Biomimetic Architecture: Adaptive Building Envelopes in Complex Buildings

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BIOMIMETIC ARCHITECTURE: ADAPTIVE BUILDING ENVELOPES IN COMPLEX BUILDINGS

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Cultural Background

The causes of climate change are several, complex and interconnected and that they largely depend on the anthropic action on the ecosystem. Although urban centres occupy only 3% of the planet's surface, they are the places where most of human activities are concentrated and, on a global level, they are responsible for a considerable expenditure of energy and for a significant emission into the atmosphere of climate-altering gases. Currently, more than half of the world's population resides in urban centres, while some projections indicate that the rate of global urbanization will reach 60% by 2030, with a significant increase in Countries with arid or tropical climates. It will determine, by 2060, the substantial balance between the energy needs for summer cooling and that for winter heating (Ecorys, 2014).Therefore, the management of the metabolism of the built environment represents a problem that requires the identification of solutions capable of significantly reducing the consumption of resources and the anthropic environmental impact. In the practice which progressively consolidated, the design approach for the mitigation of urban impact and climate change mainly refers to sustainability achieved through not adaptive technical solutions. However, through the adoption of a new conception, which requires the building organism to perform new and multiple functions through the acquisition of adaptive and autopoietic capabilities as they were defined by Humberto Maturana and Francisco Varela (1985), it is possible to reduce energy demand, achieve indoor comfort and even give rise to regenerative processes, remedying past and present environmental damage. The building can be conceived, according to systems thinking and the theory of complexity, as a self-organizing node of a wider self-organizing system, characterized by mutual and multiple relationships and interactions between the built environment, ecosystem and inhabitants. This conception can drive technological innovation and architectural design and suggests to exploit the biomimetic analytical approach, introduced in the scientific literature in the '60s and which has become, over the last few decades, a topic of growing interest thanks to numerous studies including those of Benyus (1997), Vincent (2006) and Jeronimidis (2012), whose domain consists in the investigation of functional processes in the natural world in order to emulate them in the technical-scientific field.

Objectives of the research

Traditionally, biomimetic in architectural design has been addressed and limited, in most of the cases, to zoomorphism, both formal and structural, neglecting many other aspects related to functionality and even less to the exploitation of biological processes for energy-environmental issues. The imitation of nature for the transfer to architectural design has been declined, over time, first as a pure imitation of the form, therefore as bio-inspired investigation applied above all to the structural conception, finally, more recently, as an aware imitation of processes of adaptation of living organisms to external environmental actions. The research intends to establish whether it is possible to evolve the paradigm of biomimetic design in architecture, providing the building with unprecedented capabilities and giving life to a cognitive, adaptive and autopoietic organism, capable of taking part, as a symbiont, in wider and more widespread ecosystemic metabolic processes. The adaptability of a building organism is usually more evident in the design of its envelope as it is the interface for regulating the exchange of energy and matter with the external environment. This addresses the research towards the study of adaptive envelopes which are technological systems conceived to respond dynamically to environmental stresses and even trigger regenerative processes. They are among the most topical technological subjects in biomimetic architectural research. Thanks to new active functions, building envelope can optimize indoor well-being, reduce energy demand and even contribute to the ecosystem regeneration (IEA, 2013). Literature reports many experiences carried worldwide which, in order to achieve dynamic adaptation, exploit mechanical actuators (Fig. 1), the responsiveness of materials (Fig. 2) or the integration between technology and biology (Fig. 3). The research aims to draw a scientific framework to investigate how to reduce complexity and structural fragility of adaptive technological systems, improve their control capabilities, minimize energy expenditure for actuation and even generate power or enable positive ecological processes. The objective is to provide the architectural design with effective tools to make requirements and performance capabilities converge through responsive and regenerative processes inspired by biomimetics and identify some premises for the conception of new biomimetic adaptive envelope systems.

Methodology

Biomimetic research relies on a systemic methodology and assumes multidisciplinary know-how as a mandatory requirement for adequate design. It can inspire the design process from the conceptual phase to the subsequent stages. Thanks to multiple and multidisciplinary analytical and design methodologies including those developed by Janine Benyus, Achim Menges, Rupert Soar, Adrian Bejan and Sylvie Lorente or the implementation of the TRIZ heuristic method by Julian Vincent and Denis Cavallucci, research can be carried to achieve the evolution of the building organism. The critical analysis of biomimetic architectural projects, design methodologies, operating principles, through the identification of the strengths and weaknesses, will constitute the basis for achieving the objectives of the research.

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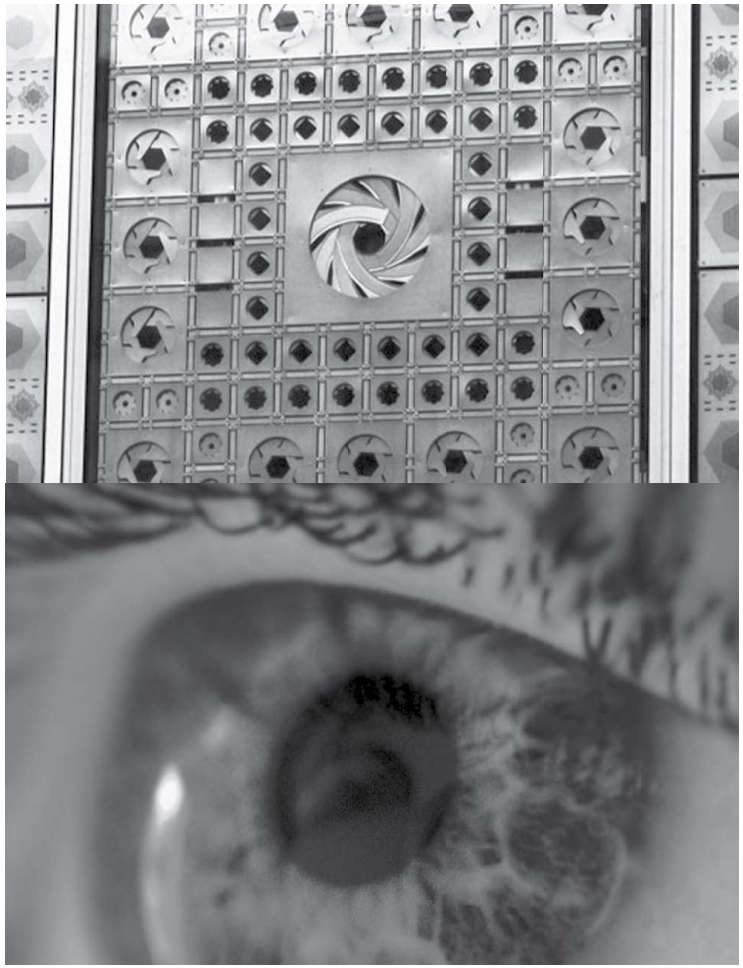

Jean Nouvel, Institute du Monde Arabe, Paris, 1987. Comparison between a module of the façade with a human eye © Luca Saverio Valzano

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"The PhD Program in Architecture. History and Project (DASP) was born out of two long lasting traditions of doctoral level studies and research in the area of Architecture at Politecnico di Torino. The PhD Program programmatically investigates the complexity of architectural cultures starting from the multi-disciplinary and trans-disciplinary interweaving between the history and the design of buildings, cities, territories.

On the one hand, in fact, urban and architectural composition and technology of architecture favor an interpretation of the project as a tool for measuring the stratifications of theoretical elaborations, technical innovations and modifications of built environment.
On the other hand, the historical disciplines for architecture and the city, far from a local vision and thanks to the cooperation with other histories (the economic, social, anthropological and aesthetic ones), trace paths that can be traveled by architects and urban planners, but also by other humanities scholars, such as philosophers and linguists"

Marco Trisciuoglio

(from the document Proposal for the accreditation of doctorates - a.y. 2023/2024, presented to the Italian Ministry of University and Research on June 5th, 2023)

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