

Digital fabrication and art-exhibition design: a case study

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Abstract

One of the countless applications of technology in the architecture practice that goes beyond simple representation and can contribute directly to the design process is digital fabrication. It allows the automated production of physical objects from digital models and its use can range from explorative model making during the design process to the production of final products. An example of the application of digital fabrication techniques in cultural heritage is presented here, not just as a representation technique, but as an effective aid during the design process. The aim of this undergoing research is to produce physical models of exhibition spaces as an exhibition planning tool. The purpose of these models will be to help a team of curators and exhibition designers to experiment with the location of paintings and sculptures in a collaborative way, while planning the remodeling of an art museum's permanent exhibition. The digital fabrication techniques that are being used in this project include 3D-scanning, 3D-printing, and laser-cutting.

Keywords: digital fabrication, design process, exhibition planning

1 Introduction

One of the countless applications of technology in the architecture practice that goes beyond the simple representation and can contribute directly to the design process is digital fabrication, which includes rapid prototyping (RP) and other automated techniques. It allows the production of physical objects directly from digital models and its use can range from explorative model making during the design process to the production of final products. An example of the application of digital fabrication and RP in culture heritage is presented here not just as a representation technique, but as an example of the use of new digital technologies during the design process.

The aim of this undergoing research is to produce scale models of a museum's exhibition rooms, with the purpose of planning new layouts, i.e., as a design tool. Digital fabrications techniques will be used in the construction of scale models of the rooms and the art work. These models are expected to help a team of curators and exhibition designers experimenting with the location of paintings and sculptures in a collaborative way.

2 Digital fabrication

The objective of the Laboratory of Automation and Prototyping for Architecture and Construction (LAPAC) of the School of Civil Engineering, Architecture and Urban Design of the University of Campinas is to explore applications of digital fabrication technologies in the process of design and planning, exploring all the possibilities proposed by Mitchell and McCullough (1995).

According to Schodek (2005), the difference between the new production methods based on digital models and the mass production methods is that they do not intend to produce identical copies of the same product. On the contrary, they are systems that adapt themselves to produce a great number of solutions in different forms. This new concept is called "mass customization" and was first used in architecture by José Pinto Duarte (2001).

The new production methods are not just mechanic, but computer controlled, like CNC – Computer Numeric Control machines, usually associated to milling machines. The automated production methods of digital models can be categorized by (1) their purpose, (2) the number of axis they work with and (3) the way objects are produced.

Regarding their purpose, they can produce from mockups and functional prototypes to final products, such as architectural elements which can be placed directly in the building. In the former case these methods are referred to as prototyping methods, while in the later case they are referred to as fabrication or manufacturing systems.

In regards to the number of axes, these systems may have two, two and half or three dimensions. An example of a two dimension system is a vinyl cutter, because it can only cut papers or thin materials. A CNC milling machine working with a single spindle can cut flat figures and emboss, but it is not able to produce three-dimensional complex models. For this reason this kind of equipment is frequently called 2.5D. Meanwhile, a machine with 3 spindles or a 3D printer are considered effectively 3D (Figure 1).



Figure 1: 3D printer – an effectively 3D system.

Regarding the way objects are produced, the automated methods can be subtractive, formative or additive. Subtractive systems can sculpt blocks of material using a drill that moves automatically in three directions, sometimes with the help of a rotating axis that moves the block. It starts with a block and machines away the material that is not required, such as in CNC mills. Formative systems work like a versatile model that adapts itself to different forms by bending or folding metal sheets and tubes according to a digital model. It can cut, shape or cast material in a mould. Finally, additive systems consist of adding layers of material until the 3D object is formed (Volpato, 2007). To do that, the software needs to create horizontal slices of the digital model that are printed layer by layer or cut and glued one on top of the other.

According to Buswell (2007) this type of digital fabrication method can be categorized according to the material used. Five different methods are described below:

(1) FDM - Fusion Deposition Modeler – In this technique a narrow bead of hot plastic is extruded and selectively deposited where it fuses to the existing structure and hardens as it cools;

(2) SLS - Selective Laser Sintering - This type of machine uses a laser to partially melt successive layers of powder. Each layer of powder is deposited over the bed area and the laser targets the areas that are required to be solid in the final component;

(3) SLA – Stereolithography - In this type of machine, liquid photopolymer resin is held in a tank. A flat bed is immersed to a depth equivalent to one layer. Lasers are used to activate the resin and cause it to solidify. The bed is lowered successively so the next layer can be built;

(4) 3DP - 3D Printer - This technique is based on inkjet printer technology. The inkjet selectively deposits a liquid binder onto a bed of powder. The binder effectively ‘glues’ the powder together;

(5) LOM - Laminated Object Manufacturing – This process uses a carbon-dioxide laser to create successive cross-sections of a three-dimensional object from layers of paper with a polyethylene coating on the backside. Each layer is glued to the previous to form the object.

According to Buswell (2007), “Rapid Manufacturing, Rapid Prototyping, Solid Freeform Fabrication, Additive Manufacturing Technologies, all refer to the same family of processes”. It means that all these processes produce components by adding, or building up, material to form an object; that is the reason why they are called additive methods.

Another method that is frequently associated with digital fabrication is 3D scanning, which is used for acquiring 3D data in reverse engineering, and in the evaluation of final products. There are different methods for acquiring 3D data from physical objects: mechanical, laser-based, and image-based. The later method is less precise but less expensive, and can be either partially or completely automated.

Although areas such as industrial design and mechanical engineering are already well set with Rapid Prototyping and other digital fabrication techniques, the use of these methods in the architecture and cultural heritage fields is still in the beginning. According to Wohlers (2007) the use of Rapid Prototyping for architecture has been increasing significantly since 2006, but is still a long way behind if compared to the consumer products and electronics fields, the leading sectors (Figure 2).

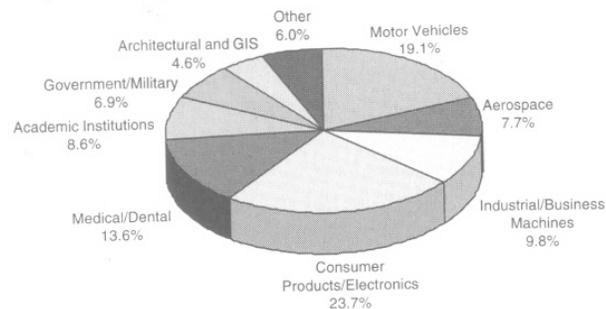


Figure 2: Main applications of Rapid Prototyping in 2007 (Wohlers, 2007).

3 The museum

Founded in 1905, Pinacoteca do Estado was the first art museum to open its doors to the public in the city of Sao Paulo, Brazil. It is today one of the largest museums in the country, with an area of approximately 4.000 sq m (43.000 sq ft), a 6.000 works collection of 19th and 20th century Brazilian art and more than 20 exhibition rooms. Pinacoteca is installed in a historical building located in São Paulo's downtown, next to the city's main train station, Estação da Luz. The three-story, classical style building was designed by a famous Brazilian architect, Ramos de Azevedo (1851-1928), and built in the final years of the 19th century, as Sate School of Arts and Crafts, but it was never completely finished (Araujo, 2002). In the 1990's, the Museum director, Emanuel Araujo, hired architect Paulo Mendes da Rocha to completely remodel the building, adapting it to contemporary museum space standards. Nowadays temporary exhibitions are displayed on the first floor, and the permanent collection is shown on the upper floor. Technical areas are located on the ground floor.

One important challenge to be faced by Pinacoteca's curatorial team in 2008 will be the remodeling of the permanent collection exhibition. The exhibition that currently occupies the upper floor of the museum is more than 10 years old and needs to be modified not only in terms of the works on display, but also regarding the communication of the exhibition (wall texts, labels and multimedia).

The project for redesigning the layout of Pinacoteca's permanent collection will include a series of interviews with the public of the museum as well as with specialists invited to give their opinion during the process. The new exhibition is intended to be on view in 2010, when the museum celebrates its 105th year of existence.

In order to make the design process more effective, the curators of Pinacoteca initially asked LAPAC to develop computer renderings of the new arrangement of pictures and sculptures in the galleries. A research was conducted to find out about digital exhibition planning tools. Although digital databases are used for exhibition management (Moon and Kim, 2008), and virtual reality is often used for online exhibitions or interactive exhibitions inside the museums (Sparacino et al, 1999; Hirose, 2006), not much was found about the simulation of exhibition spaces with digital means. Woolner and Howard (2007) describe a virtual reality system developed to "extend the physical exhibition (...) in response to the need for greater public access". The passage below describes the system, called Panoramic Collections Viewer (PCV), which is shown in Figure 3:

"Within the PCV's Room & Asset Selection environment, the collections management information is explored to select and group appropriate assets into folders using the Organiser, where the gallery files in which the assets are to be displayed are also selected. Layout plans of the rooms are displayed on screen, as are thumbnail images of the assets. The assets, with or without their attached metadata, are

placed on the walls, floor and plinths or even floating within the environment using a simple and user-friendly method by which they are automatically scaled and orientated using the guides available to indicate sightlines. Immediately the viewing environment enables 360°x 360° navigation of the gallery spaces with the exhibition assets in position” (p.2).

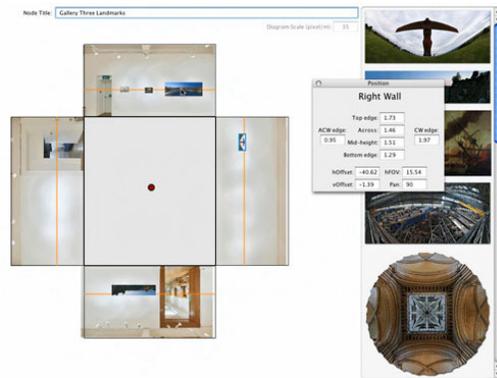


Figure 3: Woolner and Howard's (2007) Panoramic Collections Viewer.

Although the purpose of PCV is to create virtual exhibitions for the Internet, the system could easily be adapted as an exhibition planner for curators. However, a virtual system would still be hard to use by a team of curators, and would give them a fragmented view of the museum space.

The next hypothesis was to build a scale model of the museum, which would be more interactive and easier to manipulate by multiple designers simultaneously. During the research, nothing had been found about the use of physical models as a planning aid for museum curators, even in journals such as *Curator*, *Archives and museum informatics*, *Museum international* and *Museum management and curatorship*. The curators liked the idea, but the model would have to be carefully planned, in order to meet the following requirements: portability and storability, the possibility of showing the museum as a whole and at the same time of being used by different teams of curators, the possibility of previewing room views at eye level, the possibility to repaint the model's floor and walls to change their colors when needed, the possibility of easily "hanging" pictures on the model's walls, and the reproduction of not only scale paintings, but also scale sculptures. These questions such were carefully discussed with the museum curators.

4 The model

Just like in any kind of construction or product development, a scale model of a building needs to be carefully planned. The objectives and requirements of the model need to be defined, and materials need to be specified in detail. In this case, the availability of digital fabrication tools at LAPAC determined the production techniques to be used: laser cutting and 3D-printing. The design process started with sketches and practical experiments in the laboratory (Figure 4).

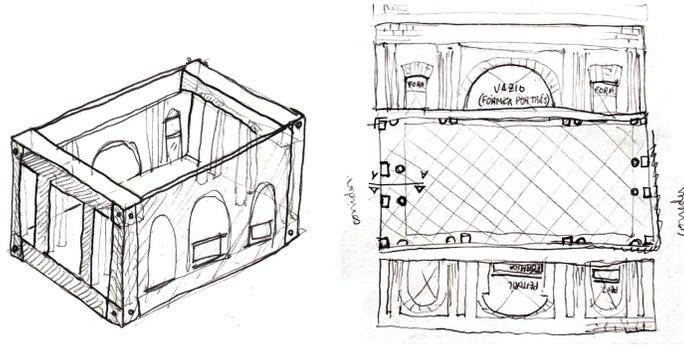


Figure 4: Initial sketches for the museum's scale model.

Scale

In order to decide which would be the best scale for the models, mock ups of the larger and the smaller exhibitions spaces were produced in corrugated cardboard at 1:50 and 1:25 scales, along with samples of paintings and sculptures (Figure 5). Photographs of these mockups were taken through their door openings, in order to show the curators the type of image that they would be able to obtain once the model was ready (Figure 6).



Figure 5: Mockup scale comparison: 1:50 and 1:25.



Figure 6: The 1:25 mockup furnished and a view through an opening.

In the 1:50 mockup the smaller paintings and sculptures were too small to handle and displayed a very low level of detail. The 1:25 scale was chosen by the museum curators, despite the resulting larger size of the model (approximately 2x3m overall), which would make it more difficult to store.

Modularity

Since the new exhibition has primarily to deal with the best of the museum's collection, displaying pieces from early 19th century until contemporary art, the project will be developed by different teams, which will work according to their area of expertise. One important requirement for the making of the model was the possibility to work with it in separate parts – in a way that each team could be able to study and make propositions for its section – still keeping the connection to a master plan. Therefore, the model needed to be split in separate parts, so that each team can bring part of it to its own department. At certain times, however, they will need to put the connecting rooms together in order to see the exhibition as a whole.

For this reason, instead of making one large model, the LAPAC team decided to build separate boxes for each room. The curators will be able to connect the boxes, when necessary, by placing them on top of a 1:25 scale plan of the museum, printed on a foldable canvas, which is easy to store (Figure 7). This strategy allows the model to be easily transported and stored.

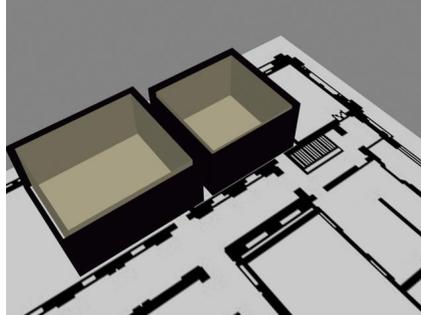


Figure 7: Models of two exhibition rooms over the canvas base.

Materials

6mm-thick MDF was chosen for making the models, due to the possibility of easily cutting this material in LAPAC's 60watt Universal Laser Systems machine. 3mm-thick MDF was also used for applying extra volume in places where the walls are not flush (Figure 8). To avoid gluing the parts of the boxes, L-shaped aluminum brackets were used to connect them, with large bolts on the bottom and the top of the models (Figure 9). A floating floor system was developed, in such a way that the lower bolts would not be seen in the inside of the boxes (Figure 10). The floor boards lay on top of invisible aluminum brackets. This strategy allows to easily disassemble the models for storage or in order to change the colors of the floor or the walls.

0.4mm Formica was used for making details such as skirting boards and door moldings (Figure 11). This material can be easily cut and scored by laser.

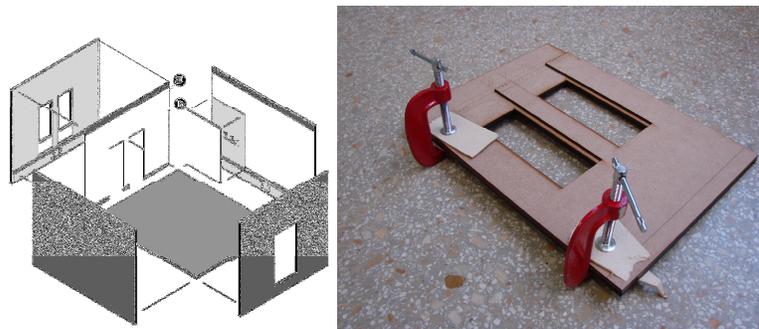


Figure 8: Applying add-ons where the walls are not flush (a and b).

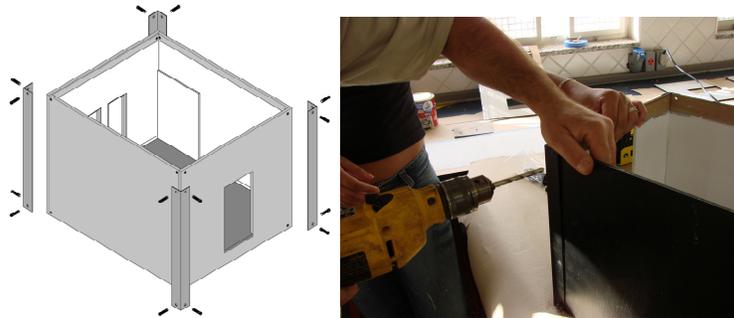


Figure 9: Aluminum brackets and bolts for connecting the walls.

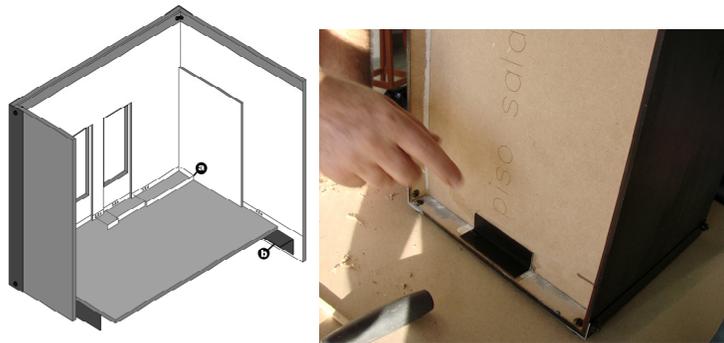


Figure 10: Floating floor laying on an aluminum bracket (b), and the application of the Formica skirting board (a).



Figure 11: Door moldings made up of 0.4 mm Formica, cut and scored by laser.

Functionality

In order to allow the curators to freely play around with paintings on the models' walls, magnets were used. Tests were carried out in order to decide whether the walls would receive a coat of magnetic paint or metal stripes. The initial tests with the magnetic paint showed its efficiency with the application of three coats of painting. A final coat of white paint had to be applied, because the magnetic paint is grey (Figure 12).



Figure 12: Application of magnetic painting.

Production techniques

2D digital drawings were prepared in CAD software to be sent to the laser cutter to cut the walls in MDF sheets (Figure 13).

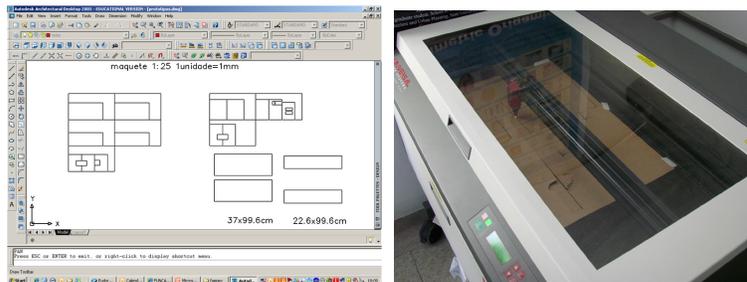


Figure 13: Laser-cutting the CAD drawings.

The museum equipment, such as display boxes and benches, were also Cad-drawn and laser-cut (Figure 14).



Figure 14: Benches and display boxes.

The museum paintings, which have already been photographed, were printed with a high resolution color laser printer, and mounted on top of magnetic sheet bases, with laser-cut frames made of 1mm bass wood (Figure 15).



Figure 15: Magnetic paintings placed on the model's walls.

The next phase of this work-in-progress will include the production of scale models of the museum's sculptures. Three different 3D scanning techniques are presently being tested for this purpose: a laser system, a structured light system (Figure 16), and a photogrammetry software. The resulting 3D models will be rapid-prototyped with a 3D-printer.



Figure 16: Testing the structured-light system for 3D scanning at LOPCA, a laboratory at UNICAMP's School of Chemical Engineering (FEQ).

5 Discussion

So far, one third of the model has been completed and delivered to Pinacoteca (Figure 17). The museum curators are very optimistic about its use as a truly collaborative design environment. According to Ivo Mesquita, one of the head-curators, the model will give the team the possibility of seeing the museum as a whole, and not only as separate rooms. The model will allow the curators to have full control of the narrative about Brazilian art they are trying to put up without actually moving the works from place to place. It will make it easier for curators to experiment with different displays, exploring alternative dialogues between the works that are intended to be on view.

At the same time, the model will be an important tool for planning the correct location of information on the works and on artistic movements, such as wall texts and labels. The scale chosen will enable the analysis of the relationship between the works of art, considering their particularities of subject-matter, artistic style, technique, dimensions, mounting, framing, etc (Figure 18).



Figure 17: The museum curators observing the model.



Figure 18: A comparison between the actual museum space and the model.

When the model is complete, the design process that will take place around it will be registered, in order to assess the adequacy of the scale and materials used. Questionnaires will also be used, in order to check the curators' opinion about the model as a design tool. With this experiment we expect to collect data to help producing other models for helping museum curators plan new exhibitions.

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