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DIGITAL TOOLS AND ROBOTICS IN ARCHITECTURE: ENVISIONING THE FUTURE INEDUCATION AND PRACTICE

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Keywords: Architecture, Education, Technology, Digital Tools, Robots

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Abstract

In a world advancing at a vertiginous speed, technology is directly affecting almost every single aspect of contemporary human life. It is therefore crucial nowadays for both the professional and the educational sectors to constantly update themselves with the latest trends in their fields. Once students graduate, they should first be familiar with the needs of the highly competitive market, and at the same time to be prepared for challenges facing the practice in order to improve it and stand at a higher level from competitors. For such reason, students need to be aware that high tech tools are vital in defining the way professionals work and advance. In this sense, the educational field shall play a leading role to conscious students about such line of work that is contaminating all professional areas, including architecture. This paper therefore will focus on the ideas of how to deal with the latest trends in digital tools and robotics at the academic level in order to awake and motivate architectural students to rationally use them as a helping set of tools that will have a direct impact on the way they work. Exploration at the level of freedom that such means can offer to enhance students at the creativity level will be directly analyzed throughout a workshop conducted, based on digital tools and robotics in architecture, and linked to the intentions related to architectural design challenges by involving students in site visits to projects where cutting edge work is being applied such as the Sagrada Família, one of Antoni Gaudí's masterpieces. Conclusions will be based on the principles helping students dealing with advanced tools to transform their intentions from digital to analogue means as part of a controlled system intended to innovate design and construction principles.

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ABSTRACT

In a world advancing at a vertiginous speed, technology is directly affecting almost every single aspect of contemporary human life. It is therefore crucial nowadays for both the professional and the educational sectors to constantly update themselves with the latest trends in their fields. Once students graduate, they should first be familiar with the needs of the highly competitive market, and at the same time to be prepared for challenges facing the practice in order to improve it and stand at a higher level from competitors. For such reason, students need to be aware that high tech tools are vital in defining the way professionals work and advance. In this sense, the educational field shall play a leading role to conscious students about such line of work that is contaminating all professional areas, including architecture. This paper therefore will focus on the ideas of how to deal with the latest trends in digital tools and robotics at the academic level in order to awake and motivate architectural students to rationally use them as a helping set of tools that will have a direct impact on the way they work. Exploration at the level of freedom that such means can offer to enhance students at the creativity level will be directly analyzed throughout a workshop conducted, based on digital tools and robotics in architecture, and linked to the intentions related to architectural design challenges by involving students in site visits to projects where cutting edge work is being applied such as the Sagrada Família, one of Antoni Gaudí's masterpieces. Conclusions will be based on the principles helping students dealing with advanced tools to transform their intentions from digital to analogue means as part of a controlled system intended to innovate design and construction principles.

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1. INTRODUCTION

When going back in time, it is very hard to find issues related to themes such as nanotechnology, genetics or robotics, among a series of diversified multidisciplinary trends of approaching architecture. It is not appropriate to say that back then there was less to learn, however definitely the arrival of new technologies in a relatively short period of time has led to a significant change thus defining a challenge to really reflect about them in the standard architectural practice. Changes in technology have manifested themselves in many different ways. The alteration and advances in technology assisted on how we procure, fund, design, choose the proper materials, and build. At the same time, architecture does not stop with buildings, but also embraces cities, landscapes, and environments with both virtual and actual components. Traditional and well-defined designs and construction methods are constantly being questioned by emergent archetypes.

For instance, at the beginning of the digital revolution, many architects were experiencing, throughout the digital world, modeling, shaping complex surfaces, and parametrizing geometrical relations for highly complex results, but only very few dared to take the architectural challenge of translating what is seen on the screen to a physical matter to a higher level. (Corser, 2012) Quickly

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3D printers, rapid prototyping machines, and numerically controlled machines took the stage to translate designers' dreams into reality. Later on, robots, from the automobilistic industry, were adapted to take architectural formal complexities to a higher level of concretization, in extremely creative processes, and at the same time provided a more advanced level of freedom away from the restrictions that were quickly identified in automated systems of fabrication with the use of industrial tools such as the Numerical Control (NC) system and later the Computer Numerically Controlled machines (CNC).

With a level of freedom to craft any material with a level of perfection higher than the conventional architectural needs, digital and robotic tools are being able to help in shaping, developing and testing materials, in addition to providing possibilities to apply a more customized ways of construction. High tech is deeply contributing in the fusion of digital and physical procedures with the aim of optimizing engineering performance. (Kolarevic & Klinger, 2013) Thus, it is a big challenge for architectural schools to cope and pace themselves with this miasma of change and progress. This is, despite some uncertainties, a continuing dangerous, but a very exciting path that can lead to implementing results that are helpful for the present, the near future, and even the very far one.

2. HIGH TECH TOOLS BETWEEN ACADEMY AND PRACTICE

When students start their academic career at the school of architecture, the usual procedure guiding them to complete their studies also escorts them to learn and perfect their drawing skills, technicality in drawing, creativity in design ideas and procedures, in addition to increasing their theoretical background. Aside from main course requirements, as a secondary plan, some Computer Aided Design (CAD) courses appear in order to provide students with the possibility of achieving perfection in their skills especially for graphic purposes. From the beginning of the students' career, appreciated is the consistency in the process of acquisition of knowledge and elements of skill perfection. However, CAD systems stop most of the time at the virtual level with a variety of advanced design and analysis software. (Gu & Wang, 2012) Sometimes, they are exposed to some sort of virtual to physical experience by acquiring components for models with the help of a laser cutter, a tool extremely helpful in order to get components for assembling models.

In professional practices, far from architecture, there have been parallel technological platforms supporting the CAD systems, which merged with digital tools, such as the Computer Aided Manufacturing (CAM). (Schodek, 2005) This was an example of a system that provided great help in fusing the digital with the physical aspects in areas such as mechanical engineering. Thanks to the presence of advanced drafting systems, and although with some delay, CAD-CAM is becoming an effective process, with potential for great advances in the formal and material performance levels that are currently being more appreciated in architecture, and which have some important level of application in the professional field.

If we go to our routine in life, it is more than clear that technology is driving us to use it. Older generations have become able to adapt themselves to the newer life trends such as the mobile technology and its infinite applications, more than the ability of the newer generation to adapt themselves to old fashion trends. For instance, there is no more need to memorize contact numbers since the phone does, and if anything happens to the device, the data is stored somewhere in a virtual space. This is something that is helping in the process of globalization but at the same time showing the dependence on technology in order to survive. Nevertheless, taking it in the positive way, it is providing options to develop every single aspect of life and its needs.

The tools available for a comfortable level of life today are much higher than those available a long time ago. At the same time, professional practices are indulged into being more dependent on technology. For instance, when talking about advanced tools increasing in popularity, the 3D printer is one of the best examples available since it is being used in a diverse variety of academic and professional fields, in addition to merely personal purposes. (Meijs, 2014) According to the varied sizes, specifications, and prices, any person interested and with enough awareness about such a tool can acquire one. In architecture for example, it has taken the practice by storm, since one of the basic processes during the design stage includes model making. The process of 3D printing a model provides precision and possibility for more complex outcomes, in addition to allowing designers to optimize time, where they can, for example, take advantage of the time saved to perfect their design proposals, or just to prepare presentations.

According to Vitruvius, *"the architect should be equipped with knowledge of many branches of study and varied kinds of learning, for it is by his judgement that all work done by the other art is put to test"*. (Vitruvius, 1914) The architect is always responsible for his design decisions which are implemented in the construction of buildings, foreseeing what is supposed to happen on site. So what is seen in reality is a reflection of his thoughts. Logically, the outcome dialogue between designer and component should not be different when dealing with machines since what is supposed to get out of it is also a series of instructions set by the architect himself. He is the one held responsible for articulating every single detail in the model that will be built and this issue brings us back to the theme that architects should control every aspect of the design. In this sense, the use of such technology is one of the factors boosting creativity in architectural design, contributing to reach extreme levels of experimental design and advanced construction processes with the help of the computers thus simulating advanced construction and foreseeing problems, while machines execute the work to perfection according to the designer's data introduced.

Awaking and preparing students for such challenges require great efforts from the academic faculty members, whose job are to try to coordinate all the courses, within each academic level, in a horizontal manner and then in a vertical one, in order to optimize students' learning outcomes and expose them to the maximum extent of available situations. In the technology branch, and due the constant appearance of new tools, structural coordination should happen. However, it is important to note that not all that is coming out of the technology branch is for its straightforward use in the professional area. Nevertheless, it is important to foresee its use in the future and for that, there is a need to introduce the application of technology into the academic institutions, not just relying on the foundation but rather having a constant upgrading of proper advanced interface labs, such as modeling and fabrication labs, with the aim of causing contamination in the architectural culture, which starts right at the academic level and spreads to the profession with design ideas and construction principles which should be as innovative as ordinarily expected.

3. ADVANCED TOOLS FOR MODELING AND FABRICATION NEEDED IN EDUCATION

Since the beginning of the CAD revolution, architectural profession has seen an emergent amount of incorporation of digital tools for designing and building. (Schodek, 2005) Due to the versatility of such tools, challenging formal and structural geometries assisted by computational methods are becoming more predominant. In addition, the design and construction work flow is being developed more consistently with the introduction of integrated software settings. Within this environment, advanced softwares are emerging and imposing themselves in architectural education as being key components of design processes. For better or worse, digital tools are used progressively in design studios. When, where, why and how these utensils are implemented in the curricular structure make a recognizable difference not only in whether the full capabilities of these tools are employed or not, but also in the way the future architects develop the necessary complex set of skills needed to deal with contemporary and upcoming architectural challenges.

One of the greatest challenges of the digital world is the link to the physical one. The advent of the computer has brought about a revolution in modern manufacturing which has gone through numerous phases. As a result, manufacturing has become immensely diversified and sophisticated.

The process of design and production in the architectural expanse moves towards digital environments throughout a series of CAD systems, and can be complemented by Computer Aided Manufacturing (CAM) in an automated, optimized and precise manner. Physical models can be produced with rapid prototyping and CAM tools such as 3D printers, routers, milling machines, and robots. However, these tools require an adopted familiarity of seeing, thinking, and enclosing of spaces that cannot be refined through only digital means. Thus, there must be a certain balance between CAD systems and principles of manual production, hand drawings and models as part of the essentials of architectural thinking, and kept as part of the foundation year in architectural education. Through a strong background of tridimensional space experience and tectonic awareness, tools can be used to their full potentials for solving rather than just to generate doomed geometries.

In order to follow such steps at the academic level, schools of architecture need to enhance their experimental labs. They can be divided into different categories such as the computer labs, where digital modeling or environmental issues can be tackled, and a workshop, a place to create models of buildings, components and prototypes. With many technological tools at the service of architecture, it is possible for many universities to integrate in their spaces, equipment that would be able to transform vectors and complex volumes seen on the screen into physical features. After the laser cutter, rapid prototyping quickly took the stage with the advent of 3D printers. The principle of work relies on the additive process of accumulating layers of material according to shape. Still, a large number of additive processes are now available for transforming designs into feeding data to 3D printers, being the stereolithography (STL) the most popular.

Blending the virtual with the physical is definitely one the main goals of a contemporary architect, as it is only a small part of the job to have his efforts being appreciated only on screen. One of the first who saw the potential for such possibilities previously being developed in areas outside architecture was Greg Lynn (Fig.1). In the digital realm, he was one of the first architects to utilize animation software not as a medium of illustration, but of form generation. He affirms that the predominant "cinematic model" of motion in architecture eliminates the force and motion from the articulation of form and reinstates them later, after the fact of design, through optical demonstration of concepts and techniques. (Lynn, 1998) By dealing with advanced design conditions such as motion and inflections, the process of design implied in the evolution of form and its shaping forces. At a later stage, Lynn went further by arguing the idea of translating virtual ideas into analogue means by developing the Embryological House, a project totally conceived and produced by digital means.

Fig. 1 Model of the Embryological House by Greg Lynn produced by a 3D printer, being it one of the first architectural projects experimenting such technology
Reference: photo from the web www.glform.com

This period witnessed a revolution in the architectural design era where architects got carried away by the digital tools and where their works were being developed at a more radical formal basis, up to a point of assuming the risk of being considered architectural or artistic images rather than architectural projects. The strength of the digital media providing endless possibilities of highly sophisticated formal development and not being able to cope with some of the essential principles of the architectural practice led to a point where the architects and students were not able to translate ideas form the screen into the physical state, either due to the complexity of its architecture, or due to its only esthetics and lack of consistency in some parameters such as the formal, structural or material.

By then, very few computer labs at universities would struggle to improve as new technological trends appear. But this was the beginning of the technological contamination of the architectural trend. From computers with advanced processor to last generation software, this has become a race against time to form and update themselves as fast as possible. The idea of labs has been transformed today into digital environments with an enormous number of computer tools constantly updated and being developed on a daily basis. The strength of parametric programs for instance is at the level of being used as an interactive tool between designers and machines. There is the option of taking the project to unseen complexity levels and at the same time linking outcomes to an optimized and rationalized construction process. Associating software tools with hardware is what has been causing a great upheaval in the digital architectural era. And in the computer labs, this becomes the place to find the proper balance between design and fabrication outcomes.

Among the many benefits of the computerized vectorial and complex surface drafting schemes, CAD systems compromise new ways of exploring architecture with the option of supporting designers to conceive more complex projects in a faster and precise way. They open up the possibility of exploring themes such as non-standard architecture, mass customization, parametric design and sustainable design. Robotics is also feeding those fields of research by building faster, being more precise, and using a series of experimental materials in the process of development. In some schools of architecture, a great deal of effort is required in order to catch up with other faculties. There must be a time where disciplines fuse together in order to develop engineering processes that will benefit the end result targets. As of today, the technology at stake can and must be used by many fields, especially among academic faculties. For instance, as much as the robot is used build a car or a boat, it should also be customized to build the walls of a building.

The application of CAD/CAM systems in architecture started in early 1990s with very few projects dealing with digital tools and fabrication assisted by computers. One of the first, and curiously due to its complex shaped combination of geometrical relations never seen before, is the Sagrada Família in Barcelona by Antoni Gaudí (Fig.2). (Bonet, 1997) The great effort put by designers at this masterpiece started with the introduction of the NC and CNC technologies in order to apply Gaudi's complex but rational geometric relations to fabricate stone elements. The process basically consisted of transforming a CAD drawing into an alphanumerical file to be fed into a machine which would later saw stone by moving in space according to the data. At the end of the production of one of the first architectural components ever fabricated by an automated system, it was shown that this project, conceived in the late 1890s, not just celebrated the geometric conceptualization created by Antoni Gaudí as something ahead of his time, but it also opened the doors for possibilities in achieving a greater degree of complexity and innovation in architecture with the help of advanced tools for design and construction.

Fig. 2 Interior of the Basilica of the Sagrada Família, Barcelona, where the columns were some of the components fully fabricated by automated systems, Reference: photo from author

The American Center in Paris, developed by Frank Gehry, and before the Guggenheim museum in Bilbao, was also an early project where designers were given the opportunity of exploring and consistently applying trends in CAD/CAM. By fabricating curved stone cladding components from surfaces of double curvature, the challenge required pushing technology to its limits by trying to properly fuse the advanced languages of computers and machines. (Shelden, 2002)

At the early stages, abiding by any automated system of construction was an expensive support needed to concretize specific tasks. However, as machines like 3D printers, CNC machines and robots increase in performance and popularity, in addition to the higher competitive market supply, they becomes relatively cheaper to acquire. These facts are helping companies and institutions such as universities to create strategies to acquire such technologies. The amount of investment to be made into CAD-CAM technologies is still considerable, but as dependency is increasing, their demands are helping to set the trends for the digital era. Also, it is essential to create an effective taskforce with enough experience to carry out at the beginning the main jobs in order to later transform the environment into an effective lab with enough resources to experiment and advance. Last, it is crucial to keep up with technology since advances are being made constantly and updating trends requires a lot of effort. And nowadays, one of the most advanced themes in architectural technology is the use of robots, which by linking it with advanced digital design can produce highly sophisticated elements. It cuts, molds, assembles, and articulates components according to orders set up by designers on the computer software. Parametric design has been definitely the most innovative and effective tool to create a sort of consistent language between computer and machine, totally controlled by the architect.

4. CASE STUDY: DIGITAL TOOLS AND ROBOTICS IN ARCHITECTURE WORKSHOP

Being aware of the latest strategies in design and construction is something that designers interested in high tech trends should abide by, especially when dealing with highly creative processes of design. But at the same time, intellectual background should be constantly and progressively increasing in order to recognize and appreciate what has already been done and later assume the proper strategies on their design decisions. The workshop “Digital Tools and Robotics” was an opportunity to explore the latest trends in architecture and technology which has been given by experts in the field. The Digital Fabrication Lab (DFL), from the Faculty of Architecture at the University of Porto hosted the workshop and gathered 66 students from the Faculty of Architectural Engineering from Beirut Arab University. All students participating in the workshop were enrolled at least at the third year level at the faculty of architectural engineering and had a good level of maturity to understand the challenge involved in the workshop. In addition to the city of Porto, Barcelona was the scenario set to appreciate how technology is applied to architecture. In addition, students were be able to widen their cultural background by visiting a series of iconic projects by pioneer architects in both cities, in addition to discovering new cultures.

Strategically, the two weeks workshop was divided into a one week dedicated experimental design and the other to analytical exploration of buildings related to the theme of the workshop. The first week of the workshop was based upon the use of a series of digital modeling tools, a parametric design toll, fabrication processes, 3D printers and a robot to produce the final design result. The second week was dedicated to a traveling studio in the city of Barcelona, Spain, in order to appreciate in details what was learned during the first part in Porto and to analyze, in greater depth, the construction principles of special architectonic forms. In addition, students were exposed to a series of iconic projects, by pioneer architects, in addition to having the possibility to widen their cultural background by meeting and experiencing the Portuguese and the Catalan ones.

The Workshop “Digital Tools and Robotics in Architecture” was an introduction to the use of advanced digital design and fabrication processes in order to assist the development and construction of architectural projects today. Taking advantage of the technological resources at the DFL, the participants from the Beirut Arab University were requested to develop a short design experiment to be robotically manufactured at 1:1 scale. The relevance of conducting research in this field relies on the fact that these technologies have dramatically expanded the geometric design possibilities and allowed for nonstandard mode of production, from the scale of the building component to that of the building form.

In order to allow the experimentation of different design topics, building materials and robotic fabrication processes, students participating in the workshop were divided in 3 classes and taught by a specific group of tutors. On each class, the students were organized in groups of 3 to develop a short project on a specific design and construction challenge. On a mid-term review, all participants would vote and elect one solution from each class to be robotically fabricated. A final presentation would document and exhibit the whole work produced during the workshop.

In order to inform the generation of the design solutions for the Workshop, students were expected to bring six pictures taken while visiting the city of Porto before the beginning of the Workshop. These pictures had to capture some geometric motif or perspective from the city building landscape like, for instance tiling, façade, or a building detail. In the class, and with the help of the tutors, each group would analyze the pictures and select one of the motifs to perform a series of geometric manipulations in the development of the design project. This pre-workshop assignment also served to strengthen the engagement of the participants in the workshop with integrating the particular features of the city of Porto. The fabrication process, defined as themes for each class, were assigned as “brick positioning” for the first class, “milling” for the second, and “2D cutting” for the third.

In the first class of the workshop, students, who gathered in groups of three, had to explore the use of a robotic arm and a gripper attached to it in order to build a non-standard wall with solid cork bricks. The end result robotically mounted and supposed to measure 120 cm in length and 200 cm in height, had to start with inspirations from geometric motifs previously seen in the city of Porto, such as tiles, facades, buildings, among others. The bricks would then be positioned so that variations would provide volumetric effects. For this matter, Rhinoceros and Grasshopper were used as the design tools to produce different static and parametrically-driven three-dimensional surfaces which would inform the bricks’ positions, with later instructions shown for the programming of the robotic fabrication. Concerning the fabrication process, the brick bond used had all the blocks parallel to each other, in a running bond fashion. The bricks used were 200x150x70mm, and had their longest edge perpendicular to the main surface. To overcome slight variations in brick sizing, gaps larger than 10mm were considered as part of the design process.

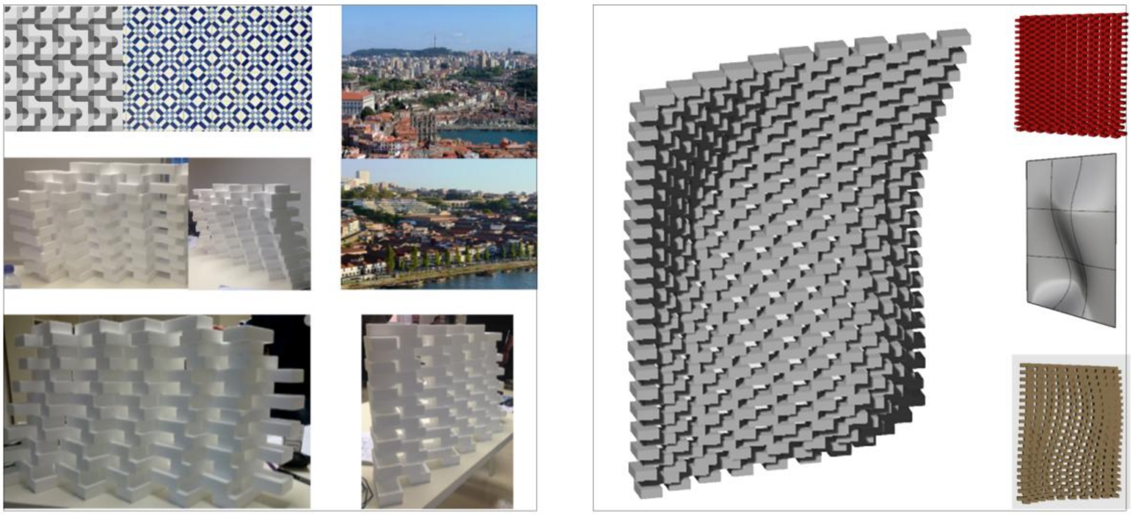

Fig. 3 Inspired by local patters, students developed an abstraction of a wall by first analyzing the desired effect with the help of manual models, and later applying digital means to define the surface and the patterns of the bricks to be robotically mounted.
Reference: image from Afaf Abou Zahr, Ali Saad, and Samah Zaatari

According to the participant level of expertise, a variety of approaches was used to achieve the three-dimensional surfaces that would ultimately generate the brick layouts. Among them, many students suggested following strategies using digital tools to loft and sweep surfaces further parametric combinations and transformations (Fig.3). In addition, some followed the procedure of defining curves, points and meshes to create patched surfaces. Few students also worked with topographic generation strategies by using grayscale images and predefined height field from image commands before applying grasshopper definitions to generate a more complex parametrically controlled surface.

The second class of the workshop dealt with one of the most attractive trends in fabrication, assisted by computer in architecture, with the milling fabrication process using a robotic arm. Specifically, the machine was equipped with a milling end-effector in order to carve eight 50x50x60 cm EPS blocks, forming a 120x200 wall, with a maximum thickness of 50 cm. Milling is a fabrication process specifically suited for the creation of freeform surfaces and textures. As such, the aim in this class was to develop an expressive 3D surface, inspired by motifs previously encountered in the city of Porto and similar to the brick positioning class. Design strategies for this class were similar to the first one. Rhinoceros and Grasshopper were the digital platforms used as the design tools to produce the tridimensional geometries and simulations of the robotic arm for the later fabrication stage.

The chosen project to be fabricated at the milling class was inspired from the curvilinear patterns of the pavements of the city of Porto, where the intention was based on transforming the curved lines into tridimensional composition on which an extrusion of the pavement square tiles on a surface representing the hills, would make the pixels disappear as they go downhill to create a sense of rough ups and smooth downs, defining the topographical imagination of the city merged with the pavements on its roads (Fig.4). During fabrication, the pixels would align themselves with the original material module, where the final product resulted in a fusion between rough pixels and smooth parts of a surface, creating a seamless formation between the two entities.

Fabrication conditions during milling stages set a series of restrictions (Fig.5). Therefore, students had to take into consideration such factors during the design process in order to limit surfaces variations. The milling tool is cylindrical, has diameter of 20 mm and a maximum cutting depth of 150 mm. As such, very intricate textures would be hard to fabricate accurately. In addition, very steep slopes greater than 80 degrees and deeper than 15cm were advised to be avoided in order to prevent collisions with the row material. The designed geometry had to be confined to a 200 x 120 x 50 cm. Nevertheless, voids were possible and encouraged to be developed even though only one side of the original material could be milled.

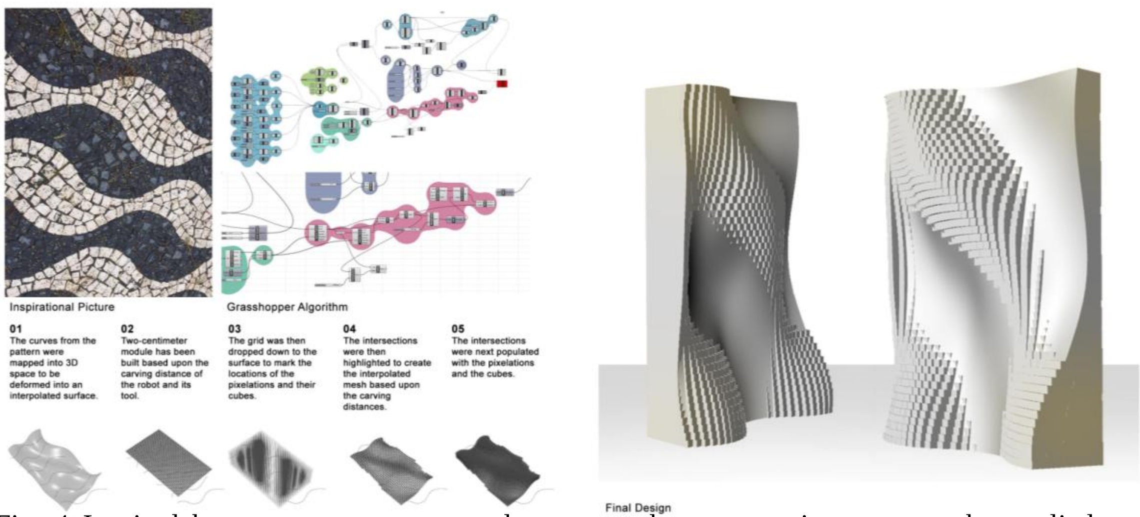

Fig. 4 Inspired by pavement patters, students created a parametric system to be applied on a surface in order to provide a sense of fusion between the smoothness of the surface and the roughness of pixels.

Reference: image from Nemr Nabbouh, Nour Rmadan, and Rami Sabbagh

Fig. 5 Gathering with students at the fabrication lab for explanation of the restrictions between design and production processes (left) and stage of fabrication of the milling class project where a block of EPS is being machined by the robot (right).

Reference: image from author

In the 2D cutting fabrication class, the robotic arm and a drill bit attached to it were used to cut and engrave two 120x200 cm colored wooden panels, also known as Valchromat, with 2D patterns inspired from geometric ideas The drill bit attached to the robotic arm was of cylindrical shape with a diameter of 12 mm head and a flat end. Therefore, an offset of 6 mm from each side of the cutting path was taken in consideration as part of the design as the void left by the tool, noting that the cutting path was an offset from the design contours. Among the design strategies, students applied a diversified use of curves with lines, array, offset, and rebuild commands to draw a basic pattern. Later, with the help of Grasshopper, a parametric system was defined in order to create a series of variations from the original patterns (Fig.6). Before fabrication, a parametric reinterpretation of the original design was set in order to generate a more abstract geometric pattern.

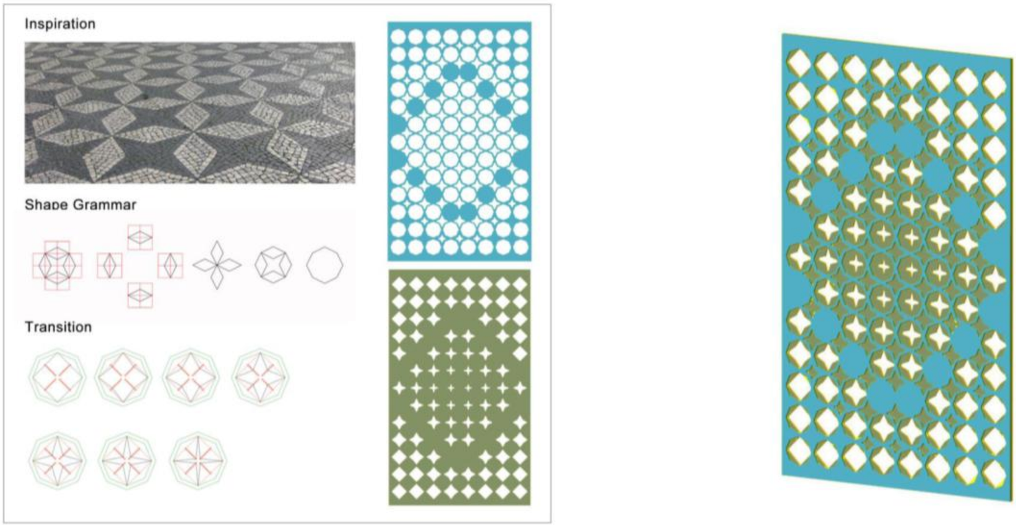

Fig. 6 Based on the shape grammar of patters, students were able to parametrize and alter geometries in a varied and at the same time fusing systems like the transformation of stars into squares, thus creating a systematic evolution for later fabrication.

Reference: image from Khodr El Jannoun, Mohamad Koubar, and Mohanad Dandashli

In all classes, most of the students showed a very strong level of conceptual approach, using highly creative ideas for a diversified series of results. Experiencing a great degree of freedom fused in the conceptual and design phases, allowed students to come up with unconventional results that, once rationalized, were able to be presented and produced at a small scale with the use of 3D printers. The chosen proposals for fabrication also proved that the balance among ideas, design processes, and fabrication were satisfactorily achieved.

Students at the workshop had the possibility to experience the implementation of the parametric thinking set up as the main strategy during the design process, which allowed them to experiment a variety of formal variations in order to balance it with their intentions, in addition to linking such processes with advanced automated fabrication. Such ways of advanced design and production requires a way of thinking where variations play an important role in the process of acquiring non-standard design approaches and formal results. Since ideas, processes and fabrication links require a more dynamic way of thinking from the traditional one, targets and programs are set in more complex ways. This innovative principle was an opportunity to expose students to such trends and at the same time to increase their design cultural background, leaving creativity open to possibilities that were first taken to extreme levels, and later finding a balance with restrictions for further concretization of proposals. It is worth mentioning that the general feedback obtained from the majority of students right after the workshop was very positive as most of them commented that this event has actually influenced them to be more technologically oriented, and motivated them into applying more advanced strategies in their coming design projects.

The workshop has been taken in the course of intensive days of work, which helped students to quickly react to the challenges facing the process of design and fabrication using advanced tools. Some students were not familiar with such trends before and the exposition to such conditions motivated them to rapidly learn new tools and to come up with quick and creative responses. In a struggle to understand the principles behind a final picture, students were required to make deep geometrical descriptions and to generate complex shaped definitions of the basic design in order to apply a series of parameters that would be later translated as the starting point of their designs. Once defined the parameters, they would think on ways to increase the level of complexity of the patterns in order to reach a more complex product, and to explicitly show the effects of their inspirations. With a tight schedule set up to fulfil the academic curriculum, the workshop was the ideal environment to experiment contemporary technology trends that are becoming as imposing as promising in the provision of innovative alternatives in the architectural field.

Being aware of the values of technology and what it can do nowadays was one of the main goals of the workshop. Its result helped students to quickly analyze the design and construction principles of buildings of advanced spatial complexities and to understand in a broader perspective the link among concept, design process and building using advanced construction principles. For instance, having looked at Antoni Gaudi's work in Barcelona, especially at the Sagrada Família, where his ingenuity of conceptual approaches extracted from nature and mixed with innovative geometrical principles that lead to the challenge of building architectural forms never seen before, made greater sense to students at the time of understanding the reasons behind the continuous inhabitation of technology in such a project until recently (Fig.7).

Fig. 7 Robot fabricating a stone component for one of the facades of the Temple of the Sagrada Família.
Reference: image from the archive of the Sagrada Família

By introducing high tech tools, both software and hardware, the process of designing and building of the Sagrada Família has become more dynamic, keeping the reliability of Gaudí's design principles, in addition to a faster, optimized and totally consistent product which comes directly from the designers' parameters and guidelines. (Burry, 2002) With the help of high tech systems, it was possible to optimize time and material in construction, in addition to defining a series of options for components before approval, with the aesthetic precision needed to be followed in order to comply with Gaudí's principles. With such a system, it was possible to build an architectural component fully automated in the early 1990s, being this fact not just a total success, but an unprecedented way to build architecture with the help of high tech tools. Advanced softwares, 3D printers and robots are commonly used to face the challenges left for the completion of the project, supposed to be concluded by 2026.

Other projects by Gaudí such as the Park Guell, La Pedrera and Casa Batló were also able to intricate students by questioning how to interpret formal complexities conceived before the digital era and to assess the effort put to translate such projects into reality, thus making of technology a luxury for those who have it at their hands today, and at the same time, to appreciate how innovation can be achieved. It is important to value historical achievements so as to set targets for the future since if we lose track of history and traditions, it becomes hard to trace a track for the future. Exposing students to such conditions leave no doubts to express the need to bridge education with practice, especially when dealing with high tech, since this is still a trend being in the continuous process of development, and due to its impossibility to define limitations, it will stay as it is, a trend, and not a style.

5. CONCLUSIONS

It is indispensable to value the history of technology in architecture. Pioneer architects are keen to using technology in the service of the professional practice. However, it has to be clear that technology is constantly advancing and it has to be successfully imposed so that it becomes a tradition. At the same time, the danger of tradition lies in the growing difference between culture and technology in our contemporary world. If we lose track of traditions, it becomes hard to trace a track for the future.

It is hard to have imagined technology manifestations and at the same time to predict what is to come in the technology expression of designing and building. And in this sense, academic institutions are crucial to the development and for the progressive evolution of active, dynamic, and connected environments. Such features are fundamental to making an institution successfully up to date. However, due to the attack of technology and the changing nature of architectural practice, constant update is required. Such needed approach is often utterly opposed to much of the rigid, unpredictable and outdated methods to teaching students in many schools. 20th-century thoughts, concepts and ambitions should be changed to 21st-century ones. But architectural technology is not only limited to structural systems, CAD, 3D printing, and robotic fabrication of advanced shapes.

Many educational institutions have seen some of the changes to come, but have fallen into the irrationalities of some digital tools and robotics. This is an experimental platform where intentions and trends are slowly defined through awareness, progressive research, and constant experimentations. Adequate environments should also be provided to students in order to generate motivation and at the same time boost investigation in a rational manner. Today, even the most dedicated in the machine revolution cannot escape the digital world's willingness, temptations and frustrations. As designers, a rapid movement between the real and the virtual constantly happens. The workshop which was conducted as an experiment involving students to react to cutting edge trends, has proven that they were able to cope with both creative processes and restrictions regarding fabrication procedures, thus finding an adequate balance between merging digital data and physical results. What and how it is visualized have drastically multiplied, therefore beliefs and principles of the last century are almost obsolete and must be updated. It is crucial for architectural schools to involve students in tasks requiring mental and spatial abilities rather than dynamism principles of clean lines, pure boxes, glass walls and instructions beyond reproach.

REFERENCES

- Bonet, J. (1997) Experimentació tecnològica sobre l'arquitectura de Gaudí a la Sagrada Família. In: Butlletí de la Reial Acadèmia Catalana de Belles Arts de Sant Jordi, n. 11, 1997, pp. 279-290.
- Burry, M. (2002). Gaudí and Information Technology: An Architecture of Real Absence and Virtual Presence. I:n Gaudí 2002: Miscel-lània. Barcelona: Editorial Planeta, pp. 200-215
- Corser, R. (2012). Fabricating Architecture: Selected Readings in Digital Design and Manufacturing. New York: Princeton Architectural Press, 10-13.
- Dun, N. (2012). Digital Fabrication in Architecture. London: Laurence King Publishing.
- Gu, N., Wang, X. (2012). Computational Design Methods and Technologies: Applications in CAD, CAM, and CAE Education. Hershey: Information Science Reference
- Kolarevic,B., Klinger, K. (2013). Manufacturing Material effects: Rethinking Design snd Making in Architecture. New York: Routledge, 20-36
- Lewis, R. (1987). Trends in Computer Assisted Education. Blackwell Scientific.
- Lynn, Greg. (1998). Animate Form. Princeton: Princeton Architectural Press.
- Meijs, P. (2014). Rapid Prototyping and 3D Printing in Architecture. San Francisco: Blurb, Incorporated.
- Schodek, D., Betchold, M., Griggs, K., Kao, K., Steinberg, M. (2005). Digital Design and Manufacturing: CAD/CAM Applications in Architecture and Design. Wiley
- Shelden, D. (2002). Digital Surface Representation and the Constructability of Gehry’s Architecture.
- Vitruvius. (1914). The Ten Books on Architecture. Harvard University Press, p. 3.