

KEYWORDS | COMPUTATIONAL DESIGN · DIGITAL
FABRICATION · TEACHING AND RESEARCH LABORATORY

PALABRAS CLAVE | DISEÑO COMPUTACIONAL ·
FABRICACIÓN DIGITAL · LABORATORIO DE ENSEÑANZA E
INVESTIGACIÓN

Teorías y tecnologías en la
arquitectura contemporánea: el
Laboratorio de Automatización
y Prototipos de Arquitectura y
Construcción de la Universidad
Estatal de Campinas, Brasil

| ABSTRACT |

This article summarizes the work developed at LAPAC for the past seven years. The laboratory was created to start a new line of research in computational design at the School of Civil Engineering, Architecture and Urban Design at the State University of Campinas, Brazil.

| RESUMEN |

En este artículo se resume el trabajo desarrollado en LAPAC durante los últimos siete años. El laboratorio fue creado para iniciar una nueva línea de investigación en el diseño computacional de la Facultad de Ingeniería Civil, Arquitectura y Diseño Urbano en la Universidad Estatal de Campinas, Brasil.

GABRIELA CELANI*

Theories and technologies in contemporary architecture

The Laboratory of Automation and Prototyping
for Architecture and Construction at the State University
of Campinas, Brazil

INTRODUCTION

In 2002 I finished my Ph.D. in Design and Computation at MIT, under the advice of Professors William Mitchell and Terry Knight. My thesis was about the use of computational design concepts to enhance design creativity, implemented through CAAD programming techniques. At MIT I had the opportunity to use one of the first digital fabrication laboratories in an Architecture School. When I came back to Brazil I accepted the challenge to create the first digital fabrication laboratory for architecture in the country, at the Department of Architecture and Construction at the State University of Campinas Unicamp). But buying a bunch of machines would not have been enough for establishing the field of Computational Design at our University. This article summarizes what we have been doing at LAPAC for the last seven years.

In 2006 we established a research group called **Contemporary Theories and Technologies applied to Design**. The group is registered by the Brazilian National Research Council, CNPq, and has three main lines of research:

1. Design automation (CAD scripting and Parametric modeling).

2. Generative design (Shape grammar, Genetic algorithms and Fractals).
3. Digital fabrication (Additive, Subtractive, and Formative processes and 3D digitation).

These fields correspond to the three subjects that we have been teaching at the graduate program of the School of Civil Engineering, Architecture and Urban Design. Initially, we taught these subjects in the **Graduate Program in Architecture, Technology and the City**. These subjects are also offered to undergraduate students as electives. Besides, I teach CAD in the Creative process, which is a mandatory subject in the Architecture and Urban Design program.

In **Design Automation**, we started working with textual scripting languages (AutoLisp and VBA) and then moved to visual programming and parametric modeling (Grasshopper and Generative Components), which can be learned much faster.

In the field of **Generative Design**, we have worked initially with Shape Grammars in the analysis of modern Brazilian architecture and landscape design. Presently we are participating in the Digital Alberti project, headed by Professor Mário Krüger, from Coimbra University, in which Shape Grammars are being used to

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1. Our first machines: 3D-printer, laser-cutter, 3D-digitation system and CNC-router. New machines are being acquired at this moment.

understand the relation between Albertian rules and Portuguese/Brazilian colonial architecture. We also have students working on fractals and evolutionary design for design synthesis.

In the field of Digital Fabrication, we started using of a laser cutter and a 3D printer simply to produce scale models. With the CNC router we evolved to larger formats, and finally got to full scale fabrication, using a plasma cutter from a nearby industry.

In 2006 we started the process of creating the Laboratory of Automation and Prototyping for Architecture and Construction (LAPAC), as part of a larger research project at the Department of Architecture and Construction that aimed at studying the architectural design process. That project was funded by FAPESP, São Paulo state's research funding agency.

THE LABORATORY

The initial configuration of the laboratory consisted simply of a 3D Printer (ZCorp 310 Plus) and a laser cutter (Universal Laser Systems X-660). The first machine the ZCorp arrived in January 2007. In 2009 we were granted more funds by CAPES, a Brazilian federal research agency, to buy a CNC router. We bought a large machine from a small company in Southern Brazil, but unfortunately we were not very lucky. Although this router gave us a lot of headaches, it allowed us to explore subtractive fabrication. We realized that this type of fabrication is very complex, because it involves many parameters and different possible strategies. In 2012 we were granted funds from CNPq, another federal research agency, to buy a 3D Digitizer (Micro Scribe). That equipment allowed us to close the pipeline between digital/physical/digital models. In 2013 we are planning to buy more equipment, including a new, better quality CNC router and some formative system, with a new grant from FAPESP.

The initial location of the laboratory was a mezzanine above the School of Architecture's model shop. This strategic location gave us the



opportunity to make the machines available to all undergraduate students from the very beginning, thus creating a «digital culture» at the school from the bottom up –that is, from students to other professors. In the beginning it was not rare to hear studio professors complaining the laser-cut models (in the same way that they had about CAAD drawings some years before), but since the students were so enthusiastic about the new technologies, soon the complaints stopped. Soon the space became too small and we had to buy a couple of containers to expand the lab. Right now we have just won the right of occupying a floor at a new research building that is being built at the campus to house innovative, interdisciplinary research groups.

As an education-oriented, non-profit laboratory, at a public university, LAPAC would never have been viable without the financial support of public research funding agencies (FAPESP, CAPES and CNPq) and of Unicamp's Office of Research (PRP-FAEPEX). Unicamp's social service (SAE) has also been extremely helpful by providing scholarships to our monitors. Since the very beginning, the Rapid Prototyping Lab at CTI Renato Archer, a federal high technology research center in Campinas, has been our greatest partner outside of Unicamp, offering technical support and allowing us to produce prototypes with their machines whenever we needed. Private companies, such as DS4, a CNC machinery industry, and Oxipress, a plasma-cutting industry, have also been important partners, allowing us to reach 1:1 scale production with their machines.

PEOPLE AND EVENTS

Although space and machines are important, the most relevant aspect of the laboratory is the people who have been collaborating with LAPAC. It includes not just professors from our University, but also graduate and undergraduate students, visiting researchers and colleagues who teach at other schools but often participate in our events. Undoubtedly, LAPAC interns are the most important people in the lab. They help other students use the machines in the laboratory, prepare tutorials for each machine, maintain the laboratory's website up to date, schedule appointments and organize the space. So far we have had 10 undergraduate interns and 6 graduate interns. Undergraduate interns work 15 hours every week and receive a scholarship by SAE, Unicamp's Social Service. They have come from different programs, such as Civil Engineering, Civil Construction, Mechanical Engineering, Agricultural Engineering, Dance and Nursing. Graduate interns are Master degree and Ph.D. students who volunteer to stay at LAPAC to help other students and supervise the laboratory. By doing so, they learn about how to manage a Digital Fabrication Laboratory in terms of human and physical resources, gaining administrative and technical skills.

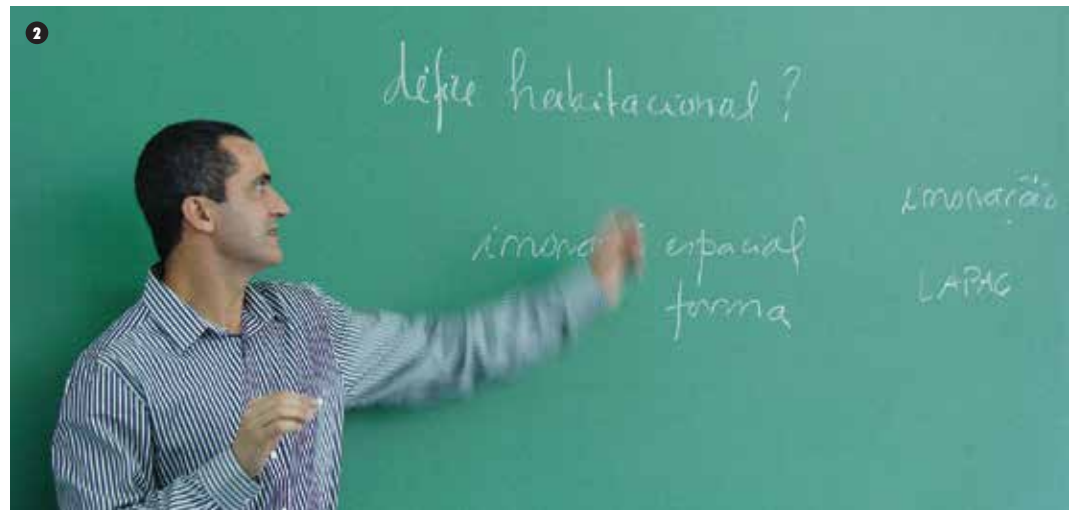
LAPAC has also received undergraduate and graduate exchange students for internships, and has sent students over to TU Lisbon, MIT and ETH Zurich. Whenever it's possible, LAPAC team visits digital fabrication labs abroad and attends conferences, short courses and workshops to keep up to date with the new technologies and

2. Professor José Duarte (UTL), speaks during an event at LAPAC.
3. Sigradi 2009 Digital Fabrication workshop: Mari Tosello and Cecilia Zorzón assembling their sculpture.
4. Sigradi 2009 Digital Fabrication workshop: Rivka Oxman, Gabi Celani and Eduardo Nardelli and one of the sculptures produced during the CNC workshop.

new trends in research in the field. In order to bring new ideas to our group, we have also invited professors and researchers from different universities and laboratories to give lectures and teach courses, such as Affonso Orcioli, from Universidad Internacional de Cataluña, José Duarte, from Universidad Técnica de Lisboa, Helen Sakano, from Bartlett, Andre Chaszar, from Delft Technical University, and Beurecueil and Franklin Lee, from the Architectura Association, London, among others. While some researchers volunteer to visit us and talk to our students, longer stays are usually funded by research agencies such as FAPESP. Besides, LAPAC's team is also available to make presentations at universities and conferences, whenever invited.

The organization of events has been another key issue for the group. LAPAC has offered workshops, trainings and demonstrations with two purposes: to train our students and professors on the use of digital fabrication techniques and to spread the word about digital fabrication to students and professors from other universities. Our workshops have been offered in house and at conferences and other events.

For example, during Sigradi 2009 conference, which was held at Mackenzie University, in São Paulo, LAPAC's team was in charge of organizing



the workshops. Three workshops were offered to show all the possible physical/virtual/physical conversions: 3D-scanning, rapid prototyping and digital fabrication. The 3D-Scanning workshop, which had the contribution of prof. Arivaldo Amorim, from UFBA, included demonstrations of 3D scanners by CCS Engineering and Digital Manufacturing, a Brazilian representative of 3D-scanning systems. Two systems were presented: a medium-range ZF-laser scanner and a short-range Konica-Minolta Vivid 9i. The Rapid Prototyping Workshop, offered by Regiane Pupo, used LAPAC's machines to produce the

work developed. The machines were presented by video-conferencing. The Digital Fabrication Workshop, taught by prof. Affonso Orcioli, from UIC, used a CNC router set up at the conference site by DS4, a Brazilian manufacturer of CNC machines. An exhibition was organized with the products that resulted from this workshop.

TEACHING

The courses taught at LAPAC vary every year, even if they have the same name or code. We



5. Students in the lab.
6. Digital prototyping and fabrication: a parametrically designed, CNC-cut «tree» developed in this course stands at the entrance of the lab.



try to incorporate new issues, technologies and discussions in every new session of the same subjects, and sometimes our courses are offered by visiting professors, or we have visiting professors who evaluate our outcomes. Some of them are described below.

DIGITAL PROTOTYPING AND FABRICATION
Prof. Regiane Pupo, post doc fellow
aug-dec 2010

The objective of this course, offered to undergrad and grad students, was to introduce digital fabrication techniques and produce from small scale models to 1:1 prototypes. While some students developed smaller objects, like lamps and shelves, one of the teams designed a 3m-height tree-like structure, which was made in MPU aluminum-coated boards, cut in our CNC router.

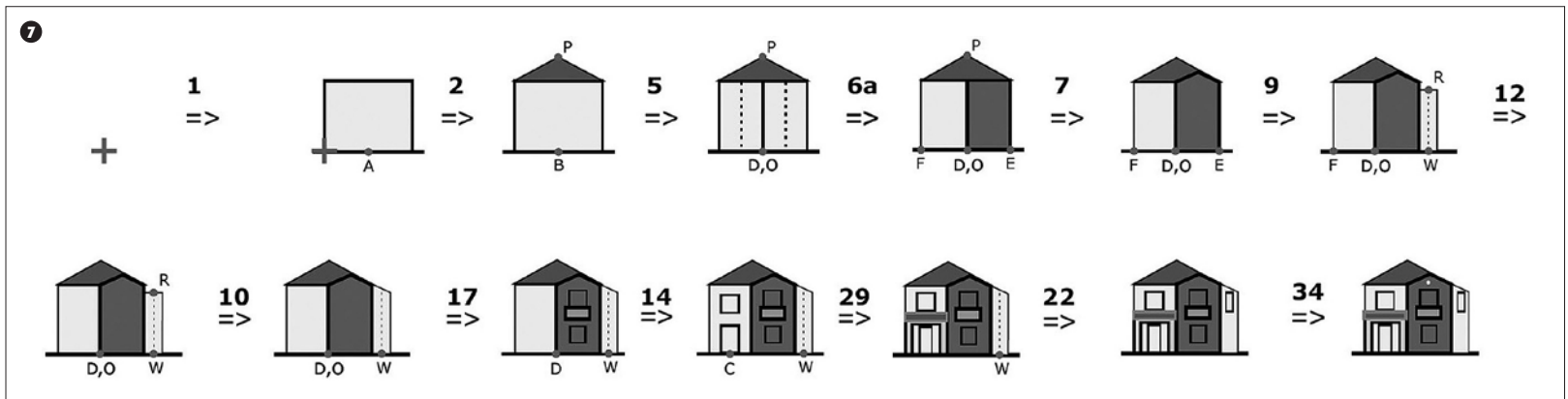
SHAPE GRAMMAR
Prof. Terry Knight, MIT, visiting professor
jan 2011

The objective of this summer workshop was two-fold: introduce Shape Grammars as an analytical tool, with all its technical specificities, and analyze neocolonial architecture in Campinas. Besides the participation of prof. Terry Knight, we had the collaboration of Silvia Zakia, who was then developing a research at FAU-USP about the architecture of Campinas in the 1930-40's.

The workshop started with a field trip to document existing neocolonial houses in downtown Campinas. Students were also given old plans and photographs to help them analyze the buildings. After an introduction to shape grammar techniques, each group selected a specific aspect of a small corpus of houses to develop their grammars: plans, façades, massing or ornamental details. In the final review professors Terry Knight, George Stiny and Sotirios Kotsopolous, all from MIT, commented on each team's work by video-conference.



7. Shape Grammar: derivation using the rules of one of the grammars developed.
8. Shape Grammar: Prof. Terry Knight, from MIT, discusses Shape Grammar strategies with students at FEC-Unicamp.
9. 3D Inventory: 1:2000 scale model of the neighborhood.



3D INVENTORY

Professors Regina Tirello and Gabriela Celani
mar-jun 2012

The objective of this course was to introduce both 3D digitation and digital fabrication techniques for the production of scale models of historical buildings. We used two digitation techniques: digitation software based on photography for the documentation of whole buildings and large objects, and a touch probe digitation device for the documentation of small objects. For the production of scale models we used 3D printing and laser cutting.

The object of study was again neocolonial architecture in Campinas. The course started with a survey of a whole neighborhood in which most of the neocolonial houses are located in the city. Next, a 1:2000 scale model of the whole neighborhood was produced, showing which buildings can be classified as Brazilian neocolonial, Spanish mission and hybrid styles. For this categorization, the shape grammar developed in prof. Knight's workshop was used.

Next, each team selected a couple of buildings to model with a good level of detail. The buildings were 3D-modeled and 3D-printed

in 1:100 scale. Finally, specific details of each building were digitized or modeled and 3D-printed at a larger scale.

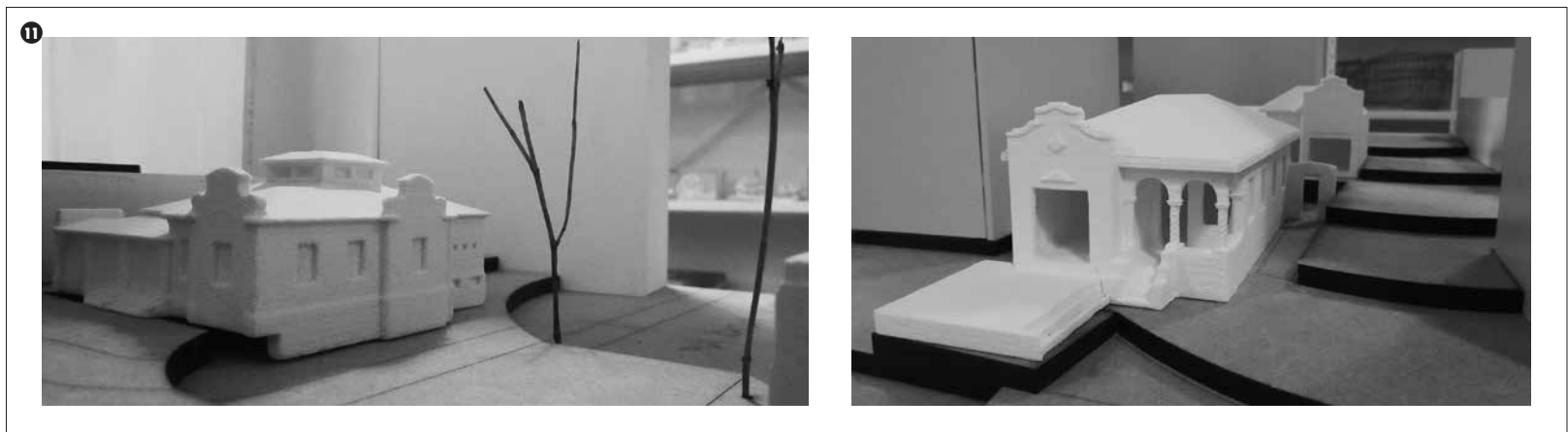
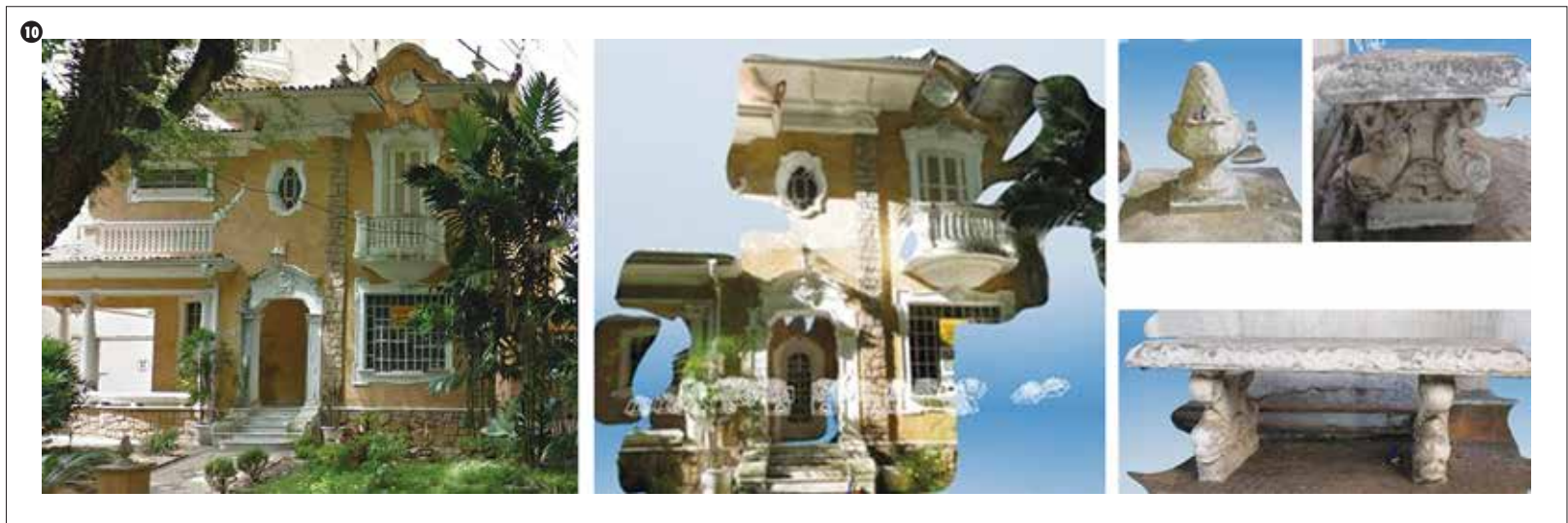
AUTOMATING STEPS OF THE DESIGN PROCESS

Prof. Gabriela Celani
mar-jun 2012

This CAAD programming course was the first one in the Design Computing field to be offered at FEC, starting in 2005. At that time we still did not have any digital fabrication machines but we could teach programming as an automation

10. 3d Inventory: 3D digitation of a house and two decorative details.

11. 3d Inventory: two 1:100 3D-printed scale models.



technology for the design process. Back then, there was no Grasshopper and Generative Components was just starting, so students had no option but learning scripting languages, and we used AutoLisp and VBA for AutoCAD. In the past years, we have moved towards visual programming, but still want students to learn at least the basics of textual programming. In the 2012 session of this course, students were asked to develop the same project both in Grasshopper and in VBA for AutoCAD, and the compare the two strategies in terms of learning curve and quality of results.

RESPONSIVE ARCHITECTURE

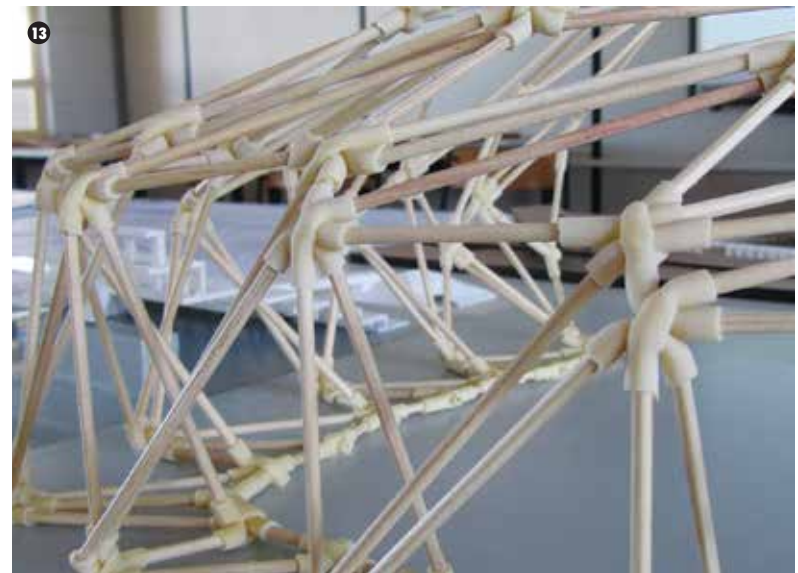
Prof. Anne Beaurecueil, AA London, visiting professor
aug-dec 2012

In this elective subject offered to undergraduate students from the Architecture and Urban Design program, we developed design proposals for the «Glicério Sports Community», a social project created by Aunt Eva in downtown São Paulo. The architectural programme consisted of na official soccer field with covered bleachers, changing rooms, administrative areas and spaces for recreation and study for the children that are helped by this entity. Moreover, students should

incorporate to their projects and old Police Headquarters which is going to be converted in a museum.

The methodology proposed by prof. Anne consisted of using the «articulated ground» theory, developed by her and Franklin Lee in workshops offered at the Architectural Association, based on ideas from well-known architects, such as Zaha Hadid and Oscar Niemeyer. Besides, she suggested that students considered energy efficiency and environmental comfort issues as a generative method, by means of using environmental analysis software combined with parametric modeling tools.

12. Automating steps of the design process: LAPAC students discuss their final project with Marcelo Bernal and Pedro Soza, from Georgia Tech, 2012.
13. Responsive Architecture: Students discuss their final project with Marcelo Bernal and Pedro Soza, from Georgia Tech, 2012.
14. Housing typologies of layouts generated by instantiation of a residential type defined as an object-oriented programming language class (Gelly Mendes).

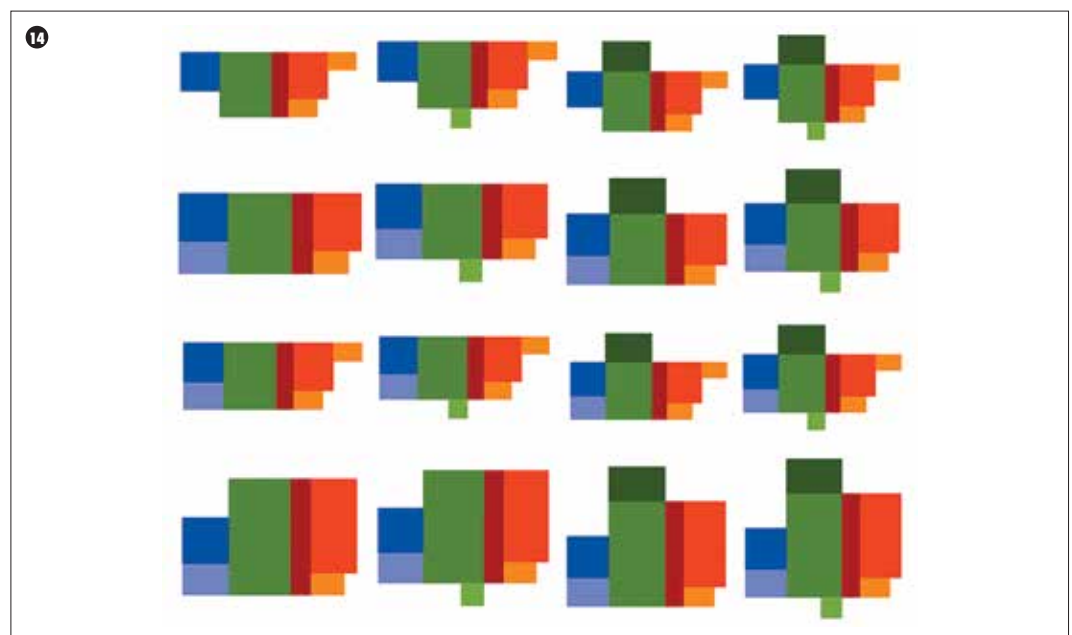


Prof. Anne encouraged students to produce a large number of scale models and prototypes at different scales along the whole semester, with the use of digital fabrication equipment. These models had the purpose of testing design hypotheses and not just representing them. Prof. Arthur Lara, from FAU-USP, acted as an external reviewer in the final presentation of the work developed.

RESEARCH

Four levels of academic research are developed at LAPAC: Scientific Initiation, Master Degree and Ph.D, which usually last one, two and four years, respectively. LAPAC can also receive post-doc fellows. Researchers from all levels can apply for scholarships from CNPq, CAPES and FAPESP.

Scientific Initiation research at LAPAC has been carried out by undergraduate students from different fields. So far we've had students from Architecture, Civil Engineering and Computational Engineering. Master degree and Ph.D. researchers at LAPAC belong either to the program in Civil Engineering or in Architecture, Technology and the City, both at FEC, Unicamp's School of Civil Engineering, Architecture and Urban Design.

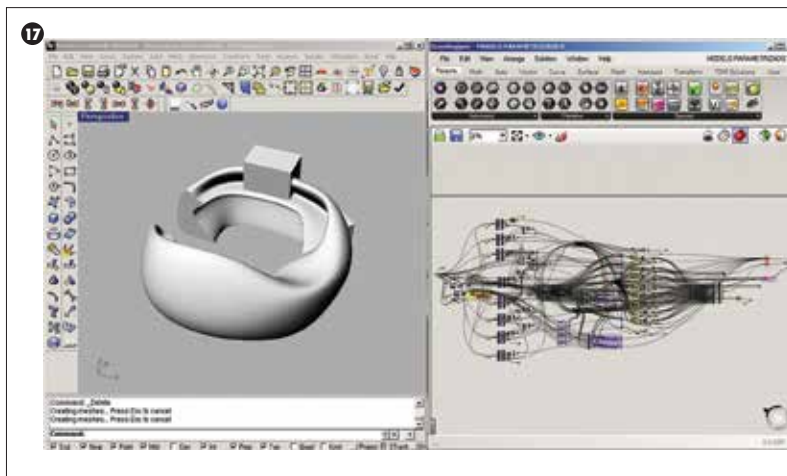


The results of the research developed at LAPAC have been presented in the main international CAAD conferences, such as Sigradi, eCAADe, CAADRIA and ASCAAD, and published as papers and book chapters in local and international publications. Besides that, LAPAC's team spreads out the word about what is going on in Computational Design, by

publishing reports about the main conferences in the field.

Due to space limitations, just a few images of some of the research projects developed at LAPAC are shown below, but almost forty research projects at undergraduate and graduate level have been completed so far.

- 15. A shape grammar for the houses in Monte Alegre do Sul (Giovana Godoi).
- 16. An undergraduate research project, which studied CNC-cutting, formwork assembly and concrete pouring (Danilo Higa da Rocha).
- 17. From -parametric modeling to CNC plasma-cutting- a master degree study by Wilson Barbosa Neto.



- 18.** Regiane Pupo, a post-doc at LAPAC, during a CNC router demonstration for public school students from Campinas.
19. Scale model of Unicamp's campus: topography made with melamine laminate and buildings in SLS.

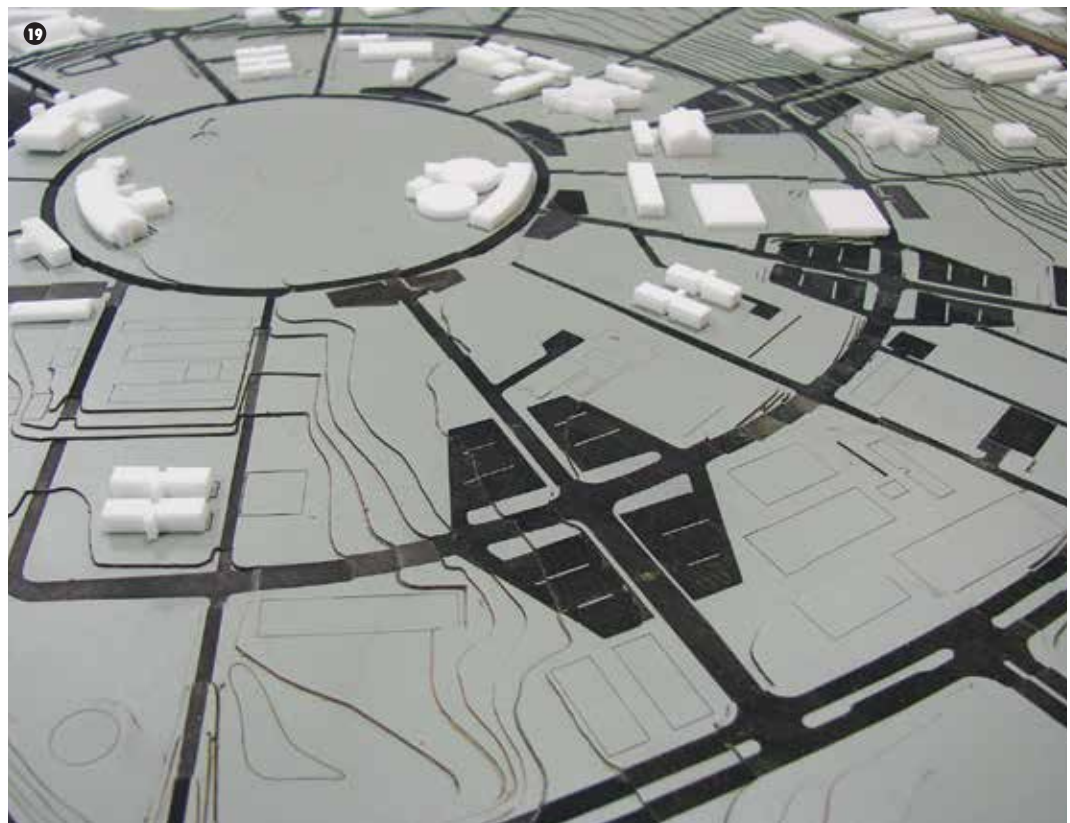
EXTENSION

Lapac has also developed extension projects, especially through educational activities and the production of scale models. Among the first, the participation, since 2009, in Unicamp's Summer Science and Arts camp is worth of note. During this Science and Arts Summer camp, LAPAC offers weekly laboratory sessions in which public high school students can get in touch with all our 3D technologies. Our monitors and researchers volunteer as instructors, making demonstrations and answering questions.

Regarding the production of scale models for the community, LAPAC has produced a model of Unicamp's campus that sits at the entrance of our main library. The topography was produced with laser-cut melaminic laminate and the buildings were 3D modeled by a student (Juliana Matsubara) and produced with a Selective Laser Synthering (SLS) machine at CTI Renato Archer, a partner research center. A tactile model of the library building for orientation of visually impaired people was developed by another student (Luis Fernando Milan) and produced with the SLS technology. It also sits at the entrance of the library, and is very useful for those looking for the Braille reading room. Another important scale model was produced by LAPAC's team for the team of curators of Pinacoteca do Estado, a public museum located in São Paulo. The curators used that model to plan the remodeling of the museum's permanent collection in 2011.

Finally, the laboratory has been used for extension projects developed by students from Unicamp's mechanical engineering school, such as the Aerodesign, the Baja and the SAE Formula international students' competitions.

LAPAC has offered open activities on digital fabrication and computational design for the academic community, such as workshops during SIGRADI 2009 (described above), SAL 2011 and SBPQ/TIC2013. These often involved the collaboration of colleagues from different states and countries, such as Arivaldo Leão (UFBA), Affonso Orcioli (UIC/UPC) and Hernán Ascui (Bio-Bio), among others.



The laboratory has also been used for extension projects developed by students from Unicamp's mechanical engineering school, such as

the Aerodesign, the Baja and SAE Formula international students' competitions.

- 20. Pinacoteca's scale model being used by the museum's team of curators.
- 21. The workshop during SAL2011 (Seminario de Arquitectura Latinoamericana), in which participants had the chance to visit a plasma-cutting industry. This workshop had the participation of Wilson Barbosa Neto, from LAPAC, and Hernán Ascui, from the University of Bío-Bío, Chile.
- 22. Some examples of scale models produced by undergraduate students at LAPAC.

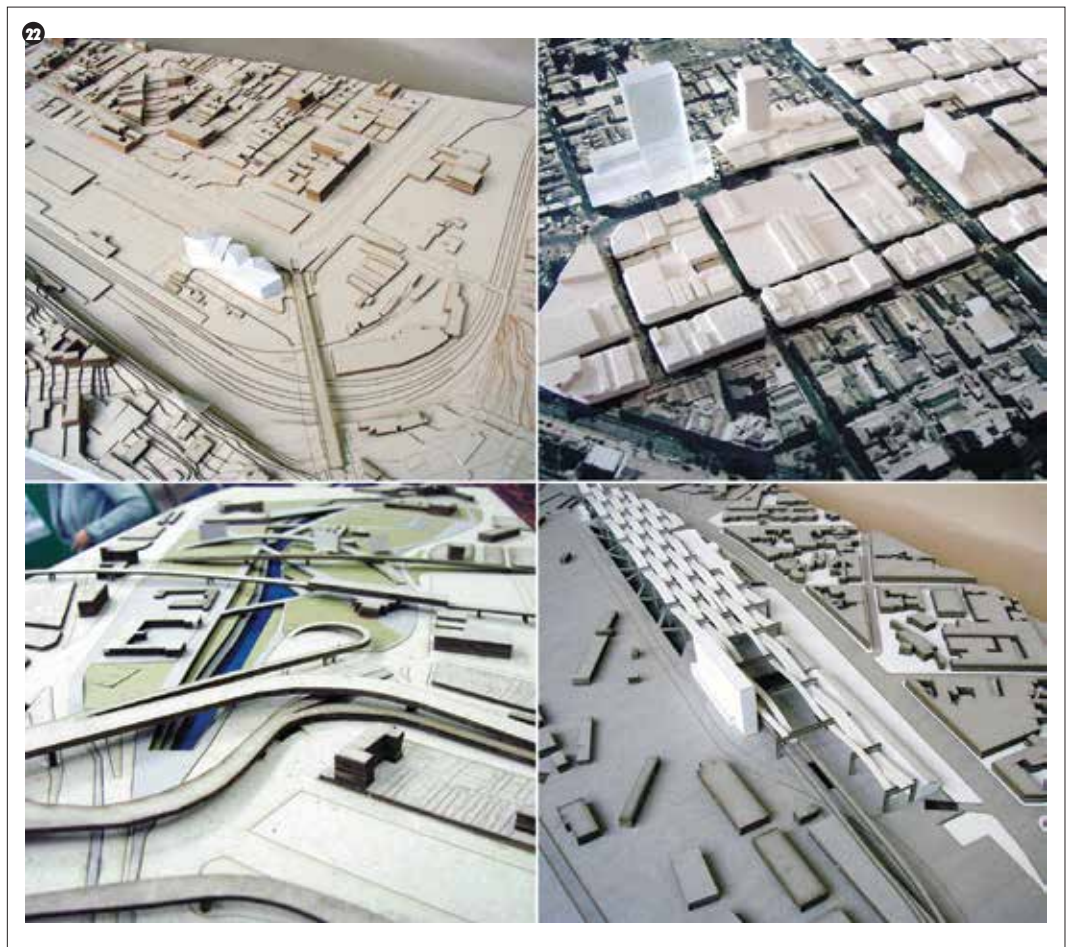


DISCUSSION AND FUTURE WORK

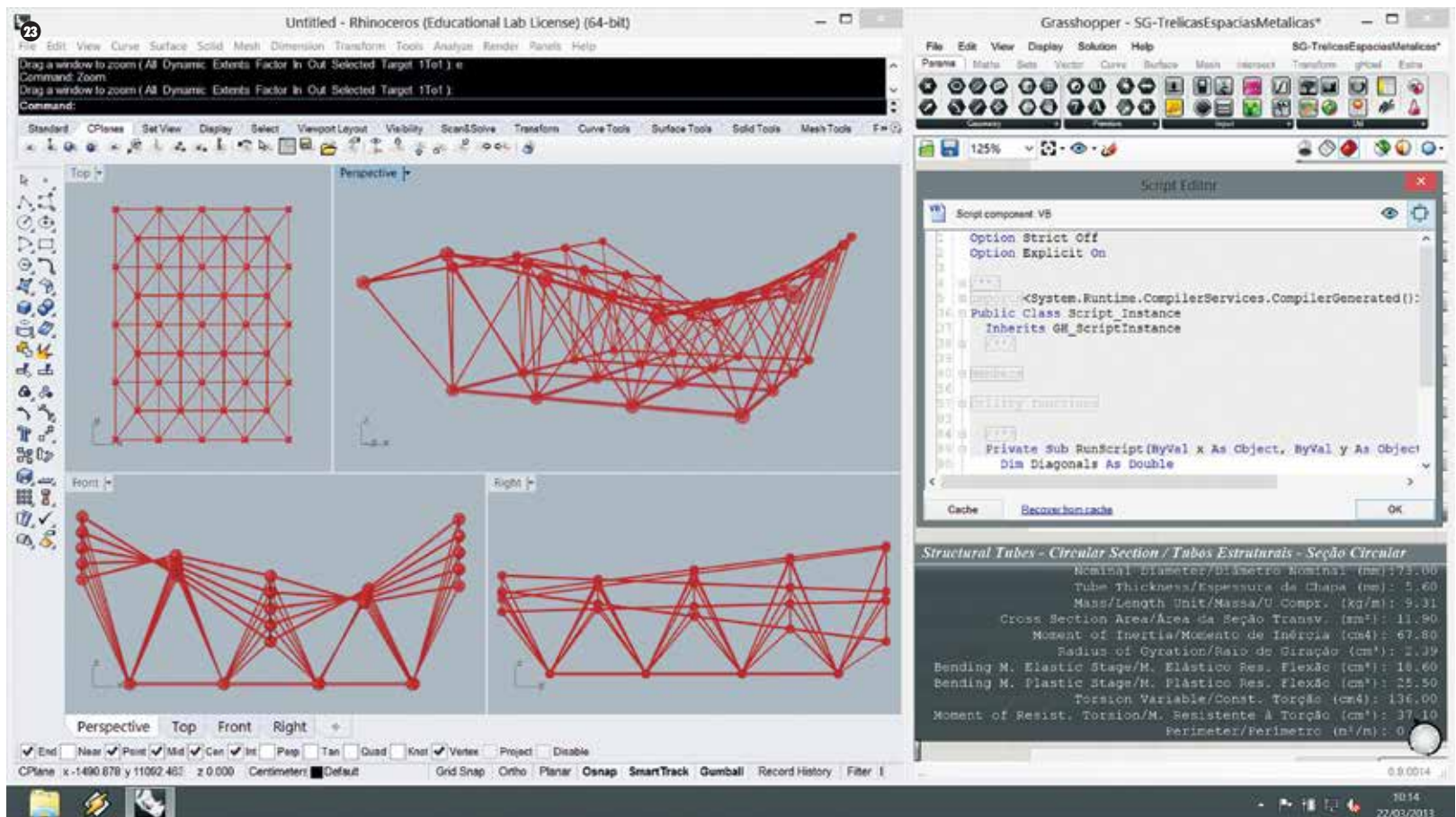
After seven years of work at LAPAC it is possible to draw some conclusions about the impact of the laboratory for our students and, to some extent, for architectural education in Brazil.

Created in 1999, Unicamp's Architecture and Urban Design undergraduate program had always had a strong emphasis in digital design tools. However, physical models were not very common, or were used solely for representation at the end of the design process. The very first consequence of the availability of digital fabrication machines for students was the increase in the number and quality of architectural scale models, especially after we started offering workshop and elective subjects on digital fabrication.

A second important consequence was the introduction of a new field of research in the graduate program of the School of Civil Engineering, Architecture and Urban Design: Computational Design, which includes theories and technologies. This new field of research attracted researchers in all levels –from undergraduate to post-doctorate, and from different areas, architecture, engineering and computer science– to develop «hands-on»



23. Research on the use of textual + visual programming for generating free-form trusses, by André Araújo, a researcher at LAPAC.



research in architectural design, research that goes beyond literature review and theoretical speculation, resulting in computer programs, scale models, descriptions of new processes and so on. There was also a growing interest in parametric modeling and CAD programming, and elective subjects were also offered on these topics.

As the third consequence of LAPAC is the dissemination of a general interest in Digital Fabrication machines for producing scale models in architecture schools in Brazil. This type of laboratory is in fact becoming more common in our country, but other Brazilians may have also been influenced by what is going on in other countries. But it is also true that we have trained students and professors from other universities, most of whom had their very first opportunity to see and operate a digital fabrication machine at

LAPAC. Besides, two of our graduate alumni are now professors at Federal Universities in other states, where they are promoting the introduction of computational design and digital fabrication in the curriculum and creating new labs.

After seven years our machines are becoming old, our space is becoming too crowded and our objectives are becoming wider. Instead of making just small scale models we are now interested in producing full-scale building parts. Besides the additive and subtractive processes we now want to experiment with formative processes. On top of teaching the new generation we want to go out of the University and start influencing the industry.

We are now in the process of acquiring two new CNC routers (one of them with a fourth axis),

a new laser cutter, a vacuum forming machine and a few powerful computers loaded with state-of-the-art software. We have also been promised a 180 square meters space in a new building, which will be shared with other four professors who are also interested in using digital fabrication for different purposes.

We foresee a lot of interesting activities for the next years at LAPAC, but our greatest challenge will be to complete a mission that we have just started. In Brazil, CAAD is still considered as just a means of representation for most architects. Perhaps, with BIM software, some of them now see CAAD as a smart way to represent architecture. However, very few of them understand that computers are a new medium that can be used in a new way; not just for simulating drafting and crafting.

In our understanding, true contemporary architects should know how to use the generative power of computational design techniques, in order to give new meaning to their projects. We hope to be able to develop meaningful examples of that use that can inspire architects in Brazil and abroad.

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