we concretely consider measures for these two parameters of the built environment and we plot different classes of polygonal shapes in the plan among these two measures, in order to try to bring out clustering patterns between the shapes.

## 3 Influence of shape on circulation

# Ulrika Karlsson, KTH
# Biotic interferences

This presentation is more on research in pure design than in spatial analysis, but is closely linked to it because of the underlying systemic approach in the design process. It presents a work of integrated design lead by a multi-disciplinary team at servo Stockholm and KTH, including researchers from several disciplines such as Design, Architecture, Ecology of biodiversity, Composition of built materials. The project was called hydrophile, in relation to its particular aspects that we will see in the following.

## Presentation

To define the project in itself, which name is "biotic interference", we need to come back to the initial definition of these words : biotic means related with living organism, and interference should be taken here as the emergence from sharing by agents of a system. Here the abstract aim of the project is to create such positives interferences within a biotic system. It lays on the line of relationship between technical design (mathematical aspects) and architecture.

An ubiquitous idea is the overreaching presence of nature, almost a symbiosis between all the dirts of nature and human being, as it can be feeled in the introduction sequence of the swedish film *Melancholia*, or in the artwork *Partially Buried Woodshed* by Robert Smithson.

In the 70s, Banham built in Los Angeles the first green roof building, in a exceptionaly innovative way, through the elegant combination of glass walls with the turf roof. He was one of the first to propose ecology-oriented analysis of urban systems and environmental designed architectural projects. He wrote theorical explanations in [2]. One ambitious aim of the project is to reinvent, to rethink that concept of green roof, in a innovative approach called the hydrodynamic green roof.

An overview of the project can be seen on figure [].

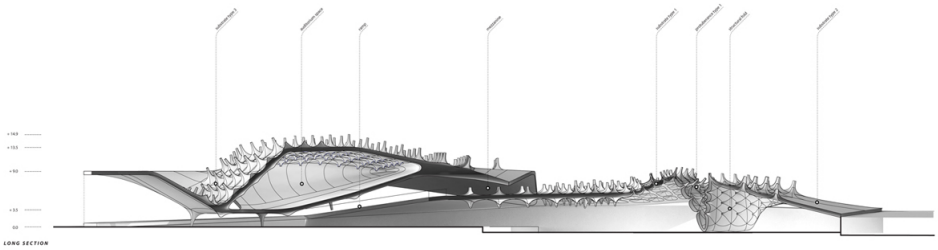


Figure 1: Global view of the hydrophile

## Particular aspects

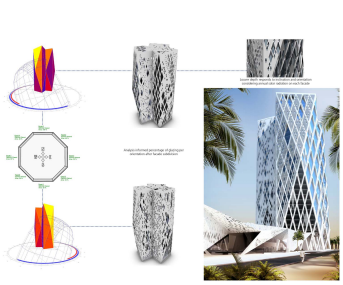
# Christian Derix, AEDAS Architects R&D Computationnal Design and Advanced Spatial Modeling

## 1 Context of the work of Aedas R&D

The company proposes to its client powerful applications of computational design and advanced spatial modeling to design problems, oriented towards sustainable solutions.

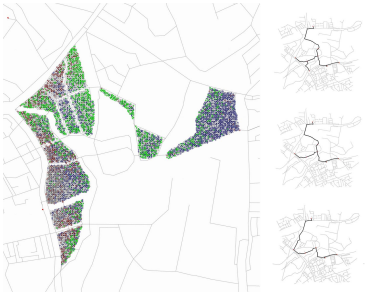
The models that are created can be at several different space scales, but also include people and their interactions between them and with their environment ; that can be seen as the switch from original space syntax to computational models for social logic [*Note : In fact, Aedas does in that case nothing more than complex social system modeling and analysis, but according to their client profile that are architects and designers, they market it as an evolution of space syntax*].

Examples of outlines of different projects are shown on figure [] (from [1]).



(a) Modeling of solar repartition for towers in Abu-Dhabi

(b) Mapping of cycling flows



(c) Global spatial planning solutions

Figure 2: Results of Aedas projects

Figure 3: Hong-Kong southern Polytechnic University

## 2 Examples of recent research projects

### Study for masterplan

It is possible to apply directly syntax to help design ; this example of project shows how a proposal of masterplan is done and how the designer can move pieces of it to see the consequences through the self-organisation of the rest of the plan. The modification can be done at different scales, from furnitures sometimes to the overall floor.

The techniques used are "agent-based aggregation", what seems to be a computational design of possible configuration (not more precisions since it appears to be confidential for the company).

The figure [] shows the final result for the Hong Kong polytechnic University, after the created masterplan has been integrated to the other sections.

### Distribution of densities

For the planning of a new business district in China, there was the need to decide the local densities of activities (in order to then directly apply it to the local design of buildings). For that, a tool was created, that allowed the designer to fix some points at a given density and observe the generated global field of density that resulted from these imposed values.

The method used to extract the interpolating field seems to be not far from non-parametric estimation (see [6]) : with $n$ given points $(M_1, ..., M_n)$ in space and the expected values $(y_1, ..., y_n)$, the problem is to find a function $f$ such that for all $i$, $f(M_i) = y_i$. That can be done for example by kernel estimation aggregation.

### Visibility study

The construction of the new huge tower on the right bank of the Tamise in London has raised interrogations about its impact on the visual landscape of the city. The aim of that project was to model the visual impacts of that new landmark.

To do that, it is possible to calculate by ray-tracing if the tower is visible from a given point, what was done for a big part of the city for which the 3D data of building shapes were available. Then for each point, we can judge if the visible impact is significant, and also see the total proportion of places for which it has a real impact.

### Pedestrian traffic analysis

For the construction of a new railway station, the locations of entries for pedestrians had to be decided and a pedestrian flow simulation model was created.

Concretely, it is an easely parametrizable model, for which test could be done on localization of "source" and "sink" points for pedestrian flows. From an external points of view, it is quite similar to the problem of distribution of densities, although here the interest is more on the flow quantities resulting from fixed potential points. But the method to solve the problem is exactly at the opposite, since for densities it was solved by a top-down calculation, by global mathematical calculations, and here the model used is a bottom-up approach, since it simulates the flows through individuals agents that are the pedestrian themselves.

### Mapping architectural controversies

Urban studies are also sociological studies, as this project testify. Through newspaper articles analysis, it was possible to proceed to "social mapping", and identify trending subjects and social clustering around these key subjects.

What is really interesting is to make the parallel between the social system and the architectural system analysis.

## Questions

Question : Do a global comparative knowledge emerge from all these research projects?

Question : Was network self-generation already considered in one of the projects?

## Åsmund Izaki, AEDAS Architects R&D
## Algorithmic aspects of spatial analysis

That last presentation is a short overview of computer science issues that occur when doing spatial analysis and investigative modeling.

### Complexity of algorithms

When doing computations, the speed depends on the machine on which they are done, but what is really important is the intrinsic complexity of the used algorithm. For example, there exists many ways to sort a set of number, and the best ones (quick sort or fusion) will have a mean complexity in $O(n \cdot ln(n))$, what can be assimilated to a linear time as a function of the size of the set, whereas bad ones will execute in $O(n^2)$, what is quadratic and can quickly lead to impossible calculation times on big data.

This aspect is particularly important in spatial analysis because of the size of the data and the natural complexity of graph exploration problems, that's why finding "good" algorithms for spatial analysis is necessary.

### Difficulty of problems

### Examples of applications

## Conclusion

The architectural solution for a project is a particular response to the context of the project, a local proposal in space and time, but it is also a proposition for architecture in general. Architectural theory builds itself from concrete responses to concrete cases

# References


[1] Aedas architectes webpage, 2013.

[2] Reyner Banham. *Architecture of the Well-tempered Environment*. University of Chicago Press, 1984.

[3] Italo Calvino. *Invisible cities*. Mariner Books, 1978.

[4] Jane Jacobs. *The Death and Life of Great American Cities*. Vintage, 1956.

[5] Alison Smithson. How to recognize and read mat-building: Mainstream architecture as it has developed towards the mat building. *Architectural Design*, 44(9):573, 1974.

[6] Alexandre B Tsybakov. Introduction to nonparametric estimation. (introduction à l'estimation non-paramétrique.). 2004.