Journal of Systemics, Cybernetics and Informatics (2022) 20(7), 92-120
https://doi.org/10.54808/JSCI.20.07.92

Post-Anthropocene_2.0: Alternative Scenarios through Nature/Computing Coalition Applicable in Architecture

Yannis Zavoleas[1]

[1]Department of Architecture, Polytechnic School, University of Ioannina, Ioannina, Greece
Arts, Design & Architecture, School of Built Environment, University of New South Wales, Sydney, Australia
[1] y.zavoleas@uoi.gr, y.zavoleas@unsw.edu.au

Abstract[1]

Concepts of the Post-Anthropocene often depict dystopian futures where land is occupied by giant machines performing repetitive tasks and replicating and fixing other machines. This speculation amplifies what is to be today's solution for the efficient management of available assets, supported by hardware, software, and Artificial Intelligence technologies. However, it also portrays a dehumanising future where Earth has totally been succumbed to the machinic dogma, and for which architecture is no longer made for people. In response to this unsettling scenario, an alliance between nature as a source of references and computing explaining its systemic logic is considered, offering a pathway to reharmonize architecture's scope with the greater ecology. Moreover, semantic analogies are drawn between holistic models of physical space and nature's operational and organisational principles developed since early modernism. This sums up to a paradigm shift that employs cross-disciplinary concepts, cultural knowledge, political ideologies, technology and computing altogether to respond to critical challenges of sustainable thinking for the Post-Anthropocene introduced in architecture's core discourse.

Keywords: *Post-Anthropocene; sustainability; ecosystems; nature's logistics; systems thinking; agent-based; data-driven; field patterns; dynamic mapping; topology*

[1] This article has been reviewed by: Marie Davidová, Cluster of Excellence IntCDC, University of Stuttgart, Stuttgart, Germany; and, Susu Nousala, Industry, Management Practices and Economics (IN4ACT), School of Economics and Business, Kaunas University of Technology | Creative Systemic Research Platform (CSRP) Institute, Helsinki, Ticino, Shanghai, Melbourne. Peer review and final proofreading by Thomas Marlowe of Seton Hall University.

1. Introduction

> Anthropocene Epoch, unofficial interval of geologic time, making up the third worldwide division of the Quaternary Period (2.6 million years ago to the present), characterized as the time in which the collective activities of human beings (Homo sapiens) began to substantially alter Earth's surface, atmosphere, oceans, and systems of nutrient cycling. A growing group of scientists argue that the Anthropocene Epoch should follow the Holocene Epoch (11,700 years ago to the present) and begin in the year 1950. The name Anthropocene is derived from Greek and means the 'recent age of [hu]man' (Rafferty, 1998).

A new era has risen, where the bio/geosphere undergoes irreversible transformations at a planetary scale. Admittedly, the Anthropocene Epoch's great achievements have mostly reaffirmed human/nature separation, where human has been the dominant subject and nature the object to tame. This situation has led to a point where human activity is the major cause of most environmental changes the world is facing (Apostolopoulos, 2019). Additionally, life experience is steadily departing from what would be a human condition, at least as this has been identified since the Paleolithic Epoch. Physical space is increasingly occupied by machinery, industry, data and energy infrastructures, warehouse, and industrialized agriculture (Young, 2019, pp. 8, 10). Under such circumstances, humans contained within habitats and living with machines and among robots could act, live, and be pronounced as 'robots'. The intrusion of machinic activity into all ecosystems of the planetary sphere characterises what is often noted as dystopian scenarios of the post- or un-human society (Bratton, 2019, pp. 16, 20).

In reaction one might attempt to restore past systems, but due to the enormity, complexity and extent of the phenomenon, and to permanent or extremely long-lasting changes that have occurred, this isn't always possible. Seeking alternative pathways, other studies have delved to reinstate the capacity for ecosystemic functions and processes; accordingly, to maximize potential evolutionary adaptive responses to climate change as opposed to saving all species or picking winners; to increase connectivity and probability of persistence for many organisms; to realign or entrain ecosystems with current and expected conditions and to allow novel ecosystems to emerge (Martin et al., 2014; Zavoleas et al., 2020). A new philosophy about life is proposed, impacting the total of human activities, advocating that other-than-human species of the biotic spectrum ought to be installed at vital roles of existence, not just biologically and socially but in the very structure of thought and logic, affecting art, ethics, culture, and politics, or the ecognosis; a view that necessitates that human will "become acclimated to the strangeness of the stranger" (Morton, 2016, pp. 92-162). The greater ecology must be rethought by a new culture that does not place humans at the epicentre. Instead, humans need to learn from nature and live in co-existential relation with non-humans, accepting the occurring mesh one can never escape from (Harris, 2016, p. 305). In summary, it does not suffice to manage natural and human systems separately from each other, or to concentrate on certain species meanwhile assuming others to be of minor importance, but instead, humans should rethink their presence alongside greater sustainability structures. Inevitably, this requires reconsideration of architecture's purpose as an activity mainly directed towards anthropocentric aims (see **Figure *1***).

Figure 1: Dovecote structures, Tinos Island, Greece. Triangular, rhomboid and other geometric shape patterns installed on external walls of dovecote buildings found all around the Mediterranean Sea. The pigeons being bred are used as a sustainable food source as well as collection of fertilizer. Image courtesy of Yannis Athanasopoulos.

In tackling such a task, architecture may assist in coordinating individual initiatives towards more strategic action plans. Since architecture has traditionally operated in the cross-disciplinary ground between culture, nature, and technology, in the current framework it may succeed in that role by occupying a central spot. As Young and Davies (2013, p. 44) suggest, architects are in a unique position to synthesize diverse and complex factors,

pose alternative scenarios and counter-narratives, and express them with imagination and precision. Architecture may assist to link space to its dynamic complexities and influences that produce the concept of ‘place’. Especially with the integration of advanced computational technologies supporting information networks and cross-communication among different specialisations, more and different opportunities arise for the creation of new associations with physical space that favour holistic thinking.
The above approach suggests a new prospect about technology, that is other than to divide nature and human, an issue that has often been raised to ‘demonize’ technology. For example, in the mid-1980s, Donna Haraway revisited the concept of cyborg to criticize perpetual separations and polarisations of western culture, notably between human, nature, and machine. Haraway describes the dehumanized self as a by-product of the new world society (Haraway, 1991, pp. 150-151, 162-163). Her proposition is a hybrid of machine and organism, a kind of disassembled and reassembled without gender, a Chimera that holds the parts as its bionic components together and whose functions could be defined through the technology that has been incorporated into its system. Additionally, excessive uses of technology altering the Earth’s geo/bioconsistency, and unrestrained technological progress have been denounced as ‘hubris’ (Casagrande et al., 2017, pp. 24-25), further linked with human’s so-called divine destiny to ‘civilize’ as ‘humanize’ and ultimately control life on the planet; historically a dubious role often attributed to humanity that has often been evoked to justify actions what would otherwise be recognized as mere atrocities.

In this present case, technology is called first for an in-depth understanding of natural phenomena as evidence to design, then to promote references, methods, and solutions for architecture in alignment with nature’s activities and cycles. It must be noted however, that to integrate this set of aims with the systems of production and profit by which architecture is possible in the first place presupposes extensive cross-disciplinary analysis and consequent adjustments for any of the participants and roles being involved. Such an undertaking requires studying the economic and socio-political ramifications of the above approach, which is outside this paper’s scope. Instead, the current focus is on the possible collaborative links between nature as an asset of knowledge and technology as a means to adapt that knowledge into architectural making, aiming to add insight to ecological and humanistic concerns of the Anthropocene of the present time. In short, this paper is structured as explained below:

As a start, the study constructs an intellectual basis with references engaging architecture with nature from early modernism up to this day. This source is offered as a critical framework for architecture in its transitioning towards the Post-Anthropocene Epoch. Several nature-borne analogies introduced during that period have informed architectural thinking with context-based concepts applicable across all sizes, also design methods, and techniques, as some of them are relevant nowadays. This brief historical revisiting shows that nature consists of a recurring model of thought in architecture and one that is still pertinent especially through computing. Bio/geological models may assist architecture to redefine its principles, goals, and practices with respect to global eco-sustainability challenges. Consequently, the paper bridges earlier endeavours with later studies where nature's properties and performances are scrutinized with computing to inform structures and organisations of the physical space. The results are being suggestive of an architecture that is compatible with nature's operative and systemic principles. Nature's alliance with computing is thought along with a moral dimension and responsibility of which Anthropocene it is to be (Ellis & Trachtenberg, 2013), preparing a vision for architecture of the Post-Anthropocene to put into action.

2. Bio/Geological Models of Modernism

In modernism, the forged links between nature, space and form incited new cross-disciplinary concepts of systemic thinking in architecture. As many of those novelties have gradually been incorporated into the mainstream building industry in the ensuing decades, it may be argued that modernism has prepared a key role for architecture to coordinate sociocultural and technoscientific action in response to current challenges. Particularly, architecture's growing ecological and ecosystemic interest may be related to modernism's focus on nature's operations, structures, patterns, and solutions informing design decisions.

Architecture's interest in nature as reference to design was expressed as early as in the dawn of modernism. Seminal architects of the late Nineteenth and early Twentieth century such as Emmanuel Viollet-le-Duc then influencing the Art Nouveau movement, achieved better structural performance by uniting the architectural elements into a smooth aggregate not defined by pure cartesian references (Burry & Burry, 2010; Zavoleas, 2021). Around the same period, scientist Patrick Geddes studied the dynamic patterns of distribution and growth with reference to natural system hierarchies, the earth topography, and the geomorphic characteristics of the greater landscape then applied upon large urban structures (Geddes, 1915). Geddes' analysis stresses the significance of organic flows of information, energy, and matter along with cooperation, integration, adaptation and change in making the city, as the ultimate expression of social union and environmental merging (Bally & Marshall, 2009, p. 556). Nature translates to an idea that human habitats from single units to whole cities may follow the same principles related to nature's incessant striving for readjustment, reorganisation, mutation, competence, and evolution underlying broader bio/geological systems.

In the following years, nature's themes were further combined with anthropocentric reasoning. Modernism drew variously upon the development of livable, viable, and equitable cities for all. Nature was used as an element to ease urban density and provide a healthier environment in the metropolis. Le Corbusier's Athens Charter published in 1943, restated architecture and urbanism's main scope to meet human needs through functional efficiency, ergonomic solutions, health, and comfort. Even though the machine model was the main conceptual vehicle by which to carry out such tasks (Zavoleas, 2013), the techniques employed would often support expansion and change following natural patterns of dynamic adaptation and growth (Le Corbusier, 1943; Kostof, 1991; Bally & Marshall, 2009). Machine's operative characteristics, such as repetition and automation, were met with a quest for ecological balance and organic development.

Several studies followed the above track, which found its peak in late modernism. A persistent quest on nature's principles prompted to think of urban space with regards to time. Nature favoured flexible, expandable, and evolving systems applicable to urban space management. Related concepts would connect the dematerialized structures of sociopolitical life with a need for open spaces, public squares, and parks (Smithson, 1968). Data and characteristics about the city, the environment, society, culture, politics, economy, even ethics, outlined a multitude of relationships among the parts and across different strata as influences that could be included in the greater system model (see **Figure *2***).

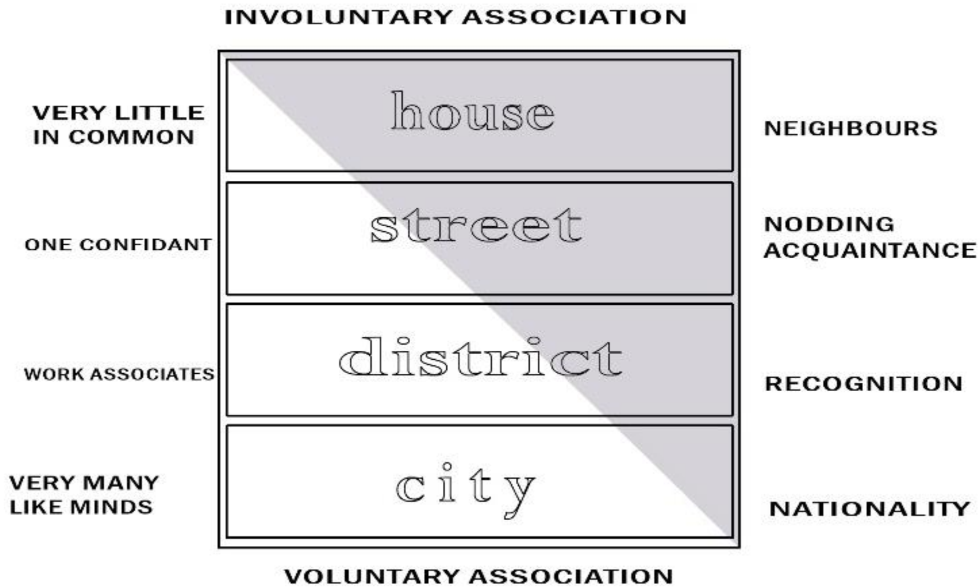

Figure 2: Alison and Peter Smithson, 1951. Cross-scalar links from the house to the city through intermediate spaces for social interaction. CIAM X, Dubrovnik. Diagram redrawn from original.

A variety of shapes ranging from lines, axes and stems and others infinitely expanding were proposed as agile pattern structures supporting the intricacies of urbanisation. A series of multicentered and evolving schemes bringing together regional planning, the landscape, and the urban territory with architecture and the interior offered extended interoperability of spatial systems to alleviate any of the downsides of post-war development attributed to rigid applications of zoning. The patterns were hybrid organisations with dynamic and at the same time regulatory aspects, by which to distribute the flow of activities, information, and energy throughout the inhabited space, much like the networks of arteries, veins, neurons, and nervous systems of living organisms (Doxiadis, 1966) (see **Figure *3***). Different space units were 'com-puted' meaning they were put together and in relation to one another and their features were calculated, compared, and tested to interact with other units partaking in the 'com-position'. Other studies were applications of elaborate systems by which to engage geometric patterns with nature's topological abundance. An infill system with the potential to expand infinitely was put forward, instead of an ultimate form that could be preconceived, or be fully anticipated (Candilis, Josic & Woods, 2006, p. 99). Webs, cells, molecules, and hexagons were employed as flexible instances setting infrastructures that could grow, densify, and adapt to different contexts (see **Figure *4***).

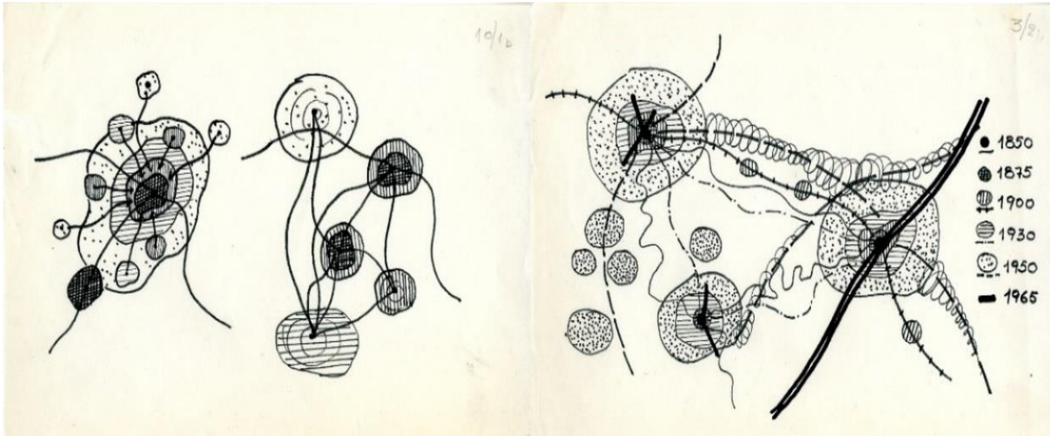

Figure 3: Constantinos A. Doxiadis, 1966. Drawings explaining human settlements as organic systems that could expand in space/time. Doxiadis presented this idea in the lecture “Human Settlements: Challenge and Response” at the Committee on Government Operations – Subcommittee on Executive Reorganisation, United States Senate, December 1966. © Constantinos A. Doxiadis Archives. Constantinos and Emma Doxiadis Foundation.

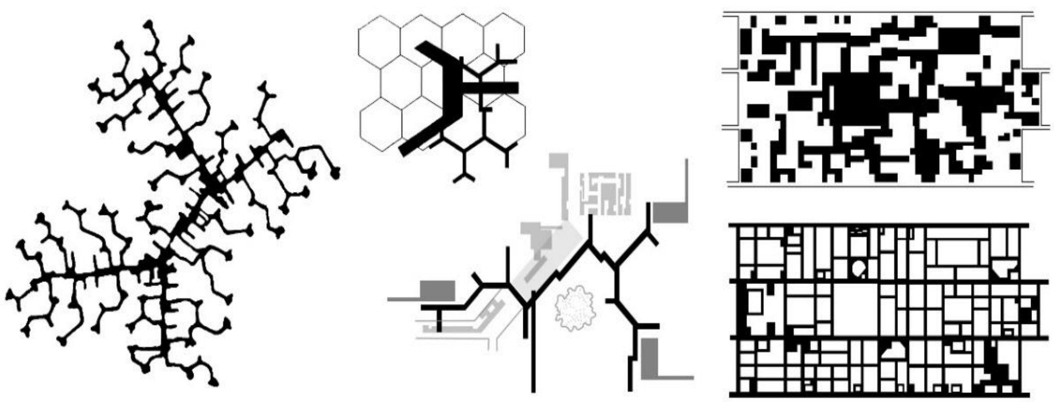

Figure 4: Georges Candilis, Alexis Josic, Shadrach Woods, 1961–1963. Urban studies on dynamic spatial organisation by an evolutionary logic to respond to complex social and programmatic scenarios also with reference to natural patterns. These diagrams served as concepts for some projects of the group, notably Toulouse-le-Mirail and Free University of Berlin among others. Schemes redrawn from originals.

Formal and structural pluralism were common among late modernism’s pioneering works, the result being expressive freedom as aberrations of the norm. Several structuralist, topological, and form-finding approaches defied the autonomy of form, and the completeness and self-referentiality of the building (Zavoleas & Taylor, 2021). In addition, as Claude Parent and Paul

Virilio (1996, p. 12) suggested, space's structural logic could be set in conjunction with inclined terrain walls resembling mountain slopes, in so doing challenging the vertical and horizontal lines of artificial structures. Architects of Team 10 favoured multicellular patterns (Van Heuvel, p. 18), whereas Frei Otto's form-finding shapes were in fact direct translations of physics joining the structure with the natural forces and the greater milieu (Burry & Burry, 2010, p. 12). The space-and-form composite would not simply look organic, but had to be an organism of its own, emerging out of processes, resistances, and pressures by which it occurs. A comprehensive approach to design in architecture and the urban scale was set to redefine the building's relationships with nature and the ecosystem, sought alongside social dynamics. Heterogeneity, agility, and character were developed within a homeostatic total as a hyper structure capable of encompassing spatial instances of any kind into its body. Admittedly, there are profound advantages of this status of the architectural object as energies, flows and actions result in variety and intimacy with the inhabitants locally, meanwhile prompting towards integration with culture and nature at the local and the global setting.

Modernism's examples span across a wide spectrum of the natural analogue seen as a comprehensive apparatus – both ideological and methodological one – that would become relevant again later. As the related ideas suggest, a space unit of any size consists of a systemic entity; it involves an extended infrastructural network of energy distribution and information dissemination; it expresses systemic logic along with high levels of performance and control; and it is set so that it may contain and associate with entities of various purposes. With its broadened agendas, modernism also introduced cross-collaboration between natural sciences, statistics, engineering, space management and the building industry serving humanistic values and nurturing a deeper sense of awareness and responsibility into architectural discourse.

Following the above trajectory, modernism has equipped the younger generations of architects to explore new liaisons with nature facing climate change and energy crisis. Moving forward and into the present era, a primary task about architecture would be to turn its focus as any of its works and the inevitable by-products of anthropocentric activity back in alignment with the ecosystem's cycles (Young & Davies, 2013, p. 40). Energy and matter are active participants informing design proposals. Accordingly, natural and socio-cultural elements may be brought into cooperation through malleable systems and sustainable structure replacing rigidity and stasis. More recently, computation has prompted towards further advancements. Augmented digital-and-analogue-combined working platforms support abstraction, diagramming, dynamic processing, real-time simulation models, recursive and iterative testing and linking with extended datasets. As suggested next, new ecosystemic analogies point at nature again to uplift architecture's corpus.

3. Data-Driven Design: Field Patterns, Topologies, Agent-Based Models

3.1. New Ecosystemic Analogies with Anisotropic Values

In biological organisms, form is considered an evolutionary output of systemic operations, and related theories suggest lifeform as the result of interactions among different organisms and their environment (Thompson, 1917). Every organism negotiates between internal and external causes as a system within systems always in context and never in isolation or solely in simple dependencies. After the initial stages of a cell's development, form signifies a complex set of data processing controlled by the DNA code. DNA encodes (with epigenetic influences) information about variable structures, behaviours, and exchanges for the realisation of a system's vital functions. Individual species follow DNA rulesets adapted to external pressures while still allowing responses to competitive drives. The energy transfers among different lifeforms are indicative of metabolic actions being crucial in the development of specific morphologies, even more so of new relationships between similar and varied individuals (Weinstock, 2010; Greenberg & Jeronimidis, 2013, pp. 25-26). Metabolism is regulated by information and instructions concerning an organism's ability to construct and to support itself through energy intakes and outflows with the environment. Additionally, it involves the system's whole size range, from molecules and cells to the intermediate sizes and the greater structures (Besserud et al., 2013, p. 87). From an operational point, metabolism is sustained through pattern and form readjustment. Different energy and information management tactics cause new patterns within the collective with higher functionality and performance, and the emergence of new species (Weinstock, 2010, pp. 119-120). Variety happens through natural selection as individuals with certain genotypes compete and interact with the greater system in a particular set of conditions by and in response to which they develop new traits and skills (Kirschner, 2009, pp. 27-28).

As these concepts are transferred into architecture, ecosystemic thinking entails that every instance is described by a set of variables held together by dynamic pattern organisations. The study of patterns is thus being translated to an exploration of the limits of organisational sets through systemic feedback (Spuybroek, 2009, p. 7; Rahim, 2009, pp. 41-43). In respect, in the late 1990s, Allen (1997) compared various field patterns applicable in architecture and urbanism. Specifically, he performed a series of explorations where ecosystemic logic produced malleable space-field conditions showcasing patterns' capabilities to variation. Allen's patterns call upon those of late modernism, but in a more playful, artistic, and elaborate style. Abstraction becomes a major feature by which to perform spatial complexity. Pattern making introduces a recursive process that assists looking at the relationships and the richness of experience that correspond to local manipulations of adapting and transforming. Allen's quest is an implicit interrogation of rigid geometric structures and above all the grid, suggesting 'soft' pattern solutions in meeting with the multiplicity of problems of the urban scape in more nature-compatible modes. Reciprocity and intimacy are developed as cause-and-effect phenomena linking actions with pattern and form. The output schemes can be mosaics, block compositions at varying sizes, semi-open semi-closed clusters, striated and felt tissues, patchworks, vector and line assemblies and other aggregates, where proliferation of simple elements causes the system to grow naturally, that is with some consistency, offering anisotropic variation through semi-guided freedom.

The idea that space is an anisotropic field rather than an unchanged reference that imposes its rules upon the system, introduces topologically defined locality as a means to restore global balance. The anisotropic field induces a loose perception of space and structure that grants flexibility at the small scale while maintaining relevance with the general context. To this direction lies Toyo Ito's programmatic analysis of Sendai Mediatheque developed in the mid-1990s. The scheme translates the program by a semi-natural scape of stacked platforms and tree-like hollow supports offering remarkable freedom as it accommodates various functional requirements. Complex architectural and social effects are met by applying simple rules upon a soft pattern. In respect, Ito started his study by modifying Le Corbusier's Dom-ino to an alternative configuration of slabs and columns, and so he came up with an organic system of floors with thin edges and woven columns over a repetitive type (Allen, 2012, pp. 11-12). Movement, fire safety, vertical transport, and mechanical and environmental engineering become active factors. More than signifying structure's function to merely carry the load of the building, the occurring hollow areas also host multiple activities of the program. As Allen (2012, p. 12) describes, "architecture, as much as it is a tectonic support, is also the creation of a localized artificial atmosphere that connects in turn to larger information networks. It is in these more ephemeral aspects of building that architecture can reshape social interaction today". The program's inherent ability to trigger social interaction through heterogeneity is inscribed as metamorphoses of the field pattern. The socio-spatial and structural imperatives are captured as input variations met by the same adaptive system logic.

Expanding such explorations with computing may produce several hybrid results following ever-changing data values, as Greg Lynn presented with the Embryological House proposal, developed between 1997 and 2001. Hybridisation is an emergent quality of systemic linking of data about the object and its outer environment causing variations of form. From a technical point, variation is due to iterative simulation and blending performed upon a range of architectural, animation, product, and communications design software (Bird & LaBelle, 2010, p. 244). Following up with this idea, Lynn also drew upon non-standard modes of production, an idea Bernard Cache had elaborated a few years earlier, stating that an object may not be defined as a fixed entity, but as one that exists in a state of constant transformation relative to parametric relations internally as well as with other parts (Cache, 1995). Form becomes a dynamic effect, or as Lynn puts it, “a system of regulation and order that proceeds through the integration and resolution of multiple interacting forces and fields” (Lynn, 1999, p. 26). Independent variables can be linked to influence one another, producing a “concept of an envelope of potential from which either a single or a series of instances can be taken” (Lynn, 1999, p. 14). Deformation sets a system of regulation and order by a topological pattern that unfolds dynamically with varying performance absorbing multiple influences (Lynn, 1999, pp. 18–26). Different outputs can be created sequentially, being suggestive of an evolutionary timeline of computation-driven DNA-like form-finding design method. That process facilitates generative, genetic, rule-based, phenomena adding more flexibility compared to systems where form is the result of geometric shapes and Cartesian volumes controlled by x, y, and z coordinates. In effect, the house type becomes a soft topological reference that can be transformed by data tweaks. Here, the notion of ‘type’ responds to the flux of formative causes, performances, and ongoing internal and external pressures (Zavoleas, 2016, p. 201). Guided by the given constraints, translations of data to form create smooth typologies about space and structure identified by procedural consistency and evolutionary order. In analogy to biological processes, external changes are registered as input variations causing new types as new species and subspecies to emerge.

3.2. Dynamic Integration with Algorithmic and Diagrammatic Techniques

In a networked framework, a project's database is updated with changing values by any of the parts being involved. The data may be of all sorts such as about the site, its adjacencies and relationships with others, the program and the frequency of activities, pedestrian traffic, vehicular and other flows, climate, water and landscape, views, orientation, permanent, temporal, and recurring characteristics, and practical, socioeconomic, and cultural inputs. This is an open list of influences that may also include forcefield phenomena, so that space is set to grow, evolve, and be fully rendered by topological features such as diffusion, flow, and gradual transforming. The sum of pressures and desires about the project prepares the occupational strategy by which these features can be compared, assessed, and met by a scheme. Such a task is typically carried out by organisational and other semantic forms of data management. In a computational setting, this process is supported by algorithms (Spuybroek, 2004). The algorithm is the project's code in analogy to an organism's genetic code ensuring consistency through genotype/phenotype linking (Zavoleas, 2015, pp. 1071-1073). The outputs occur through codified processes so that data changes produce variations. The algorithm is also the intermediate that facilitates communication and exchanges across different specialisations, stakeholders, and platforms, accordingly their translation by a design solution (Zavoleas, 2020). In that sense, computation may direct all-systemic performances about space's matter and energy assets (see **Figure 5**).

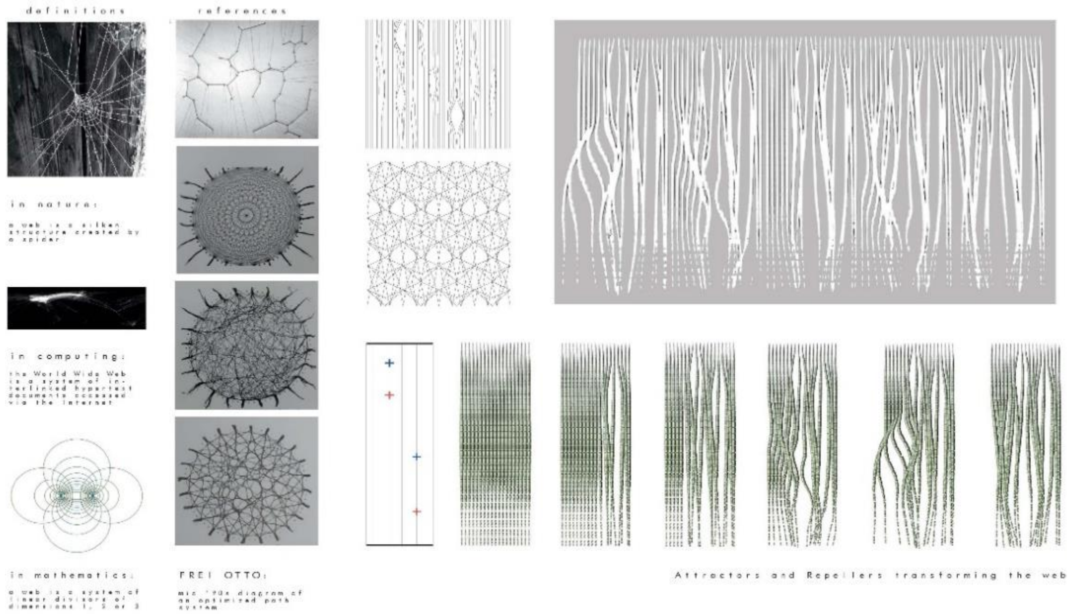

Figure 5: Nikolas Michelis, Konstantina Tzemou, with Yannis Zavoleas. Inter_Web: Dynamic interconnections as a spatial experiment. Analysis of a spiderweb as a natural phenomenon and its translation to a flexible pattern system of codified connections and stresses. The study builds upon Frei Otto's form-finding studies, expanded with computational techniques (simulation and scripting). Variations of the pattern is an effect of displacement of attractors and repellers, also of fluctuation of intensity values over time, combined with the web's material properties related to bending, resistance, and stickiness. 'Weak Typologies' design course, University of Patras, Greece, 2013.

As complexity levels increase, algorithms can be applied into agent-based dynamic simulation models. Notably, architects of the early 2000s such as Lars Spuybroek and Patrik Schumacher developed computational processes to bridge the heterogenous inputs of analysis with synthesis through parametric associations (Spuybroek, 2004; Schumacher, 2016). The underlying idea is to relate space's features with economy, social group usage, navigation, utilisation, arrangement and merging of activities, also assessment criteria about efficiency, encounter frequency and relevancy, density, variety, and duration. The parameters may include measured data alongside debated information such as socio-cultural values, even hypothetical scenarios. The manifold quality of these dynamic processes is intensified by merging programmatic and user group requirements with the site, the social values, the landscape, and the ecosystem. The scheme's character corresponds to a range of spatial meanings about intimate, personal, and public, also openness and enclosure. The result is organically driven shapes, evolving typologies and a loose architectural language and syntax as opposed to fixed building blocks.

To involve diverse features into the process assumes working with cross-scientific platforms, tools, and techniques. In such cases, diagrams are preferred because of their suitability to express and to compare the properties of phenomena, without having to show them in a descriptive, or representational, way. Linking the diagram to data and performances is a direct consequence of its instrumental significance (Lynn, 1999, p. 39). The diagram isolates relationships in a 'deterritorialised' manner, and information is momentarily stripped from the phenomenon it refers to (Deleuze & Guattari, 1987, pp. 140–142). Its reality is unsubstantiated, reduced, and conceptual, allowing operations that in the physical world would have been impossible. The diagram's main function to abstract phenomena suits the development of design models for studying purposes. In respect, in the 2010s, Pablo Lorenzo-Eiroa performed a series of information mappings examining environmental forces (Lorenzo-Eiroa, 2013a). Information mapping was suggested as topographies of abstract data visualisations inducing opportunities for landscape intervention. Several multi-layered diagrams were created as references by which to map, analyse, compare, and reorganise instances of reality by a collection of crosslinked registrations.

Mapping can be expanded with other abstract techniques such as those utilising scripting, binary datasets, genetic algorithms, and generic, geological, logarithmic, and artificial patterns. Mapping plays an essential role at a cognitive level. Among its aims is to translate information from conceptual to perceptual and so to reveal a cartography of influences and cross-relationships beyond early assumptions. Mapping satisfies "a necessity to work by layering information in a multi-dimensional space surpassing the constraints of three-coordinate space" (Lorenzo-Eiroa, 2013b, p. 207). A key feature of mapping is that the projected information assumes a code, by which a pattern and a structure emerge. Mapping creates a system that even though remains abstract, it constructs space where data is fully active. Information systems manage data through interfaces that regulate this flow. In effect, mapping induces a topological setting where data undergoes evolutionary processes and time-based adjustments.

Mapping explorations with computing encourage to fully integrate bits, codes, and relationships within the dynamic plan system. Progressive topological data mapping reinforces a performative aspect in the work, triggering a formal generative capacity and dynamic space plots (Lorenzo-Eiroa, 2013a, p. 18). Non-linear computational processes linked to topology and swarm intelligence entangle multi-dimensional data being applicable to multi-scalar projections and cross-disciplinary scenarios (Lorenzo-Eiroa, 2013b, pp. 206-207). The sum of this material comprises a comprehensive system that organises information forming environments by which architecture is produced (Lorenzo-Eiroa, 2013a, pp. 10-13). Parametric design software and differential calculations address deeper structural levels of displacement, where meaning and significance are redefined through relationships. The otherwise rigid references that have dominated the discipline describing space and form as static entities convert to an indetermined state that is receptive of temporal associations and dimensions (see **Figure *6***).

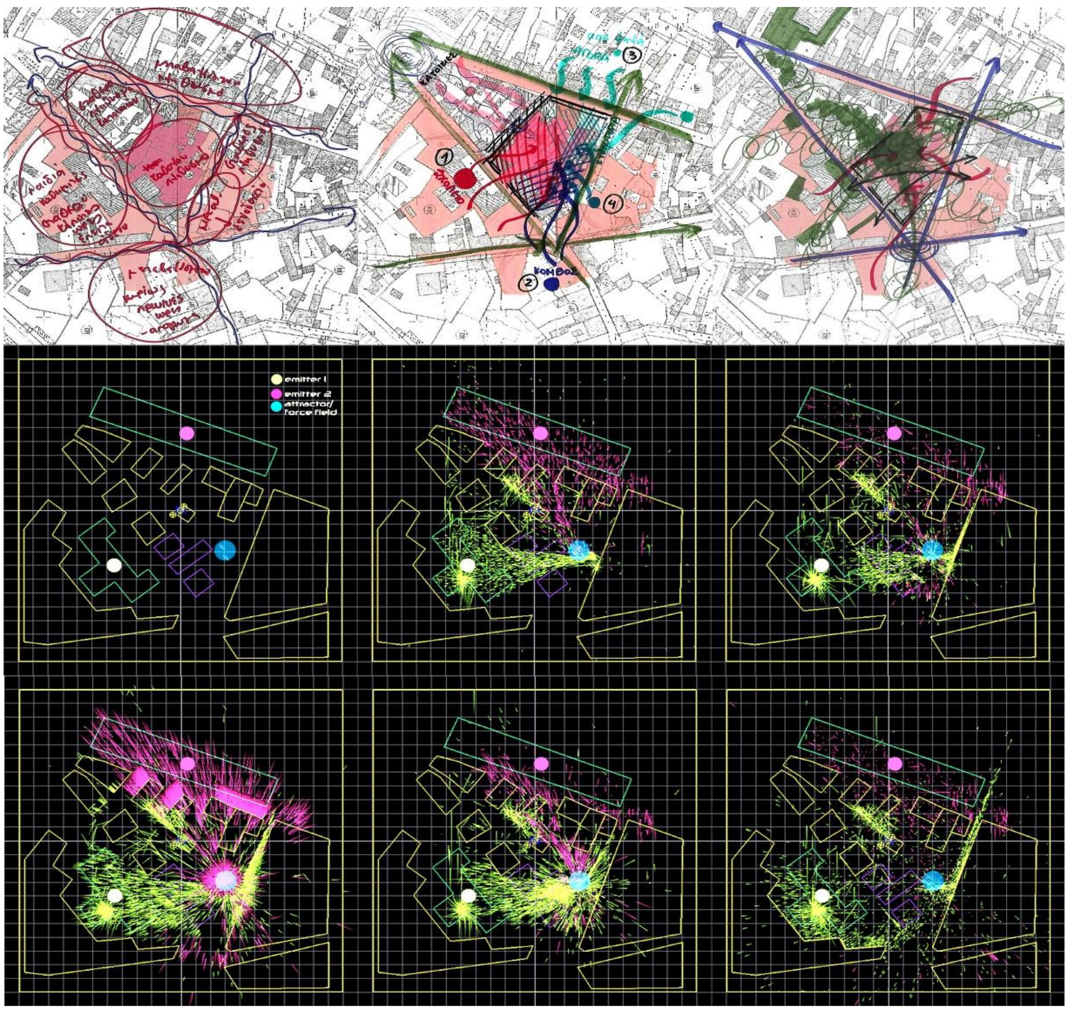

Figure 6: Helen Koukouli, Maria Tsitou, with Yannis Zavoleas. Dynamic mapping experiments applying emitters, attractors and forcefield techniques. These elements signify influences among different energy phenomena and sources related to urban activities, facilities, interactions, and population movement. In this case, these are linked to Education

(yellow), Market and Bank (blue), and Housing (purple). The progression of images shows spatial different instances of engagement in the morning, the afternoon, and the early evening). ‘Almost Architecture’ design studio, University of Ioannina, Greece, 2021–2022.

The various energies of the space system may concentrate and/or diffuse smoothly into one another. Equilibrium and harmony are bottom-up qualities emerging out of constant reconfiguring as opposed to fixity and top-down order. Micro- and macro- climatic data mapping along with natural and human related factors become agents in the development of spatial scenarios affecting values for distribution, density, and change. The output is not the result of an imposed idea or source, but of the system’s ability to adjust to external influences and internal needs, in analogy to natural systems. As the next chapter suggests, nature’s input/output adaptation processes may further be scrutinized for architectural aims, starting with the analysis of contextual data, then informing assessments, iterations and testing towards design ideas and solution schemes.

4. Deep into Nature’s Logistics

4.1. Revised Strategies for Holistic Management: Nature’s Pattern Forming

As with natural systems, information about physical space can be remarkably diverse. Ideally, various data about spatial phenomena, registered with different degrees of fuzziness and/or precision, may equally be relevant. Along with human-related information, the descriptions may also involve the total assets of the bio/geosphere such as the distribution of flora, fauna, insects, microorganisms, and marine life, along with climatic values, environmental characteristics, and terranean and subterranean features, forces, and streams. These inputs consist of the environment’s active agents, since they incite new functions, reactions, and behaviours, often causing the birth of new systems (Zavoleas, 2013, p. 273). An extended network of multiple nodes about human and ecological activity whose impacts overlap and diffuse as gradients into one another produces what may be described as the general system.

Integrating multiple units into the spatial system promotes cooperativity, contribution, and mutual significance. In a balanced system, the activities and exchanges of all biotic and abiotic instances should generally be based on equitability and without harmful competition, conflict, or terminal damage for any of the parts. A unit's integration with the greater system is the result of its properties and functioning being inseparable from its internal organisation logic. Consequently, each unit performs the necessary changes within its subunits to support communication and the making of synapses with those units set outside. These internal activities cause constant matter and energy reconfigurations and redistributions according to a unit's vital needs and in response to other stimuli. Such phenomena are common to the whole biological spectrum, but notably they are fundamental to the inanimate world too, witnessed for example in experiments with gasses, liquids, solids, and other matter/energy instances. Generally, every instance is an aggregate compound of interlinked units and subunits making one hyper system structure (see **Figure *7***).

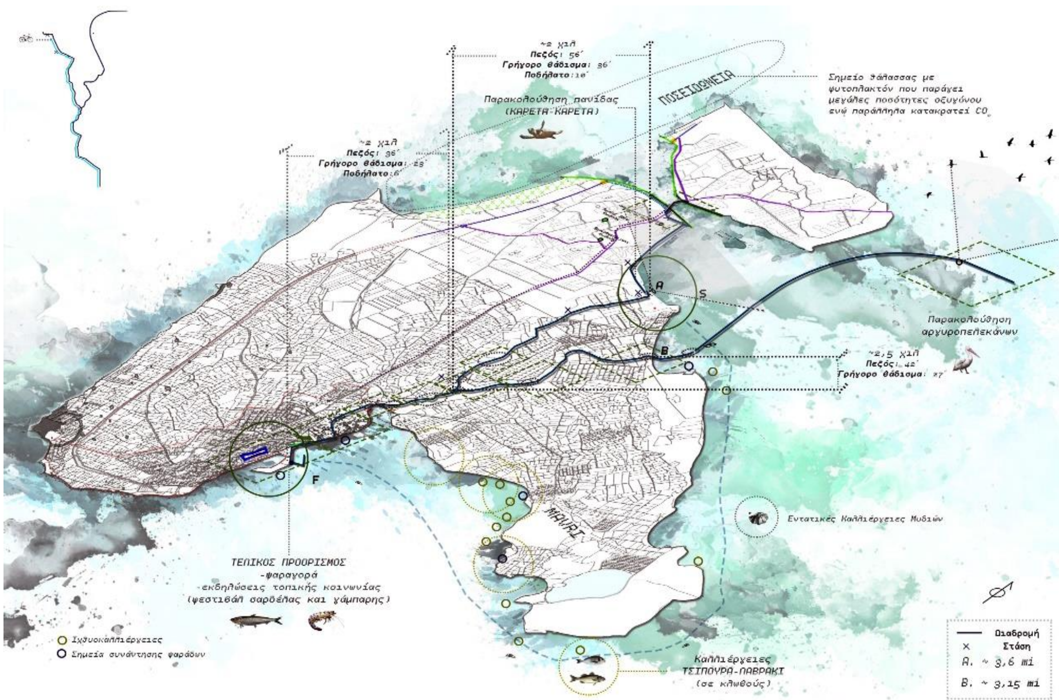

Figure 7: Katerina Kyriazopoulou, Aspa Papachristou, Helen Papaspyrou. Ambracian Gulf, Greece. Spatial mapping of ecosystemic influences of the greater wetland region across different species and humans with regards to sheltering, breeding, recreation, and economy. Registration includes a loggerhead sea turtle (Caretta caretta) nesting site, mussel, shrimp and various fish farming locations, a marine algae (phytoplankton) site, a Dalmatian pelican conservation shelter, a bottlenose dolphin spot, and other natural reserves, integrated with an extended network for mild human activities such as walking, jogging, cycling, bird monitoring, and mingling variously with nature. University of Ioannina, Greece, 2021.

The above organisation is suggestive of processes of formation in nature across all sizes. In respect, Gilles Deleuze and Felix Guattari have explained natural units by their formative properties as ‘abstract machine’ outputs, or consolidated matter-and-function assemblies (Deleuze & Guattari, 1987, p. 141), whose substance and form correlate horizontally and vertically, inwards and outwards, above and below, and in cross-stratified manners also with other units. This synergy expresses natural dynamics as a system of interactions performed through associations across units producing crowd phenomena and various populations. The code and set of rules of this global linking may refer to nature’s ‘logistics’, that is a protocol that is responsible for a unit’s articulation, presence, and performance in relation to its surroundings encrypted within its composition, for example the DNA code of biological organisms (Deleuze & Guattari, 1987, pp. 30, 41, 511). Information about nano- micro- meso- and macro- values describes the structures, the properties, and the behaviours by which a unit partakes into all natural processes (Biloria, 2008). Changes of this code may result in reconfigurations of the internal organisation and the output morphology. Variety is indicative of code differences and a unit’s proclivity to adaptation, which explains continuity by evolutionary logic (Thompson, 1917).

Nature’s characteristics evince the complexity of ongoing and emerging phenomena, being the result of back-and-forth exchanges and adjustments. A natural phenomenon may refer to the actualisation of communication between different abstract machine instances, as in Deleuze and Guattari’s terms. Natural phenomena involve interactions among these instances set through spacetime constraints. A unit’s adjustment denotes its ability to postpone disintegration by maintaining consistency and composure for certain duration. Adjustments are manifested internally through pattern transforming due to multiple pressures and for the period that an organisation can hold itself into some sort of stability, as before and after that, it was, as it will also be, something else. Additionally, the shape properties of natural patterns correspond to an organism’s ability to manage external forces (Ball, 2016). As such, natural patterns are never fixed or rigid, but they constantly evolve and adapt in relation to the pressures they endure. They often start from being small and simple and they may grow and get increasingly complex until they reach a critical moment when extreme transformation or breaking occurs. During their lifepath, they present remarkable qualities related for example to sustainability, perseverance, expandability, and resilience, being indicative of a unit’s properties and overall behaviour. The dynamic characteristics of patterns being registered onto physical form are abundant in any biotic or abiotic instance. They are identified as topological variations of natural compounds such as the formations of smoke, spiderwebs, liquid mixes, tree branches, leaf veins and artery bifurcations, skin and earth surface cracking, rock and bone porosity, tree barks, skeletons of organisms, and coral aggregates, as that list may infinitely expand. Natural pattern forming is a result of dynamic flux unfolding among various units in a spacetime continuum. As such, it consists of a polyvalent source of knowledge about efficient management, dynamic adjustment, robust performance, and smooth distribution of all natural occurrences.

Given its widespread applicability, natural pattern forming may inform the architectural design process, even cause it to update its scope. A deeper analysis of the related processes shows typological and procedural analogies at a fundamental level between phenomena that at first glance seem to have nothing in common. In consequence, striking similarities of patterns and forms may be observed across living and non-living instances, whose topological features and field conditions often follow the same mathematical definitions (Thompson, 1917; Ball, 2016). Additionally, dynamic simulations and other technically advanced approximations of natural phenomena have prompted towards new concepts about the birth and the evolution of nature-borne patterns. These analogies provide consistent ways of dealing with any sort of interaction, negotiation, and collision with a default sense of acknowledgement and reciprocity in search of new balance points. The results are offered as systemic templates producing architectural meaning.

4.2. Extended Models Supporting Urban/Ecosystem Synergies

The study of physical space with reference to natural systems is facilitated by the use of computational models. In a computational working environment, materials and patterns can be combined with code instructions about function and performance to study a system's behaviour (Rahim, 2009; Glanville, 2012; Zavoleas, 2015). Space is approached likewise as a system of great complexity, an emergent phenomenon embedded within the environmental flows of the greater ecology, promoting reciprocity at a variety of temporal and organisational scales (Weinstock, 2013, p. 17). Following the analogy, dynamic models may serve as drivers to urban and landscape design, where socio-cultural strategies are implemented alongside territorial system management (Zavoleas, 2016). Stratified flows and energy exchanges set a broad spectrum of crosslinked activities for material and structural transforming being suggestive of design processing mechanisms. Metropolitan regions, districts, even buildings invoke biological systems with respect to how they manage their assets through feedback loop cascades.

Experimenting with computational models has shown new possibilities to study integrated space system structures through expanded platforms. Besserud et al. (Besserud et al., 2013, pp. 88-90) begin with a broader understanding of how human systems impact energy, information, and matter within regional ecosystems. The focus shifts on movement and traffic, studied along with energy and data flows and engineered by infrastructure systems. Water, electricity, waste, heat daylight, solar radiation and, of course, people are constantly being processed as systemic responses to maintain efficiency.

In another approach, Castro, Ramirez and Rico (2013) examine the potential for ground and water synergy to set compound ecological infrastructures. Infrastructure becomes a giant machinic system that engages the regional with the urban, the architectural and the local altogether. The urban ecology encompasses nature, ground, buildings, and supports in one total whose joint features guide the program and the making of new typologies. As a result, public activities are placed in proximity to wet areas as a dynamic network of canals, streets, nodes, and experiences moderating temperature, sound, nature, and culture, and knitting the site with its outer milieu.

In another case, Greenberg and Jeronimidis (2013) propose a spatial model for sustainable urban morphology based on processes of microclimate moderation and equilibrium in the rainforest. The sectional height and density differentiation of trees presents a pertinent example to manage densities, heights, energy flows, and gaps by which to distribute network supplies, green spaces, gardens, and other productive surfaces and to accommodate facilities and programs. These models emphasize heterogeneity of the urban fabric, and they also call for cities that are efficient in energy resources, meanwhile providing liveable spaces for social and cultural interaction. Topography, and the landscape are thought inseparably from urban intervention strategies, the architectural scale, and small-size modifications. Multilevel associations incite new spatial and tectonic configurations. Concepts about a unit occur through urban/land scape conjoined analytical models that include information of other disciplines such as sociology, economics, and material science. Urban and landscape design merge with ecological with socio-cultural system thinking to leverage knowledge and to reinforce cross-disciplinary connections (see **Figure *8***).

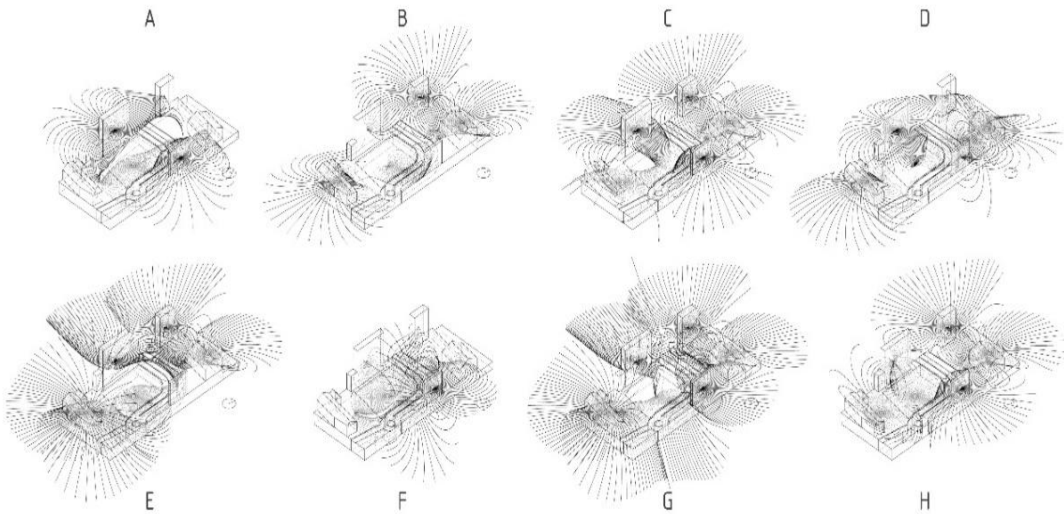

Figure 8: Derrick Chu, Tom Dufficy, Samuel Pateman, with Yannis Zavoleas. Separated elements and hard edges (façade/ground/waterfront) turning into a gradated scape due to contextual factors. 'Re-morphing the Amorphous' design studio, The University of Newcastle, Australia, 2017.

Synergy is carried out by codified assemblies generating different outputs. Variations expand upon the model's functioning as a semi-automated process that creates rough schemes. These intermediate results respond back to systemic interactions: simple formations grow into compounds as points turn into cloud aggregates at varying densities, lines shift, bend, expand and unfold, and basic geometric references such as grids, triangles and n-corner shapes produce swarm-like, rhizomatic, dendritic and other fractal assemblies (Zavoleas & Taylor, 2021). Meanwhile, the system is enriched with data from the greater topography, water and energy distribution, climate, and socio-cultural values. It is therefore critical that the early schemes are not treated as rigid references, but as malleable entries. Geometry and mathematics are system features too, set by means of efficiency, resilience, and endurance. Either of natural or artificial intent, design is a multifaceted act that joins all inputs, seeking a new state of equilibrium with the greater structures (see **Figure *9***).

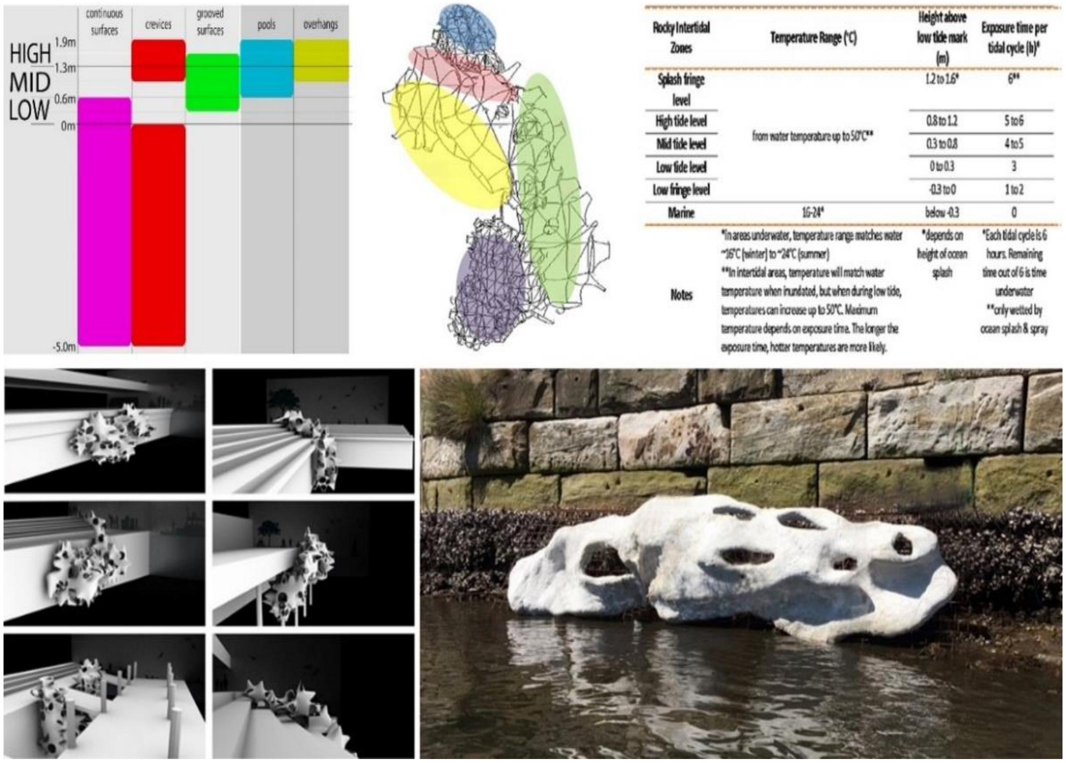

Figure 9: Bio-Shelters. Cross-disciplinary inputs are set to design reef habitats to improve the water quality along heavily urbanised coastlines. Parameters about organisms and site conditions are included into a script to create variable results. One of the design outputs has been prototyped and placed at Sydney Harbour for further assessment. Yannis Zavoleas, M. Hank Haeusler, Kate Dunn, Melanie Bishop, Katherine Dafforn, Nina Schaefer, Francisco Sedano, K. Daniel Yu. University of New South Wales, Macquarie University and University of Seville, 2018-2022.

Computation allows for more automation in managing the system's operations. Animation and simulation techniques interfering with soft shapes, material behaviours, changing properties, and particle aggregates, create a rich platform to incorporate natural processes into urban system study. The design's course is informed by eco/bio/geological and cultural data, also geographic information system (GIS) mapping and analysis, through tracing, topological visualisations, and rough connections since the early stages of analysis (Zavoleas, 2020). Due to the dematerialised character of the computational model, modifications, readjustments, and data tweaks cause transformations in a direct manner. The knowledge gained by employing nature's overarching principles is transferred in the relationships, the resistances, the densifications, and the mutations explored in the design process. In that sense, a computational approach may employ evolutionary also context-framed procedures to create works that are more in consonance with nature's performances. The alliance formed between nature as a source of references and computing as a means to expand them sets a paradigm shift, in which advanced technologies and interdisciplinary models assist to produce, test, and verify design by the habitability, compatibility and integration with the general structures (Davidová & Zavoleas, 2020). Additionally, information of the natural setting may be employed alongside human constraints as variables of the same system code (Zavoleas et al., 2020, p. 522). The datasets may be just as elaborate as the versatile inputs of an architectural project. The model may include behavioural and operational criteria together with dynamic features and scientific measurements. These can be about the environment, ground, climate, materials, also typological, bio/geological, and terrestrial considerations. At any stage, the process and its results are harmonized with those of the ecosystem.

5. Conclusions

So far, this paper has constructed an intellectual foundation for architecture in support of non-dystopian scenarios for the Post-Anthropocene Epoch. This aim has further been guided by a quest to implement nature as a model of thought in architecture. Additionally, the integration of computation into all stages of the production workflow has propelled an interest to link design with nature's operative principles. At the same time, architecture's purpose has been rethought, following the observation that a future for humanity should be sought alongside all other forms of bio/geospheric activity. Although entirely novel ideas in architecture are often necessary to respond to unforeseen challenges relating to the environment, climate, society, politics, and culture, such an undertaking will have a long-lasting effect if it aligns with the discipline's intellectual and practical structures.

For this purpose, the paper drew upon previous cases of the architectural avant-garde developed since early modernism as a basis for current discourse, directions and set of goals. Early and late modernism's pioneering works have incited alternative themes, terminologies, action modes and crossings between architecture and other fields of knowledge. Many of the concepts being introduced especially with regards to patterns and systems directed to structural efficiency and spatial organisation favour cohesion through organic development and dynamic adaptation of any of the parts into greater compounds, much in analogy to nature as a main subject. This systemic approach sets the foundation upon which to develop comprehensive solutions about physical space. Even more so, it promotes nature as a polyvalent reference to architectural thinking applicable across all scales and size ranges.

With the employment of computing, modern architecture's focus on nature as a reference has been provided with a new potential. As architecture has met with computing, it has been possible to integrate nature's systemic features and the codified description of biological phenomena into generative processes of form-finding controlled by algorithmic procedures. Computational processes related to simulation, mapping, and scripting have been employed to analyse dynamic phenomena of the urban and landscape environment, driving decisions with regards to spatial organisation and common infrastructures. New associations between human and natural systems can be explored (and possibly even discovered) through data-driven approaches, forcefield patterns, soft topologies, and dynamic simulation models where architectural design's scope is guided by a quest for full harmonization with nature's operations. To that end, computation is turning to a highly influential support, first as a platform that invites dynamic data entering in the system, then as a toolset that promotes extended flexibility through iterative testing, and self-learning, also with a varying degree of fuzziness and/or precision until the final stages and guided by a holistic view granted through extended coordination, critical thinking, participation, and control. As it turns out, modernism's legacy is current again with a revived interest on nature as a model to design, this time prompted by computing.

The nature/computing coalition has caused re-examination of architecture's priorities by studying the metabolic and other nature-compatible features of a design outcome. In respect, Deleuze and Guattari's 'abstract machine' philosophical concept has infused new significance to nature's operations directed to system thinking. Datasets, properties, codes, and calculations may assist to explain bio/geosystemic functioning, also the efficient management, and coordination of different matter/energy resources. The sum of these operative activities speaks about nature's logistics, a concept manifested through its space/time strategies and applied upon its instances. Nature's 'technologies' are promoted to ever-ending processes of intelligence and rigour performed and refined through iterations, recursive trial-and-error testing, and feedback, and by which its 'designs' adapt, mutate, respond, and evolve by being integrated into different contexts (Davidová & Zavoleas, 2020, p. 204).

In analogy to the 'abstract machine' concept, spatial operations can be described as codified semi-controlled semi-automated system routines producing dynamic phenomena. In a typical course, a natural system produces new matter/structure organisations through typologies, patterns, species, and forms with varying nano-micro-meso-macro features set by DNA code instructions. Meanwhile, recursive testing and feedback serve to advance knowledge causing code updates, also new types, variations, alliances, and species. Any of the results is set within the spectrum of interactions, exchanges, synergies, and hierarchies with the ecosystem, and belongs to an ever-evolving hyper organism. Similarly, the computational models allowed integration of information of the greater socio-cultural, economic and production structures and any other human activity as dynamic inputs into one system. Computing and technology are sought by a unifying perspective as framework agencies studying the architectural project alongside ecosystem performance. In effect, nature-loaded study models have variously engaged design thinking with ecosystemic knowledge resulting in politically updated agendas about architecture and the greater spatial management.

The prospect set above may outline architecture’s new role in the Post-Anthropocene Epoch, being to promote extended sustainability values by considering the long-term impact of its works upon society and the environment, with the hope to alleviate any of the stresses due to human activity. It should involve the ecosystem’s cycles, including the lifecycle of all biological organisms such as animals, plants, insects, and microbes, also water quality and reserves, ground and subterranean conditions, and terrestrial characteristics. Accordingly, the main priority of architecture concerning its works as part of greater system structures is to minimise its environmental footprint, to not interfere with life-sustaining natural phenomena, and to maximise compatibility with the ecosystem’s principles and operations. Meanwhile, it would be false to assume that the rhetoric being proposed about a fully sustainable architecture could ever be applied from a stance that transcends the greater anthropocentric framing it belongs to. Nonetheless, architecture’s updated goals can be set and pursued by a style of work that considers all forms of life on an equal basis. A nature-led work ethics supported by computation may outline a new culture for architecture in the Post-Anthropocene Epoch to respond to the challenges lying ahead.

6. Acknowledgments

The research was partly supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany´s Excellence Strategy –EXC 2120/1 –390831618.

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