ARCHITECTURE DEGREE PROJECT: USE OF 3D TECHNOLOGY, MODELS AND AUGMENTED REALITY EXPERIENCE WITH VISUALLY IMPAIRED USERS

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ABSTRACT

Web 3.0 technologies provide effective tools for interpreting architecture and culture in general. Thus, a project may have an emotional impact on people while also having a more widespread effect in society as a whole. This project defines a methodology for evaluating accessibility of architecture for people with visual disabilities and the application of this to visiting emblematic buildings such as the Basilica of the Holly Family in Barcelona, designed by the architect, Antoni Gaudí.

Keywords: Augmented Reality, Disabled Users, Accessible Architecture, User Experience, Visual Impairment

1. INTRODUCTION

Architecture and cultural places of interest are manifestations of evolutionary progress in society. People have a right to access these: "*Everyone, as a member of society ... [is] entitled to the satisfaction of economic, social and cultural rights indispensable for his dignity and the free development of his personality."* [1]

Society has a responsibility to bring this knowledge to anyone, whether or not mental or physical disabilities might impede that person's access to this information.

Access to architectural culture (visits to museums, emblematic buildings, exhibitions, etc.) for disabled people is in most cases difficult. The effectiveness of the access depends on the information provided to the user. Access also includes allowing interaction with the physical spaces. The senses, such as touch, sight and hearing are the main channels through which users can be helped. Students should be alert as to how these senses can provide the initial information.

For disabled people it is important to be able to visit exhibition spaces, museums or other places of interest in order to complete the user experience. Previous teaching experiences using sensory and other adapted materials provide the starting point for research and development of methodologies based on the response to these stimuli by disabled people themselves..

Thus, previous project experience shows that involving end users in the different phases, results in better accessibility of the contents of any cultural event. More specifically, a development team composed of teachers, technicians and students of architecture increases the potential of a theoretical to fulfill this objective.

This project is designed by disabled people and students of architecture. They have worked on definitions for development and the practical application of design. The experience of students as users and content developers will allow us to assess empirically the usability and accessibility of the built environment. The methodology is aimed at achieving a satisfactory experience for developers and end users.

2. STATE OF THE ART TECHNOLOGY

The French philosopher Diderot said, "... *of every sense, sight is the most superficial, the ear the sense most arrogant, the most voluptuous is smell, taste, the more superstitious and more variable, touch is the deepest and philosophical* " [2]

Currently, there are many museums and organizations that offer alternatives for accessibility. Some museums have art galleries especially dedicated to people with disabilities. The most representative examples are:

- Typhlological Museum of ONCE, Madrid, Spain.[3]
- Touch Museum in Athens. [4]
- Social Work Cataluña Caixa, building La Pedrera, exhibit '*La pedrera touch'*. [5]
- Louvre Museum, Paris. [6]
- National Museum of Archaeology, Anthropology and History of Peru. [7]

Some of these experiences have been made in the field of architecture and access to the built heritage. These are experiences that are related to the project.

The Typhlological Museum of the ONCE exhibits the cultural heritage of the organization and develops temporary exhibitions of works by blind artists and permanent exhibitions of the organization's history.. In both cases the objective is to promote and meet the cultural needs of people with severe visual impairment and to showcase the integration and standardization efforts pursued by the ONCE.

Today, the Typhlological Museum is a space conceived in order to allow visitors to see and touch the exhibits. But what really makes it original and unique is the fact that its very origin came at the behest of its users, and that it was designed entirely to meet their needs. The models are the main tools used to convey concepts to the blind and the severely visually impaired. For this audience, a good model is a three-dimensional figure. This has the property of being observable from different points of view and at different levels of detail, while allowing an overview of the whole.

This is especially significant when we speak of architectural monuments. Their size means that they are not accessible to touch or sight.

Apart from their didactic nature, the models on display in the rooms of the ONCE museum are designed to facilitate tactile reading of their content, which influences the choice of materials and dimensions.

The collection features an audio guide system, which provides information about the parts articulated at two levels: basic, corresponding to the tactile path of the model and at a second level that provides information on the style and period of the monument.

In the specific framework of the Architecture Degree, the new technologies provide new tools for representing architectural forms and their content related to the projects. These new tools, such as mobile learning, augmented reality (AR), or 2D constitute new ways of accessing information, and of providing the potential for the concept of teaching Web 3.0.

3. METHODOLOGY

The current project is a continuation of the practices developed in previous ones [8] [9], which established a new research line with disabled users by the students of the Architecture Degree. The methodology is defined in six phases. The previous project developed the first one. The next stages for development in this paper are Phase numbers 2 and 3:

- **Phase 1:** Practical development of a project and evaluation of the different phases
- **Phase 2:** Definition and implementation of a theoretical methodology
- **Phase 3:** Analysis of results of the proposed methodology
- **Phase 4:** Modification of the methodology based on the results
- **Phase 5:** Analysis of the new methodology
- **Phase 6:** Definition of the final methodology and iteration in other frameworks.

In the previous phase of the project we obtained initial results, which will be defined in the implementation of this present second phase. The main points to consider in this new phase are as follows:

- **Analysis of results of the previous phase:** The results will allow us to improve some aspects of the workflow in the new stages, incorporating advances in technology and training methodologies.
- **Implementation of Web 3.0 training methodological approaches:** The collaborative workflow method that involves several team profiles allows us to add new experiences to the common objective of the project.
- **Evaluation of new techniques of representation:** In this phase we will evaluate and analyze new techniques developed using augmented reality (AR) and their possible incorporation in the application of the project.
- **Implementation of the methodology:** The application of new techniques of representation and increasing participation of the agencies involved will improve the final experience.

The technology that helps to improve all these situations is AR. AR’s creators [10] define it as a virtual reality variation, where the user can see the real world with virtual objects mixed or superimposed. In contrast to virtual reality, AR does not replace the real environment, but instead uses it as a background to be registered. The final result is a dynamic image of a 3D virtual model superimposed on a real time video of the environment. This scene is shown to the user on a computer screen or through other devices, such as projectors, a digital board, special glasses, or a 3g cell phone.. The main difficulty in architecture and building construction is solving the problem of integrating virtual objects with real images. The overlap must be accurate and at the right scale, in order to achieve its hypothetical situation and size matching in the real scene.

The distinctive feature of AR technology, i.e., the merging of virtual information with a real environment, is usable in a wide range of engineering and construction applications. It could offer potential advantages in all stages of the construction process, from initial planning and working on conceptual design problems, to the management and maintenance of building systems throughout their lifetime.

We believe that it could be useful in scoping out tasks, or planning facilities control too. AR technology could even facilitate the interpretation of drawings, technical documentation and other specifications. These systems can also generate a real image superimposed on a specific stage of the construction process, and these can then be stored in a database, from whence users can access different levels of information, depending on their specific queries.

In the development phase of our experiment, the definition of the parameters relating to the past experience has brought to our attention the need for a more complex training process, broken down into the following steps:

- **Step 1, the context:** The project developed in this paper is a continuation of the first phase addressing the needs of disabled users and carried out last year. The theme of the work is the Basilica of the Holy Family (Gaudí, Barcelona, Spain) and the geometry of some of its architectural elements.
- **Step 2, development of prototypes:** The student projects are carried out using CAD technology and involve the definition of constructive elements and their representation in 3D.
- **Step 3, evaluation of geometric models by disabled users**: The students have the opportunity to consult disabled users on their experience of the effectiveness of the models used in the previous step, and to evaluate the results.
- **Step 4, trial with 3D models in AR:** Evaluation of new imaging techniques for future possible incorporation into the project content. This step in still in an experimental process, but it opens new lines to guide the contents to other user profiles.
- **Step 5, new user experiences:** Iteration of user experiences in this second general phase with the final models, descriptive text and raised panels, following the direction of the project. The students have the opportunity to redefine the content of their teaching material.

- **Step 6, presentation and public exhibition of the didactic adapted materials:** The works are presented in this stage in a box with all the material. The exhibition takes place in a public location at the university.
- **Step 7, visit of the monument:** Teachers, students, disabled users, rehabilitation experts and disabled guides visit the monument to share the experience and evaluate the results [Figure 1].

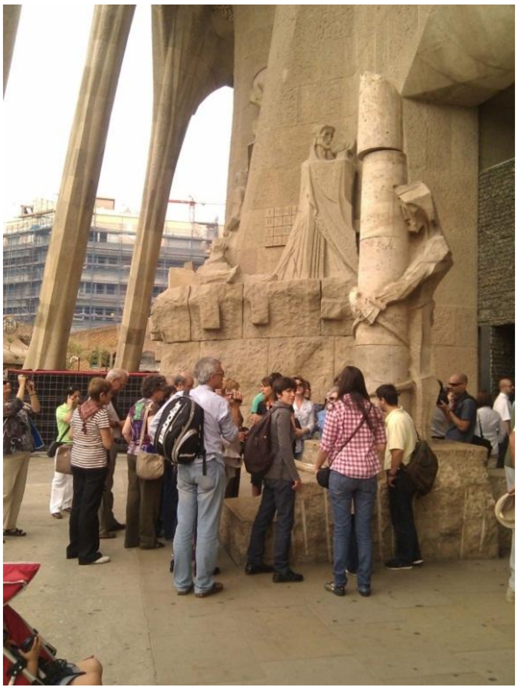

Figure 1: Basilica of the Holy Family visit

- **Step 8, analysis of results and methodology:** The project ends with the conclusions and evaluation of the experience of the whole process.

The project is developed in the context of the University of Architecture and aims to become a leading teaching experience in training for Web 3.0 in the field of architecture as part of a real project with the final users. This implementation process is itself a project developed over time, and the contents presented in this paper are the result of specific case studies. Participating students are now in their third year of the Degree of Architecture and are developing techniques in the area of representing icons of modern architecture.

4. DEFINITION AND IMPLEMENTATION OF A THEORETICAL METHODOLOGY

As we have indicated in the previous section, we will now develop the work process described in phase 2 of the project. The proposed steps are:

Step 1: The context

The proposal continues the research from an earlier piece of work. Students work in collaboration with organizations representing people with disabilities. The project lasts six months and occurs in the third year of the Architecture Degree.

The group consists of twelve students and a teacher. Volunteers include three technical people and four volunteers with disabilities. The final visit comprises three tour guides to the building with a group of thirty people, including at least 15 whose are either partially sighted or totally blind.

The technicians of these organizations provide initial training on aspects to be considered in the project design adaptations. ONCE, the national organization for partially sighted and blind people, also provides students with the technical resources to develop teaching materials. The volunteers with disabilities will participate in the process of project design.

Step 2: Development of prototypes

The prototypes are designed with 3D models in specific CAD programs (Rhinoceros, AutoCAD). Students learn new techniques for developing models (laser cutting, 3D printing, silicone molds and resin).

Students use their knowledge of the properties of these materials in order to apply appropriate techniques in their own studio projects. The process for creating 3D models is as follows:

- The prototypes are designed as wooden elements (conceptual prototypes of architectural geometry). [Figure 2].

Figure 2: Conceptual prototypes of architectural geometry

- Students apply a plaster finish and latex to the wooden models [Figure 3].

Figure 3: Student with the prototype in plaster

- The models are placed in a container upside down and covered with silicone rubber (a process that needs time to dry).
- Later, it is necessary to invert the mold to fill it. Epoxy resin will be the final finish.

Other didactic materials are developed in one of ONCE's departments using writing machines and Braille printing tools as well as molded plastic panels.

The project includes a description of the theme developed by each group of students. This text document has an extension of approximately 200 words and appears in large font (24 points) and also in Braille format. People with impaired vision can read these files when applying these formats [Figure 4].

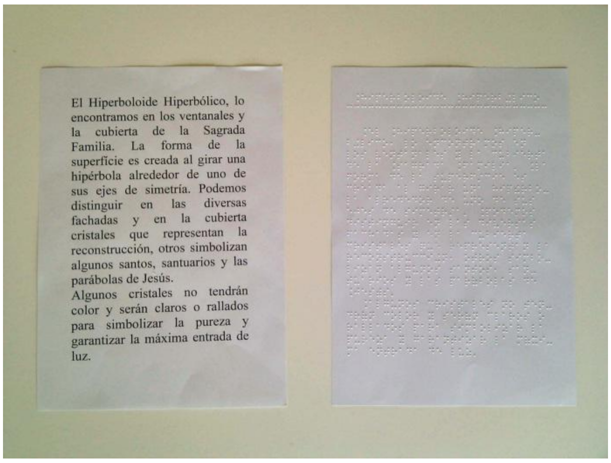
El Hiperboloide Hiperbólico, lo encontramos en los ventanales y la cubierta de la Sagrada Familia. La forma de la superficie es creada al girar una hipérbola alrededor de uno de sus ejes de simetría. Podemos distinguir en las diversas fachadas y en la cubierta cristales que representan la reconstrucción, otros simbolizan algunos santos, santuarios y las parábolas de Jesús.
Algunos cristales no tendrán color y serán claros o rallados para simbolizar la pureza y garantizar la máxima entrada de luz.

Figure 4: Description in Braille format

Another element is a plastic sheet with relief [Figure 5]. This sheet is formed with a device that applies the relief on an array. The result is a textured relief for reading supporting documentation. The information can be set out in graphics and diagrams. This material helps people with impaired vision, because they can use touch to recognize shapes, textures and geometric concepts related to the project.

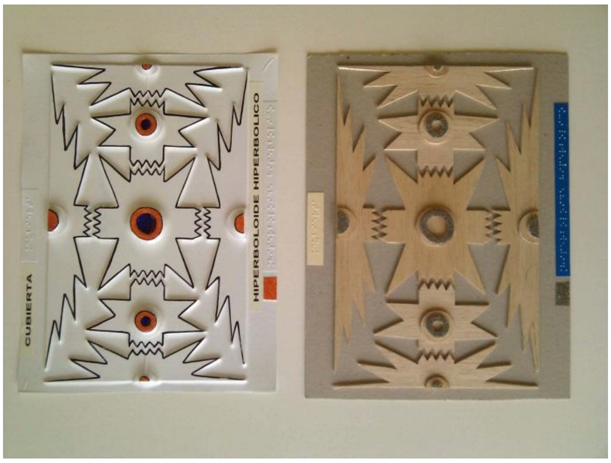

Figure 5: Example of plastic sheet with relief.

Step 3: Evaluation of geometric models by disabled users

The volunteers with disabilities participate in the design definition phase. Architecture students can carry out experiments with the users and evaluate prototypes through surveys that reflect the effectiveness of the work.

The suggestions of the volunteers will be critical to the suitability of the designs for further evaluation. The surveys are incorporated into the information system of the university's Intranet so that the overall results of the project can be discussed.

This consultation phase has the support of ONCE. This organization is actively involved because they give the university department technical support, providing access to the classrooms in their premises and human resources for making appropriate contacts with users who might contribute to the project [Figure 6].

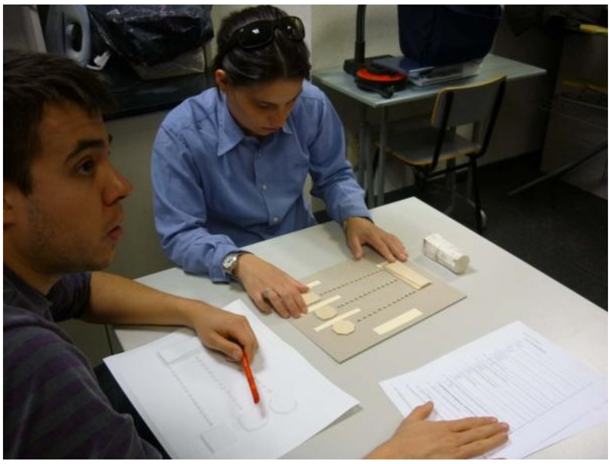

Figure 6: Evaluation of geometric models by disabled users

Step 4: Training with 3D models in AR

Students test new augmented reality techniques to assess their possible incorporation into the project with people with disabilities.

This phase will be a test for future projects in which new ways of implementing applications for mobile devices are integrated into the course.

One objective of the project is to approximate the experience the students will have as they make specific applications of their skills in their own exercises during other courses of the Architecture Degree [Figure 7].

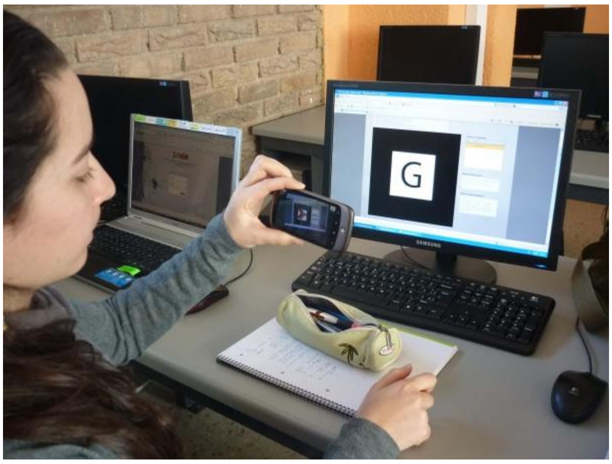

Figure 7: Trial with 3D models in AR

Step 5: New user experiences

The second stage of development of the project is also led by volunteers and students. During the second visit the test materials are adapted and improved based on the changes suggested during the first experience.

There is also testing of new content adaptation. These are relief panels, panels with large font size and Braille texts with descriptions of 3D models [Figure 8].

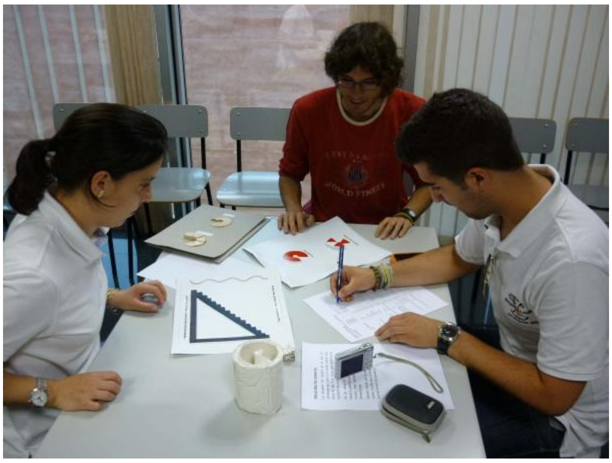

Figure 8: New user experiences

Step 6: Presentation and public exhibition of the adapted didactic materials

The presentation fits into small briefcases. This contains all of the materials adapted and protected in order to use them on a tour. In the last phase, these briefcases are used for the group of disabled people inside the Basilica of the Holy Family [Figure 9].

Figure 9: Adapted didactic materials

Step 7: Visit to the monument

The last step is to visit the place with all the project participants: students, teachers, volunteers, disabled users, rehabilitation technicians, guides and leaders from the basilica. In this step adapted models of the basilica and the contents generated by the students are used. The visit is conducted in several stages:

- **Description of the research project and the Basilica of the Holy Family**: The project is presented in the annex building originally used as a school for the children of the workers who first constructed the basilica**.** This explanation also includes the experience of touching the models and the adapted material realized by the Architecture Degree students [Figure 10].

Figure 10: Students' explanations to disabled users

- **Tour visiting the exterior and interior of the Basilica:** Accompanied by the guides and students, disabled users cover all the spaces and pay attention to stopping at particular points. On this tour the users can touch the materials and experience the feeling of space by means of acoustic perception. Students also experience the difficulty of accessing architectural tours of particular buildings from the perspective of the disabled users [Figure 11].

Figure 11: Tour inside the Basilica of the Holy Family

- **Tour at the exhibition "Gaudí and Nature":** In this permanent exhibition space placed inside the basilica, the users can touch models of architectural features made with reference to nature. The chairman of the exhibition speaks to visitors and can also observe the reactions of the disabled users [Figure 12].

Figure 12: "Gaudí and Nature" tour with adapted material

Step 8: Analysis of results and methodology

Finally, we evaluate the experience and the result of featuring these materials developed by the students in a guided tour of the basilica.

The graphic material collected during the tour and all comments from the users are analyzed to obtain new conclusions for improvement of future experiences.

5. CONCLUSIONS

The most relevant conclusions of our study areas follows:

- In the previous phase, the disabled experts usign the basilica visit, have facilitated the undestanding of the structure of the project for the students. The objective and methodology to be followed are defined in this first step. This system has been evaluated positively by students.
- Protoyping and its evaluation by users in the design process (into two stages, initial and final process), is a system that helps to improve the models for the explanation during the monument visit at the end of the course. The volunteers with disabilities considered that their participation had been essential for the improvement of the student proposals.
- The geometry is easily interpreted, but not in all cases, due to the different levels of participant knowledge related to the matter. This is an aspect to improve in future activities: the adequacy of the contents in terms of definitions and the terminology to be used.
- The extent or lack of visual impairment is not the determining factor for understanding the geometric models, as touch and text description along with raised panels are crucial for quick interpretation. For this reason, participants need to be given an even greater clarity of understanding.
- The architectural project is another important factor. In this research project, the Basilica of the Holy Family is very complex, but the selection of singular elements facilitates understanding of the whole. It is necessary to realize projects with other similar buildings that are historic monuments to compare experiences and methodology.

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