Transforming our World through Universal Design for Human Development
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Toward an Inclusive and Independent Fruition of Architecture: The Use of Scale Models and Augmented Reality

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Abstract. While there are many places in Italy that cater to the population with low vision or who is blind, for example the "Museo Tattile Statale Omero" in Ancona, the remarks made by the Unione Italiana Ciechi e Ipovedenti (U.I.C.I) of Bologna on the issue state that "the issues produced by perceptual barriers, inherent in visual disabilities, do not find adequate answers in the current accessibility regulations". To integrate the accessibility of museums and other cultural services, considered by UNESCO as a fundamental human right that must be granted to people with disabilities (article 30, Convention on the Rights of Persons with Disabilities) the authors present a design, in its early stages, of a system that aims to make the fruition of scale models independent for users with low vision or who are blind. Said system aims to integrate some sort of augmented reality to haptic perception by reproducing sound cues to help users with disabilities navigate a single, or a series of models without any outside aid. The system is based on the deployment of technological plinths to support the scale models. This approach is well fit for retrofitting existing scale models while integrating the navigation system in an effective fashion. The activation of the plinths will be triggered using a smartphone app (either using NFC or Bluetooth) and will reproduce a set routine to guide the user in the haptic exploration of the models. On the outer rim of the plinths a series of triggers and devices will be placed for the user to interact, while leaving some space between the elements to house details at a larger scale or braille plaques. The triggers will be distinguished by their shape, a proud start trigger and a recessed end trigger; the interface is completed by an array of 8 speakers (one each 45°) with the possibility of ulterior sound emitting elements embodied in new models. The current design also defines the properties of the material that will be used in the prototyping phase by excluding rough surfaces that could introduce haptic noise and suggesting the use of thermoplastic polymers or stabilized wood over metals (since a metallic surface could be problematic in exterior installations due to its high thermal conductivity). The concurrent deployment of multiple plinths will consent the independent navigation and queuing of users in a contained exhibit by triggering a positional sound to guide them, while in urban context the app will have to be integrated with systems that implemented detailed voice guidance such as google maps. The paper ends by describing the future prototyping stages the system is expected to go through to fine tune the preliminary design.

Keywords. low-vision, blind, accessibility, architecture, cultural heritage

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1. Introduction

The issue pertaining the accessibility of cultural heritage by people with disabilities is, at its core, a matter of human rights. As stated in "A guide for World Cultural Heritage Information Centers" (Manz K. et al., 2018):

The chance to experience and explore cultural and natural heritage should be afforded to every interested individual. This includes people with various disabilities, be they related to motor skills, sight or hearing, or mental and cognitive faculties [1].

Said remark by UNESCO is elaborating on article 30 of the United Nations Convention on the Rights of Persons with Disabilities (CRPD) stating that people with disabilities should have the right of "Enjoy access to places for cultural performances or services, such as theatres, museums, cinemas, libraries and tourism services, and, as far as possible, enjoy access to monuments and sites of national cultural importance" [2].

In Italy such principles have been included by the MiBACT (Ministero per i Beni e le Attività Culturali e del Turismo) in the guidelines for overcoming architectural barriers in places of cultural interest (P.E.B.A.) in 2018, defining accessibility (of places and objects) as a broad and multidimensional issue that should be solved by the joint effort of universal design and personnel formation.

When restricting the field to people with low vision or who are blind, the main issue is making mainly visual media, such as architecture or paintings, accessible to them. In this sense in Italy one can find a series of structures that specifically cater to them like the "Museo Tattile Statale Omero" in Ancona (housing mainly replicas of sculptures that are geared, when necessary, with elevators to allow the user to feel them at a large scale) or the "Museo Tattile Anteros" in Bologna (housing relief models of paintings); while other museums, such as the Capitoline museum in Rome, have some form of tactile support for people with low vision or who are blind installed while not being a dedicated structure.

The paper addresses said accessibility issues by presenting a system, in its early design stage, that aims to grant the independent fruition of architectural models by people with low vision or who are blind via the interaction with technological elements (plinths) activated by an app.

2. Integrating Haptic Perception with Augmented Reality

Making mainly visual media accessible through haptic perception is an issue vastly studied in literature, the state of art suggests that some cultural expressions are easier to convey with tactile models, since "the all-round copies of sculptures and reproductions of architectures are easier to understand, because the blind person is more familiar with three-dimensional reality"[3], but some aspects are nearly impossible to convey because of some hard limitations, as said by Grassini "for a blind born color is just a name, an abstract word"[4].

While producing tactile models, nowadays, is easier than ever thanks to 3d scanning and rapid prototyping technologies there is still the issue of the scale at which the model can be effective in conveying its features to the user. As stated by Mechini and Sicuranza "the characteristics relevant to 3D reproduction are that it be proportional to the real object, appropriate for the needs of tactile readability, i.e., within arm's reach of the user, capable of being explored with both hands, and small enough to move around it without losing the sense of the whole"[5].

A study conducted in the field of architectural representation conducted by Scianna and Di Filippo experimenting with the reproduction of buildings along the streets of Vucciaria in Palermo found out that, in their sample of people with low vision or who are blind, the preferred scale for architectural prints was 1:50 with scales as small as 1:75 still effective, while the 1:100 scale was considered too small to appreciate the details of the model. This study is concluded with the following statement “It would be interesting to equip the 3Dmodels of sensors capable of giving indications on the architectural parts of the 3D model, so as to make tactile exploration even more accessible.” [6]

Integrating haptic representation with sound could be beneficial not only in terms of the accessibility of the single model but also extended to aid people with low vision or who are blind in being independent in their fruition of architecture.

As Tinti et al. highlight in their study, haptic perception allows for only one item to be processed at a time, moreover, “all objects present visual features but do not necessarily, for example, emit sound. Even more importantly, vision allows us to perceive distant, out-of-reach objects, whereas haptic perception does not” [7].

Using a mobile AR system to layer on sound cues to out of reach objects would allow users with disabilities to integrate their experience without outside aid.

3. Navigating Architecture: Triggers and Routines

The independent fruition of architecture by people with low vision or who are blind could be achieved via the coordinated use of a mobile app and a series of technological elements placed in the interested site.

In case of a single model (such as scale model of a building placed nearby the actual structure), a closed loop system would be defined, where the reproduction of an audio guide and the corresponding sound cues would be contained in a limited space.

Scaling up the problem to a wider tour or a museum exhibit an open loop would be needed, where a series of models are connected by a navigational aid to help the user reach each station.

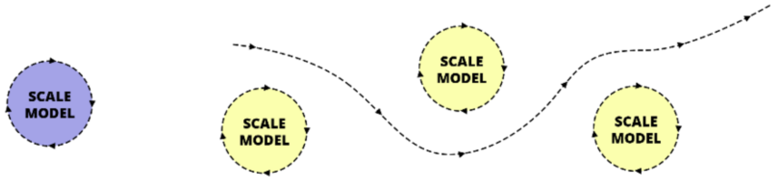

Figure 1. Diagrams of a closed loop (left) and an open loop (right).

In both cases the single model should have a system that, upon request, must be able to start the relative routine to aid the user in experiencing the model. In the case of an open loop a second trigger is needed to start the navigational aid to reach the next model, this should not happen automatically since the user may want to go back and feel again the previous model or could simply want to take a moment of respite before proceeding.

For the triggering of the routines the app could use an NFC (near field communication) or Bluetooth system. The use of NFC could also allow the use of a device other than a smartphone, allowing cultural heritage sites and museums to have cards working effectively as physical tokens. Moreover, NFC makes accidental triggering more rare, due to an accuracy of about 10 centimeters, and represents a sustainable option for off-grid installation since even the active party in the transaction draws little power and can be left in idle all the time with minimal consumption. [8]

Regarding using Bluetooth to trigger the routines it would surely be of a more agile implementation, especially for standalone models, since the technology is ubiquitous in the smartphone market. The drawback to using this solution is relative to a more taxing power consumption (if confronted with NFC), and a major risk of accidental triggering for the routines, since, even if a high-quality beacon could allow a precision comparable with the activation field of NFC, it is more commonly an order of magnitude higher.[9]

Once triggered, the routine played on the single model is composed by an audio-guide paired with distinctive sound cues directing the user to the described spots, allowing them to navigate even a large model autonomously. At the end of the routine, in the case of an open loop, there will be an option that can be triggered using the app that will direct them to the next model in the tour.

To allow this series of operation around a model the authors theorized the installation of a technological plinth that will support the model at a comfortable height, while hosting the components that will allow the described operations.

4. The Technological Plinth

To house the technological elements driving the system a solution has been designed that uses the, already needed, support to raise the model from the ground. This is crucial in thinking about retrofitting existing models since it would be sufficient to move them on this kind of support and design from them the necessary routines.

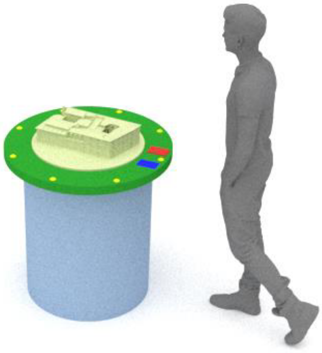

Figure 2. The technological plinth – 3d diagram.

The supports have been designed to take advantage of tactile feedbacks regarding the elements with which the users will have to interact, making significative areas either proud or recessed on a mainly smooth surface.

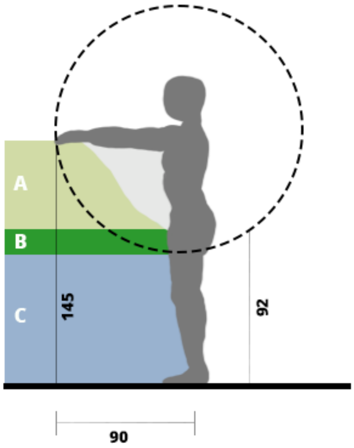

Figure 3. Dimensional diagram, h-zones.

The overall dimensions for the plinth are determined by the average human range of motion. Three height-zones (h-zones) have been identified: h-zone A is between 92 and 145 centimeters from the ground, it allows the comfortable touching of the models, but high elements should be placed further away to allow users to bend; h-zone B is between 95 and 85 centimeters, here will be placed braille inscriptions (when needed), relief of various details, and lastly the triggering interfaces to start the routine; h-zone C represents the interval that could not be reached comfortably by a person standing.

Regarding the dimensions in plan of the plinth, 90 centimeters has been identified as a comfortable overall diameter, with a 15 cm strip housing the elements described in the previous paragraph and a zone for the scale model with a diameter of 60 cm.

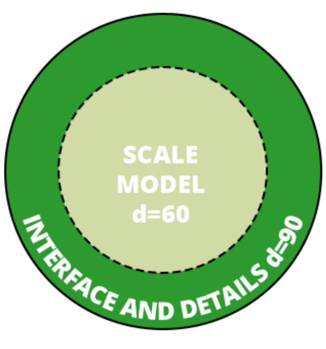

Figure 4. Dimensional diagram, plan.

On the outer rim of the plinth there will be 2 areas, the proud one (depicted in red in the diagram present in figure 5) will be the start trigger, approaching this element with either a phone or an NFC card will start the routine. The sound cues will be produced by an array of 8 speakers (one each 45°, represented in yellow in figure 5) to conduct the user around the model, these speakers could be also integrated by elements placed inside the model and geared to either produce sound or vibrate to guide the hand to a detail in particular. Lastly the recessed area (depicted in blue in figure 5) will be the end trigger that, upon activation, will signal with an audio cue the next user in line about the availability of the model.

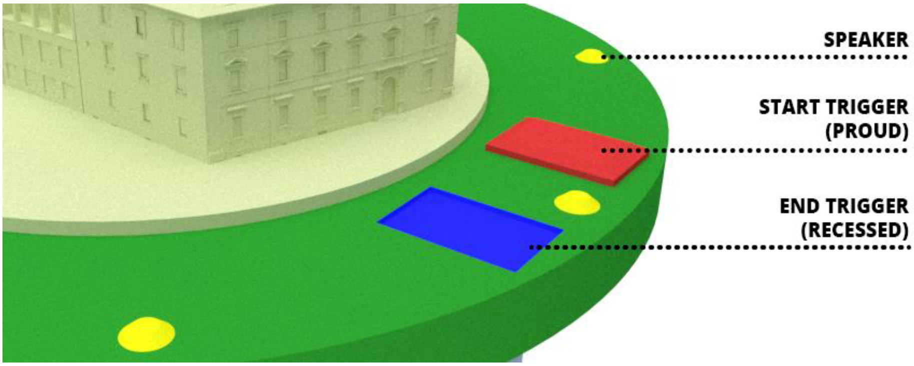

Figure 5. Technological plinth, interface elements.

The materials used to build the plinth should present smooth to the touch, not introducing noise, to avoid interference with elements at a larger scale that could be integrated in the outer rim, these elements could serve as a medium to represent a detail within reach of the user. Another use of the space in-between elements could be relative to the installation of plaques with braille writing allowing a low-tech fruition of the models while building some form of redundancy in case of a malfunction or a power outage.

The choice of materials for the plinth depends on their location, in case of indoor installation they could be realized in stabilized wood or using thermoplastic polymers to grant a uniform and smooth surface. For outdoor use at the time of writing the materials being evaluated are reconstructed stone or concrete so to increase the durability of the plinths when exposed to the weather. In both cases the use of a metallic casing has been considered not adequate, since the high thermal conductivity can hinder the experience of the user in environments that are either too hot or too cold.

The app driving the system will be speech based, its role as key to activate the plinths will be paired with a series of services to grant the independent fruition of architecture by people with low vision or who are blind. In idle, it will warn the user of the availability of a scale model or a dedicated museum nearby, this function is instrumental to the independent discovery of sites while, for example, roaming a city.

It will aid the user in localizing the nearby attraction, by either giving the chance to activate a sound cue from a beacon at the entrance of the museum or making an external installation signal itself. Moreover, in case of an open loop it will conduct them from one model to the next (playing a sound cue from the following plinth), or in case of cities or archeological sites it will rely also on the support of systems such as google maps that implemented detailed voice guidance.

Lastly, in case of an on-site installation (when the model is installed, for example, in a space prospicient the actual building) the system could be integrated with a series of stand-alone beacons that would direct the user toward a specific portion of the actual building to allow the user to feel a particular detail or material on the architecture itself.

5. Conclusions

Granting people with low vision or who are blind an independent fruition of architecture is a matter of rights, rights that could be allowed by an innovative use of existing technologies.

The proposed approach to the issue could make possible for them to both know the position and have a “guided tour” of the models without any outside aid, improving the accessibility of architecture not only on a physical but also on a cultural level. It could be a step in the right direction since, as made clear by the remarks of the Unione Italiana Ciechi e Ipovedenti (U.I.C.I.) of Bologna "the issues produced by perceptual barriers, inherent in visual disabilities, do not find adequate answers in the current accessibility regulations".

On Aisthesis, the audio review of the Museo Tattile Statale Omero, Andrea Sòcrati closed an article about how the development of medias in the history of humanity changed the way we relate to synesthetic perception of things paraphrasing Diderot.

“Three centuries ago Denis Diderot asked the blind man of Puiseaux if he would be happy to have eyes to see; the blind man answered that he would have liked to have longer arms, because the hands would have allowed him to know better than the eyes of seeing peoples what happens on the moon”[10]

The broad implementation of this design could be beneficial in allowing people with low vision or who are blind to go beyond what is at their arm’s reach without little to no outside aid, granting them the long arms the blind man of Puiseaux wished for.

6. Further Developments

The preliminary design described in the paper, at the time of writing, has defined the necessary elements (both on the hardware and the software side) to move on to the prototyping phase.

The first round of prototyping will be conducted to test the interface (using a simple mockup routine) on people with low vision or who are blind. This first phase will be conducted using rapid prototyping technologies (such as FDM 3d printing) to implement the necessary tweaks in a timely fashion. In this phase will be also tested if the use of colors with a stark contrast between them could aid people with low vision in using the interface.

Once the physical interface is tuned further testing will be conducted regarding materials used to grant an adequate level of resistance both to ordinary wear and tear and regarding the exposition of external installations to the elements. External testing will pair the usual issues regarding waterproofing with stress-tests to determine if the noise generated by the superficial degradation of the selected materials can hinder the performance of the system due to an excessive level of tactile noise.

To improve the synesthetic fruition of the models, during this phase, it would be of interest to experiment the use of different material composing the model itself to convey in a better way the material composition of architectures.

Lastly, the development of the app will be conducted to deploy a pilot installation of the system and test the navigation features.

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