THE INHUMAN CITY

Arachno-Computational Languages for Urban Design

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ABSTRACT

The Inhuman City aims at mobilizing multiple forms of intelligence, human and non-human, to redefine the urban.

In this paper the authors describe design as an activity carried on by a biotechnological apparatus, or extended mind, that includes different forms of intelligence: human, artificial, biological. By connecting biological models, digital simulations and advanced fabrication technologies, information is looped between the physical and the digital realms, extracted from material systems and processed with computational simulations, to be materialized through fabrication and fed back into matter.

The specific case of the Arahnocomputer is described, a biotechnological apparatus which includes spiders and their silk webs. The results of this research demonstrate the potential of the notion of ambiguous computation, intended both at epistemological level and in its spatial actualisation.

The Inhuman City rethinks the urban in a post-capitalistic future which is designed as form of inhuman society by constructing and investing on extended minds such as an Arachnocomputer. This computational synthesis operates not as analogy but proper mechanism of furthering metabolic processes on the planet avoiding rifts and dead ends. The Inhuman City becomes our starting point for the urban and therefore the planet of the post-Anthropocene.

1. INTRODUCTION

The inhuman city is a research agenda of planetary inhumanity. We as humans have allowed under specific political, financial and epistemological models to introduce metabolic rifts of planetary scale. As such we have transformed the cosmic dynamism of the planet into ever decreasing metabolic processes that we habitually call Earth. Processes that are not participating in the changes and transformations, but that introduce stops and rifts forcing resources and species into dead ends. Ends that are directly responding to the many human needs generated by capitalistic forces worldwide. As a consequence, man-made systems aim at ever increasing exaggeration of production that is not participating towards the dynamic metabolisms of the planet.

In this sense we assume that a proper recognition of Anthropocene should not be focused on human species in a totalising manner but should be focused on specific financial, political and epistemological premises that define human as Anthropos; the Anthropos of the Anthropocene. To our understanding therefore a forward-thinking strategy is not to reform Earth in its past conditions neither to terraform it into make it habitable again of and for humanity.

We envision a strategy to reproach the planet in its inhumanity (Pasquero, Zaroukas, 2016). By inhumanity we assert the condition where a hypothetical presence of human as an actor that maps and organises solely the processes of the planet is absent. In that direction we assume a first contact with an inhuman planet. A planet like the Solaris of Stanislav Lem, whose encounter and observation leads us to question modes of existence (Lem, 1961).

From within this conceptual framework, the Inhuman City project aims at mobilizing multiple forms of intelligence, human as well as non-human, to redefine the urban. The projects presented here connect biological models, digital simulations and advanced fabrication technologies at multiple levels. Information is looped between the physical and the digital realms, extracted from material systems and processed in the digital environment, to be materialized through fabrication and thus fed back into matter. This coupling is essential in order to move from a paradigm of computation as problem solving to a form of cybernetic conversation capable of evolving and redefining the materiality of the planet we inhabit.

Within this framework data are no longer understood but they are always experienced in the form of patterns, the aesthetic of these patterns becomes a form of novel design language.

2. THE EXTENDED MIND

In this sense the authors see bio-computational design techniques as an integral part of the way we understand the process of developing a project. They constitute a design as well as a cognitive tool. At an intuitive level, the adoption of different tools (from the simplest ones such as pen and paper, rulers, to 3d modelling software and beyond) to sketch, develop and curate ideas create radically different design scenarios. This is mainly because the cognitive apparatus at work is deeply transformed by the presence of a tool instead of another (Clark, 2003). In its most advanced, contemporary applications, the extended mind can be described by the coexistence of two forms of intelligence, human and artificial. Moving from these premises the research presented here questions how to extend this paradigm by incorporating in the extended mind a third actor: biological, inhuman intelligence. Design is then an activity, a process carried on by a thinking entity or a biotechnological apparatus that includes three main forms of intelligence: human, artificial and, biological.

3. THE ARACHNOCOMPUTER

Which kind of epistemological shift could the notion of bio-computation and the engagement with alien form of intelligence bring to Architecture and Urban Design? If we go back to the Latin meaning of the word ‘computing’, which would be ‘con-puto’ or ‘thinking with’, the operation of computing does not simply solve a mathematical problem but embodies a cognitive act; the first modern computer were in fact an hybrid between men and machine, as they required the presence and co-operation of humans to function. A bio-computer is here a computing entity, which is made of biological material, rather than silicon.

Which kind of alien intelligence can become part of this system? The typically recognized form of biological computation is the Slime Mould, or in scientific terms Physarum Polycephalum (Adamatzky, 2010), that the authors have discussed elsewhere. Yet that is not the only one available for experimentation: in this paper we will concentrate on the description of what we have called Arachno-computation.

In the last few years the authors shifted their research focus to insects, with a special interest on silk spinning creatures such as silkworms and spiders. Initially the interest in spiders was driven by a curiosity about fibrous morphologies, which was explored by pairing digital simulation of fibrous morphologies and biological models of spinning creatures. Then an understanding of the wider relevance of spiders for the design discourse was formed.

Recent scientific research shows how silk webs are tools which the spiders use to extend their cognition, by mediating, processing and transferring information from the environment (Apyassú, Laland, 2017) (Vollrath, Selden, 2007). Silk itself is the focus of much research, for its potential in textile and medical applications (Hennecke, 2013). While at a symbolic level, the presence of spiders in popular culture is strong and timeless. Arachnids appear in painting, literature and song-writing in various forms, often associated to a nocturnal dimension or the unconscious.

Beyond mediating cognitive processes, the spider web itself can be understood as the output of a computation performed by the spider, a biocomputer whose input is the environment where it lives, and the output is the morphological transformation of the spider web. Intensive and extensive properties from the environment inform the spinning activity and the shape of the web at any given time.

By designing and controlling such environment, the computation of the spider can be influenced and oriented. This apparatus has been tested as computational tool for architectural design. From the Greek 'arachno' (spider), we decided to name this the Arachnocomputer. We modelled the Arachnocomputer as an extended mind that includes human, artificial and biological intelligence.

In technical terms, at present, the Arachnocomputer is composed by the following components:

. a site model

. a biological model

. a digital representation of the biological model

. a digital simulation model

. the flow of information between them

The site model is an abstraction of the actual context of the architectural intervention. Such model relies exclusively on data representations to model both the extensive and intensive qualities of the physical world.

The biological model is fundamentally constituted by an transparent box (in the case of this experiment realized in 3mm acrylic), that contains the spider and a 3d printed substratum within it, and acts as a frame for the biological simulation. Geometrical features of both the box and the lattice, size and shape, are determined by information extracted from the site model. The biological model constitutes an experiment whose observation is performed through a variety of media including photographic recording as well as laser scanning of the emerging silk formations and tracking of the position of the spider. Such observation sets the ground for the creation of a digital representation of the biological model, which is accordingly populated by the digital processing of the silk patterns and movement of the spider. This information is then used to feed a simulation model that controls the design of digital fibrous morphologies. The digital simulation is thus oriented and governed by information extracted from the biological model. Eventually such morphologies are merged with the site model. Such combined model constitutes the fundamental outcome of the design process.

The Arachnocomputer proposes a computational paradigm which overcome computation as a problem-solving tool and propose a self-organizing and systemic reality which cannot be understood by separating the computer from what is computed.

4. BIOLOGICAL MODEL: PRELIMINARY EXPERIMENTATION

Over the last two years, an extensive experimentation with living spiders has been carried out at the UCL The Bartlett School of Architecture, Urban Morphogenesis Lab, with the goal to understand how their computational activity may be integrated in design prototypes. The researchers worked mainly with two types of spiders: Asian Fawn Tarantula (Chilobrachys Huahini) and Indian Ornamental Tarantula (Poecilotheria Regalis) (Figure 1). These two species of spiders proved to have very different behaviours in relationship with the experiments proposed.

While the former has a solitary attitude, and tends to spin a web with a volumetric, tubular shape, the latter has a collective spinning

Figure 1:
Asian Fawn Tarantula (Chilobrachys Huahini). Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

attitude, and the morphologies of its web are less distinctive. The Asian Fawn also seemed to be more generous in its spinning in all the experiments that were executed. The case studies described below and the Arachnocomputer feature only the Asian Fawn, which the researchers chose for both the geometrical properties of its web and the ease to perform an experiment with.

As a general indication, the interest of such experiment was to understand how the computation of the spider web, and its

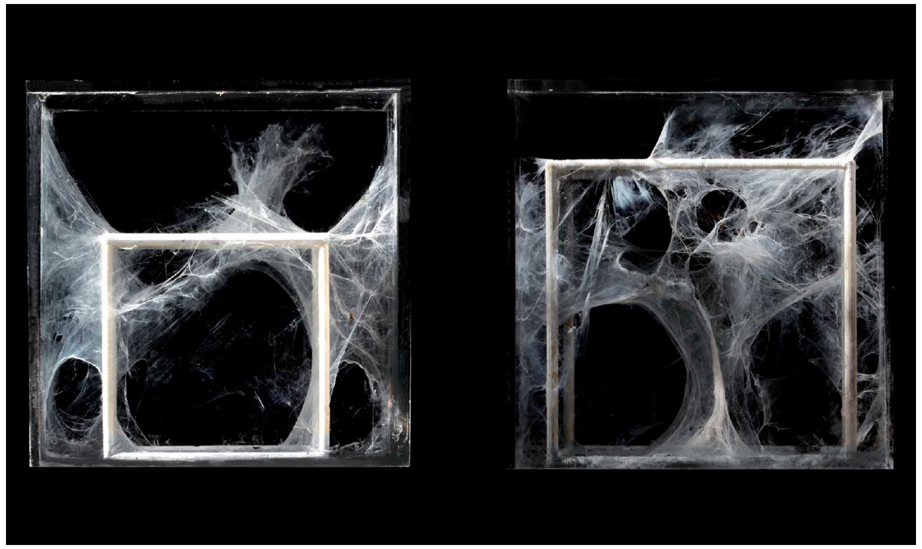


Figure 2:
Relationship between spider's web and 3d printed substratum.
Image by C. Pasquero, F. Nassetti, E. Zaroukas, H. Chen, X. Guo, X. Zhang.

morphology, may be controlled or oriented via the design of the environment into which the spider is placed (Oxman, 2013).

Most of the experiments featured the same basic setup: a transparent acrylic box, within which a 3d printed lattice structure and a single spider are being placed. The size of the acrylic box, and the resolution and shape of the lattice vary from experiment to experiment. An observation system completes the apparatus, composed by one or more digital cameras locked in a stable position, lighting and a protocol indicating when the recording is meant to happen.

A first set of experiments (Figure 2-3) shows how the size of the basic cell of the 3d printed lattice is influencing the shape of the web.

There is a relation between the anatomical size of the spider and the

Figure 3:
Relationship between spider's web and 3d printed substratum.
Image by C. Pasquero, F. Nassetti, E. Zaroukas, D. Guan, K. W. Wang.
Figure 4:

one of the geometrical features of the environment within which it spins. The Asian Fawn would tend to spin a tubular web, but both below and above certain dimensional thresholds, this cannot happen, as the web needs some kind of scaffolding to be tensioned against.

A second set of experiments, culminated in the model Xenoderma (Figure 4-5-6), demonstrates how this dimensional thresholds can be established and similar experiments iterated. In Xenoderma, a prototype for a building facade that includes farming units for the production of spider's silk, the shape of the lattice within each unit changes according to an overall gradient.

A third set of experiments took as reference an experiment from NASA (Noever, Cronise, Relwani, 1995) where the spider was fed with different psychotropic substances with the goal to observe their influence on the formation of the web. The researchers worked mainly with coffee and alcohol with the goal to understand whether their use can drive or orient the morphogenesis of the web. Different patterns of spinning related to different substances were observed.

5. BIOLOGICAL MODEL: INFORMATION EXTRACTION

In order to link the biological model to the digital simulation model, and have the computation of the spider influence the design morphologies, a flow of information between the two must been established. This requires the creation of a digital representation of the biological model.

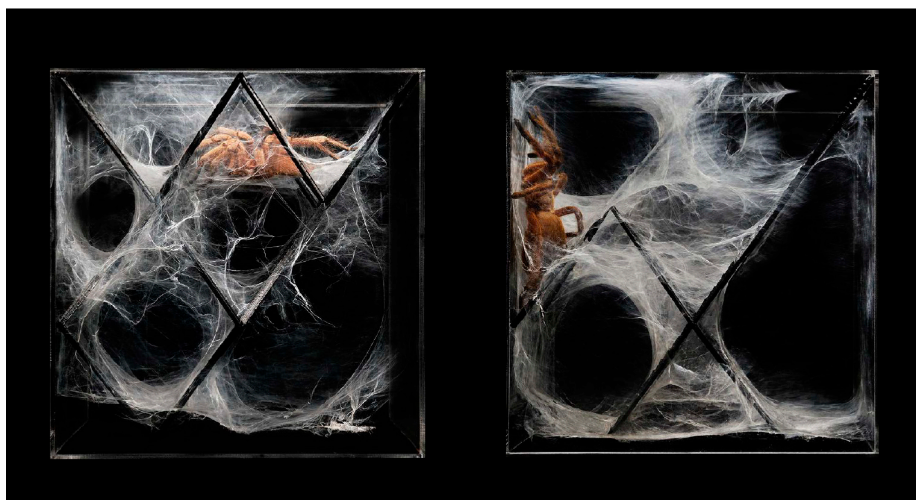
The following methods have been explored to obtain a digital representation of the biological model:

. density mapping of the spider's web

. tracking of spiders movements

. 3d scanning of the spider's web

Density maps can be created by taking pictures of the biological



Xenoderma, units. Image by C. Pasquero, F. Nassetti, E. Zaroukas, M. Li, X.Liang.
Figure 5: Xenoderma, full model.

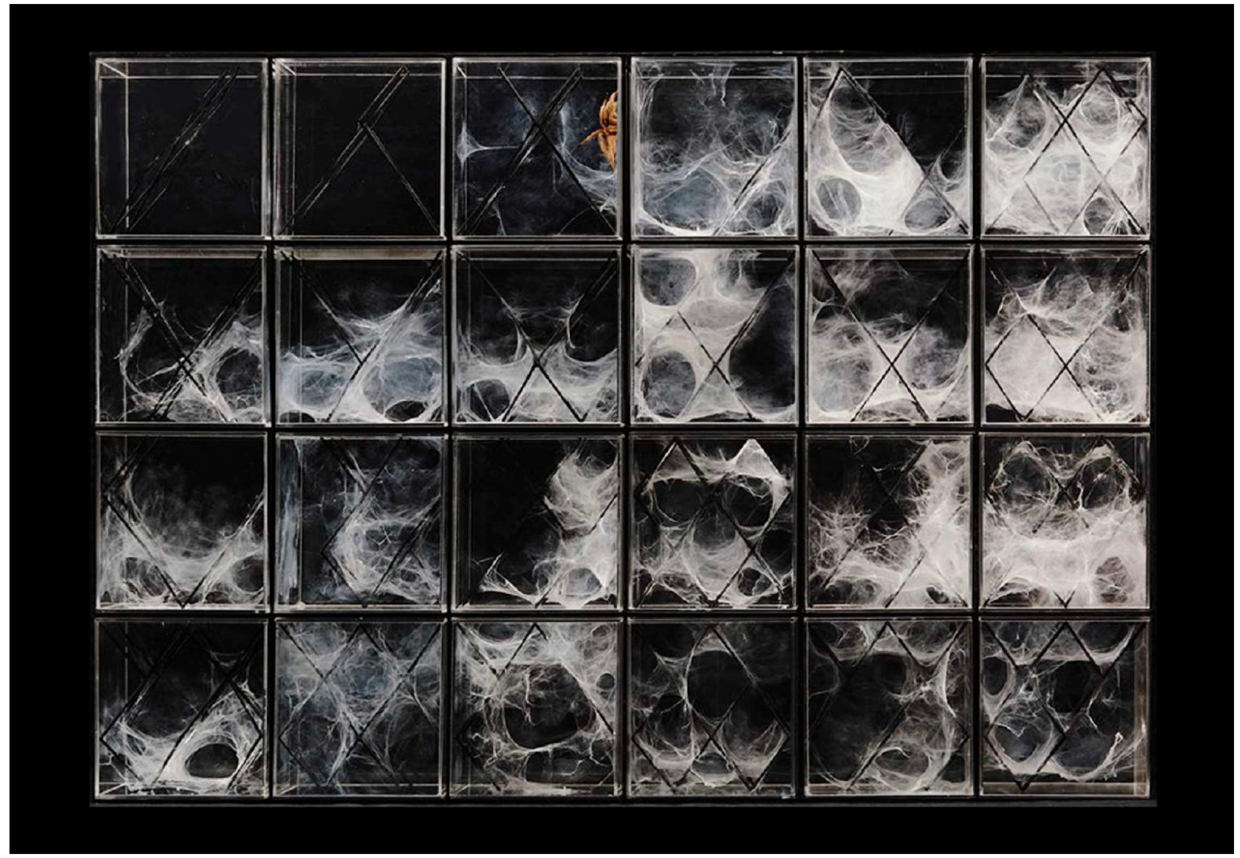


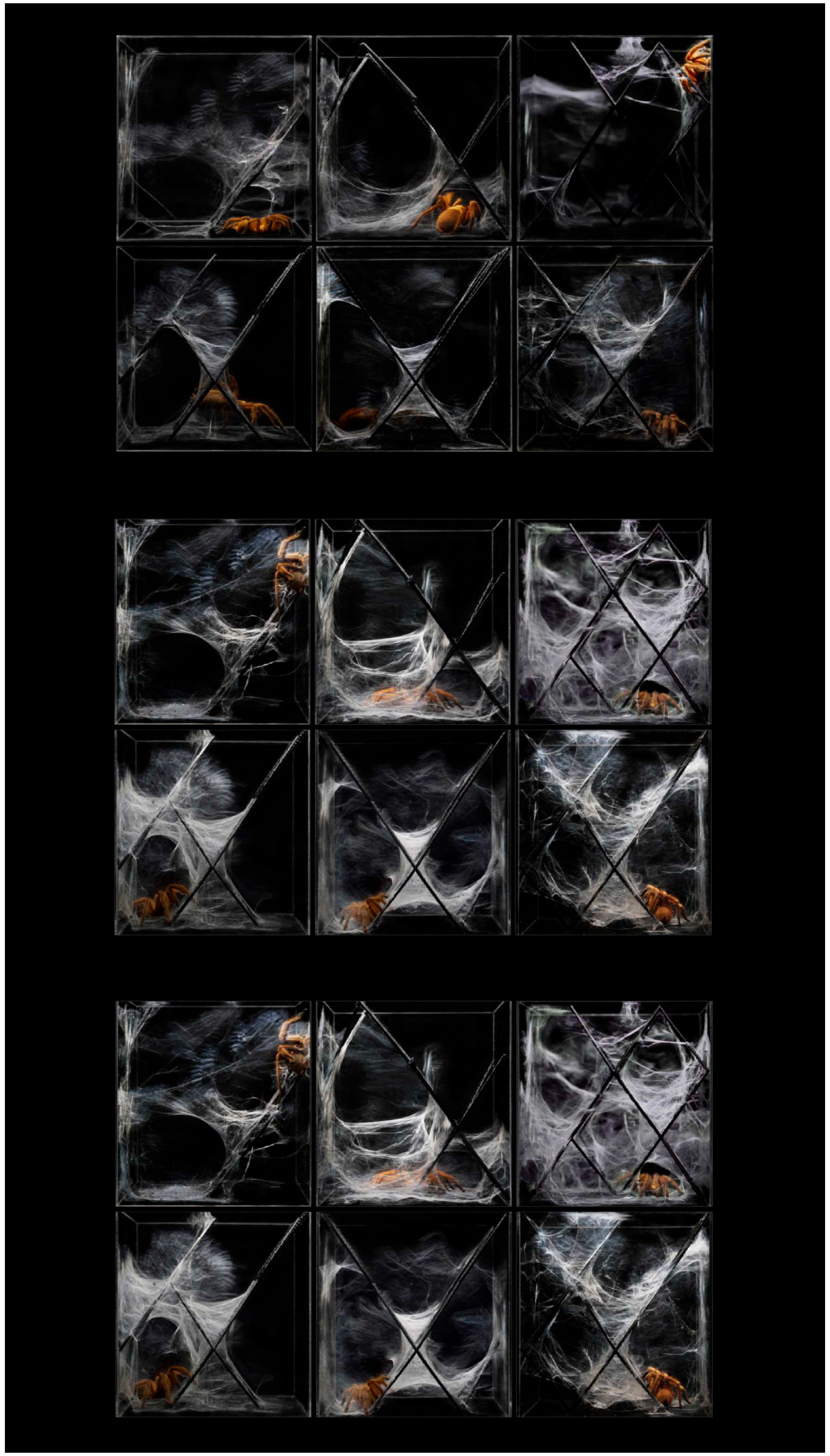
Image by C. Pasquero, F. Nassetti, E. Zaroukas, M. Li, X.Liang.
Figure 6 (previous page): Xenoderma, growth sequence. Image by C.

model, analysing the densities of the spider's web by measuring the intensity of its white colour in the images, and distributing points accordingly in a bidimensional graphic representation.

The movements of the spider can be tracked by using two cameras that record its position within the experimental unit at regular intervals of time; points in 3d space can thus be identified and a curve interpolated between them, that approximates the trajectory of the spider. The 3d scanning of the web is performed with the use of a laser light and a camera (Su, 2018). The light is moved along the depth of the acrylic box in order to progressively show one section of the web at a time, which is then shot and recorded. The individual images are processed by analysing the densities of the web and distributing points accordingly, as described above; it is then possible to stack all these data in a single 3d file and extract a points cloud that approximates the distribution of material of the web.

6. DIGITAL SIMULATION MODEL

The digital simulation model and the design fibrous morphologies it controls are based on an extensive use of the shortest walk algorithm, in the A* implementation that extends Edsger Dijkstra's 1959 algorithm. In graph theory, the shortest path can be defined as the problem of finding a connection between two nodes in a graph such that the sum of the weights of the edges that constitute the



Pasquero, F. Nassetti, E. Zaroukas, M. Li, X.Liang.

connection is minimized (Figure 7). In the simulation model of the Arachnocomputer, the graph coincides with a three-dimensional grid overlaid to the site model. The start and end nodes of the paths being computed are defined by the input of the simulation model, specifically information being extracted from the biological model. The shortest path algorithm computes connections along the grid whose length is minimized.

Different types and resolution of grids can be used, which profoundly affect the outcome of the simulation. The researchers worked mainly with 3d Voronoi diagrams and octahedra/tetrahedra packings. In both cases, edges of the composing geometries are being considered as basic constituents of the graph onto which the shortest walks are computed (Figure 8-9-10-11).

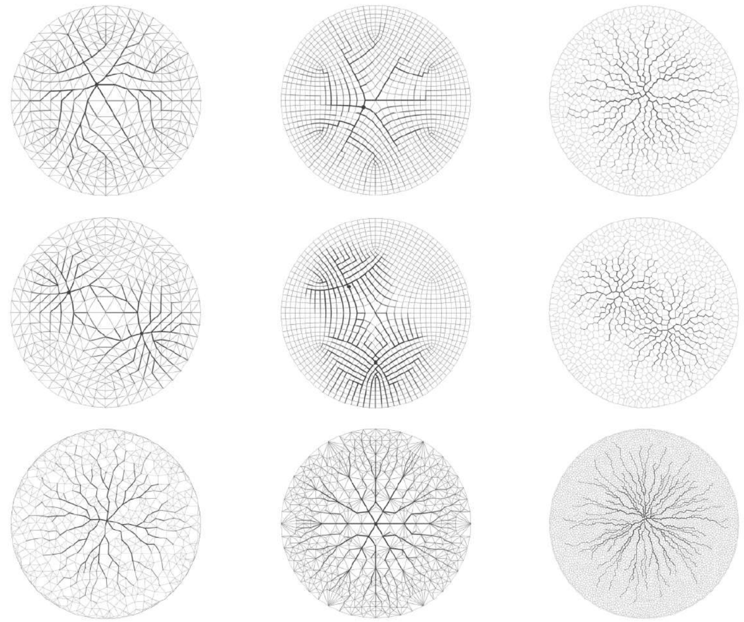
7. THE ENTONOMO CITY

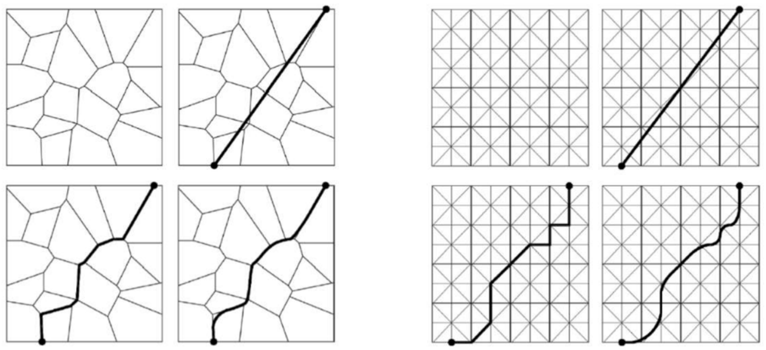
The Arachnocomputation material interface has been applied to the design of the Entonomo City project in the Siam shopping district, in Bangkok. The proposal promotes an entomophagy attitude in the city and makes use of urban morphology as a medium to organize human as well as insects' spaces in the city. Insects are considered by many the food of the future, due to their intense proteins content, at the same time their presence in urban context defines an increase in urban ecology as well as biodiversity.

The researchers identify three main human leisure activities: walking, eating and contemplating associated with a set of four building prototypes dedicated to production, consumption and inhabitation. The prototypes are materialized by a set of redundant fibrous systems 3D printed across the cityscape and defining a synthetic layer over Siam which is simultaneously natural and artificial. The prototypes are identified by the morphology of their patterns and by the numbers that have been generating them, they are form of abstract materialism. In this project, the design of the Arachnocomputer focuses on a skywalk that crosses the Siam district. It is a pedestrian space underneath an elevated train line which the designers seek to transform in a space for distributed food-related activities such as market stalls and gathering spaces. A specific segment is isolated, and abstracted in a digital model, to constitute the site model (Figure 12).

Such site model indicates the relevant features of the biological model with spiders: notably, the size and proportions of the acrylic box constituting in this case the biological simulation framework; the shape and densities of the 3d printed lattice within it. The former mirrors the proportions of the site model, the latter is related to a diagram of the main walking trajectories and pedestrian flows (Figure 13). An Asian Fawn spider is then placed inside the acrylic box and its behaviour is observed and recorded over several days. The spider spins its web in relation to the geometrical constrains of both the lattice and the acrylic box.

The spider is then extracted from the acrylic box once the simulation





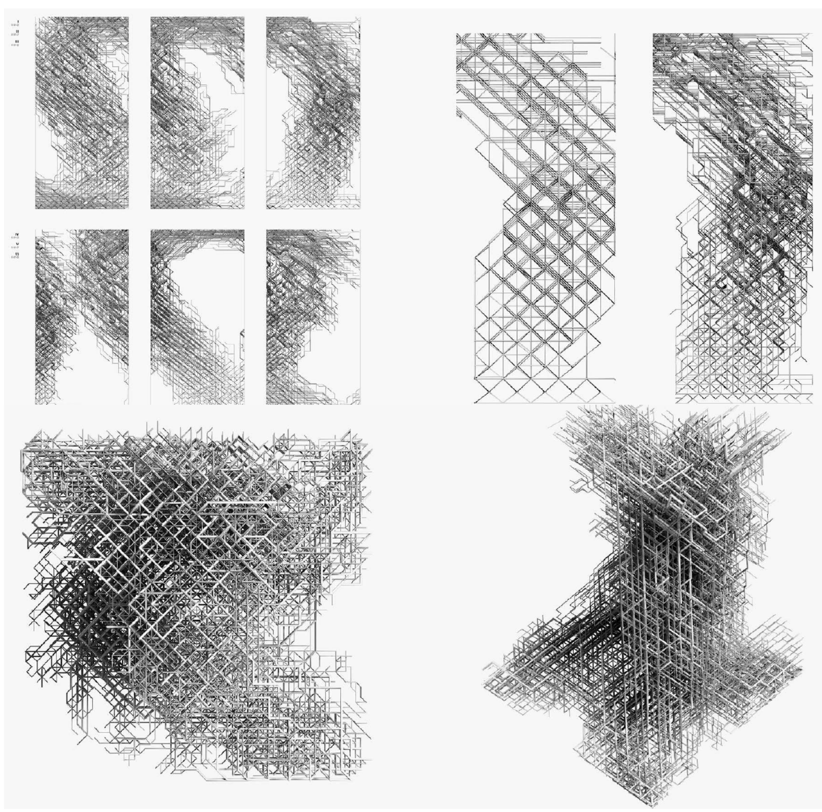


Figure 7
(top previous page):
Shortest walk algorithm.
Image by C. Pasquero, F. Nassetti, E. Zaroukas, T. Casucci, C. Yao, H. Jiang, B. Dong.

Figure 8
(center previous page):
Digital simulation model, octahedral grid. Image by C. Pasquero, F. Nassetti, E. Zaroukas, Y. Huang, Y. Yang, F. Jiang, Q. Luo.

Figure 9
(bottom previous page):
Digital simulation model, octahedral grid.
Image by C. Pasquero, F. Nassetti, E. Zaroukas, H. Chen, X. Guo, X. Zhang.

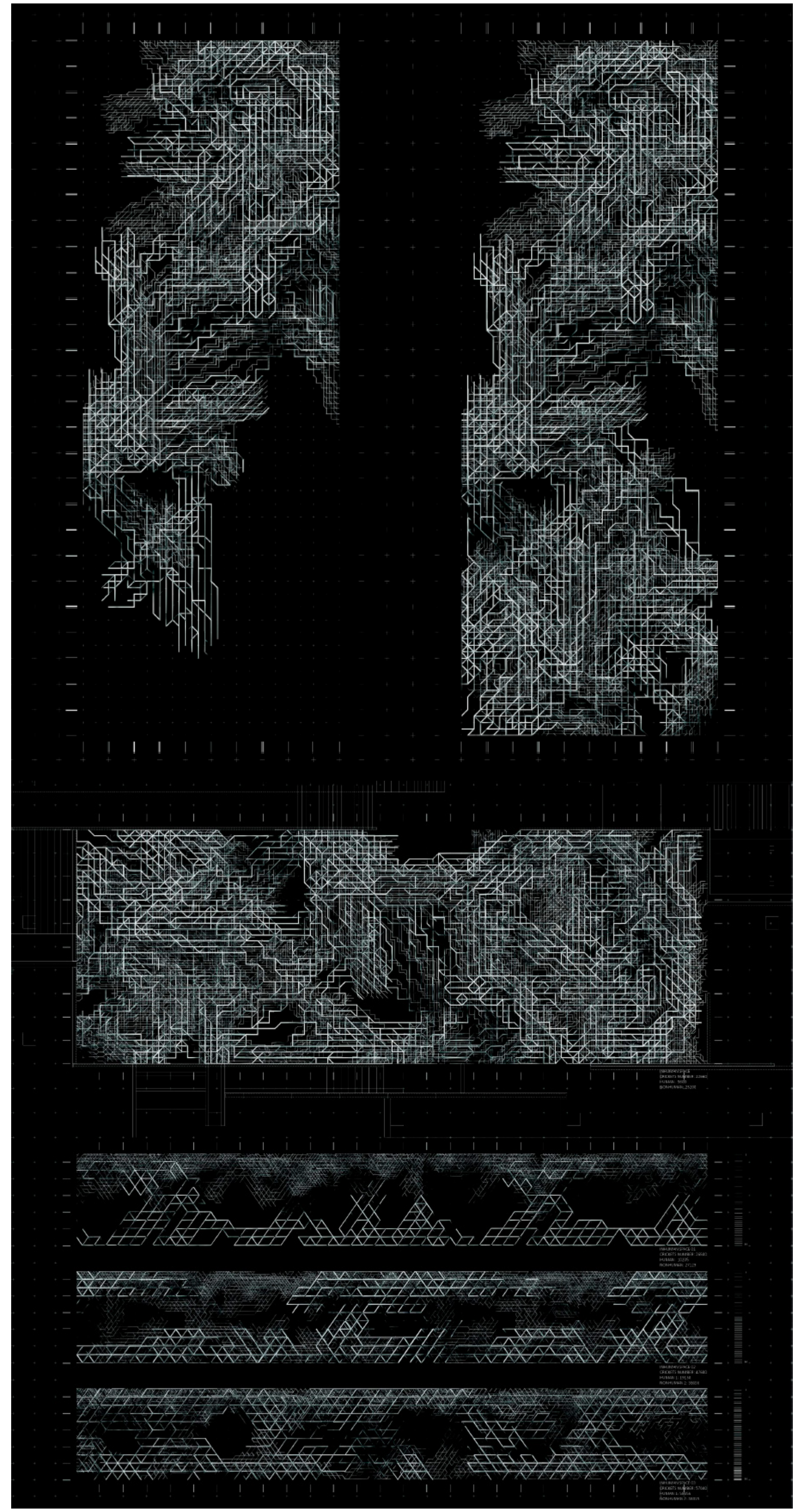


Figure 10 (top):
Digital simulation model, growth sequence.
Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

Figure 11 (bottom): Digital simulation
model, prototype plan and sections. Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

Figure 12:
Bangkok, Siam district, skywalk.
Image by C. Pasquero, F. Nassetti, E. Zaroukas.

reach saturation and the spider web is 3d scanned. The spider's web point cloud is then fed into the digital simulation of fibrous morphologies. The resulting formations change in density, orientation and shape according to the variations of the spider's web (Figure 14). The simulation model is then extended to cover a wider part of the Siam district, envisioning how the same organisational logic and aesthetics can be applied to an extended food district. Patterns of densities extracted from the 3d scanning of the web act as diagram to formulate a protocol of relations with human activities and insects' farming, which is then proliferated to the extended site. The fibrous morphologies of the simulation model are organized according to multiple resolutions and grids, each of which distributes and controls a different programmatic layer of the food district (Figure 16-20).

8. CONCLUSIONS

In conclusion, rather than recalling memories of a better past the inhuman planet forces us to reposition ourselves within a thick metabolic network of processes that recognise no distinction between nature and culture, natural and artificial, organic and mechanic.

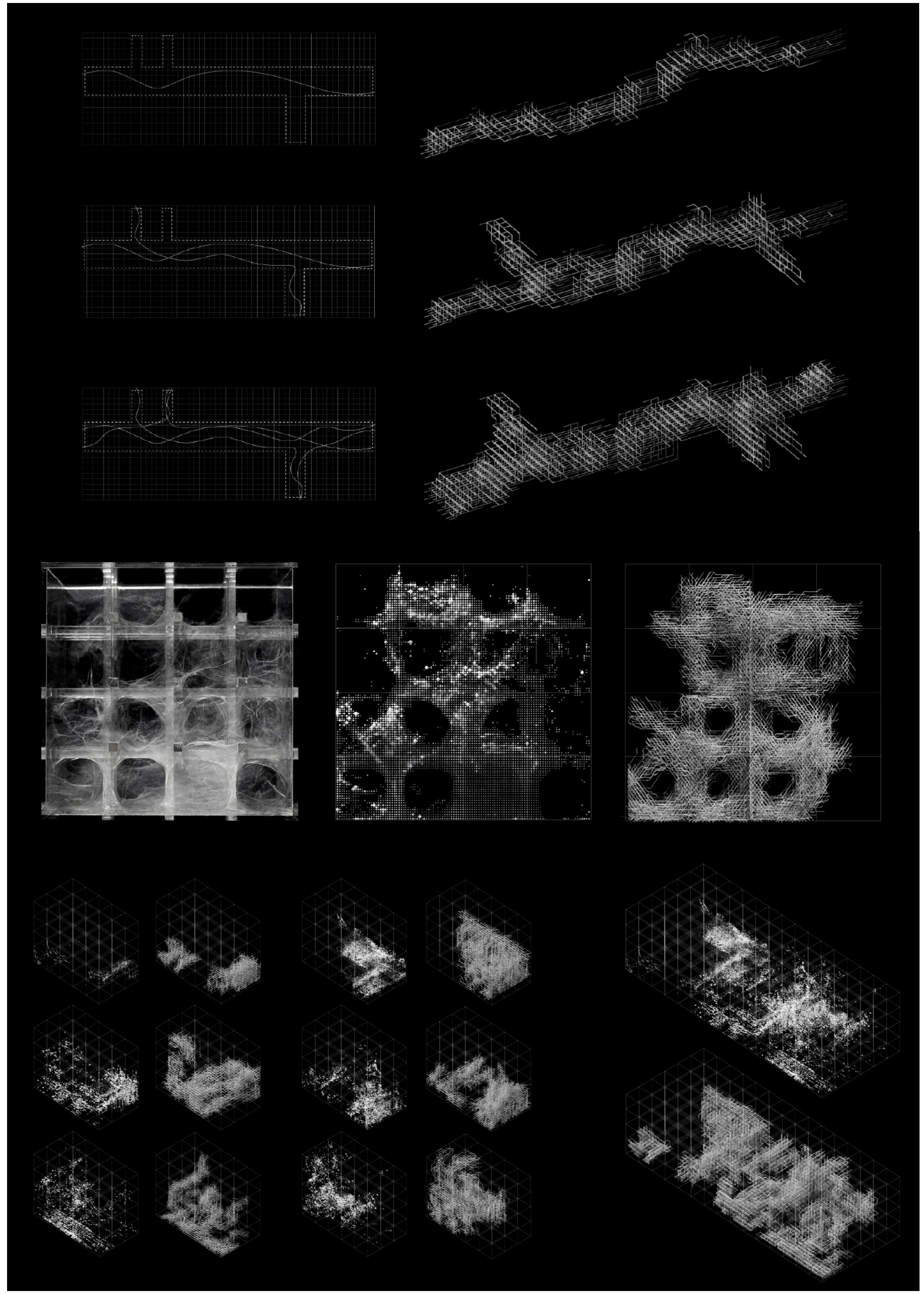
By connecting biological and digital models at multiple levels, the experimentation and projects presented here aim at defining a design method based on the establishment of an extended mind where different forms of intelligence interact: human, artificial, biological. Boundaries among them are uncertain and objects become ambiguous. We are aiming at reforming the planet into a new Earth and in order to do this we are looking to redefine urbanity at cosmic scales of dynamic metabolic circuitry that weaves together processes of heterogeneous genealogies of the machinic that is from biological to computational to mechanical to urban.

The projects discussed in the article bring forward the notion of the

Figure 13
(top next page): Relationship between site model (walking trajectories) and biological model (3d printed lattice).
Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

Figure 14:
Spider's web information processing: from biological model to digital simulation model.
Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

Figure 15
(bottom next page): Spider's web information processing: from 3d scanning of the web to digital simulation model.
Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.



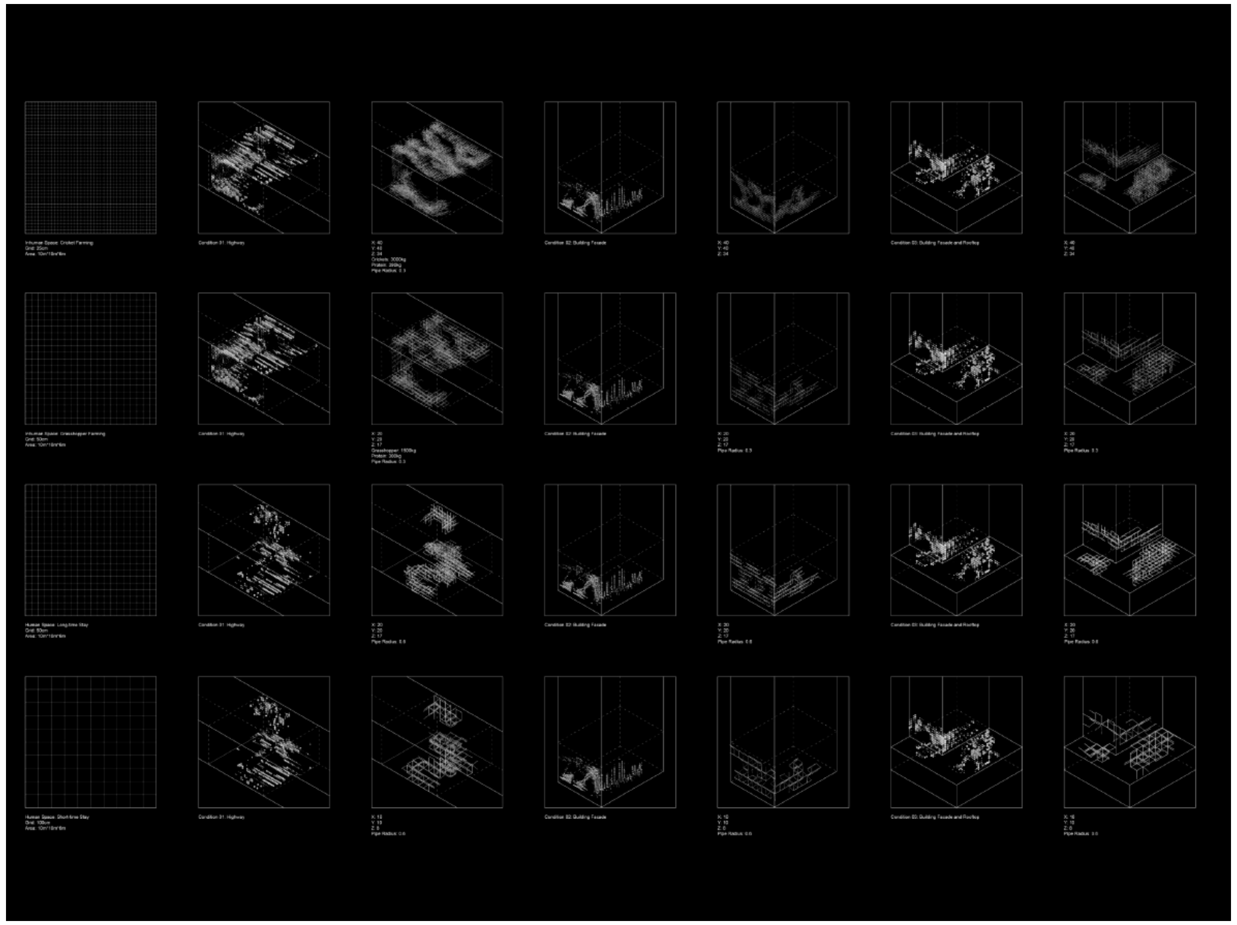


Figure 16: Relationship between spider's web densities and program, catalogue of conditions. Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

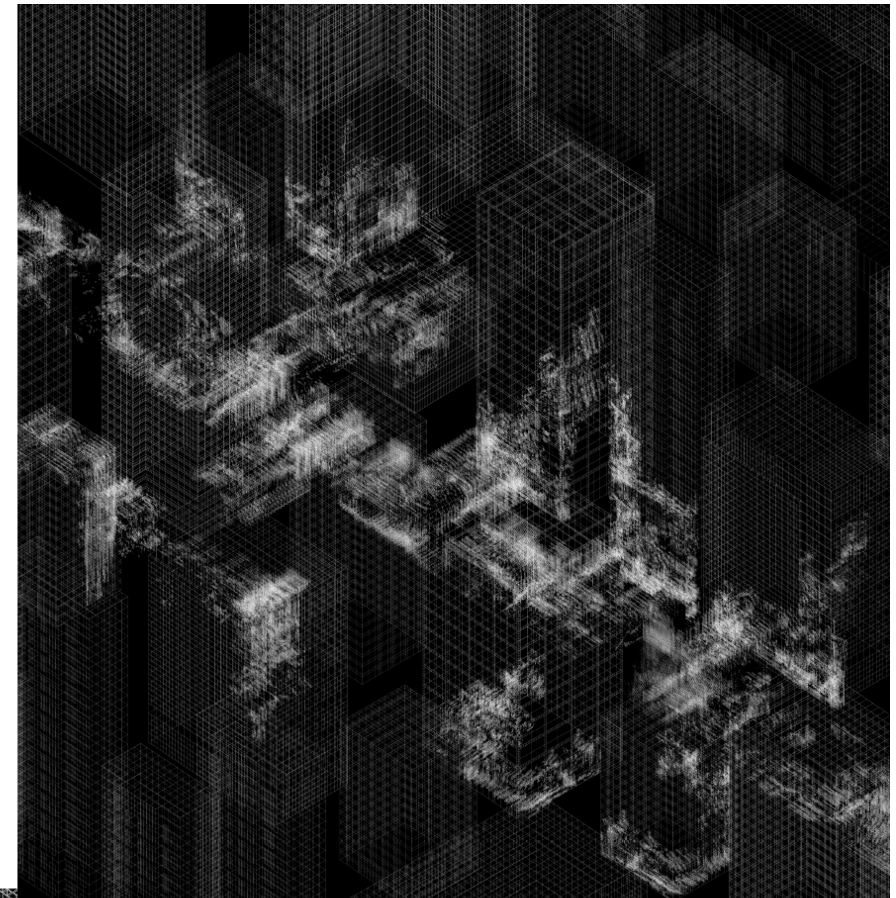
inhuman city, it rethinks the city and the urban in a post-capitalistic future which is designed as form of inhuman society by constructing and investing on what we have called an arachnocomputer.

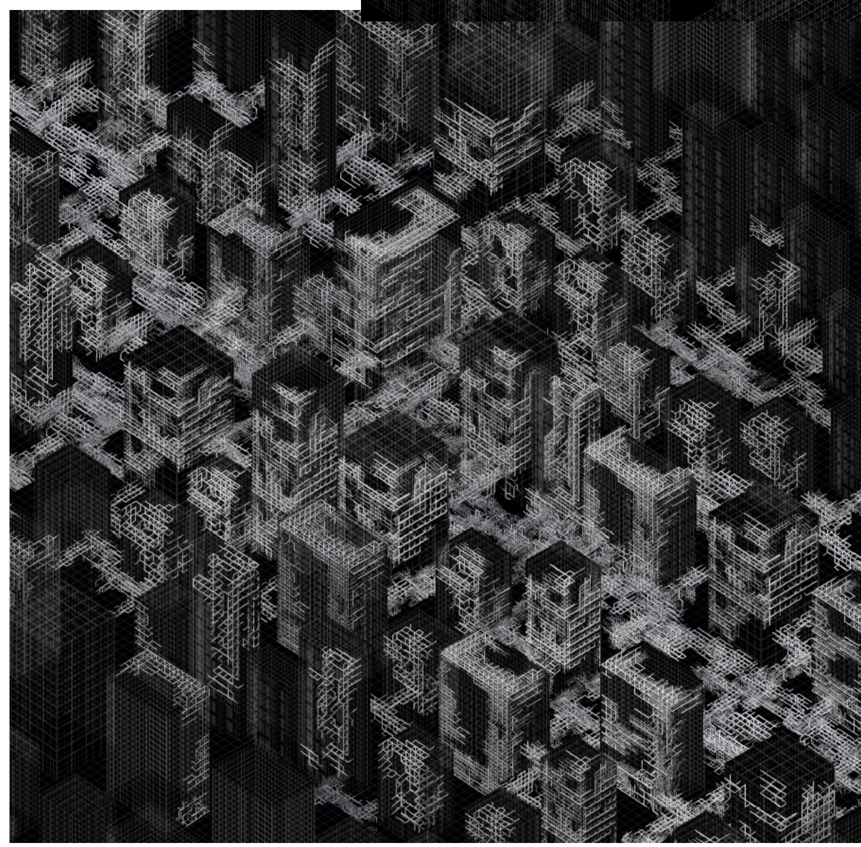
This computational synthesis operates not as a model or analogy but as a proper mechanism of furthering metabolic processes on planet avoiding rifts and dead ends. The inhuman city becomes our starting point for the urban and therefore of a planet of the post-Anthropocene. The authors feel the need to stress again the importance of understanding the Anthropos of the Anthropocene not as the generic and totalising human but the human of a capitalistic order with specific political directions and well established human centric epistemologies.

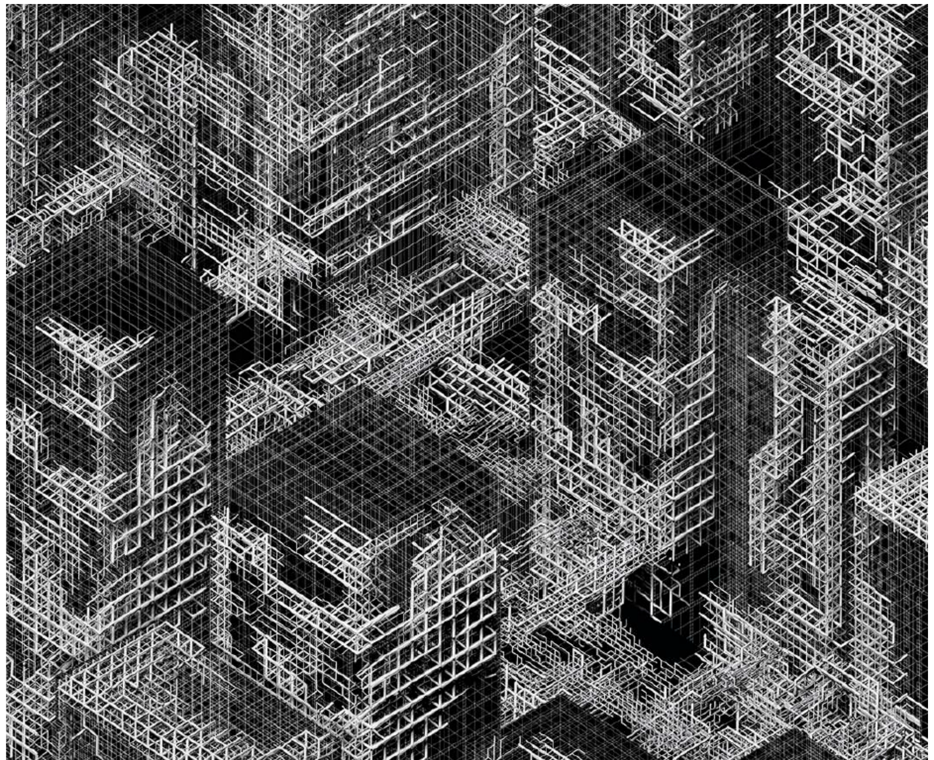
The Inhuman city is our starting point to re-plan the urban in details. Planning in our sense is provisional speculative strategy re-evaluated on the go by context specific tactics.

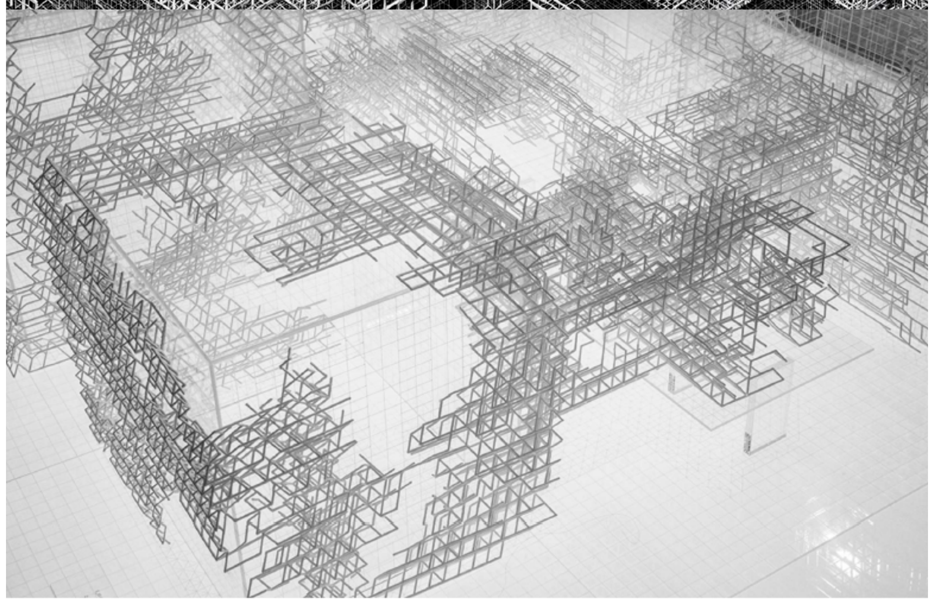
Figure 17 (top): Extension of spider's web information to the whole site. Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

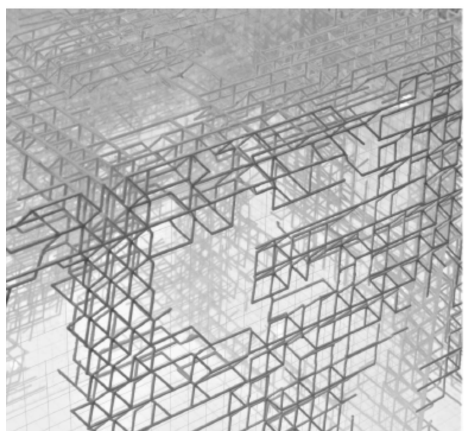
Figure 18 (bottom): Design model, whole site Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.











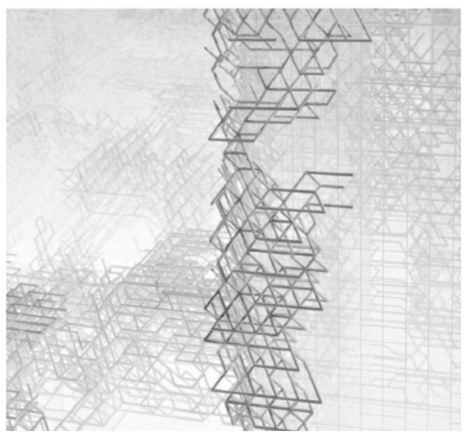


Figure 19
(top previous page): Design model, detail. Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

Figure 20
(bottom previous page): Design model, 3d printed model. Image by C. Pasquero, F. Nassetti, E. Zaroukas, L. Zhu, Y. Sun, H. Ye.

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