Tactile scale models: three-dimensional info-graphics for space orientation of the blind and visually impaired

Gabriela Celani

Architecture and Building Prototyping Laboratory, School of Civil Engineering, Architecture and Urban Design, State University of Campinas (UNICAMP), Brazil

Luís Fernando Milan

Undergraduate course in Architecture and Urban Design, School of Civil Engineering, Architecture and Urban Design, State University of Campinas (UNICAMP), Brazil

ABSTRACT: The present research started with the two following research questions: What kind of architectural details should be present in a tactile model? Is it possible to build a tactile model with rapid prototyping techniques? To answer these questions it was necessary to study, on one hand, the spatial perception of the blind and visually impaired and the production of tactile models, and on the other hand the available rapid prototyping techniques and materials, as well as 3d modeling procedures for outputting correct STL files. As an outcome of the research, tactile models for UNICAMP's central library were produced in two different scales with the Selective Laser Sintering (SLS) technique, at the Rapid Prototyping Laboratory of CENPRA (Centro de Pesquisas Renato Archer, Campinas). The models were evaluated and tested by people with different types of visual impairment, with a qualitative method. Many conclusions could be drawn, some of them related to the physical characteristics of the models and other related to spatial perception. For most of the people interviewed the models were very helpful for spatial orientation. One of the most interesting conclusions was that blind people, like people who can see, can have different levels of easiness to understand abstract representations of space.

1 INTRODUCTION

The present research was developed by Luis Fernando Milan, an undergraduate student in architecture at the state university of Campinas (UNICAMP), advised by professor Gabriela Celani. To develop his study, the student received a one-year grant from CNPq (Brazil's national research funding agency). The interdisciplinary theme of the research was the result of the student's attendance to two different classes: "Universal design", taught by professors Doris Kowaltowski and Nubia Bernardi, and "Digital modeling", taught by professor Gabriela Celani. In the first subject the student learned about accessibility and special actions for adapting buildings for the blind and visually impaired. He also produced a tactile model that served as a pre-test for the present research. In "Digital modeling" the student learned to develop 3D digital models using different software, such as AutoCAD and 3DStudio, and learned about the possibilities of automatically producing architectural models with rapid prototyping. By relating these two topics of his interest he was able to formulate his research questions.

The present research started with two questions, one concerning the desirable characteristics of a tactile scale model and the other concerning the possible techniques for producing such a model:

Question 1: What kind of architectural details should be present in a tactile model?

Question 2: Is it possible to build a tactile model with rapid prototyping?

To answer these questions, the student had to develop researches on these two topics.

2 TACTILE SCALE MODELS

The construction of a mental image of the environment can help visually impaired people to aquire self-confidence and become independent for moving around. Independency and mobility facilitate socialization and result in better life quality.

Different methods can help the blind and visually impaired people in the construction of mental images of the space. The most common method is direct experience within the space and memorization of its main features and physical obstacles. Although eficient, this method is time-consuming and not always possible, especially in larger spaces, where experimentation has to be limited to the main pathways.

Tactile maps and models can also help in the memorization of space. A tactile map is an abstract representation of a space, mostly concerned with pathways and the references along them. A tactile model is less abstract. It shows the spaces in correct scale, displaying architectural details (such as doors, windows and railings) and equipment (such as furniture and appliances). Another form of representation is called "wall map", a kind of model with very low walls.

According to Ungar, S., Blades, M. & Spencer, C. (1995), tactile maps and models are especially eficient for adults with sub-normal vision, allowing them to quickly form a precise and complete mental image of a space. Some studies (Ungar, S., Espinosa, A., Blades, M., Ochaita, E. & Spencer, C., 1996) show that the same result cannot be achieved through direct experience, because motion results in the loss of spatial references and therefore the loss of orientation.

Sensorial stimuli, such as tactile floors, sound and olfative signs, are also very important as a complementary help for the spatial orientation of the visually impaired, and can be combined with the use of tactile maps and models.

In regards to the use of symbols and keys in tactile models, Ungar, Blades & Spencer (1995) point out that such symbols should be inserted in a way that they are not confused with architectural features. The rendering of architectural details should be done in a precise, yet careful way, to avoid misleading. The reader should be able to define his or her own path based no the information displayed in the model.

According to Holmes et al. (1998) visually impaired people prefer diferent types of representation depending on the use of the space. Tactile maps and wall maps are helpful to plan routes across larger spaces, while detailed models are more useful for getting to know a smaller room in detail.

While some researchers have focused on the psychological aspects of tactile models, others have focused on materials and techniques that can be used to produce them (e.g. Jehoel, S., et al., 2005). Ideally, surfaces should neither be too smooth nor too rough, allowing for the rendering of good resolution detail and the reproduction of Braille characters in the correct scale. The present study has focused on both aspects, proposing the use of a rapid prototyping technique for the production of tactile models.

Two types of models were produced in this research: one for orientation within a large building (UNICAMP's central library) and another one for orientation inside a smaller room inside the library - the so-called Acessibility Laboratory, where special material and equipment for the blind is kept. The first model had low walls and displayed a path going from the entrance on the first floor to the accessiblity lab on the second floor. It had two parts, representing these two floor plans. The second model showed the interior of the lab with all its equipment and appliances, but no routes inside it.

3 RAPID PROTOTYPING

Rapid prototyping (RP) is the automated production of physical objects based on digital models. Applications of RP range from explorative model making to the production of final products. Although there are different types of digital fabrication techniques (additive, subtractive, formative, etc.) most authors consider additive systems (such as 3D printing and stereolithography) the only proper types of RP. In such systems digital models are built by the successive addition of thin layers of fused material (e.g. FDM - fused deposition modeling) or the successive solidification of layers of powder or liquid material (e.g. SLS - selective laser sintering, 3DPrinting). The additive technique allows the production of virtually any shape, except for enclosed volumes.

The term "rapid" in RP is relative: depending on the machine and the size of the file, some models may take several hours or even days to be produced. The cost of rapid prototyped objetcs is high if compared to large-scale production techniques, and can only be justified in the case of custom objetcs that require great precision.

The models for this research were produced at the Rapid Prototyping Laboratory of Centro de Pesquisas Renato Archer (CENPRA), in Campinas, Brazil. The models were produced by a machine called Sinterstation 2000 (by 3D Systems), wich is a selective laser-sintering (SLS) station. In this type of machine a laser beam is used to fuse powder Nylon layer by layer to form an object.

4 MAKING THE MODELS

Two models were produced in this experiment, as pointed out in section 2. The objective of the first model (Fig. 1) was to show blind and visually impaired people how to get to the accessibility lab, on the second floor, from the library's main lobby. This model had two parts, one representing the first floor and the other representing the second floor. Both parts displayed a pathway with arrows leading to the staircase and from there to the lab's door.

The objective of the second model (Fig. 2) was to make the accessibility lab's users aware of the position of the shelves, computers and other equipments. For this reason, it was produced in a larger scale.

The production of the models started with a metric and photographic survey of the library and the geometric modeling of the spaces in AutoCAD. Certain abstractions and simplifications had to be done, in order to avoid confusion with certain aspects of the spaces. The thickness of the walls and other features was increased, in order to make the model more resistant to constant manipulation. The width of all passages was also augmented to allow a medium-size finger to go through them. Braille symbols and a legend were added to the models, with the Braille text size recommended by the Brazilian norm (ABNT – NBr9050).

The production of the models in CENPRA's SLS machine took 144 hours and cost aproximately R$13.000,00.

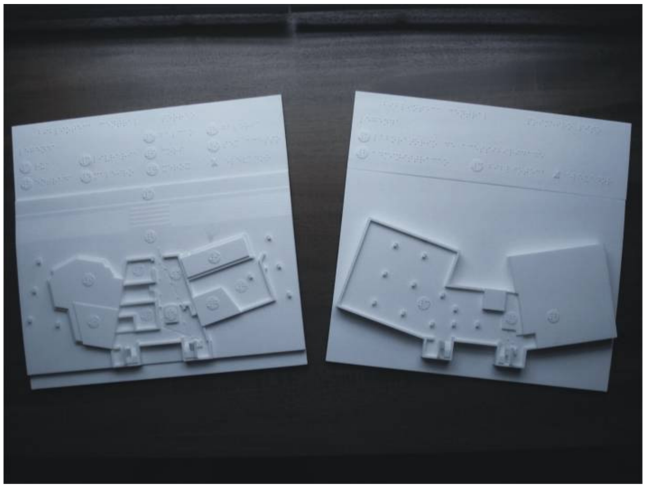

Figure 1. First and second floor models of the library (30cm x 22cm each).

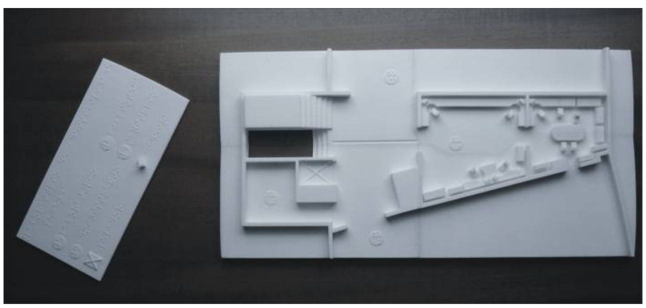

Figure 2. Model of the accessibility lab (40cm x 20cm).

5 EVALUATING THE MODELS

The models were evaluated by six volunteers at the library, in two steps. In the fist evaluation session only the whole library model was tested, and in the second both models were tested (Fig. 3).

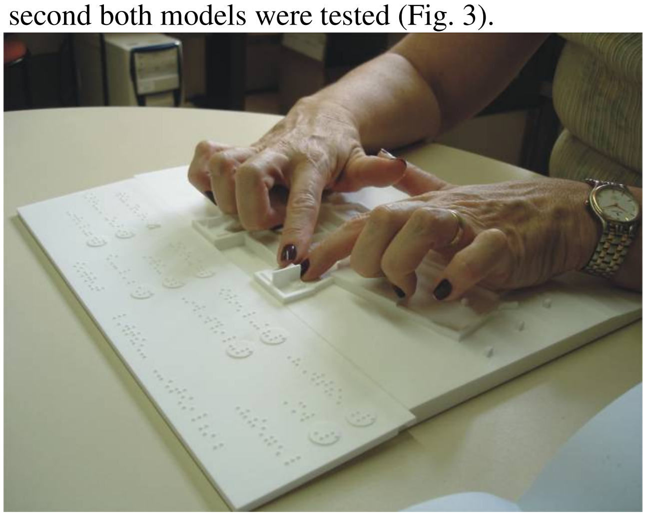

Figure 3. Testing the models.

Before each evaluation session, the objectives of the research were presented and an explanation about RP was given. The models were formally presented to the volunteers, with explanations about the material used, the symbols included, the legend, and the relationship between one model and the other. Next, the volunteers "read" the models and experienced the corresponding spaces. Finally, each of them was interviewed in a semi-structured manner - they were simply asked to comment on the experience, focusing on certain aspects, such as the efectiveness of the model and the adequacy of the material.

The conclusions drawn from the first evaluation session were taken into account in the making of the second model. The changes introduced concerned especially the scale of the details, which were rendered in a larger size in the lab's model. In the library's model some of the details, such as the stairs, were too small for some people's fingers to touch and feel.

The six volunteers who participated in the two evaluation sessions of the models were both men and women, with different ages and levels of instruction and with different types of visual impairment. Most of them had had previous experiences with tactile maps or models. It is not possible to say that the experiment had statistical representativity. However, the experiment did result in interesting feed back.

Some of the volunteers pointed out to the importance of certain elements featured in the models, such as the stairs, which represent a hazard to the visually impaired. However, other people had dificulties understanding the way that these elements were represented in the model.

It was possible to notice that it is important to allow people to freely manipulate the models, bringing them closer to their eyes (especially in the case of the low vision volunteers) and rotating them as they move around and compare their features to the objetcs they can feel and touch. The cognition of the model and thus the formation of the mental image of the space always started with the identification of a reference object in the real world and its corresponding representation in the model. Most volunteers had dificulty understanding how to get from the first to the second floor, since the plans were represented separately and displayed side by side. Displaying one floor over the other could probably have avoided this dificulty.

In the second experiment, some volunteers showed some dificulty due to the fact that the scale of the lab model was different from the scale of the whole library model. This indicates the need for using different scale models separately.

In both experiments, locating the legend was also a problem for most volunteers, which indicates the need for standardization for the positioning of legends and captions in tactile models. Some volunteers also complained about the use of architectural symbols (such as an "X" inside the elevator well), which were not known by them. A Braille key should be used - they suggested - as in the other features represented by numbers.

In regards to the material used, the models were considered very efficient both by the volunteers and by the authors, who had previously made tests with handmade tactile models made of cardboard and other soft materials.

6 FINDINGS AND CONCLUSIONS

Many conclusions could be drawn, some of them related to spatial perception and others related to the production technique.

For most of the people interviewed the models were very helpful for spatial orientation. However, the way in which the models helped people veried a lot, depending on many variables, such as:

-The type of blindenss (if the person had been born blind or not; if the person was partially or totally blind - for example, if he or she had perception of the light);

-Previous knowledge of the space (if the person had already been to the library and to the accessibility lab, at least once);

- Previous experience with tactile maps and models (if the person had already used tactile maps for other spaces).

Since the group of volunteers that could be gathered for the evaluation process was not homogeneous in respect to the characteristics above, the evaluation process was done in a qualitative, rather than quantitative manner, focusing more on how people felt about using the models.

Interesting phrases were said by the volunteers during the interviews, such as:

"The easiness in understanding depends on each one; I myself do have an hability for spatial orientation."

"The use of tactile models makes the process of building a mental image of the space much quicker."

"It helped me remembering the image I used to have of the library."

"It's more efficient than a tactile map, for it has more references."

"I had never been to this library. With the model it was possible to perceive everything. The path I had to go through was very clear."

"It's more practical [to use this model] than to ask someone to take me where I need to go."

"We need to study [the model] with calm."

The quotes above show how the models can be useful, although they are still not very common in public buildings. Volunteers who had no previous experience dealing with tactile models presented more difficulty in understanding this type of representation. One of the most interesting conclusions that could be drawn was that blind people, like people who can see, have different levels of easiness to understand abstract representations of space.

In regards to the use of the SLS technique for producing the model, the experiment was very sucessful. The resolution of the machine allowed for a perfect rendering of the Braille key texts. Besides, the models were light, yet durable and resistant to the type of use expected. The only inconvenient was the high cost of the technique.

In conclusion, it is possible to say that the two initial reserach questions were answered: (1) a tactile model should have certain level of abstraction but at the same time a certain level of details that allows readers to establish a relationship with physical references in the space; and (2) it is possible to make a tactile model using rapid prototyping, more specifically the SLS technique. However, new questions emerged with the research: (1) which should be the characteristics of models made for people with different levels of visual impairment, different levels of knowledge of a building, etc., and (2) which other rapid prototyping techniques could be used for producing tactile models in a reasonably economical way? These quastions will be addressed in the authors' next research.

7 ACKNOWLEDGEMENTS

The authors would like to thank the following people and institutions for their kind contribution to this work:

-The School of Civil Engineering, Architecture and Urban Design's *Coordenadoria de Projetos* (CEPROJ), for providing the library plans.

-UNICAMP's Central Library's Accesibility Lab, for gathering volunteers for the evaluation sessions of the models.

-All the lab's users who volunteered for evaluating the models.

-*Centro de Pesquisas Renato Archer's* (CENPRA) Rapid Prototyping Lab, for producing the models.

-UNICAMP's *Serviço de Apoio ao Estudante* (SAE) and CNPq, for providing the one-year scholarship.

-UNICAMP's *Pró-reitoria de Pesquisa* (PRP), for providing the funds for participating in this conference.

-Professors Doris Kowaltowski and Núbia Bernardi, for their many suggestions and helpful comments.

8 REFERENCES

Jehoel, S., et. al. 2005. An Evaluation of Substrates for Tactile Maps and Diagrams: Scanning Speed and Users' Preferences. *Journal of Visual Impairment & Blindness* v. 99 (no. 2): p.85-95.

Holmes, E., et. al. 1998. Wall versus path tactile maps for route planning in buildings. *Journal of Visual Impairment & Blindness* v. 92 (no. 7): p.531-4.

Ungar, S., Espinosa, A., Blades, M., Ochaíta, E. & Spencer, C. 1996. Blind and visually impaired people using tactile maps. *Proceedings of the Association of American Geographers Annual Meeting*, Charlotte, North Carolina: Association of American Geographers: p.1-5.

Ungar, S., Blades, M. & Spencer, C. 1995. Visually impaired children's strategies for memorizing a map. *British Journal of Visual Impairment* v. 13: p.27-32.