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Computationally-Enhanced Ecologies, Organisms, and Parasites. Speculative Explorations of Symbiotic Oscillations

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ABSTRACT¹

This paper presents theoretical and practical research related to computationally-enhanced environments, analysing speculative explorations of media technologies that extend our understanding on alternative modes of architectural realities. An analysis is made concerning this transformation of interior spaces that realise immaterial dimensions and hidden layers of information, demonstrating strategies for computationally-enhanced ecologies that become an essential organism of the functions and aesthetics of space. The case studies presented in this work attempt to focus on how technological development and cutting-edge media practices are utilized to create objects and systems within the physical space for augmenting and amplifying creative processes, and exploring not only new and novel applications, but rather redefine behavior, thought-process, context, and symbiosis.

CCS CONCEPTS

• **Human-centered computing** → Interaction design; Collaborative and social computing; Human computer interaction (HCI) • **Applied computing** → Architecture (buildings); Arts and humanities • **Computing methodologies** → Artificial intelligence → Distributed artificial intelligence

KEYWORDS

Architecture; Computational Media; Artificial Ecologies; Interactive Design; Speculation

1 INTRODUCTION

The architectural practice is being reshaped by the emergence of computational media and contemporary developments in sensor interfaces, communications, and engineering, which allow hard structures to facilitate new purposes that alter our perception on the spaces we occupy. Screens, electronic objects, mobile devices, and digital systems have been accepted by our contemporary lifestyles as elements of the built environment, which is now highly multifunctional and multilayered.

Examining this transitional phase in our post-digital societies, trends and patterns begin to flourish and reproduce, demonstrating that the creative exploration is not limited to traditional tools and resources, but spans across electronics, digital media, artificial and evolutionary systems, virtual cyberspaces, as well as organisms, bodies, and cells. The new ecologies that are formed radically expand on multiple dimensions, generating uncharted cartographies that invite experimentation on the grey areas of the development spectrum.

This work facilitates a speculative approach (both on its theory and practice) that attempts to assist our understanding on specific contexts where contemporary technologies affect and (re)define the relationships between architecture, interior space, inhabitant, and computational media. It is necessary to investigate the possibilities that exist in the development of spaces that propose new ecologies that incorporate ethereal and immaterial structures, data-driven environments, algorithmic machines, organic systems, and artificial life, with an overall aim to bring an alternative viewpoint to the discussion concerning the evolution of media architectures.

In this paper three case studies are presented that have been developed by the author and the i-DAT research group (<http://i-dat.org>), with additional collaborators from Greece, UK, Denmark, and China. The case studies are site-specific installations that explore computational media, informatics, and interaction design practices, and speculate on the notion of computationally-enhanced ecologies. In short: *Plinthos Pavilion* is a hybrid space

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where ubiquitous media are composed and actuated by human behaviour; *This is Where We Are* consists of interactive and responsive augmented objects that function with the use of data-driven algorithms in order to co-author generative audiovisual landscapes; *Beyond Digital Towards Biological* is an artificial ecology, which consists of synthetic chemicals, organic/soft-robots, communication networks, and machine learning agents, with an aim to create an autonomous state of hybrid evolution.

This collective, attempts to present a process for speculating on the utilization of experimental practices and technologies within the architectural space. Through these practices it is demonstrated that the computationally-enhanced environment is a dynamic, augmented, actuated, and ever-changing process, with calibrating agents that are able to reveal a multi-dimensional landscape that extends from a cell, to the cloud, and ultimately to the city as well.

2 THE CONSCIOUS ECOLOGY

Data-driven algorithms, computational media, machine intelligence, and deep learning are terms that are already part of our daily lexicon. These properties have managed to radically affect and define the way we experience our physical and digital environments, and their firm establishment is directly reflected on the speed and wide extend of developments that we witness taking place. These computational apparatuses not only affect our public and personal ecosystems, but also create multidimensional possibilities in sensing, collecting, and identifying information from a range of domains. Patterns extracted from unseen choreographies of our surrounding environments provide rich information for constructing knowledge and accumulating further understanding.

Our biological senses, although remarkably complex and diverse, are limited to a certain extent, which makes it impossible for us to be able to detect micro and macro substances – from molecules, cells, frequencies, to the range of the city or the cosmos. However, this hidden spectrum of information is an important and vital aspect for our lives, as these properties directly affect and define the environments we occupy and, in addition, our bodies, and the conscious understanding of reality and existence. Anthony Dunne in 1999 coined the term “Hertzian Space” [1], referring to the invisible properties that surround us, and how technology assists in altering the way we perceive and experience objects and environments. The experimentations that Dunne suggests, help us reflect on the poetic exploration of the immaterial space through speculative design of objects and hybrid systems:

Electronic objects are disembodied machines with extended invisible skins everywhere. They couple and decouple with our bodies without us knowing. Working on microscopic scales, often pathogenic, many electromagnetic fields interfere with the

cellular structure of the body. Paranoia accompanies dealings with such hertzian machines. How do they touch us? Do they merely reflect off our skin, or the surface of our internal organs? In other words, do they merely ‘see’ us, or can they ‘read’ us too, extracting personal information about our identity, status, and health? [1]

Dunne is curious to explore how the electronic object affects the material world, the human body, and our imagination. The affected properties, although many times undetectable by the human senses, may cause great interference, disturbance, or discomfort to the human subject. Following Dunne’s view, we find several artists, designers, and technologists experimenting with this “invisible” space, such as Ingeborg Marie Dehs Thomas’ “Bubbles of Radio” [2], Christopher Warnow and the design studio Onformative with the “Immaterials” [3], and Richard Vijgen’s “Architecture of Radio” [4].

By examining the microscopic scale of our environments, we find an abundance of substances, ranging from cells, bacteria, molecules, and atoms, which have a substantial impact on organic and inorganic entities – architectural structures, physical material, biological bodies, digital information.

As an example, air, which is one of the most fundamental properties of this planet and a primary condition for life, it can radically affect material and organic properties. The air in the troposphere consists of numerous chemicals, such as nitrogen, oxygen, argon, neon, methane, carbon dioxide, helium, krypton, hydrogen, xenon, ozone, nitrogen dioxide, iodine, carbon monoxide, and ammonia [5], and it very often contains chemicals, particulate or biological molecules that are harmful and lethal to many organisms, such as sulfur oxides, nitrogen oxides, carbon monoxide, particulates, lead, mercury, ammonia, radioactive pollutants, a large number of hazardous air pollutants, and persistent organic pollutants, among others [6].

Sensor technologies and related devices are constantly being invented and introduced to public, industrial or more niche markets, providing solutions for monitoring and identifying these unseen properties. A relevant example that is found in the literature is Stavros Didakis’ “DataGrid” [7], an experimental monitoring device that is able to extend the sensorial dimensions of the space by measuring invisible matter and identifying a range of properties (chemicals, particles, frequencies), which are then being stored securely on a database for further analysis according to the needs of a particular context [7]. The designed system offers a middleware to the user/inhabitant for distributing the analysed/processed information to remote devices with access to the cloud, and promote further possibilities for awareness that can be embodied or diffused into the built environment.

Extended awareness from additional scales and dimensions is necessary; e.g. macro scale for example, as planetary, climate, geomorphological, and weather conditions constantly affect ourselves and the surrounding space. Momentary affective states (those produced by the weather) influence judgments about happiness and satisfaction [8, 9, 10], the moon's gravity causes tides that affect human behaviour [11], and Ultraviolet Index (UV) produces or initiates carcinogenesis in the human skin [12]. Furthermore, social [13], hegemonic [14], and cultural factors [15] also play an on-going role on how we respond to an environment, and, in addition, social media can be used to indicate specific events that are regarded as temporally authentic microscopic instantiations of public mood states [16]. The monitoring of social trends can reveal aspects that greatly influence the habitat [17], and political and economic events, fluctuations in the stock market, crude oil price indices and major happenings in media and popular culture reflect significant, immediate and highly specific effects on various dimensions of people's mood [18].

The conscious ecology needs to be able to collect, analyse, and accurately perceive all the diverse properties that exist within it, developing a perceptual image of its own enhanced reality. It is necessary for us to consider this eco-system as a multi-dimensional map in which its elements are autonomously linked according to time and context. Computational systems can provide a set of resources in identifying, logging, and processing these properties, and by utilizing a range of media, sensor interfaces, and computing intelligence resources, the ecological consciousness can be abstracted and perceived.

3 MAPPING OF THINGS

The map is open and connectable in all of its dimensions; it is detachable, reversible, susceptible to constant modification. It can be torn, reversed, adapted to any kind of mounting, reworked by an individual, group, or social formation. It can be drawn on a wall, conceived of as a work of art, constructed as a political action or as a meditation. [19]

Gilles Deleuze and Felix Guattari in their book "A Thousand Plateaus" explain the concept of the *rhizome*, an image of a thought process that consists of assemblages of dissimilar properties such as "words, things, power, and geography" [19]. The assemblages can organize themselves in non-hierarchical lateral networks, and they are capable in developing their own experimental intelligence by creating new and heterogeneous connections between them. The rhizome is never static but always changes form, characteristics, and properties, according to new assembled connections – becoming infinitely multi-dimensional.

Benjamin H. Bratton, inspired by the studies of Deleuze & Guattari, attempted to illustrate the geopolitical

architectures of complex computational structures, considering the combination of their properties as a "metaplatform of an alternative counterindustrialization" [20]. His proposed model, the *Stack*, consists of six elements (User, Interface, Address, City, Cloud, Earth) where each of them contains its own computational dimensions, however, all elements are interconnected – having the network act as an "armature of the social itself" [20] – and allowing us to conceive an informational megastructure as the ultimate cybernetic system.

A similar approach is also to be found in the studies of Stavros Didakis, who proposes the *DomoNovus* (The New Home), a speculative framework for the future of the domestic space [7]. In this scenario, the home becomes an interconnected interface of diverse and dissimilar properties that link micro, meso, and macro scales. Here, the concept of "home" is redefined, as the fundamental properties of the environment are the data collection and analysis agents, the API protocols that allow fluent communication between physical and virtual properties, as well as the machine algorithms that provide automation awareness. The main function of DomoNovus is to enable a distributed authorship that is mutually defined by the domestic space, its inhabitants, the computational machine, and the wider ecology of the city.

By utilizing these approaches as theoretical guidelines in relation to how properties, substances, agents, and systems are mapped, merged, and used, the following examples attempt to interpret in a practical form aspects of this multi-dimensional manifestation, and explore through physical and digital interactions embryonic rhizomes on multiple spaces and scenarios.

4 CASE STUDIES

The case studies that follow here include rich and diverse development practices that are associated through a critical conceptual link related to the computationally-enhanced spaces that are formed through various media and technologies. The interiors never remain static, but rather continuously reform according to a range of variables that force their behaviour to shift, demonstrating possibilities that exist in the development and understanding related to the relationship between humans, their environment, the associated media devices, and the translocated databases and computational infrastructures that utilize algorithmic processes and machine learning techniques to assist (or define) hybrid-living contexts.

4.1 Plinthos Pavilion

Plinthos Pavilion is a collaborative project developed by the author and the architectural office mabarchitects (www.mabarchitects.com), and was a commissioned artwork for the Interior Design Show '09 (Metamorphosis, Athens), also exhibited in the 7th Biennale of Young Architects 2013 (Benaki Museum, Athens). The installation space utilizes a range of input, processing, and output

technologies to trigger visitors’ stimuli, awareness, and engagement.



Figure 1. Plinthos Pavilion (2010, Copyright of mabarchitects & the author)

The project is inspired and informed by the lighting immersions of James Turrell and Olafur Eliasson, the architectural media objects of NOX, as well as the psychotropic environments of J.G. Ballard [21]. In the permanent installation Son-O-House for example [22], the architectural metallic structure is transformed into a never-ending sonic landscape with the interactions of the visitors, allowing them to “not just hear sound in a musical structure, but also [to utilize the architecture and its functions] as an instrument, score and studio at the same time” [23]. The information that is tracked from the physical world is statistically analyzed, and rules and conditions define the way sound is generated, distributed, and experienced.

In a similar sense, Plinthos Pavilion consists of an architectural structure with an embedded sensorial skin, which invites visitors to navigate within thousands of perforations and multiple media layers that blend to create a performative and responsive space, triggering stimuli through masterfully articulated poetic mediations. Each layer is responsible for an aesthetic and compositional part that responds according to context and location; however, elements inter-communicate with each other when necessary to exhibit an orchestrated intelligence as one of the structure’s fundamental extensions.

Plinthos (also known as clay brick) is a standard construction element that provides strength, durability, resistance, absorption, and isolation. In this installation, more than 20,000 hollow bricks were used to complete the floor plate and walls; but each plinthos reaches a paradox – an identity crisis – as transformation is achieved via misuse, stacking the bricks on end so that vertical voids are oriented horizontally. Inevitably, the porous sides are revealed, thus creating surfaces; openness is accumulated and transparency is employed, allowing the flow of air, light, and sound through them. At certain oblique angles,

the structure becomes a conventional wall; however, direct view shows a high degree of porosity.

The installation space is built within a “black box” with a single-entry point that leads to a space between outer and inner skin, which acts as a service area. The pavilion does not include an external façade, but instead offers a theatrical entrance, which reveals only a glimpse of the interior. The entry sequence is carefully choreographed as the visitor moves from the brightly lit exterior of the exhibition hall to a dimmed monochromatic all-brick interior. Based on visitor proximity to the curved wall, ventilation devices are triggered, blowing fresh air through the porous skin of the structure, allowing transparency to fully emerge. Space breathes through its permeable walls that sync with the synthesized soundscape and the expanding lighting system, transforming the structure into a living organism in which the visitor is completely immersed. Behind the walls of the vertically rotated stacks of bricks, a big roll of reflective white paper wraps the environment as a protective membrane with its main intention to reflect light emitted from a series of interconnected LED bars positioned on the bottom of the exterior wall. The light fixtures are tilted towards the white paper, to reflect a uniform lighting coating that can be viewed from the interior through the transparency that is created by the bricks’ open cells.

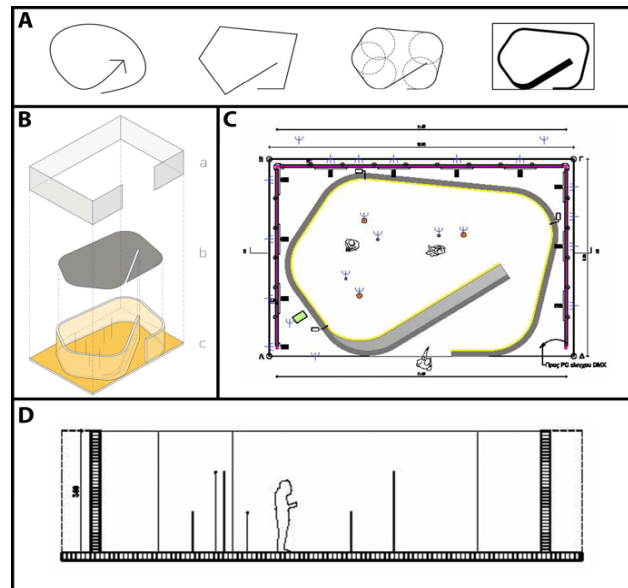


Figure 2. Plinthos Pavilion Diagrams: (A) Plan Diagram, (B) Axonometric Design: ([a] outer skin, [b] reflective black stretch ceiling membrane, [c] brick floor and wall), (C) Media & Lighting Plan, (D) Side View (Copyright of mabarchitects & the author)

Plinthos Pavilion does not remain in stasis, but rather reacts to conditions such as patterns of human behaviour that shift and affect its compositional properties. Sound, light, and air become expressional elements of the environment, synthesizing a harmonious sensation and

inviting exploration through tactile, auditory and ocular channels. A computer vision algorithm scans and analyses visitors' interactions such as motion, presence, position, circulation, energy, or formation clusters, providing multi-dimensional information about spatial occurrences that help the system identify patterns and control media layers accordingly. This process creates a dynamic organism that completely immerses visitors in never-ending patterns of lighting compositions that oscillate in response to visitors' actions. The accompanying sonic layer enhances this feeling of immersion, extending the perceptual levels using aural excitation mechanisms.

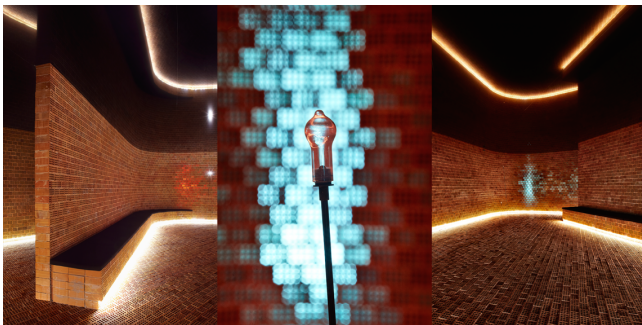


Figure 3. Plinthos Pavilion – Main space & stem lights
(2010, Copyright of mabarchitects & the author)

An extensive database of both pre-recorded and synthesized sounds is fed into the main processing system that composes in real-time the soundtrack of the space. The final result is projected using a multi-channel speaker configuration that surrounds the environment (audio equipment remains augmented within the surface). The sonified environment aims to activate perceptual images of harmony and exhilaration, communicating aural awareness, closeness, and affection. Aside for the short-

term memory of the spatial activity, Plinthos has long-term (and more specifically episodic) memories stored in its prefrontal cortex, mostly referring to recollections of its genesis – samples recorded during the space was being built. These memories remain hidden unless visitors activate them using the stem lights that appear in the middle of the structure, which closely resemble hair cells found in the human ear, acting as sensory receptors of tactile input, having direct access to digital memory space.

Specialized flex sensors are embedded within the lighting objects to allow the system to track changes using haptics and object movements. The amount of motion defines the aggressiveness of the sound pressure and the processed texture applied. The number of triggered light movements defines the selection of specific database categories that represent an equivalent level of complexity from the recorded material that was created during the construction of Plinthos – such as brick hits, smashes, scrapes, and breaks. These sonic triggers allow visitors to listen and experience these events as past snapshots of the structure's embryotic state, and to provide a space for exploration that reacts to the way visitors engage, behave, and act.

Media prosthetics are fundamental components of this *cyborgian* object, transforming its porous structure into a mystical – almost sacred and ritualistic – organism that breathes, reacts, and communicates. The goal, therefore, of this work's development is to speculate on the hybridization of architectural interiors with embedded media layers that contrast the old hard surface with ethereal and responsive qualities of media and computational technologies.

4.2 This is Where We Are (TIWWA)

The second case study presented in this paper is an interactive public installation developed by i-DAT, an Open Research Lab for playful experimentation with creative technologies that is hosted in the University of Plymouth, School of Art, Design, and Architecture². The work developed in i-DAT focuses on fostering interdisciplinary practices in art, computational media, immersive environments, and scientific research, having diverse outputs such as public installations and performances, cultural prototype making, and disruptive technological developments. A fundamental consideration in many of these works is to use (or re-use) data as manifestations that emerge through digital interactions.

² Professor Mike Phillips is the Director of Research in i-DAT. The author has been a research member in the group since 2010, and has been involved in the development of technologies associated to projects and outputs.

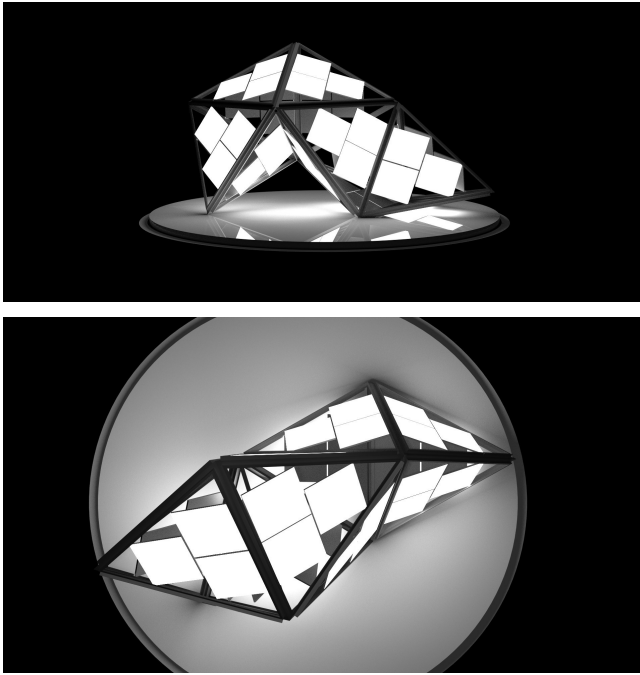


Figure 4. TIWWA – 3D designs (2016, Copyright of i-DAT & OnePolygon)

TIWWA is an interactive algorithmic media sculpture exhibited in Tate Modern Switch House on the 17-19 June, 2016, created by i-DAT with Tate Collective in partnership with the University of Plymouth, Affinity, InterCity, GaiaNova, Immersive, The Picture Works and TR2, through support from Arts Council England and Tate. The sculpture “breathes” data generated from online and offline human (and bot) behaviours, allowing the audience to engage and interact with the content that manifests through generative audiovisual swarm algorithms [24].

This project demonstrates similarities with works found in the literature such as the Bloomberg Headquarters’ installation ICE (Interactive Communicative Experience) by Klein Dytham Architecture and Toshio Iwai [25], where visitors can playfully interact with data in tangible and experiential ways. With ICE, the FTSE and NASDAQ financial data are disseminated and redesigned in an interactive media form, personalizing the space by utilizing the body as a biofeedback mechanism.

TIWWA is a dynamic data-driven artwork as ICE, but utilizes content generated through social media (sentiment analysis from Twitter data), as well as information tracked in the real space (presence and haptics) in an attempt to represent the identified interactions using realtime visualizations and sonifications. The intelligence of the system is driven by Quorum, a computational initiative in cultural computation, ludic data and playful experimentation, which focuses on analyzing audience behaviour that emerges from physical and digital interactions. The system incorporates bio-inspired algorithmic swarm decentralized decision-making

processes to generate a dynamic and evolving collective behaviour. Its computational infrastructure integrates subjective and objective data, considering its temporal and predictive aspects, variety and quality and correlations with Artificial Neural Networks, Deep Learning and Self-Organising Maps.

TIWWA utilizes a range of data inputs that are collected and distributed to its processing units, to comprehend the complexity of the surrounding space, which is not limited to a physical, but also the digital realm. Behavioural data such as individual and collective movement and touch are extracted through the use of sensors that are installed on the physical space. The process provokes audience to engage on an instant temporality according to the reactions of the media sculpture, challenging the communication patterns exchanged between humans and the computational machine. Social media data are used through the extraction of specific keywords that collect content and sentiment from present and distant audiences. Natural language processing and Artificial Intelligence is used to analyse the content that is identified as relevant to the system’s performance, allowing it to build its own subjectivity and sentiment intensity.

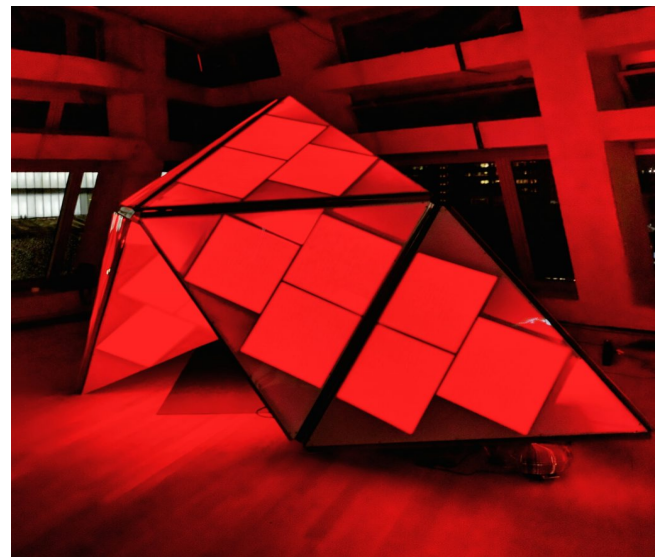
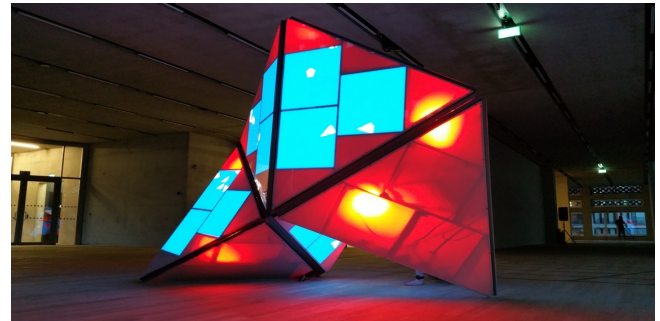


Figure 5. TIWWA installation in Tate Modern (2016, Copyright of i-DAT)

Finally, the last parameter that is used for the system input is environmental data such as CO₂, temperature, humidity, and energy consumption captured by Tate Modern's Energy Management System. This information becomes important as it represents vital aspects of the architectural space, and how the environment affects inhabitants' lives collectively.

TIWWA challenges us to realise the complexity of our surrounding and immersive spaces and the possibilities that materialize through computational intelligence, transforming our apprehension and appreciation of the hybridization that occurs. By fusing a range of parameters to the system's input and processing the content with the use of the aforementioned computational processes, a range of meta-cognitive elements begin to emerge, allowing us to perceive an extended map of agents and relationships that form between them. This experience becomes critical in the way our environments are conceived, materialized, and used, pushing us forward into theorizing and speculating on the additional dimensions and possibilities that computational media may offer into our contemporary development practices.

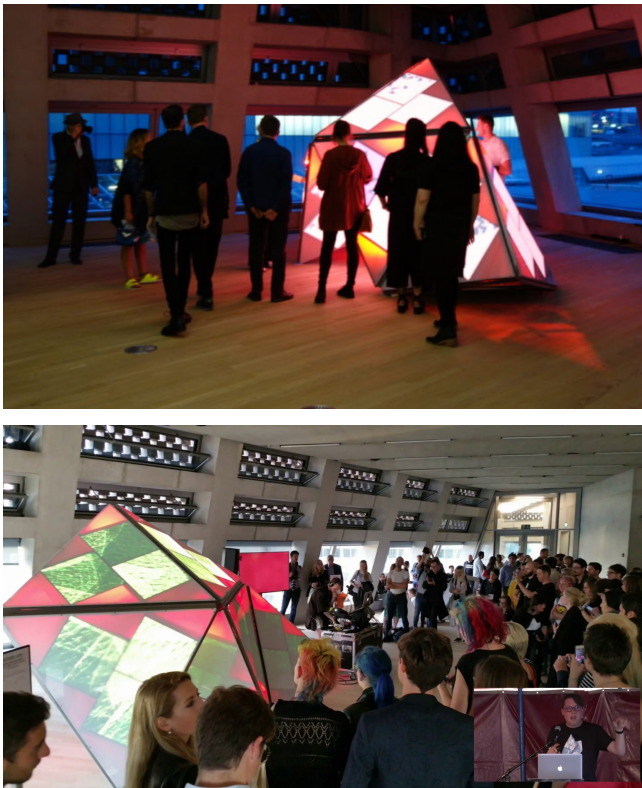


Figure 6. Audience Interacting with TIWWA (2016, Copyright of i-DAT)

4.3 Beyond Digital Towards Biological

This project was funded by the Danish Ministry of Science, Technology and Innovation and it was developed in collaboration with colleagues from the IT University of Copenhagen – Laura Beloff, Jonas Jørgensen, Stig Anton

Nielsen, and David Kadish – during an art residency in Chronus Art Center (<http://www.chronusartcenter.org>), a nonprofit art organization in Shanghai, dedicated to the presentation, research, creation, and scholarship of media art. The main aim of the work was to develop a framework for techno-organic practices, exploring emergent innovations at the intersection of digital technology and organic matter, and to speculate on the development of a computationally-enhanced ecology that attempts to autonomously evolve.

An inspiration for this work is Phillip Bessley's *Hylozoic Soil*, an environment that acts as a giant lung and digestive system, able to breathe in and out around its occupants. The installation becomes organic and almost life-like, “a visceral experience exploring the nuanced relationship between the biological and the artificial” [26]. In Bessley's installations, we witness near-living, responsive, and adaptive architectures that emerge from integrated digital fabricated structures and embedded sensor networks, which result in synthetic organic environments with immersive and performative characteristics.

In a similar sense, in this installation, the researchers enabled conditions for a wide spectrum of life-forms to assemble (artificial chemical life, to biological life, and computational life in silico) into novel configurations with unique and emergent dynamics, creating a proto-environment, a hybrid ecology, that contains living, semi-living, and non-living actors. The main aim in this work is to explore the symbiotic oscillations of the synthetic environment, and observe how biological matter and artificial processes merge into an autonomous system that informs our understanding and practice.

In more detail, a hanging small-scale robot was developed that can move freely in three dimensions, and position itself within an area of 5x5x3 meters. The robot includes two main components: a pipet that contains a variation of synthetic chemicals, and a light emitting tube; both of these components are controlled autonomously according to the conditions that exist within the ecology. Therefore, the pipet releases the synthetic chemicals only when the robot reaches the petri dish box, so that the artificial chemical life that evolves within it can be nurtured and maintained. When specific conditions are met, the hanging robot will navigate to a different location and identify the position of various organic/soft-robotic structures that were also developed as part of this project. By utilizing the light tubes, the soft-robotics begin to emerge in aeriform, solid, and liquid matter as they are able to decode the lighting patterns of the hanging robot using their embedded sensors.

To accommodate and actuate this choreography, a computational system has been implemented (embedded within the petri dish box) that tracks, analyses, and identifies changes into the generated patterns of the synthetic chemicals that exist in the petri dish. By utilizing

a wireless communication system between the computational system and the robotic agents, the varied responses identified control the behaviour of the agents independently, and therefore, the collective performance that is orchestrated in the space.

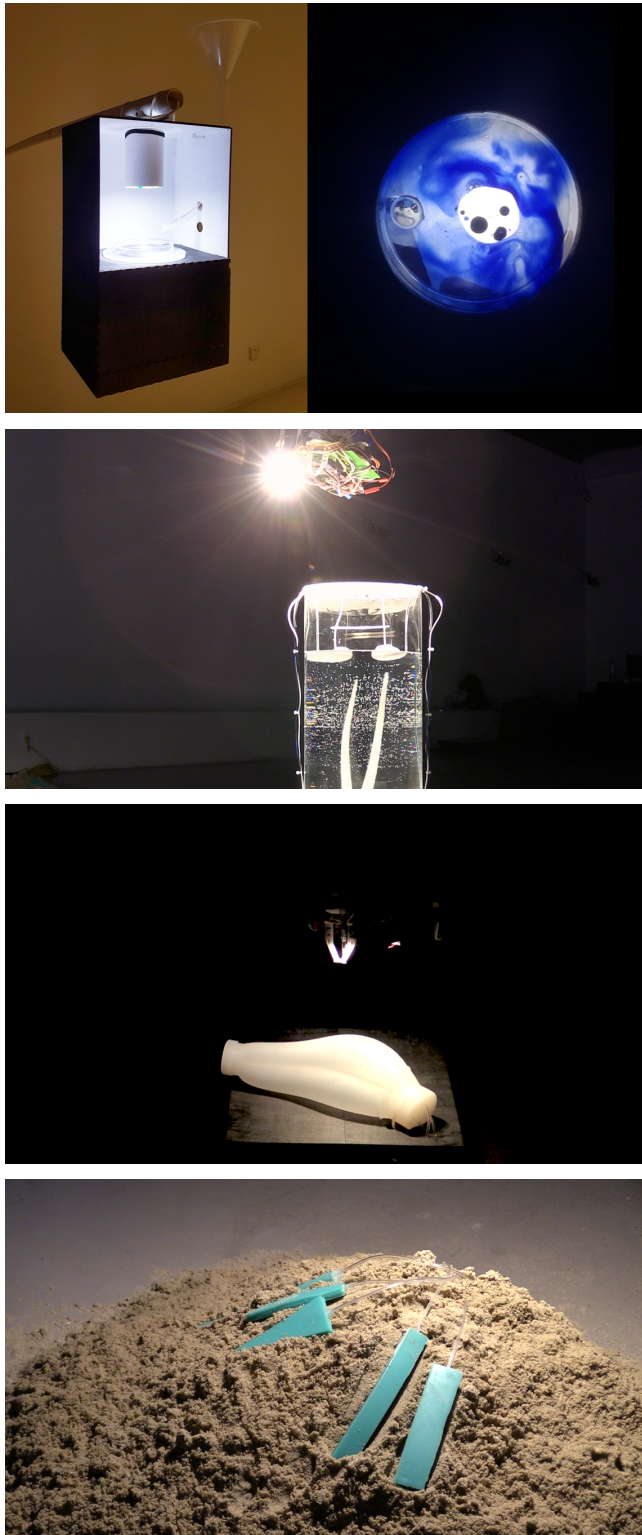


Figure 7. BDTB Installation (2017, Copyright of the author)

This research project invites us to consider the implications of a computationally-enhanced ecology that autonomously maintains its functionality (by nurturing its own parts), and in addition to demonstrate a scenario in which artificial and synthetic life can evolve into a new and unknown state, informing the practices of media design, architecture, and engineering in relation to the repercussions of non-living intelligence that manages to actuate its own self and redefine tasks and functions for the eco-system as a whole.

5 DISCUSSION

In 1973, Crawford S. Holling [27] published a paper on the resilience and stability of ecological systems, where he presented his findings on the behaviour of ecologies that is affected by external events of multiple levels of criticality. Holling was interested in observing how external forces impact the state of dynamic equilibrium, that is, how these forces cause fluctuations both in amplitude and frequency in relation to the parameters of the ecological system. According to the level of resonances, the state of equilibrium can be destabilized, and in some cases fractured or even destroyed. No matter if the changes are devastating, the fluctuations cause repercussive effects that establish new domains of attraction. Therefore, even when the ecology reaches and over-exceeds a critical limit, adaptive shifts emerge, which is a natural way for the system to survive and evolve.

The phenomena observed on the dynamic resonances that are caused by the computational technologies on the substrata of the human experience, directly relate to Holling's studies on the resilience and stability of ecological systems. The understanding of our *Umwelt* (and what constitutes constructed reality), is greatly influenced by the (cybernetic) surrounding, as within the current hybrid spaces that we occupy – physical, virtual, augmented – adaptive shifts take place, and radical changes in the routines, rhythms, and properties of our lifestyle manifest, triggered by the technological and scientific development that redefines human understanding and nature.

Our techno-organic environment is in a state of flux, as multiple agents that exist on its “pragmasphere or functional universe” [28] such as inorganic, biological, and digital, all strive to achieve dynamic equilibrium. Despite the destabilizing forces that are exerted, the ecosystem becomes resilient enough to absorb the impacts and adjust itself to the new changes, which, in consequence, result in emergencies (creative, functional, aesthetic), as the equilibrium over-exceeds its original limits.

Humberto Maturana and Francisco Varela in their studies related to autopoiesis and cognition [29] claim that a “structural coupling” is formed between “a living system's connection to its environment, and the mutual communicative connections between the two systems” [29]. If we accept this statement as true, then we can also

accept that there is a structural coupling with the cognitive and perceptual connections between ourselves and our computationally-enhanced environment, which directly define our *Umwelt* with new augmented and hybrid realities that redefine our understanding and our ecosystem as well.

As it is known, within an ecology not all organisms benefit equally from each other at all times, but rather to a varying degree [30]. Thus, the symbiosis can be commensal (a symbiont benefits from another), parasitic (a symbiont benefits on the expense of another), and mutualistic (symbionts benefit equally from each other). Mutualism promotes the term of collectiveness, exploring the environment as one organism with different parts that, nevertheless, can maintain an ecological balance. The creative exploration of the networked and media apparatuses becomes an integral part of the ecology's regulation mechanism that attempts to achieve *homeostasis*, a term coined by Norbert Wiener in 1920s to describe "the body's organic mechanism for maintaining healthy, stable states of internal equilibrium through a balance of self-regulating actions and reactions" [31].

The case studies presented in this paper demonstrate diverse computationally-enhanced ecological systems that attempt to achieve a symbiotic state through the dynamic interpolations of constantly shifted equilibria, utilizing new tools and conditions for biological, hybrid, and artificial agents that link and extend their functions and properties. Via the demonstration and analysis of these works, a necessary consideration would be to acknowledge the divergence of relationships between dissimilar properties, and realize structural couplings between them, enhancing our practice and understanding in relation to the orchestration and design of hybrid environments, with explorative "alchemic" techniques that "might free us from architectural deadlock" [32].

Plinthos Pavilion, TIWWA, and BDTB utilize a range of diverse methods and tools for the delivery of speculative artefacts that intend to engage us in further reflections towards the computationally-enhanced landscape – and what that might include. It is necessary to investigate how a dynamic equilibrium between inorganic, biological, and digital entities can be achieved (and challenged) within the technologically enhanced space, and, more importantly, to stretch and exceed critical limits through speculative developments that reveal new dimensions to the domestic, private, public, and urban experiences. The aim of speculation, therefore, is not to propose implementable and functional solutions, nor to offer answers to the questions they pose, but rather to utilize an explorative practice that instigates "contemplation and discussion" [33].

The case studies do not attempt to provide a methodological context where i.e. interactivity, media design, or the constructed space are evaluated, but rather

to present a range of environments as processes that demonstrate symbiotic speculations, ecological state traversing, and evolution of rhizomes, which are formed with the utilization of experimental approaches that investigate physical, organic, virtual, digital, and hybrid realms in a range of scales (micro, meso, macro). The computationally-enhanced environment becomes a pool of multidimensional space with interconnected entities that never remain static and predefined, but rather augmented, actuated, and ever-changing.

The calibrating agents of the constructed rhizome extend our understanding on the development possibilities for media architectures, as a range of properties, interconnections, and new concepts emerge. This challenges our ecologies to reflect on their current (or hetero-chronological) aspects, not only regarding individual quantitative and qualitative data, but also to comprehend and define the relationships between their numerous and hugely diverse agents.

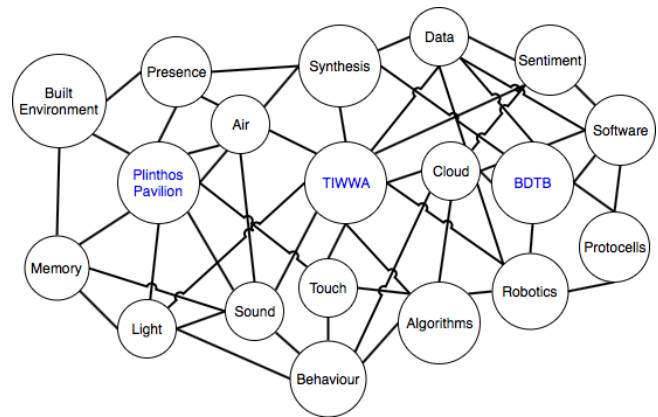


Figure 8. Map of practice (Copyright of the author)

A fundamental goal of this paper is to construct an argumentation regarding the properties that emerge in the rhizome of our surrounding eco-system that becomes a highly complex multi-dimensional space. Following the studies of Deleuze, Guattari, Bratton, and Didakis, it is evident that properties might link from molecules, to the cloud, the interface, the city, and the user. The wide array of information that is now more easily accessed, can reveal a range of creative and imaginative pathways where further experimentation on dissimilar properties and connections is needed, from tangible immaterialities and invisible architectures, to manifested digitizations and hybridized experiences.

6 CONCLUSION

This paper describes a framework that consists of a theoretical investigation on speculative design, conceptual mapping, and ecological systems, and practical developments as case studies that explore computational media, informatics, and interaction design practices, with a focus on computationally-enhanced ecologies. The work intends to demonstrate a methodological approach for the

cartography, analysis, and exploration of our diverse hybrid environments by utilizing physical, augmented, and digital systems and processes. Through these practices it is demonstrated that the computationally-enhanced environment is a dynamic, augmented, actuated, and ever-changing process, with calibrating agents that radically affect our surrounding spaces and ourselves.

In summary, the case studies presented in this paper explore development practices that have been utilized to speculate on computationally-enhanced ecologies, summarized as (a) the development of a hybrid space where ubiquitous media are actuated by visitors' behaviour, (b) data-driven algorithms that co-author the generative audiovisual landscape, and (c) an autonomous hybrid ecology that consists of synthetic chemicals, organic/soft-robots, communication networks, and machine learning agents.

The transitional phase of the fourth industrial revolution is accompanied with threads and opportunities that forces us to be critical in considering how the apparatuses provided by science and technology assists and enhances the development of conceptual multi-dimensional maps filled with assorted properties (from a range of scales – micro, meso, and macro), and develop a critical and perceptual stance on the hybridization of our validated, augmented, and virtual realities.

Interlinked dissimilar properties define the way we understand and experience our surrounding worlds – architecture, urban planning, and the city – developing symbiotic spaces that are enhanced in terms of awareness and development possibilities. The computational advances in computational intelligence assist us further in categorizing, indexing, and processing the collected information, and providing solutions to problems such as logistics, automation, environmental protection, but, more importantly, they provide the means to be creative, curious, explorative and poetic, allowing us to abstract on the collective rhizome.

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