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## In Quest of Code

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### Abstract

Architects who apply their generative modelling and scripting skills for creating virtual and prototypical spaces through the usage of algorithms and bespoke coding are increasingly confronted with an application in the real material world. The article suggests computational design strategies and two different architectural and urban prototypes for an era in which intelligent material, robotic assistants, smart geometries, changing human habitat converge with demographic, cultural and natural earth data to govern a global rethinking of socio-architectural ecologies. Since the beginning of humankind our ecosystem planet earth has served as feeding ground and shelter. Civilisation and industrialisation have triggered a verification of territory, ownership, economic wealth and power. Henceforth ethical rules, societal regulation and intuitive values were partly overridden and replaced. Long-distant transport vehicles such as cargo ships and trains allowed for accelerating the mixing up of goods and technologies. Architects solved industrial and infrastructural problems with new ideas and emerging building types; shaping urban and peripheral environments. A great idea manifested through extensive exchange of cultures and knowledge - however, strangely enough climaxed in an ultimate exploitation of our natural resources. A situation we can hardly understand or handle. As a result we are facing a situation of re-scripting our human, urban and architectural ecological system. Thus the article touches upon this very shift starting in the 18<sup>th</sup> century traversing through the implementation of the Internet, to regulate our physical world and data-autobahns filled with informing bits and bytes. The question is, which questions to ask for the best solution we can offer.

**Keywords:** code, systemic mesh, information, invisible conversation, socio-ecological, systems, robots, Anthropocene

## In Quest

Architecture in the Anthropocene is a construct that we may or may not engage with. Either way it is being served to us on a silver plate to respect, to embrace and also to take on board as the beginning of a new era in architecture. The task is to transfer *utilitas*, *venustas* and *firmitas* to an earth-friendly architecture that, at the same time can serve our immaterial digital needs, geographic mobility and modification of social and economic structures. In fact we are looking for *An invisible Architecture of Nothingness*, which relates to an architectural typology fully integration into the earth's organism.

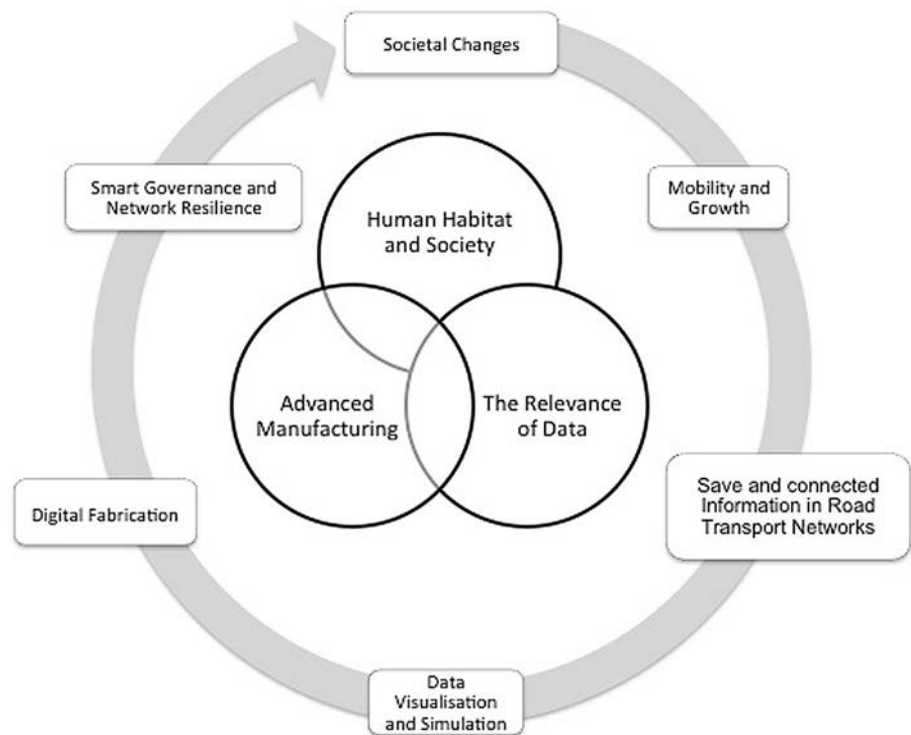
Projects presented in this article yet begin to fulfil the requirement of invisibility or nothingness by developing principles for design operations with intrinsic decision-making capabilities. Hence acting with minimal effort. The desire for such an architecture stems from three somehow disturbing phenomena. Firstly as Buckminster Fuller stated in his *Operating Manual for Spaceship Earth* 'Now there is one outstandingly important fact regarding Spaceship Earth, and that is that no book came with it.' (Fuller 1969a). Secondly the furnishing of buildings with decorative ad-ons in order to harvest energy or activate ventilation has become a popular tool for subsidising the 'sustainability' industries rather than engaging with architecture. And thirdly *the quest of code* for architecture, which this paper focuses on. How can we use code, what is it made of and which data is relevant in order to arrive at coded information that will help us to be *better* architects and to tackle the urgent and important issues. The generalization from a specific human/machine problem to any aspect of the world that can be expressed as time-series data, presents an early glimpse of strategies that would define cybernetics.

Living in the Anthropocene, means living the Anthropocene and following its rules and regulations. Building materials, the use of geometry and technology are set to become smart and intelligent through the Internet of things and other gadgets ready to improve the built and virtual environment. The desire is, however, that such an optimisation does result in trading resources that are essential for the survival of the planet and the creatures living on and in it. A usable *Operating Manual for Spaceship Earth* as Buckminster Fuller envisaged does not exist yet. Nevertheless attempts have been made. The first generation of photovoltaic in the early 1990s, used as testing bed,

has now been developed further into large sun-fields, such as the world's largest solar power facility, Ivanpah, in the Mojave Desert located south of Las Vegas. The field generates the energy for 140.000 homes and applying a cooling system that does require less water than a golf course. The downfall is the concentration of more than 340.000 shiny mirror surfaces in a sensitive natural and very hot environment. Birds who mistake the mirrors as water surfaces, enter the field's solar flux and simply burn at a temperature of up to 200°F; an undesired side effect. The crux lies in the understanding and the treating of earth as a systemic-mesh accommodating interacting subsystems.

In recent years the architectural world has been confronted with numerous ideas, plans and strategies of how to use our novel tools and instruments. The adoption of genetic and biological principles for designing using computational means and digital tools proved to be one of many challenging tasks architects were pursuing in the end of the 20<sup>th</sup> century. On our journey we sometimes found ourselves in the trap of succulent and seductive beauty of strangeness that we designed in moments of digital surprise. We played and blobbed with shapes and still do, emphasising on data in relation to digital material, gradient surface subdivision (occasionally for differentiations sake), fetishising evolutionary algorithms, voronoi-ism, meshing, symmetry, agents, and the random use of Brownian motion. A tinkering not to be missed and certainly crucial to insert the new tools into our intuitive ubiquitous repertoire of architectural design elements. A tinkering not to be missed, either; for it allowed us to learn from performance-driven form-finding processes found in nature. A strange combination has led to biomimetic phantasms serving as good foundations to carry on. The article features two projects trying to tip over the tipping point in their conceptual approach and utilisation of coding software. Projects are developed in continuing research under the title *Architectural Ecologies: Socio-ecological Systems and Human Habitat*. The term *Architectural Ecologies* is certainly not new per se, but in light of the Anthropocene has received a new meaning.

Fig. 01: Three strands of architectural research embedded in in issues of governance and change.

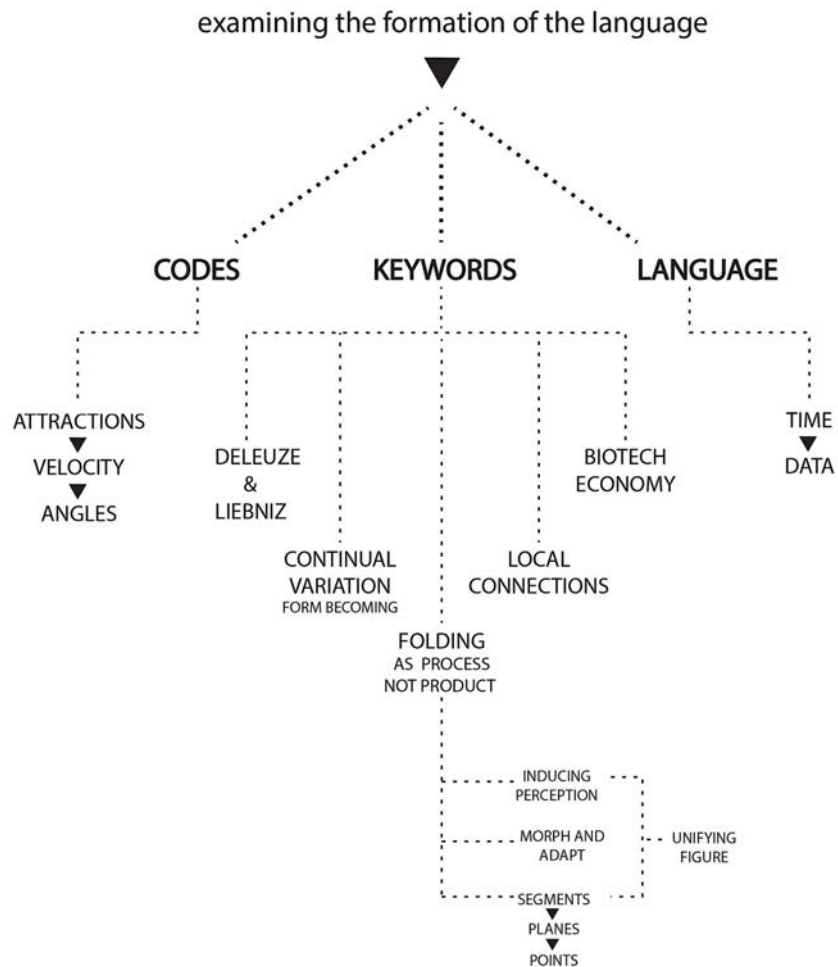


*Ecology* was originally allocated to individual phenomena and disciplines such as biology, nature, botany, sociology or geometry in the 18<sup>th</sup> and 19<sup>th</sup> century. Alexander von Humboldt (1769 - 1859), the great scientist and *world-measurer*, travelled extensively to research the ecology of botanical and geological geography. In 1845 he extended his essay *Idea for a Plant Geography* (Humboldt 1805) to a lexicon on the globe including meteorology and climatology, hydrology, geology, magnetism, zoology, anthropology and ethnography. Humboldt was the first who tried to comprehend the world system (as a system) as an organism and thus elevated and extended the term ecology to a science in itself. Approximately one century later the issue of CO<sub>2</sub> greenhouse global warming and climate change arose. Yet, it should take until 1988 for the *Intergovernmental Panel on Climate Change* (IPCC) to be established and further ten years for the Kyoto Protocol to be adopted.<sup>1</sup> Unforeseen sudden natural disasters such as the Thailand Tsunami (2004) or Hurricane Katrina (2005) as well as long term transformation such as the 2015 Californian epic drought and more direct man-made ecological calamities set new tasks.

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<sup>1</sup> source: <http://unfccc.int/timeline/> [last accessed 20150922]

Fig. 02: Diagram by Natalie Belous and Kamel Lokman describing three components of architecture as syntactic construct between mathematics, philosophy, technology and time. *Studio Codes in the Clouds – Topology Frequencies, DIA*



*Architectural Ecologies* interacts with such phenomena. It operates on the level of adopting sound material, fabrication and coding knowledge and pairing it with emerging theory and philosophy to arrive at an architectural culture that embraces a multi-ordered cybernetic model of and for the new world owning a multitude of facets, classes of information made of data and ways of learning. A systemic mesh - a general environmental awareness has become the driving force for handling our daily activities.

The *Quest of Code* aims at developing design strategies based on gathering an understanding of the environmental situation, current economic and demographic changes, intentionally located in contexts extremely affected by the action of mankind. It includes ideas about collaboration between drones and robots to face natural disaster relief situation, engage with the question of how to use big data for, suggest post-digital urban habitats and foster adaptive, soft insertion into natural environments.

*Noo-Topia: The After City* and *Atrophic Re[T]opography* work on two complimenting levels: firstly they act conceptually and foster the phenomenon *complexity* as host to nourish a computational architectural theory, and conversation space in which the design of architecture is governed rather than created;<sup>2</sup> secondly they work realistic and engage with the material world in a serious and critical fashion. The research is confronted with the *Quest of Code*, with a systemic approach of a model for architectural domains, digital and cultural taking in consideration that

“the architect is no longer a designer of discrete objects, matter and space, but a designer of systems with complex components and multi-layered relationships, and we have started handling the scripts, but we are still very far away from thinking the protocols, from defining the definitions for the tools needed.” (Werner 2014)

*In Quest of Code* on a technical level investigates compatibility and usage of scripting languages and tools and the appropriate application of different software packages, algorithm and strings of code in different situations.<sup>3</sup>

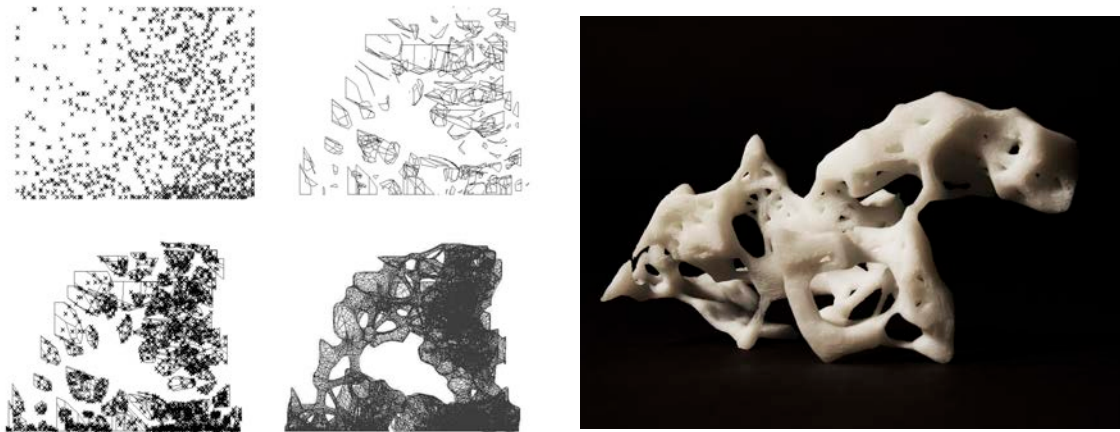


Fig. 03a and b: Development from point cloud via mesh (a) to 3D-print (b). *Atrophic Re[T]opography* by Nana Choi, Elizabeth Song, Michael Jeffers, Studio Codes in the Clouds, Carnegie Mellon University

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<sup>2</sup> *Conversation Space* relates to ‘Conversation Theory’ and ‘Entailment Meshes’ developed by the British architect’s cybernetician Gordon Andrew-Speedie Pask. In his *Conversation Theory* (CT) Gordon Pask differentiates p-individuals with ‘consciousness’ and m-individuals with ‘mechanical’ individuals. He allows for conversations between the conceptual, biological and mechanical, encouraging human/machine interaction (Pask 1976)

<sup>3</sup> E.g. Processing for multi-agent behaviour, Karamba3D for structural optimisation, Weaverbird for optimising mesh topology, Python versus C#.

It tries to find out when to rely on a generative design strategy and at which point to withdraw from total selflessly and un-authored self-organisation in order to enter the material world of fabrication and production. On a socio-ecological level the quest traverses in the midst of a digital-society-universe with - as Nicholas Negroponte stated in 1995 – ‘the individual as free-floating unit’ immersed in ‘digital living [that includes] less and less dependence upon being in a specific place at a specific time, [where] the transmission of place itself will start to become possible.’ (Negroponte 1995) *In Quest of Code* proposes a critical learning, testing and creating of tools fit for the Anthropocene and for a genealogic evolution of architecture alike.

### **From Voronoi-ism to Ecotome**

The two featured projects aim at a clear deviation and separation from so-called *Digital* or *Bio-Digital Architecture* whose shapes and forms have excited us with surprise, novelty and adrenalin; that we fancied for many years - in fact until now. Yet, since the late 2000s a novel architectural culture of seriousness has emerged. The accessibility of world data combined with improved tools for real-time-data analytics on one hand and collaboration platforms for developing open source code on the other (GitHub) have contributed greatly to this development. We can witness a steady departure from merely ‘borrowing’ from the life science and steering towards an extension of architectural impact beyond the object to the objectile<sup>4</sup> and performative. Extensive archi-hacking with limited interdisciplinary exchange, however, still bears the risk for computational digital architecture to remain in its inherited role as representative, formalist stylistic betrayal; rather than comprehending, and adopting concepts of behaviour, information, and biological-cognition as the design-process leading to form. During our playtime in last 20 years we started comprehending the tools and toys invented and created an overwhelming amount of outstanding architectural creatures and new organisms, hiding the secret to form more than ever. Architecture in this sense becomes a cybernetics model of learning, establishing and living. The form of architecture derives from how it is crafted with

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<sup>4</sup> The objective refers to Deleuze’s notion of the new object as variation, as mathematical function. It becomes a parameter. Deleuze states “the goal is no longer defined by an essential form, but reaches a pure functionality, as if declining a family of curves, framed by parameters [...]. The new object we can call objectile.” (Deleuze 2006)

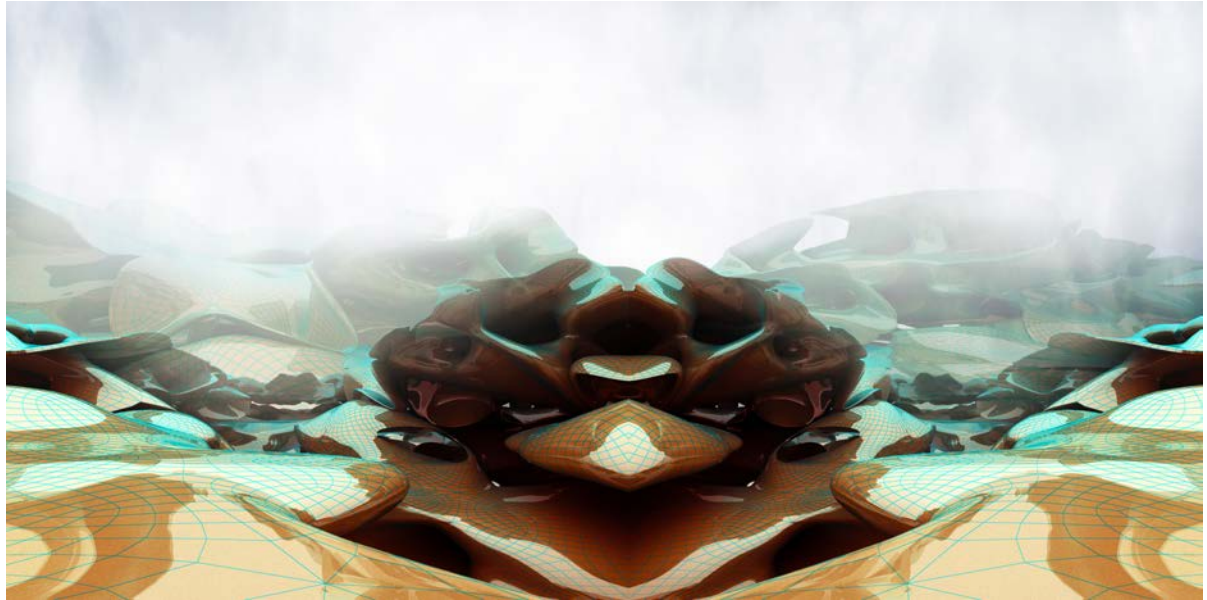


which tools. Coding and scripting in this respect also is a tool that requires appropriate crafting skills to be mastered. If we agree, that architecture is a result of its makers epistemological and heuristic decision-making capabilities in conjunction with the instruments and finally materials used we are - at least to a certain extent - approaching a paradigm of emergence of form. If we regard form as a verb - and I am referring strongly to Wentworth d'Arcy Thompsons *On Growth and Form* (Thompson 1961) - and not a noun the contemporary decision-making process for creating architecture undergoes a slippage into the paradigm in which mainly the operators *information* and *physical forces* create beauty, rather than the operators *will* and the *autonomy* initiated by the architect or designer. The quest of code merges with the quest of a general design and decision-making strategy. Meaning that we may be able to bear hug our current fetish for a) form and b) information processing and create a kind of *Medial Ecology* as architectural strategy simultaneously. Katherine Hayles suggests 'that the relationship between different media are as diverse and complex as those between different organisms coexisting within the same ecotome, including mimicry, deception, cooperation, parasitism, and hyperparasitism' (Hayles 1999). The *new architectural ecotome* therefore is the interstitial liminal space between the human brain, architectural ontology, the computer as such and the first generation of cyberspace, the Internet and wet data. At this stage the architecture is in a state of evolutionary development, conceptually, anatomically and physically. The *new architectural ecotome* can act as breeding ground for architecture combining algorithms, cognition, heuristics and archi-hacking, the phenomenal, material and biological. The dilemma, the crux, the sneakiness lies in the observed almost epic inherent relationship of tool and form leading to the digital architecture we see on a daily basis when hovering through related websites and project pages of our best architecture schools. Driven by interacting agents residing the *Ecotome*, it has inherited a particular aesthetic featuring topology, folds and curves. Mario Carpo refers to a ubiquitous *malumianism*<sup>5</sup> at the turn of the century (Carpo 2011). A roundness

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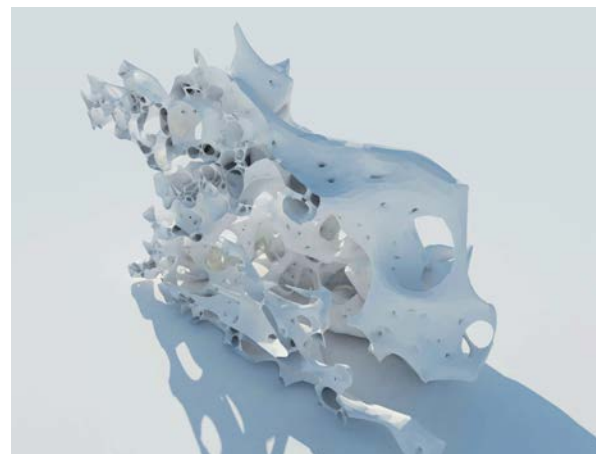
<sup>5</sup> Mario Carpo takes the term 'malumian' from the historian philosopher of art Wolfgang Köhler, who in 1915 differentiated between angular and round shapes as 'takete' and 'maluma' for angular and round shape. See CARPO, M. 2011. *Alphabet and Algorithm*, MIT Press.

highly influenced by software that sneaked into architecture from the movie and aviation industries paired with an obsession with Deleuze's fold.



*Fig. 04a (top) and b (bottom): Stigmergic Scape by Ali Farhan in PARA-rchitecture Contingency, Studio Codes in the Clouds III – 2112 AI Maribor, DIA: StigMergic Scape suggests a future conception of space as difference-reality, where the boundary of virtual and physical blends. It describes an argument to construct and rethink architectural spatial logic.*

A Zeitgeist without which the next stage in where 'the natural and artificial environments will merge, enabling the built environment to become integral to the very shaping of our planet's future' (Frazer 2012) would be hardly possible. John Frazer calls this a self-organising process, which he defines as architectonics: 'A new form of designing artefacts interacting and evolving with natural forces through pervasive computing and artificial intelligence.' (Frazer 2012). Automation and the virtual invaded almost every household, and most of the atom-based machines and wires transferring information morphed into small devices featuring a rather amoebae-like, multi-dimensional existence, machinic and virtual. An unforeseen convergence of technology and human culture that describes a further industrial revolution. At this moment in time we are approaching the next step from bits to biology. For architecture this means that there is a shift from architectural autonomy - which still exists when applying algorithms to *find* form - to architectural biology. Architecture as living system that 'if [it] enters into a cognitive interaction, its internal state changes in a manner relevant to its maintenance, and it enters into a new interaction without loss of its identity.' (Maturana 1970). So even in the case that adaption in architecture - through learning (AI) - results in structural and behavioural change affecting the form, the principles of architecture remain the same. Computation with embedded ecological awareness would become the new structure of and for architecture (Lorenzo-Eiroa 2015). The challenge now is to understand the body plan of this new structure, how to use the tools and skills established throughout the last five decades within the architectural digital and computational evolution and start designing the protocols for a bio-digital and genetic architecture in all its formal facets; embracing the cognitive capabilities in biological design processes, new architected materials, soft tectonics and the relevance of integrating the right data into the design process.



*Fig. 05: Rendering derived from point-cloud import (Processing to GH) via meshing for 3D-print. Atrophic Re[T]opography by Nana Choi, Elizabeth Song, Michael Jeffers, Studio Codes in the Clouds, Carnegie Mellon University.*

## **Noo-Topia: The AfterCity**

“In the same ways that hypertext removes the limitations of the printed page, the post-information age will remove the limitations of geography.” (Negroponte 1995)

*The AfterCity* was driven by the fascination of allowing nature to claim back the earth's surface and seas to allow for a natural environment with sufficient natural resources for all - mankind, animals, plants and other creatures. A place that would contain all the population in the world bringing balance to the planet, giving back space. This would be the only way to guarantee that all other regions could be left for recovery, on the way out of the Anthropocene. In order to achieve the given goal a world city had to be designed. It could accommodate a population of more than 7.3 billion people from several hundred cultures and countries.



Fig.06: *The AfterCity*. Carlos A. Naranjo Astoria, Eliot Marin-Cudraz, Yin Zhang, *Studio Codes in the Clouds – Nootopia*, DIA

The project *After City* on a technical level, acted as projection screen for the future. It was designed out of the understanding that architecture now is an alloy of programming, data mining, digital tooling, art and science. Thus the entire design process utilised earth data for climate analysis, geography analysis and demographic statistics as well as

conceptual design proposal. The vision for *one world one city* is radically utopian idea forcing to rethink the human condition on a philosophical level and human behaviour on a performative one. The design process tested an evolution from clear boundaries towards blurry perimeter lines of post-human, post digital and almost non-disciplinary typologies in form of a cybernetic causal development beyond the evolution in technology to find new ways of communication and socio-political configurations, within architecture and urban world design. The project understood and critiqued the fact that

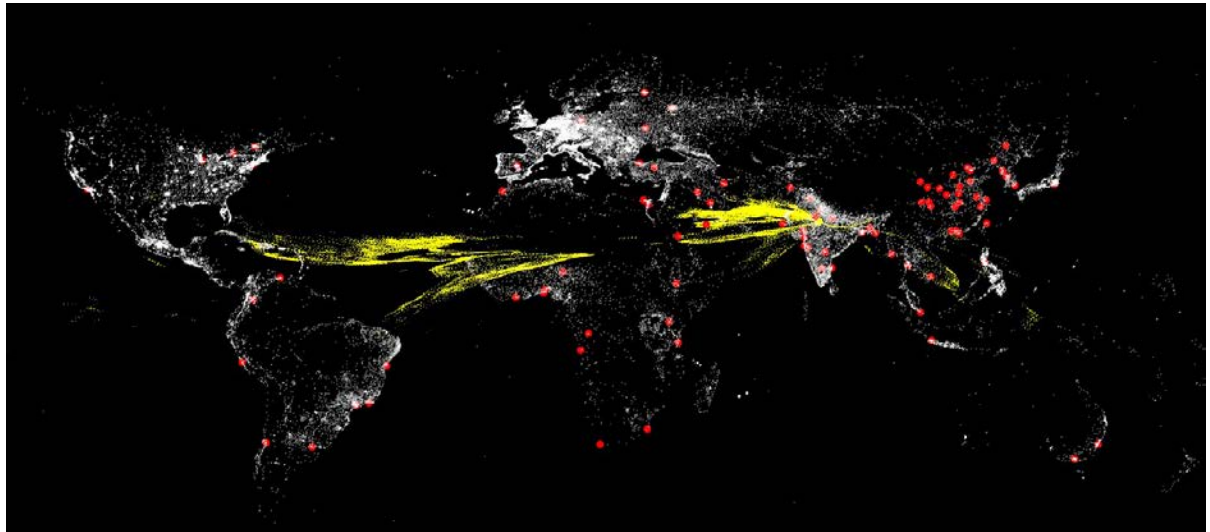
‘Urbanisation, one of humankind’s most successful and ambitious programs, is the triumph of the unnatural over the natural, the grid over the organic. [...] One side effect of urbanisation is the liberation of vast depopulated territories for the efficient production of ‘nature’’. (Mau 2014)

Planet Earth provides us with approximately 510.000.000 km<sup>2</sup> of surface, of which 148.900.000 km<sup>2</sup> is land area. 35.745.000 km<sup>2</sup> are reserved for mountains, 49.150.000 km<sup>2</sup> for desert and 64.000.000 km<sup>2</sup> for possible living area.<sup>6</sup> Accordingly an analysis for finding a site was initiated, driven by idea of densification instead of urban sprawl. A first investigation was directed towards understanding how the world’s population is currently distributed. The question then related to simulating scenarios where more than one *AfterCity* would exist.

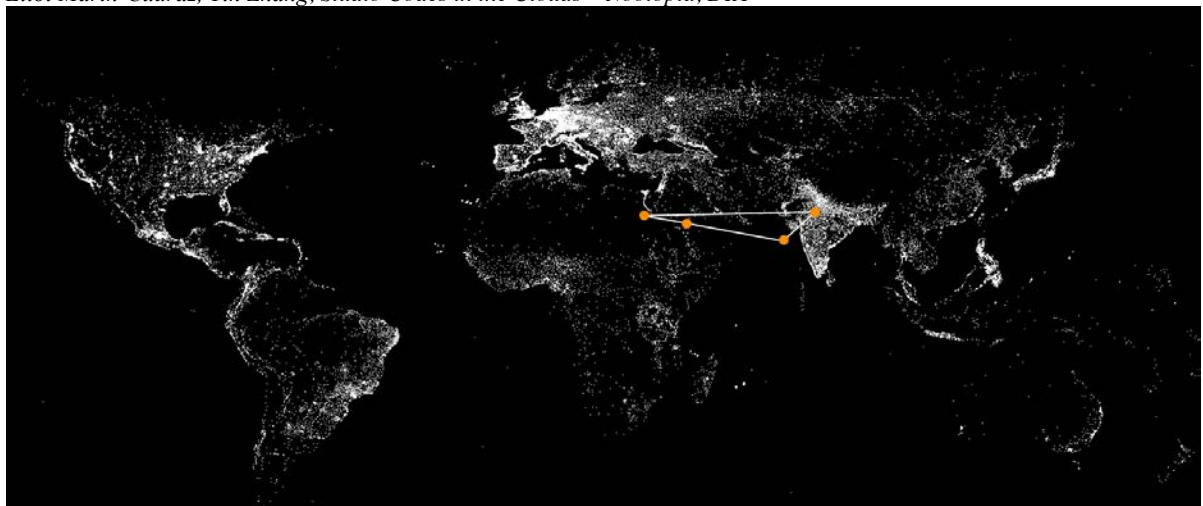
The simulation utilised a multi-agent swarming behaviour with set attraction circumferences around some of the largest cities on earth and agent internal repellent characteristics. Instead of new cities emerging, existing urban environments were further populated. A result that implied a number of insuperable challenges, e.g., how to extend urban systems, which are not working anymore in the first place? Or, how to recreate an equal energy harvesting and distribution system next to existing energy sources incompatible with architecture in the Anthropocene.

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<sup>6</sup> For better understanding, the US covers apron 9.826.000 km<sup>2</sup>, the UK 243.600 km<sup>2</sup>



*Fig. 07: Diagram showing urban clustering attracted to the 100 largest cities in the world. Carlos A. Naranjo Astoria, Eliot Marin-Cudraz, Yin Zhang, Studio Codes in the Clouds – Nootopia, DIA*



*Fig. 08: Diagram showing triangle with fur possible sites suitable according to climate analysis. Carlos A. Naranjo Astoria, Eliot Marin-Cudraz, Yin Zhang, Studio Codes in the Clouds – Nootopia, DIA*

Four cities, Mexico City, Paris, Shanghai and Dhaka were taken as research examples for high-density human environments. A country analysis showed that the world's population would geographically fit into Uruguay if a density of 39.000 inhabitants per km<sup>2</sup> (similar to Dhaka) was decided upon. For the *AfterCity* did not depend on existing infrastructure site parameters were reduced to a minimum for human comfort, in light of climatic changes in the next 100 years and not in accordance with geographical facts. The analysis was based on an average temperature between 18°C and 25°C, proximity to water, a mix of plain and mountainous land, solar energy potential, agricultural zones and sufficient rainfall. The Adriatic Sea enveloped by Italy, Croatia,

Albania and Greece turned out to be the most appropriate site on planet earth. Design of accommodation was driven by factors such as generosity of space versus economy of space, enclosed built space versus unbuilt free space, infrastructure and sufficient sun light. *Conway's Game of Life* (Conway 1970) served as a conceptual starting point for testing a design strategy that can be applied to customised mass housing as envisaged by the *AfterCity*. An adjustment of the rules allowed for a regulated generative designs strategy, which guaranteed individualisation within the overall pattern and at the same time provided enough freedom for adjustment. A series of script iterations was tested in Processing combined with Unity3D. The *AfterCity* objective was to engage with contemporary advanced tools and the approach and idea to create an architecture that bears a quality for living rather than focusing on creating alien shapes. The maximum size of a tower in The *AfterCity* was set to 700m with 2-3 horizontal connections to neighbouring habitats or parks, three public volumes four private volumes and one commercial volume at the bottom of the tower, to disperse into the landscape. The volumes are made up of elements measuring 7x7x3.5m distributed according to set rules.

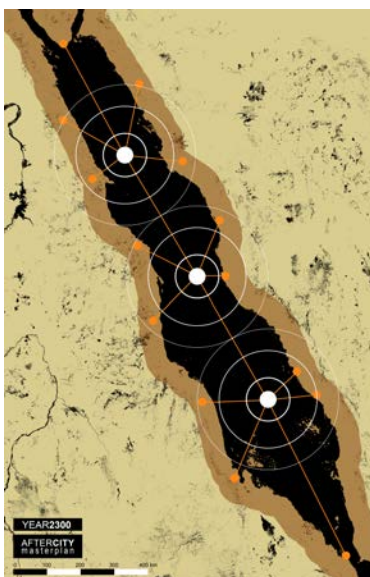


Fig. 09



Fig. 10

Fig. 09: Diagram of site concept. Carlos A. Naranjo Astoria, Eliot Marin-Cudraz, Yin Zhang, Studio Codes in the Clouds – Nootopia, DIA

Fig. 10: Diagrams showing rule-based component distribution relating to proximity and number of neighbours. Carlos A. Naranjo Astoria, Eliot Marin-Cudraz, Yin Zhang, Studio Codes in the Clouds – Nootopia, DIA

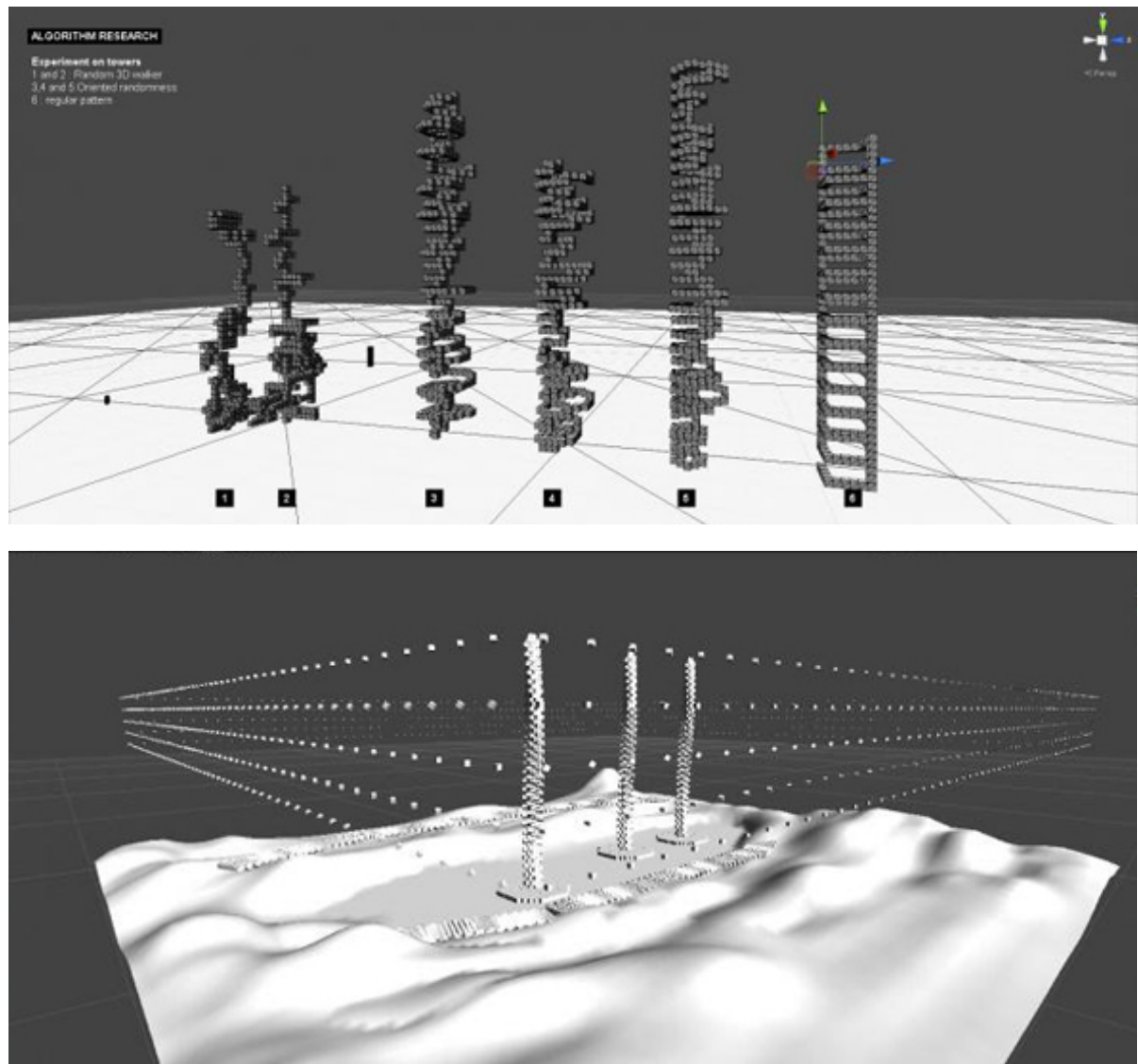


Fig. 10a and b: Diagrams showing component distribution relating to typology based on parameter intensity. Carlos A. Naranjo Astoria, Eliot Marin-Cudraz, Yin Zhang, *Studio Codes in the Clouds – Nootopia, DIA*

It is to mention that the *After City* is the first step, a conceptual project, which at this stage still requires adding parameters such as demographics, economy, health etc. The script focused on the distribution of compartments. At this stage it failed at refined definition necessary for arriving at an urban landscape including all the pleasure and interaction (digital and analogue) a city ought to offer. Nevertheless, Christopher Alexander's notion on *The City is not a Tree* (Alexander 1966) as well as local phenomena like Rem Koolhaas' *Downtown Athletic Club* originally designed in 1978 (Koolhaas 1994) as well as the *Unite d'Habitation* (1952) where taken into account. The



*AfterCity* clearly is a utopian project, which in its somehow nostalgic but also fairly extreme way decides to suggest a novel way of living. Issues of how a large population in one region could be fed and how exactly social, economical or political structures would crystalline at this stage cannot be answered. The project does propose a scenario of communal living as we can witness happening in cities such as Berlin. In response to high real-estate prices, political discontent and a change in social structures and thus behaviour, a sharing and caring community has developed over that last decade. Part of it is to exchange resources that go beyond goods and products and include knowledge or skills as valuable cognitive capital to share, trade and give away. The *AfterCity* may act as an urban manifestation or concept to trigger a rethinking of the complex interaction between mankind, natural resources, industrial and information systems.

The proposal takes on Buckminster Fuller's observation

“that the complex and previously subconsciously-operating total ecological support of this *metabolic regeneration*<sup>7</sup> of man has now been complexedly externalised into what we call the industrial [...] complex. The industrial complex [...] now makes man progressively independent of the a priori ecological support [...]. One of the major facts which we must now face is that the *industrial complex* relates *inherently to total earth* - because the resources of earth are very unevenly distributed - and relates always to the *total intercommunicated experience of all men everywhere in all time.*” (Fuller 1969b)

Thus the project acts as a prototype for what I may want to call *Cybernetic Urbanism*. The idea is still an incomplete diagram since e.g., governmental structures and policy-making has not been taken into consideration<sup>8</sup>, which would be absolutely crucial in order to set up a system for design and regulation of a one-world city. Differentiation among diverse relationships would need to be taken as an advantage to grow and to nourish a social-ecological system that is fit for the Anthropocene. Architecture may play an important role, but cannot serve as substitute for regulation.

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<sup>7</sup> Buckminster Fuller refers to the metabolic and energetic regeneration process of mankind dependent on ecologically supporting environment.

<sup>8</sup> See McGinnis and Ostrom suggest a systematic approach to social-ecological systems. E.g., variables for a social-ecological system including resource system (RS), governance system (GS), related ecosystems (ECO) as well as properties for governance systems including regime type (GS4), rule-making organisations (GS5), network structure (GS9). Published in *Ecology and Society*, 2014. <http://dx.doi.org/10.5751/ES-06387-190230> (McGinnis 2014)



*Fig. 11: Perspective view within the AfterCity. Carlos A. Naranjo Astoria, Eliot Marin-Cudraz, Yin Zhang, Studio Codes in the Clouds – Nootopia, DIA*

### **Atrophic Re[T]opography**

#### **an autonomous construction system based in robotics and artificial intelligence**

Decay and rebuilding of cities has become a pressing issue in most parts of the world, due to abandoning of regions, towns and cities. Reasons vary. The economic or political situation may affect the liveliness or survival of a region or war might destroy buildings to such extent that living in becomes impossible. A third reason for the destruction of buildings, cities or whole regions are natural sudden natural disasters or slow and steady decay of structural building material and/or the disappearance of steady ground. Examples include the decaying facades and building material on coastal fronts, especially world areas such as Southeast Asia - mainly Vietnam, Malaysia and Indonesia suffer from damage to buildings and infrastructure including dams and bridges. Severe winds and strong currents add to drifting sand and beaches interfering with human and animal habitat, bush fires increase the amount and distribution of haze blankets consisting of fine particles, extreme dangerous for all species. New Zealand took action already in 1913,

when the Royal Commission set up the New Zealand State Forest Service to take action against drifting sand by installing wind barriers to protect the land in the future.

The Anthropocene entails climate change in general, extreme weather conditions and global warming in particular resulting e.g., in an increase in sea salt corrosion caused by wind, sun and salt spray. In this respect the changing climatological conditions set the task to start thinking about how we can steer against - or with - corrosion and decay to save or re-script human habitats and therefore stabilise a secure living on the planet. Again, we are not necessarily subjected to a completely new and pressing situation, since humankind has always been dependant on the evolution of nature, climate changes, geological shifts as well as geographical variances triggered by governmental decisions. Nevertheless based on growing communication tools, the harvesting and public availability of extremely detailed earth-data and its visualisation intensifies most individual's interest in global matters regarding life on earth and the ecological footprint. The project seeks to suggest novel architectural ecologies that do not reside in the paradigm of buildings but in the paradigm of architectural processes. Architectural ecologies here extend the term ecology as discussed earlier are prone to elevate digital tools and computational thinking to a status where they actively and interactively respond to the architect's decision-making processes. *Atrophic [Re]Topography* takes on board the design of systems and tools; in the widest sense it starts 'designing design' in its extreme. It goes beyond a dynamic, non-linear, cognitive data-driven design, as e.g., explored by John Holland, Oliver Selfridge, Marvin Minsky and alike in the early 1960s who trained artificial neurones with the capability of open-ended learning or Norbert Wiener's attempt who 'attacked the problem of predicting the flight paths of aircraft taking evasive action, which he reformulated as predicting the future value of a pseudo-random functions based on its statistical history.'<sup>9</sup> (Mindell 2000) *Atrophic [Re]Topography* acts on two complementing levels. Firstly on the level of computational theory of architecture suggesting a scenario in which not just executing scripts are coded, but also protocols on a meta-level. And further provoke an architectural vocabulary that allows the architecture of the near future to depart from the 19<sup>th</sup> century understanding of

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<sup>9</sup> Norbert Wiener drew the analogy between the behaviour of digital computers and that of the human nervous system.

predetermined form per-se towards architecture of code, self-organisation and agent-based formations. Secondly the work acts on the level of elevating such a computational theory of architecture to the stage of serious and realistic application - even if flavoured with a waft of fantastic vision.

#### Beersheba - or a Masquerade for Venice

“Intent on piling up its carats of perfection. Beersheba takes for virtue what is now a grim mania to fill the empty vessel of itself; the city does not know that its only moments of generous abandon are those when it becomes detached from itself, when it lets go, expands.” (Calvino 1974)



Fig. 12: Diagram showing areas of acute danger to fall apart, centre of origin of swarms and destinations. *Atrophic Re[Topography* by Nana Choi, Elizabeth Song, Michael Jeffers, *Studio Codes in the Clouds*, Carnegie Mellon University

Looking into developing general principles for a material based rebuilding of affected areas including the once created through the phenomenon of abandoning, Venice was chosen as a site. The wooden foundations of the city, inserted in a fluid environment emerged in the architecture of Venice as architecture of romantic debris and equally the manifestation of an absence for repair and decay. Natural circumstances and human activity force the city to sink by 0,1 - 0,4 inches per annum. Venice is not the only

sinking city, New Orleans, a true victim of human insertion sinks by approx. 1inch per annum. The Scientific American reports that the disastrous development is caused by the opening up of 16% of wetlands to the open sea in order to dredge canals for extracting and harvesting oil and natural gases between 1930 and 1960. As a sinking city, subject to Aqua Alta, gravity and structural and material instability it provided the birth-ground for advanced architectural systems and ideas, which worked on either, a phenomenological, surreal level or a level of advanced architectural design engineering. The project suggests an automated construction service that sensors the most affected areas in the city and analyses the level and exact location of disrepair. In the next step it collects decaying material, re-assembles it on a molecular level to a stronger resistant building element and repositions the material on top of the decaying structure. The system, called the SWARM can be installed on several sites at the same time. A pre-programmed protocol also may send the SWARM to areas of extreme disrepair autonomously if desired. Attempts were made to abstract implicit generative rules governing the city's observed collective behaviour derived from its immediate environmental influence into explicit codes, in order to computationally generate and further formulate new iterations of spatial and tectonic configuration.

Drawing from knowledge about what Steven Johnson called '*Emergence. The Connected Lives of Ants, Brains, Cities and Software*' (Johnson 2001) *Atrophic [Re]Topography* takes on board the attempt to design *Stigmergic Wrihting Autonomous Robotic Machinations*. Essentially it is a design proposal for a swarm based autonomous system re-materialising and re-building decaying or decayed built spaces. The system operates according to stigmergic behaviour and robots owning intelligence in order to take appropriate design, or rather building decisions. Main features include a fully functioning flight system with high precision accelerometer, chemotaxis sensory pray, material acquisition and survey instruments, material recomposition forge, tactile sensory array and an on-board pre-programmed instruction set. The SWARM is an automated semi-biological construction service whose drone-like agents carry out operations of re-materialising the built environment through an internal metabolic system. Agents are being activated through interaction with other agents based on different kinds of pheromones.

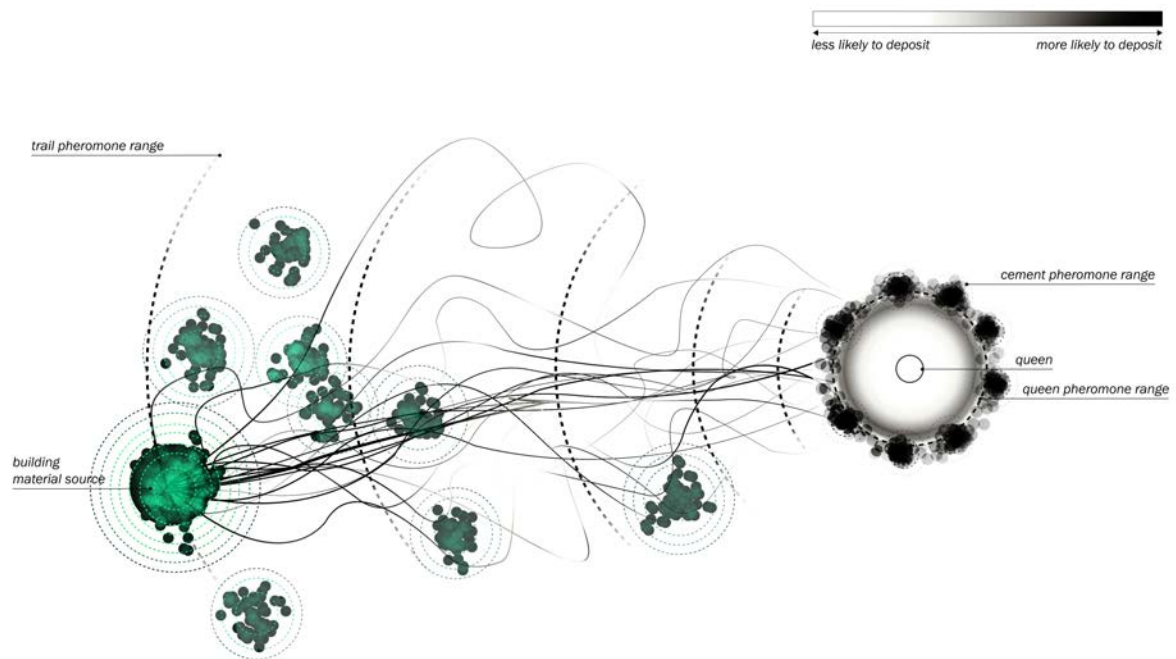
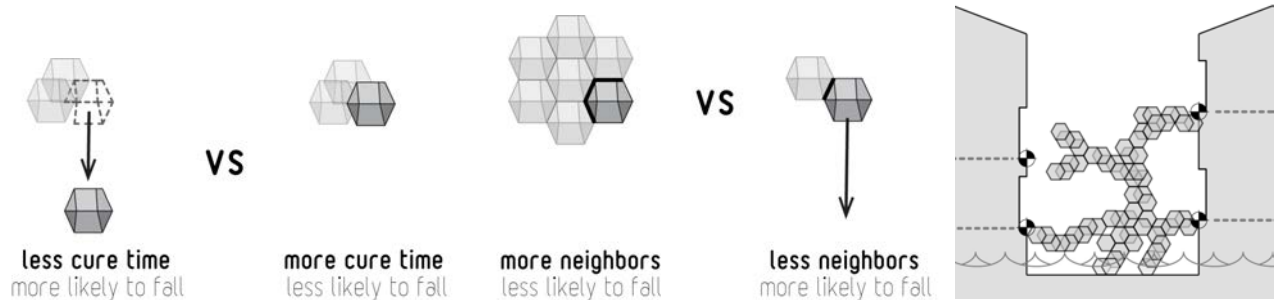


Fig. 13: Diagram showing the principle of ant behaviour based on pheromone trails. This behaviour describes the foundations of the script for the project. *Atrophic Re[T]opography* by Nana Choi, Elizabeth Song, Michael Jeffers, Studio Codes in the Clouds, Carnegie Mellon University

Scripted and tested in Processing, agents were equipped with rules for the deposition process based on a defined search and deposition range and rules based on spatial targets. Each individual agent receives real-time feedback on its own spatial location. Parameters included the *pheromone* type affecting the build pattern and cluster sensibility (connectivity) to steer stability. The latter is relevant for the actual assembly process of the 5x5x5 mm small building components. Only if a component has enough connection points to other components it can add to a stable structure. If it has not enough connection points, it may simply disconnect and drop off the new structure to build. Each new component is the result of a metabolic process and once formed and deposited still in a process of curing. Cure time and deposition process are computed in conjunction with gravitational force. Once a component is cured it becomes static and performs with maximum of stability. The architecture created through the autonomous construction service aims at building a second generation of Venice based on and out of the existing, resilient and sustainable.



*Fig. 14; Diagram of construction principle, showing the relationship of cure time and stability through clustering. Atrophic Re[T]opography by Nana Choi, Elizabeth Song, Michael Jeffers, Studio Codes in the Clouds, Carnegie Mellon University*

### Phase 01

Agents seek advantages build surfaces using their tactile sensors. These are openings and articulations in the facade surface.

### Phase 02

As water levels rise, deposits release trapped chemical triggering a state change in the local agents. An activation pheromone is released, which triggers a new set of agent rules and response behaviour. This may allow for additional, previously irrelevant pheromone types to be considered, or merely change the build pattern.

### Phase 03

The phase03 threshold pheromone emerges through the concentration of the activation pheromones in phase02. Thus it is airborne, non-surface-bound and flux. Spatial constructs derived from the bubbling chemicals in the phase02 build pattern, follow the wind-direction, as the pheromone field becomes distorted through the movement of air. Scripts were developed by phase according to goal, means and result of each individual phase:

#### Phase01:

Goal: Provide means of circulation above flooded street condition.

Means: Building occurs at and along alleyway conditions and starts on wall surfaces. Edges are most attractive and are detected by random-wandering agents, deposit of a pheromone that labels the edge as a viable build surface.

Result: Infill of void / span in alleyway, producing walkable surface that transverses the alley-space.

#### Phase02:

Goal: Create and prepare new build plane, significantly higher to provide more permanent solution to circulation patters, and allow for surface on which to build full-scale spaces independent of old-city structures.

Means: Build is directed upwards towards localised target elevation

Result: Columnar-tree like field building up from ground or building, providing a large build-surface at target elevation

#### Phase03:

Goal: Create spatial structures to house soon-to-be homeless, and space-less Venetians escaping their flooding quarters.

Means: Pheromone concentrations from phase2 overlay to create a signal pattern, introduction of existing air movement and wind

Result: At the point of highest concentration agents are instructed to build in proximity to, but not within a particular pheromone intensity of the wind-swept distorted pheromone pattern.

General rules for all phases included that

1. Phasing is determined only by concentration thresholds of pheromones.
2. Given a particular amount of deposition in an area, agents within a defined radius will undergo a state-change and follow a different set of algorithms that determine its build-pattern behaviour, response to environmental factors, and other end conditions.



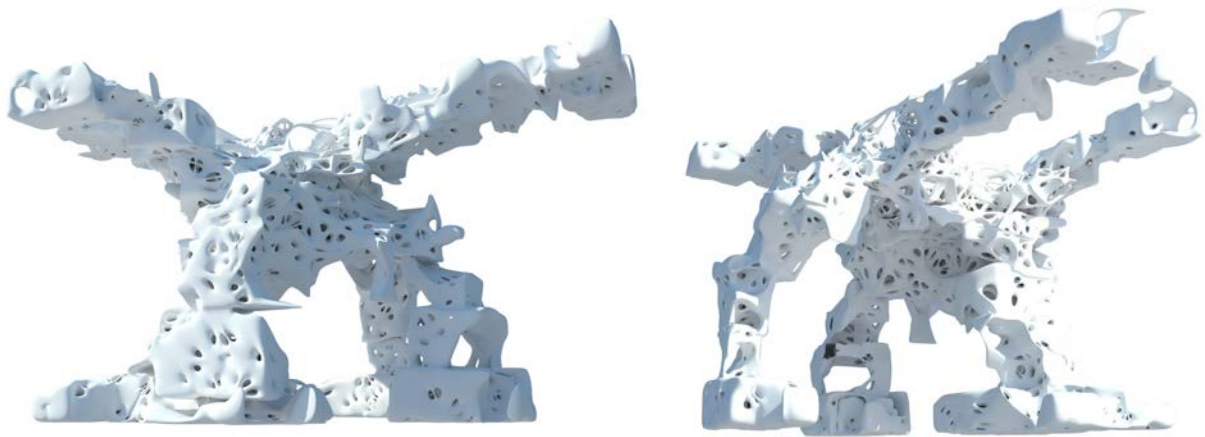


Fig. 15a and b; showing iterations of the construction process. *Atrophic Re[T]opography* by Nana Choi, Elizabeth Song, Michael Jeffers, *Studio Codes in the Clouds*, Carnegie Mellon University

### **What is beyond the Tipping Points**

The article *In Quest of Code* tries to embed architecture's role within the Anthropocene. By doing so questions on the human condition, economics, socio-ecological and cultural codes are becoming elemental guides for design decisions. In times of the tipping point it is crucial to test and analyse a large variety of design strategies, since it seems illogical to apply existing solutions for novel challenges. Either way, solution, strategy and challenge are structurally coupled and henceforth share one concept, one red thread. In a way one could argue that a challenge need to be able to communicate with a solution through the communication system design strategy. It may be a cybernetic approach, and surely it is a biological and mathematical understanding of systems. In the article I suggested the following strands of how to operate in the current situation and what could be or happen beyond the tipping point.

- a. Learning how to make novel computational tools, such as scripts work for architecture in a generative cognitive way rather than a descriptive way. Meaning taking the risk to include artificial intelligence and learning algorithms actively and according to a specific situation, rather than leaving this powerful tool with the paradigm of pure form-finding.

- b. Rethinking design-strategies from linear to complex, systematic and cybernetic. In this respect a transfer from comprehending an object through its function may want to be replaced with comprehending an object through its objectile and properties.
- c. Including environmentally sensing and responsive agent deployment systems in order to remediate a problem that is dynamic in magnitude, location and scope. This may also include operations in disaster relief situations.
- d. Simulating acquisition and depletion of building material for construction needs to be dealt with on a city scale. Here a new typology of architecture accommodating robotic systems may occur.
- e. Through changing social and economic structures policy-making and governmental decision-making processes will be re-thought and changed. Architecture plays a role in the sense that it inevitably connected to the creation of human habitat, public, private and industrial spaces as well as serving as a kind of educator, delivering knowledge on craft or the notion of inside and outside,<sup>10</sup> which essentially reflects societal structures.

The above is a cybernetic approach, a biological and mathematical understanding of a system, in which architecture has to re-establish itself. As mentioned at an earlier stage, the task is to transfer *utilitas*, *venustas* and *firmitas* to an earth-friendly architecture that, at the same time can serve our immaterial digital needs, geographic mobility and modification of social and economic structures; and finally to continue establishing a computational theory for architecture, or rather an architecture for a computational theory for architecture. I guess we have developed sufficient tools and instruments; the protocols are in the make and with them, eventually an *Operating Manual for Spaceship Earth*.

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<sup>10</sup> The boundary between inside and outside is seen as the first difference to make space. It indicates a distinction (see George Spencer Brown, *The Laws of Form*, 1969)

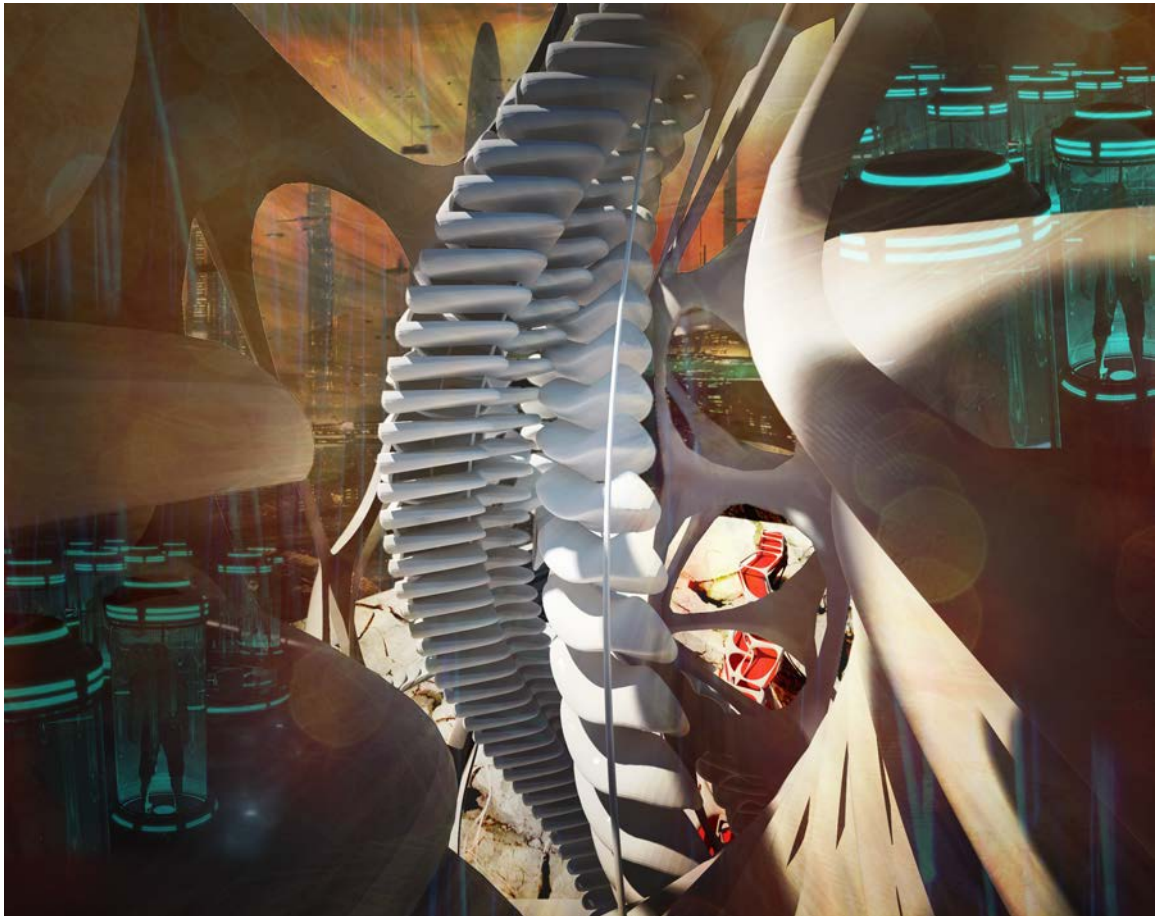


Fig. 16: *Excessive Repetition* by Alan Haddad, *Studio Codes in the Clouds*, DIA

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