RESPONSIVE CITIES SYMPOSIUM

DESIGN WITH NATURE

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RESPONSIVE CITIES: DESIGN WITH NATURE
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THE ROLE OF NATURAL COMPLEXITY IN ADAPTIVE ARCHITECTURE

Eco-based design: Nature as pattern and architecture element

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KEYWORDS
Adaptive architecture, eco-based design, resilience, metereosensitive architecture, More-than-human design

ABSTRACT
In the broader context of an ongoing doctoral research, it is possible to consider adaptive architecture as a possible solution for designing resilience. Despite the large use of technology, it is possible in fact to recognise different design approaches that involve Nature in the whole process, form the initial conceptual phase toward the effective construction stage. Among these different ways, which underline a biomorphic common perspective, this paper would focus on two of them, underlying the role of nature in the design approach. The first is referred to the consideration of Nature as design material and is shown through the projects of the American architectural firm SCAPE, 'Living breakwaters' and 'Oystertecture'. The second approach instead will introduce the use of natural pattern as a way to conceive architecture through geometries, as shown in 'Hygroscope' and 'Pad Hygroskin', two projects conceived within the Institute for Computational Design, University of Stuttgart. The aim of the paper is to show different vision of the More-than-human approach in architecture, envisioning a more responsible way to think of the built environment through Nature to design resilience.

1. INTRODUCTION

Analogies and contradictions have characterised the dialogue between architecture and nature for centuries, in a continuous exchange of roles for a formal supremacy led by technical knowledge. From the constructions of the ancients (guided by a close relationship with the natural context), through the different concept of Nature of the Modern Movement (passing from functionalism to organicism) up to critical regionalism and the most recent approaches on digital design, nature has always played a crucial role in the process of understanding and intervening on the existing. This long and articulated path has also allowed the parallel development of numerous branches of technology, in order to support man's desire to understand, control and overcome the natural element. This desire to control technological data, however, has led recent literature to consider man's current ability to make as superior to his ability to predict the effects of his actions (Galimberti, 2011). The attitude of not being able to control technical and technological data requires to reflect on the way architecture should intervene today, progress on the one hand, by incorporating technological and on the other, by understanding the renewed needs of a complex environmental system. What is noticeable nowadays is a succession of environmental changes, which often generate unpredictable and uncontrolled natural disasters, with which contemporary architectural design is called upon to deal. Rethinking the way of conceiving design therefore also implies a review of the potential induced by architectural transformations, not only on the human or urban scale, but also on the macro environmental scale, constituting in itself a tool for understanding what exists. Designing for Nature and with the Nature, in such a complex context of inter-scalar relationships, constitutes a vast portion of the scaffolding of knowledge that enables the development of the theme of resilience. Resilience is therefore firstly a means of understanding what exists and then a tool for implementing processes of adaptation and transformation, in a dual and heterogeneous relationship between architectural design, technology and the environmental dynamics at different scales. Therefore, with the aim of understanding the importance of architectural design on the natural environment and the urban tissue, especially in the light of continuous environmental and climatic changes and their tragic consequences, it is important to question the way in which we make architecture, think about it and realise it.

In fact, it is believed that the aim of resilience can be achieved, in the architecture field, not only through new social policies and cutting-edge technological tools, but also through new design approaches that make transformation and interaction as formal features. In fact, with the advance of time and technologies, different design approaches have developed, based on the heterogeneous degrees of interaction with the outside world. The introduction, also in the architectural field, of new technologies has then allowed the design of architectures capable of changing partially or totally in their spatial layout, identifying different levels and types of adaptability, due to the involved components (Elmokadem et alii, 2016). In an additive sequence of complex systemic features, interactive architecture and responsive architecture give way to adaptive architecture, which incorporates the previous features and makes the temporal component its core element (Fig.1). The fact that a building or an urban project is able of modifying its constituent elements through a digital and technological mechanism makes possible to identify a parallelism with natural ecosystems, which are innately capable of reforming themselves and adapting to external adversities. Therefore, it is possible to recognise different types of adaptive design that consider the natural element in different phases of the creative process, from the initial conceptual phase to the actual construction phase.

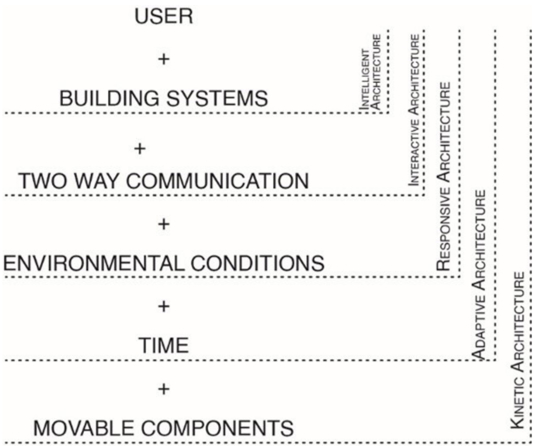


Figure 1:
Graphical visualization of the scheme proposed on Elmokadem, D.A., Ekram, D.M., Waseef, D.A. and Nashaat, B. (2018), "Kinetic Architecture: Concepts, History and Applications", in International Journal of Science and Research, Vol. 7, No. 4, pp. 750-75 (credit: Andaloro, 2021).

2. HOW TO DESIGN WITH NATURE

Within transformable architectures, be they responsive or adaptive, it is fundamental to consider the role of digital components, as new tool for the representation of transformative processes, as well as for understanding and interacting of architecture with the external environment. The importance of these elements (which appreared iwith the architectural tool for the first time with the experiments of the English architect Cedric Price on the Fun Palace or the Generator Project) is crucial for the understanding of the systemic feature of these creative processes. In fact, at the core of this process is future interaction that the project will be able to convey through its architectural materials. Interaction, which can be active (the two subjects interact bilaterally) or passive (one subject acts and the other perceives) guarantees, on the one hand the passage from 'data' to 'information', and on the other, the passage from physical to virtual. In this frame, the transition from data to information is crucial for the understanding of the Information Technology Revolution on society and on architectural design, i.e. the shift of design attention from the object to the subject (Saggio, 2010). Information technology introduced the concept of automation, or the possibility of automatically processing data, according to the rules and principles of computer science and transforming them into information. From this point of view, in 1989 Russel Ackoff defined data as a collection of symbols and signals (the signifier), that is, stimuli, which cannot be used unless they are discretized and made comprehensible through the establishment of a reading system of reference that is capable of attributing a specific meaning. This is where the difference between these two elements is revealed: data is identified as raw material, without explicit intentionality, while information is defined as knowledge that is the result of a description (Fig. 2). 'Data with a purpose' therefore, participate in the knowledge process by triggering reflections and design actions (Ackoff, 1989; Kitchin, 2014).

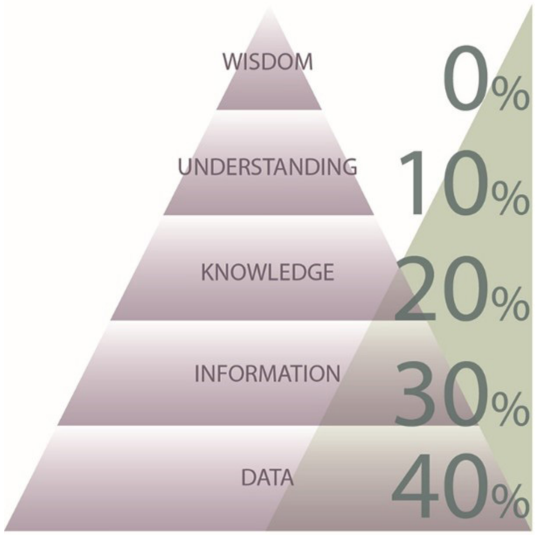


Figure 2:
Structure of human mind in the knowledge process. From: Ackoff, R. (1989), "From Data to Wisdom" in Journal of Applied Systems Analysis., vol. 16, pp. 3–9 (credit: Andaloro, 2021).

The conscious use of information for the comprehension of a design problem is a crucial point in the definition of adaptive architecture, which elaborates a spatial, temporal and scalar transformation in response to an external crisis within the architectural system. Through interaction between users, building and environment, many projects use the information related to a specific external condition (a risk, a crisis) in order to com-pose the architectural materials in a unique relationship that makes the adaptability of the building possible. This correlation then show the role and the impact of digital elements and technologies in the process: the building is conceived after a catastrophic event which, on the one hand, provides the necessary information to understand the ongoing current; on the other hand, it could be used to augment the built environment with an interactive learning process.

In this perspective, therefore, it is possible to identify different design approaches that relate the digital element (mainly identified in the capture of data from the external environment) to the natural system. The natural element (as well as data at the beginning of the digital revolution) can be considered as a real design material (capable, moreover, of autonomous and specific reactions and behaviours) or as a pattern of information, whether genetic, parametric or behavioural.

2.1 DESIGNING WITH NATURE: A MORE-THAN-HUMAN DESIGN

Considering Nature as a common design element means widening the horizon of the project's potential, introducing the features of multi-materiality, multi-scalarity and multi-temporality, all recognisable in adaptive architecture. After the ideas of the ecologist and philosopher Dave Adams in the early nineties, many design theories have been developed about the 'more-than-human' component on a par with the human one (Abrams, 1997). In parallel with the theories on the new Anthropocene, the design approach centred on the integration of the natural element (in the form of animals or plants) is quickly widespreading, especially in the fields of landscape design and biotechnology. In the architectural field, instead, as will be shown below, it is possible to design an integrated complex system where the natural element participates in the social process that the urban space puts into place.

2.2 DESIGNING WITH NATURE: A BIOMORPHIC DESIGN APPROACH

From the inclusion of Nature in architectural design derives the definition of different currents of thought, developed around the character that defines them. The three currents, which we can identify as ‘genetic’, ‘parametric’ or ‘behavioural’ are all related to a common factor, namely the biomorphic tendency of architecture. Designing in a biomorphic way therefore implies conceiving a project that semantically or conceptually simulates the different behaviours of living beings (animals or plants). This is made possible by the vast technological range of tools for analysing and implementing biomorphic mechanisms, as well as by nano-technologies and nano-materials, capable of reproducing the physical characteristics of other living organisms. Within the biomorphic macro-category we therefore find the 'genetic', 'parametric' and 'behavioural' approaches. The first current, of a 'genetic' kind, extracts the distinctive elements of individual species from the natural world in order to transfer their main characteristics to the component of the architectural project:

Figure 3:
François Roche: (top): Dustyrelief, Bangkok , 2002; (bottom left): (Un)Plug, Paris, 2001; (bottom right): Olzweg, Paris, 2006.

examples of this are some of the projects of the French architect and artist François Roche, who introduced an 'embodied' conception of the cognitive aspect (Di Raimo, 2014) (Fig. 3). Among others, Dustyrelief (designed for Bangkok in 2002), (Un)plug (designed for Paris in 2001) and Olzweg (designed for Paris in 2006). The ‘parametric’ current, refers to the connection of parameters from the natural systems to different (usually technological) components. This approach will be explored in more detail through the projects developed by the Institute for Computational Design of the University of Stuttgart. Finally, it is possible to emphasise ‘behavioural’ traits of animal species or other living beings that can be reproduced in the form-finding process, as in the research of the Greek architect Theodore Spyropoulos at the Architecture Association Design Research Lab (Spyropoulos at al, 2013).

3. AN OYSTER-PARK FOR THE SHORELINE OF NEW YORK

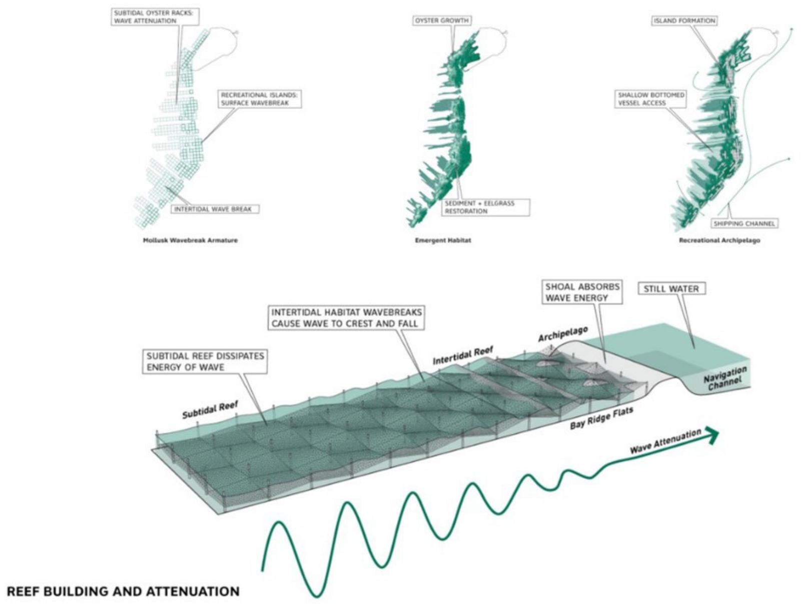
More-than-human' design plays an important role in the definition of projects that involve other living beings as effective constituent elements of the entire architectural or urban system. This is then a way of conceiving architecture in the whole respect of other species and in order to implement the sustainability and the resilience of different eco-systems (Orff, 2016). In order to achieve this purpose, a continuous adaptability of the system is guaranteed, thanks to the inter-scalarity of its components, which respond to a swarm paradigm (Oosterhuis, 2003), in a mutual dialogue between the parts and between the parts and the whole. Presented as a pilot project for the 'Rising Currents' exhibition (hosted at the Museum of Modern Art of New York in 2010), the Oyster-tecture project by the American studio SCAPE opens up an unusual and heterogeneous scenario to introduce, yet ten years ago, the theme of urban resilience through multi-disciplinarity. Far from being a way of recalling the idea of a New York of the past (in which the cultivation and sale of oysters was a key element of the city's economy and the entire ecosystem of the Bay) or even being understood as a different form of speculation (e-flux architecture, 2010), the Oyster-tecture project proposes to build an active oyster barrier, capable of reinvigorating the marine life and the playful potential of New York harbour and waterfront (99percentinvisible, 2017). The project, initially designed in 2010 and subsequently developed and presented at the Rebuild-by-Design competition in 2012 under the name of Living Breakwaters, proposes a solution based on a full and profound understanding of the biotope in which oysters live and which they help to modify. The installation of a sub-layer of rope on the seabed of the New York Bay is in fact functional to the implantation of new oysters, which otherwise could not survive the level of pollution of the current seabed (Fig. 4). Similarly, the oysters are instrumental in helping new species of fish to populate the marine environment and in purifying the water of the waterfront, thanks to the biotic filtration processes of the oysters themselves (Figg. 5,6). Furthermore, with their 3D texture, they are able to break large tsunami waves before they reach the shore, thus also slowing down sea currents and ensuring a climate-proof environment. Oyster-tecture first and Living Breakwaters later (Fig. 7) provide a model for eco-based adaptive design, which places all living beings at the centre of the project to modify the existing environment and once again demonstrates the great potential offered by the constant and continuous interaction between architecture, the external environment and its users.

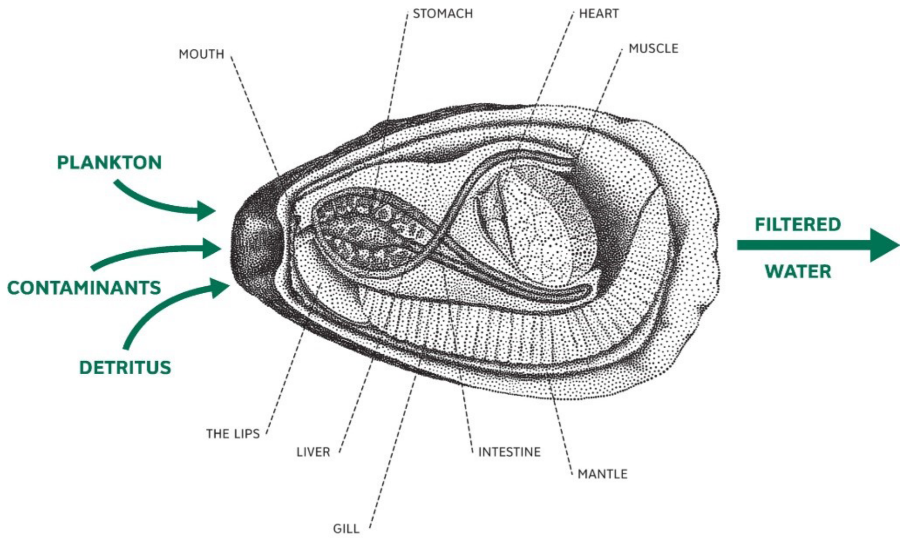
Figure 4:
Oyster-tecture, general overview of the project, as presented for the 'Rising Currents' exhibition in 2010 [Source: https://www.scapestudio.com/projects/oyster-tecture/].

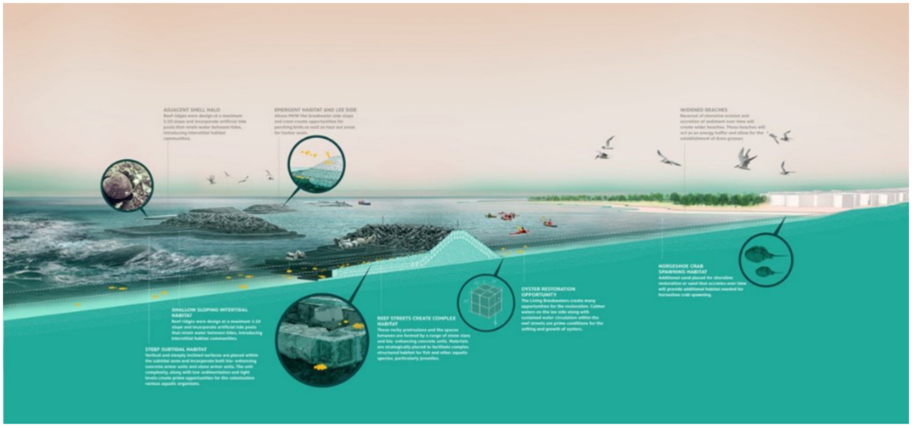
Figure 5:
(top)
Reef building and attenuation, Oyster-tecture, SCAPE, Exhibition project, 2010 [Source: https://www.scapestudio.com/projects/oyster-tecture/].

Figure 6:
(center)
The filtering system of the oysters shown between the submission documents of the project. This underlies the importance of 'More-than-human' components in the whole project. Oyster-tecture, SCAPE, Exhibition project, 2010 [Source: https://www.scapestudio.com/projects/oyster-tecture/].

Figure 7:
(bottom)
Living Breakwater, SCAPE, New York, 2012. General overview of the project [Source: https://www.scapestudio.com/projects/living-breakwaters-design-implementation/].







4. HYGROSCOPE AND HYGROSKIN: TWO WAYS OF DESIGNING WITH NATURE AND GEOMETRY

Another way of approaching adaptive design through the complexity of nature is through the discretization of the properties of natural elements into geometric compositions. The abstraction that derives from geometry allows to design from a rule by defining the relationships between different elements. In other words, natural elements with complex geometry provide the basis for parametric adaptive architectural design. Two projects developed between 2012 and 2013 by the Institute for Computational Design, University of Stuttgart) can demonstrate it: 'Hygroscope' (Menges Achim, Steffen Reichert, in collaboration with Transsolar Climate Engineering GmbH) and 'Hygroskin' (Menges Achim, Oliver David Krieg and Steffen Reichert). The first, 'Hygroscope', consists of a first attempt to create a metereosensitive architectural element on a medium scale, capable of changing (according to opening and closing mechanisms) based on external environmental variations in humidity (Fig. 8). The second, 'Hygroskin', is the realisation of a meteorosensitive pavilion that opens and closes autonomously in response to external meteorological changes (mainly related to the humidity level of the air) without any kind of mechanical intervention (Fig. 9).

Figure 8:
Hygroscope, ICD (Menges Achim, Steffen Reichert, with Transsolar Climate Engineering GmbH), Centre Pompidou, 2012 [Source: https://www.icd.uni-stuttgart.de/projects/hygroscope-meteorosensitive-morphology/].

Both promote a kind of 'metero-existential architecture', which is achieved through the use of design strategies that do not require mechanical or electronic controls to function (Menges et al., 2015). In particular, these two examples are sensitive to external climatic conditions and are able to change their characteristics (shape, position) to provide better comfort. Furthermore, they are realised as prototypes at different scales, through automated construction methods derived from computational design. In particular, the computational process integrates the ability of the material to physically calculate the shape in the elastic bending process, the structure of the resulting building components, the computational detailing of all joints and the generation of the machine code required for fabrication with a 7-axis industrial robot. Motion operation is fully automated and made possible by the same material that defines the structure of the architectural element, namely wood. Its ability to change its shape in relation to the perceived humidity rate has made it possible to predict, calculate, simulate and implement the spatial transformation of the shading elements, so that they can be opened and closed: in essence, the structure of the material itself is the machine.

Figure 9:
Hygroskin, ICD (Menges Achim, Oliver David Krieg e Steffen Reichert), FRAC Centre Orleans, 2013 [Source: https://www.icd.uni-stuttgart.de/projects/hygroskin-meteorosensitive-pavilion/].

5. CONCLUSIONS

In conclusion, it is believed that the examples shown and the approaches identified provide a broad overview of the way to conceive the relationship between natural elements and architecture, especially adaptive architecture. Indeed, this should be explored in its several facets, involving in different ways the digital component, as a means of interaction between architecture, its users and the external environment. Designing "with nature, for nature" is therefore possible, in an attempt to identify a possible resilient response to the needs of the ecosystem in which we live. Thus, even beyond the use of the most modern sensor technologies (which also constitute an important strand of adaptive and responsive architecture), it is possible to construct systems, buildings and architectural components capable of responding adaptively to external changes, exploiting the performative capacities of the natural elements themselves.

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