Metaxu: Reading Favelas' Material Landscapes with Self-Organised Maps

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Abstract. The paper addresses the concept framework, design and fabrication process of an artefact exhibited at the Venice Biennale 2023. The artefact results from a workshop with architecture, civil engineering, and design undergrad students. The concept spun around exaptation as a possible strategy for resilient landscapes – in our case, in the context of favelas. The object expresses a machine reading of favelas to create an abstract landscape from its materials. The landscape was obtained with a pipeline of unsupervised learning algorithms and parametric design that read images from favelas, extracted their features, and translated their latent space into geometry. The paper focuses on the methodology without neglecting a critical view of conceptions and meanings of favelas. It covers four parts: 1. Discuss the preeminent concepts; 2. Detail the design phase steps and methods; 3. Describe the fabrication techniques; 4. Discuss the results and exaptation from the favela's point of view.

Keywords: Cultural Landscapes and New Technologies, Favela, Exaptation, Machine Learning, Self-organising Maps.

1 Introduction

The global change now underway not only brings history to the world but also makes the power of the world precarious, infinitely fragile. Once victorious, the Earth is now a victim. (Serres, 1995).

For, in the end, there is only one world. It is composed of a totality of a thousand parts. Of everyone. Of all worlds. […] We are all part of it, and we all have a right to it. The world belongs to all of us, equally, and we are all its coinheritors, even if our ways of living in it are not the same, hence the real pluralism of cultures and ways of being. (Mbembe, 2017).

This paper narrates the concepts, methods, discussions and fabrication process of an artefact exhibited at the Collateral Event "Global mass, living mass: Students as Researchers" as part of the Venice Biennale 2023. The

event was idealised, held and curated by Marcella del Signore and Maria Perbellini from the New York Institute of Technology, with the participation of 23 other universities worldwide and influential architecture studios, such as OMA, Zaha Hadid Architects and Morphosis.

The exhibition title evoked two arguments to provoke the participants. First is Emily Elhacham's publication in Nature Journal announcing that the anthropogenic mass exceeded the living mass in 2020. As a result, *beyond biomass, as the global effect of humanity accelerates, it is becoming ever more imperative to quantitatively assess and monitor the material flows of our socioeconomic system, also known as the socioeconomic metabolism* (Elhacham et al., 2020). With this statement, Elhacham's group invite researchers to investigate the material basis of society, its mass composition, material stocks and flows on local and global scales. The study also emphasises the overload of buildings and infrastructure, composed of concrete, bricks, aggregates and asphalt, as the dominant human-made mass category. In other words, it puts the urban footprint and architecture's material foundation spotted on.

The second argument underlines the paramount role of the coming architect's generation – the students – in finding potential solutions. Their freshness stimulated by a threatened future may fuel the creation of new tools to mitigate the problem instead of using the same tools that originated the situation in the first place to fix it. Thus, participants were stimulated to create new radical pedagogies that break down the traditional role of teachers as knowledge transmitters and students as passive receivers. The moment calls for an innovative approach in which educators become facilitators and learners are encouraged to question, explore, and actively engage with the matter. Together, as a team of co-creators, standing shoulder to shoulder.

The curators assigned a space of a 50 x 50 x 50 centimetres cube for each participant institution to develop an artefact to convey the proposed theme. From the conceptual standpoint, the hosts proposed the umbrella concept of *exaptation* (Gould & Vrba, 1982) as a possible architectonic strategy to build more resilient landscapes in the face of climate change.

In our proposal, we elected the context of *favelas* – the Brazilian version of slums – as our case scenario based on another critical urban milestone: in 2008, the urban exceeded the rural population. Although the shift towards urbanisation is a global trend, and its environmental impacts challenge humanity worldwide, the adverse outcomes tend to be unequally distributed and concentrated in marginalised and low-income areas. Indeed, urban informality is often the primary mode of 21st-century metropolitan space production (Roy, 2009), making informal housing builders the largest in the 21st Century. Thus, they are creating the cities of tomorrow.

Conceptually wise, instead of exploiting new paths in the same trail of spending natural resources and disrupting ecosystems, the aim was towards a "natural contract" (Serres, 1995), able to balance the power of our global, artificial, and needed interventions with the world's naturalness. In this setup,

the emerging academic student is a *knowledge troubadour* (Serres, 1995) engaged in a public talk outside the academic trench. Artificial Intelligence is the instrument to process the massive corpus of formal and informal knowledge; unsupervised learning is the tool to explore unlabelled data, and man-machine cooperation is the method to depict complexity.

2 Methodology

The design studio had an intense workload with a strong collaborative research atmosphere. The team gathered six undergrad students from architecture, design and civil engineering, the author – a trained architect – and one PhD candidate in design. Over three months, the team met three times a week, each session spanning five hours. The studio project unfolded through three sequential phases: first, the formulation of a robust conceptual framework; second, a series of design experiments to create the object while iterating upon the proposed framework; and finally, the intensive fabrication phase, marked by extended hours including weekends, to expedite the artefact's production and delivery. Each step is detailed in the next session. The following tools and methods were used to navigate through each phase.

- Individual research, followed by presentations to the group and collective discussion: this method was essential to quickly cover the largest possible number of publications. At the same time, the communal debate enabled us to build a critical view of the concept and, more importantly, to criticise each raised concept in the contexts of architecture and favelas.
- Collective readings of philosophy authors, followed by discussion and group interpretation: the philosophical analysis brought the abstraction and distancing necessary for expanding and strengthening the conceptual construction, thus avoiding self-absorbed understandings.
- Use of murals as recording devices: a physical mural was used to list, study and build relationships between words and concepts arising from discussions in a more spontaneous interactive manner. The online platform Mural was used for presentations and to store and share discoveries, word clouds, references, history of design experiments and syntheses.
- Construction of a trustworthy, hierarchy-free environment where all attendees were empowered to talk, propose, and disagree.

2.1 Conceptual framework

The research had its kick-off with well-defined beacons by the hosts, as seen above. Less obvious was to reach an accurate definition of exaptation. What is precisely exaptation, and how does it differ from adaptation or side effects? And

more importantly, what would it mean in architecture and favelas' environments?

Three conceptual guidelines imposed their significance in this context. The first is Michel Serres's (2013) expanded multi-disciplinary idea of "the parasite" as a metaphor for understanding the interconnectedness of natural elements, society, and culture. The book examines how parasitic relationships in language, technology, and cultural dynamics influence growth and adaptation. Serres' parasites catalyse evolution and innovation by maintaining diversity, favouring cultural traditions' diversity and uniqueness and fighting against the homogenisation of culture. In Serres's view, parasitism plays a crucial role in shaping our world since dominant cultural and technological forces often stifle the creative potential of parasites of less favoured classes, such as favelas. Serres' parasites provide a powerful figure for exaptation, as both concepts deal with something adapting to evolve to fulfil new unforeseen purposes or functions.

The second guideline is the concept of gardening, inspired by Carolina Levis' (et al., 2017) research team on how Amazonian civilisations domesticated the forest, which serves as a design guide to bypass the parasitism to symbiotic parasitism. The definition of landscape accepted worldwide – an area perceived by people whose character is the result of actions and interactions between humans and/ or natural factors – already carries a robust anthropogenic aspect. However, the discovery of Amazonian gardening challenges the established vectors of *hemeroby* (Sukkop, 1972): How can we measure the naturalness of "natural" areas? What materiality are we cultivating in favelas?

The last concept came from Byung-Chul Han's publication "Saving Beauty": the thought-provoking *aesthetics of the smooth* (Han, 2017). Han provided a critical guide to contemporary aesthetics by opposing the "natural" and "digital" beauty. He criticises the absolute objectivity of modern society that transforms, discretises, and calculates nature as if it was a mirror of humanity: oriented to efficiency, productivity and positivity, to be integrated as merchandise and valued by its utility. Furthermore, Han inspires an intriguing conflict about the digital. On the one hand, it helps us engage with massive datasets and variables. But, on the other hand, this same complexity is customarily dissolved into an "average", an "aesthetics of the smooth". Thus, Han denounces eliminating the otherness, the strange, the odd, and the consequent loss of the ability to appreciate beauty in unexpected and informal environments such as favelas.

Those three concepts were confronted with the hosts' proposition around exaptation. The term coined by Gould and Vrba in 1982 refers to traits or features that have evolved for one purpose but later served a different function. Essentially, a trait initially with no adaptive value or different values might become advantageous in a new context. A classic example is the birds' feathers, likely evolved for insulation or courtship displays but later exapted for flight. Exaptation is, thus, *the missing term in the science of form* (Gould & Vrba,

1982) that opposed the orthodox evolutionary theory and reinforced the importance of multiple environmental pressures in biological formations (Thompson, 1917).

But what distinguishes ‘adaptations’, ‘exaptations’ and ‘side-effects’ (Buss et al., 1998)? Charles Darwin, the father of evolution, introduced the concept of adaptations in his book “On the Origin of Species” (1859). In short, *adaptations* are traits that have evolved to increase an organism’s fitness or ability to survive and reproduce. They are often the result of natural selection, the process by which organisms with traits better suited to their environment are more likely to survive and reproduce, passing on their genes to the next generation. For example, a polar bear’s fur is an adaptation that helps it stay warm in cold climates. On the other hand, side *effects* or *by-products* (Gould & Lewontin, 1979) are traits that are not directly beneficial to the organism but are not harmful either. They are often the result of other adaptations or exaptations but do not affect fitness.

One last insightful biologist completed the work’s theoretical foundation; this turn, with contributions to think about the generative process of the artefact’s design. Richard Dawkins (1986) argued that the “design” by a designer, which he calls the *watchmaker*, will never excel the “design” perfected by natural selection, evolution, and exaptation in elegance, complexity, and finesse. Despite being a blow to design-related professions, Dawkings validated the pursuit of generative design in architecture. After all, it is the same engine beneath natural selection. A *generative method* is, thus, a nature-inspired process to create complex forms and optimise design solutions (Hovestadt et al., 2020).

Alessandro Melis (2020) introduced and further developed (Melis & Pievani, 2022; Melis et al., 2022) the term exaptation in architecture. Melis proposed two main groups - niche construction and redundant structures - from which he derived a five-categories taxonomy (Melis et al., 2020): (1) Functionalisation of existing geomorphologies; (2) Integration of function in existing structures; (3) Re-functionalisation of function in existing structures; (4) Integration or change of use; (5) Temporary appropriation of space. Melis distinguishes adaptation as the architectural design *per se*, which assigns a function *a priori* to the designed structures, while exaptation is a form of adaptation-non-adaptation because it occurs by functional co-option *a posteriori*.

Melis has a thought-provoking interpretation that instigates reflections. However, a salient observation that becomes apparent is his focus on function. Although the debate around function and form is complex and long-established in Architecture, Dawkins (1986) shows that it differs from Biology in at least two seminal points: purpose and agency. In Dawkins’ (1976; 1986) view, biological functions emerge from a long process of evolution, devoid of any *a priori* purpose or intelligent agent’s deliberate design. In contrast, engineers, architects and designers are conscient agents who create design stances with specific purposes in mind, even in functional repurposes of spaces *a posteriori*. Looking through Monod’s (1974) lenses, in Biology, a function is a contingency;

in Architecture, it is a necessity. Although the function of an architectural structure can change over time, it is always driven by human necessity. Ultimately, the very notion of function is human. So, how do we redefine exaptation in architecture as an internally emergent trait rather than an externally designated function by humans?

The question forked into material-based explorations and less focused on spatial-functional approaches. After all, favelas are the place *par excellence* for constant change, innovation, appropriation and adaptation. Thus, architecture's materiality seems a convincing way to introduce exaptation in favelas.

2.2 Design explorations

In spite of the robust conceptual framework, translating theory to design was challenging. The design stage enclosed two stages, both founded in generative processes. The group experimented with a more "traditional" parametric design approach with Rhino and Grasshopper in the first attempts. The plug-ins Culebra, Stella, Heteroptera and Physarealm, empowered with agent-based modelling components, were first tested. Despite the compelling results, two questions were raised: 1. it would forsake exploring exaptation from the optics of materiality instead of behaviour; 2. ironically, the beauty of the generated objects laid on their complexity, which, in turn, was too complex to materialise with the available resources and time.

The next stage took a step further to artificial intelligence algorithms. Initially, students used generative AI text-to-image platforms like Mid-journey and Dall-e for inspiration. Then, they modelled the most attractive outcomes in Rhino using point cloud algorithms to translate shapes into a 3D model. The difficulty here was translating the dense concepts framework and the challenging context of favelas into effective prompts.

Figure 1. Images produced by the students and created with text-to-image in Dall-e and Runwayml. Source: Author, 2023.

Next, the team experimented with a workflow of generating interpolated images with stable diffusion models in Google Collab and then building a 2.5D form using Grasshopper. The students used a customised algorithm to search and retrieve images from keyword queries. The words could express any of their interest, such as “mycelium”, “thorns”, and, of course, “favela”, and related words like “barraco”. After selecting the desirable ones from approximately 5,000 images crawled, the data was loaded in Runwayml, an open AI toolkit platform, to generate the frame interpolations. A post-process step extracted the alpha channel of each frame created. The dataset was finally loaded in Grasshopper, and the plug-in Monolith produced the 2.5D from the stacked images. The purpose of this exercise was to manifest favelas’ complex materiality spatially. Yet, despite the appealing outcomes, it did not scream exaptation loud enough.

2.3 Final concept

The journey, interspersed with several high-level design exercises and critical confrontations with the conceptual framework and exhibition briefing, played a crucial role in instrumentalising the team to elaborate and materialise the final design idea. The group stepped back, turning to the exhibition slot - the cube: a platonic solid, loaded with cross-cultural symbolism, that expresses, among many meanings, spatial reasoning. Favelas are indeed self-organised urban fabrics that may look purely entropic and unreasonable to an external observer. However, a closer examination reveals careful calculations, space optimisations and hidden patterns. So, how could we express such a “self-organised rationalism”, and what AI method would convey that?

A self-organising map (SOM), or Kohonen map (Kohonen,1982), is an unsupervised learning algorithm that helps visualise and group complex data by finding patterns and similarities. They arrange data points so that similar ones are closer, making it easier to understand and analyse large sets of information. In doing so, SOMs imitate the human brain’s ability to recognise patterns by clustering and mapping similar features. It also emulates natural behaviour such as competition and cooperation. The advantage of AI is that it allows us to deal with massive amounts of data that usually exceed the human capacity for comprehension. Thus, SOMs are potent tools to unveil favelas’ hidden rationalities and material patterns.

To compose the Favelas’ SOM, the team filtered 1,244 favela-related images in the crawled dataset and cropped them into 224 x 244 pixels, originating 25,515 crops. This pixel size fits the VGG16 transfer learning model elected for the task. The dataset was split into 12 categories of materials in the picture: asphalt, bricks, plaster, plastic, grout, zinc, wires, concrete, humans, sky, vegetation, panoramic and objects. The objective was not to picture favelas’ materiality precisely but to have a flavour of their dominant elements.

To express the rationality in favelas, we opted for a squared SOM with 1,444 squared pictures plotted on a 38 by 38 grid, respecting the classes' proportions. Similar-looking images were placed together, forming clusters while maintaining the integrity of class categories—such a procedure created amusing border zones between types. Then, the algorithm computed the cosine proximity between every image in the grid and the remaining pictures in the dataset. Resembling images were stacked together in the grid with the same (x, y) coordinates. Finally, the point positions with the corresponding RGB values were exported to an Excel sheet and translated into geometry in Rhino/Grasshopper. Higher sticks mean more recurrent materials in the dataset. The colours indicate the dominant RGB value of that particular image. The RGB file was extracted using Python code.

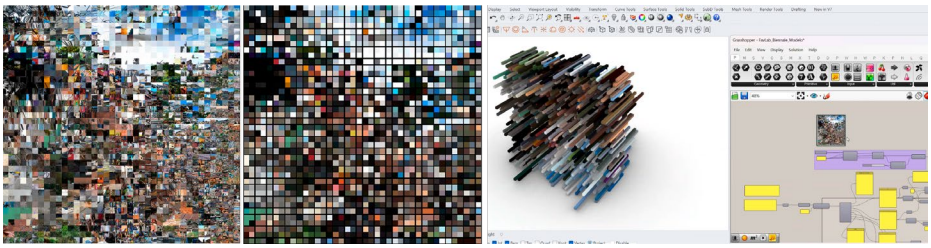

Figure 2. Favelas' self-organising map and its translation to RGB and 3D.
Source: Author, 2023.

2.4 Production

From production to assembly, it was created a model-to-machine strategy. The Rhino/ Grasshopper model concentrated all the information needed for the digital fabrication, painting, and assembly. One sensitive aspect was carefully handling information to avoid missing any part of the several layered data, especially the sticks' positions. The laborious and time-consuming production phase had three main straight-forward components:

(1) A base and a grid to support the sticks fabricated with laser cut.
(2) The sticks. The expanded PVC sticks were cut in a CNC machine, manually sanded, and numbered in an i-j matrix scheme. A colour map with the RBG values translated to available spray paint colours was created to guide the painting and the assembly.
(3) Assembly. The sticks were mounted in columns and then glued to the base. The final piece was stitched with transparent plastic wires.

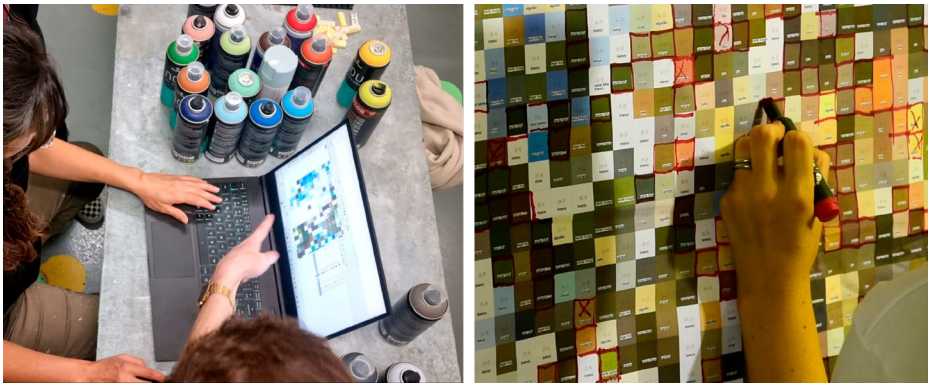

Figure 3. Colour map used in production**.** Source: Author, 2023.

2.5 Results

As a result, the proposed design reflects a constellation of ideas that are not opposed but rather work as questions, polarities or sides of the same unified world that create one shared *metaxu* (Weil, 1997): natural and artificial, favelas and city, smooth and rough, entropy and negentropy, organic and inorganic, discrete and continuous, transparent and opaque, homogeneous and heterogeneous, negative and positive, agency and inertia, material and immaterial, rational and irrational, formal and informal, form and inform.

Figure 4. The artefact at the exhibition – Centro di Studi I Documentazione della Cultura Armena**.** Source: Author, 2023.

3 Discussion

The artefact depicted in this paper aimed to experiment with favelas' material rationality in the context of an academic exhibition guided by the concept of exaptation. It is not a political statement *per se*. Nevertheless, some

ethical and social implications were not ignored. In particular, we aimed to discuss three main issues. First, favelas and their variations worldwide are usually defined by what they are not or lack. For instance, UN-Habitat (2020) uses the word ‘lack’ 24 times in a 29-page report about adequate housing and slums upgrades. From the outside, whether Rocinha or Seelampur, they are usually blurred under a veil of impoverishment and dysfunctionality (Simone, 2019). However, defining them by what they ’lack’ is no longer enough (Souza et al., 2020), but rather an imprisoned conception of identity that chains favelas to an essential image of ‘chaos’.

Second is precisely the hegemonic concept of ‘order’ and its counterpoint – the ‘chaos’, specifically the perception of ‘urban chaos’ that has dominated the ways of representing, defining and working with favelas: *we consider inadequate the representation that there is no order in the favelas; there, in the regulatory absence of the State, daily practices of coexistence were forged that allowed the construction of a rich set of codes and sociability* (Souza et al., 2020). Thus, SOM worked as a translation rather than a representation of a “displaced rationality” to be confronted with the pre-existent sense of “real rationality” (Fanon, 2008).

In this contextual framework, the objective was to offer an alternative to Virilio’s (2005) negative perspective on the inundation of media, particularly images. Rather than allowing the memories sourced from the internet to devolve into *junk shops - repositories of diverse and unrefined images, haphazardly accumulated* (Virilio, 2005: 38), devoid of narrative or historical context (Han, 2015), we harnessed AI’s logical architecture to establish causal connections between the images. Through this deliberate approach, we effectively subverted the conventional attribution of causality to favelas, culminating in constructing an innovative narrative concerning an enigmatic landscape that reconciles the grid’s structured ‘order’ and the unstructured ‘formlessness’ of clusters.

Third, this focal emphasis on transformative evolution as opposed to rigid identity (Han, 2015) orchestrates a dynamic interplay between the illumination of reason - facilitated by AI - and the obscurity harbouring latent patterns. Upon recognising each discernible pattern, the opportunity for subsequent interaction emerges. Looking at exaptation and favelas through the lenses of materiality opens up a myriad of research opportunities—for instance, the modes and materials of urban production and work organisation around its construction as imperative agents for urban transformation (Santos, 2013).

Undoubtedly, inequalities must be overcome in all their senses, including the urban conditions of people’s lives and housing. Nevertheless, it is imperative to appreciate and incorporate sociocultural variations into urban policies, preventing the imposition of standards and norms that stifle diverse experiences and communal utilisation of the space. Doing that is not to condone the contemporary tendency to disguise the negativity in favour of a positive society (Han, 2017) that creates slogans such as “the favela has won” to substitute the XX Century mote “cities without slums” (Davis, 2006). Instead, it

aims to use research to find more productive ways to tackle problems and leave the vicious circle of pointing guilt without going to the core or offering way-outs.

4 Final Remarks

The research depicted in this paper has yielded multifaceted contributions. Primarily, it has catalysed a novel pedagogical approach grounded in the ethos of discovery. We also offered a compendium of methodological tools to inspire and guide others venturing into similar domains. Moreover, our efforts have produced a unique understanding of architectural exaptation, influenced by observations drawn from a proficient machine learning method that reveals concealed materiality patterns in favelas. This newfound vantage point has, in turn, engendered a critical re-evaluation of exaptation's implications in architectural discourse and advanced an interdisciplinary framework accommodating subject complexities. Finally, addressing ethical and social concerns, the discourse expanded discussions on favelas, enhancing awareness of their intricate urban dynamics.

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