Tactiles models of elements of architectural heritage from the building scale to the detail

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Abstract. This paper describes the development of three-dimensional models, produced using digital fabrication techniques with the goal of providing a haptic experience of architectural heritage. These models were produced in three different representations: the building as a whole, elements and details. This study first undertakes a process of analysis and the formal decomposition of architectural components to identify basic or simplified elements which make it easier to understand the represented object by touching. The results obtained come from assessment tests of the tactile models as experienced by mainly blind individuals. Secondly, as part of this process, a method of constructing such models is defined. This study facilitates a greater understanding of the relationship between the represented objects (historic buildings) and the tactile models, and provides a technological and discursive basis for future implementation of tactile models in a specific context.

Keywords: tactile models, architectural heritage, digital fabrication, haptic experience.

1 Introduction

This paper describes the production of tactile models, using digital fabrication techniques, aimed at promoting a haptic experience of the architectural heritage of Pelotas City. It is the goal of this study to demonstrate that these models could be made available on site, in the buildings they represent, for the purposes of educational tourism. Furthermore, it will show that the models could also be used in specific educational contexts in schools, fairs and exhibitions. The production of these models is designed specifically for use with the blind, but sighted individuals could also broaden their experience beyond the visual using the models.

An earlier study [1], described the use of tactile models to enhance accessibility to an exhibition of photographs showing a building of heritage interest. The references

Gabriela Celani, David M. Sperling and Juarez M.S. Franco (Eds.): The Next City: 16th International Conference CAAD Futures 2015, pp. 434-446, 2015.

used in that case were mostly from the area of museology, some of which highlight the importance of touching.

Neves [2], for example, points out that the brain interprets what we see, and therefore what our brain "sees" does not necessarily reflect accurately the image which came in through the retina. Thus, this author considers the possibility of "seeing" (meaning understanding images) through other senses by adding verbal and tactile means of interpretation.

Teshima [3] describes the development of didactic three-dimensional materials for blind individuals. According to him, the key for developing materials that can enrich the universe of observation through touch is to produce models that the visually impaired have never touched before. The author divides these models into two categories: (i) objects that we cannot touch in actual size, huge or microscopic objects; (ii) objects that cannot exist naturally, they are based on an abstract idea like mathematics, curved surfaces for example.

Although digital fabrication technologies make the production of these models easier, it is important for the objects to be understandable by touching. Therefore, some guidelines need to be considered in the design of this tactile interface. These include making the object"s form simple or braking it up into parts that can be fitted together. According to Teshima [3], it is not enough to make the 3d models*; "we need to use our brains to make models which are suitable for visually handicapped persons to touch"*.

Physical models play the role of tactile media, and often more than one model of the same object is necessary for a tactile comprehension of it. Therefore, the idea of drawing from the cinematographic scenes described by Bernardet [4] is reviewed in an attempt to achieve a fluid communication between the different models that build up a specific object.

Sarraf [5] considers that visual communication is losing its capacity of seduction; thus, he developed a communication theory using the five senses in cultural spaces. For this author, sensorial communication is key for the democratization of cultural and artistic heritage.

In the context of architectural heritage, we can consider the city as a cultural space which preserves historically relevant buildings for which public access and awareness must be made more democratic. Considering the cases outlined by Teshima [3], these historic buildings can be sorted into the first case: huge objects. Although the buildings can be touched, their form cannot be perceived by touching the object in actual size. Thus, the production of models of these buildings in reduced scale can provide a more comprehensive tactile experience. Furthermore, the fascination produced by these models is evident in people of all ages, thus bringing valuable attention to the architectural heritage of the city.

The importance of the tactile experience is currently highlighted in the field of architectural research, reinforcing the value of the multi-sensorial experience. Herssens and Heylighen [6] state that our experience with architecture is of a multi-sensory nature, that its appearance is important, but its feel, smell and sound also contribute to our experience. However, touching in order to achieve greater understanding of the elements of an exemplary piece of architectural heritage is often not possible due to the scale of the structure, the inaccessibility of its location or by its fragility. These authors consider that, in the context of architecture, the term “haptic” has a broader meaning than “tactile” because it involves not only cutaneous perception but also the perception of positioning, balance and movement in the built space.

Vermeersch and Heylighen [7] consider haptic perception to be a combination of tactile and kinaesthetic perceptions. Tactile perception interprets the variation in stimuli to the skin allowing us to perceive, for example, the texture of materials. Kinaesthetic perception informs through static and dynamic body postures, for example, an impression of length perceived through the relative distance between fingers. Haptic tools, according to these authors, are tools developed to provide the brain with information through the skin and muscles of the hands.

Another important aspect of this paper refers to technological matters. Many of the digital models of architectural heritage produced to date in this context were made for use in virtual reality and web viewing as static images or animations. Therefore, these models considered the possibilities of optimizing the representation of textures through the use of images. They do not have a corresponding geometry that can promote comprehension of an object through touching. The initial processes regarding the use of 3D printing techniques available in this context (additive process of plastic layer deposition) are described in [8]. Later, laser cutting also became available in this context of study, broadening the possibilities of digital fabrication. This led to a comparison between the two techniques for the production of models of several elements of architectural heritage, in particular metal railings. Thus, this study has as a starting point a recognition of the technological limits such as dimensions imposed by the machines available and the limitations of the techniques themselves, identified in these initial studies.

The architectural heritage represented is of eclectic style, rich in complex ornamentation. Several authors such as [9], [10] and [11] write about these buildings and strive to understand and explain the meaning of each element. However, very little appears in their works regarding a more detailed study of the geometrical aspects of this architecture, especially considering theories which make it possible to relate each one of the parts in a composition to the whole. Such theories could explain the logic of the facades and make the process of representation easier.

2 Materials and Methods

This research was divided into four stages:
Stage 1: Bibliographical review, identifying an interdisciplinary field according to the research examined in the previous section.
Stage 2: Establishment of a trial-theory for the production of the tactile models. This trial-theory was based on the bibliographic review and on the previous experience of the authors [1]. In this previous experiment a method was developed for the production of tactile models specifically to enhance the accessibility of an exhibition

of photographs of an industrial building. This method employed the "gradual addition of information". Therefore, the second stage of this study involves transposing our method, not from photographs but through the tactile models related directly to the three dimensional object. This stage includes the geometric analysis of the buildings, taking into consideration the meaning of each of their elements in the context of architectural history. The transposition of the method required planning of the decomposition and recomposition of the represented element and the production of models in several scales. This process is described for each object included in this study in section 3.

The selection of the elements of architectural heritage to be represented in this study was influenced by three main factors: the potential of the object to broaden the group‟s understanding of the fabrication techniques available in this study context; the existence of a previous digital model of the object produced for virtual reality; and the interest in generating information about buildings belonging to the University in which this study takes place.

Figure 1 shows the buildings chosen for this study named as Case 1, 2 and 3. Only the building in Case 2 does not belong to the University, but rather to the municipality. However, it was chosen for this study due to its importance to the city and a recent partnership between the municipality and the University aimed at promoting the architectural heritage of the city through tourism, education and cultural initiatives.

Fig. 1. The three buildings chosen for the study

Stage 3: In this stage the experiment was carried out by a team of professionals from a range of disciplines including occupational therapy, architecture and broadcasting.

After the analysis of the data collected in the experiments with the tactile models for the photographs, a brainstorm exercise was carried out in order to transpose, in a critical manner, the gradual addition of information. In this process, the need to have a more fluid transition between the layers of information was identified, which led to a search for new references and to the hypothesis that cinematographic language could contribute to this process. Thus, the method of gradual addition of information was re-interpreted. The framing of the camera defines each one of the three-dimensional models as the scene of a layer of information, while the zoom movement of the lens defines the detail of this information, determining the scale of the model, either to explain the location, the overall form of the building or each one of its components.

Personal perception was also examined during this brainstorm process, as a factor that would affect how accurately the models would be decoded. Testing the models with a blindfolded sighted person was suggested as a possible means to measure the precision of the development of the models. First the experiment would be carried out blindfolded, and then the blindfold would be taken off. This would make it possible to determine whether the mental image created by the models matched the actual 3D model.

Stage 4: In this stage conclusions are drawn about the results of the experiments, and proposals made to systemize the production of models as a means to continue the representation of the architectural heritage in question.

3 The Production of Tactile Models: Analysis, Formal Decomposition and Recomposition

The architectural elements represented for each case of this study, a dome, a balcony and metal railings, had been previously modeled for the production of photorealistic images, animations, real time viewing and anamorphic images [12]. These models were taken as a starting point for the production of the tactile models.

3.1 Case 1: From the Representation of the Dome to the Building

The dome of the building (Figure 2), characterized as Case 1 in the context of this study, is one of the most popular elements of architectural heritage in Pelotas. This building, called Grande Hotel, is characterized by its eclectic style with Art Nouveau influence. It was designed by the civil engineer Theóphilo Borges de Barros and built between 1925 and 1928 [9], it was a hotel and also a casino and is currently being restored to be a teaching hotel.

The digital model of the dome, which was initially used in this study, was produced as a didactic activity in a graduate course (image on the left in Figure 2). The first model in 3D printing of this element was produced during the process of analysis of the compatibility of the existing model with the digital fabrication technology available.

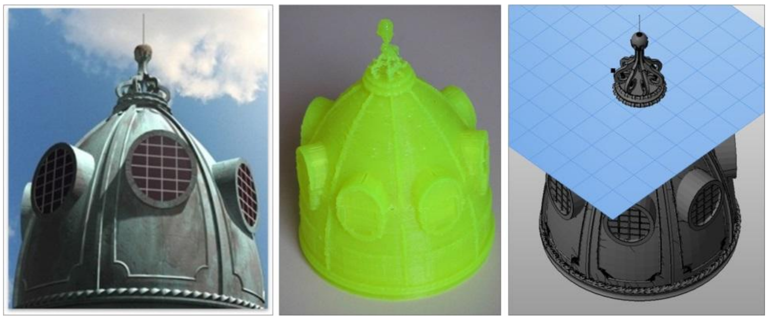

Fig. 2. Digital representations and 3D printed model of the dome.

The model had been made mainly for obtaining static images and, therefore, presented several problems for use with 3D printing such as overlapping elements and a very high number of polygons. These problems were fixed and some parts were even re-modeled to allow the 3D printing of the dome shown in the middle image of Figure 2. It is possible to observe that there were some problems with the printing of some complex elements due to the reduction in scale. The studies, at this point, were aimed at understanding the limits of the technology available considering complex geometries and compatible scale. At this point the studies did not yet consider the need to understand the model by touching. The image on the right in Figure 2 demonstrates the solution of breaking up the digital model for printing, which sought only to solve the problem of resolution of the model, and not the quality of tactile information that it could offer.

In order to apply the method of gradual addition of information, the modeling process was analyzed, decomposing the form and identifying its basic elements. Figure 3 illustrates the modeling process, highlighting the rule of cyclic symmetry, which helps in understanding the form of the dome.

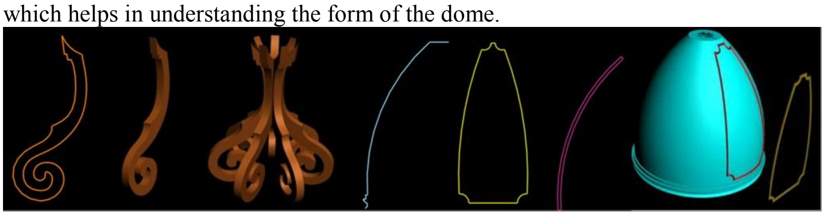

Fig. 3. Decomposition and recomposition of the dome.

Given the need to produce models of the building as a whole, and in particular to focus on the relative position of the elements on the facade, an analytical study was carried out of the geometric aspect of the exterior form of the building. Figure 4 shows an example of the kind of analysis carried out showing implicit geometric figures such as rectangles with the golden ratio and square root ratio, both very common in buildings of that era. This analysis also contributed to the description of these facades regarding the position of each element, and suggested a logical sequence for the addition of information.

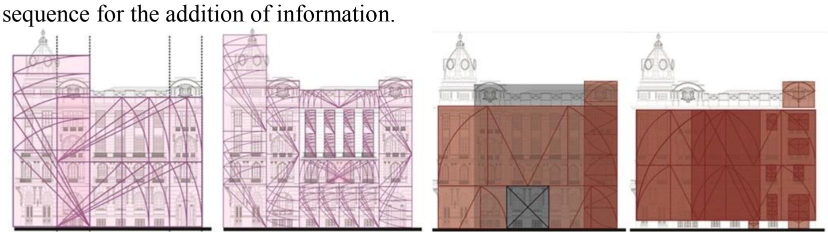

Fig. 4. Geometric studies of the main facade of the building of case 1.

Figure 5 shows, in the first line, part of the plan for producing the models of Case 1 taking into consideration the scale and how much detail to include in each model. The second line in Figure 5 shows the tactile models produced, from left to right: the location of the buildings of Cases 1 and 3; a simplified model of the building, which allows whoever is touching it to understand the overall shape of the building, the number of floors, the position of the dome, and the shapes and number of the windows; the dome in a larger scale with all its ornaments: this model lets us identify, by touching, the relative position between the elements of the dome as well as its shape. The fourth model is of one of the windows of the dome in a larger scale to allow a better understanding of its form and how it fits onto the body of the dome; the fifth model is of the crown of the dome in a larger scale allowing a better understanding of each one of its elements. This model was also produced in two formats of separate pieces for assembling (sixth and seventh images) in order to explain the underlying rules of the geometric form.

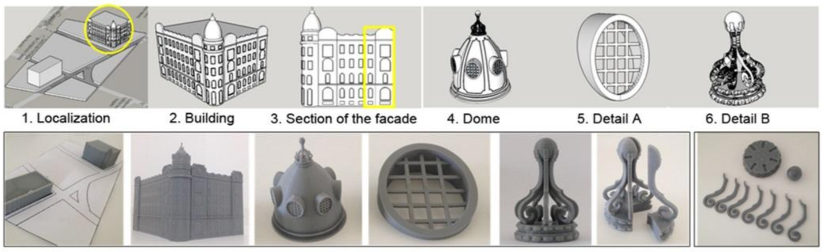

Fig. 5. Planning of the models and models made for case 1.

3.2 Case 2: From the Representation of a Balcony to the Building

The building in Case 2 is of a classic eclectic style with colonial and baroque influences [9]. It was built before 1830 in colonial style and was renovated between 1875 and 1880 when José Antonio Moreira, the Baron of Butuí, hired the architect Isella Merote to renovate the house in the eclectic style already present in the neighboring houses. Currently, it has on its ground floor the House of Culture Adail Bento Costa and the city‟s Office of Culture on the second floor.

Fig. 6. Photographs of the building of case 2 and digital models of the balcony.

The digital model of this element (image on the right in Figure 6), initially used for this study, resulted from an exercise developed in the same context as the first model of Case 1. The third image in Figure 6 illustrates one of the steps in the modeling process, which shows the study of each element, identifying the logic in composition by using symmetry procedures, translation, reflection and rotation.

For the 3D printing of this model it was also necessary to correct several problems as in Case 1. In order to do so, most of it had to be modeled again. The thinness of its components (0,5cm in natural scale) and the fact that they present a curved surface caused problems for printing the balcony in a convenient scale as shown in Figure 7. To achieve the shape of the balcony shown on the image on the right, it was necessary to also use manual techniques and the model was still too fragile. Currently, further experiments are being carried out to find alternatives using this same technology, and further experiments are being planned for the use of laser cutting, taking advantage of the experience acquired with Case 3.

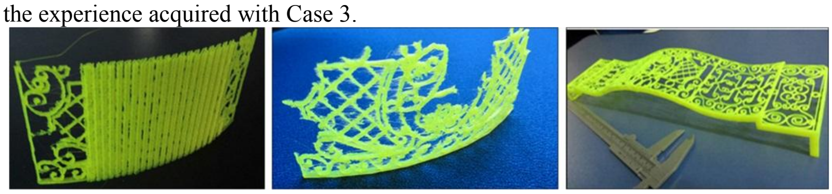

Fig. 7. Problems faced in 3D printing the balcony [8].

As in Case 1, an analytical study was carried out regarding the geometric aspects of the exterior form of the building, taking into account the need to produce models of the whole building. The aim of this analysis was to guide the process of production of the tactile models using the method of gradual addition of information.

3.3 Case 3: From the Representation of Railings to the Building.

The building in case 3 is of classic eclectic style with colonial and Baroque elements. It was built between 1884 and 1889 and belonged to the senator Joaquim Assumpção. It was gradually changed according to the family̏s financial condition [9]. Members of this family lived there until 2005 when it was sold to the university (UFPel) and became an administrative building.

Fig. 8. Building and elements represented for case 3.

Figure 8 shows the main facade of the building and the two railings used in this study. These elements had been previously analyzed and digitally modeled in an undergraduate context.

The railings on the wooden door was printed several times to evaluate the parameters both for modeling and for printing, considering the need for the model to have handling resistance, however, a suitable model could not be achieved. The search for alternatives led to the hypothesis that laser cutting would be suitable for the production of these models in order to achieve handling resistance.

Figure 9 shows the railing from the wooden door represented in a single model and also in separate portions. These parts of the railing are used as puzzle to demonstrate the implicit geometry such as regulating rectangles. These rectangles of specific proportions are laser marked so that each one can be recognized by touching. As in the previous cases, a geometric analysis of the facades was carried out to guide the study of the building as a whole.

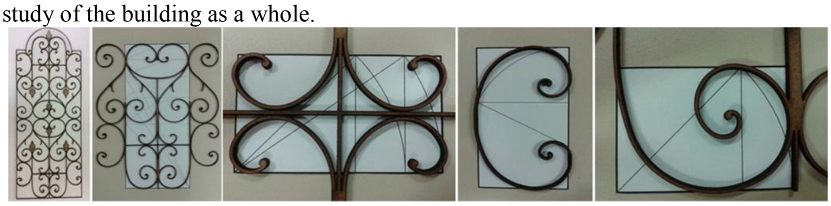

Fig. 9. Models produced by laser cutting to explain the form for case 3.

4 Experimentation With the Tactile Models Produced

Up to this moment, the experiments were carried out with the models produced for case 1. In the current stage of investigation, the experiments were focused only in observing the capacity of the models produced in informing specifically the geometric form of the architectural heritage represented. It was the goal of these experiments to evaluate the relevance of each layer of information with its proposed “framing” and level of “zoom”. Two volunteers took part in the experiments: the first, experiment 1, was carried out with a blind individual and the second, experiment 2, was carried out with a sighted individual, according to what was proposed and explained in section 2.

4.1 Experiment 1

The first experiment, was carried out with a blind volunteer of 21 years of age who started losing his sight at the age of 12 and was completely blind by 16. This volunteer has a visual memory, however, he only recently moved to this city and, therefore, has never seen the building of case 1.

The first model experienced by the volunteer was that of the building as a whole with simplified shapes on the facades (second image on the second line in figure 5). As he explored the model with his hands he started saying that he could understand it well. He identified the number of floors in the building, the difference in shape between the windows, he identified the location of the dome and its windows saying that he could make a good mental image of what the building is like.

The models touched next were those of the crown of the dome in a larger scale, both the one of the whole crown as well as the ones meant for assembling the crown (the last three images in figure 5). In his opinion, only the crown as a whole is already enough to perceive the shapes that build it up. The model made up of several pieces of the elements of the crown (last image in figure 5), was very confusing. The model in which a slice of the crown fits in with all the rest of the crown helped to notice how the shapes repeat themselves.

The next model to be handled was the one of the dome. The volunteer indicated that he had already noticed the number of windows and their position in the model of the building, indicating a redundancy in the information. However, this model was important to provoke the perception of more details in the windows and crown, to complement the connection with the larger models of these elements. In the sequence, while handling the larger model of the dome‟s window he noticed the square shapes formed by the railings on the window and asked if the other windows in the building were also like this (they are not). In this case, the need of other framings was noticed, such as the one planned to show a section of the facade.

Lastly, the model of the location of the building with its surroundings showed to be problematic. The volunteer considered that it would be better to identify the streets by a single continuous line, interrupted only by the name in braille.

4.2 Experiment 2

In this second experiment there was the purpose of observing the performance of the same models used in experiment 1, however, with a sighted person, initially blindfolded. This volunteer is a 28 year old woman who was born and currently lives in Pelotas and often walks past the building. Before the experience started she was informed about which building the representations were of.

The first model handled was one of the seven volutes of the dome‟s crown, with the intention of starting from the basic elements of information to explain the composition. Her reaction was an attempt to associate the element to the geometry of metal railings. As she touched the following model (crown with a removable slice) the volunteer stated that she could understand how the crown is composed. She put both pieces together and identified the object. The third model (of the crown in one piece) didn‟t add any relevant information, since the form had already been comprehended through the previous models.

The next model presented was the model of the dome which allowed the volunteer to notice how the windows were positioned. As she handled the model of the dome‟s window she stated never having noticed that he top of the window was thicker than the bottom, but that this made sense given the curved surface of the dome. In handling the next model, of the building, the volunteer was surprised to notice that the windows had different shapes, she had never noticed this difference.

The last model was the one of the location and, in this case, it was necessary to guide the volunteer‟s fingers explaining that the lines represented the curb of the streets. She asked the name of the streets and recognized the location.

Following this, the blindfold was removed and the volunteer expressed a great fascination by the models, continuing with the haptic experience, realizing the pleasure in handling the models, incremented by the visual experience. For her, the mental image created of the models was very close to the vision she had of the models after taking off the blindfold.

5 Results and Discussion

The results have encouraged us to continue and intensify the investment in the production of the models. Partnerships are being established with public and museum institutions to use the representations produced so far.

The method based on analysis, deconstruction and reconstruction of the form, allowed the information to be made available by layers, broadening the knowledge about the architectural heritage represented both for sighted and blind individuals. The formal relations of the buildings should be broadened with the use of the models from case 3 making the matters of proportion more explicit.

Even when the visual experience is possible, the haptic experience proved to be very positive in bringing closer elements that are too far to be noticed as well as allowing a different perception from the usual visual on site experience. Touching highlighted certain aspects of the architectural heritage involved which often go unnoticed.

The absence of the planned model of a section of the facade of case 1 which should bring the ornaments, proved to be relevant since such model could have helped in the perception of the historic period of the building especially by blind individuals. It was also noticed that the order in which the models were handled did not influence the comprehension about the architectural elements represented as long as the models were accompanied by the description of each model.

For the comprehension of the overall shape of the building, the place of the elements in the building as well as its formal aspects, the models in 3D printing by plastic deposition showed to be adequate. However, for very thin elements such as the metal railings, a stronger material is necessary and, thus, the laser cutting allowed these models to have handling resistance.

On a technological point of view, for the specific context in which this study is inserted, the experiments of production of such models from digital fabrication techniques has promoted the diffusion and acknowledgement of this technology.

6 Final Considerations

It is considered that the study achieved its goal of producing tactile models that can give information about the architectural heritage involved to blind individuals and add information to sighted individuals. However, it is important to consider that it is the intention of this study to add further geometrical and historic information with the models that are still to be tested.

The experiments carried out so far have proved to be very useful indicating several improvements to be made on the models. Further testing with individuals with different cultural levels regarding the heritage involved and with different visual abilities (individuals born blind for example) will make it possible to produce the models to reach the widest variety of profiles possible.

Acknowledgements.
The models produced for case 1 were printed in partnership with Massiva Comunicação Sólida.
This research had funding from CNPq, Capes and ALfA program.

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