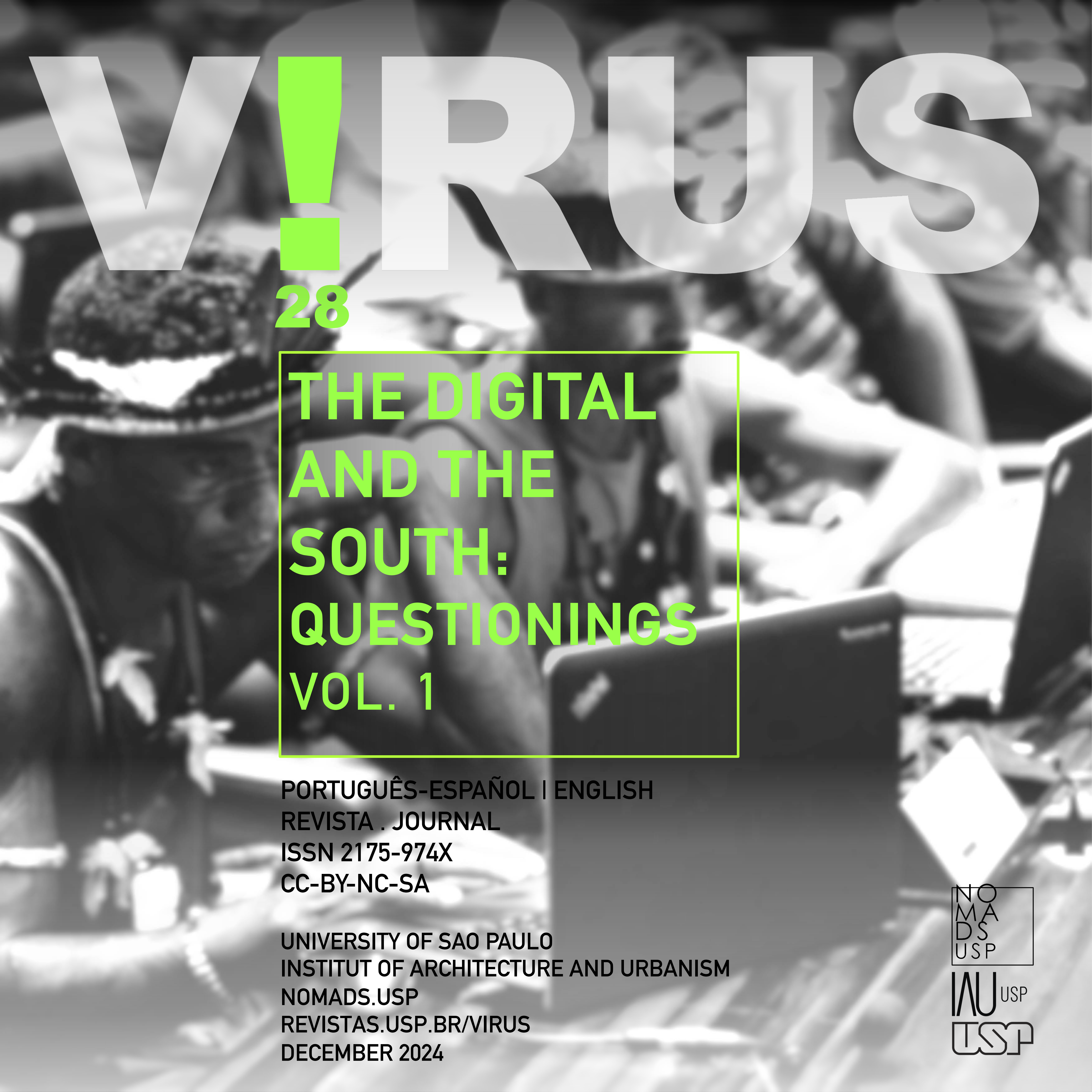

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The theme of issues 28 and 29 of V!RUS journal, “The Digital and the South: Questionings,” aims to critically explore the connections between digital media and the peoples of the Global South in various dimensions in this second decade of the 21st century. While recognizing digital culture's benefits to many aspects of human life, we also seek to highlight the inherent tensions in these connections.

This theme arises from an ongoing reflection process at Nomads.usp - Center for Interactive Living Studies, which publishes V!RUS. The Center was established in 2000 amidst the remarkable optimism that followed the Internet's opening to public access in 1994. Distributed network communication – a network of networks – brought promising perspectives for horizontal communication and free access to information. This environment stimulated the development of numerous computer programs, devices, and systems that permeated all areas of knowledge and aspects of life. Over the past twenty-four years, we have focused on exploring the limits and potential of digital, particularly in how it relates to the conception, approach, and documentation of built spaces. We have broadened this concept to include the spatialities arising from the hybridization of physical and digital environments and their dynamics.

The theme proposed for these two issues of V!RUS arises from a growing concern—one that we share—about the direction in which the digitalization of life has taken society. This trend has scrambled values and beliefs, distorted public debate, and reinforced asymmetric power relations on a global scale.

The papers published in these two issues have been selected rigorously through close collaboration among the authors, reviewers, and the journal’s editorial committee. They encompass two sets of sub-themes. The first set, presented in V!28, includes papers that analyze the applications of digital technologies and their implications for urban dynamics and architectural design and production, focusing on perspectives from the Global South. The second set, featured in V!29, includes papers that discuss the conceptual, social, political, and technopolitical aspects of the spread of digital technology worldwide, particularly among the peoples of the Global South.

Issue 28 features eight articles authored by researchers from various countries and states within Brazil. It also includes an interview with Professor *Gabriela Celani* from the School of Civil Engineering, Architecture, and Urbanism at the State University of Campinas, Brazil. At our invitation, Celani gave us the interview titled The Digital as a Collective Practice, in which she explores **collective ways of doing things** in light of her career as a researcher and educator in the field of Architecture and Urbanism.

The emerging possibilities for using **Artificial Intelligence** are addressed in two contexts: in the production of images and their political implications in the field of Art, as discussed in *Giselle Beiguelman*'s article Machinic Eugenics of the Gaze: Computer Vision, Ageism, and Gender, and in processes of form generation, examined in *Alberto Fernández González*'s article From Cellular Automata to AI and Fabrication.

Two papers address **digital at the urban scale** in cities in the South. *Vinícius Lopacinsk* discusses the impacts arising from the use of advanced surveillance and control technologies in urban spaces in the article What Happens when the Smart City Crashes?. Meanwhile, in their article Urban-digital Layers: From Global Internet Infrastructure to Dark Kitchens, *Aline Cristina Fortunato Cruvinel* and *Luisa da Cunha Teixeira* examine how platform companies influence new dynamics and urban spatial typologies.

Two contributions address **the use of digital images to study built spaces**. The first is the article Collaborative Platforms in the Global South: The Case of Arquigrafia, written by *Sayed Abdul Basir Samimi*, *Ana Ribeiro Ferreira da Costa*, *Henrique Santa Catharina Junges,* and *Artur Simões Rozestraten.* It discusses the collaborative construction of a collection of architectural representations. The second work, From a Bird’s Flight to an Overlooking Gaze: Virtuality as a Method, by *Pedro Henrique Vale Carvalho*, focuses on urban analysis guided by street view images.

Additionally, two articles concentrate specifically on **architectural design processes**. In From Computation to Fabrication: Themes and (Mis)Paths in South America, *Rodrigo Scheeren* examines various aspects of digital fabrication within South American research centers. Meanwhile, in their article titled Bridging the Gap: Empirical vs. Simulation in Green Facade Modeling, *Camila da Rocha Hendzel* and *Claudio Vásquez Zaldívar* investigate digital methods for analyzing green facades in Chilean buildings.

We are also pleased to inform you that, as of this issue, the V!RUS journal has become part of the Journal Portal of the University of Sao Paulo at www.revistas.usp.br/virus. Still, it maintains its previous website –www.nomads.usp.br/virus– as a mirror website.

We hope these two issues of V!RUS provide a qualified debate on current digital culture, especially in relation to countries in the Global South.

We wish everyone an excellent reading experience.

THE DIGITAL AS A COLLECTIVE PRACTICE

O DIGITAL COMO PRÁTICA COLETIVA

LO DIGITAL COMO PRÁCTICA COLECTIVA

GABRIELA CELANI, MARCELO TRAMONTANO

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INTERVIEW CONDUCTED ON OCTOBER 4, 2024

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> **Marcelo Tramontano**: On behalf of V!RUS journal, thank you, Gabriela, for accepting our invitation. We expect this issue on “The Digital and the South: Questionings” to stimulate reflections on how countries in the South appropriate technologies, routines, and attitudes from the North. As researchers and architects in Brazil, Latin America, and the Global South, we want to understand the meaning, validity, paths, difficulties, and our advantages in this process. We would like, on the one hand, to address your academic path, which is very expressive and can help younger researchers understand their choices, opportunities, and difficulties in this field, and, on the other hand, to build together a critical reading on the current challenges of teaching, research, and university extension activities with digital media in a country like Brazil. I propose we start talking about how your interest in digital began and later became your field of research in Architecture and Urbanism. What were the main achievements and accomplishments along this journey, and what were the main obstacles overcome or still to be overwhelmed?

Gabriela Celani: I enrolled in the undergraduate course at the School of Architecture and Urbanism at the University of Sao Paulo in 1985. At that time, computers were not part of the daily lives of Architecture and Urbanism students, nor were they part of most architecture offices. In 1988, during my fourth year of undergraduate studies, the school offered a computer drawing course taught by Professor José Jorge Boueri Filho. Since the school had few computers, there were few vacancies, and Professor Boueri began teaching us Paint Brush. I believe he did not yet have a copy of AutoCAD since the course was quite improvised.

In the same year, I did a year-long internship as a draftsman at the office of architect Gian Carlo Gasperini, one of the few architecture offices in Brazil that had already implemented the use of computers. At that time, drawings were still done with Indian ink, while computers were limited to perspective views, produced as follows: an office employee would build the 3D model on the computer and print, on a plotter, in Indian ink, the general lines of the building's perspective, both from the inside and the outside. This drawing, composed only of lines, was passed on to the artist, who then placed tracing paper on top and, with colored pencils, rendered it by hand, using the lines of the printed perspective. This way was how computers were used then. In any case, the process of designing the computerized 3D model was very time consuming.

What I saw at Gasperini’s office instigated me to learn more. An event at this office that significantly contributed to my interest in using computers was when one of the architects asked me to design a layout for a shared garage. I was supposed to draw several parking places, but the architect asked me to change the drawing several times. First, I drew the places at 90 degrees, then altered the drawing to 30 degrees, and after looking at it again, she asked me to draw them at 45 degrees. I thought there should be a way to make the computer do this process, which led me to reflect on the need to automate this type of task, as I found it depressing to have to redo the drawing repeatedly by hand.

The following year, I started my Degree Final Project and decided to draw it entirely on my husband's computer, who got me a copy of the AutoCAD program. In addition, I also used In-a-Vision, which was widely used for layouts. After finishing all the work on the computer, I needed to figure out where to print it since plotting bureaus did not yet exist, and I ended up printing the boards on a dot matrix printer, which contained an A3 continuous form. I used the AutoShade program from AutoDesk to produce the renders based on the project's volumetric that I had done in AutoCAD. Then, I photographed the computer screen and enlarged the colored photos to show the renders in the Project presentation. I was the only student in the class who did the work on the computer. The teachers were quite impressed.

After graduating, I moved to Rio de Janeiro and started working in the architecture department of a building company. Even though they did not use computers for architectural drawing, I continued to use my desktop to do parts of the work at home. I then moved to the city of Sao Jose dos Campos, where I heard they needed someone to teach AutoCAD at the Universidade do Vale do Paraíba, Univap, in the Architecture and Civil Engineering programs. At that time, the chair of Computer Science Applied to Architecture and Urbanism had become mandatory by the Ministry of Education's Ordinance No. 1770/9,4. Still, Univap did not have an expert to assume it. I did not hold a master's degree and was not thinking about becoming a teacher, but they told me that, to teach, I would need to be at least enrolled in a postgraduate course. I then applied to the School of Architecture, where I graduated, and joined the Master's program studying multimedia and hypermedia, two topics in high demand.

I moved to Boston in 1997. As soon as I arrived, I contacted a temporary labor placement company. They informed me that local architecture offices had a high demand for people skilled in using computers to draw in AutoCAD, but there were not enough professionals in the market to meet their needs. They asked me to prove my skills by drawing some things with AutoCAD, and I was hired. The company sent me to offices for specific jobs, usually to transfer hand-drawn drawings to the computer. Sometimes, offices had other people already drawing on computers, but they often needed more knowledge. I arrived with a high status at those companies as I was the person who helped with computer issues and, occasionally, taught the people who were starting.

I did not see any level of automation in those offices, which still frustrated me. I used to draw on the computer, but I still found myself in the same situation as an intern at Gian Carlo Gasperini's office, like drawing parking places by hand. I was doing it on the computer but had not yet added any intelligence to the process. I preferred to take advantage of my time in Boston to expand my education, applying to the Massachusetts Institute of Technology, the MIT, where I was accepted. It was only then that I started programming.

I was happy to enroll at MIT because I saw that they were realizing the real potential of the transformations that were taking place. I started getting familiar with the bibliography on the subject, such as the work of Professor William Mitchell, who published the book *The Art of Computer Graphics Programming*, co-authored with Robin S. Liggett and Thomas Kvan in 1987. At its launch, they used the Pascal language to create parameterized drawings. In 1977, Professor Mitchell published the article *The Theoretical Foundations of Computer-aided Architectural Design* in the journal *Environment and Planning B*, which discussed the potential of using computers for generative design. In this text, he addressed different generative processes, also from a historical perspective. Mitchell treated the creative process as a combinatorial process, in which everything can be automated, and listed the several levels of the designer's desire to use the computer. According to him, the lowest level of desire would be its use only for representation. The next level would be its use for analysis. The highest level would be its use for generative uses. This text profoundly influenced my doctoral thesis, supervised by Professor William Mitchell and Professor Terry Knight, which deals with teaching computational design for architects' training.

Since the program's first semester, Professor Mitchell said I should learn to program within the CAD system. I had never heard an architect or professor say that his students should learn to program. I took Java classes with JBuilder and AutoLISP and learned Visual Basic for Applications from AutoCAD. The whole idea of automation made sense to me. I was starting to find answers to the question of why architects should do repetitive work that machines could do perfectly well and even more efficiently. After defending my doctorate dissertation in 2002, I returned to Brazil. In 2003, I passed a competitive exam at UNICAMP, The State University of Campinas, taking on the position of professor in the Architecture and Urban Planning course one year later.

> **MT**: At UNICAMP, you found very supportive ground, as they had courses on computational design, which was, at that time, a rarity in Architecture and Urban Planning programs.

GC: The UNICAMP program was created in 1999 and included several applied computer science courses. However, these courses were all related to the field of representation. When the program underwent its first evaluation by the Sao Paulo State Department of Education, they criticized us because the courses were not integrated into the design process despite having many computer science courses. At the same time, the university had just created a mandatory course called CAD in the Creative Process. I started teaching this course and was very excited because it had everything to do with my doctoral thesis. The course load was only two hours per week, so I started teaching shape grammar and Visual Basic for Applications programming, but I soon realized there was no point in offering an extra course if it was not related to the design process. As I gained space in the program, I tried to incorporate generative processes and CAD programming. Later, I started teaching design courses and tried to use generative design, but not all students were interested in this process.

In the CAD in the Creative Process course, I tried to use Generative Components, a Bentley program that was being used by Norman Foster's office, but it was too complicated and did not produce good results. In 2008, when I participated in a workshop in Barcelona with David Rutten, the creator of Grasshopper, I could foresee its use in design studios. But it was only in 2010, during a sabbatical semester in Portugal with Professor José Duarte, that I had time to formulate and teach an architectural design course introducing Grasshopper. With Carlos Vaz, who was my doctoral student and was there with me, we structured a didactic project.

After all, it is not enough to know the computer program. We need to develop experience to apply it in the classroom. I began to use these processes in the design course I taught at UNICAMP, assisted by graduate students who acted as teaching assistants. We published some articles together, for example, with Victor Calixto, Felipe Campos, and Juarez Moara Santos Franco, the latter a postdoctoral fellow. Such collective work was crucial as it is not enough for a professor to teach a computer program. As we worked collectively, students were better advised since there were thirty students per class, and they learned how to use automated methods for generating parameterized models.

However, I realized that not all groups of students were happy with the work. Some loved the process, but for others, it was torture. Some students prefer a rather analog creative process and use the computer like a drawing board. Gradually, I understood that these courses should be elective so that students could look for the design course with the process that best aligned with what interested them. In many countries, design studios have different teachers for all students, and in many cases, the student can choose between several design studio options with other methods. In the CAD in the Creative Process course, I have been using Grasshopper for many years. Some students bring what they have learned to the Verticality design studio, which deals with the design of tall buildings, seeking to deepen their knowledge of the plugin. However, other students prefer traditional processes, which depend on personal interest, where they are doing their internship, and several different reasons.

> **MT**: Here at the University of Sao Paulo, we began using computer programs in architectural design in the undergraduate courses I taught with my colleague Renato Anelli. We were in a very different situation from the UNICAMP program, which already included this use in its original formulation. On the contrary, we faced enormous resistance from several colleagues who prohibited using computers in other courses, leading to resistance from students in design classes. This situation has changed over the years due to our classroom work and the naturalization of digital design processes in the professional environment. Looking back on the fourteen years that have passed, I see that, for several years now, it has no longer been necessary to convince and encourage students. They are very open to digital design processes and demand this training.

GC: Even though UNICAMP created the Architecture and Urban Planning program with several computer science courses, design professors still needed to accept the use of computers in design studios. Several have not always allowed the presentation of computer-based projects in our course, which is still the case. The curriculum included these courses, but they took place outside the design studio, and many design professors were—and still are—resistant. But in the meantime, something interesting happened, which I think is important to tell here. In 2006, FAPESP[1] approved a Thematic Project led by Professor Doris Kowaltowski, in which I was a principal investigator. The project was entitled "The Design Process in Architecture: From Theory to Technology" and included, among its proposals, the creation of LAPAC[2], a rapid prototyping laboratory for which I was responsible. We acquired a Z Corp 3D plaster printer and a Universal Laser Systems laser cutter. They were intended for research, but I proposed allowing undergraduate students to use them since their demand was not very high. There was a very intense debate about whether or not to enable undergraduate students to use the machines since some researchers thought handling the equipment was too complicated.

Little by little, this situation changed. I was supervising a PhD student who was researching the use of these devices in architectural design processes. The research's target audience was undergraduate students in Architecture and Urban Planning. We, therefore, needed to use the machines, and so we resorted to subterfuges since, strictly speaking, they were reserved for research activities, not teaching. When undergraduate students first started getting access to the equipment to make their models, a design professor came to me and said that she didn't want her students to create their models on the machines. I asked her why, and she argued architecture students had to learn to make hand-made models. I agreed but told her she should inform her students because I wouldn't close the door on them. If I did that, I would create distinctions, deciding who could and couldn't enter the lab. Ultimately, she didn't dare to talk to her students, and they kept using the machines. Indeed, once you get used to laser-cut models, you won't want to go back. It got to the point where when the cutter stopped working or the laser burned out, the students stopped working because they no longer wanted to make models without the laser cutter.

> **MT**: I believe that around this time, you were also expanding your interests beyond the specific field of Architecture, covering urban issues, right?

GC: I taught two courses. One of them was the Complexity Project course, in which Leandro Medrano and I worked on the urban design of blocks and neighborhoods in the city of Sao Paulo, such as Barra Funda and, within the scope of the Nova Luz Project, Cracolândia. In this course, we made models using digital fabrication on an urban scale. I also advised graduate and undergraduate students seeking techniques

1 Editor's note: Sao Paulo State Research Support Foundation, FAPESP in the Portuguese acronym.
2 Editor's note: Automation and Prototyping Laboratory for Architecture and Construction, LAPAC in the Portuguese acronym.

for representing the city using digital fabrication. Since our production was linked to a Thematic Project, we developed undergraduate, master's, and doctoral projects to use these technologies. Most of these works are recorded in a LAPAC book[3], a collection of summaries of all the work carried out in the laboratory between 2006 and 2013 related to digital fabrication. The evolution of this process led us to receive a commission for a model from the university itself. As in Campinas we have the excellent Renato Archer Information Technology Center, the first rapid prototyping center created in Brazil, we used their selective laser sintering machine to make the model of the university buildings.

> **MT**: It is interesting that you mention this commission because a significant debate today in Brazilian public universities, specifically in the three Sao Paulo state universities, concerns the curricularization of university extension. Within this debate is the issue of the use of digital media in both extension actions and their curricularization. What is your opinion about this?

GC: First, I think it is important to emphasize that the word extension has many meanings, attributed by different people, according to each one's perspective. For a few years, I was one of the directors of the UNICAMP Exploratory Science Museum. One of my contributions was the creation of a digital manufacturing sector in the museum, making 3D printers and 3D scanning systems available through free mobile apps. Since many groups from public schools and some private schools came to visit the museum, we started offering workshops open to the public, including on weekends, mainly for children, and receiving scheduled groups of schoolchildren during the week so that they could learn about and learn about these technologies.

The museum had a truck called *Oficina Desafio*[4], which welcomed students to the museum but also went to schools. We created scripts containing challenges that the children had to solve, using some equipment available in the vehicle, such as a jigsaw and a drill. The *Oficina Desafio* proposed hands-on activities, which were very successful. In addition, the initiative involved undergraduate students from the university who worked at the museum as monitors for the children and learned how to use the digital fabrication equipment as they had to teach the children how to use it. It was a large team, with teachers and students from different science programs, and so the challenges were almost always related to physical-chemical events and biological phenomena. It was a way of associating digital fabrication with science education and putting university students, as scholarship holders, to work with children from these schools.

Another university initiative we have been involved in for a long time is the Science & Arts on Vacation Program. FAPESP supports the project by providing financial aid to some public high school children from the greater Campinas region, selected through an essay. Each child has a teacher assigned as their supervisor to develop a brief research project over four weeks between January and February of each year. In addition, once a week, the students work in groups in a laboratory. For many years, LAPAC has offered laboratory activities for the project children during these four weeks, involving scholarship holders for scientific initiation and master's and doctoral programs. We organized a workshop in which, over a day, the children would go through different stations. They learned the basics of modeling, scanning, 3D printing, and laser cutting. In the end, we printed something they had made so they could see the results of the process.

At the end of each summer course, we had the opportunity to invite some of these students to participate in the Junior Scientific Initiation program, another university initiative, with a CNPq[5] grant for one year. The projects always involved our scientific initiation, master's, and doctoral scholarship holders, who helped to guide children who had just finished high school. One of the projects, for example, involved the production of tactile models for visually impaired people. In this project, we worked with a visually impaired postdoctoral student who accompanied a group of scholarship holders on a visit to the Latin America Memorial in Sao Paulo. This visit allowed the students to understand the difficulties blind people face. At the Memorial, there is a small tactile model of the buildings in bronze, and they watched the postdoctoral student use the model. Back at the university, they learned the basics of 2D drawing and modeling throughout the year. They learned how to find, download, and correct digital models for 3D printing, how to draw 2D streets, and finally created a tactile model of the Latin America Memorial. The model was later given to the Accessibility Laboratory of the UNICAMP Central Library so that visually impaired people could learn about the buildings of the Latin America Memorial through touch. I consider this a university extension action because

3 Celani, G. (2013). *Lapac 2006-2013*. Campinas: Biblioteca Central Cesar Lattes.
4 Translator's note: The Challenge Workshop.
5 Editor's note: National Council for Scientific Research, CNPq in the Portuguese acronym.

we were bringing high school students from the public network for the vacation period and to enable the continuity of training work through Junior Scientific Initiation. Scaling this initiative is a bit difficult and requires a lot of people to be involved, but it was an exciting experience.

> **MT**: During the period you mentioned, scientific meetings in Brazil consolidated, undoubtedly linked to the restructuring and expansion of postgraduate studies in all areas of knowledge. However, while these transformations have occurred here since the 2000s, in other Latin American countries, the national postgraduate and research systems still need to be better consolidated. Even within Brazil, significant inequalities persist between institutions in different regions. How do you see these asymmetries in the area of Architecture and Urbanism?

GC: The initial period of my education was quite instrumental because there was not much knowledge produced in the country, either in terms of programming and algorithm construction or digital manufacturing equipment. During my doctorate at MIT, I used digital manufacturing equipment but didn't give it much importance. When I returned to Brazil and realized it didn't exist here, I understood paying more attention to this issue was necessary. Little by little, public and private universities began to acquire equipment and make it available to students, helping to put into perspective the controversy of professors who were against digital manufacturing. I think we have overcome this phase and have evolved.

Regarding research, I dedicated myself for some time to supervising studies focused on how to apply these techniques effectively in projects. One example is Maycon Sedrez's doctoral work, which studied fractals in architecture by analyzing the work of different architects. During his research, we came across a project designed in the context of a competition for the UNICAMP Science Museum building, in which one of the facades was covered with perforated sheet metal, with a supposedly fractal design. Upon investigation, Maycon discovered that this facade was the representation of a fractal, but it had not been designed using the fractal algorithmic process. And that was because the architects lacked the programming knowledge to produce fractals.

I am not criticizing these architects because I find it interesting that many of them bring the concept of fractals into their projects. However, in Brazil, architects, in general, need to prepare actually to reproduce algorithmic processes. I have supervised several studies dedicated to thinking about this issue and understanding the integration of these procedures in the design process. We gathered these studies in another book, *Arquitetura Contemporânea e Automação*[6], from 2018, and were the result of a regular FAPESP project, coordinated by me, which aimed to understand the relationship between digital processes and their impact on architecture at different levels and scales. For this book, we conducted many interviews and events with various architects and key figures in the field. I use “we” in the sense of community since these events were open access. LAPAC researchers learned a lot about the subject by listening to these various architects and researchers describe the process by which they had arrived at specific results.

Honestly, I have studied the subject so deeply and for so long that I felt the need to explore other areas. At UNICAMP, the undergraduate program in Architecture and Urbanism has only thirty places, and there are only a few professors, which means that there is one professor for each subject, and the research topics are somehow personified. I remember Arivaldo Leão de Amorim, a professor at the Federal University of Bahia, saying that when he joined UFBA, they called him “the computer boy” because he had created the Laboratory of Advanced Studies in Cities, Architecture and Digital Technologies, LCAD, which was the first CAD lab in Brazil back in the 1980s. At UNICAMP, I had become “the 3D printer girl,” but now I am no longer a girl, and I don’t want to remain isolated in this area.

During the pandemic, I made a significant change. Working as an advisor to the university's Dean's Office, I had the opportunity to set up Plasma, a maker space and coworking space for the entire university. At the same time, I moved all of LAPAC's equipment there. I did this because I felt the need to experience other things. I also distanced myself a little from conferences in the area, not because I didn't particularly appreciate participating in them, but because I am focusing on other topics today. This change doesn't mean that I am leaving my past behind. I continue to use all of that, but I am looking for ways to make the work more collaborative so that it can involve diverse knowledge and does not remain exclusive to those who preach the same creed of digital media. Of course, not everything is always rosy. There are conceptual differences between people, but in the end, things flow.

6 Celani, G.; Sedrez, M. (Org.) (2018). Arquitetura Contemporânea e Automação [Contemporary Architecture and Automation]. Sao Paulo: ProBooks.

This opportunity arose with the purchase by UNICAMP of the Argentina farm, part of the former Campinas High Technology Pole. The occupation of this new area requires a planning effort and raises the need to contribute to urban sustainability. As part of the project team, we made a model of the land designated for the International Hub for Sustainable Development using a milling machine to model the terrain in Styrofoam to allow a projection of the territory's evolution on this land. We offered an online specialization course with the International Hub for Sustainable Development as its theme, as was proposed for the area. I am currently working with a postdoctoral student to develop an algorithm to generate the occupation of the blocks as optimized as possible within this land. These actions became a research project, which brings together people from different areas. Not everyone is connected to digital media in architecture. Each one comes from a different field. Some of my students, who are more familiar with these media, and I contribute by making the models and implementing digital processes when necessary. Digital is no longer the center of attention in this project. The focus now is on providing the territory with vitality and sustainability.

The project includes a professor of public management, a biologist and urban ecologist who is a professor of civil engineering and architecture and urban planning, and several other professors who work with infrastructure, urban planning, and landscape issues. We formed the group based on the university's need to reflect on this new territory. Together, we began by studying the concept of a technology park, understanding that it is a territory to produce knowledge in the city. Finally, we arrived at a formulation based on the idea of a territory that provides fourth-generation knowledge, understanding that it must include social involvement and environmental concerns. In other words, we are seeking to envision ways to help the university and the city of Campinas take ownership of this territory, located in a technology park that did not address these concerns when it was built in the 1980s. Therefore, another relevant issue concerns the effort to adapt its infrastructure. This process has been fascinating. It's always really motivating to start learning new things.

Our initial idea was to work on a subject that none of the professors involved were familiar with, new to everyone so that everyone could contribute from different perspectives. The Public Management professor contributes by thinking about ways to manage this territory, while another professor investigates the insertion of this territory in areas of environmental fragility, preserving its ecological characteristics. I contribute from the perspective of City Information Modeling, or CIM, exploring ways to model and extract information from this city. Postdoctoral student Marcela Noronha is studying the creation of digital twins of the territory for the implementation of urban circularity. Laura Martins, a sociologist and postdoctoral student, is also working on the cycle from food production to composting. Zahra Alinam, Iranian, thinks about environmental psychology issues, and Silvia Stuchi is about mobility. In short, it is a project that concerns ways of bringing people together around a common theme. One reflection that this project provoked in me is that, in university departments where each professor researches a specific subject, it is essential to bring a new topic that no one is familiar with so that everyone can learn together without personal vanity. This project deals with something new that the university needs, and each person, with their expertise, will contribute. This dynamic has to do, therefore, not only with the theme itself but also with the issue of relationships and dialogues within the university.

> **MT**: In your academic career, you tend to weave close relationships between research, industry, and public authorities. However, we know that these relationships are often tricky because of each actor's different interests and timings. How do you experience this?

GC: One of the most successful projects I have supervised, supported by this type of collaboration, was the master's research of Wilson Barbosa Neto, who interned at a plasma steel cutting industry, where he was able to conduct a series of experiments. Industries are not always willing to open themselves up to these processes. In general, they see collaboration as a waste of time and prefer more objective processes because the timing of the university is different. At the same time, throughout my career, I have always visited industries and construction sites to learn how things happen in the production phases. For example, in the Verticality course, we encouraged students to use engineered wood in their projects, and during the course, we visited the companies Rewood and Crossland with them. Last week, I visited the Henkel Innovation Center for Latin America's construction site in the nearby city of Jundiaí, which uses engineered wood and has a lot to do with our Technology Park project. Perhaps my interest in working with industry is realized, in a certain way, when we work with urban spaces, where not only these industries are present but innovation in general.

Another example is the Center for Studies on Urbanization for Knowledge and Innovation, which we started two years ago, resulting from a call from FAPESP in 2021, linked to a broader project by the Foundation, which aims to establish new Science Centers for Development. This call is similar to a thematic project but requires associating with a State Secretariat and establishing partnerships with industries and

NGOs. In addition to these actors, one of FAPESP's requirements is to submit proposals for the Small Business Innovation Program, the PIPE Program. The project lasts five years. After the first two years of dedicated time to the theoretical-conceptual foundation, we started to think about projects for PIPE. A postdoctoral researcher proposed implementing a platform for comparing cities from an environmental perspective. We will reduce the scope of this research so that it can be a platform for comparing technology parks, which is a more viable approach for the study. Thus, we contribute to the project while preparing and submitting projects to PIPE, with the possibility of obtaining funding for its implementation.

In short, we are beginning to think about products that can be transformed into small businesses, linked to both the issue of technology parks and the issue of sustainability and social participation. This is a way for us to also connect with the business sector, something that FAPESP supports. The call for proposals for the Development Science Centers proposes that the university work with the government and industry to contribute to society so that knowledge does not remain confined within the university. We already have a partnership with the Campinas City Hall. We are also concluding a partnership with the Secretariat of Science, Technology, and Innovation of the State of Sao Paulo to train city managers who want to implement knowledge production territories.

> **MT**: One of the subthemes of this issue of V!RUS is the tension caused by the use of digital technologies produced in the global North in architectural and urban research and design processes in the South. In most cases, users of these technologies from the South constitute a residual contingent since most of the current computational developments for our field aim at the immense number of clients from the North. As a result, when using these technologies, we strive to adapt our research procedures, the ways of conceiving architecture, and even the final projects to means and criteria mainly relevant to the countries of the North. We end up training architects who will hardly implement these ways of thinking and designing in their professional activities, as well as researchers who will face difficulties in continuing their research in institutions that do not have access to these means. I would like to propose a brief reflection on what would be specific to Brazil or Latin America regarding research and architectural production, considering the interests of the South. What topics could make up an agenda for this debate?

GC: This point is crucial and sensitive for me because, since I returned from the United States, having completed my doctorate at MIT, I have often been criticized for purchasing imported equipment. I agree with these arguments but have never received an answer about an alternative. I remember David Sperling's warning about the risk of using imported equipment and replicating what is done abroad. I agree, but I think that, on the other hand, we cannot simply ignore these technologies and fall behind, as we did under the market reserve imposed by the Computer Law in the 1990s. Now that I am involved in this project, which has more to do with aspects of urban sustainability, the issues are much more specific. We cannot rely on technology parks from other countries. We can draw some inspiration from them, but we must formulate a model that works for our reality. This discussion depends on what aspects we consider when bringing models from abroad and applying them here. Buying a 3D printer abroad and using it here is less harmful than bringing a technology park model and implementing it here. It is essential to understand the scale of how harmful each import is. A small machine that will execute something does not make much difference. However, management and land occupation models have a much greater potential to be harmful.

Working on a territorial scale, we have more responsibilities because a great diversity of actors are involved. UNICAMP, for example, holds the Indigenous university entrance exam and receives many Indigenous students who demand to be heard and served. One question we could ask about this technology park is: how can we include people with different backgrounds, such as indigenous people? What knowledge can they contribute, and what innovative products can they propose? In a workshop on Indigenous entrepreneurship with these students, one from the Institute of Language Studies presented his project for a computer application for translating Indigenous languages into Portuguese. We imagined he could create a startup dedicated to producing a computer application for translating official Brazilian government websites into these and other Indigenous languages so Indigenous people of all ethnicities could understand them. This possibility made us reflect on which companies we want to have in this territory, which we call the International Hub for Sustainable Development. To answer this question, we have to understand the demands and the issues regarding the treatment of the territory. For example, we must reforest Permanent Preservation Areas that have been deforested. We will also expand the PPA and ecological corridors. The indigenous people also ask for the opportunity to contribute to selecting plant species to be placed in these areas. They want indigenous medicinal plants planted and studied at the School of Medicine and introduced into the University Hospital because there are plans to build another hospital in this new area. So, we started listening to our community, and the answer is here: we are not the ones who will invent it. The answer is a result of that listening.

MT: What would you say to young researchers about choosing paths, attitudes and themes?

GC: I would say: do what you like because if you don't do what you like, you will not do it well. Whatever results from what you like will certainly be helpful. As time goes by, our paths will cross with those of other people, and we will evolve. The starting point is always to do what excites us. I have always been very enthusiastic about everything I have studied. Yes, there may come a time when we decide to take other paths. But this happens because one of the things we like is to impose new challenges on ourselves precisely.

MT: Gabriela, this last question is the same one we ask all our interviewees: does the future seem promising to you?

GC: I am and always have been an optimist. I keep believing that the future will be better. Lately, I have been a bit pessimistic about the intensity with which climate change is affecting us. Still, some things keep me optimistic. For example, I was invited to be part of the university's Sustainability Advisory Committee, which will develop a climate change mitigation plan. For me, this is promising and gives me hope. If everything goes well, I will go to COP-29, representing UNICAMP. And if ten percent of what we planned is achieved, we are already on the right track. Even though I see opposing forces at work, I am hopeful that this will benefit the university.

MACHINIC EUGENICS OF THE GAZE: COMPUTER VISION, AGEISM, AND GENDER

EUGENIA MAQUÍNICA DO OLHAR: VISÃO COMPUTACIONAL, ETARISMO E GÊNERO

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Abstract

This article analyzes computer vision as a device that shapes the contemporary gaze and points to its political and aesthetic implications in everyday social life. The text discusses the social production of data, highlighting the racist, ageist, and misogynistic biases of artificial intelligence (AI) architectures for synthesizing images, commenting on the biopolitics embedded in these processes. Special attention is given to computational biometric techniques, such as facial recognition, highlighting their connections with Francis Galton's composite portraits, which he called "statistical paintings," and their dissemination in the contemporary imaginary. The text considers how computer vision—and its pattern-based structure—updates the foundations of the eugenic imagination. It defines fields of visibility that will not imply genocidal racial wars but algorithmically exclude certain subjects and bodies from the social and political field. Based on ongoing artistic research (*Poisonous, Noxious, and Suspicious*, about forbidden plants and women erased from the history of art and science), the article points to the need to deconstruct the potentialities of the emerging machinic eugenics of the gaze through counter-hegemonic practices, and images that deviate from the norm, elaborated from the Global South.

Keywords: Computer Vision, Eugenics, Ageism, Racism, Women

1 Introduction

Computer vision is a system that reads, interprets, and extracts data from digital files. Its broad application encompasses OCR (optical character recognition), medical examinations, search engines, 3D modeling, surveillance, biometrics, self-driving cars, and various image editing techniques (Szeliski, 2011). Present in various activities, computer vision systems operate as filters and lenses in our daily lives and, in this sense, are understood as "devices." In terms of Michel Foucault (Foucault, 2008, pp. 93-94), later updated by Giorgio Agamben, the device refers to "a heterogeneous set, linguistic and non-linguistic, that includes virtually anything under the same title: discourses, institutions, buildings, laws, security measures, philosophical propositions," resulting "from the intersections of power relations and knowledge relations" (Agamben, 2009, p. 29, our translation).

It is through this intersection between power relations and knowledge relations that computer vision is discussed in this essay. By "interpreting" images, computer vision algorithmic models shape fields of visibility and invisibility, producing new forms of exclusion and control. Interpretation, in this case, does not involve hermeneutic operations. Just as computers do not see, they also do not understand images at any level of representation. The image has no semiotic or aesthetic meaning for machines. In technical terms, it is a matrix of points and blocks, which allows artificial intelligence (AI) to identify patterns such as edges, shapes, textures, curves, corners, and colors, grouping them through filters. Therefore, computers do not see, much less simulate human vision. This seems obvious, but the recurrence of metaphors around AIs makes this primary instance opaque.

This type of metaphor structurally refers to this technology's anthropocentric and colonialist paradigms. First, there is the basic assumption that to be intelligent is to be human. That intelligence must mirror attributes such as human vision or natural language processing (NLP), where "language" means human verbal language, with American English as the standard for its modeling. No less relevant is the assumption that intelligence is an exclusive attribute of the human brain, even though different multispecies and cosmopolitical approaches, such as those of Donna Haraway (1991, 2016), Eduardo de Castro (2018), Anna Tsing (2022) and James Bridle (2023), among many others, show that, within the scope of current scientific research, this assumption does not hold up. This does not mean that the attribute of intelligence cannot be associated with machinic systems. It simply means that there are distinct forms of intelligence besides human intelligence, the subject of a dizzying essay by Brazilian semioticist Lucia Santaella (2023).

Problematizing the anthropocentric foundations that underpin metaphors such as neural networks, which refer to our brains and seek to compare human and non-human systems and ways of being, is beyond the scope of this article. However, it is essential to note that when we refer to computer vision, we refer to a type of machine learning (particularly convolutional neural networks, or CNNs). Deep learning *involves* the development of algorithms and statistical models that allow computers to learn and make decisions or predictions based on data without being explicitly programmed to perform a specific task. Despite differentiating AI from all the technologies that preceded it, its generative potential does not make artificial intelligence an abstract framework that applies its rules to an autonomous parallel universe. It is a cultural construct firmly rooted in historical dynamics of power and exclusion that are the starting point of any artificial intelligence model: the datasets used in machine learning from which a model will result.

2 The Society of Biased Data

Several studies show how biased data reinforces gender and racial stereotypes and makes black people more vulnerable in surveillance systems and potentially excluded from job selection and intellectual recognition processes (Buolamwini, 2017; Noble, 2018; Silva, 2020). In addition to system errors, these occurrences need to be understood as instances of the social production process of data. The health sector, in which AI is becoming increasingly essential, is a fertile field for this understanding, given that biased data can determine access to specialized services and, therefore, the right to life or not. This is the case of an algorithm analyzed in a study on automated triage processes in American hospitals. The AI model in question uses as its main anchor the total costs already invested in a patient to determine their priority for care, without considering that the health system in that country historically spends less on black patients because they have, for a series of social issues, less access to these services. By disregarding this "variable," automated screening reinforces processes of racial injustice and highlights the social and transdisciplinary scope of the impacts of using artificial intelligence (Owens & Walker, 2020, p. 1327).

Therefore, biased data does not "emerge" from AIs, so the debate on different data review strategies has involved many experts. In this sense, it is suggested that information about the collected data be made public (Zou & Schiebinger, 2018) and that technologies be developed to debug distorted information (Steed & Caliskan, 2021). However, algorithms do not perform their tasks spontaneously. Analyzing ImageNet, a *dataset* used by many computer vision systems, Crawford and Paglen showed the genealogy of the biases they embed, starting from labeling the data that will feed the development of an AI model. As an illustration, we will take the category "human body," which was analyzed by the authors. It is in the branch Natural object > Body > Human body, and its subcategories are distributed between males and females, according to their age profile (adult or juvenile). “The “adult body” category contains the subclasses “adult female body” and “adult male body.” We find an implicit assumption here: only “male” and “female” bodies are “natural.”” (Crawford & Paglen, 2019).

Workers hired for specific tasks on remote platforms such as Amazon Mechanical Turk (AMT) often initiate the labeling process. These workers constitute an emerging global precariat, performing decontextualized and atomized tasks in a platformed labor system. Underpaid and unprepared to interpret images, they reveal what Marx, in his Economic-Philosophical Manuscripts of 1844, defined as alienation in the labeling processes: the disconnect between the work and the worker's experience (Moreschi et al., 2020; Grohmann et al., 2022; Dias, 2024). Economic and geopolitical factors also contribute to the creation of biased data. The increasing use of unsupervised systems, which employ models pre-trained on unlabeled images, amplifies misidentification and bias. Thus, pre-trained models used in facial recognition for security can be applied in employment selection processes, perpetuating these biases in the screening process (Harwell, 2019; EPIC, 2019).

Finally, the other factor in the biased data production chain is geopolitical. In computer vision, 45% of the 14 million labeled images on ImageNet come from the United States, constituting 4% of the global population. In contrast, China and India, representing 36% of the global population, account for only 3% of the images in the same database (Zou & Schiebinger, 2018). Thus, it is understood that data asymmetry, more than a technical problem, reflects asymmetries of power of a social, economic, and political nature, which underpin the practices of datacolonialism or data colonialism. The notion of data colonialism assumes that "the social relations embedded in data are part of a broader colonial (and not just merely capitalist) legacy" (Couldry & Mejias, 2019, p. 84). Playing out power dynamics, these relationships do not replace traditional forms of expropriation and include mechanisms of social invisibility through standardization processes in a new form of eugenics, which I call machinic eugenics of the gaze.

3 Towards Machinic Eugenics

"Eugenics" is a word derived from the Greek *eugenes*, meaning well-born, of good stock, and noble race. The British scientist Francis Galton (1822–1911) coined the term in 1883 in his book *Inquiries into Human Faculty and Its Development*. His motivation was to counteract the "slowness" of the processes of natural selection that Darwin, his second cousin, theorized and to "improve" the human species. Proposed as a science, eugenics soon became, in the 1920s, a social and international movement (Turda, 2022, p. 2741). In 1907, the Eugenics Education Society of the United Kingdom was founded in England. In the same year, the first laws on the sterilization of blacks and the prohibition of interracial marriages were passed in the United States. The Eugenics Record Office existed under that name until the late 1960s (National Human Genome Research Institute, 2021; Stern, 2011). Another country at the forefront of this field was Brazil, whose Eugenics Society dates back to the 1920s. Led by physician Renato Kehl, it had several enthusiasts among the Brazilian intelligentsia of the time, such as Monteiro Lobato, Paulo Prado, and Alfredo Ellis Jr., among others (Wegner & Souza, 2013; Souza, 2024).

In Germany, where the Medical Society for Sexology and Eugenics (Ärztegesellschaft für Sexualwissenschaft und Eugenik) had been active since 1913, eugenics became official state policy from 1933, during the Nazi era, and resulted in an alarming number of deaths: 6 million Jews, 250,000 gypsies, at least 200,000 mentally ill people, an unknown number of blacks, and many thousands of homosexuals, communists, and political opponents, classified as “antisocial” (Beiguelman B., 1997; Amidon, 2008). To develop his eugenic theories, Galton created a photographic method, which he called “composite portraits,” superimposing several faces with multiple exposures on the same plate and erasing all individual characteristics to obtain a generic face that identified a specific biological and social profile (Figure 1). The aim was to achieve "with mechanical precision a generalised picture; one that represents no man in particular, but portrays an imaginary figure possessing the average characteristics of any given group of men" (Galton, 1879, pp. 132–33). He inferred this supposed precision by interpreting his methodology as a form of "statistical painting" in 1883 (Galton, 2001, p. 233), moving from the perceptible to the datafied, or from the empirical to the "irrefutable" scientific proof (Sekula, 1986, pp. 18–22; Lee-Morrison, 2019, p. 95).

Fig. 1: Composite portraits of the “Jewish Type” by Francis Galton, c. 1877-c. 1890. (Wellcome Collection). Available at: https://wellcomecollection.org/works/ngq29vyw. Accessed: 03/11/2024.

The links between the history of photography and biopolitical control have been widely discussed and refer directly or indirectly to Michel Foucault's seminal analysis of the panopticon (Foucault, 1999; Machado & Huber, 2010; Fischer, 2019; Azoulay, 2019). However, no discriminatory scientific discourse supported by images has had the influence and longevity of the ideas and methodologies created by Galton, impacting everything from facial recognition to the revival of eugenics in contemporary biotechnologies in the context of the debates on the Human Genome Project[1]. In Galton's view, his technique of composite portraits would contribute to the "improvement" of the British population. In terms of computer vision, neural networks, whether convolutional (CNNs) or generative (GANs), do not have these purposes but operate similar processes when searching for identities between the different data in an image, discarding the particularities to synthesize other new images (Figure 2).

1 The eugenic theories mobilized under the pretext of the Human Genome Project (HGP), the largest collaborative scientific project in history, and the strong emphasis on genetic algorithms that accompany them transcend the limits of this article and were addressed by the author in another publication, in which she clarifies not the eugenic vocation of the PGH, but its instrumentalization in this perspective. (Beiguelman, G. 2023, p. 103-138).

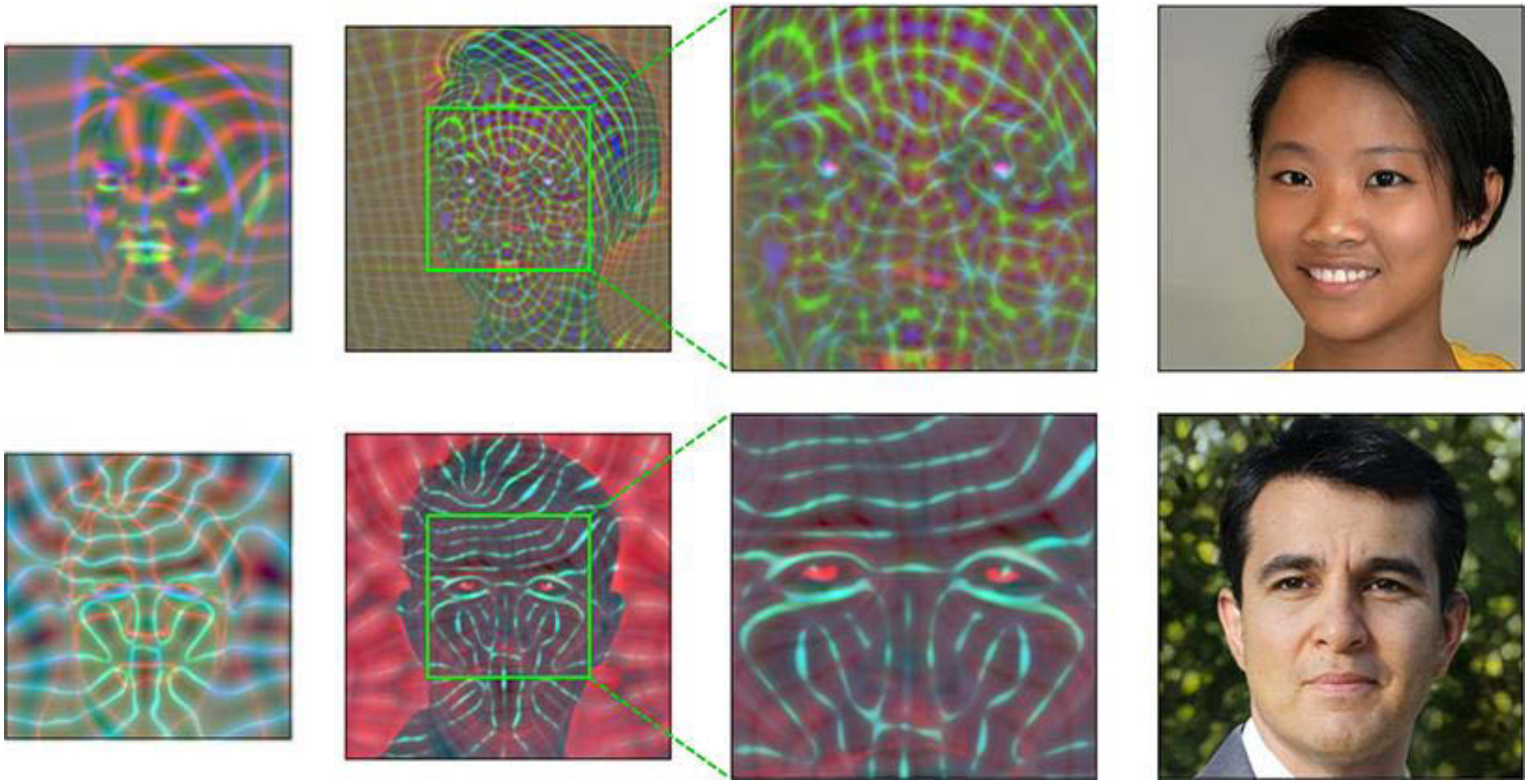

Fig. 2: A comparative study between three GAN models shows the analysis of internal patterns of images until they reach a generic face. Source: Karras, T., Aittala, M., Lain, 2021. Available at: https://nvlabs.github.io/stylegan3/. Accessed on 11/03/2024.

4 From Pictorial Statistics to Statistical Photography

Galton called his composite portraits "pictorial statistics" not for the rhetorical effect of the definition but because he is the father of regression statistics, a paradigm of any machine learning process (McQuillan, 2022, pp. 86-92). Although these neural networks use deep learning techniques beyond traditional regression methods, this concept is still relevant for adjusting parameters during the model training process to find the line (or curve) that best fits the data. From this perspective, it can be said that:

> Most of the contemporary applications of machine learning can be described according to the two modalities of classification and prediction, which outline the contours of a new society of control and statistical governance. Classification is known as *pattern recognition,* while prediction can be defined also as *pattern generation*. A new pattern is recognised or generated by interrogating the inner core of the statistical model. (Pasquinelli & Joler, 2020, p. 13).

The problem with this statistical standardization system becomes more serious when one takes into account the importance of social networks today and the significant increase in pre-trained vision and language models (VLP), leading to distorted representations of specific social groups, such as black people, women, and transgender people, and contributing to the unequal distribution of resources and access (Lee et al., 2023), which echoes the eugenic principles of selective advantage based on appearance traits. No less relevant than the selective approaches of AIs about race, gender, and sex are discussions about ageism, making older adults practically invisible on networks and in health services or job recruitment, of the type we discussed at the beginning of this article. Note that these biases are projected in an intersectional way so that they become increasingly oppressive and socially unjust as individuals add characteristics that place them in several groups simultaneously (black, transgender, and older people, for example; or cisgender and older women, and so on).

In AI ageism: A critical roadmap for studying age discrimination and exclusion in digitalized societies, Justyna Stypinska (2023) addresses the issue of ageism in the context of artificial intelligence and its social impacts. To this end, she identifies five interconnected forms of ageism: age-biased data (technical level), stereotypes and prejudices of actors such as AI labelers and programmers (individual level), lack of debates about old age in AI discourses (discursive level), discriminatory effects of the use of AI technology on different age groups (group level) and their exclusion as users of AI technology, services, and products (user level, through different types of interface design). Thus, despite the aging population, on the one hand, and the increasing digitalization, on the other, which should be elements of pressure for greater attention to the issue, what is happening is precisely the opposite, converging to transform a treacherous synonymy between health, youth, whiteness, perfection, and competence into a standard.

4.1 Eugenics Never Ended

Beauty fiction is crucial in eugenic dynamics, mediating social interactions on popular platforms such as Instagram and TikTok. Offered as filters and editing tools that allow users to alter their appearance, these apps function as devices to conform to specific beauty standards, promoted and marketed on these platforms. Popular apps such as Facetune, AirBrush, Perfect365, and YouCam Makeup feature filters to lighten skin tones, reinforce traditional gender roles, such as long eyelashes for women or a strong jawline for men, and smooth out wrinkles. In addition to provoking feelings of inadequacy and low self-esteem, especially among young people (Chaderjian, 2022; Rowland, 2022), these "beautification" apps embody eugenic assumptions that deserve consideration within the scope of this article. The correlation between standardized beauty ideals that generally extol whiteness, thin bodies, and youth, especially women, is striking (Gehl et al., 2017). While this type of "cosmetic gaze" is not expressed in past racial cleansing policies and is not a result of, or specific to, social media, it also emphasizes a constant repackaging of oppressive cultural standards that used to target women (Wegenstein, 2012, p. 151).

The claim about the eclipse of eugenics after World War II is recurrent but not valid. Eugenics never ended, now masquerading as “newgenics”, a concept that philosopher Robert A. Wilson uses to discuss how the eugenic mentality manifests itself in contemporary society, focusing on certain bodies and social subjects based on biotechnological advances. Instead of being characterized as unfit or degenerate, as in Nazism, bodies evaluated as outside the norm are "regarded as less healthy" or as having "medical irregularities or abnormalities." They are thus subjected not to "state-mandated practices of euthanasia and sterilization " but to practices of "prenatal screening and selective abortion offered as matters of individual reproductive choice" (Wilson, 2017, p. 176). What we see in this strategy is a new guise of the myth of the standard of normality. The widespread dissemination of artificial intelligence technologies calibrates this myth. Given that the controversial concept of standard, a prerogative of any definition of normality, is fundamental to processes involving machine learning.

The biopolitical aspect of this binomial (regular/standard) allows us to situate current forms of AI image processing in a broader perspective, understanding their invisibility procedures within the framework of a set of social and political vectors, in which one can consider the possibility of an emerging machine-like eugenics of the gaze. It is unlikely that AI will be able to control our gaze in the sense of physically forcing us to look at something. Even so, computer vision techniques can influence what we see and what we pay attention to, shaping the visuality and invisibility of certain bodies and subjects. In this sense, this article assumes that when we speak of vision, we also speak of its forms of social fabrication. Suppose vision is a biological attribution and visibility a social fact (Foster, 1998). In that case, the gaze is the interaction of both aesthetic regimes, the political field that “defines what is visible or not in a common space" and who can or cannot have a part in that space (Rancière, 2004, pp. 12-13), like the elderly women, who have become one of the challenges of an artistic research project I am currently working on.

5 Poisonous, Noxious, and Suspicious

The project explores models based on the so-called Natural Language, which creates images from texts and other images. I borrowed its title, *Poisonous, Noxious, and Suspicious*, from a 19th-century scientific manual published in England by the Christian Scientific Society, written by Anne Pratt (1857). The focus is on plants that were banned by the colonial "civilizing" process due to their use in sacred rituals, hallucinogenic and aphrodisiac powers, and ancestral healing practices that are often confused with religious practices. Several of these banned plants were, over the centuries, "reintegrated" into society and privatized by the pharmaceutical industry, such as *Cannabis*, various artemisia derivatives, and curare. Others continue to be surrounded by misogynistic prejudices. I draw them with artificial intelligence, using as reference botanical illustrations of women erased from the history of art and science, creating speculative biographies that intersect the stories of these botanists with those of "suspect" plants.

This is not about advocating for the total release of the consumption of these plants, ignoring that their toxicity depends on dosages and knowledge (ancestral and scientific), but about recognizing the cultural and economic foundations that banned them (Baratto, 2022; Luz, 2015). Even because several plants, such as "carnivores" (in reality, insectivores) and orchids, about which prejudices abound, refer not to their toxicity but to heterologies, as "sciences of the other," shaped in the process of colonization (Souza, 1993, pp. 24-25). They also refer to the stories of fear in the face of the different othernesses that have demonized women since the Middle Ages as "agents of Satan" and malevolent figures (Delumeau, 1989, pp. 310-344).

However, during my research, I noticed a particular recurrence of tragic stories that led several of these pioneering scientists to die abandoned, sick, and alone, with posthumous recognition centuries after their death, such as Maria Sybilla Merriam (1647-1717), the first to identify the process of metamorphosis of caterpillars into butterflies. This is also the case of mycologist Maria Elizabeth Banning (1822-1903), whose beautiful manuscripts and watercolors were accidentally found behind a chicken taxonomy cabinet in a museum in New York in the 1980s. Based on these and other stories, I decided to create fictional portraits of these scientists, combining the few images available online with the plants and aesthetics to which they dedicated themselves (Figure 3).

Fig. 3: Processing of Maria Sybilla Merriam's portraits with Artificial Intelligence from a drawing published in James Duncan, *The Natural History of British Moths*, Sphinxes, & co. (Edinburgh, 1841). Source: Author, 2024.

However, none of these stories interested me as much as that of the Brazilian Maria Bandeira (1902-1992), the first female botanist at the Rio de Janeiro Botanical Garden. A bryophyte specialist, she collected and identified more than 500 specimens of plants, fungi, and lichens in the 1920s. Bandeira was never recognized because, as she did not publish the results, her authorship was ignored by the men who controlled the scientific journals (Bediaga et al., 2016). In short, Bandeira did everything that became synonymous with impetus for scientists and confined women, at best, to the attribute of "adventurers" (Lopes, 1998). Despite all these obstacles, she exchanged extensive correspondence with foreign specialists and even studied at the Sorbonne in France. She was on a successful scientific path when she decided to join the Order of Discalced Carmelites and move to a convent in Rio de Janeiro's Santa Teresa neighborhood, where she lived in full monastic enclosure. Experts say that this may have been related to the death of her parents, the emotional breakup with her brother, and the loss of an essential scientific reference, Viktor Ferdinand Brotherus, who died in 1929.

I wonder if it was not her brother who confined her to the convent. I also speculate whether Brotherus was her great love and secret companion, whose absence she could not bear. I imagine Maria Bandeira living among her bryophytes, working at the Rio de Janeiro Botanical Garden. I struggled for two days with artificial intelligence to make her portrait at 90. The mechanical eugenics of the gaze, due to all the issues previously discussed (biased data, asymmetry between the number of images of young and old women, abundance of "beautification" resources), is my main obstacle. I realize that it is challenging to work with wrinkles, especially in women over 30 and with eyes that are not blue. I took a rare photo of her outside the laboratory, at the Botanical Garden, as my starting point. She is the only woman among several men, and I erased them all, in addition to colorizing them, to facilitate the work process of artificial intelligence (Figure 4).

Next, I summarized her portrait as a happy octogenarian in her workspace. In the first result, the AI assumed I was referring to a black woman when I spoke of a Brazilian personality. To this end, I use text-to-image and image-to-image processing resources on platforms such as Runway and DALL-E, starting from an exhaustive search of images and bibliographies in scientific collections and libraries. I describe her as white, and the results refer to a stereotypical view of old age, of a dejected woman, echoing gerontophobic approaches (Butler, 1969; Esteban, 2021). To get around the problem, I insert into the prompt the information that the portrait should reflect haughtiness. However, the situation worsens with the output of a woman who looks like she stepped out of *a* 1970s television series, like *The Waltons* (Figure 5).

Fig. 4: Maria Bandeira at the Rio de Janeiro Botanical Garden. Source: Museu do Meio Ambiente/JBRJ, n.d., and photo cropped, enlarged, and colorized with AI by the author (2024). Source: Bediaga et al., 2016. Available at: https://doi.org/10.1590/S0104-59702016005000002. Accessed: 11/03/2024.

Fig. 5: Failed attempts to generate an AI portrait of Maria Bandeira at the age of 90, merging her with bryophytes. Source: Author, 2024.

After much processing, I arrived at a result that I approved (Figure 6), recovering, in this odyssey, a path that converges with the studies I have been doing on the mechanical eugenics of the gaze. Even so, the image did not reflect the haughtiness and smile that had so caught my attention in the analysis of his portrait in the field (Figure 4), demanding work of reconstructing texts to prepare the *prompts* that extended for another two months until I reached the final result (Figure 7).

Fig. 6: Fictional portrait of Maria Bandeira, made with AI at 90, in the Botanical Garden of Rio de Janeiro, merging with the bryophytes to which she dedicated so much. Source: Author, 2024.

Fig. 7: Fictional portrait of Maria Bandeira, made with AI at 90, in the Botanical Garden of Rio de Janeiro, merging with the bryophytes to which she dedicated so much. Source: Author, 2024.

6 Conclusion

As discussed in this article, the gaze goes beyond the field of vision and refers to our vision of the world. The potential of artificial intelligence to shape fields of visibility will not imply genocide or racial wars, as did the eugenics movements of the first half of the 20th century. However, it can establish new forms of invisibility and social exclusion, which impact the Global South through technological procedures that deepen racist dynamics. This technopolitical framework is combined with new processes of exclusion, with a strong ageist bias, exacerbating the erasure and social alienation of women, particularly older women. Suppose machinic eugenics refers to using technology or machines to implement or facilitate eugenic practices or policies. In that case, the machinic eugenics of the gaze refers to ways of seeing according to the standards established by artificial intelligence. For this reason, computer vision is a device (not just a tool) that can transform it into the hegemonic visual apparatus of our time.

Alternatives to improve computer vision models through data curation and improvements in machine learning processes will undoubtedly allow for specific problems to be solved, but not the pattern-based model of current AI systems, and therefore not their power dynamics and forms of distribution of the sensible. New questions, not answers, will come from counter-hegemonic structures rather than from adjustments to current models. These counter-hegemonic models refer to perspectives from the South, feminist and *queer studies*, standpoint and post-normal theory approaches, and different educational systems towards a "post-machine learning" culture and practice, as defined by Dan McQuillan (2022, pp. 104–108). Such an agenda suggests different approaches to artificial intelligence beyond the anthropocentric "man-machine" opposition and its prerogatives based on conceptions of pattern, deviation, or error. Following the irregular and unpredictable path, such an alternative agenda points to multiple ways of seeing and making worlds, taking what is outside the norm not as its model but as its starting point.

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FROM CELLULAR AUTOMATA TO AI AND FABRICATION

DESDE AUTÓMATAS CELULARES HACIA AI Y FABRICACIÓN

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Abstract

This paper presents research on workflows for architectural design through the integration of Cellular Automata (CA), Artificial Intelligence (AI), and Digital Fabrication. This study aims to explore how these technologies can optimise both structure and aesthetics in architectural design, providing an efficient and innovative framework. The methodology combines the generation of complex patterns with CA, the use of AI diffusion models for geometry optimisation, and the digital translation of these designs using Autodesk Fusion, enabling comprehensive project management and facilitating interdisciplinary collaboration. The methodology focuses on generating Cellular Automata (CA) patterns using a combination of bespoke and existing algorithms (e.g., Langton's Ant). CA patterns are developed within the Processing environment, leveraging local rules to create complex configurations. AI models, specifically diffusion models, are employed to iterate and optimise these geometries, facilitating continuous refinement of architectural designs and ensuring precise adaptation of the CA-generated patterns. This work develops a workflow aligned with the adoption and transformation of technologies in the Global South, particularly by integrating AI into the creative process. It opens pathways for adapting these methodologies to resource-constrained contexts, proposing a comprehensive framework that combines innovation and efficiency. The study significantly contributes to the future implementation of these technologies, promoting their accessibility and adaptability.

Keywords: Cellular Automata, Artificial Intelligence, Digital Fabrication, Workflows, Architectural Design

1 Introduction

The field of architecture is constantly evolving, seeking innovative methods to enhance design processes, particularly in structural optimisation and aesthetic refinement. In the context of the Global South, these emerging technologies present significant potential to overcome infrastructural and resource limitations, offering adaptable and accessible solutions that address specific local challenges. This approach encourages a rethinking of how adopting computational design technologies, such as Cellular Automata (CA), Artificial Intelligence (AI), and Digital Fabrication, can contribute to more inclusive architectural design and foster decolonial debates within the discipline.

Traditional practices, often reliant on manual drawing and static models, are laborious and limited in their capacity to explore complex forms and dynamic systems (Ball, 2011). The advent of digital technologies has triggered a substantial shift towards computational design methods, which offer greater flexibility, precision, and efficiency (Batty, 2007). One of the most promising advancements in this area is the integration of complex computational strategies, such as CA and AI. CA, a discrete model in computational mathematics, involves a grid of cells evolving through simple rules based on the states of their neighbors (Beigy & Meybodi, 2004). This method can generate intricate patterns and structures that mimic natural processes, proving to be a powerful tool for architectural design (Beigy & Meybodi, 2006). Similarly, AI, mainly through machine learning and diffusion models, can analyse large datasets to identify optimal design solutions that balance form and function (Gilpin, 2018).

This research aims to explore the effectiveness of CA and AI, specifically diffusion models, in generating architecturally appealing geometries that are both structurally and aesthetically refined (Glover et al., 2021). Diffusion models in AI simulate the propagation of particles or information over time, refining architectural designs through iterative enhancement of initial concepts (Beigy & Meybodi, 2007). This iterative process can lead to innovative solutions that may not be immediately evident through traditional methods (Beigy & Meybodi, 2008).

The study emphasises the use of depth map technologies for translating 3D models, bridging the gap between conceptual design and structural performance (Beigy & Meybodi, 2010). Depth maps represent the distance between surfaces in a 3D space and are key for converting 2D patterns generated by CA and AI into three-dimensional structures (Berlekamp et al., 1982). With the support of these technologies, architects can create detailed and precise models ready for structural analysis and optimisation (Betka et al., 2020).

Additionally, different studies have examined how these technologies can be applied in the Global South to address resource constraints and adapt to local contexts (e.g., Oxman, 2017). The integration of CA, AI, and depth-map technologies enables architects to push the boundaries of traditional design, creating buildings that are both aesthetically interesting and structurally strong (Fernández González, 2023b). This approach can potentially revolutionise architecture across diverse contexts, offering new pathways to develop sustainable and efficient designs inspired by organic forms or nature-inspired patterns.

2 From Generative CA to AI

This research represents a significant improvement in the field of architectural design. It demonstrates the practical application of Cellular Automata (CA) and Artificial Intelligence (AI) in form-finding processes, with a particular focus on structural optimisation. By integrating these advanced computational tools, the study provides a coherent framework for exploring new architectural forms while enhancing efficiency and creativity in the design process (Fernández González, 2023a), as illustrated in Figure 1.

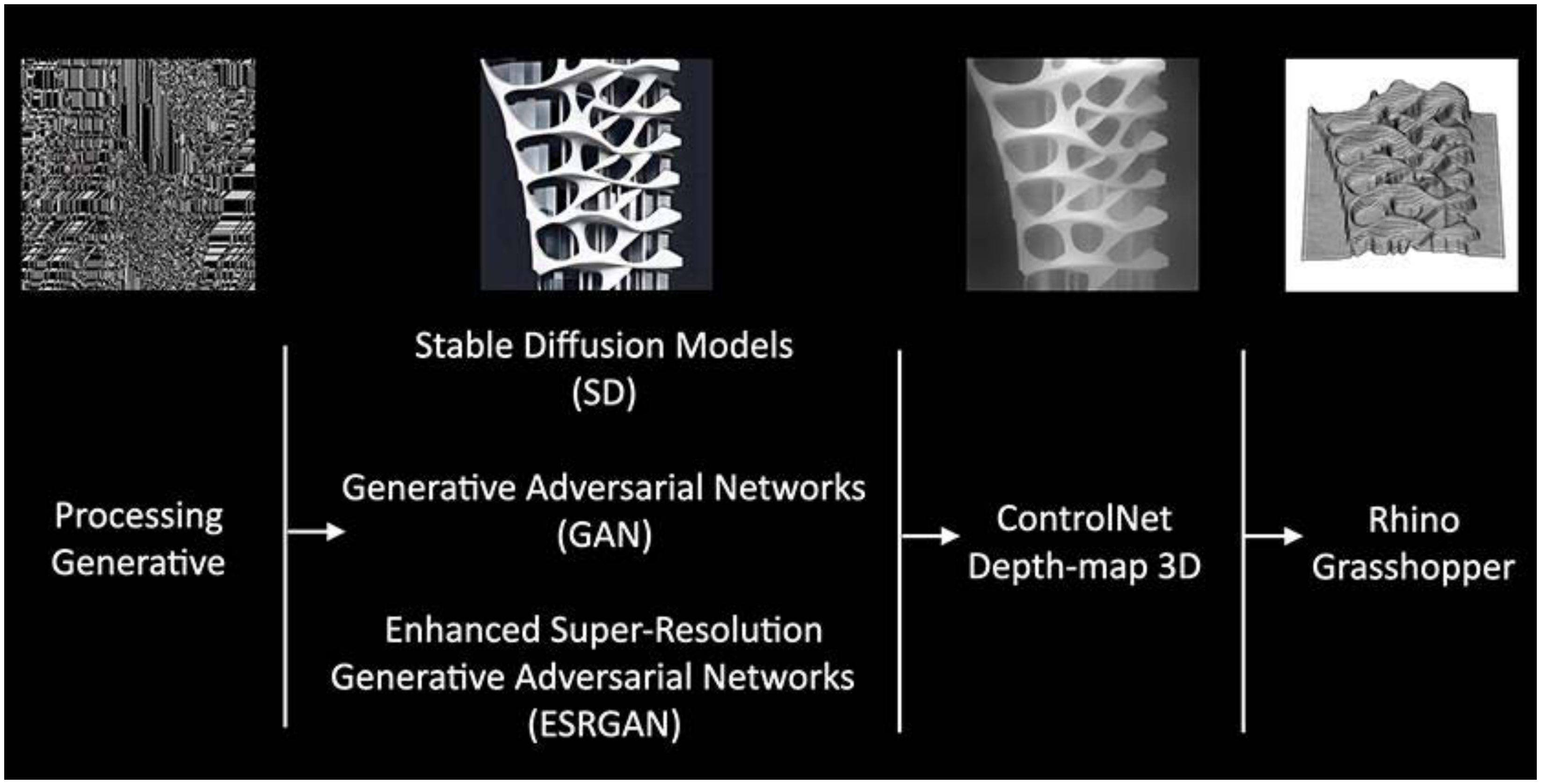

Fig. 1: Proposed workflow from Generative CA to AI. Source: Author, 2024.

The integration of CA and AI demonstrates the transformative potential of combining computational design techniques with AI algorithms and depth map technologies. Cellular Automata, as a computational model, enable the generation of complex patterns and structures that mimic natural processes (Beigy & Meybodi, 2004). This ability to simulate growth and form through systems based on simple rules provides architects with a powerful tool to explore innovative and efficient structural solutions. Diffusion models, which simulate the propagation of particles or information over time, facilitate the iterative refinement of architectural designs. This iterative process allows for continuous improvement and optimisation, leading to design solutions that balance aesthetic appeal with structural performance (Beigy & Meybodi, 2007).

Figure 2 demonstrates how depth map technologies play a crucial role in translating 2D designs generated by CA and AI into 3D models (Beigy & Meybodi, 2010). This process bridges the gap between conceptual design and structural performance, ensuring that aesthetic innovations are supported by practical viability (Berlekamp et al., 1982). The ability to accurately model and analyse complex geometries in three dimensions is essential for developing designs that are not only visually compelling but also structurally efficient and sustainable (Betka et al., 2020). Depth maps enhance the precision and detail of architectural models, enabling a more comprehensive understanding of spatial relationships and structural dynamics. This capability is critical in high-resolution architectural design, where intricate details and complex interactions must be represented and analysed precisely (Christen & Del Fabbro, 2019).

Fig. 2: Translation of an AI-generated image from a CA pattern to a 3D depth map using ControlNet. Source: Author, 2024.

By facilitating a deeper integration of these technologies, this research opens new pathways for developing sustainable, efficient, and aesthetically appealing architectural designs (Oxman, 2017). The combined use of CA, AI, and BIM enables the creation of structures optimised for both performance and resource efficiency, contributing to broader sustainability goals in architecture. This approach can lead to more energy-efficient buildings, produce less material waste, and are better adapted to their environmental context (Glover et al., 2021). The study's focus on high-resolution architectural design, incorporating intricate details and complex interactions, aligns with the principles of sustainable design. By leveraging computational tools to optimise both form and function, architects can create buildings that are not only beautiful but also environmentally responsible and economically viable (Beigy & Meybodi, 2008).

The study underscores the relevance of computational methods in addressing contemporary architectural challenges. As the demands of architectural design grow increasingly complex, encompassing sustainability, resilience, and adaptability, the need for advanced computational tools becomes more evident (Ball, 2011). This research demonstrates that the integration of CA, AI, and BIM can meet these demands, providing a comprehensive framework for innovative and practical design solutions (Mitchell, 2009). The ability to simulate and analyse complex interactions within architectural designs enables more informed decision-making and enhances the overall quality of the built environment, where innovative design solutions are essential (Kolarevic & Malkawi, 2005).

3 Methodology

The study adopts a multi-stage methodological approach, beginning with the generation of 2D patterns using customised Cellular Automata (CA) algorithms based on the Langton Ant model. These algorithms were modified with specific repetition rules to promote Class 4 distribution patterns, according to Wolfram's classification, enabling the creation of complex and adaptive configurations. The resulting patterns are exported in .txt format, with each point described by x, y, and z coordinates, and subsequently imported into Grasshopper, where they are reinterpreted as point maps ready for further exploration and transformation.

The next phase of the process involves the integration of Artificial Intelligence (AI) models, specifically stable diffusion models, which reinterpret the patterns generated by CA. This integration allows the conditioning of prior patterns, creating bio-inspired architectural representations with continuous forms and a high level of detail. The ability of diffusion models to produce precise and detailed variations facilitates creative exploration in architectural design, enabling the discovery of solutions that balance aesthetics and structure.

To translate the designs into 3D models, depth map technologies are employed in Grasshopper, allowing the transformation of 2D configurations into detailed three-dimensional geometries. These 3D models are then exported to Autodesk Fusion for structural analysis and final optimisation. This iterative process of translation and refinement combines computational design with AI knowledge and Building Information Modeling (BIM) coordination, ensuring that architectural forms meet aesthetic and structural criteria.

Comparison with similar studies: Unlike previous approaches that focus solely on exploring CA patterns without deeply integrating AI, this study stands out for its innovative methodology combining CA and diffusion models, achieving a cohesive and adaptive workflow. This combination offers new possibilities for generating bio-inspired architectural structures, positioning this research at the forefront of innovation in computational design.

Summary of Methodological Stages:

A Initial Design Exploration: 2D patterns are generated in Processing and Grasshopper using CA algorithms based on Langton Ant, with modifications to create Class 4 patterns. This process establishes a rich geometric foundation for subsequent refinement stages.

B AI Integration: AI diffusion models reinterpret the CA patterns, expanding design possibilities and guiding the results toward bio-inspired and highly complex configurations.

C Translation to 3D Models: Using depth map technologies in Grasshopper, the 2D patterns are transformed into 3D models, which are then optimised in Autodesk Fusion to ensure structural feasibility and architectural precision, as illustrated in Figure 3.

This methodological approach enables a unique synergy between CA, AI, and digital fabrication technologies, establishing an innovative and adaptable framework for diverse architectural contexts regardless of available resources.

4 Digital Experiments and Results

By applying CA algorithms within the Processing and Grasshopper environments, initial 2D patterns were generated as the first step of this experiment, serving as a foundation for developing more complex geometries. Governed by simple local rules, these patterns evolve into intricate forms that can adapt to diverse architectural needs. The iterative nature of CA allows for the continuous refinement of these patterns, as indicated in Figure 4.

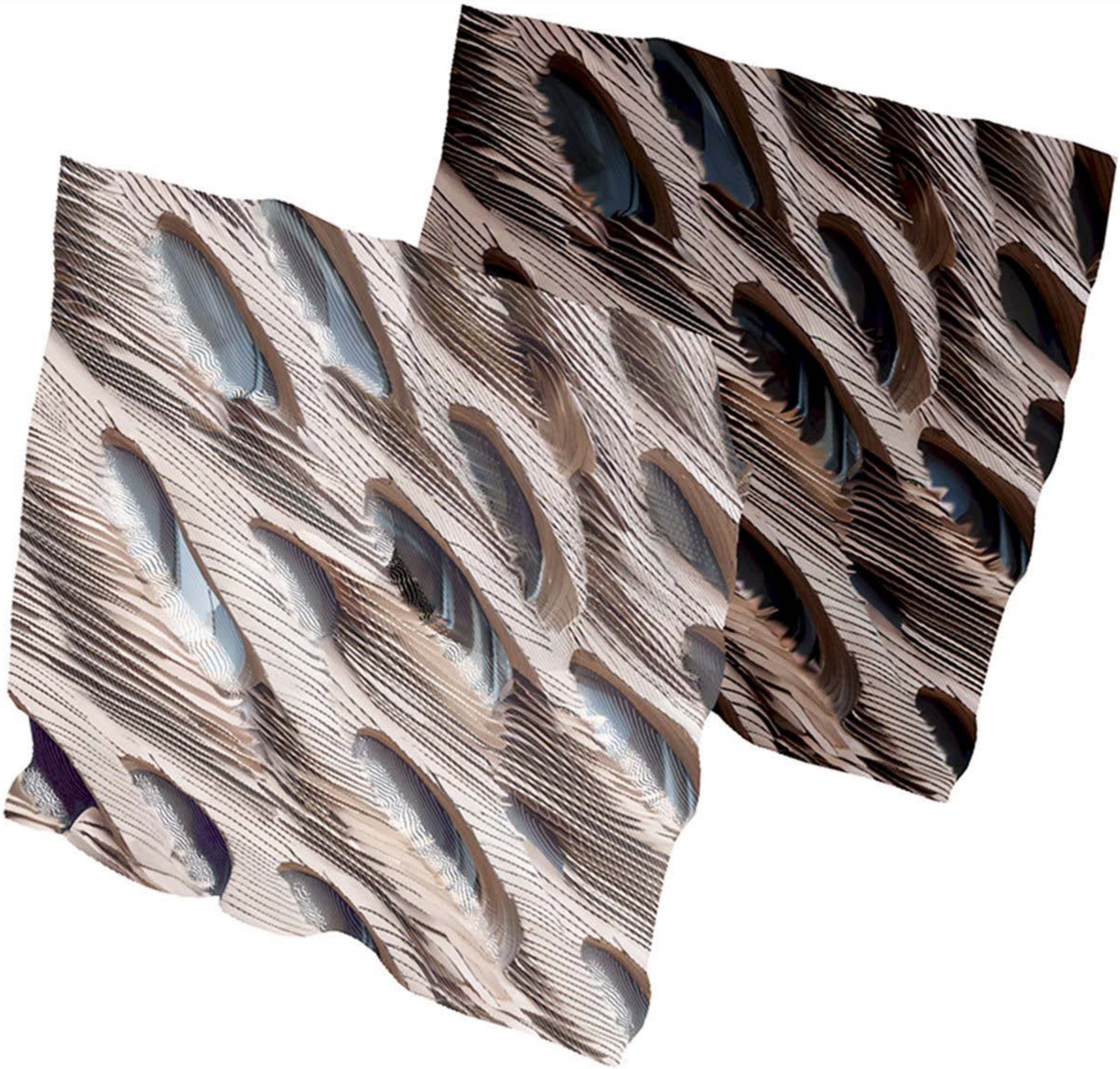

Fig. 3: Translation of a 3D CA model to AI-generated images using a custom Processing node based on depth map data. The results are saved as a point cloud and an OBJ file for Rhino. Source: Author, 2024.

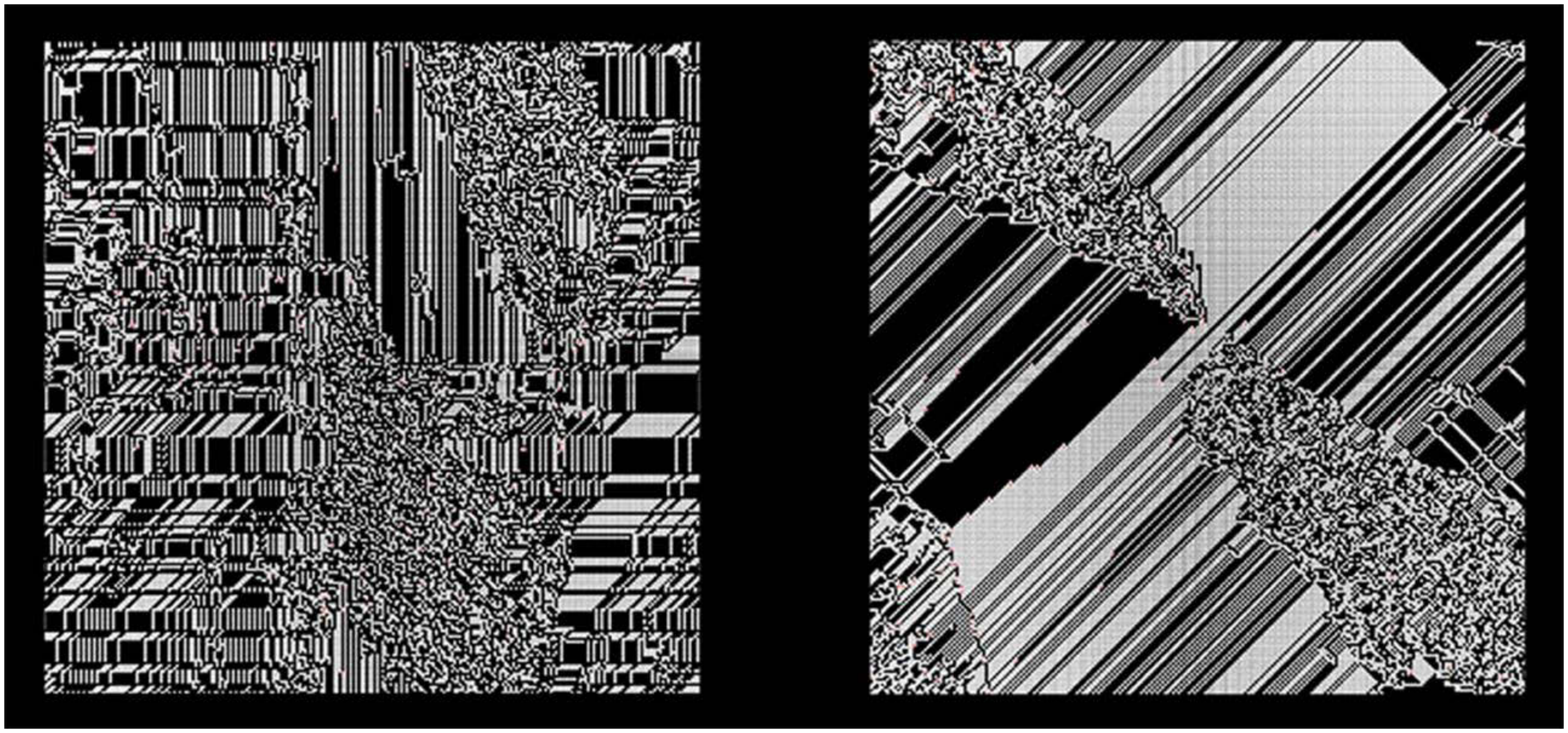

Fig. 4: Patterns generated by CA as the first step in this workflow. Source: Author, 2024.

Step 1: The first step in this workflow involved generating 2D patterns using Cellular Automata (CA) algorithms within the Processing and Grasshopper environments. The initial patterns, structured by simple local rules, were developed from algorithms based on the Langton Ant model, customised with modifications to repetition rules to generate Class 4 patterns, as defined by Wolfram's classification. This class of patterns offers high adaptability and complexity, which is crucial for architectural applications where functional and aesthetically unique configurations are sought. The resulting patterns were exported in .txt format with x, y and z coordinates, enabling easy import and manipulation in Grasshopper.

An important advantage of using CA is its ability to produce results with low memory and processing requirements, making this approach particularly suitable for resource-limited environments. This stage lays a foundation for creating more complex geometries, adaptable to various architectural needs, from facade creation to internal structural optimisation.

Additionally, the research examines how these technologies can be applied in resource-constrained environments and adapted to local contexts. The CA algorithms employed consume minimal computational resources, making them easily adaptable to pre-existing patterns in local realities, potentially serving as the basis for future work. In such environments, CA's ability to generate complex configurations from simple rules is especially relevant, enabling design exploration without reliance on sophisticated or expensive technologies (requiring no more than 16GB RAM and simple processes). Governed by basic computational principles, these patterns can be implemented in resource-limited contexts, allowing architects in the Global South to experiment with architectural configurations that respond to local specificities. The iterative nature of CA allows for continuous refinement of generated patterns, which is crucial for achieving solutions that are not only visually appealing but also functional and feasible within these contexts.

Step 2: The next step in the experiments involved integrating Artificial Intelligence (AI) diffusion models, which significantly expanded the design exploration space. These AI models, particularly diffusion models, simulate the propagation of particles or information through a medium, enabling a more sophisticated exploration of form and function. This capacity to explore a wide range of design possibilities is fundamental to architectural innovation, as it allows architects to discover configurations that may not be apparent through traditional methods (Gilpin, 2018).

Through thousands of iterations generated by these diffusion models, the process identifies optimal configurations that balance aesthetics with structural performance. In contexts where resources may be limited, this approach allows for adaptive experimentation, maximising material efficiency and tailoring the design to specific environmental conditions. In this sense, AI becomes a tool not only for optimisation but also for creative exploration, enabling specific adaptations to local needs and promoting decolonial and sustainable design practices.

The AI diffusion models also facilitated the exploration of various design scenarios, including the impact of different materials and diverse contextual conditions. The application of depth map technologies in translating these designs to 3D is essential for creating complex architectural forms that meet subsequent spatial analysis and material performance requirements.

Depth maps, which represent the distance between surfaces in a 3D space, are critical for converting CA- and AI-generated patterns into detailed and precise three-dimensional structures. This translation process bridges the gap between conceptual designs and their practical manufacturability, enabling the creation of structures that are not only visually appealing but also structurally coherent and economically viable in resource-limited contexts, as indicated in Figure 5.

Fig. 5: Set of variations of a CA pattern in the search for a potential architectural-structural solution. Source: Author, 2024.

Step 3: The application of depth map technologies proved to be a critical component in translating the 2D patterns generated by CA and AI into detailed 3D models within Grasshopper. Depth maps, which represent the distance between surfaces in a three-dimensional space, allow precise control over the final shape of the 3D model. This control is essential to ensure that architectural models are not only aesthetically appealing but also structurally robust and manufacturable. In the experiments, depth maps were generated to translate the 2D CA patterns into detailed 3D models within Grasshopper, as shown in Figure 6. Figure 7 shows how this technology provided precise control over the three-dimensional form, enabling the creation of highly detailed and accurate architectural models. Additionally, depth maps facilitated the integration of complex geometries into the overall building design. By accurately representing spatial relationships and the interactions between different structural elements, depth maps ensured that the final designs were not only aesthetically innovative but also structurally viable (Christen & Del Fabbro, 2019).

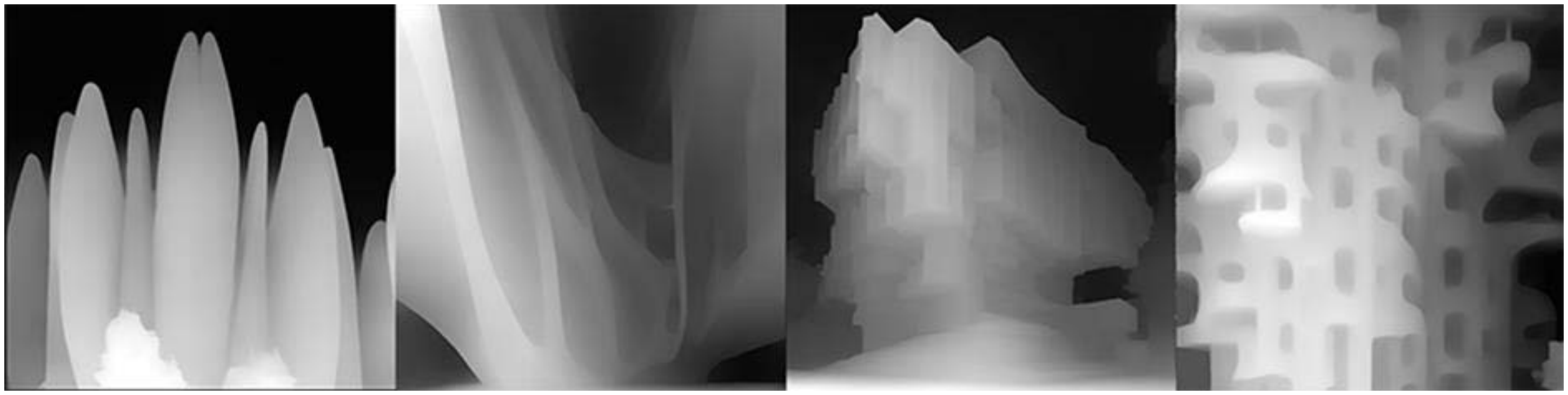

Fig. 6: Set of depth map variations based on a CA pattern in the search for a potential architectural solution. Source: Author, 2024.

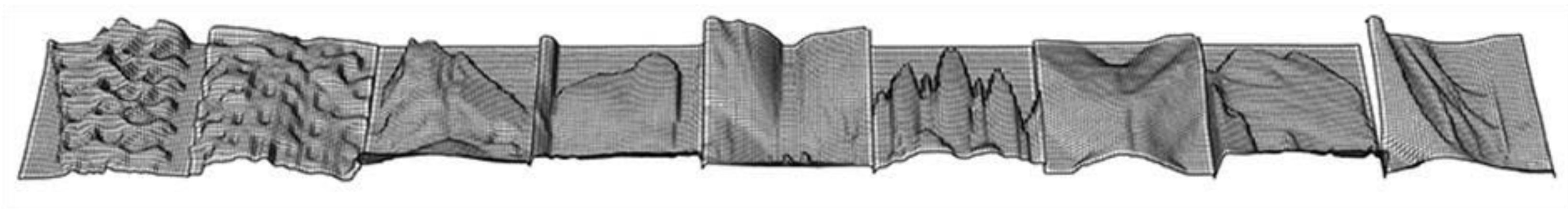

Fig. 7: Set of depth map translations with varying densities into Rhinoceros as a preliminary step towards the final 3D translation. Source: Author, 2024.

Step 4: The 3D models generated using Cellular Automata (CA), Artificial Intelligence (AI), and depth maps were subsequently refined and analysed using Autodesk Fusion, an advanced tool that facilitates precise evaluations of structural feasibility as the final step in the process. At this stage, Autodesk Fusion provides a robust platform for assessing the structural integrity of architectural designs, enabling designers to identify and address potential weaknesses in the structure before proceeding to fabrication. This analysis is critical to ensuring that the proposed architectural configurations are not only visually appealing and conceptually innovative but also capable of withstanding the loads and conditions they will face in real-world environments.

During this refinement process, aspects such as load distribution, material strength, and overall model stability were evaluated. The simulation in Autodesk Fusion illustrated in Figure 8 enabled iterative adjustments to optimise the model, modifying structural parameters and improving design efficiency in terms of material usage and strength. This iterative approach ensures that the final model is ready for implementation in the fabrication phase, minimising risks and guaranteeing that the design meets the safety and performance standards required in architectural practice.

Although work with Autodesk Fusion is typically conducted within an academic setting where the cost of the tool is mitigated by educational licenses, this reliance represents a limitation in research, particularly when considering its applicability outside academia. Future research proposes the use of Rhinoceros and Grasshopper as viable alternatives, simulating the structural evaluation processes currently performed on the Autodesk platform. This approach would allow broader access to the techniques developed in this study, facilitating their adoption in professional contexts and regions where access to Autodesk Fusion may be constrained by economic restrictions.

Depth map technology played a crucial role in this process, facilitating the conversion of 2D patterns generated in earlier stages into detailed 3D geometries that were then integrated into a 3D printing and fabrication workflow. This transition from flat patterns to three-dimensional structures enables architects and designers to explore complex configurations and test their structural feasibility in a digital environment before physical fabrication. The results of this evaluation and optimisation process demonstrated not only the feasibility of the design but also its structural integrity and visual uniqueness, highlighting how the integration of CA, AI, and digital fabrication can produce innovative architectural solutions tailored to the current demands for sustainability and structural efficiency (Fernández González, 2023b).

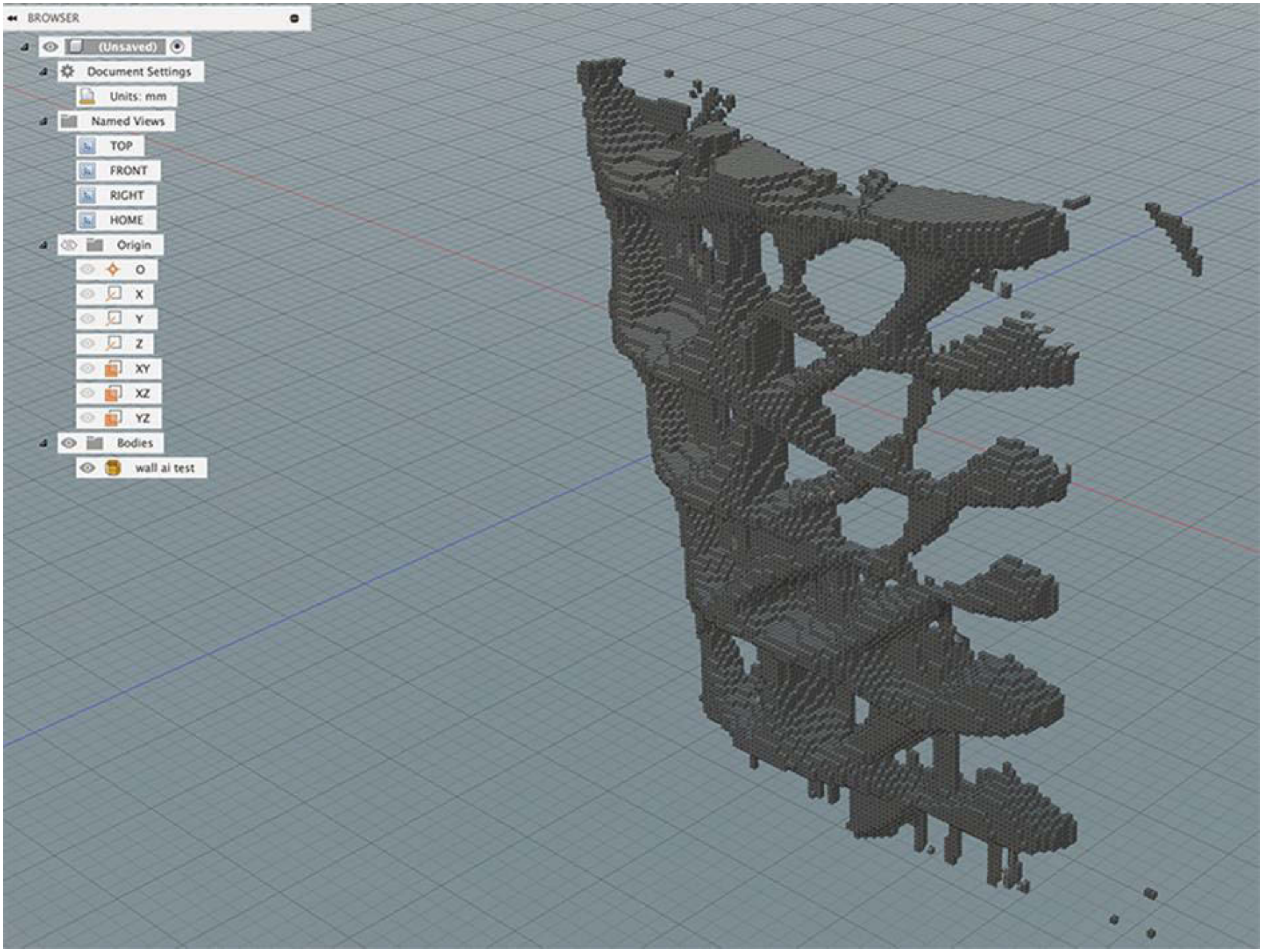

Fig. 8: Autodesk Fusion: Discrete Continuity of the 3D Model. Source: Author, 2024.

Finally, the refined 3D models were integrated into a digital fabrication process using PLA filament 3D printing techniques, allowing the complex geometries developed in earlier stages to be materialised. A key step in this phase was the discretisation of the form in Autodesk Fusion, which simplified the structures into modular and consistent components. This discretisation not only facilitates 3D printing by creating geometries tailored to the fabrication process but also significantly reduces the need for additional supports, thereby optimising the time and resources used during printing. By minimising the use of supports, the resulting model is not only more material-efficient but also higher in quality, avoiding imperfections caused by excessive support use in complex structures.

The fabrication phase, demonstrated in Figure. 9, not only validated the feasibility of the design but also highlighted its visual uniqueness and the structural integrity of the created models. The 3D prints, such as the one shown in the reference image, capture the precision of patterns generated through Cellular Automata (CA) and Artificial Intelligence (AI), demonstrating how these technologies can produce detailed and visually striking structures that maintain consistency during the printing process.

The results demonstrate that combining CA, AI, and digital fabrication offers an innovative and efficient approach to architectural design, capable of producing structures that are both aesthetically appealing and structurally sound. The implementation of discretisation and the reduction of supports enables the exploration of bio-inspired forms optimised for printing, resulting in sustainable and resilient models that meet contemporary architectural demands.

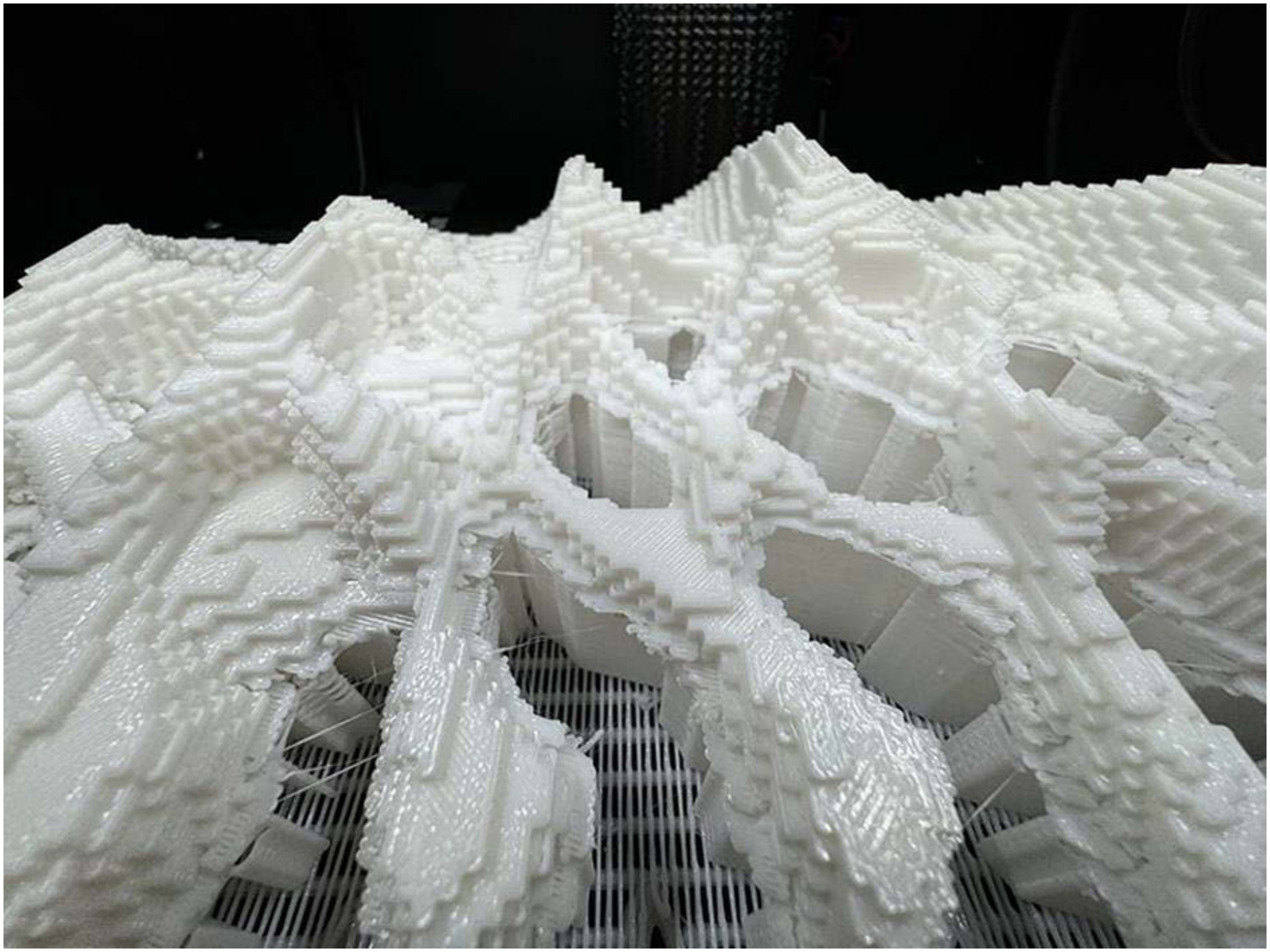

Fig. 9: Discrete 3D Model Printed in 3D. Source: Author, 2024.

5 Concluding Remarks

This study demonstrates that integrating Cellular Automata (CA), Artificial Intelligence (AI), and digital fabrication into a coherent workflow provides an innovative and robust approach to architectural design. This process enables an enriched exploration of forms, spaces, and structures, facilitating the creation of complex designs that maintain consistency throughout fabrication. Specifically, using CA for generating intricate patterns, combined with AI for optimising geometries, offers an adaptable and efficient method that addresses contemporary architectural demands for sustainability and aesthetics. Additionally, the discretisation of models in Autodesk Fusion simplifies forms for 3D printing, reducing the need for support and optimising resources, a feature particularly relevant in resource-constrained contexts.

Applying this workflow in Global South contexts opens new possibilities for architectural design in regions with limited infrastructure and access to advanced technology. CA's capacity to generate results with low memory and processing requirements makes this methodology viable in such settings, enabling architects and designers to experiment with innovative solutions tailored to local needs. This approach fosters decolonial design practices by adapting advanced technologies to be accessible and relevant to the Global South. As such, this workflow becomes a tool for democratising access to advanced design methods, promoting a more inclusive and contextually appropriate architecture.

Future steps include exploring Rhinoceros and Grasshopper as alternatives to Autodesk Fusion for structural simulation and evaluation, potentially expanding the applicability of this approach in non-academic environments where Autodesk Fusion's educational licenses may not be available. Further research could also focus on developing more advanced AI algorithms to enhance adaptability and customisation in the design process, optimising CA-generated models to better respond to the material and structural load conditions of specific projects.

The results of this study suggest that combining CA, AI, and digital fabrication not only enriches the formal, spatial, and structural exploration process but also provides a consistent framework for creating viable architectural structures. This workflow enables architects and designers in the Global South to overcome accessibility barriers and explore new design forms that are both aesthetically innovative and functionally robust, contributing to the development of an architecture that meets contemporary challenges sustainably and efficiently.

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WHAT HAPPENS WHEN THE SMART CITY CRASHES?

E QUANDO A *SMART CITY* TRAVA?

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Abstract

From a photograph of a malfunctioning digital sign, this article discusses the interplay between the concept of Smart Cities and the impacts of using advanced surveillance and control technologies in urban spaces, questioning the system's failure and its consequences on citizens' lives. The text addresses the specific challenges faced in implementing Smart Cities in the Global South, examining the operation of new forms of colonialism and a new model of capitalism based on the data market. Primarily based in the Global North, these models can distort the relationships between individuals and their connections with the world and cities, highlighting their role in exacerbating socioeconomic and cultural tensions. The text presents Smart Sampa, a project underpinned by the concept of Smart Cities under progress in Sao Paulo, Brazil, as a means of elucidating the complexity of programs that promise to manage cities through labyrinthine digital networks that integrate everything from surveillance cameras to government services on a single platform. The study prioritizes diverse knowledge frameworks, employing a non-hierarchical and cross-cutting approach that connects empirical findings and scholarly sources and fostering a debate on the myths of infallibility and neutrality surrounding these control technologies. The article is an investigative exercise that examines concepts, approaches, and potential gaps within the Smart Cities framework, which inspire artistic and activist actions that challenge the assumed normalcy imposed by such technologies.

Keywords: Smart city, Surveillance capitalism, Data colonialism, Global South

1 Introduction

In the Brazilian city of Sao Paulo — a Southeastern economic, industrial, and cultural powerhouse — on March 4, 2024, around 11 AM, an attentive crowd on Rebouças Avenue noticed that a digital sign was not serving its purpose. Strategically positioned before the descent into the tunnel, the electronic panel, instead of providing information about vehicle traffic in the vicinity, displayed the following phrase: "Windows could not", as shown below in Figure 1. 42

Fig. 1: Digital sign in Sao Paulo. Source: Author, 2024.

Building on this incident, the recorded image, and the associations it evokes, this article examines the operation of surveillance and control technologies used to manage urban spaces, governmental processes, and bureaucracies. The investigation crosses the developments of the conceptualization and construction of Smart Cities, given their reverberation in the development and analysis of contemporary cities, which are, by excellence, the spaces where social and power clashes occur, as a subject to transformations at local and global levels (Morozov & Bria, 2019). Moreover, the entire arrangement and instrumentalization of urban infrastructures closely connects to processes related to data mining from digital networks, data colonialism, and surveillance capitalism (Couldry & Mejias, 2019; Zuboff, 2020). These concepts, addressed later, reveal the colonial relationships that persist and, as a result, dominate the Global South based on strategies that create dependency and erode sovereignty in the dominated countries (Quijano, 2019).

Neoliberal-aligned technocrats argue in one-dimensional narratives that only computational assistance can effectively manage large and complex urban centers (Greenfield, 2013). In opposition to such arguments and in order to develop a discussion that privileges the multitude of knowledge produced on the subject proposed for this article, the methodology adopted favors the transversal and non-hierarchical association among various forms of knowledge production (Rancière, 2016), enabling a dialogue between diverse approaches to the same object. Beyond articulating concepts through a bibliographic review, the Smart Sampa program in Sao Paulo (an initiative grounded in Smart City concepts) serves as an illustration of the main issues related to the impacts of this type of development imposed on contemporary cities, distorting the citizens' relationships with one another and with the urban environment and the world. The decision to choose this project is based on its launch in 2023 and its continuous implementation since then, allowing for monitoring of the most relevant discussions and issues within the context of Smart Cities in the Global South and highlighting the spaces of dispute and tension as the project progresses. Furthermore, considering that the field of art is prolific for understanding the contemporary world, literary references, cinema, and other artistic productions are drawn upon to clarify the understanding of the concepts addressed in the article.

2 Smart Sampa and the Smart Development Standard

The Smart Sampa[1] program, announced by the Sao Paulo Municipal Government and continuously implemented since late 2023, is presented as a set of solutions regarded as intelligent for the administration of Brazil's largest metropolis. The project is yet another representative, among many in Brazil and worldwide, proposing a centralized management platform for governmental processes and surveillance and control systems in urban spaces. Underpinned by the conceptualization of Smart Cities, the popularized term smart – which seeks to infuse intelligence into every aspect of life and everyday objects, from toothbrushes to vacuum cleaners – as seen in the platform's name, is not used naively. As Morozov and Bria (2019) argue, the term is part of a contemporary vocabulary that seeks to represent a constellation of meanings, ambiguous and vague, facilitating a multiple and broad semiotic approach. In short, the so-called intelligence in the context of cities is observed in the use of advanced technologies aimed at better management and production of resources and the alteration of citizens' behavior, promising better connectivity and security. Smart Sampa is embedded within the broad concept introduced by the authors.

Given the global scope of this movement, the use of existing urban infrastructures in established and continuously expanding cities – targeting a smart development standard – provides critical examples. In Brazil, the Operations Center of Rio (COR), in the city of Rio de Janeiro, a Southeastern coastal cultural hub, has been under operation since 2010 and is regarded as an emblematic case of intelligent urban development. The similarities between COR, Smart Sampa, and many other Smart Cities are evident. The projects integrate surveillance cameras, various types of sensors installed in the urban fabric, and databases sourced from public services. These elements are incorporated into programs designed to secure real-time management of the cities they control. In the analysis of COR, researcher Fernanda Bruno (2018) points out that the project is responsible for extracting and processing a large quantity of data, effectively ruling out any form of negotiation (more precisely, consent for processing personal data) between citizens and the system. Driven by algorithms, this type of management can alter the individual's experience in the city, such as a traffic sign that, based on processed information and data, may indicate routes to be followed or avoided by vehicle drivers. Moreover, as Greenfield (2013) observes, the information generated by COR may have been used

1 The information regarding the operation and implementation of the Smart Sampa program was based on the Terms of Reference published in the context of the call for bids for the platform's implementation (Prefeitura do Município de Sao Paulo, 2022).

in the execution of forced evictions in favelas in Rio de Janeiro, indicating questionable uses concerning marginalized populations in the context of authoritarian movements typical to the realities of the Global South.

A point to consider relates to how this urban development standard is implemented in the Global South. As Iara Schiavi (2021) emphasizes, the conceptualization of Smart Cities does not respect the constituents of urban space in their cultural and social dimensions, being developed generically. More specifically, this type of project is spearheaded by the public power in essential collaboration with private entities, primarily represented by significant technology and data industries. In Rio de Janeiro, COR was funded by the Rio de Janeiro Municipal Government in partnership with IBM, known for operating real-time policing and crime prevention solutions in cities such as Atlanta and Chicago (Morozov & Bria, 2019). In the case of Smart Sampa in Sao Paulo, the city government subcontracted the Smart City SP alliance through a bidding process, bringing together companies from various sectors, notably Camerite, which, together with Microsoft, develops city monitoring solutions through Artificial Intelligence and integrated surveillance cameras, as stated on the institution's website (Camerite, n.d.).

Unquestionably, the analyses of Smart City projects should consider that the conceptualization of this urban management model is subject to socioeconomic and geopolitical frameworks that stem from the Global North and whose development is underpinned by neoliberal ideals (Morozov & Bria, 2019). There is an evident colonial relationship when observing that the companies operating in public-private partnerships in the Global South are located geopolitically in the Global North countries that have been considered colonizers and continue to hold such control. The technologies used in Smart Cities in the Global South are developed in response to urban issues from the Global North (Schiavi, 2021), establishing dependency relationships and reaffirming power structures. As Aníbal Quijano (2019) argues, all these structures are subjected to the theory of European superiority, which has become an aspiration for the countries of the Global South. This idea leads to the uncritical importing of such means of domination by the Global South countries as if they could participate in colonial power. It is the evolution into new forms of colonialism.

3 Context, Concepts, and Impacts

Philip K. Dick's short story Minority Report (2002), alongside its eponymous film adaptation, is seminal in addressing how implementing advanced surveillance and control systems, deemed as solutions to crime in cities and characteristic of Smart Cities, can impact societies. In the plot, the head of the institution, who operates predictive systems based on extracting and processing citizens' data after being confronted as the perpetrator of a crime in the future, questions the infallibility of such technology and the limits of privacy and free will. Furthermore, the narrative provides context for the technologies that can be used to operate control and surveillance systems and the data processing and extraction in cities, as proposed by Smart Cities.

Regarding urban safety, crime prevention, and resolution, no other surveillance technology has raised so much concern as facial recognition cameras installed in public places – a key proposal of Smart Sampa and a fundamental aspect of the definition of Smart Cities. The program follows the international trend of increasing the use of biometric readers, even though this tool has been highly criticized. Access Now (2021), an organization that advocates for human rights in digital networks, in association with other institutions that promote discussions on facial recognition technologies, published an open letter calling for a global ban on these types of systems in public spaces and in situations where surveillance cannot be avoided. According to the coalition, deploying this technology is incompatible with human rights and freedom as it violates privacy, leads to discrimination, suppresses liberties, and runs without transparency or consent. In various countries and cities in the Global North, implementing facial recognition systems in public spaces is prohibited or operated under stringent legislation. Meanwhile, Brazilian legislation does not show effective strategies for regulating the use of this technology (Branco, 2022).

Researcher and activist Tarcízio Silva (2022) states that, although these technologies are often regarded and marketed as neutral, they are otherwise political and technical reflections of the existing discrimination and racism in societies. The author contends that these technologies and social-technical imaginaries are developed under the white-privilege logic, resulting in an unequal distribution of knowledge, resources, and violence against non-white groups, thus reaffirming the points made by Quijano (2019). Biased databases, built on a hegemonic standard of physical characteristics through which facial recognition aims to identify a specific individual, cause significant errors in recognizing Black individuals. This results from technological development intertwined with structural racism (Silva, 2022).

However, discussions on Smart Cities do not end with the approach to video surveillance and the promise of enhancing urban security. As outlined in the concession RFP (Request For Proposal) for the Smart Sampa program, this project aims to bring together as many public and private services and databases – both public and private – as possible into a single platform. Cross-referencing information from different aspects of daily life would allegedly enable the effective management of urban spaces. The issue is that this technological arrangement, which relies on data shared across networks and stored in massive servers worldwide, implies what Nick Couldry and Ulisses Mejias (2019) refer to as data colonialism, drawing an analogy to the processes of domination carried out by colonial powers during mercantilism in the 16th century. This exploitation model generates wealth by processing vast data and extracting patterns and regularities that reveal trends and potentialities in consumption and desire. Much of the mined information is often extracted without the individual associated with it even knowing.

Data colonialism is a fundamental part of the economic model that Shoshana Zuboff (2020) calls surveillance capitalism. User information mined online – often considered useless until recently – is extracted by large tech companies (such as the companies mentioned earlier, IBM and Microsoft, as well as Google, Cisco, Facebook, and Amazon, among others) and feeds data processing systems. Once translated into behavioral consumption patterns, this information is sold to those who can take advantage of it. These operations, used in marketing strategies and the sale of consumer goods and services, can reorganize the desires and needs of individuals, and distort social relations. Social media, the protagonists of this new model of control, encourage users to share all aspects of their lives in a mix of exhibitionism, voyeurism, and spectacle, promoting self-exposure practices and trivializing behaviors of surveillance and data extraction (Bruno, 2008). A crucial issue within data colonialism is that data sharing is the primary protocol for functioning systems connected to digital networks, leading Clare Birchall (2017) to neologism shareveillance. Therefore, data production becomes continuous and inevitable, and as a consequence, "we are traceable by what we share" (Beiguelman, 2021, p. 49, our translation).

It is thus possible to see that surveillance does not only aim at the physical body that moves through public spaces and commits crimes. The data generated by all types of online interaction and sharing are subject to being extracted and used for purposes that sometimes are not known. The notion of the panopticon, the gaze of a few who watch over many – widely criticized and explored since Michel Foucault's (2008) conceptualization of disciplinary societies – does not represent the multitude and heterogeneity with which surveillance can affect individuals in the contemporary context. In search of a concept that better clarifies this theme, Bruno (2010) uses the term distributed surveillance, which refers to surveillance embedded in all kinds of devices installed in everyday places and for personal use and which often does not have surveillance as its primary function. It is exercised in a heterogeneous and decentralized manner, diffusely, with the liquidity (Bauman & Lyon, 2013) necessary to occupy any empty capillary of human existence. There is also the creation of an imagined sense of collaboration, where all citizens are involved in the struggle for desired security: "The vigilant gaze and monitoring of crime and criminals are not restricted to inspection and security institutions but extend to every individual with access to the Internet" (Bruno, 2010, p. 164, our translation).

In Foucauldian disciplinary societies (Foucault, 2008), power was exercised in relatively hermetic spaces—prisons, sanatoriums, barracks, and schools. Deleuze (2013) argues that a new form of power emerged in the so-called control societies with the development of telecommunications and satellite transmission technologies. It is a power that transcends the limitations of institutions and physical space, using the immediacy provided by technological advances to exercise control in an extraterritorial and global manner. Television was one of the first such instruments, allowing a direct connection with the viewer, the controlled citizen, who is continuously bombarded with advertisements that mold new consumption patterns and information that distort the relationship between the individual and the world, serving imperialist and colonialist interests.

4 Problematizations

From dystopia to everyday life, Smart Sampa, the COR, and the conceptualization of Smart Cities represent the use of public power to impose security, surveillance, and control systems operated by companies from the Global North. These companies are indifferent to discussions about the value of privacy or the issues – notably, those related to the specificities of the Global South context – already highlighted by doctrine, thus silencing struggles and expanding state oppression against vulnerable populations. The discussion suggests that using data sourced from these control systems further drives the growth and consolidation of big tech companies as the actual managers of cities, societies, and human behavior.

Myanmar's experience illustrates this phenomenon. According to journalist Max Fisher (2023), until 2013, Myanmar was governed by an isolationist and prohibitionist regime that restricted internet access, mobile phones, media, and foreign visitors. With a shift in government, a technological opening started. Facebook capitalized on the opportunity to expand its influence by subsidizing smartphone purchases and offering free internet access with state support. This permission allowed the company to test its algorithms as if in a laboratory on a population largely unfamiliar with connectivity technologies without adequately considering the risks of such intervention in a country with severe ethnic and political conflicts. Negligence in moderating extremist content on such a vulnerable ground led to severe consequences. Despite numerous warnings from the scientific community, Facebook quickly became one of the country's primary sources of (mis)information and failed to curb abuses, mainly due to the lack of Burmese-speaking moderators. For an extended period, only one professional was available to oversee all posts made on the platform.

In a tragic episode, the population was incited to pursue, attack, and kill Muslims of the marginalized Rohingya ethnic group after the spread of a fake news story accusing two individuals of raping a Buddhist woman. The platform amplified hate speech, escalating tensions between Buddhists and Muslims and pushing Myanmar to the brink of civil war. This example demonstrates Global North tech companies' lack of responsibility in their subordinate societies. The complexities and specificities of countries already facing high internal tensions are ignored due to the socioeconomic and cultural strains they are involved in precisely because of the destructive historical interference of colonizing nations.

Taking Smart Sampa and Sao Paulo, Brazil’s biggest metropolis, which already exceeds twenty million inhabitants according to the latest census conducted by the Brazilian Institute of Geography and Statistics (IBGE) as examples, the economic and control potential that can be exploited within the context of data colonialism and surveillance capitalism is substantial. It is important to note that, despite being widely discussed from the perspective of large companies with an ostensive internet presence, public institutions can also benefit from such operations. In 2013, Edward Snowden, a former systems analyst at the US National Security Agency, disclosed to the British newspaper The Guardian an abusive scheme run by the US government and technology companies that monitored and mined information from phone calls, emails, cloud-shared files, and other data from the social media of citizens and political figures from various countries. The purpose of such data extractions remains unexplained. However, since they are known to be meaningful to the government, this has sparked an intense debate about digital rights, privacy, and data governance (Lyon, 2018).

In Brazil, there are various public services available through mobile apps that extract data from citizens, such as name, email, date of birth, address, CPF (Similar to Social Security Number, it is a unique identifier for individuals in Brazil mainly used for tax and legal purposes), RG (state-issued ID card), facial biometrics, and, in some situations, the citizen's location, operation time records, and which resources were used within the platform. Often, even data stored on devices can be accessed through meaningless authorizations in the operation of the service provided (Abreu et al., 2018). The concern is that centralized information and data models, like those presented earlier, are prone to misuse and abuse (Doneda & Kanashiro, 2010). The arguments validating this digitization of public services correlate with the proposal for social inclusion and creating an image of a country that overcomes its technological delays, reflecting and uncritically importing models and technologies developed in the Global North context.

The scenario presented by filmmaker Ken Loach (2016) in the film I, Daniel Blake exemplifies some of the possible developments and challenges of the digitization and outsourcing of government services. The Kafkaesque character who names the film is on his journey in search of the promised disability insurance after suffering a heart attack that prevents him from working. In the mentioned context of public-private partnerships, some public services (including the one sought by Daniel) have been subcontracted, exacerbating the strain on those seeking rights guaranteed by the state. The film raises questions related to the disparate asymmetries faced by some citizens regarding technologies imposed in state bureaucracies. Operations considered simple by those familiar with digital devices and processes may be enough to limit or hinder access to certain services that are often indispensable for ensuring the dignity and life of the citizens.

The themes previously discussed, from surveillance and security to data colonialism, constitute a complex web of technological systems and services that broadly shape the proposals for Smart Cities. Despite various difficulties and criticisms, this type of development continues to expand. One conflicting issue that complicates the understanding of how a future Global South city transformed into a Smart City might operate is that this model, as conceived and promoted by technocrats, demands cities with clearly defined boundaries, free of ambiguities and conflicts at their edges (Rozestraten, 2018), which is definitely not the context of the large and complex cities of the Global South. The fact is that, despite extensive criticism – whether due to the dismantling of privacy and the blatant violation of the fundamental right to data protection guaranteed by Article 5, Section 79 of the 1988 Brazilian Federal Constitution or due to the lack of evidence supporting the accuracy of these technologies in avoiding errors and injustices –, the Smart Cities project continues to be implemented without effective resistance.

5 Living in the Gap

However, what happens when the Smart City crashes? What damages could failures in these control systems cause? Returning to the image that sparked this discussion, what was it that "Windows could not" do? Is it possible to manage complex contemporary cities using technologies developed under Global North models? Could Windows perform efficiently, given the vicissitudes and idiosyncrasies of a city in the Global South? What are the possibilities of breaking away from the standards imposed by these technologies managing the city and its social life? Where is the gap between existence and resistance? Giselle Beiguelman (2021) points out that, for being connected to other digital networks, the technologies previously explored are vulnerable to intrusions and activities that subvert the norms imposed by these technological arrangements. Artistic productions represent part of this investigation into gaps that exist to subvert dominant codes.

In the work *Google Maps Hacks*, presented in Figure 2, Simon Weckert (2020) explores the impact of decisions made by the urban navigation algorithms apps that rely on the geolocation data shared by its users. Using approximately a hundred mobile phones connected to Google Maps transported in a wheelbarrow, Weckert caused chaos in the app: it indicated large traffic jams on the streets he passed, even though they were empty and motionless. The performance reflects on the potential consequences of understanding the level of control imposed on everyday actions. Being confined to his own home in China after criticizing the Chinese government, Ai Weiwei (2012) reversed the regimes of visibility imposed by cameras monitoring outside his residence, installed by the state to ensure the political prisoner would not escape. The artist made all his daily activities available through streaming videos on the internet, mocking the surveillance and control he was subjected to. His images showed more than those from the government cameras and could be accessed by anyone, including government institutions.

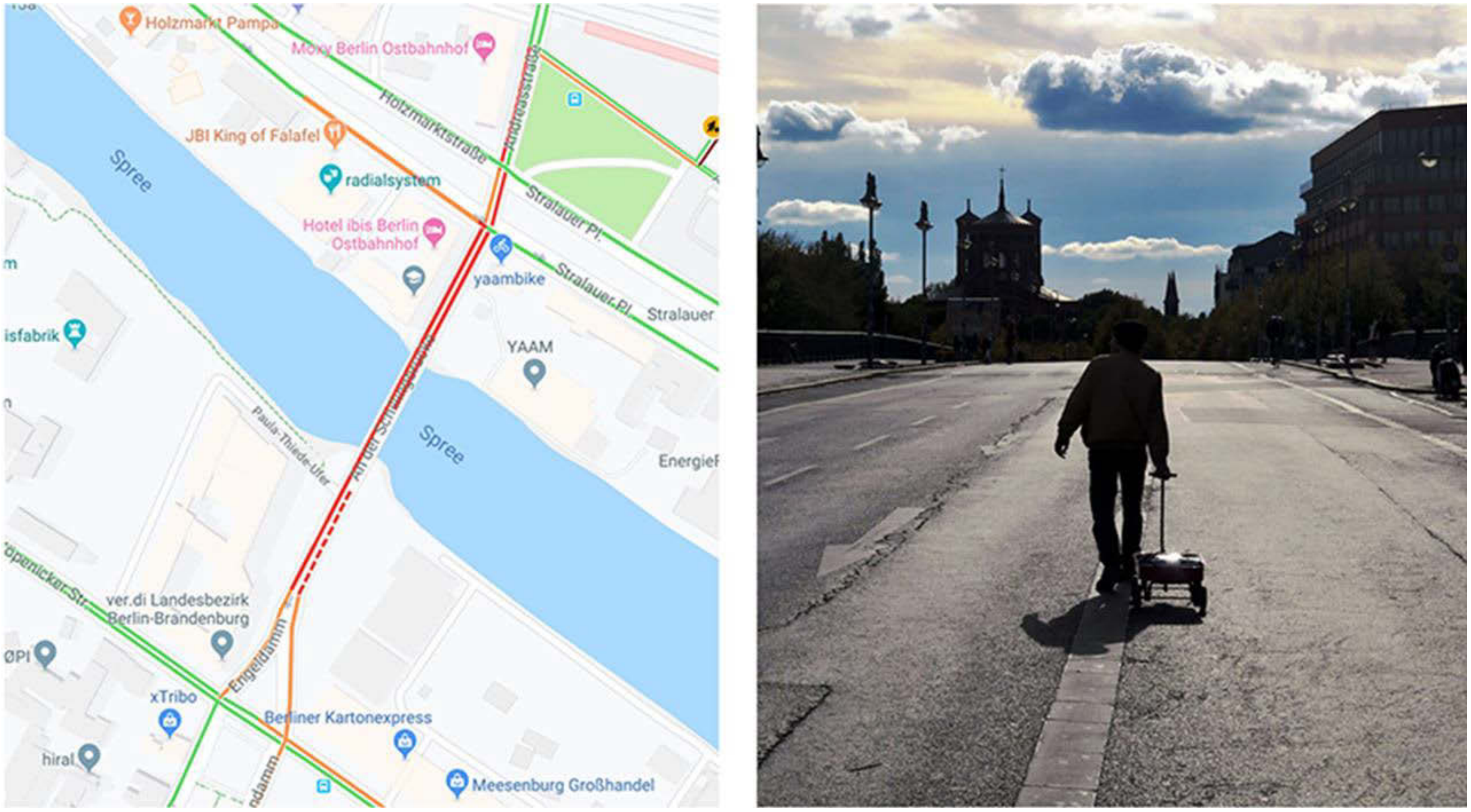

Fig. 2: Google Maps Hacks. Source: Simon Weckert, 2020. Available at: https://www.simonweckert.com/img/googlemapshacks/maps_13_2.JPG

Resisting facial recognition technologies, Adam Harvey (2010) and Leo Selvaggio (2014) create masks or facial interventions using makeup to generate biometric patterns that cannot be identified or linked to anyone. This disruption of the regular pattern in such works examines the limited capacity of facial biometric identification systems, which are easily fooled by strategies that prevent the correct reading of the essential facial points required for precise identification. In the context of the Global South, Mexican artist Rafael Lozano-Hemmer (2015), in his work Level of Confidence, as shown in Figure 3, inverted the militarised logic of technologies designed to hunt criminals or suspects by training systems to tirelessly search for the faces of forty-seven missing students, likely killed in an operation involving the government, police forces, and drug cartels. Visitors' biometric data were read and interpreted to reveal which of the students' faces bore the most resemblance, highlighting the traceability and control exerted by facial recognition systems.

Fig. 3: Level of confidence. Source: Rafael Lozano-Hemmer, 2015. Available at: https://www.lozano-hemmer.com/showimage_emb.php?proj=level_of_confidence&img=montreal_2018&idproj=295&type=artwork&id=1

The point these examples seem to prove is that no technology or system is infallible or immune to unexpected external interventions. The Smart Sampa initiative, which will soon centralize a significant amount of data and information about Sao Paulo's residents, could also be hacked, even for criminal purposes, revealing a complex paradox for public safety and management programs. It is also important to remember the potential manipulation of captured images through well-known techniques such as deep fake, which could end up incriminating innocents or exonerating criminals. Furthermore, citizens' sensitive data could be potentially exposed to anyone who might benefit from it. Given the complexity of the integrations and databases that will form the platform, it is difficult to predict the impacts that this type of criminal intervention could cause. Still, it is true that while some gaps may be exploited for criminal purposes, others open up avenues for creating and democratizing access to digital networks as a form of activism that seeks to hack current regimes of visibility and control (Beiguelman, 2021). History, nonetheless, has been categorical in favoring hegemonic systems, conjuring dystopias, and consequently destroying this kind of hope.

6 Final Considerations

Countries in the Global South face problems stemming from earlier colonial periods that predate the control stage proposed by supposed development models such as those of Smart Cities and, therefore, the Smart Sampa program, taken as an example of a project in continuous implementation and evokes reflections and criticisms. Such instrumentalization of the city with surveillance technologies and data extraction and processing is embedded in the context of data colonialism and surveillance capitalism, an advanced model of domination based on information located in digital networks (Couldry & Mejias, 2019; Zuboff, 2020). It is the continuation of power systems imposed through development standards that bear no relation to the socio-economic and cultural discrepancies in colonized and dominated societies. What should be a paradigm for significant development in the cities of the Global South, which could be better managed for progress in socio-economic and cultural fields, reveals a conflicting issue since it is precisely these technologies created and implemented following the challenges of the Global North and used for urban management that fail to achieve satisfactory and just results in colonized countries (Quijano, 2019; Schiavi, 2021; Branco, 2022; Fischer, 2023).

The critical analyses developed during the implementation of Smart Cities programs in cities of the Global South must consider that the development standards imposed do not respect or value local multitude and specificity. More assertively, driven by private economic interests, this type of project shows no connection "to the real-world problems of real people" (Morozov & Bria, 2018, p. 2). It is, therefore, necessary to explore, within the various fields of knowledge production, the possible gaps of non-dominant existences within a colonial arrangement that seeks, by any means, to extinguish the heterogeneities present and necessary for constructing truly smart cities. As Beiguelman (2021) observes, the city is no longer just the focus of the gaze; it presents itself as a space of articulation between informational and physical territories, with new relationships and possibilities for subversion. In the failure of Windows, possibilities arise to build new critiques and counter-hegemonic knowledge about the management of cities in the Global South.

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COLLABORATIVE PLATFORMS IN THE GLOBAL SOUTH: THE CASE OF ARQUIGRAFIA

PLATAFORMAS COLABORATIVAS NO SUL GLOBAL: O CASO DO ARQUIGRAFIA

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Abstract

Rooted in historical, economic, and technological inequalities between Global North and South, digital inequality affects the born-digital contents and collaborative platforms. This study examines Arquigrafia (www.arquigrafia.org.br), a Brazilian collaborative platform for sharing architectural and urban space images, to explore similar platforms' challenges. The article examines Arquigrafia's technical and collaborative aspects within the Global South digital landscape, highlighting how the platform addresses infrastructural limitations and power imbalances. It demonstrates Arquigrafia's role in countering digital hegemonies while promoting cultural preservation in the South. Using data from Arquigrafia's database, we quantitatively analyzed users' characteristics and image uploads with MySQL and SPSS. Interviews with fifteen experts from various fields involved in the project were qualitatively analyzed, using the Affinity Diagram method to provide insights on the platform's evolution. Results show that the lack of user-provided information impedes personalized content delivery. Collaboration peaked in 2016 but declined afterwards. Interviews emphasize the need for collaboration in both content contribution and platform development. The study concludes that Arquigrafia needs a unified vision, improved collaboration, and sustainable maintenance. Recommendations suggest ways to enhance users' engagement, leveraging educational partnerships and adopting open-source models to ensure long-term success.

Keywords: Digital Inequality, Collaborative Platforms, Global South, Arquigrafia

1 Introduction

Digital inequality and knowledge control between the Global North and the Global South is a universal issue. It is deeply rooted in historical, economic, and technological inequalities. The development of digital infrastructures illustrates what Quijano (2020) describes as the coloniality of power: the persistence of asymmetries between core and peripheral countries, sustained by the perpetuation of Eurocentric knowledge systems and forms of subjectivity inherited from colonization, even after the political independence of former colonies. This article explores these tensions through a counter-hegemonic initiative, the Arquigrafia platform, focusing on how resource and infrastructure gaps hinder the development and preservation of cultural heritage and knowledge about urban environments in digital formats.

There are notable examples of these applications. Lacerda describes a collection of photographs from Rockefeller Foundation archives, which document the foundation's work on public health issues in Brazil from 1920 to 1940 (Lacerda, 2002). Vasconcellos and Rodrigues demonstrated how photographs were used by hygienists in early 20th-century São Paulo to document urban environments and educational settings (Vasconcellos & Rodrigues, 2006). Abrantes used the photographic archive of the Brazilian Institute of Geography and Statistics as a historical source to show representations of female labor in Brazil during the 1950s and 1960s (Abrantes, 2013). Silva examined the establishment of the Archive of Projects of the Library of the School of Architecture and Urbanism and Design of the University of São Paulo (FAUUSP), the treatment of the Collection Jacques Pilon, as a documentary source to show the constitution of the architectural field in Brazil (Silva, 2016). Finally, Stewart compared photographic albums to document the architectural and urban changes in Brazil over decades (Stewart, 2019).

Historical images, especially, offer invaluable insights into past events, cultural practices, and architectural developments. Collaborative platforms that enable access and contribution to such image databases are not just beneficial but essential for academic research, public education, and cultural preservation. In Sweden, the DIGARV platform is a collaborative tool for working with cultural heritage and research data, including born-digital content (Åhlfeldt & Matsson, 2024). In Brazil, Arquigrafia, launched in 2010, stands as a prime web-based collaborative environment (Rozestraten, 2020), that plays a crucial role in sharing, preserving, and providing access to the iconographic memory of Brazilian architecture and urban spaces (Lima & Rozestraten, 2018; Lima et al., 2016) (Fig. 1).

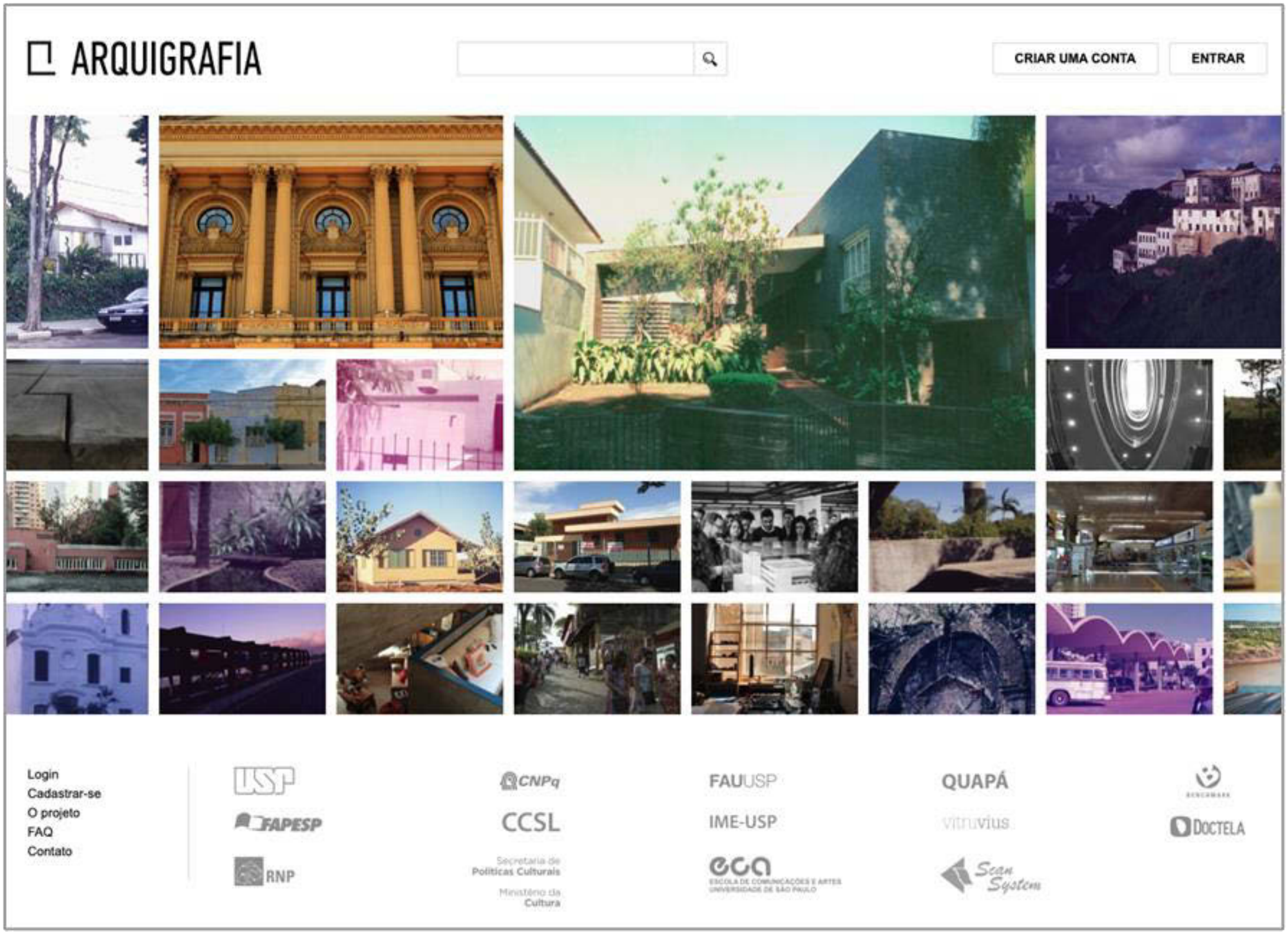


Fig. 1: Arquigrafia's homepage (www.arquigrafia.org.br/home). Source: Authors, 2024.

The spirit of collaboration at the core of the Arquigrafia project distinguishes it from institutional image databases on the Internet, as it involves a heterogeneous network of collaborators (Lima et al., 2020). It serves as a reference for other projects that aim to be instruments for the sharing and collaboration of design information (Pierce, 2011; Rong et al., 2022).

Few initiatives can be fully compared to Arquigrafia as a free and open Web initiative with continuous growth. While Wikipedia and Wikimedia Commons offer some similarities, they each have significant limitations. Wikipedia's focus on written content restricts the inclusion of iconographic information, impeding its utility for creating and maintaining collective imaginaries. Wikimedia Commons, although allowing free media sharing, predominantly features content from the Global North, thereby marginalizing other cultural perspectives. Another initiative with similar principles but a different methodology is the *Photographers en Rhône-Alpes* project, which shares historical photographs of the Auvergne-Rhône-Alpes region online. Although local residents submit photos, not all images are publicly available due to a screening process (Rozestraten, 2020).

Despite its initial success, Arquigrafia has experienced a reduction in user collaboration and activity. This research aims to analyze Arquigrafia as a case study to understand the specific challenges that collaborative digital platforms in the Global South encounter. The study seeks to answer the following questions:

- How does Arquigrafia address digital inequalities in the Global South?
- How do users' characteristics affect the success of the platform?
- How can Arquigrafia's development address current challenges and maximize its potential for cultural preservation and education?

By addressing these questions, this paper examines Arquigrafia's role as a collaborative platform in the Global South, highlighting how it fosters a counter-hegemonic model for preserving digital cultural heritage and positions itself as a resistance to digital hegemonies within Quijano's (2020) concept of "coloniality of power".

2 Historical Development of Arquigrafia

Since the 1950s, the educational community has photographed buildings and urban spaces, donating images to enrich public collections and aid the education of generations of architects and urbanists. When the slide projector was replaced by data show, these images were set aside from most formation activities and remained invisible inside drawers and lockers. In the early 21st century, the web lacked diversity and quality in images, with many historical images and maps missing from classrooms and research environments during the transition from analog to digital.

To address this issue, the Arquigrafia project gathered a multidisciplinary team and began by scanning historic photos from the Library of FAUUSP, and uploading them onto an open-access online platform, creating a collaborative environment where users could share images. This initiative has provided an opportunity to study these digital media from different and complementary perspectives. Arquigrafia is a conjecture about the potential of web-based collaborative image environments, envisioned as places where people could share and curate images, exchange opinions, and offer aesthetic judgments, organizing them into continuously growing visual constellations. The historical development of the Arquigrafia project can be divided into four major phases, each characterized by differences in associated research teams, funding received, and user activities on the platform.

Phase 1. Foundation of the Platform (2008 – 2012)

The platform was conceptualized in 2008, with FAUUSP researchers defining the project requirements and interface design. After coding, it was launched in 2010, featuring an infinite image wall, an image cataloging system, and a user-based image evaluation tool (Fig. 2). These functionalities remain central to the platform today. The Brazilian Network for Education and Research (RNP) and the São Paulo Research Foundation (FAPESP) were the main supporters of the project during this period.

Fig. 2: Arquigrafia's first homepage and an image catalog record. Source: Authors, 2024.

Phase 2. Partnership with the FAUUSP Library and Support from the PRCEU-USP (2012 – 2016)

2012 marks the beginning of the partnership between Arquigrafia and the FAUUSP's Library. While the library provided part of its iconographic collection of architecture and design (consisting of photographs, posters, and architectural project boards), the Arquigrafia platform served as a digital environment for the storage and preservation of such materials. In addition to providing 7.428 images to the site's collection, this partnership resulted in the production of the Manual of Technical Procedures of the Arquigrafia Project (Rozestraten et al., 2019). A publication documenting the process of cleaning, scanning, and cataloging the iconographic material from the FAUUSP's library.

The University of Sao Paulo's Pro-rectory of Culture and University Extension (PRCEU-USP) supported the project in this phase. This support ensured that the project had a dedicated team of researchers. However, in 2014, the University of São Paulo implemented a new financial management policy aimed at reducing expenses. This policy and the lack of external financial support severely impacted the project in 2017 when the funds were suspended.

Phase 3. Decline of the Platform's Activity (2017 – 2021)

The The lack of financial support led to the demobilization of the Arquigrafia's team, which no longer had research grants to compensate its undergraduate and postgraduate researchers and development team. However, occasional events organized by the project, such as workshops, guided tours, and individual research efforts, contributed to maintaining the site's collection during this period. As an example, research conducted by Ferreira added several new images of residences to the collection (Ferreira, 2016, 2017).

This phase of the project is also influenced by two external factors that have altered users' behavior regarding the storage and sharing of images. The first is the popularization of the Instagram social network among Brazilians. The second factor is the increase in the number of smartphones among the population, reaching the mark of one device per inhabitant in 2017 (Meirelles, 2017). Launched in 2010 and with few major changes since then, the Arquigrafia website performs better on desktops than mobile devices. It lacks Instagram features such as a personalized feed and stories, which were introduced in 2016. These external factors, rooted in the Global North, have directly contributed to the decline in the use of the platform.

Phase 4. Project Revitalization (2022 – Now)

Following the pandemic years, the project underwent a restructuring of its objectives. The new focus set up from critical questions on the mainstream Internet and the challenges for the coming of a Web 4.0[1] aiming to promote mutual enrichment in relation to urban ordinary sensitive experience and the construction, organization, representation, and retrieval of knowledge about cities in the present, in memory, and in the design will for tomorrow. These questions thus guide an interdisciplinary investigation of the current conditions for the establishment of autonomous collaborative environments on the Web that require an experimental field (FAPESP, 2022). In 2022, the project received support from FAPESP as a thematic project. This phase is characterized by the presence of a dedicated team of over 30 associated researchers and a full-time computational development team.

3 Materials and Methods

This study adopts a mixed-method approach, combining literature review, platform database analysis, and expert interviews to provide a comprehensive understanding of Arquigrafia's historical development.

The platform's database includes uploaded images, detailed tables on users' account information, and the metadata of uploaded images. MySQL software and Structured Query Language (SQL) were used for queries of data from these datasets in April 2024[2]. From the table related to the metadata of images, we extracted the data related to the identification of the users who uploaded the images and the year that the images were uploaded. Considering the identification of users, we extracted data related to the year of the account's creation, the country of the user, the region (if from Brazil), gender, education level, and age of users. We joined these two tables to connect the information related to images and the users who uploaded them. The newly joined table was then imported to SPSS[3] for analysis of frequencies and

1 Web 4.0 represents the potential for Internet development through interactions between hegemonic (GLAMs) and counter-hegemonic media, involving collective intelligence, social networks, georeferencing, and augmented reality.
2 MySQL is an open source relational database management system (RDBMS) that's used to store and manage data. SQL, which stands for Structured Query Language, is a programming language that's used to retrieve, update, delete, and otherwise manipulate data in relational databases.
3 SPSS or Statistical Package for the Social Sciences is a statistical software suite for data management and advanced analytics.

cross-tabulations. The result and discussion section analyzes these tables and shows how the major phases of the historical development of Arquigrafia have influenced the user's collaboration.

To discuss the platform's future and current issues, semi-structured interviews were conducted with 15 Arquigrafia experts from March to April 2024 (Flick, 2014). All of the interviewees have various educational backgrounds, from bachelor to post-doc, and expertise in project-related disciplines, including architecture, librarianship, computer science, and design. The interviews covered three main topics: a) past experiences with the project, b) current views of the platform, and c) visions for Arquigrafia's future. All interviews were analyzed using the Affinity Diagram method, which groups related ideas into clusters to reveal patterns. (Holtzblatt & Beyer, 2017).

4 Results and Discussion

The platform underwent an update in 2015, which caused the loss of some data related to user accounts' creation and image upload dates. Considering this limitation, the below analysis considers the number of users and images as a whole for the period of 2010 to 2015.

4.1 Users' Profile

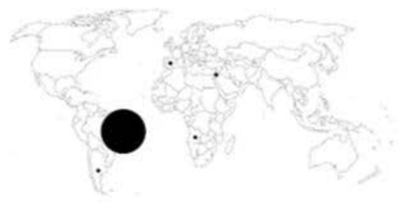
There are a total of 5.237 user accounts in Arquigrafia. The creation of an account is necessary for uploading images and collaborating with providing comments, following other accounts, and sharing information. As of 2015, Arquigrafia had 1.625 user accounts. The peak year for new registrations was 2017, with 1.033 accounts (19.8%). This was followed by 2016 and 2018, while new user registrations drastically declined in 2019 and beyond (Table 1). The reason for this decrease can be related to the further popularization of Instagram and the start of the COVID-19 pandemic, followed by the lockdown.

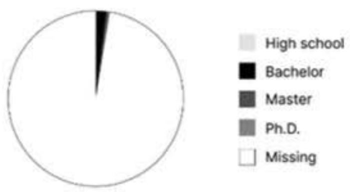
Year	New users			
	No.	%	Cum. No.	Cum. %
2010-15	1.625	31,1%	1.625	31,1%
2016	710	13,6%	2.335	44,7%
2017	1.033	19,8%	3.368	64,4%
2018	697	13,3%	4.065	77,7%
2019	269	5,1%	4.334	82,9%
2020	247	4,7%	4.581	87,6%
2021	194	3,7%	4.775	91,3%
2022	131	2,5%	4.906	93,8%
2023	314	6,0%	5.220	99,8%
2024	17	0,3%	5.237	100%
Total	5.237	100%		

Table 1: Number of accounts created by users per year. Source: Authors, 2024.

Arquigrafia covers a wide range of users from various regions of the country with different levels of education. However, the majority of users do not provide information on their profiles, resulting in a lack of data about all users. Therefore, the aim is not to generalize the contents of this analysis but to provide information about the existing available data and provide insight. As shown in Table 2, the majority (80.4%) of users who indicated their locations are from the Southeast region of Brazil. There is an almost equal diversity of female and male users. In terms of level of education, the majority of users have a bachelor's or master's. The lack of user data shows that the absolute majority of users prefer not to provide demographic information. These data can be important for suggesting personalized content.

Users characteristics		Users		Charts
		No.	%	
Country (Missing: 4.939)	Angola	1	0,3%	
	Argentina	1	0,3%	
	Brazil	294	98,7%	
	Spain	1	0,3%	
	Israel	1	0,3%	
	Total	298	100%	
Regions of Brazil (Missing: 5.074)	Central-west	7	4,3%	
	Northeast	7	4,3%	
	North	4	2,5%	
	Southeast	131	80,4%	
	South	14	8,6%	
	Total	163	100%	
Gender (Missing: 5.070)	Female	87	52,1%	
	Male	80	47,9%	
	Total	167	100%	
Education level (Missing: 5.101)	Highschool	4	2,9%	
	Bachelor	98	72,1%	
	Master	27	19,9%	
	Ph.D.	7	5,1%	
	Total	136	100%	
Decade of birth (Missing: 5.122)	1970s or before	12	10,4%	
	1980s	21	18,3%	
	1990s	79	68,7%	
	2010s	3	2,6%	
	Total	115	100%	





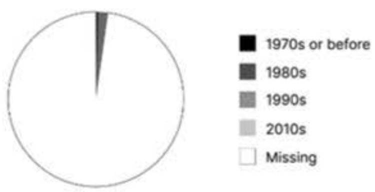


Table 2: The user's characteristics. Source: Authors, 2024.

4.2 Analysis of Collaborated Images

As shown in Table 3 and Fig. 3, in total, 14.154 images have been uploaded to the platform, 5.237 users registered accounts, and the ratio of images per user is 2,7. From 2010 to 2015, 5.700 images (40.3%) have been uploaded to the platform. The number of image uploads reached its peak in 2016, with 3.622 images (25.6%) uploaded that year. This was followed by 2017 when users added 3.401 images (24.0%) to the platform. The upload of new images drastically decreased in 2018 and continued to decrease for the following years. The ratio of images per user was at its highest in 2016, with 4.0 images per user. However, it continued to decrease. This decrease shows that users are collaborating less by providing new images but are using the platform as a source for downloading images.

Year	New images				Users	Image/ total User
	No.	%	Cum. No.	Cum. %	Cum. No.	
2010-15	5.700	40,3%	5.700	40,3%	1.625	3,5
2016	3.622	25,6%	9.322	65,9%	2.335	4,0
2017	3.401	24,0%	12.723	89,9%	3.368	3,8
2018	574	4,1%	13.297	93,9%	4.065	3,3
2019	427	3,0%	13.724	97,0%	4.334	3,2
2020	76	0,5%	13.800	97,5%	4.581	3,0
2021	27	0,2%	13.827	97,7%	4.775	2,9
2022	40	0,3%	13.867	98,0%	4.906	2,8
2023	239	1,7%	14.106	99,7%	5.220	2,7
2024	48	0,3%	14.154	100%	5.237	2,7
Total	14.154	100%	-	-	-	-

Table 3: The frequency of upload of new images and image/user ratio. Source: Authors, 2024.

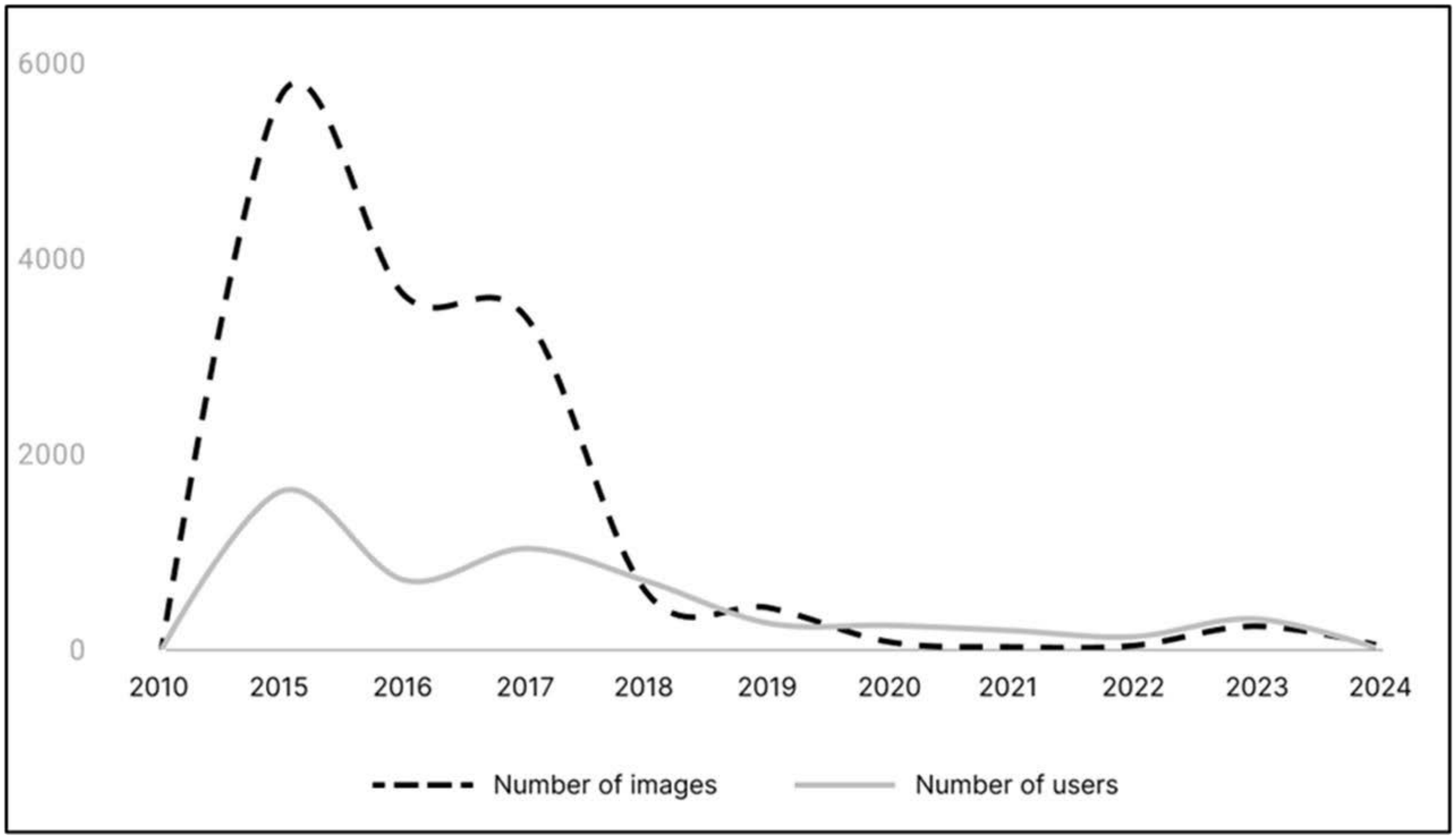


Fig. 3: The frequency of new users and new images for each year. Source: Authors, 2024.

As shown in Table 4 and Fig. 4, of the total 14.154 images, 9.170 (or 64.8%) were uploaded by users who created their accounts in 2015 or before. There are 1.625 users in this category, and their image per-user ratio is 5,6, which is the highest. The 2016 generation of users is also active in terms of collaboration and providing new images for the platform, considering they are responsible for uploading 3.387 images (or 23.9%). These years coincided with phases 1 and 2 of the project when the project received support from RNP, FAPESP, and PRCEU-USP. As mentioned, the number of new account creation was relatively high in 2017; however, this generation of users, by uploading 899 images (6.4%), collaborated relatively less by uploading new images. In this year the project lost the financial support from PRCEU-USP. The collaboration of other generations of users who created their accounts afterward drops. Furthermore, the generation of users who registered in 2016 or earlier continued to collaborate relatively more in recent years. However, the users who registered in 2017 or afterward tend to collaborate punctually, mainly in the year of their account creation. In general, collaboration with the platform by uploading new images has dropped drastically since 2018, and there has been a loss of financial support for maintaining the system updated.

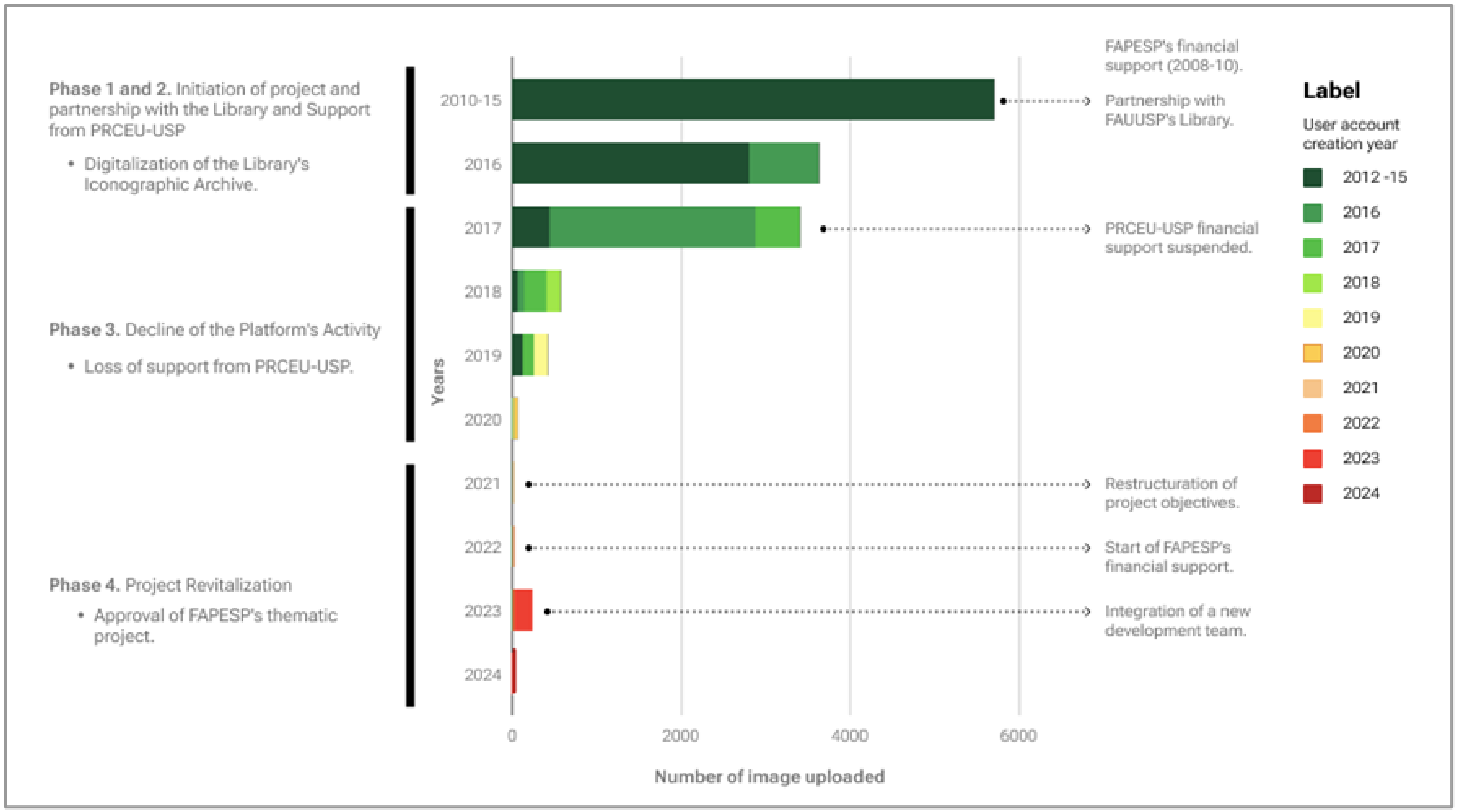


Fig. 4: Number of uploaded images and the major phases of the project. Source: Authors, 2024.

		User's account creation year																				Total	
		2010-15		2016		2017		2018		2019		2020		2021		2022		2023		2024			
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Image upload year	2010-15	5.700	62,2%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.700	50,1%
	2016	2.794	30,5%	828	24,4%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.622	31,9%
	2017	447	4,9%	2.438	72,0%	516	57,4%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.401	29,9%
	2018	81	0,9%	74	2,2%	253	28,1%	166	99,4%	-	-	-	-	-	-	-	-	-	-	-	-	574	5,0%
	2019	129	1,4%	0	0,0%	130	14,5%	1	0,6%	167	97,1%	-	-	-	-	-	-	-	-	-	-	427	3,8%
	2020	0	0,0%	22	0,6%	0	0,0%	0	0,0%	4	2,3%	50	79,4%	-	-	-	-	-	-	-	-	76	0,7%
	2021	12	0,1%	0	0,0%	0	0,0%	0	0,0%	0	0,0%	9	14,3%	6	42,9%	-	-	-	-	-	-	27	0,2%
	2022	4	0,0%	7	0,2%	0	0,0%	0	0,0%	1	0,6%	0	0,0%	8	57,1%	20	57,1%	-	-	-	-	40	0,4%
	2023	3	0,0%	15	0,4%	0	0,0%	0	0,0%	0	0,0%	3	4,8%	0	0,0%	15	42,9%	203	97,1%	-	-	239	2,1%
	2024	0	0,0%	3	0,1%	0	0,0%	0	0,0%	0	0,0%	1	1,6%	0	0,0%	0	0,0%	6	2,9%	38	100%	48	0,4%
Total images		9.170	100%	3.387	100%	899	100%	167	100%	172	100%	63	100%	14	100%	35	100%	209	100%	38	100%	1.4154	100%
		64,8%		23,9%		6,4%		1,2%		1,2%		0,4%		0,1%		0,2%		1,5%		0,3%		100%	
Total users		1.625		710		1.033		697		269		247		194		131		314		17		5.237	
Image/user ratio		5,6		4,8		0,9		0,2		0,6		0,3		0,1		0,3		0,7		2,2		2,7	

Table 4: Cross-tabulation of the year of upload of images and the relevant user's account creation year. Source: Authors, 2024.

As shown in Table 5, from all images, 4.827 (34.1%) were uploaded by female users, and male users uploaded 870 images (6.1%). It shows that collaboratively active female users provide relatively more data related to their profile. From all images, 9.412 (66.5%) were uploaded by those who have bachelor's and master's educational degrees. This shows the popularity of the platform in universities. Considering the available data, the platform's use is diverse among different age groups. With 1.909 uploaded images (12.8%), the platform is more popular among those who were born in the 1990s.

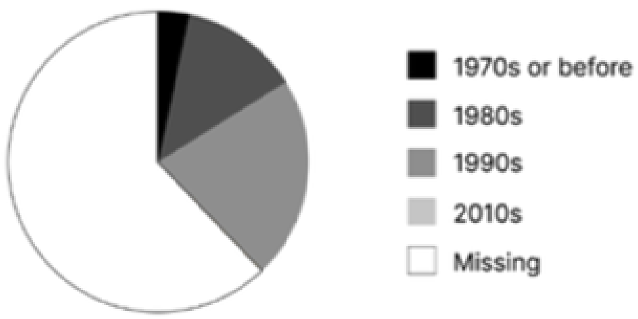
Users characteristics		Frequency of uploaded image		Charts
		No.	%	
Gender of users	Female	4.827	34,1%	
	Male	870	6,1%	
	Missing	8.457	59,7%	
	Total	14.154	100%	
Education level of users	High School	3	0,0%	
	Bachelor	4.886	34,5%	
	Master	4.526	32,0%	
	Ph.D.	4	0,0%	
	Missing	4.735	33,5%	
	Total	14.154	100%	
Users decade of birth	1970s or before	472	3,3%	
	1980s	1.809	12,8%	
	1990s	3.073	21,7%	
	2010s	1	0,0%	
	Missing	8.799	62,2%	
	Total	14.154	100%	

Table 5: Cross-tabulation of users' characteristics and the frequency of uploaded images. Source: Authors, 2024.

4.3 The Future of the Arquigrafia

To discuss the platform's future and current issues, we used data obtained from semi-structured interviews with experts' opinions on the project. For most of the interviewees, being a collaborative platform is what differentiates Arquigrafia from other known initiatives. For this reason, they believe this feature should be nurtured within the project. The success of collaborative digital platforms depends on positive organizational culture and communication, not just the technology (Cardon, 2016). Online interaction and social networking can play a vital role in cultivating an unspoken cyberculture that may shape users' opinions, sense of belonging, and values. An online collaborative platform can promote this cyberculture (Tan et al., 2010). Following these ideas, collaboration efforts should include both software development and the promotion of a collaborative culture among users.

The interviewees view collaboration from two perspectives: as a strategy for building the site's iconographic collection and as a means for the platform's development, including computational work. From the standpoint of forming the site's collaborative collection, there is an agreement that the system's permission for anyone to upload an image ensures that the platform provides a diverse view of what constitutes architecture. In this regard, there is a desire to expand the project's reach. Examples of such activities include partnerships with Sob Olhares SP[4], Estudio Ceda el Paso[5], Digital Collections[6], and improving Arquigrafia's social media[7], expanding its outreach to diverse audiences. The platform's plan to develop interactive digital 3D-modeled representations and city routes aligns with this idea, too.

Researchers have conflicting views on the platform's collaborative development. Half believe users can program the system like open-source software, while the other half think it should be associated with a larger academic institution. This is indeed a significant concern for the project, as the existence and intensity of its activities have always been directly related to the availability of financial resources. The presence of research grants has emerged as a significant motivator for researchers to join and remain in the project. Although seeking funding is a concern, the majority believe that the project should not adopt self-financing models based on advertising or charges for using the website. For them, the project should retain its public, open, and counter-hegemonic character.

Even though collaboration is declared as a fundamental principle for the platform, there is no consensus among the project's areas regarding whether this should be the focus during the newly updated version of the platform to be released in 2025. The lack of consensus can be a crucial issue for the project, as a successful collaboration necessitates a shared vision and common goals (Small, 2001). While the Design and Architecture teams believe the site should emphasize functionalities that encourage user collaboration, the Computer Science and Librarianship areas think that working on measures to ensure accurate and reliable information is a fundamental principle for the project's success (Fig. 5). This shows the two main requirements of the platform that need to be balanced, collaboration and reliability.

4 https://sobolharessp.com.br/
5 https://estudiocedaelpaso.lojavirtualnuvem.com.br/
6 https://www.acervosdigitais.fau.usp.br/
7 https://www.instagram.com/arquigrafiafau.oficial/

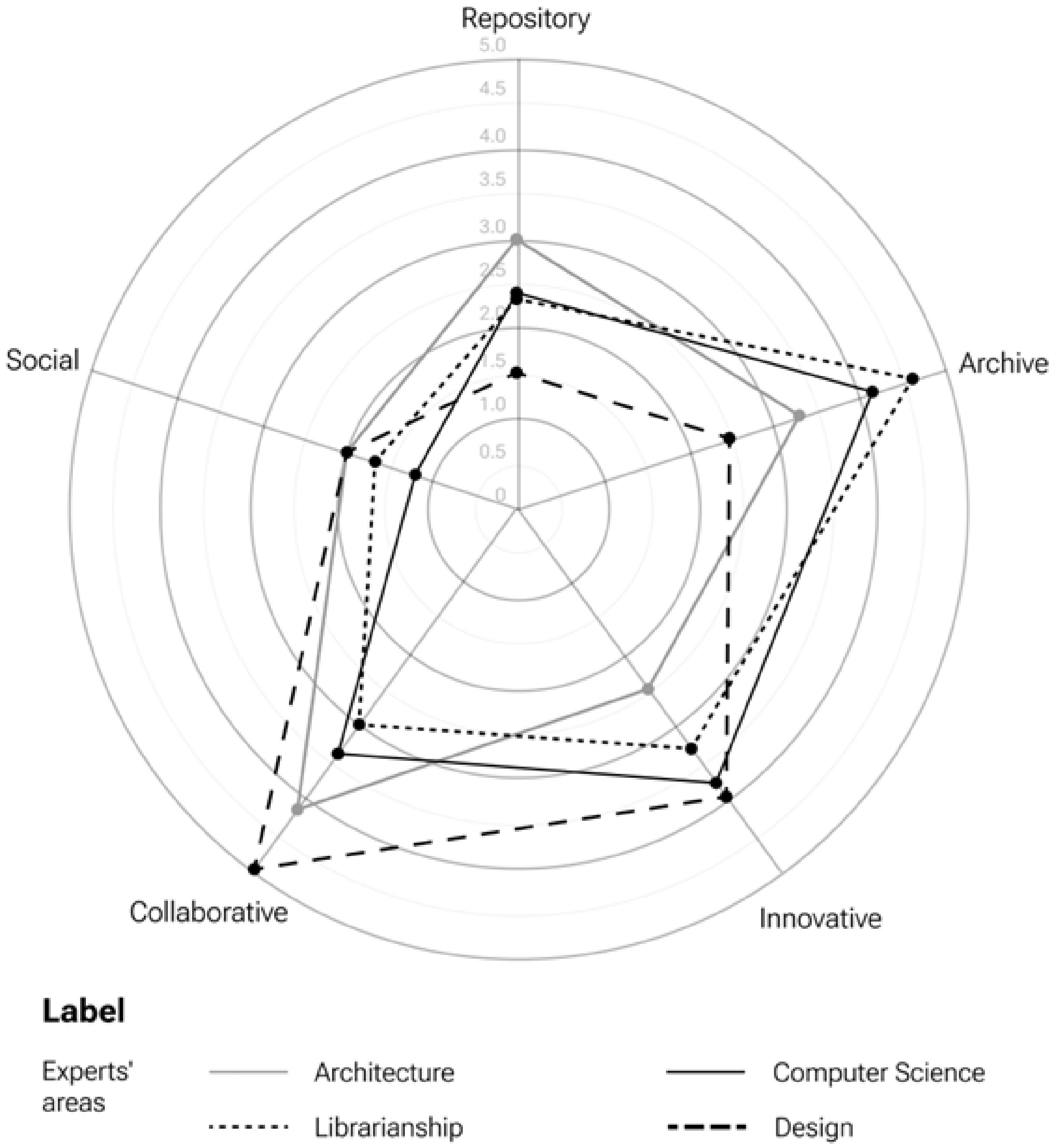


Fig. 5: Arquigrafia's future emphasis by experts' areas. Source: Authors, 2024.

From its early stages of existence, Arquigrafia was referred to as a social network (Rozestraten et al., 2010; Ferreira, 2016). Currently, there is consensus among the areas regarding the social aspect of the platform. Considering hegemonic social network models such as Facebook and Instagram, almost all the interviewees declare that the site should not emulate such models. Instead, there is a desire for the platform to continue operating within the academic sphere, following the success of other initiatives such as VERGILIUS, a collaborative platform that provides a valuable training tool for students (Capozzoli, 2021). By maintaining its academic roots, the system's mobilization for educational activities could be significantly enhanced.

5 Conclusion

There is a significant lack of images representing Brazilian architecture in born-digital formats. This lack is common in many countries in the Global South, where nations in the Global North have historically controlled media and knowledge. Arquigrafia aims to address these historical inequalities by providing a collaborative platform for Brazilian architectural and urban space images (Lima et al., 2020).

The project has evolved significantly since its inception, demonstrating the potential of collaborative platforms in preserving and sharing architectural and urban space images. The predominant role of Arquigrafia has shifted from being a digital archive-oriented platform for architectural and urban space images to a primarily collaborative platform. However, in recent years, followed by the popularization of

Instagram, the loss of external support, and the lockdown due to the COVID-19 pandemic, it has been used mainly as a source for image downloads. To ensure sustainability, active user collaboration by uploading images is essential.

To address these challenges, the project has developed new partnerships, initiated social media campaigns, enhanced its interface, and implemented usage analytics. For continued success, it is recommended that the culture of collaboration be improved, strategies to attract new users be introduced, and the platform's use as a teaching resource be explored. Furthermore, Arquigrafia faces critical challenges in maintaining diverse development teams and managing costs associated with server maintenance. As the platform currently relies on short-term scholarships for its development team, establishing collaborative processes at the programming level and seeking institutional and governmental support is vital for its ongoing development and sustainability.

As Arquigrafia prepares for its 2025 update, it aims to address digital representation inequalities and enhance collaboration, potentially enriching the understanding of urban history and architecture in Brazil while serving as a model for similar initiatives in the Global South. The platform highlights the tension between the Global South's need for representation and North-centric infrastructures, enabling the South to assert its cultural identity and counter digital exclusion in global discussions on hegemonic cultural frameworks.

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FROM COMPUTATION TO FABRICATION: THEMES AND (MIS)PATHS IN SOUTH AMERICA

DO COMPUTACIONAL À FABRICAÇÃO: TEMAS E (DES)CAMINHOS NA AMÉRICA DO SUL

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Abstract

Digital fabrication has been slowly assimilated into South America over the last two decades. However, given the narratives and economic models of the Global North, it constantly faces the challenge of finding meaningful ways to apply these technologies in the local context. The article aims to critically reflect on the narratives, tensions, and disputes over technological hegemony in the relationship between the Global North and South, based on the recent panorama of digital fabrication glimpsed in South America, in cases that indicate themes and trends, application strategies, and local arrangements. It proceeds by reviewing concepts and events originating in countries with advanced economies and industries, analyzed in light of the relationship between coloniality and domination. Based on the mapping of information and systematic literature review, it presents elements of influence on the imaginary of recent production in the South American context, identifying thematic categories that validate unique emerging processes, converging the digital, cultural diversity, and intersectionalities into the production of design, architecture, and construction. The results show initiatives that seek autonomy by proposing experimental construction practices, investigating new materials, integrating and democratizing activities, and innovating products and industrial production processes.

Keywords: Digital fabrication, Computational, Technological appropriation, Digital colonialism, Global South

1 Introduction

One of the main challenges for architecture and design lies in expanding the act of designing, proceeding from idea to execution. Digital fabrication techniques and technologies have become central factors in industrial development procedures, product innovation, support for new practices and pedagogies, prototyping, and design solutions. They are emerging as new ways of exploring and experimenting with advanced and automated systems. When we mention the subject, we refer to technological apparatuses classified as additive – 3D printers –, subtractive – milling machines and laser cutters –, formative – thermoforming machines –, and assembly or flexible – robotic systems. However, digital fabrication is not limited to machinery. According to Picon (2019), an expanded understanding of digital fabrication involves contradictions and ambiguities about new material and poetic expressions, political and social agendas, and the relationship between the objective and narrative dimensions.

Digital fabrication in South America is part of dynamics related to technological appropriation (Bonsiepe, 2012), representing a condition of asymmetry and dependence. This trajectory began slowly in the 2000s and spread more intensely in the 2010s. Digital fabrication technologies are not yet fully integrated into education, design, and architectural production in the South American continent. Moreover, there is a tendency for interest in some sectors to wane in the face of material difficulties, sustainable continuity of their activities, and links to the production system. Faced with this changing scenario, it is worth reflecting on the cultural diversity and intersectionalities in the production of design, architecture, and construction in South America, with the assimilation of digital fabrication. In this way, projects of coexistence are emerging (Canclini, 1997), in which innovative impulses do not replace local traditions, since the multicultural heterogeneity that characterizes us must be understood in terms of emancipation, expansion, renewal, and democratization.

We face contrasts between the Global North and South, with their socioeconomic perspectives, political and power relations, dependencies, resistances, and inequalities. The globalized establishment of the technical-scientific-informational environment generates hegemonic activities, spaces, actors, and times (Santos, 2013), full of technologies that promote processes of production and exchange at the highest level, where the forces that regulate actions elsewhere are established. Globalization evokes the logic of modernity and coloniality (Mignolo, 2017), which has allowed the emergence of structures to control and manage economic relations, power, gender, knowledge, and the formation of subjectivities. The dynamics of digital fabrication are part of this framework, discreetly enchanting and generating new forms of technological and market domination, forming a hegemonic mode of operation dependent on advanced practices and systems.

Our starting point is a set of hypotheses for reflection: The application of digital fabrication in design, architecture, and construction connects to computational uses that require technical mastery, supra-specialized knowledge, and skills. Exploratory and experimental use of this combined digital technology in projects and constructive practices is an essential but not privileged condition. In this way, technological incorporation, usually through importation, promotes aspects of digital colonialism of territories of knowledge and ways of culturally grasping ways of doing things, influencing imaginaries and production alternatives. It idealizes the possible paths to follow while leaving possibilities behind, challenging the sense of autonomy and cultural identity. The paper seeks to recover notions of technological appropriation, the diffusion of its technical knowledge, and the centrality of local socio-economic and cultural issues to innovation in the face of global narratives.

2 Objectives

Based on extensive research (Scheeren, 2021), we delve deeper into the critical reflection of North-South technological relations from the perspective of digital colonialism, which determines narratives, socioeconomic conditions, power, and subjectification. We revisit local authors linked to the areas of culture and design, among others, for their critical stance on the dominant relations arising from the center, redefining their considerations due to the dynamics of digital fabrication. We present and discuss cases from South America, expanding on previous works (Scheeren & Sperling, 2020, 2024), which represent efforts towards autonomy, emancipation, and contextualization of the experimental dimension with local arrangements but also demonstrate variations, cadences, and mismatches in the themes.

3 Methods

The content presented comes from mapping information on the Internet, a narrative review of concepts and themes connected to the technical and technological perspective, based on a literature review and systematic review of publications related to digital fabrication. Case studies, organized into thematic categories that emerged as trends in the last decade, are addressed qualitatively. Discussion and critical reflection on tensions and controversies in technology and its applications.

4 Global North Panorama

Between centers and peripheries, dominant structures produce not only technologies but discourses that become hegemonic. This is the case of digital fabrication, which has become an important buzzword in the technology scenario. On the Google Trends platform, the term stood out in searches in the second half of 2007[1], with fluctuations until 2009, maintaining a constant level of interest with small variations. It is important to understand why these techniques and technologies have reached this status in the Global North, integrated into architecture, product design, and construction. The first theme is automation, an industrial imperative that involves using control systems to execute processes with precision, efficiency, and adequate logistics for distribution. Capable of operating through computers, data analysis and machine learning techniques, numerical control devices, and robots, they eliminate the human presence in repetitive, difficult, and dangerous tasks.

Despite the hope that automation will free us from several burdens and give us more free time, one of the criticisms is that creating a continuous and cheaper workforce will result in the replacement of jobs. This post-human turn (Greenfield, 2017) would reshape our way of living and acting not according to human needs and desires, but according to those of the systems that serve us. It is no wonder that companies such as Amazon, among others, seek to automate their services, from online customer service to the selection and packaging of objects in warehouses, to optimize the logic of consumption. Data published by Brynjolfsson & Mcafee (2014) show that non-routine cognitive and non-routine manual work has increased, as sensory and motor skills require sophistication and enormous computational effort, while abstract reasoning requires simpler processes.

Another topic is Industry 4.0, a subsidiary of the concept of the Third Industrial Revolution, a project developed in Germany in the early 2010s, initially called Factories of the Future. The proposal aimed to defend physical production, an area in which Germany was strong (Sangüesa, 2018). This narrative emerged in line with the Fourth Industrial Revolution proposal by economist and World Economic Forum founder Klaus Schwab (2015), which concerned business as much as governance. Industry 4.0 promotes the re-founding of infrastructure and production systems, from simple digitization to the combined innovation of technologies such as artificial intelligence, robotics, IoT, autonomous vehicles, 3D printing, nanotechnology, biotechnology, and materials science. More recently, the complementary term Industry 5.0 has emerged, focusing more on humans and their collaboration with robotic systems, green transition with energy and resource efficiency, and circular economy, in addition to the operation of an industry more resilient to external situations (Madsen & Slåtten, 2023).

1 Data on the interest in the term digital fabrication over time: https://trends.google.com/trends/explore?date=2004-01-01%202024-07-21&q=digital%20fabrication&hl=pt

Another recurring theme is innovation, the systematic introduction of a new process, method, device, or even a significant change to something already in place. One of the concepts of innovation is related to the idea of disruption (Christensen et al., 2015), a model that not only improves processes, products, and other services, but also focuses on underserved users in specific segments, providing features at a lower price, and creating markets and producers where none existed before. An emblematic case is the adaptation of machines in non-industrial areas, such as 3D printers. After open projects and a patent expiring on FDM technology, there has been a growing commercialization of small machines by brands like MakerBot in America and Creality in China. The use of numerical control technologies and also Computer-Aided Design (CAD) emerged at the intersection of military, industrial, and academic interests funded by the United States government at the beginning of the Cold War, illustrating a hegemonic vision of technology as key to the national project of supremacy and global competitiveness (Llach, 2015).

Advanced industrial countries are revitalizing their manufacturing sectors, creating more skilled jobs, and increasing productivity and development by adopting digital automation technologies. This requires training a new class of technicians to control manufacturing processes using programming languages. Global North and South countries understand that sustainable economic development cannot be achieved without improving an internationally competitive manufacturing sector (Hauge & Chang, 2019). The United States and European countries have repatriated some of the manufacturing of commoditized goods carried out in China and other emerging economies to remain pioneers in the production of advanced industrial machinery and systems, accompanied by the return of some specialized jobs.

Many of these concepts originated in management, economics, and production engineering, but they are also motivated and directed to governmental interests and the needs of advanced capitalist economies (Brynjolfsson & Mcafee, 2014). Such practices, technologies, and processes imply the expansion of corporate power without changing the tendency of economic concentration or improving the scenario of income concentration (Silveira, 2018). A transformative perspective for architecture, design, and construction emerges from the digitalization of production processes, characterized by customization, the adoption of new materials and technologies, the accessibility of machines, and local production. Thus, integrating technologies and promoting technology transfers from other sectors repeats what happened in the 1990s, with the appropriation of methods from industries such as naval, automotive, and aerospace (Kolarevic, 2005).

Architects have explored digital tools to overcome geometric and notational limitations, to create free forms, and to materialize them using computer-aided manufacturing (CAM). The use of complex or irregular geometries, which were previously difficult to achieve, began to be used intensively by representatives of contemporary architecture, such as Frank Gehry, who paved the way for the assimilation of digital fabrication by applying the logic of mass customization. In addition, the gap between design and production has been narrowed by the logic of new digital tools (Carpo, 2017). End-user access to machines has also contributed to product prototyping, developing pedagogical strategies, and responding to the social environment. Neil Gershenfeld's (2005) proposal, based on the discipline How To Make (almost) Anything, started in 1998 at the Massachusetts Institute of Technology - MIT, led to the emergence of the Fab Labs laboratory model, funded by the US government through the National Science Foundation.

Such projects are emerging as a two-way street. By becoming a network of laboratories beyond the walls of the university, installed in hundreds of locations around the world, they would democratize access to digital machines and equipment, fostering alternative modes of production while transferring "canned" models to countries with different realities and contexts. Without appropriate support structures, the initial stimulus of openness can be distorted into entrepreneurial logic, creating fragmented and individualized situations and distancing from the postulation of emancipatory alternatives (Fonseca de Campos & Dias, 2018). Fabrication devices are still of little use, costly, and located where they are least needed, to the point that Greenfield (2017) questions whether it is possible to make a revolution with a $2,000 printer.

Implementing Industry 4.0-related frameworks in the construction sector involves challenges and obstacles. The complexity of projects, specificities of each location, number of interrelated processes and participants, uncertainties related to the lack of specifications, the fragmented supply chain, short-term thinking, and the culture resistant to change are some of these factors (Oesterreich & Teuteberg, 2016). To overcome them, research laboratories, universities, technology centers, and companies incubated in these spaces have developed experimental projects that present and test techniques, materials, and applications of technologies that are not yet regulated. An example of this is the DFAB HOUSE (Graser et al., 2021), developed by ETH Zurich as part of the NCCR Digital Fabrication, a space to demonstrate a set of construction systems and materials generated and fabricated digitally, with technologies that involve everything from robots producing on-site to automated systems generating prefabricated products.

5 Global South Panorama

Actors and networks have gradually emerged in South America, integrating advanced computational processes and digital fabrication (Scheeren, 2022). Fascination and euphoria marked the initial technological assimilation towards the new possibilities of modeling, prototyping, and fabricating between exclusionary statements and processes. The introduction of CNC milling machines and routers, laser cutters, and industrial 3D printers initially complemented the model shops of universities in some South American countries, such as Chile and Brazil. Meanwhile, the ability to generate complex shapes and elements has opened up new creative opportunities. The last decade has become a relevant period for digital technologies, from private initiatives to the diffusion of experimental practices in curricula, research, and professional activities, as witnessed in the Global North.

With the expansion of interests, knowledge, and capacity to acquire technologies, prototypes, and representation models have evolved to execute projects on a large scale. Thus, there was a shift in design tasks, previously concentrated in the initial phases of the process, to the execution of components for new architectural possibilities (García Alvarado, 2009). Based on the research update, it was possible to identify trends related to digital fabrication, which were used as categories to organize the presentation of some cases. The selection of projects was based on criteria of emergence in the last ten years, diversity of techniques, strategies, and use of technologies, besides results that present efforts of emancipation, autonomy, and contextualization of the experimental dimension with local arrangements. This approach expands and complements previous work (Scheeren & Sperling, 2020), focused on artifacts that used digital fabrication in their design and execution.

A recurring theme is pedagogical, whether in the design of models or playful elements for learning. In the city of Pelotas, Brazil (Dametto et al., 2014), virtual reality, augmented reality, and 3D printed models have been combined to create a record of the memory and heritage of the city through graphic depictions of historic buildings of diverse characteristics. This digital documentation is used in the educational processes of the Federal University of Pelotas to facilitate the visualization of the architectonic characteristics, disseminate information, and renew the population's interest in the city's architecture. The exploration of geometric patterns in compositions using folding techniques was an exercise proposed at the Universidad Nacional del Litoral, in Santa Fe, Argentina, generating flexible and dynamic modular systems that can be used as protective skins for facades (Chiarella et al., 2014). In this way, the combination of modeling, environmental simulation, and construction of objects, the generation of prototypes using a laser cutter, and a microcontroller board with mechanisms and sensors, brings the design and execution phases together.

The theme of tactical actions represents the application of digital fabrication technologies beyond teaching and research laboratories, integrating external communities into social actions. The FavLab Maré proposal was carried out in the Maré Favela, Rio de Janeiro, Brazil, by students and professors from PUC-Rio and an institute linked to the favela, creating a playful and interactive installation, with voice-activated lighting in the external area of the children's library (Natividade & Dias, 2019). After joint modeling and design workshops, the result had the participation of the community, executed with a CNC milling machine and 3D printer. Another model of action is the Mobile Laboratory, as does PRONTO3D, from the Federal University of Santa Catarina in Florianópolis, Brazil. Besides spreading knowledge about technologies, it promotes problem-based mathematics education, using games and playful elements in municipal primary schools, produced with a laser cutter and 3D printer (Pereira & Pupo, 2018). Through workshops, students understand how to design projects and prototypes to materialize their ideas and create games based on the content learned in the classroom.

New spaces are emerging to manipulate bio-fabricated materials, using digital equipment, mainly 3D printers, to explore techniques and processes for generating objects based on nature or using organic materials. One example is Biofab.uc[2], the Biofabrication Laboratory of the Faculty of Design of the Pontificia Universidad Católica de Chile, in Santiago, a recently opened space that offers, through workshops, experimentation, and basic research practices with materials found in the region. Another laboratory moving into this area is the Fab Lab of the University of Chile[3], also in Santiago, developing digital equipment such as bio-mixers and 3D printers adapted to generate raw materials, such as bioplastics. It is also worth mentioning the extensive research work with bio-textiles and local bioagents produced by the Valdivia

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2 Instagram BioFab UC: https://www.instagram.com/biofab.uc/
3 "Nodo Biofabricación Digital" initiative at the Fab Lab of the University of Chile: http://www.fablab.uchile.cl/proyectos/491/nodo-biofabricacion-digital/

Biomaterials and Biofabrication Laboratory[4], in Chile, which includes expeditions by its collaborators to remote Chilean territories to obtain fungi and shells.

In the industrial manufacturing sector, we have identified the adoption of integrated digital technologies from design to manufacturing in some areas connected to construction. Crosslam, from Suzano, Brazil, a company specializing in producing cross-laminated timber (CLT) parts, has been manufacturing panels and structures on demand for projects since 2009, using a large-scale 5-axis CNC milling system to cut the parts. The company Zeromaquina, from São Paulo, Brazil, has been using conventional CNC milling machines since 2014 to machine wood and other composite materials in the design of objects, furniture, and components for construction, offering workshops and services for architectural firms that want to carry out their projects. The MSH Group, based in Buenos Aires, Argentina, is an industry that combines project development services and customized solutions. The company produces custom-made objects in metal elements for facades through computer modeling, simulation, and manufacturing with plasma cutting and bending machines.

In the construction sector, the digital prefabrication of heavy elements is still experimental, both in the process and the need for large-scale machinery. In 2016, the company Conconcreto[5], from Medellín, Colombia, created a CNC gantry displacement system and large-format 3D printer, which, when integrated with BIM project data, allowed the construction of a housing prototype using 32 prefabricated concrete parts, the Origami House. Another company investing in prefabrication is BAUMAX[6], from Santiago, Chile, which developed an automated production line for the manufacture of panels with varying geometries and openings, carried out by robotic arms that cut and smooth the mortar after it is deposited in horizontal metal molds. Once molded, the parts of the installations are incorporated and the pieces are transferred to the curing chamber, a renewal of the 1972 KPD[7] panel system of the Salvador Allende government, which aimed to mass-produce housing after the 1971 earthquake. Complementary is the research work developed at the Research Center for Construction Technologies (CITEC) of the Universidad del Bío-Bío, in Concepción, Chile, which explores the use of robotic arms and compositions between local materials and concrete for the production of on-site and prefabricated parts[8].

Companies and individual initiatives have made progress in creating digital equipment and machinery, with projects aimed at the service, industry, and social action sectors. One of them is the company Trideo3D from Buenos Aires, Argentina, a company producing small-scale 3D printers for the general public since 2014, as well as medium- and large-scale machines that enable the manufacture of prototypes and final products for industry. Another company is DuraPrinter 3D from Itaboraí, Brazil, which has been producing small and medium-scale delta-model 3D printers since 2017, using a layered deposition system of clay and similar materials to fabricate ceramic artifacts. The development of a research project guided the construction of a low-cost CNC milling machine inserted in the complex environment of a favela in Belo Horizonte, Brazil (Bernardo & Cabral, 2014). In this way, the initiative proposes an alternative model that is not dependent on commercialized machines, contributing to diversity in the production of objects based on local needs, with the challenge of culturally adapting this equipment by combining high and low technology.

The diversity of the themes presented follows trends in Europe, the United States, and Japan, such as construction 4.0, sustainability and the construction life cycle, circular economy, multidisciplinary technological integration, and specialized technical training. The interest and fascination in the Global South arose from this narrative dimension originating in the Global North, which focused on the digitalization of production chains based on the technological combination. They thus became hegemonic spaces that conceived hegemonic technologies and established "new ways of producing" (Santos, 2013, p. 58), determining hierarchies and the transfer of knowledge, techniques, and technologies. Similarly, China is at the forefront of developing automated production systems in the Global South and has a long history of low-cost component manufacturing. As a result, the channeling of equipment formerly confined to manufacturing factories into the design, architecture, and construction industries creates niche markets where the sales of technologies benefit the central countries through the transfer of financial capital (Bonsiepe, 2012).

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4 Instagram LABVA: https://www.instagram.com/somoslabva/
5 Large format 3D printer from Conconcreto, Colombia: https://conconcreto.com/sala-de-prensa/conozca-la-primera-impresora-3d-gran-formato-de-concreto-en-colombia/
6 Reportagem sobre a fábrica automatizada da Baumax, Chile: https://construye2025.cl/2024/08/29/boetsch-y-spoerer-ingenieros-revelador-caso-de-integracion-temprana-en-proyecto-habitacional-con-sistema-baumax/
7 "KPD" prefabricated panel system, Chile: https://www.archdaily.cl/cl/623067/en-detalle-especial-sistema-de-panel-prefabricado-kpd
8 3D printed concrete cabin at the Universidad del Bío Bío, Chile: https://www.archdaily.com/1011919/3d-printed-cabin-universidad-del-bio-bio

This situation highlights the task of technological innovation being concentrated in the centers while leading the peripheries to the condition of importers through a material and cultural transfer (Bonsiepe, 2012). In addition to the narratives, it brings to the Global South the exploratory potential of machines that carry out automated and complex procedures with multiple effects on and from materiality. Unlike what Picon (2019) points out, in our reality, the assimilation of digital fabrication does not arise from nostalgia for the restoration of the lost unity between those who design and execute, as happened in the era of artisans, who had John Ruskin as the reference. It is not a mere use because of the appreciation for ornamental production. Digital fabrication inevitably consists of advances in industrialization and, for the users not in these sectors, means of producing responses to more urgent needs. The challenge lies in developing, in local frameworks, emancipatory objects that do not provide a reason for new needs and dependencies (Bonsiepe, 2012), besides those already existing.

As we have seen in the cases presented, autonomy always appears in a conditioned manner. Activities that aim to solve teaching challenges or expand and decentralize actions in communities are limited to the available technologies and, in part, influenced by narratives of external models. When new materials are extracted from the local environment, the challenges of adapting or creating machines that can process their specificities and result in projects based on their models arise. When there is an opportunity to manufacture complex elements on a large scale and with durability, there is limited flexibility in their making because of the assimilation of the machinery available on the market and the low cultural identification of production with local events. If machines are created locally, they emerge based on other projects that serve as a reference. We have seen advances in private initiatives and the professional and academic spheres, indicating greater diffusion of technologies and opportunities for application.

The hybrid condition emerges in different ways and themes. The pedagogical aspect uses the mediation of prototypes to facilitate the interpretation of some local field conditions with new instruments, either by valuing history and its narration or by materializing projects adapted to climate conditions and architectural language. In tactical actions, there is a sense of awareness through the approximation of digital technologies to different realities and daily lives, promoting the participation of non-specialists with professionals. In bio-fabricated materialities, the cultural panorama of existing nature becomes institutionalized and merges with traditional techniques and uses of the equipment. From design to fabrication, there is a synergy between actors from different areas and disciplines for conception and materialization. Digital prefabrication rearticulates propositions of historically existing projects or existing demands with new ways of producing. When designing machines, the challenge is to establish local developments with technologies adapted from global projects.

Accessibility to digital fabrication can sometimes be restricted by the type of intellectual work involved, as it requires the ability to control information and adapt the same machinery for different purposes. The technical and social conditions, rather than the natural resources, are responsible for achieving such productive specialization (Santos, 2013). Therefore, it is understandable why this situation becomes ambiguous or even contradictory. To achieve a high technological level, it is necessary to learn how to operate the standards of each machine. These standards are configured in their places of origin and with their determined purposes. This condition prevents the uninitiated from getting directly involved in its operation, almost always requiring mediation. Although technologies make it easy to vary objects, there are limitations in the digital tools available, which do not allow for an expansion of their functionalities. Despite this versatility, the tendency is towards the formation of a subjectivity that accompanies the inclination to copy models and projects in a non-critical manner, obliterating forms of innovation that can support processes for solving problems related to the territory and the local scale (Fonseca de Campos & Dias, 2018).

6 Final Considerations: Paths, Mismatches, and Possible Futures

The trends presented in this article emerge from a broader context, such as those identified in the last decade, and point to relevant and current issues, applications, and strategies related to digital fabrication technologies in South America. The scenario presented highlights the potential and limitations of the Global South in the face of the Global North. To strengthen the autonomy of existing cultural and social dynamics, it is not enough to think of ways to appropriate technologies, but to develop our projects, avoiding a mere reproductive capacity and a certain self-colonization through cultural dependence (Bonsiepe, 2012). This cultural dimension of digital production is a constant site of contention and, in the same process that integrates and hybridizes, it also segregates (Canclini, 1997). Based on the order of the discourses of the Global North, there is an effort to maintain the world economic regime of some sectors in certain regions at the expense of delays and asymmetries in others.

In this way, it is necessary to promote an approach that allows the creation of processes, prototypes, and artifacts considering the limitations of the available machinery, in addition to other complementary analog and digital means, with the results aimed at practical solutions consistent with local problems. Technologies could contribute significantly to social innovation if they “combine the efforts of various actors and institutions, including government, education, research and the productive sector” (Bonsiepe, 2012, p. 15). Fab Labs and individual initiatives have ups and downs; especially when not associated with a supporting institution, they become service centers. Networks of cooperation between actors, universities, and research institutes are essential for knowledge acquisition and dissemination, training activities, social integration, and connections with the productive sector.

The cases presented reflect a search for automation, process openness, and sharing through education in various areas. Although the imperatives of Industry 4.0 are being integrated in a fragmented way, there is enormous potential to explore these topics in construction techniques and new materials. With the constant need to innovate locally, it is plausible to think of accessible factories or technology centers for the development of projects that could be connected “to an industrial sector or a local production arrangement, in the form of associations or cooperatives” (Bonsiepe, 2012, pp. 50-51). However, the creative capacity of applying digital fabrication must also exalt the human factor and override the supposed automatisms: improvisations, makeshift solutions, and disobedience.

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FROM A BIRD'S FLIGHT TO AN OVERLOOKING GAZE: VIRTUALITY AS A METHOD

DO VOO DO PÁSSARO AO OLHAR DEBRUÇADO: O VIRTUAL COMO MÉTODO

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Abstract

Objects, concepts, and images are only fully understood when contextualized in their temporal and interpretative dimensions. As a method, Montage includes its disassembly, revealing the intrinsic complexity of objects and images. This article proposes the exercise of a dialectical triad (assembly-disassembly-reassembly), where images and meanings are constantly reinterpreted when mobilized to inform the realities of the Global South. With the massification of digital platforms such as *Google Street View*, there has been a transformation in collecting and interpreting images, facilitating new interactions and appropriations based on the generalization of phenomena. This article presents a research methodology based on virtuality, using *Street View* to analyze self-constructed layers — the *Puxadinhos* (pronounced *poo-sha-dee-nyos, these* are self-built housing extensions, done mainly without any permits) — in housing complexes, identifying a movement when we connect the Aerial View to the First-person View in the face of the participant gaze in the territories. The collection of images of housing complexes in several Brazilian and Latin American cities highlights the presence of self-built layers, challenging the hegemonic view of the housing complex as a complete solution and demonstrating a generalization of self-construction in countries of the Global South. The incorporation of technologies is advocated to broaden the understanding of territories, emphasizing the need to observe the city based on the everyday images that technology generates, which continue to be capitalized but do not override the need to keep a physical presence in the territories.

Keywords: Images, Google Street View, Representations, Scientific methods, Popular architecture

1 Introduction

In Remontée, remontage (Du temps), Didi-Huberman (2007, 2016) states that things, real and abstract, only appear when they take a position when they are situated in their origin and their end, in the past, in the present, and the future. Not only in what historicism presents to us but as complex constructions, subject to multiple layers of interpretation and appropriation. The montage thus exists as a methodological procedure anchored in its disassembly (Didi-Huberman, 2007). This movement, rethought and reconfigured, predisposes ruptures that can contain and reveal dynamics and conditions inherent to what is positioned or intended to be positioned. Other layers reaffirm the complexity of objects, images, senses, and associations to which these elements must be submitted.

As a dialectical movement that tensions the representations of the Global South, we can then think of the construction of a triad of montage from the collection of images (ASSEMBLE – DISASSEMBLE – REASSEMBLE), which as thesis, antithesis and synthesis, exists from its ‘negation and overcoming at the same time’ (Didi-Huberman, 2010, p. 180, our translation) and from a recognition of what are the contradictions that inform while emerging from the analysis of the images. We, therefore, attribute values and meanings as we mobilize them, bringing them closer to or distancing them from their meanings, being re-presented.

Aby Warburg, in his way, also materialized this triad. In his Atlas Mnemosyne (Der Bilderatlas Mnemosyne, 1924-1929) and his Library on Cultural Sciences (Kulturwissenschaftliche Bibliothek Warburg), it is possible to perceive the visualization of this “complex system of images” (Samain, 2011, p. 39, our translation) and books assembled, disassembled and reassembled in their meanings. Grouped, respectively, in mosaics and by neighboring relations, the act of collecting these images allows us to tension what the positions of the senses and objects were, in a chronology of history and art that until that moment had been chained in a specific stability, based on historical events, and in the construction of a narrative identity. This means that, when it comes to images, the creation of a movement, its mobilization, that is, the action of assembling and disassembling reality itself, provides essential information and readings about the construction of meanings about elements and their dynamics.

With the transformations brought about by the Internet in the way we operate with images, that is, the establishment of an “image economy” (Gunthert, 2009, p. 2, our translation), we have observed a simplification of the provision of online content associated with more significant interaction between users. Determined by the logic of the web, we have also observed a paradigm shift in how we collect images and assemble them. Ease of access allows users to appropriate images, expanding possibilities and transforming how collecting them materializes in the field of representations. This reality not only places images and representations on a new level — now also virtual — but also tends to generalize their presence. In this sense, the tendency to attribute to reality the perceptions we have from images, as stated by Susan Sontag (2004), reinforces the capacity for control that images can exert over the thing represented.

One such example of image generalization is the *Google Street View Platform*. Launched in 2007, but conceived by Larry Page since 2004, the platform emerged as a complex idea for mapping through images and with the main objective of creating a 360-degree map of the world. Seventeen years after its launch, the platform has reached one hundred and two countries and territories, including large coral reefs, fjords in Greenland, and deserts, using a navigation system with virtual routes superimposed on the real world that brings together billions of panoramic images captured by *Google* equipment and local collaborators.

This article is anchored on these two bases of representation and the idea of a dialectical triad of the collection of images. It also intends to present the construction of a research methodology anchored in virtuality, based on the collection of images using *Street View* that presents the constructive materialities of the *puxadinhos* (*poo-sha-DEE-nyos*) concerning the preexistence of the housing complexes, as an expression of socio-spatial inequality (Carrasco, 2015, 2017). This article is informed by the methodology used in the development of the doctoral research[1] entitled "Puxadinho: unveiling self-constructed layers in the public provision of housing". It seeks to illustrate the movement between the Flight of the Bird and the Overlooking Gaze, in a work of identifying the practice of self-building — which presents considerable dynamism — in tensioned urban realities of Brazilian cities and with examples in other Latin American contexts, manifestations of a peripheral capitalist Global South.

This digital movement, as well as its fragmentation, establishes a method that identifies self-constructed layers and their interactions with the environment. Considerations that result mainly from the action of collecting, assembling, disassembling, and reassembling the images, "pulling" from this space a sequence of captures/frames that deal with positioning the objects, in what we describe as a movement that solidifies the leap between the Flight of the Bird and the Overlooking Gaze. This dialectical triad is also reiterated by the vortex and the rectilinear and digital movement that results from a displacement of the image itself, as we can see in the decoupage present in Figure 1.

1 Doctoral research in progress at the Postgraduate Program in Architecture and Urbanism at the University of Sao Paulo, Brazil. Linked to the Housing and Human Settlements Laboratory - LabHAB and with CAPES funding.

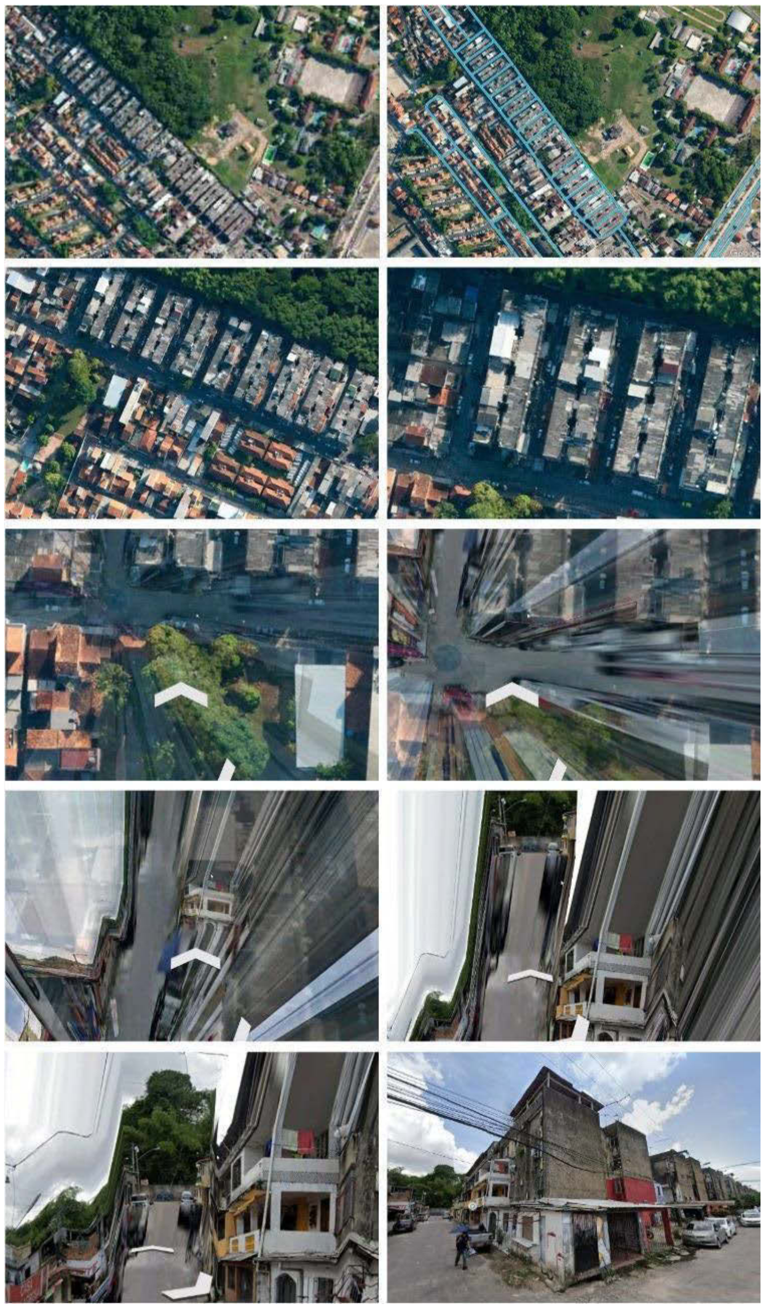

Fig. 1: Decoupage shows the Vortex from the Bird's Flight to the Overlooking Gaze - Império Amazônico Complex (Belém-PA). Source: *Google Street View* adapted and created by the Author, 2024

By replicating this movement, we arrived at a large group of cases formed by fifty Housing Complexes in thirteen Brazilian cities (Belém/PA, Macapá/AP, Fortaleza/CE, Recife/PE, João Pessoa/PB, Campina Grande/PB, Salvador/BA, Maceió/AL, Belo Horizonte/MG, São Paulo/SP, Rio de Janeiro/RJ, Porto Alegre/RS and Alvorada/RS) and eight Latin American cities (Barranquilla/COL, Santiago/CL, Havana/CUB, Mexico City/MEX, Buenos Aires/ARG, Lima/PE, Bogotá/COL and Montevideo/UY). This group initially outlines the presence of these layers of self-construction in dialogue with a structure of public housing provision, the housing complexes, which exist as meager solutions that are disconnected from the needs and desires of living. It also demonstrates the expansion of the territorial scanning capacity that the digital space and its mediation provide as a methodological procedure.

As a methodological exercise that touches on everyday life through mediation carried out in and through the digital world, towards a participatory perspective, this article and its material and virtual structures provide a multi-scale and transdisciplinary view of the discussions that operate in the sociopolitical and housing reality of the Global South. Engendered in peripheral capitalism and a dispute for hegemony, the group of countries that seek to share the same position in terms of technological and digital development allows themselves to host technologies that reveal but also capitalize on their own daily lives, as is the case of the *Google Street View* Platform. Based on this complex tension, we stimulate debate through the limits and perspectives of digital media, which colonize while at the same time acting as mediators of pertinent analyses and research on everyday life, images, conditions of popular housing, and access to the city and housing.

Taking into account the complexities and varieties of circumstances that guide the development and urban planning of this group of cities, as well as their formation, temporality, and form of elaboration of urban public policies for housing provision, themes that contextualize the article, it is believed that this process of collecting and assembling images allows for a broader approximation, as a panoramic perception, of the presence of *puxadinhos* in the public provision of housing. Furthermore, it indicates a preliminary approximation of the hypothesis that guides the doctoral research communicating this article, that is, the identification of a process of generalization of self-building that puts pressure on the housing complex form as an innocuous total solution for the conditions of life and housing in popular territories in the periphery of capitalism.

2 From a Bird's Flight to the Overlooking Gaze

We know that images do not reveal the truth of reality (Didi-Huberman, 2007, 2016), and have limitations. We know, however, that they "simultaneously create a symptom, as an interruption of knowledge, and knowledge, as an interruption of caos" (Didi-Huberman, 2007, p. 214, our translation). They contain and present us with elements that maps and aerial images lack. This intermediate and mediating movement of the leap between the flight of the bird and the overlooking gaze – as a gaze that exists in excess – starts from an identification of the territory of the housing complexes and an approximation, which displaces the image from a point of reference. An image that captures a moment, a dialectical image that becomes legible in the present, in the real, and in the digital, as Walter Benjamin (1969) so well conceptualizes.

This digital and mediated procedure, which we will call movement here, as in physics, represents the situation in which the position of a body changes, over a certain period, in relation to a reference, demanding a careful look at the morphology of cities. It therefore involves the action of unflattening the gaze (Sousanis, 2017) in the leap between the flight of a bird, the aerial image, the map, the satellite, and the overlooking gaze focused on ground level, the incursion into territories and the *Street View* tool. The use of this "movement" reaffirms not only the inevitability of incorporating technologies and tools into the research process but mainly the need to look at territories based on what they are and the importance that images – temporally and territorially situated – have for understanding cities and their dynamics.

In an age of drones and satellite images, with updates in increasingly shorter time frames, we draw attention to the continued prominence given to the aerial, planned view, to the Flight of the Bird — almost like a fetish for the map — to the detriment of the leaned-in (Didi-Huberman, 2015) and unplanned view (Sousanis, 2017). As an expanded academic field of Architecture and Urbanism extols the "power of the aerial view" (Taylor-Foster, 2015, p. 1, our translation), another field tries to understand how the urban landscape — and therefore also the practice of urban planning — will be impacted by the massive production of drones and the increasing occupation of the airspace of cities (Rawn, 2015). These are not antagonistic issues, but complementary. When we address the dependence of architects and planners on plan representations, we highlight the permanence of this convention of orthographic projections as a total form of representation. Foster (2015) even indicates a "stylistic" limitation of the representation in plans for understanding the complexity of the urban space, but credits aerial photographs, the "top views", with overcoming this insufficiency.

Do we believe in the idea propagated by Taylor-Foster (2015) that aerial photographs capture perfect shadows, unexpected patterns, areas of worn soil, and compositions of roofs, in addition to the traces of people, animals, and vehicles, bringing architecture and the urban to "reality"? In Henri Lefebvre's (1991) terms, yes and no. Essentially, the visual exercise of identifying everyday marks in images greatly benefits from the appropriation of new forms of capture and collection by Architecture and Urbanism, but we cannot guarantee that this format has a totalizing power of perception. We work with an infinity of territories that contain their specificities, especially when we talk about popular territories. We work with a complex and changeable city morphology observed in Figure 2 and that is far removed from the stability and fixedness preserved by architectural and urban projects. In this sense, a mere aerial and broad perception of these territories does not seem sufficient to understand their totality.

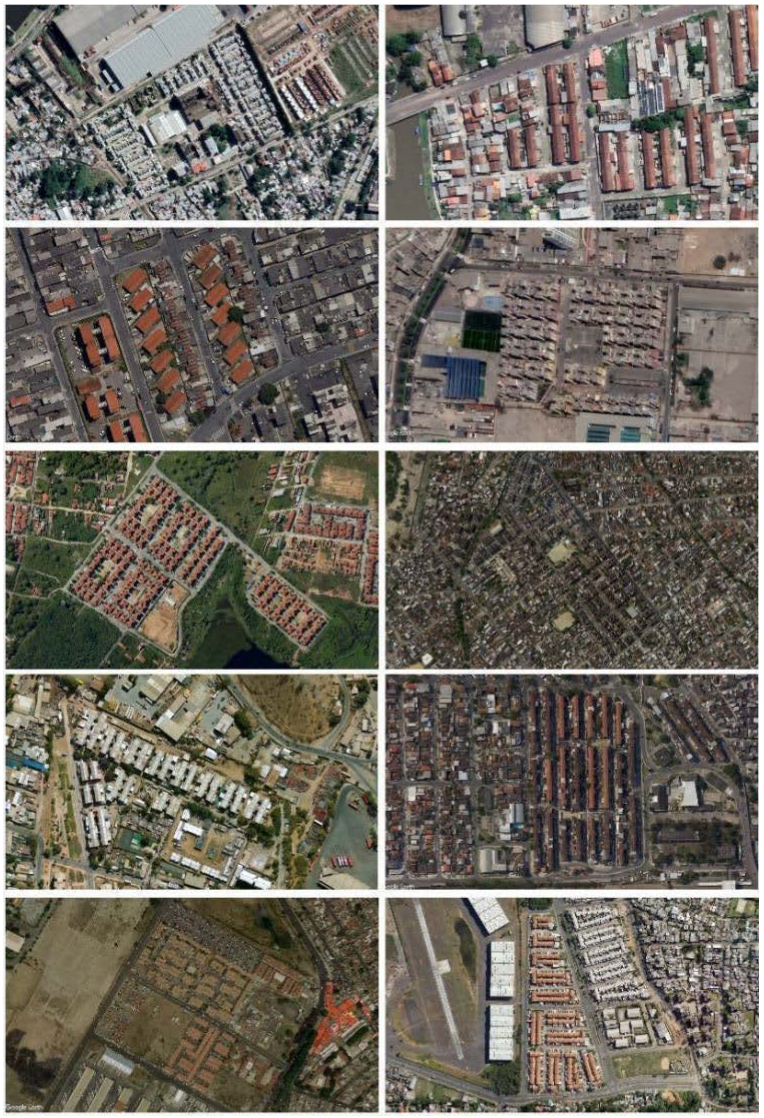

Fig. 2: The Flight of the Bird. Source: *Google Street View* adapted by the Author, 2024

Despite this, and at first glance, Taylor-Foster's understanding does not seem entirely inaccurate. If we consider the contribution of aerial images taken by drones, orthophotos and aerial photogrammetric restitution to the mapping of favelas and popular communities (Dimitrov & Alvim, 2021), as territories that are not always included in official maps, topographic images can allow some overcoming of the lack of information about these territories, but above all, new possibilities for their survey, analysis and intervention. We can observe this from what Foster (2015, p. 3, our translation) considers as “a gap between the tangible and the intangible”, showing the urban context and the natural conditions of the territories that do not appear in plans and orthographic projections, but that appear in drone images and new image collection platforms.

Also between the tangible and the intangible, we situate this article in an intermediate space. Although it is impossible to disregard the contributions of aerial images in the forms of representation of popular territories and their analysis with greater complexity of layers, the hegemony of this form of “reading architecture” transferred to the form of “reading the city”, enhanced by access to online mapping services and by teaching architecture and urbanism that starts from planning, also simplifies our assimilation of these territories and the dynamics present there. For this reason, in this article, we reflect on a method that accommodates new technologies and virtualities, but that incorporates what we consider to be the so-called “movement” between the Flight of the Bird and the Overlooking Gaze to reveal dynamics possibly erased by the prominence of a single view of the city, of everyday life and of architecture itself. A vision that, combined with the set of valuable data that empirical experiences provide us, still does not equip us with a total perception of reality but brings us closer to it.

We understand that, in the case of Self-Building and Housing Complexes, this reflection is even more evident. The cartography and aerial images shown in Figure 2, important tools and languages for the elaboration of analyses on urban insertion, land regularization, building density, topography, as well as the study of space syntax and urban morphology, present limitations when compared to the eye-level images represented in figure 3. The close and distant ways of looking at and conceiving space (Cazetta, 2009) present, on the one hand, layers of urban insertion and forms of relationship with the surroundings, and on the other hand, they mask the presence of self-built layers, the *puxadinhos*. More than that, they reaffirm readings of housing complexes as static, watertight constructions that do not transform, since they are considered, in their origin and end, as complete architectural solutions.

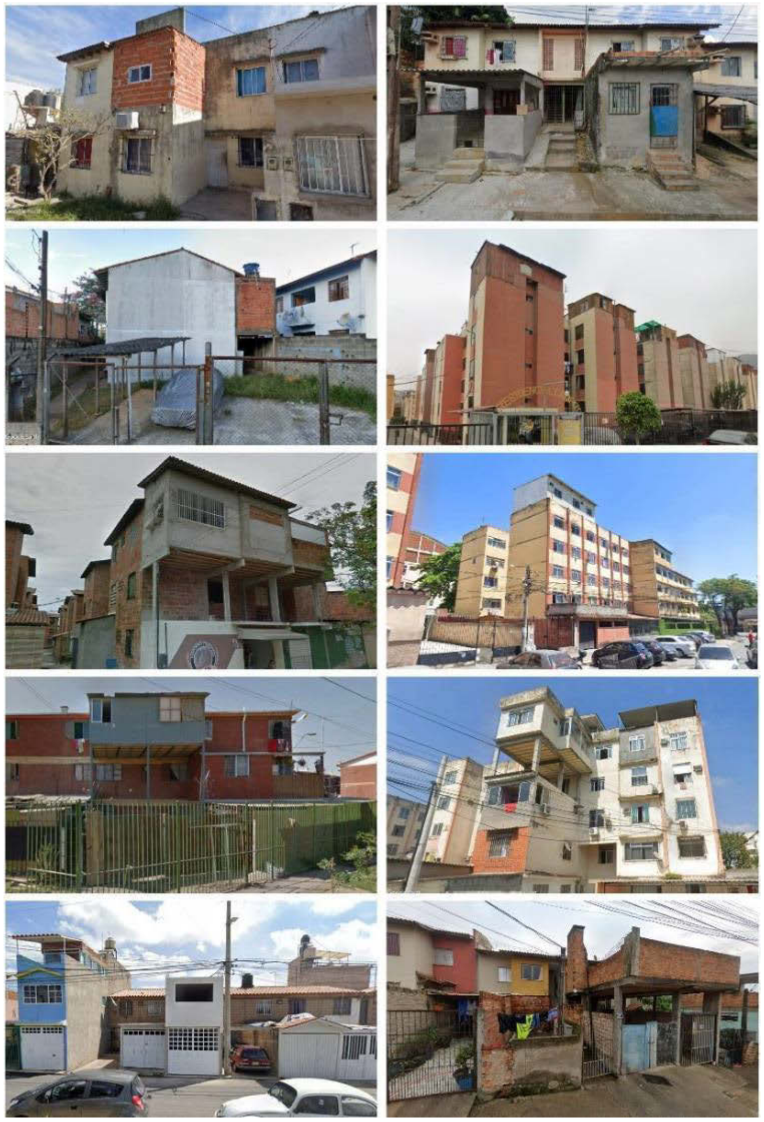

Fig. 3: The Overlooking Gaze. Source: *Street View* adapted by the Author, 2024

We have in movement and tension, from left to right and from top to bottom, the following territories: Villa Tranquila (Buenos Aires, Argentina), Cidade Tiradentes (Sao Paulo, Brazil), Conjunto Miguel Arraes (Fortaleza, Brazil), Conjunto Habitacional Oscar Castro (Santiago, Chile), Unidad Ex Lienzo Charro (Mexico City, Mexico), Residencial Raimundo Cardoso I (Belem, Brazil), Residencial Campoy (Lima, Peru), Conjunto Rua da Gazela (Rio de Janeiro, Brazil), IAPI Padre Miguel (Rio de Janeiro, Brazil) and Conjunto Porto Novo (Porto Alegre, Brazil). This group of images, which is part of an even larger collection of examples, demonstrates an expandable capacity that virtual spaces have – like *Street View* – to allow an initial approximation, based on the positioning of the images and their subsequent collection, of a complex set of territories. Spaces that share similar dynamics despite being in different Latin American conjunctural conditions.

This image operation is therefore not merely instrumental. It is critically informed and objectively tension-provoking. The panoramic and leaned-in view, now also mediated by technical devices, also requires a prior repertoire of the typical morphology of housing complexes, in a way that the image search through the researcher's gaze is a requirement for the investigative discovery and the critique of the form itself. There is thus a participatory action through this repetitive operation that can always be complemented in the field. As quite distinct, non-hierarchical conditions, this transition between the virtually mediated overlooking gaze and the participatory, onsite view are equally important and complementary.

That said, we believe that only the overwhelming panoramic view of aerial images together with a participatory, scrutinizing view can bring us closer to the real dynamics present in these territories. Note that we do not intend to present a complete solution here, but rather a means of approximation, an intermediary space that has the images and their collection as a starting point and not as an end in itself. There are many contradictions present when we choose to instrumentalize scientific research in an online tool, especially in one that presents itself as a totalizing, comprehensive perception of reality. To complicate this debate, let us think about one of the most complex relationships to date, the “Space-Time” relationship.

3 Virtual Time and Real Space - Virtual Space and Real Time

The main element that communicates the *Street View* Platform is the Space category. Representing the basis of all geographic thought, space is an important element for understanding society, constructing identities, and propagating cultures. It is a set of objects and relationships that are realized in themselves from intermediary objects susceptible to human action on space itself (Santos, 1988). When we talk about the reality of life, everyday life is composed of a set of mechanical and human repetitions (Lefebvre, 2001) that are mutually related and situated in a temporal measure, seconds, minutes, hours, days, weeks. This is the dual reality that blends as the backdrop in each panoramic photo captured by *Google Street View*. This dual reality, observed from the images, contains the main elements that inform the urban and architectural dynamics that we want to highlight. The transformations of space in time, are presented in a latent form in Figure 4.

Fig. 4: Physical transformations of a housing complex in the Cidade Tiradentes neighborhood between 2010 and 2023 (Sao Paulo, Brazil) Source: *Google Street View* adapted by the Author, 2024

In the digital world, these realities overlap and become confused. Unlike what we can perceive through grounded participant observation, the analysis based on the collection of images captured by *Street View* has its greatest contribution as its greatest weakness. While visually we can see the intensity with which the sets are complemented with self-built layers, which validates the dynamics we are observing as well as the hypothesis that situates this methodological article, we have some vulnerabilities in the space-time relationship. Physical transformations are present while social transformations and daily events in that territory are absent, but not always. These dynamics do not coincide temporally with the moment in which the images are captured.

The arrangements that make the process of self-building possible are also absent. Later stages of the research, carried out locally through visits and interviews, confirmed several of the perceptions learned through the images, but brought new layers of relationships that are important for the reproduction of self-construction in these territories. These are the dynamics that the image, no matter how situated and detailed it may be, is limited to in this digital relationship between space and time. While we have access to a time frame that would be almost impossible to produce as a researcher — images captured at various time intervals — these images, like the method itself, are not total perceptions of reality. Much less are they a unique perspective on the dynamics of the space.

We have a dichotomy, then. The real and the digital, conditions are conditioned by time and space. In this dialectical relationship — always very welcome — we reaffirm the capacity that images have to coordinate the thing represented and, when mobilized, confronted, and superimposed, they can communicate the development of scientific methods supported by virtual and digital tools and which are territorially comprehensive, as is the case in the example presented. By promoting an experience of digital immersion, in time and space, the use of the platform seems to require reformulations in the theory of communication, in the theory of representations, and research in the expanded field of architecture and urbanism. Its use, in the face of technological acceleration, has already been leading to ways of reading and intervening in the city that cannot be ignored, much less underused.

5 Final Considerations

As an instrument of power, we cannot ignore that the *Street View* platform perpetuates power virtually by "extracting data from our social lives" (Mejias, U., n.d., as cited in Orazem, 2021, p. 2, our translation). Given the situation, we can reflect on the capacity to subvert this colonizing intention of thought by using it to foster an expansion, in terms of territorial scope, of the dynamics present in Latin American countries located on the periphery of capitalism, the Global South. By mobilizing images mediated by the perspectives of Latin American subjects. To do so, we need to popularize research that uses these digital tools as scientific methodology.

In this sense, the article presented here makes an effort to contribute to the reflections, to a certain extent, on the teaching of architecture and urban planning, on images, representation, production, and intervention in urban spaces. Especially in those dense territories, where most of the population lives and where transformations are even more latent. The elaboration of this article also starts from a methodological concern, present throughout the Covid-19 pandemic period and which coincided with the beginning of the elaboration of the thesis that supports this work.

While the discussion is also situated in the field of representations, the extensive use of aerial images does not intend to reinforce any hegemony in the way of viewing architecture; it also has the role of complicating the search for generalization of a phenomenon that is very recurrent in the periphery of capitalism. The instrumental mediation carried out by the use of *Street View* then makes it possible to scan territories without the need to visit them. This is an important initial prospecting for the composition of what we understand as Atlas research. Digital allows for expanded research that deals with recurrence and generalization. The central idea of the article starts, above all, from an appreciation of the materiality that populates the movement carried out between the aerial view, the digital mediation experienced by *Street View,* and the participatory, social, and everyday gaze made possible.

It also comes from an attempt to collaborate with other works and researchers who use digital tools, such as *Google Street View* and others, and who still see their work inserted in unfilled gaps in the expanded field of Architecture and Urbanism. No less important, it exercises the possibility of dialectically articulating the area of Urban Planning, the Production of Popular Housing with the Theory of Representations. Positioning images in the real and the digital, not only as a beginning or an end, but as an intermediary element that can assemble, disassemble, and reassemble perceptions about a given reality even when mediated virtually.

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URBAN-DIGITAL LAYERS: FROM GLOBAL INTERNET INFRASTRUCTURE TO DARK KITCHENS

CAMADAS URBANO-DIGITAIS: DA INFRAESTRUTURA GLOBAL DA INTERNET ÀS DARK KITCHENS

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Abstract

In recent decades, the increasing number of digital platforms, such as Uber, iFood, and Airbnb, and their influence on how cities are produced and managed have stimulated debates about the relationship between digital and urban spaces. Given this scenario, this article aims to analyze the development of the Internet as an infrastructure at different scales and historical moments, based on its spatial aspects, to constitute what we call urban-digital layers. We initially present the development process of the Internet as a global and national infrastructure in the 1990s and 2000s. Next, we analyze the presence of iFood dark kitchens in the Glória neighborhood of Rio de Janeiro, Brazil, indicating how the platform spatializes a service infrastructure locally. We extracted data on one hundred establishments from the Ifood website using Python code. Each establishment was searched on Google Street View and classified as a traditional restaurant or a dark kitchen. Of this total, 64% are dark kitchens, generally concentrated in less central and less busy streets. Based on this and other processes, we indicate how platforms have constituted urban-digital layers that complicate the process of city production and management, generating new dynamics and spatial typologies. Finally, we propose an interpretation of the relationship between the digital and the urban in Brazilian cities, based on global trends and the socio-spatial particularities of each location, as an expression of the presence of digital platforms in the Global South.

Keywords: Digital platforms, Urbanism, Infrastructure, Internet

1 Introduction

Digital communication technologies have significantly affected social interactions with urban spaces and have been extensively studied for over a decade. Although the first public call made by a cell phone took place in 1973, it was only more recently that the phenomenon became popular, along with advances in wireless Internet, that it significantly impacted society (Katz, 2008) . Since then, mobile communication has substantially changed the dynamics of urban sociability, adding new information layers. Today, the convergence of location technologies, GPS, wireless Internet, and social networks makes it possible to create several devices for interacting with the city based on location (De Souza & Silva, 2013). At the same time, the portability of interface devices, such as smartphones, allows access from virtually anywhere in the city, transforming how we interact with and within urban spaces. Developing mobile location technologies stimulates the debate about changes in urban and digital interaction.

These changes vary from one place to another, influenced by geopolitical dynamics, historical processes, and local specificities, giving rise to tensions in the Global South that are often not evident in the countries where the dynamics of digital platforms originate. Navarrete Escobedo (2020) exemplifies this phenomenon by demonstrating how the Airbnb platform has transformed real estate dynamics in connection to the historically established relationship of inequality between Mexico and the United States. Pollio (2021), in turn, indicates how Uber and urban infrastructure interact in the Indian and South African contexts, acquiring specific expressions according to the characteristics of the preexisting city. This article aims to analyze the development of the Internet as infrastructure at different scales, based on its spatial aspects, to constitute what we call urban-digital layers. We trace an analytical path from the global to the local scale, beginning with the constitution of the global Internet infrastructure, moving on to its implementation in the Brazilian context, and concluding with the analysis of dark kitchens — one of the new spatial typologies that unfold from the interaction between the digital and the urban — in the built environment of the Glória neighborhood, in the city center of Rio de Janeiro, Brazil.

2 Methodology

We start analyzing the Internet's global infrastructure through narratives highlighting critical aspects of the development process of computers, the Internet, and the Web. We then present the physical elements that make up this infrastructure. Subsequently, we summarize the Internet development in Brazil with articles and reports from the Brazilian Internet Steering Committee (CGI.br). We then propose the category of the urban-digital layer to analyze the interaction between the digital and the urban and deliver a study about iFood's dark kitchens in the Glória neighborhood. We present the company's history and collect data from the platform using Python code and web scraping techniques. We improve this data by consulting the addresses of the dark kitchens on Google Street View and present an analysis of this data, focusing on the spatial aspects of the dark kitchens identified. Finally, we return to the analyses made in the first two sections, emphasizing how contemporary cities acquire increasingly complex urban-digital layers to argue that their analysis must consider the multi-scalar character of the digital today.

3 Digital as a Global and National Infrastructure: Internet and Urban-digital Layers

The 1960s can be considered the starting point in the Internet's history, as indicated by existing narratives about the development process of the Internet and the web (Ryan, 2010; McCullough, 2018). During this period, the first networks for connecting computers began to be developed, based on decentralizing the structure of telecommunications networks and formulated for sharing military information (Ryan, 2010). The Internet resulted from the need for information to circulate, similar to traditional telecommunications networks established from the 19th century onwards and whose final devices were the telegraph, telephone, radio, and television. In the 1990s, the Internet experienced its diffusion moment with the development of the World Wide Web (WWW, or simply the web). As a system for circulating hypermedia documents (such as texts, images, audio, and videos) linked by hyperlinks, the web made it possible to browse the Internet. In this same process, computers stopped being large machines aimed at extraordinary activities. They became leaner and more versatile, used for trivial activities, intensified in the 1970s, and included the creation of devices such as the personal computer (PC), the laptop, and the smartphone (Ryan, 2010; McCullough, 2018).

Although the Internet is often interpreted as invisible, immaterial, magical, and superhuman, especially after the development of wireless technologies and mobile devices, its materialization can be seen on different scales. Today, the global Internet infrastructure consists of a network of 529 submarine cables that total approximately 1.5 million kilometers in length (TeleGeography, 2023) and derive from the telegraphy infrastructure initiated by Great Britain in the 1860s (Winseck, 2017). The construction of submarine cables only reached a scale similar to that of the 19th century from 1997 onwards, defining a global network built and managed by large companies, multinational consortiums, and local governments and impacted by geopolitical disputes (Winseck, 2017).

This global infrastructure is also made up of data centers, sometimes called digital factories, where the data we think of as being in an ethereal dimension, which we call the cloud, is stored. According to what Cloudscene indicates on its website, the importance of the data center real estate market is growing worldwide (Cloudscene, 2024). The telecommunications company in question estimated 10,593 data centers worldwide, according to research available on the Statista website with free registration (Taylor, 2024). Zalis (2021) emphasizes the data centers' materiality and social and environmental impacts. Much of this infrastructure — also composed of other physical elements, such as terrestrial cables, antennas, transmission towers, and domestic cabling — results from changes in the way the telecommunications industries were organized from the 1990s onwards: from monopolies, some formed by state-owned companies, to free competition between private companies of different sizes (McCullough, 2018).

The implementation of Internet infrastructure in Brazil followed this path. Although its antecedents date back to the 1970s (Benakouche, 1997), the first connection in the country officially took place in Rio de Janeiro in 1992 through an academic network developed by the National Education and Research Network (RNP) and connected during the United Nations Conference on Environment and Development (Rio-92) (Knight, 2016; RNP, 2022). In 1998, with the creation of the General Telecommunications Law (Law No. 9,742/1997), the privatization of Brazilian telecommunications placed competition between private companies as a strategy for the expansion of broadband infrastructure, with the State acting as a regulatory agent (Marques & Lemos, 2012; Knight, 2016). In the following decades, Internet penetration in the country dealt with diverse spatial, social, and economic factors. Among them, regional inequalities, divergent interests between the State and operators — who prioritized serving the metropolises since there is a more significant financial return on the necessary investment in infrastructure — and social inequalities, which were expressed in the conditions of access and in the behavior of using digital devices (Marques & Lemos, 2012; Knight, 2016).

The TIC Domicílios report, a survey conducted since 2005 by the Brazilian Internet Steering Committee (CGI.br), demonstrates the transformation undergoing in the country in terms of Internet penetration: in 2005, only 21% of Brazilian households were connected to the Internet, while in 2023, 84% of households had a connection. The changes in digital behavior are also notable: in 2005, access was mainly via desktop computer — 12.8%, compared to 4.5% via cell phone and 70.3% without Internet access in the three months before the survey. In 2023, 84% of respondents had accessed the Internet in the previous three months; of this total, 58% accessed via cell phone and 42% via cell phone and computer (CGI.br; 2006, CETIC.br, 2024).

In this process, the relationship between digital and urban space manifested differently. Back in the 1990s, the city of Piraí, in the south of Rio de Janeiro state, Brazil, pioneered digital inclusion involving physical infrastructure and training, facilitating access to the Internet for its residents. In the 2000s, a more comprehensive phenomenon emerged, such as LAN houses and spaces for Internet access that served as an alternative to a still incipient infrastructure (Barbosa & Cappi, 2010). LAN houses added a new layer to cities as a network of spaces managed by the local population, combining the possibility of access to cyberspace and, at the same time, the power of physical space as a place for meeting and sociability. During this same period, orkontros (meetings organized through the social network Orkut by groups of people who shared interests) began to occupy public spaces and shopping centers in Brazil.

This relationship has intensified with the popularization of mobile devices, making the boundaries between the physical and the digital increasingly blurred and stimulating so-called hybrid spaces, that is, spaces that “combine the physical and the digital in a social environment created by the mobility of users connected through mobile technology devices” (De Souza e Silva, 2006, p. 263). Throughout history, different expressions of the interaction between the digital and the urban have added to the city what we call urban-digital layers: layers that merge physical spaces and information in a multi-scale network structure. The history of the Internet demonstrates how it has added new elements to urban spaces located in diverse ways in cities.

Reading from different layers and scales helps us understand the dialectics of this tangle of digital and urban networks that intersect, merge, or coexist. In the 2010s, digital sharing economy platforms intensified this dynamic with applications that enable real-time interaction with the city. They complicate these layers, as they benefit from the accelerated circulation of capital and a historical process of commodification of towns. Below, we analyze the iFood platform in the context of the Glória neighborhood in Rio de Janeiro, Brazil, to illustrate how one of these urban-digital layers manifests itself on a local scale.

4 Digital Materialized on a Local Scale: iFood's Dark Kitchens in the Glória Neighborhood

IFood is a Brazilian company that deals with food delivery. It mediates delivery orders by connecting customers, restaurants, and delivery workers through the Internet infrastructure. It is the largest delivery company in Latin America and is present in Argentina, Mexico, and Colombia. IFood’s history began in 1997 with Disk Cook, offering a printed menu guide and a call center. Initially, the service used the telecommunications network to operate. Over time, the company grew and began to face typical difficulties of the telephone system, from delayed calls to signal problems and incorrectly written addresses, among others (Marques, 2023).

In 2011, the company began its website operations under the name iFood. Smartphone use was becoming popular in Brazil and was restricted to specific consumers, so most orders were placed on the website. The IFood application for iPhone, launched in 2012, worked with a geolocation system and established the platform in the market. It was capable of receiving several orders within the software at the same time. What seems simple today, at that time, represented a significant transformation since most restaurants depended on a telephone line — which, in addition to receiving only one order at a time, required a specialized employee to answer and take orders. Thus, creating a digital system connected to the Internet meant more orders in less time for the restaurant and reduced the number of employees.

The popularization of smartphones consolidates the era of digital platforms. In this process, iFood expanded and started investing in technology for user security and payment data, culminating with the app's payment system and, more recently, the launch of a meal voucher, iFood Benefícios. The delivery rider’s system – current in cities today – did not exist from the beginning, so the app was merely an ordering intermediary, and the restaurants carried out the food delivery itself. The delivery system was implemented in 2015, registering self-employed riders on the platform. In 2018, iFood consolidated this logistics model by merging with the startup Rappido, which specializes in connecting delivery workers to companies. Also, in 2018, the company acquired Pedidos Já, a competitor with a strong presence in Latin American countries, increasing its reach.

Today, the IFood platform operates in over nine hundred cities, with one hundred and thirty-one thousand restaurants and one hundred and seventy thousand registered delivery workers. It is the most well-known (96%) and used (94%) delivery app in Brazil, according to a survey conducted by Opinion Box in 2023 and published on the platform's website (iFood, 2023). iFood was created to deliver ready-made food, that is, working with restaurants. It began to diversify its operations, offering purchases from grocery stores, supermarkets, pharmacies, and other goods, with the entry of this type of competitor into the Brazilian market. The development and consolidation of digital delivery platforms in the food market also boosted a trend already establishing itself as an option to reduce the cost of setting up new restaurants or expanding units: dark kitchens.

Dark kitchens, or ghost kitchens, are commercial kitchens used exclusively for delivery operations, "food establishments that focus solely on meal delivery and do not have physical storefronts or areas for local consumption" (Hakim et al., 2022, p. 2). The location is set up with the necessary equipment to prepare meals. Still, it does not have a dining room or reception area for customer service or identification of the establishment on the property's facade. It does not allow viewing of how the food is prepared. That includes shared space kitchens, where several restaurants rent and share the same space, and residential kitchens, where small family businesses are set up.

An individual operator can sometimes manage several small restaurants in a single kitchen. From an urban perspective, they have spawned a new real estate sector attracting investors: dark kitchen coworking. In Brazil, Kitchen Central is the largest company in the industry and the Brazilian arm of the global CloudKitchens, created by Uber co-founder and former CEO Travis Kalanick. According to architect and urban planner Nabil Bonduki, they have been installed in mixed-use neighborhoods where residential use predominates. Bonduki highlights that "since licensing is done individually, the building is first licensed as a coworking space, and then each kitchen begins to operate without individual licensing" (Bonduki, 2022, p. 1).

Given its clear relevance and dominance in the market, we mapped dark kitchens in the Glória neighborhood in Rio de Janeiro, Brazil, based on data from restaurants on the iFood platform. The study's territorial scope was selected because of its diversity of urban situations. This historic neighborhood is located in the city center, on the border with the South Zone. After years of devaluation, Glória is facing a gradual gentrification process, with the implementation of urban renewal projects — such as the Dias de Glória Program — and a consequent increase in tourism. In this sense, the neighborhood presents increasingly more urban-digital layers, with a strong presence of platforms such as Airbnb and Uber, for example.

Mapping establishments allows us to analyze their effects on urban space and to perceive their characteristics through a qualitative approach, aiming to understand the patterns and demands that this establishment type generates for the place where it is installed, such as the accumulation of bicycles, motorcycles, and delivery workers on the sidewalks, or the blind facade effect, which occurs when the establishment has no storefront or entrance for customers. Hakim and co-authors (2023) conducted a study on dark kitchens in Brazilian cities in the state of São Paulo, scraping data from the iFood website and processing it manually. The authors analyzed the dark kitchen's development in three urban centers in Brazil based on iFood, showing that, despite the impossibility of accessing all the data owned by the platform, it is possible to use the data that is available to the user/customer in the interface itself, processing it manually afterward.

We started filtering the iFood website to find restaurants near the Glória neighborhood using the geolocation on the website interface. By sharing our location, we obtained a list of restaurants sorted by distance. We extracted the first one hundred establishments from that list, using a Python code written in Google Colab, based on the Web Scraping technique applied by Barbosa (2021). Running the code generated the table shown in Figure 1, downloaded in CSV format to be managed in Excel. It initially contained the name of the restaurant, the distance, the rating (from zero to five), and the type of food (Brazilian, Pizza, Snack, among others). To analyze dark kitchens, we need to classify the restaurant as a dark or traditional kitchen. No information in the delivery app interface generally distinguishes ghost establishments from traditional ones.

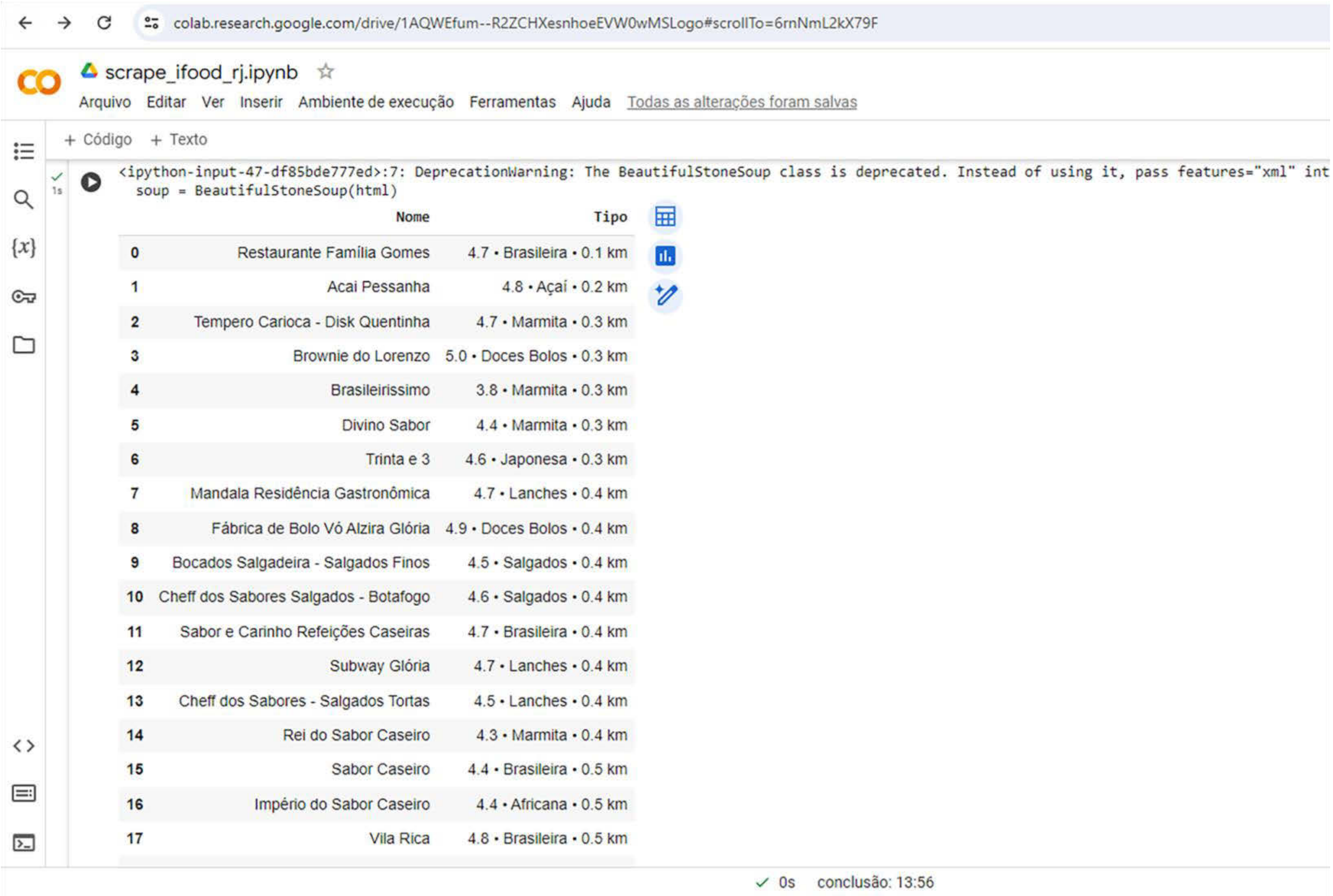

Fig. 1: Restaurants near the Glória neighborhood. Source: iFood, adjusted by the authors on Google Colab, 2024.

After excluding the establishments that we assure to be traditional, each establishment was searched on Google Street View to understand whether it was a ghost kitchen. Each restaurant's page on the iFood interface was accessed to find the addresses, and they were added to a new column, along with a column for the type of establishment, as shown in Figure 2. The situations were analyzed using the address, observing the relationship of the facade to the street, the existence of a storefront, signs, and the type of entrance, among other aspects. We went on field research for those for which it was impossible to identify if they were dark or traditional kitchens. The result was plotted on Google My Maps and classified as ghost or traditional. Thus, the final mapping was obtained, summarized in Figure 3. It is possible to visually explore the layout of dark and conventional kitchens in the territory, materializing this data in the urban space. This visualization gives rise to some critical analyses of the results obtained, which we discuss below.

Nome	Avaliacao	Tipo	Distancia	Estabelecimento	Endereco	Bairro	Cidade
Restaurante Família Gomes	4.7	Brasileira	0.1 km	Tradicional	Rua Santo Amaro, 103	Glória	Rio de Janeiro
Acai Pessanha	4.8	Açaí	0.2 km	Fantasma	Rua Santo Amaro, 160	Glória	Rio de Janeiro
Fata Alimentos	Novidade	Pizza	0.2 km	Fantasma	R. Santo Amaro, 172	Glória	Rio de Janeiro
Tempero Carioca - Disk Quentinha	4.7	Marmita	0.3 km	Fantasma	Travessa Cassiano, 12	Santa Teresa	Rio de Janeiro
Brownie do Lorenzo	5.0	Doces e Bolos	0.3 km	Tradicional	Rua Benjamim Constant, 49	Glória	Rio de Janeiro
Sushi Novo Horizonte	4.8	Japonesa	0.3 km	Fantasma	Rua Santo Amaro, 200	Glória	Rio de Janeiro
Kaydo Sushi	5.0	Japonesa	0.3 km	Fantasma	Rua Santo Amaro, 351	Glória	Rio de Janeiro
Sushi San	4.5	Japonesa	0.3 km	Fantasma	Rua Santo Amaro, 351	Glória	Rio de Janeiro
Catete Burguer e Cia	5.0	Lanches	0.3 km	Fantasma	Rua Santo Amaro, 351	Glória	Rio de Janeiro
Brasileirissimo	3.8	Marmita	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Divino Sabor	4.4	Marmita	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Pizza Arte	4.4	Pizza	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Go Home Sushi	4.8	Japonesa	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Mn Burguer	4.5	Lanches	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Manos Burguer's	5.0	Lanches	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Burguer's in House	4.8	Lanches	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Mecflix Burger	4.6	Lanches	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Zequinha Sushi	4.9	Japonesa	0.3 km	Fantasma	Rua Santo Amaro, 349	Glória	Rio de Janeiro
Suprema Pizzaria Zona Sul	4.8	Lanches	0.3 km	Fantasma	Rua Hermenegildo de Barros, 18	Glória	Rio de Janeiro
Trinta e 3	4.6	Japonesa	0.3 km	Tradicional	Rua Santo Amaro, 33	Glória	Rio de Janeiro
Ô Pastel	4.5	Lanches	0.4 km	Fantasma	Rua Pedro Américo, 759	Catete	Rio de Janeiro
Usama_food_culinaria_arabe		Arabe	0.4 km	Fantasma	Rua Pedro Américo, 218	Catete	Rio de Janeiro
Mandala Residência Gastronômica	4.7	Lanches	0.4 km	Tradicional	Rua Murtinho Nobre, 169	Santa Teresa	Rio de Janeiro
Fábrica de Bolo Vó Alzira Glória	4.9	Doces e Bolos	0.4 km	Tradicional	Rua do Catete, 30	Catete	Rio de Janeiro
Bocados Salgadeira - Salgados Finos	4.5	Salgados	0.4 km	Fantasma	Rua Pedro Americo, 76	Catete	Rio de Janeiro
Cheff dos Sabores Salgados - Botafogo	4.6	Salgados	0.4 km	Fantasma	Rua Pedro Americo, 76	Catete	Rio de Janeiro
Empada Delivery	Novidade	Lanches	0.4 km	Fantasma	Rua Pedro Americo, 76	Catete	Rio de Janeiro
Shay Sushi Delivery	4.8	Japonesa	0.4 km	Fantasma	Rua Pedro Americo, 560	Catete	Rio de Janeiro

Fig. 2: Restaurants near the Glória neighborhood. Source: iFood, extracted and adjusted by the authors in Excel, 2024.

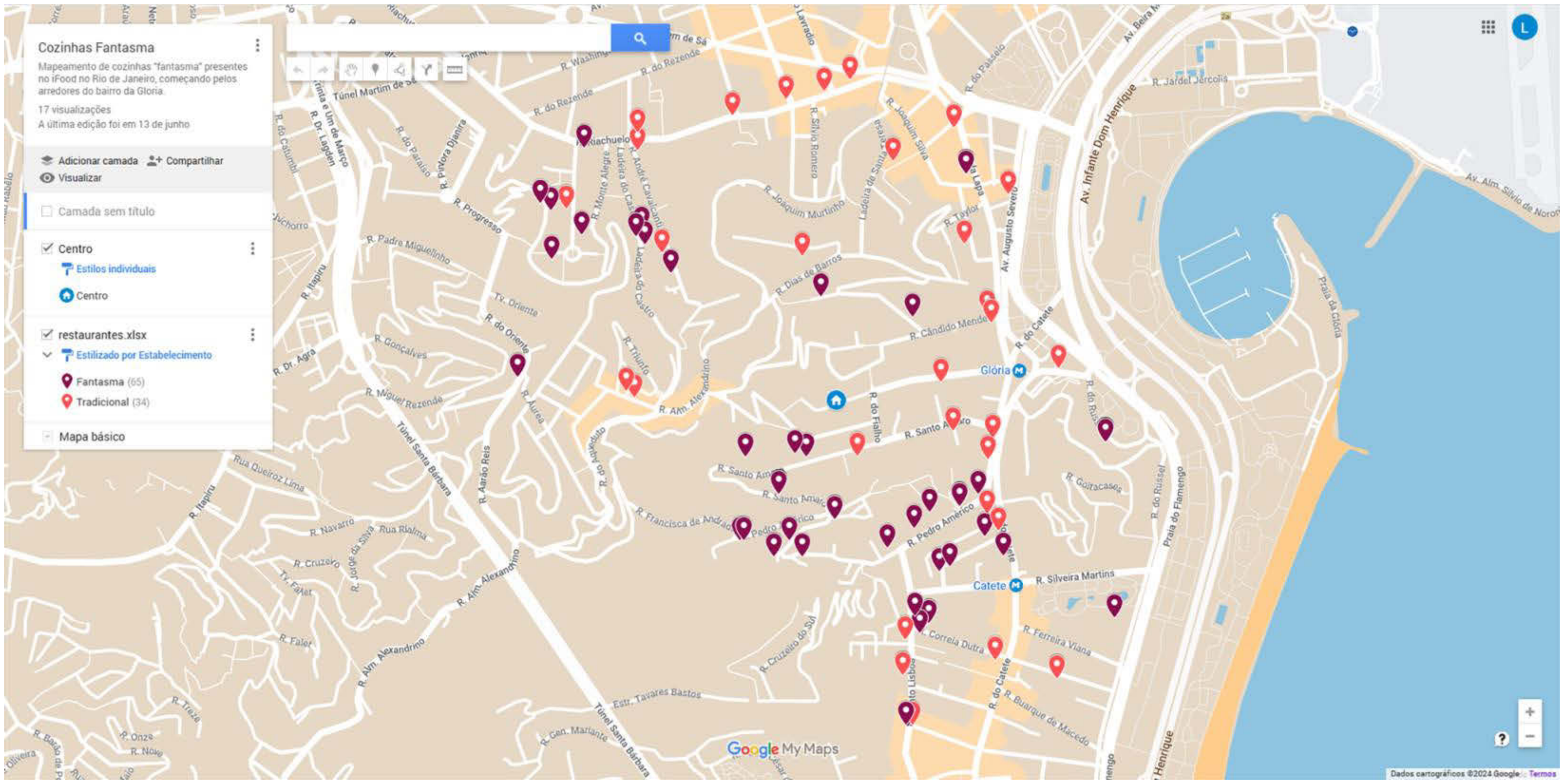

Fig. 3: Map of iFood dark kitchens in the Glória neighborhood, Rio de Janeiro. Source: Authors, prepared with data from iFood, using the Google My Maps tool and cartographic data © 2024 Google. Available at: https://www.google.com/maps/d/edit?mid=1D1X1Ik5rGsPqE4B9RCwWoNpwqgsoEMA

First, 64% of the establishments analyzed are dark kitchens, predominating within those available on the platform in this spatial section. There are, however, restaurants registered at the same address, indicating the use of more than one kitchen in a shared space. Some addresses are repeated in more than five restaurant profiles with different types of food. Hakim and co-authors (2023) indicate that restaurants may use other names to circumvent the app's metrics. The authors show that this can be an interesting strategy when, for example, a restaurant's profile receives low reviews and the platform stops showing it as the first option. Thus, creating a new profile can provide opportunities to stand out. In contrast, a virtual kitchen in a standard restaurant (with a different menu) can create new opportunities for the space.

Regarding the food type, the “Snacks” category stands out among ghost kitchens, with thirteen restaurants within a one-kilometer radius, followed by “Japanese” and “Lunchboxes.” For traditional establishments, “Brazilian” restaurants predominate, followed by “Snacks” and “Bakery”. The map analysis showed a concentration of dark kitchens on some residential and less busy streets, generally located on uphill and hillside access roads to the Santa Teresa neighborhood (next to Glória), and conventional restaurants generally on the main and busiest streets. This aspect is also present in Hakim and co-authors' study, which found a higher density of traditional restaurants in the central regions of the cities analyzed, with dark kitchens at a greater average distance from this central area (Hakim et al., 2023).

In the presented case, Rua Riachuelo and Rua da Glória are central and busiest, concentrating conventional restaurants. Dark kitchens are located on the slopes around Santo Amaro hill, between the neighborhoods of Glória and Catete, and on slopes towards Santa Teresa. Most can be classified as residential dark kitchens (Figure 4) and run as family businesses at home. The dark kitchens in Glória illustrate the urban-digital layer that emerges from the interaction between the existing city and the iFood activities. As Hakim and co-authors (2023) demonstrate, the typologies arising from this new model of urban-digital interaction result from functional aspects and dynamics specific to the platform's production circuit. At the same time, as we indicate in our analysis, this phenomenon is intertwined with the existing city, involving local urban, social, and economic aspects.

Fig. 4: Residential type dark kitchen. Source: Google Street View © 2021 *Google*. Accessed 05/07/2024.

6 Thinking on Urban-digital Layers in Brazilian Cities

Digital delivery platforms, such as iFood, strengthen the idea of the Internet as an immaterial and invisible infrastructure, a trend indicated in the first section on a broader scale and based on historical aspects. Since, within the platform, all kitchens are ghost kitchens and the food magically arrives at the customers' homes, the material context in which the food is cooked loses importance. On the other hand, dark kitchens express the materiality of most restaurants on the platforms and reflect specific characteristics of the urban context. In the case of iFood's dark kitchens in Glória, local specificities stand out, such as the presence of dark kitchens in areas and surroundings of favelas, such as Santo Amaro. As a digital delivery platform, iFood is just one of the mechanisms of interaction between the digital and the urban today and reinvents urban dynamics in Glória, creating new forms of social and urban informality.

Every day, digital networks enable interactions on different scales: from social networks, such as Instagram and Twitter, which increasingly shift spaces of sociability to the digital, to other shared economy platforms, such as Airbnb and Uber, with more evident impacts on the city's production. However, as argued, the existing and possible interactions between the layers defined by these urban and digital networks are often not evident. As developed in the first section, cities present urban-digital layers that are established differently from one place to another. This factor should not be neglected in the Brazilian context since the country's territorial extension has a social, cultural, and urban diversity that enables a repertoire of urban-digital interactions that have not yet been mapped. Considering the complexity of this global phenomenon and the Brazilian urban diversity, we see urban-digital layers as a way to understand the interaction between the urban and the digital.

7 Final Considerations

Based on its spatial aspects, this article investigates Internet development as infrastructure at different scales and historical moments, proposing an analysis based on urban-digital layers. We did it through an analytical path that revisited narratives about the Internet's history, drawing attention to its materiality on a global and national scale. Next, we conducted a case study that emphasized how the iFood platform and the urban space of Rio de Janeiro interact in the context of the Glória neighborhood, which is reflected in a spatialization of dark kitchens intertwined with the city's pre-existing features. The analysis based on different layers and scales brings to light this digital materiality. It makes it possible to understand the complexity of the relationship between the digital and the urban present today.

The residential dark kitchen typology in cities like Rio de Janeiro expresses some of the limits and potential of the relationship between digital platforms and cities in the Global South. While platforms like iFood allow small, often informal, family businesses to be promoted to numerous customers, this new urban-digital layer and its consequent material transformations in urban space are becoming increasingly present, combined with local preexisting conditions. So far, our analysis has been limited to a specific area of the city and may be expanded in future studies to better understand the dynamics of dark kitchens in other parts of the territory. Since they are established differently from one place to another, this process is material, spatial, and urban, requiring analytical exercise to understand both local specificities and regional similarities and differences, with particular contribution when we think about the consequences of the platform economy in the urbanization of the Global South.

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BRIDGING THE GAP: EMPIRICAL VS. SIMULATION IN GREEN FACADE MODELING

REDUZINDO A BRECHA: EMPÍRICO VS. SIMULAÇÃO NA MODELAGEM DE FACHADAS VERDES

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Abstract

This paper examines the transformative role of digital simulation tools in architectural design, focusing on the implementation and performance evaluation of green facades in the Global South, particularly Chile. In alignment with the theme The Digital and the South: Questionings, the study highlights how digital simulations enable a critical re-evaluation of sustainable technologies within the unique climatic, social, and urban challenges of southern regions. By addressing the performance gap – the discrepancy between theoretical design and empirical building performance – this research explores how digital tools can bridge this divide, providing essential insights that are otherwise challenging to achieve in unique climatic and urban contexts. This study examines how digital modeling can bridge this gap by providing a deeper understanding of green facades' environmental and energy impacts in different urban microclimates. Using a mixed methodology that combines case studies, empirical measurements, and advanced digital simulations, the research evaluates the potential of green facades to enhance urban climate resilience and energy efficiency. Results indicate that the effectiveness of these facades varies significantly based on local climatic conditions and site-specific characteristics, underscoring the need for tailored architectural solutions to optimize performance. By refining simulation models to capture complex environmental interactions, this paper contributes to more accurate and effective sustainable design strategies, positioning digital simulation as a critical tool for adapting architectural practices to the distinct realities of the Global South.

Keywords: Digital simulation, Green facades, Performance gap, Empirical analysis, Analytical design

1 Introduction

As cities in the Global South expand and evolve, the need for sustainable architectural solutions becomes increasingly urgent, driven by rapid urbanization and the escalating impacts of climate change. This region, characterized by diverse climatic conditions and socioeconomic constraints, faces unique challenges that demand innovative approaches to building design. These challenges are intensified by extreme climatic conditions and fast urban development, which necessitate solutions that are not only visually appealing but also functionally effective in enhancing energy efficiency and climate resilience. Integrating green infrastructures, mainly green facades, into urban architecture is among the most promising solutions to these challenges. Green facades offer a way to improve building performance while addressing environmental issues such as urban heat islands and energy consumption.

Research on green facade technologies has predominantly occurred in the Northern Hemisphere, leading to a gap in context-appropriate studies for the Global South, particularly Chile. According to a review by Mela and co-authors (2023), Europe has been the leading geographic location for research on vertical gardens, representing 51% of all publications, followed by Asia with 31%, Oceania with 7%, South America with 6%, and North America with 5%. In South America, most of the research has been conducted in Argentina and Brazil, with a smaller portion in Chile. This geographical concentration underscores the pressing need for more research in the Southern Hemisphere, where climatic conditions differ significantly from those in the North, and tailored solutions are required to address specific environmental challenges.

To bridge this gap, integrating infrastructures like green facades and green walls into architectural designs has become increasingly recognized (Su et al., 2024). These green systems not only contribute to the aesthetic and psychological well-being of urban environments but also play a pivotal role in addressing critical environmental issues such as urban heat islands and energy consumption (Bakhshoodeh et al., 2022; Fu et al., 2022). By leveraging digital simulation tools, architects can optimize the integration of these green infrastructures into building designs, ensuring that they maximize their environmental benefits and contribute effectively to the overall sustainability of urban developments.

In the context of The Digital and the South: Questionings, this paper positions digital simulation as a critical tool that empowers architects to respond to unique environmental challenges. The effectiveness of digital modeling tools in forecasting building performance depends significantly on user expertise. Despite their potential benefits, practical implementation often fails due to a persistent gap between theoretical design and actual performance, exacerbated by the limited use of advanced simulations in practice (Dwyer, 2013), commonly known as the performance gap. This gap, particularly prevalent in sustainable architecture, can lead to actual energy consumption exceeding predicted levels by substantial margins, sometimes by as much as 483% (Bai et al., 2024). Further complicating practical application is caused by the lack of standardized criteria for designing and implementing alternative infrastructures like green walls (Ascione et al., 2020).

This paper explores how digital simulation models are transforming the architectural design process in the Global South by bridging the gap between intuitive design and empirical performance evaluation. It examines the barriers to adopting these technologies and the potential for these tools to facilitate the design of energy-efficient, climate-responsive buildings that address the specific environmental conditions of the region. By focusing on the case of vertical green facades in Chile, this study aims to demonstrate the practical benefits and enhanced performance outcomes achievable through advanced simulation tools, thereby positioning digital technology as an indispensable resource in the sustainable architectural practices of the Global South.

1.1 Green Facade and Digital Modeling

The study of green infrastructure, particularly green facades, has advanced considerably over the past two decades, driven by the need to enhance urban microclimates and improve building efficiencies (Bustami et al., 2018). These advancements are marked by significant methodological developments, where computational simulations have emerged as a crucial tool that enables architects and urban planners to model and analyze the thermal effects of green facades, optimizing their designs to maximize environmental and energy benefits. Early pioneering research, like the one conducted by Stec, Van Paassen, and Maziarz (2005), utilized parametric simulations to assess the shading capacity of plants on double-skin facades, providing valuable insights into their comparative efficacy against traditional solutions like blinds (Ip et al., 2010).

Despite these advancements, the architectural field has not fully embraced the techniques associated with green facades. Current tools often fail to integrate the complex interactions between green facades and the broader urban environment (Bakhshoodeh et al., 2022). This gap highlights the necessity for more accurate and effective hygrothermal models that can consider these factors, providing more precise and practical predictions about the impact of green facades in urban contexts. Ascione and co-authors (2020) emphasize the need for comprehensive data to enhance design decisions, particularly regarding plant selection and climatic response, which are crucial for green wall performance. Digital tools facilitate scenario modeling to predict performance, thus addressing the performance gap by allowing decisions based on empirical data and enhancing design reliability and environmental impact.

The current state of the art in studying the hygrothermal impact of green facades relies on a fusion of methodologies, including computational simulations, experimental analysis, and case studies. These approaches allow the exploration of multiple scenarios and configurations, where parameters such as the cavity depth between the green facade and the wall, vegetation density, and building orientation are varied to identify the most energy-efficient configurations. Computational simulations are exceptionally fundamental in studying the thermal performance of green facades. They allow for the recreation of multiple scenarios to assess the impact of these systems in different contexts, predicting the thermal behavior of green facades and their influence on the energy consumption of buildings (Bagheri et al., 2021).

Experimental analyses provide essential data to complement these simulations. These experiments, conducted in controlled environments and actual buildings, involve measuring surface and surrounding air temperatures using temperature and humidity sensors to monitor the thermal performance of green facades in real-time (Bakhshoodeh et al., 2022). This empirical data is critical for validating and refining simulation models to predict real-world outcomes better, thus contributing to more reliable and effective design practices. Case studies in specific urban contexts further contribute to understanding the impact of green facades in actual operational conditions. These studies consider variables such as local climate, urban density, and architectural configuration, offering vital insights for adapting designs to specific conditions in the Global South. The combination of computational simulations, experimental analyses, and case studies has laid a solid foundation for understanding the thermal performance of green facades. However, a considerable gap remains in the availability and application of effective hygrothermal models (Ascione et al., 2020). This gap raises essential questions about why architecture has not fully adopted these techniques despite their proven efficacy, highlighting the need to bridge the gap between theoretical design and actual performance.

1.2 Green Facades in Chile

The need for tailored solutions in the Global South becomes particularly evident when examining the implementation of green facades in regions like Chile. While the potential of green facades to address environmental challenges such as urban heat islands and energy consumption is well-recognized globally, their effectiveness is highly dependent on local climatic conditions and the specific characteristics of each site.

Since 2016, more specific studies have emerged in Chile, mainly focused on green roofs (Reyes et al., 2016). Other studies have examined the application of green roofs on large retail surfaces in Santiago and other climates, concluding that they are more efficient in controlling cooling loads than conventional roof insulation (Vera et al., 2018). Additionally, two models for calculating green roof performance have been validated against experimental measurements, with Santiago included as a reference city (Vera et al., 2019).

For vertical green solutions, modeling studies have explored the capacity of green roofs and living walls to mitigate particulate matter (PM 2.5) in Santiago and other cities worldwide, concluding that implementing green roofs with 50-75% coverage and 25% living walls could reduce particulate matter by over 7% in the city (Viecco et al., 2021). Green roof models have also been adapted to analyze living walls in Santiago, evaluating their thermal performance on retail surfaces and finding that green roofs can reduce cooling demands by up to 15%. In comparison, living walls can achieve up to a 25% reduction, with potential combined reductions of up to 37% (García et al., 2022).

Double-skin green facades have been integrated into Chilean architecture for decades. The Consorcio Building (1990), designed by architects Enrique Browne and Borja Huidobro, is an example of the integration of vegetation into the building, demonstrating its high potential for application in Chile's climate. Similar examples exist with varying degrees of success concerning the growth and adaptation of plant species used to enhance building thermal comfort. Nonetheless, the application of these solutions has often been based on the intuition and intentions of the architects rather than on a deep understanding of their energy potential. In a study involving in situ temperature and relative humidity measurements within the air chamber of this building and three others, the thermal control effects considered attributes of such facades in the literature were fully confirmed. These effects include temperature inversions in the chamber compared to the exterior, with maximums of -8°C during the day and +5°C at night, and relative humidity inversions of +15% during the day and -5% at night, leading to increased temperatures at night (Vásquez et al., 2020).

However, implementing green facades in Santiago has been sporadic and often motivated more by aesthetic considerations than by a deep understanding of their energy potential. Examples like the Consorcio Building (1990) and the MBA Building at the Pontifical Catholic University of Chile (2007), illustrated in Figure 1, stand out for their intuitive design and aesthetic focus but lack prior evaluation to ensure energy efficiency. That underscores a broader issue: not all vertical green facade solutions are equally effective across different climates and urban conditions, highlighting the importance of tailoring these systems to specific environmental conditions.

Fig. 1: Right: The Consorcio Building (1990), Santiago, Chile. Photo by Nico Saieh (2009). Source: ArchDaily, 2009. Available at: https://www.archdaily.cl/cl/02-14392/edificio-consorcio-sede-santiago-enrique-browne-borja-huidobro. Left: MBA Building PUC (2007). Source: Puentes UC, 2019. Available at: https://www.uc.cl/temas/mba-uc/pagina2.

For instance, a study of a direct green facade in a warm, humid climate in China showed significant exterior facade temperature reductions of 20.8°C and interior reductions of 7.7°C. However, an indirect green facade in the same location only recorded modest temperature reductions of 3.1°C (Chen et al., 2013). In contrast, in the dry, high-radiation climate of Santiago, Chile, indirect green facades have shown impressive temperature differentials of -8°C and a +30% relative humidity inside the cavity compared to the outside (Vásquez et al., 2020). This example illustrates how the suitability and effectiveness of different green systems vary according to climate and site-specific conditions. In Chile's dry climates, such as the Central and Northern zones, double-skin green facades are particularly well-suited due to high solar potential and low humidity, which allow the air chamber influenced by the plant's evapotranspiration to function under optimal conditions. Additionally, in colder conditions with low solar radiation, double-skin green facades help to keep the walls warmer, with the air chamber acting as an additional insulator, reducing heat loss and decreasing the need for interior heating (Bakhshoodeh et al., 2022). This dual thermal performance facilitates energy savings in both heating and cooling, making these facades highly adaptable to the seasonal and daily temperature fluctuations typical in areas with high thermal oscillation, such as Chile's Central and Northern zones.

2 Methodology

This study aims to demonstrate digital tools' predictive capabilities in assessing green facades' thermal behavior, establishing their viability as integral components of the architectural design process. The methodology encompasses both empirical data collection from existing buildings and advanced digital simulations, providing a robust framework for analysis.

2.1 Data Collection from Case Studies

The empirical data were sourced from four buildings with green facades in Santiago, Chile. These buildings, examined in the paper Hygrothermal Potential of Applying Green Screen Façades in Warm-dry Summer Mediterranean Climates (Vásquez et al., 2020), offer a varied set of facade orientation, species, and plant maturity. This diversity enables a comprehensive analysis of different green facade configurations.

Temperature and relative humidity were measured outside and inside the cavities behind the green facades during the summer using Voltcraft DL-121TH Data Logger Thermohygrometers. These sensors were positioned at three distinct heights within each facade cavity (0.5m, 1.5m, and 2.5m from the monitoring floor) to capture detailed vertical profiles of thermal and moisture conditions. Data were collected over five days in March 2019, aligning with the peak foliage density in Chile's summer season, when office spaces are in regular use and plant leaves are at their fullest. This period was selected to maximize the representativeness of cooling and shading effects, although further studies could expand to different seasons to explore annual variations. Measurements were taken at one-minute intervals to capture dynamic thermal and humidity shifts, offering granular data to understand facade performance throughout each day.

2.2 Digital Simulation

Parallel to the empirical data collection, digital simulations were conducted using EnergyPlus software with custom routines developed in the Grasshopper platform in Rhinoceros 3D (version 7.3.21039.11201) and interfaced through Climate Studio (version 1.9.8389.21977) for enhanced simulation control. This hygrothermal model integrates conventional heat transfer equations and plant evapotranspiration, predicting how these processes impact the ambient temperature and the facade's evaporative potential.

The model includes the following variables and simulation components:

- **Incident solar radiation**: Estimated using solar geometry, cloud cover conditions, and facade orientation to calculate realistic sunlight exposure on the facades.

- **Foliage density**: The Leaf Area Index (LAI) was used to estimate solar transmittance through foliage, converting the density of the vegetation layer into a quantifiable shading factor.

- **Thermal and optic properties**: The optical characteristics of the green facades were represented using a custom Radiance material adapted to approximate the shading effects of climbing plants, following the consensus within current literature (Larsen et al., 2015). Although this simplification overlooks different plant species' specific thermal and optical properties, it provides a practical baseline.

A three-dimensional model of the building envelope and vegetation layer was also constructed to accurately represent thermal behavior. The Big Leaf Method treated the plant layer as a single, uniform solar screen covering the entire facade (Larsen et al., 2015). This approach, widely recognized in current research, facilitates a streamlined representation of shading effects without the complexity of individual leaf characteristics. The model excludes substrate thermal contributions, as these were considered negligible.

The advanced hygrothermal model calculates the cooling potential of double-skin green facades by incorporating the thermal effects of vegetation as an additional element in the building's thermal balance. This balance includes sensible heat release, latent heat absorption during water phase changes, and a small portion of the energy used in photosynthesis. The model is based on a series of state-of-the-art equations linked to create a computation engine, drawing references from studies by Allen, Pereira, Raes, and Smith (1998), Stec, van Paassen and Maziarz (2005), Susorova, Angulo, Bahrami and Brent (2013), Larsen, Filippín and Lesino (2015), among others.

2.3 Validation and Comparison

The digital models were validated against empirical data collected over the five days, focusing on comparing temperature trends. Temperature and humidity data were averaged across the three vertically placed sensors for each case to create a single representative value for calibration. Finally, results from both the empirical measurements and the digital simulations were compared to evaluate the effectiveness of digital modeling in supporting architectural design. This comparison assessed the capability of digital tools to predict the passive cooling and heating effects observed empirically, with implications for optimizing green facade designs to maximize their thermal regulation potential in varying contexts.

3 Case Studies

The study includes four case studies, each representing a unique building type, orientation, and facade structure characteristics. Case 1 consists of a twelve-story high-rise university building oriented to the North-East. This building's green facade is supported by vertical profiling and horizontal wiring positioned 105 centimeters from the facade surface. The plant species used is *Jasminum grandiflorum* (Spanish jasmine), characterized by low-density foliage that offers minimal shading and protective coverage. The plants are installed in built-in planter boxes at the bottom of each floor, leading to an uneven growth pattern across the facade due to differing maturity levels. Vegetation maintenance is managed by building staff.

Case 2 focuses on a seventeen-story office building with a South-West orientation. Here, the facade is supported by horizontal and vertical profiles that follow the building's curved shape, maintaining a 120-centimeter distance between the building and the support structure. The plant species selected is *Parthenocissus quinquefolia* (Virginia creeper), which has medium-density foliage and more woody branches near the substrate. The plants are installed in built-in planter boxes at the bottom of every three floors, providing a moderate level of shading effectiveness and an average density compared to the other cases.

Case 3 examines a four-story university building oriented to the North. The green facade of this building is supported by vertical elements and horizontal wiring spaced 82 centimeters from the glazing. *Wisteria sinensis* (Chinese wisteria) is used here, known for its high-density foliage. However, the growth varied in height and covered only portions of the facade at the measurement time, as the plants were relatively newly installed. The plants are placed in built-in planter boxes at the bottom of every two floors, resulting in a distribution of non-uniform foliage.

Finally, Case 4 examines a three-story office building oriented to the North-West. This building's facade features a support structure consisting of pillars and expanded metal mesh positioned 70 centimeters from the building enclosure. *Parthenocissus quinquefolia* (Virginia creeper) is again the selected species, now exhibiting very dense foliage that covers the entire building height, reaching a thickness of at least 30 centimeters. Unlike the other cases, the plants are planted directly into the ground, which promotes robust growth and results in the densest vegetation coverage among the four cases.

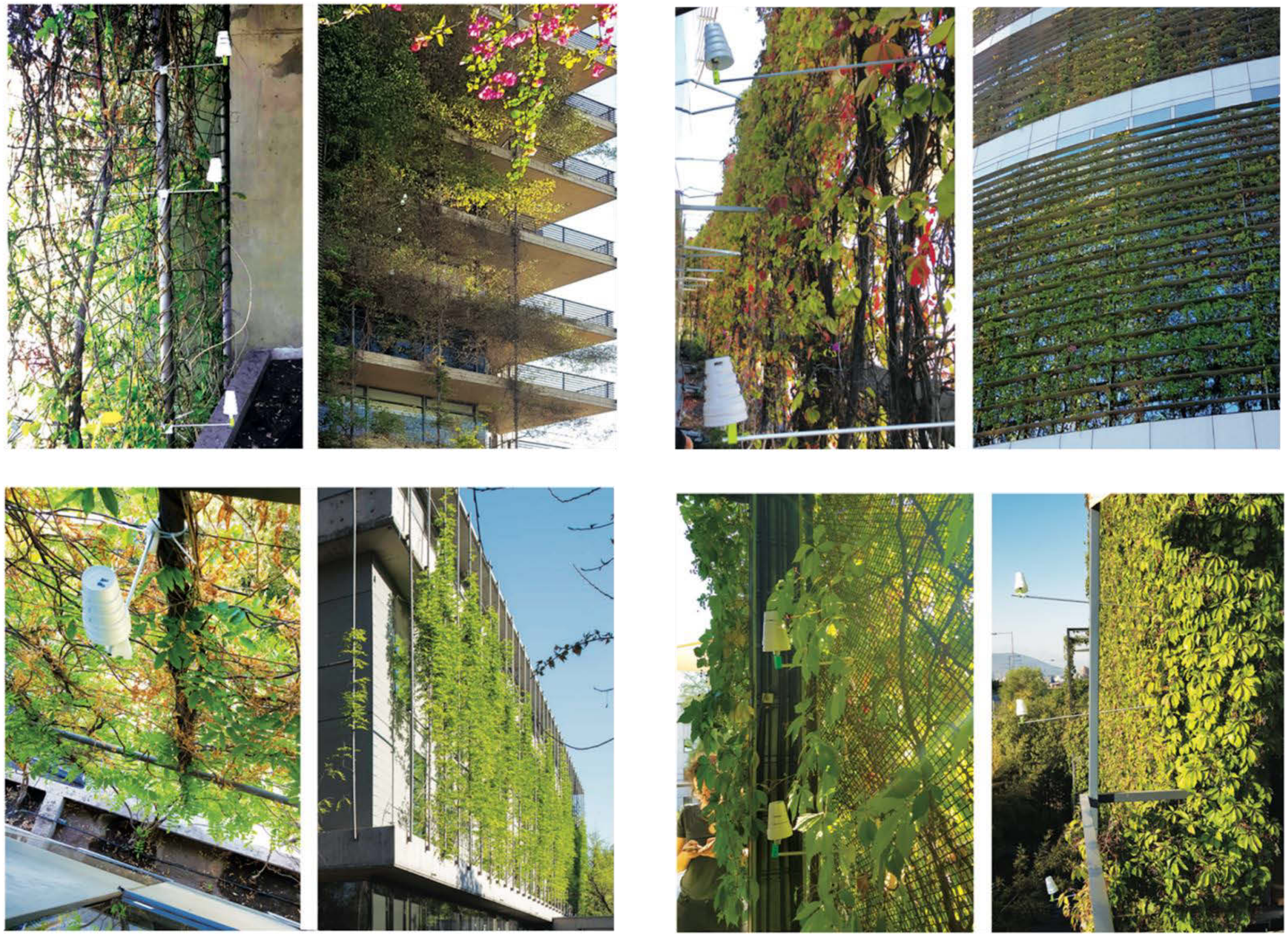

Fig. 2: Top-left: Image of the facade and buffer zone of Case 1; Top-right: Image of the facade and buffer zone of Case 2; Bottom-left: Image of the facade and buffer zone of Case 3; Bottom-right: Image of the facade and buffer zone of Case 4. Source: Vásquez et al. (2020).

4 Results

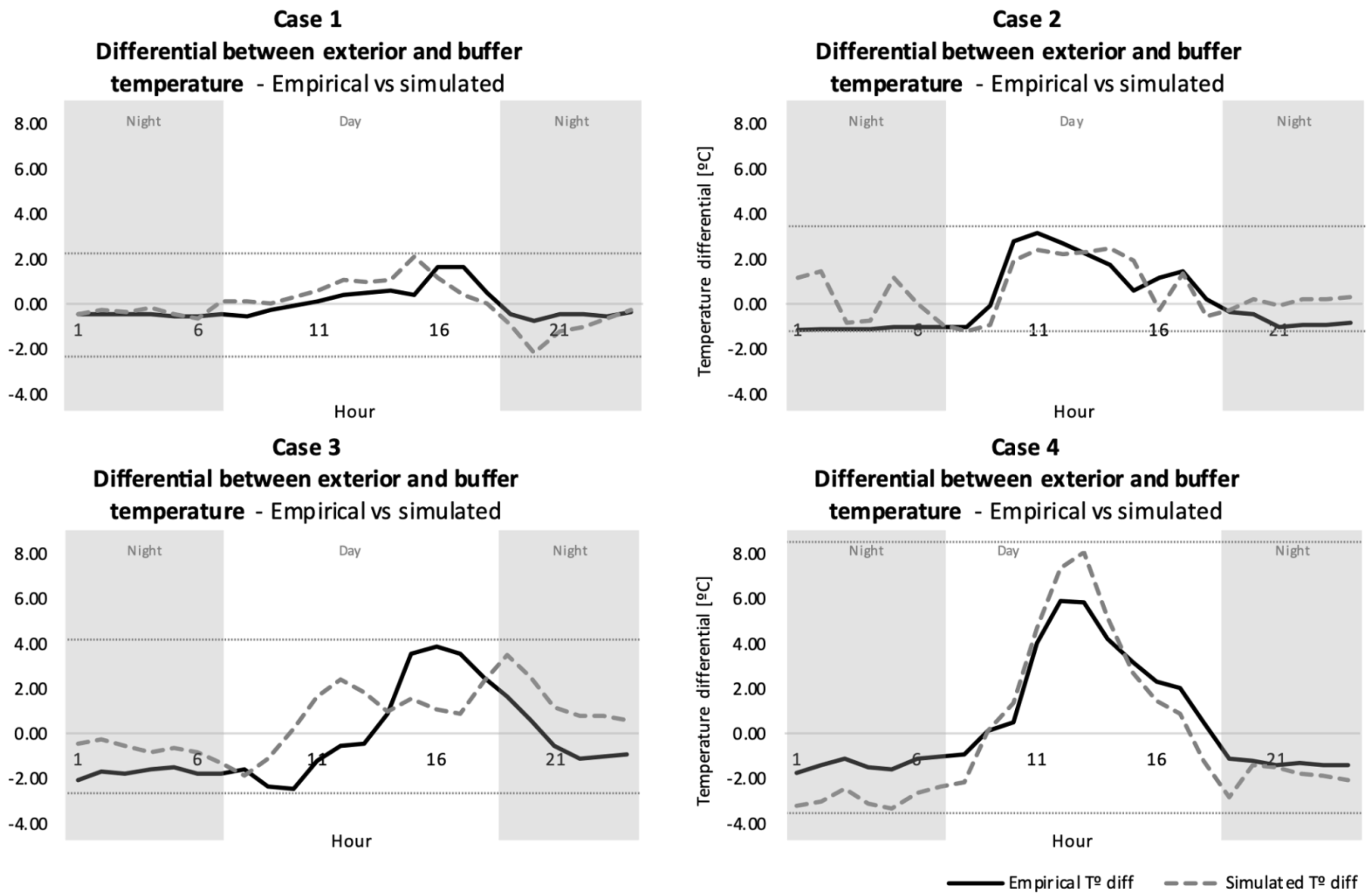

Fig. 3: This graph displays the temperature differentials between the exterior and buffer zones throughout the day, segmented by hour, for each case study. It highlights the variations between night and day, comparing empirical measurements with simulations. Source: Authors, 2024.

Across all cases, the empirical data generally showed a pronounced cooling effect during the day due to evapotranspiration and a slight warming effect at night due to the plants' insulation properties (Fig 6). However, the magnitude of these effects varied considerably, influenced by the density and coverage of the foliage. While effective in capturing the general trends, the simulations often diverged in the specifics, particularly in cases with medium or irregular foliage density.

The discrepancies between simulated and empirical data highlight the need for adjustments in digital models, particularly regarding how plant characteristics are represented and how they interact with climatic variables. One part of these discrepancies can be attributed to the challenge of accurately representing the dynamic variability of vegetal material in simulations. Typically, these models simplify vegetal components into homogeneous and static conditions, which may not fully capture the nuanced behaviors of living plants as they respond to environmental changes. Improvements in these areas could enhance the predictive accuracy of simulations, making them more reliable tools in the architectural design process.

5 Discussion

5.1 Comparative Analysis of Simulation Accuracy and Performance

To assess the effectiveness of green facades through the lens of simulation accuracy compared to empirical measurements, a comprehensive regression analysis was conducted across four distinct case studies. The analysis, centered on the coefficient of determination, R^2, quantifies how well variations in empirical temperature measurements are accounted for by simulation models.

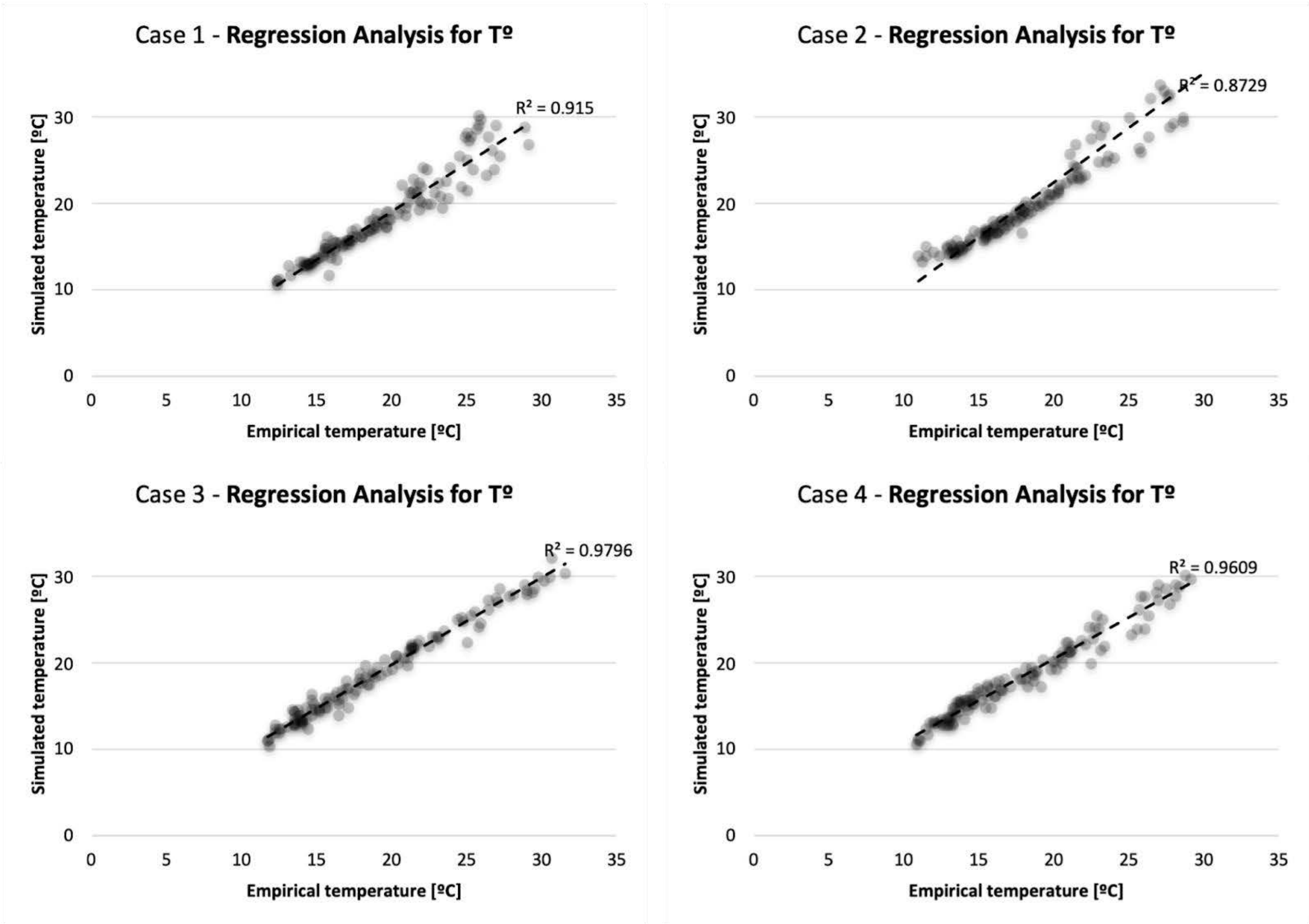

Fig. 4: This graph illustrates the values for each of the four case studies, indicating the accuracy of simulation models in predicting empirical temperature data. Source: Authors, 2024.

As shown in Figure 4, the R2 values reported in the study indicate generally strong model performance across all cases. Case 1 showed an R2 of 0.92, indicating that the simulations were highly predictive of the empirical data, capturing the thermal dynamics effectively. Case 2, with an R2 of 0.87, though slightly lower, still reflects a good level of accuracy, suggesting that even in less ideal conditions, the model performs robustly. Case 3 exhibited the highest predictive accuracy with an R2 of 0.98, demonstrating near-perfect alignment between the simulated and actual measurements. This level of precision suggests that with finely tuned model parameters, simulations can accurately reflect real-world outcomes under varying environmental conditions. Similarly, Case 4, with an R2 of 0.96, showed substantial model accuracy, confirming the simulations' reliability in scenarios with dense vegetation coverage.

These results' consistently high values across different cases underline the effectiveness of these models in reproducing the temperature dynamics influenced by green facades. Thus, they support the idea that simulation models, when appropriate, provide an effective tool for predicting the impact of green facades.

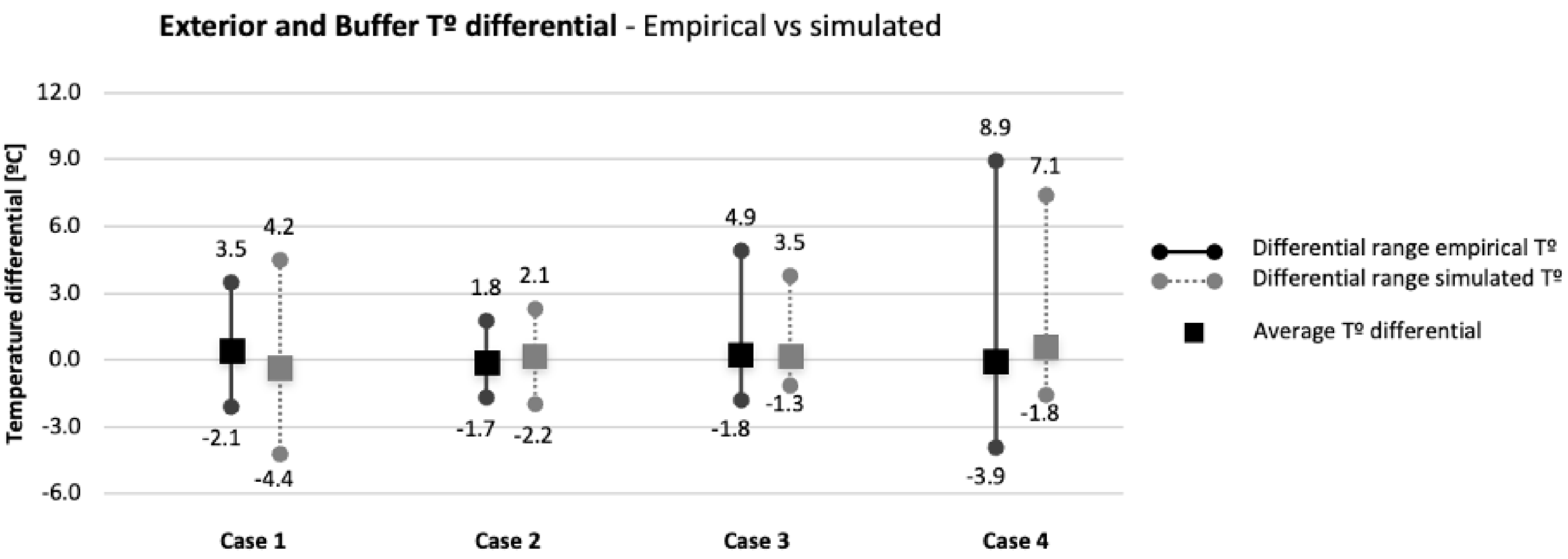

Fig. 5: This graph displays the minimum, maximum, and average temperature differentials for each case study, contrasting empirical measurements with simulation predictions. Source: Authors, 2024.

While simulation models generally predict temperature trends accurately, there are notable variations in the precision with which they capture the extremes of temperature fluctuations. For instance, in Case 1, the simulation displayed a broader temperature differential range and a lower average than the empirical measurements, indicating a model tendency to overestimate the extreme effects of temperature moderation. These results contrast with Case 2, where the simulated values closely reflected the empirical data, suggesting that the model is quite effective in predicting the actual behavior of the green facade under those specific conditions. For Cases 3 and 4, the simulations underestimated both the minimum and maximum differentials compared to the empirical data, pointing to performance gaps in the model, particularly in its ability to capture the maximum cooling potential observed empirically. This discrepancy is especially evident in Case 4, where the simulation did not fully capture the empirical minimum differential but came close to the maximum, suggesting some limitations in accurately predicting the coldest buffer conditions.

These differences between the simulated and empirical data are clearly illustrated in Figure 5 in the temperature differential graph, which shows each case's minimum, maximum, and average values. The variability in simulation accuracy underscores the complexity of modeling interactions within green facades, which are influenced by factors such as vegetation density, moisture content, and local climatic conditions. These findings suggest a need for iterative refinement of simulation models, incorporating a deeper understanding of plant physiological properties and their interaction with the built environment.

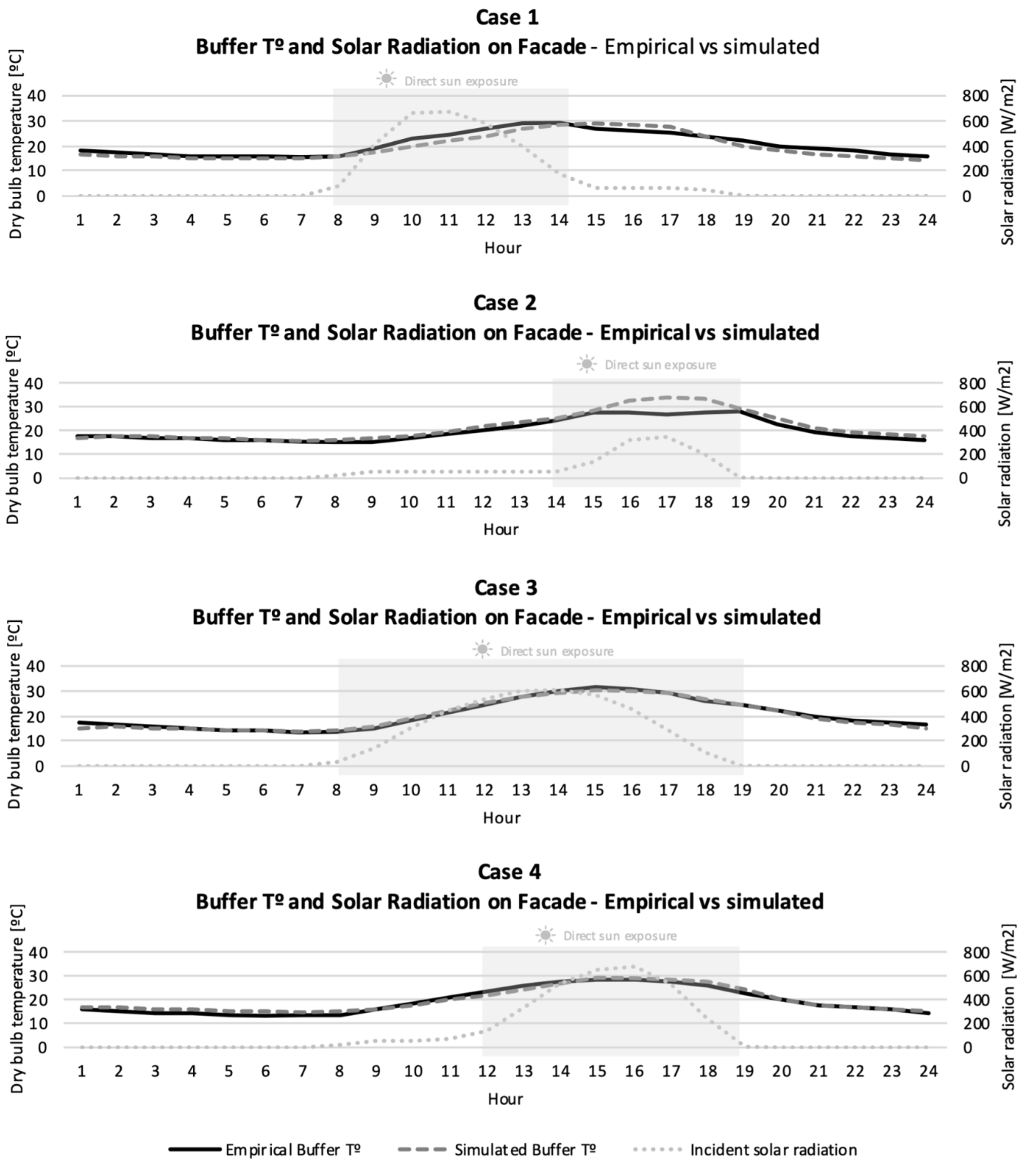

Fig. 6: This graph presents hourly buffer temperature and solar radiation data for four distinct cases, each with different facade orientations. It specifically highlights the hours of direct solar radiation on the facade, comparing empirical measurements with simulation. Source: Authors, 2024.

5.2 Sensitivity to Environmental Variables

Notably, cases with dense foliage, such as Case 2 and Case 4, showed a more significant cooling effect and enhanced humidity control. That suggests that denser vegetation can create more substantial microclimatic alterations, which contribute to lowering temperatures and moderating humidity levels around the facades. In contrast, Case 1, which featured sparser vegetation, displayed less pronounced thermal and humidity effects. This case indicates that while green facades with sparse foliage can contribute to environmental control, their impact is considerably more limited than those with denser coverage.

This variation in performance across the case studies highlights the critical role of plant selection and design in the effectiveness of green facades. It suggests that to optimize the benefits of green infrastructure, particularly in climatic and urban conditions like those in the Global South, careful consideration of vegetation type and configuration is essential. For instance, selecting plant species with higher foliage density may be particularly advantageous in environments with desired more potent cooling effects.

Moreover, the findings underscore the need for tailored architectural solutions that consider local environmental factors. By integrating specific plant characteristics that align with the climatic conditions and architectural requirements of a building, designers can enhance the sustainability and energy efficiency of their projects. This approach not only improves the microclimate around buildings but also contributes to broader sustainability goals by reducing the need for mechanical cooling and enhancing the overall energy efficiency of the urban fabric.

Figure 6 presents buffer temperature and solar radiation data for four distinct cases with different facade orientations. The sensitivity analysis revealed that all green facades responded dynamically to environmental changes, particularly solar radiation and temperature. However, the extent of this responsiveness varied by the type of vegetation and its configuration. For instance, the dense foliage in Cases 2 and 4 provided more significant cooling and humidity control, while the sparser coverage in Case 1 resulted in less pronounced effects. This variation underscores the importance of plant selection and facade design in optimizing green infrastructure for specific climatic and urban conditions. It also highlights the need for tailored architectural solutions that consider local environmental factors to maximize the sustainability and energy efficiency of buildings in the Global South.

6 Conclusions

The exploration and incorporation of green facades within urban settings, particularly in the Global South, presents a transformative opportunity to address urban heat islands and enhance energy efficiency in building designs. This study has demonstrated the potential and variability of green facades in modifying microclimates through the dynamic interaction with environmental factors such as solar radiation and temperature. Key findings from this research underscore the significant impact that plant selection and facade orientation have on the performance of green facades. Dense vegetation in some case studies provided substantial cooling effects and humidity control, proving more effective in moderating internal and external microclimates than sparser vegetation configurations. It highlights the critical role of tailored design approaches considering specific local environmental conditions and architectural needs.

Addressing the Global South's unique challenges demands innovative simulation and design approaches. Digital simulation tools have shown considerable promise in accurately predicting the performance of green facades, as demonstrated across multiple case studies. These tools allow for precise adjustments in design parameters, facilitating the optimization of green facades to achieve maximum environmental benefits and energy savings. By incorporating these tools, architects, and students can better understand the dynamic interactions between architectural elements and environmental conditions, fostering a more analytical and responsive approach to design.

Nevertheless, the discrepancies observed between simulated results and empirical data highlight the need for continued refinement of these tools to accurately capture the complex interplay between the built environment and natural elements. These differences also reveal the limitations of the current variables used in the study, including the brief data collection period, specific species characteristics like foliage density and leaf decay cycles, and variations in planting conditions. Future improvements should advance simulation algorithms and incorporate a broader range of variables. Expanding data collection to different seasons could provide insights into annual variations in vegetation behavior and facade performance, ultimately enhancing model accuracy.

In conclusion, continued research and the application of refined simulation models are essential to advancing our understanding and implementation of these systems and ensuring they meet the specific demands of diverse urban landscapes. This study contributes to the growing body of knowledge on green facades and sets a foundation for future research to bridge the gap between theoretical design and practical performance.

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