FavLab Maré Edition

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This paper introduces and discusses the first outcome of a recently created digital fabrication laboratory at Favela da Maré, a slum in the North zone of Rio de Janeiro, Brazil. The lab called FavLab is a partnership between the João e Maria Aleixo Institute, located inside Favela da Maré, and the Department of Architecture and Urbanism of PUC-Rio University. More specifically, it aims to present the lab's first activity: a workshop devoted to create and fabricate meaningful objects to the context of favela exploiting digital design and fabrication methods. Architecture undergraduates and local young residents not enrolled in the educational system participated in the studio. This paper aims to discuss in details the experience of teaching for this particular group of students, as well as the impacts of the collaborative design between university and favela students to create interactive objects in a Brazilian community. The paper aims to reinforce and remark an innovative and inclusive approach to digital design and fabrication. This paper also attempts to discuss further developments and next steps towards more profound and broader collaboration between academia and favelas' representatives.

Keywords: *Fab Labs, Favela, Interactive installation, Parametric design, Digital fabrication*

INTRODUCTION

"Architects tend to be slow on embracing new Technologies," says Mario Carpo (2017). The First Industrial Revolution (1750-1830) focused on coal, steam engines, railroads, and textiles (Gordon, 2017) had no significant impact on architecture (Carpo, 2017). It also took some time for architects to embrace new industrialized materials and technological processes (Carpo, 2017) made possible by the Second Industrial Revolution (1870-1900) carried off upon electricity, internal combustion engines, modern communications, entertainment, mass production, petroleum/hydrocarbons and chemicals (Gordon, 2017). Contrary to this historical tendency, architects were the first in the creative industry to understand the changing power of emerging digital technology of the Third Industrial Revolution (Carpo, 2017), initiated in the 1960s and revolved around computing and telecommunications (Gordon, 2017). Architects were the first to realize that digital design and technology meant to produce variations, not identical copies; customized, not standardized products (Carpo, 2017). Since then, it has been changing the way we think and produce architecture (Menges, 2015).

Fast forwards to the 2010s, the most ad-

vanced "digitally intelligent architects" (Carpo, 2017), claimed that the world has entered into a new industrial status: The Fourth Industrial Revolution. This contemporary industrial condition, which was also the central theme of The World Economic Forum 2016, is defined by the German economist and inventor of the "exclusive Davos Club", Professor Klaus Schwab (2017), as "the inexorable shift from simple digitization (the Third Industrial Revolution) to innovation based on combinations of technologies (the Fourth Industrial Revolution) ". In Schwab's vision, the key technologies driving this revolution are actually "a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres." The increasing complexity of the core machines of each revolution was nicely illustrated in the famous Achim Menges's paper "The New Cyberphysical Making in Architecture" (Menges, 2015), where the author claims an "upcoming paradigm shift in production (...) referred to as Industry 4.0", characterized by a much higher level of integration and cross-linking between the physical and digital domains. New manufacturing machines and robots have started to gain communication, monitoring, and sensing capacities, and with this, the ability to react and, ultimately, to act, opening the door for the next leap forward in production technology.

According to the economist Jeremy Rifkin (2014), an industrial revolution is foremost an infrastructural revolution that depends on a tripod of communication, energy, and transport/logistics. Schwab's main argument in favor of a new industrial revolution instead of an extension of the previous one relays on qualitative aspects of "velocity, scope, and system impacts" (Schwab, 2017). Rifkin (2014), differently argues that it is the decreasing fixed costs of digital technology, its "near zero marginal cost," and the intrinsic interconnected nature of the technology itself that has enabled a qualitative jump in scope, velocity, and systems impact for the past twenty-five years. Rifkin's vision offers a more inclusive prospect and a much broader horizon of possibilities, especially for architects working in developing countries.

In this paper, we aim to discuss a shifted, broader view on what does constitute an industrial revolution, based on Rifkin's concepts, more focused on what technology does rather than in its effects. In other words, instead of focusing on the technology itself, we aim to focus on its social implications. Digitally intelligent architects have been designing and accumulating expertise in adapting existing tools and developing their own for the past thirty years. Albeit the maker revolution coupled with the near-zero marginal production cost, both established upon digital processes, represent new opportunities, it may cut both ways: it may greatly expand the distance between the most advanced research centers and developing countries, or it may genuinely approximate both worlds, since technical knowledge and tools are more accessible than ever. Thus, it may also help growing architects' ability to act within the community and to generate significant social impact. Ultimately, digital manufacturing in architecture can be a very efficient way to democratize architectural design where it is needed the most truly. Like Cedric Price, we do believe that technology is the answer, but we have different questions, and in this work, we intend to address some of them.

OPAQUE TERRITORIES

The core definition and production of technology, as well as the technological agenda, is customarily ranked by the North developed countries. Developing countries are supposed to follow their lead and import their technology (Santos, 2002). Indeed, current techniques are universal. However, they are introduced in different modes and intensities, according to their features and the location in which they are installed. The absence of representatives from developing countries in the broader discussion panorama about any global technological commitments and concerns is remarkable. In a counterpoint, the concept of "peripheral technology", introduced by the Brazilian geographer Milton Santos (2002), a Vautrin Lud Prize winner, help us to set a distinct and inclusionary theoretical background, as well as to dis-

cuss the meaning and to add value to a bottom-up participative approach on parametric design and digital fabrication considering local and social requirements.

Santos (2002) defines as "luminous territories," those rationalized areas that accumulate technical and informational densities, and therefore, are more attractive to finance capital, technology, and organization. "Opaque territories," on the contrary, lack access to them. Santos (2002) explains that there is a limited production of rationality, that is, luminous spaces, associated with a widespread production of scarcity - opaque territories - that leads the actors outside the circle of hegemonic rationality to a self-consciousness of their exclusion which in turn, leads to the search for alternative forms of rationality, indispensable for their survival. Inorganic spaces such as opaque territories are unclosed systems that cannot be wholly subordinated to the dominant rationalities since they do not have the means to access contemporary production techniques. This experience of scarcity is the basis of a creative adaptation to the current reality. In this sense, opaque territories are the spaces of approximation, creativity, and bottom-up specialization. Opposite to luminous zones, reigned by top-down specialization of exactness, ruthless standards, and search for precision in production processes. It does not mean that developing countries are purely opaque, but rather that the development condition in architecture is uneven compared to developed countries considerations on technological innovation. Therefore, both the very notion of technology is not necessarily the same, and neither the intersections between technology and architectural design should have the same aspirations. Different problems and distinct realities should lead to diverse responses and specific appropriations of technology.

The recognition of the expertise and the technology developed locally, solidly anchored in the contextual reality of the architects working in developed countries, are fundamental factors to pave the next steps. Indeed, the technology historicist Melvin Kranzberg (1986) remarkably stated that technology is never neutral. On the contrary, in his words: *"technology's interaction with social ecology is such that technical developments frequently have environmental, social and human consequences that go far beyond the immediate purpose of the technical devices and practices themselves, and the same technology can quite have different results when introduces into different contexts or under different circumstances."*

Aligned with the logic of non-neutrality, Kranzberg goes further and explains that "nontechnical factors take precedence in technology-policy decisions." No decision is purely technical, especially when human elements are involved. The impacts of technological decisions in social terms is in particularly imperative in complex sociocultural environments such as favelas. Since technology is understood as a non-neuter artifact, technology-based entrepreneurship may acquire a social function and play a crucial role in promoting a profound transformation in knowledge dissemination and technical production. Tuned in to Melvin Krazberg's third law (1986), suitable technological solutions for one context may be inadequate for another. Thus, research on which specific questions that digital manufacturing can help us addressing to is vital.

In this sense, importing technological models from developed countries to the reality of developing countries always requires tremendous adaptation efforts, due to their asymmetric levels of socioeconomic, scientific and technical development. Emerging countries, such as Brazil, are continually struggling against their significant limitations in their development standards (Feldman, 2009). Besides, decades of low investments in high-level technology research have considerable damage to industrial processes updating as a whole, architecture included (Feldman, 2009). This scenario dramatically reduces developing countries capacity in fostering high technological content production, in generating quality employment, and in promoting social well-being (Feldman, 2009).

The technological entrepreneurship emerges as

a strategy for a gradual improvement of the internal capacity to manufacture products with technological content, and as a means to propagate knowledge generation through the production chain (Vieirra et al., 2017). Small local initiatives are much more accessible, affordable, and may address problems faced on the local level that high-end technological solutions may not (Gershenfeld et al., 2017). Plus, the high productivity of digital processes associated with extraordinary adaptability, upgrade capacities and the near-zero marginal production cost (Rifkin, 2014) together set a favorable stage to flourish a new status for architects working in developing countries, at least in theory.

However, the capacity to transform new knowledge into economic opportunities involves a set of abilities, skills, perceptions, and circumstances that are far from being uniformly and widely distributed in society (Audretsch, 2006). In this scenario, the Fab Lab network has demonstrated to be an important strategy to leverage economic objectives and to produce wealth in developing countries (Vieira et al., 2017). With the maxim "Learn, Make, Share," these spaces aim to empower its members' ability to build local, sustainable community-based solutions by using open source tools and digital fabrication technology. Besides the promotion of innovation, Fab Labs also allow the creation of low-cost products very quickly and test their acceptance by the community, leveraging improvements that will make these solutions evolve collaboratively (Gershenfeld, 2017). So, deep social bonds are a crucial aspect. Since Fab Lab is an imported model, this active social link prevents alien solutions. Instead of merely introducing technology - that is, consuming technology - these labs support the creation of technology locally (Eychenne et al., 2013).

In socially complex environments such as favelas, collaborative spaces like Fab Labs can play an influential role in providing knowledge tuned in to worldwide technological updates and access to productive means. It can breed new solutions to start reestablishing the balance between luminous and opaque territories in developing countries' communities. Fab Labs are the educational component of digital manufacturing awareness that favors the democratization of technological concepts and techniques. Fab Labs in favelas can also function as incubators of local innovation enterprises, and as decisive alternatives for those who abandoned formal education.

The well-succeeded experience of Free Fab Labs in São Paulo, Brazil, provides valuable contributions. The results of recent research on the labs' contributions to the surrounding communities point them towards a viable alternative to unemployment (Vieira et al., 2017). Foremost, the labs were indicated as a potential opportunity for a whole new generation of technology entrepreneurs fully ready for adopting the principles of sharing economy (Vieira et al., 2017). While financial scalability and sustainability remain a significant obstacle for entrepreneurship in developing countries, Fab Labs can open big windows towards digital inclusion, once they are supposed to build bridges between professionals and non-experts, high-tech fabrication and local analog technology, academics and artisans. Fab Labs in favelas can be a turning point for community members; for architects, they can be essential mechanisms for professionals interested in proposing solutions to these territories. The crucial difference is that the labs also allow the fabrication of these solutions, fostering the architect's immediate action.

FAVLAB

The adoption of digital processes in architectural design and fabrication in developing countries has been slow (Sperling, 2015). In poor areas, access to such technologies is even slower and very limited. Slums are the most opaque of the territories, where design and technology are considered unnecessary luxury compared to unfulfilled basic needs imposed on these populations. According to the United Nations (2016), favelas represent around one-third of the developing countries' territory, and they accommodate around one billion dwellers around the globe. Favelas are often recognized for what they

lack: infrastructure, urbanization, architectural quality. However, it is the same restricted access to technical means that nourishes what Brazilians call 'technology of scarcity,' where creativity and technological innovation, such celebrated concepts in contemporary digital architecture, are the means of survival fueled by the lack of resources. In other words, this "fundamental lack produces a creative discomfort" (Santos, 2002). Favela's dwellers are hackers and makers by necessity. Krazberg (1986) states that "invention is the mother of necessity." We dare to invert the sentence and say that when it comes to favelas, necessity is the mother of invention.

Architects usually understand favelas as a design problem or as an object of morphological analysis. Annually, dozens of researches carried out in slums exhibit amazing designs solutions. Most of them have low impacts on local architectural production or labor, with no significant technological knowledge transference to the dwellers or any absorption of local technologies or aesthetics. We aim to offer a different approach, in which digital design and manufacturing can play a crucial role in transforming this kind of territory. The core concept is adaptation, whether in site-specific and parametric variation design approaches or in adapting possibilities of digital design and fabrication to local conditions. The fusion of suitable technologies with access to productive digital processes opens up a myriad of possibilities regarding participatory design. It also implies new meanings to digital design in social terms.

The idea of favelas' digital fabrication laboratories - FavLab - has emerged as a way to connect the academic digital processes with the technological inventiveness of favelas. The therm FavLab is directly related to the global network of digital fabrication laboratory initiated in the MIT Media Lab, headed by Neil Gershenfeld. The FavLab was initially idealized in 2012 and presented to Fab Foundation Director, Sherry Lassiter in 2015. It finally got a kick off in 2019 at Favela da Maré, Rio de Janeiro, as the result of the collaboration between a local institution called 'Instituto Maria e João Aleixo' (IMJA) and the Department of Architecture and Urbanism at PUC-Rio.

FavLab Workshop Maré Edition

The first initiative of this recently created laboratory was a workshop between architecture undergraduates and local young residents not enrolled in the educational system, working together to design and construct meaningful objects for the favela's public space. The final location of construction could not be previously settled because it depended on negotiations between local leaders and other actors (drug lords, militia). So, parametric design played an essential role in fitting the proposals to any context. The group of 30 students - 12 from IMJS e 18 from PUC - two teachers from the university and one teacher from the community was very interdisciplinary with quite varied backgrounds.

The two-week course ran from January 28th to February 8th. It was partially held at the university and IMJA located inside the slum. Classes and digital fabrication were carried out at the university's laboratories. In the first week, students had lessons, visited the site, and developed the design ideas. A professor specialized in urban anthropology was invited for a lecture to help to set the theoretical background. In the second week, students were devoted to designing adjustments for fabrication and assembly. The workshop was divided into three phases as described in the sections bellow.

1. Modeling training and digital fabrication tooling. All students indistinctively attended to Rhinoceros, Grasshopper, Arduino and digital fabrication classes. Most students from both institutions were not experienced in any of these topics. Parametric design classes were prepared considering popular cheap materials such as bricks and pipes that could also resist exposure to weather and vandalism. Six parametric design exercises from introduction to intermediate included attractor rotation, list manipulation, cellular automata principles, pseudo-physics simulations with Kangaroo, weather-responsive behavior with Ladybug, and introduction to interaction design with Firefly and Arduino.

Digital fabrication classes included milling routines in router CNC, 3D printing, and laser cutting. Although many Maré students did not have any formal academic training, in most cases, their electronics and programming skills were superior compared to scholar participants. Therefore, the shared expertise in both directions was crucial for the whole experience achievement. One revealing observation was that learning 3D modeling or even parametric design principles were not the main barriers for favela's students, but language was since Rhino and Grasshopper installations were in English.

2. Design conception. Students were divided into four workgroups to create four different design proposals. The groups had equal proportions of students from PUC and Maré. Interactive behavior, parametric adaptation, materials, and digital fabrication process had to be considered. The proposals, illustrated in the pictures below, were presented in the favela and were submitted to the scrutiny of the local leaders. The ideas were evaluated regarding their relevance to the population, feasibility, and budget, and some adaptations were required.

Maré students were important beacons for the projects, and some compelling observations came to attention during this process. It became evident that parametric iconography, or parametricism as an aesthetic style, as Schumacher (2011) claims, was not particularly appealing for those students. Both favela's participants and architecture students were slightly more interested in parametric design as an essential platform to develop ruled-based designs, which allows quick site-specific adaptations than in its potentials of fostering formal expression. Even though aesthetics played a significant whole, the pursuit of meaningful and rational designs outshined any search for amusing meaningless forms.

Customization and hands-on approach are not fully disseminated in Brazilian architecture schools. However, it became clear that these concepts per se were not unfamiliar at all to Maré students and not especially attractive because they regard it as common ground. On the other hand, they considered prospects of digital fabrication stimulating. The main spotlight, though, was interactive design. Although it was not a workshop's premise, most understood that their projects would be more compelling to the public if they could behave in a specific manner. As a result, three proposals were performative-oriented designs, and one project focused on generative adaptative design based on cellular automata.

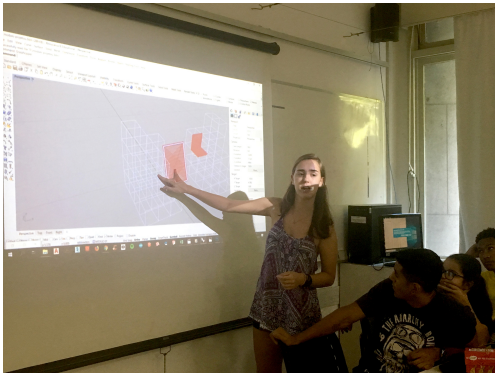

Figure 1
Student explaining the cellular automata logic applied to create an extension to the children's library.

Figure 2
The group discussing ideas.

Figure 3
Students setting interaction programming.

Figure 4
The group testing the effect of the light inside the pipes.

Figure 5
Students inside the children's library, setting the pipes for construction.

Local students chose a square next to the public library to hold the interventions. Due to time restrictions and budget limited to the equivalent of 200 Euros, the group had to decide collectively for only one proposal. The chosen one was an interactive light sculpture for children activated by the voice, to be installed next to the children's library. It consisted of a series of interlaced pipes where children could tell secrets to one another. The children's voice power activated led stripes placed inside the pipes. The louder the children, the brighter the lights. The concept behind this ludic toy was to give voice to the residents of the community, especially the children. The statement behind the funny game was making it evident that all voices are powerful, that all voices can and should be heard. Students had to combine a mix of digital and analog manufacturing processes to gather the installation. They also set up sensors, programming behavior and electronic circuits.

3. Construction. The groups were merged to assemble the interactive installation on site. The pipes were perforated to let the lights come out. A perforation routine and a CNC milling machine were used for the task. The pattern of holes was designed parametrically in Grasshopper. All the pipes received an internal acetate plastic lining to prevent sound escaping. It also acted as a light diffuser, so the led balls were not too visible. The group got the acetate by removing the black material (photo-emulsion) from x-rays leftovers with bleach.

Due to climate conditions, the assembly ran on February 20th - 21st, almost two weeks after the workshop's conclusion, with the full participation of resident children. A group of graffiti artists from Maré painted the installation wall with relevant local characters. The children's initiative in taking part in the assembly was fascinating to watch. They decided the colors of the pipes, how they should be painted and, finally, they decided to decorate the tubes themselves. The sound capture sensors and all the electrical connections were positioned inside the 3D printed speakers.

Figure 6
Led Stripes, sensors and electrical connections being set.

Figure 7
The connection between sensors and Arduino being set.

Figure 8
Children volunteering to test the interaction.

Figure 9
Children testing their new toy.

The toy was a great success. Children were amused, playing around to discover which pipes were connected and testing the volume of their voices. It is also worth mentioning that the hostile environment did not prevent the team from proposing and setting up this toy for children at a public space inside a favela. However, it would not be possible without the decisive mediation between the institutional partners from Maré and local forces, such as drug lords, residents' association, and local volunteers.

After the workshop, students answered a survey about the course. The inquiry addressed three questions on students' capacity in following classes, if they considered results relevant for the favela and if they feel that the proposition of holding a digital fabrication in a slum - the FavLab - should progress. The form also included a section for free comments. Despite the differences in educational level between participants, the students' majority declared no struggles in following the lessons. PUC's students were instructed to listen carefully to dwellers and Maré's workshop participants to beacon the projects. The strategy succeeded, since all students related to the proposals and felt a connection between design, site, and users. Finally, all students recognized the FavLab as an essential acquisition for the favela and self-declared the intention to continue in the project. In the free comments section, four testimony from a favela's participants were particularly gripping. In different manners, those students declared that the prospect of attending to a course or using a digital fabrication laboratory at the university was beyond their possibilities, especially a nonpublic one as PUC-Rio. Statements like this reaffirm the importance of the FavLab and rekindle hope in a better future.

FINAL REMARKS AND FURTHER DEVELOPMENTS

In this paper, we aimed to present and detail the background of an innovative workshop, whose basic premise was to gather students of approximately the same age, but with very distinct social origins and educational levels. The strategy was successful. Despite the limitations, all the students were able to follow classes, and the local population recognized the results relevant. Therefore, the objects proposed and constructed by this particular group of students constitute a remarkable statement. The experiment also

opens up promising prospects for the future developments of the FavLab. It also reinforces the thesis that Fab Labs can extrapolate its original function and acquire a more in-depth social service. The core assumption of social engagement promoted by the Fab Lab network may be a valuable alternative for entrepreneurship in favelas and an efficiency gain instrument for architects interested in working in these territories.

We also aimed to demonstrate that to grasp the reality of digital design and fabrication in developing countries, the adoption of a localist approach it is not enough since these technologies are universal. On the other hand, Santos (2002) advises us to avoid the "risk of losing ourselves in blind simplification" by taking into account the particularities and specificities of those territories instead of merely considering digital design and fabrication as a general phenomenon dominated by global social forces. The installation described in this paper highlights that favelas' dwellers are unconventional recipients of digital design and fabrication efforts. Including this population in the discussion open up a new, unprecedented debate with the consolidated digital communities: listening and learning from favelas, how they reevaluate the technosphere and find new uses and purposes for objects and techniques. This search for alternative paths initiated with the FavLab is an enlightened vision of the desired future that differs from present subordination of instrumental logic. It is one step closer to the democratization of a reinforced individuality established upon the digital, which goes beyond the barrier of repetitive praxis and sets in a liberating praxis, "the inventive praxis" of which Lefebvre (1958 *in* Santos, 2002) speaks.

By the time of this paper is released, the FavLab Maré implementation inside the favela will be still in process. Until then, former workshop students and volunteers agreed to continue developing their proposals for construction. The pipes toy evolved to a more significant project called *Vozes da Maré* (Maré's Voices), expansible to other slums with the title *Vozes da Comunidade* (Community's Voices). The idea is to expand the toy's function to a more politicized instrument of social action. The central goal is to build a platform of free speech and expression for the people coming from these communities, often ignored. The structure consists of a tubular system similar to the toy, equipped with sensors that capture and record sounds. Lights will be activated by a presence sensor to indicate the recording start and end. A voice recognition system transcribes speeches into text. The people's petitions, aspirations, and wishes in the textual form will be projected live in windowless façades throughout the city. Thus, they become visible to the rest of the town, extrapolating the isolation and segregation in which many favelas' dwellers live.

Of course, this renewed version of once a playful toy proposed by students depends on a series of design improvements, robust programming, research on Big Data, materials investigation, and capital investment. Tuned in to the spirit of local entrepreneurship, digital inclusion, and technology transfer as the FavLab's essential goals, the development demands the full participation of Maré's digital programmers. This project's updates and other FavLab's initiatives, including city sensing, smart 'favelas' and virtual reality for social engagement are available on website www.observatoriodefavelas.org.br.

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