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DAI Il Disegno per l'Accessibilità e l'Inclusione

A cura di Alberto Sdegno e Veronica Riavis

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Seeing architecture through hands: 3D models as an inclusive educational tool in the *In-VisiBLe* project

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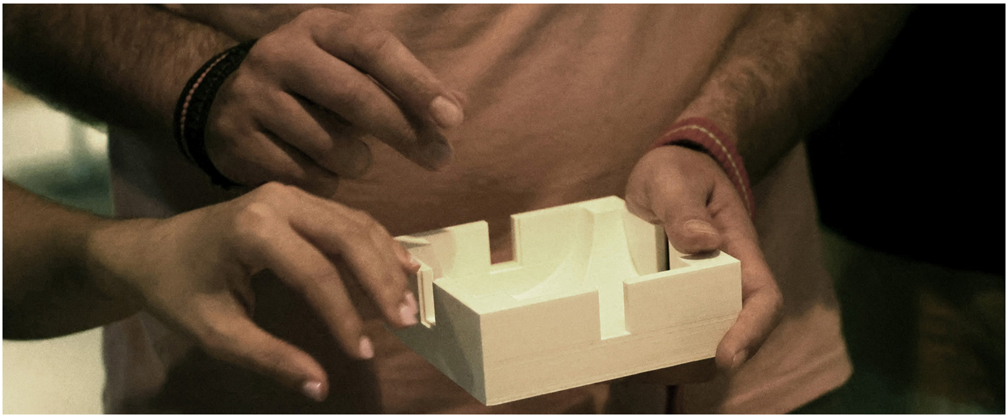


Inclusive HE systems
Innovative Learning & Teaching Practices
Cultural Accessibility
3D Architectural Models

In-VisIBLe (Inclusive and Innovative learning tool for Visually Impaired and Blind people) is an EU-funded Erasmus+ project coordinated by the University of Bologna, whose aim is to make Higher Education in the fields of Art and Architecture more accessible ensuring the full participation of blind and visually impaired students by embedding in HE courses the use of advanced technological solutions, interactive pedagogical methods, and innovative didactic tools.
The project is currently ongoing (2022–2024) and the scope of this paper is to discuss the results reached so far.

Accessibility and cultural inclusion: the *In-VisIBLe* project

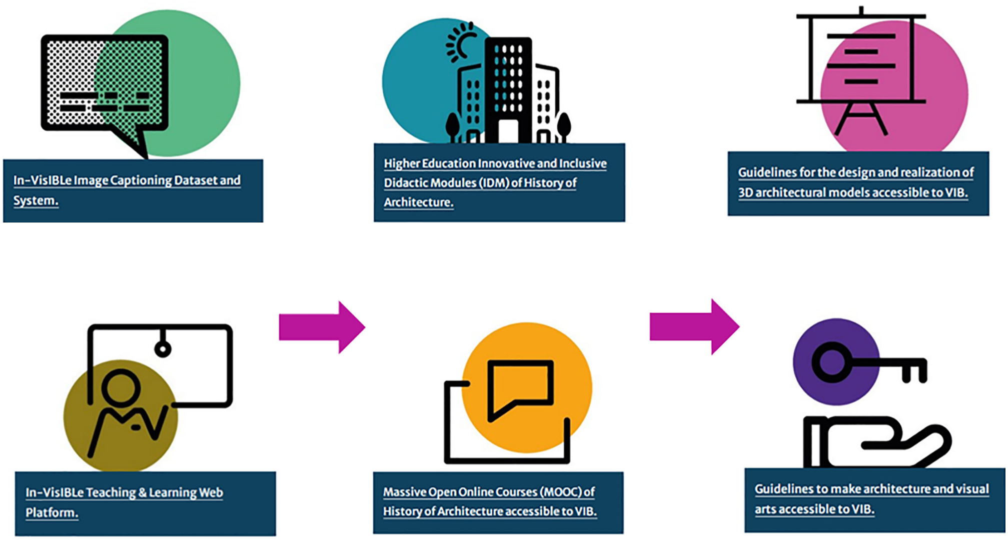
Accessibility is the core of one of the areas of action of the European Disability Strategy 2010-2020 and of the Strategy for the Rights of Persons with Disabilities 2020-2030. Culture is one of the most crucial contexts in which accessibility is declined, because of its centrality in the growth of both the individual and the society. Nevertheless, the level of education of persons with disabilities continues to be largely lower than the one of persons without disabilities. When it comes to Higher Education, despite the effort carried out by many European universities, people with disabilities are currently represented on average in 1.1% of the university degree students: thus, it is still necessary to adopt positive actions to promote access and guarantee Higher Education adapted to special needs, for the largest number of people. [United Nations 2006]

The EU-funded Erasmus+ project *In-VisIBLe* (Inclusive and Innovative learning tool for Visually Impaired and Blind people, 2021-1-IT02-KA220-HED-000031139), coordinated by Micaela Antonucci, University of Bologna [1] aims at answering to this need for inclusion, improving access to cultural contents in Higher Education for people with special needs. As there are about 30 million people with visual impairment in the EU countries, the project chooses to focus on education of visually impaired and blind people, particularly in that field that apparently excludes them without remedy: the so-called *visual* arts. Among the disciplines related to visual arts, History of Architecture is a cross-sectorial discipline which is present in almost all the in bachelor/master's degree in this field [Antonucci 2023].

The main objective of *In-VisIBLe* is to equip HE courses in History of Architecture with advanced technological solutions, interactive pedagogical methods and innovative didactic tools that make them accessible also to students with visual disabilities. Most of these tools are already available, but this will be the first time they are implemented and combined in Innovative and Inclusive Didactic Modules (IDM) and Massive Open Online Courses (MOOC), and new tools are specifically developed for this project: the *In-VisiBLe Image Captioning*

Cover image
Two blind people exploring 3D model prototypes during In-VisiBLe Multiplier Event in Thessaloniki, July 2023 [Photo: CERB].

Fig. 01
The six In-VisIBLe Project Results [<https://site.unibo.it/invisible-eplus/en>]


In-VisIBLe Image Captioning Dataset and System.
Higher Education Innovative and Inclusive Didactic Modules (IDM) of History of Architecture.
Guidelines for the design and realization of 3D architectural models accessible to VIB.
In-VisIBLe Teaching & Learning Web Platform.
Massive Open Online Courses (MOOC) of History of Architecture accessible to VIB.
Guidelines to make architecture and visual arts accessible to VIB.

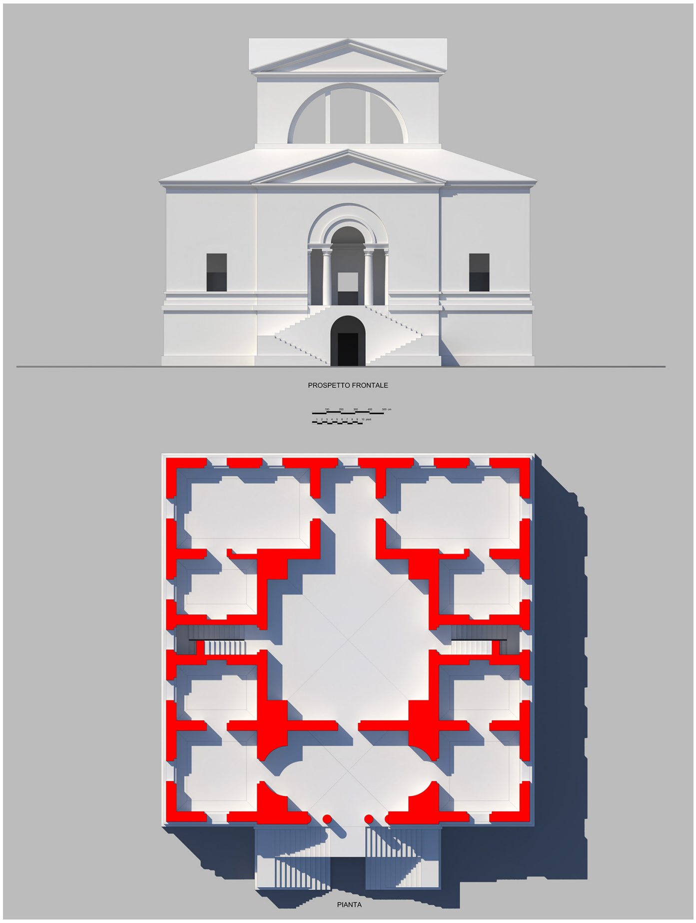
Dataset&System and the *In-VisiBle Teaching&Learning Web Platform*.

The second objective is to draw in a broader cross-section of society into HE, establishing collaborations with museums and cultural institutions, organizations for the blind, relevant stakeholders, and policy makers in the areas of education and inclusion [Friso 2017]. This is why *In-VisIBLe* consortium is composed of three EU Higher Education Institutions (Alma Mater Studiorum - Università di Bologna, Italy; Yedetepe University, Istanbul, Turkey; Akademia Humanistyczno-Ekonomiczna w Łodzi, Poland), one international research institution (Information Technologies Institute of Centre for Research and Technology Hellas, Thessaloniki, Greece), one public entity for the blind (Center for Education and Rehabilitation for the Blind, Athens and Thessaloniki, Greece) and one renowned public museum for blind people (Museo Tattile Statale Omero, Ancona, Italy). The mixed composition of the partnership ensures that the project results benefit from different fields of expertise (Architecture, Virtual reality and 3D Modelling, ICTs, Educational Sciences, Inclusive Education) and that they meet the needs of different target groups/sectors. The tangible results of *In-VisIBLe* project will consist in six Project Results (Fig. 1):

1. Higher Education *Innovative and Inclusive Didactic Modules (IDM) of History of Architecture* equipped with tools (3D architectural models accessible to VIB, tactile plates, text-to-speech, image captioning system) that make them accessible to all students enrolled, both by normally sighted and VIB students.
2. *Guidelines for the design and realization of 3D architectural models accessible to VIB*. Tactile architectural models are already in use in educational and cultural institutions and many companies specialize in their production; yet, simple, and complete instructions, accessible to all, for their design and construction are not currently available. The *In-VisiBLe Guidelines* will allow all kinds of users to follow the entire process of creating the models and adapt it according both to different users' needs and 3D printing process complexity. The guidelines will be freely downloadable from the project web platform together with the digital files of the models. Our goal is that every-

Fig. 02
The 3D digital mathematical model of Villa Valmarana, plan, and elevation [drawings of Elisa Bortolan and Martina Vanucci].

Fig. 03
The 3D digital mathematical model of Villa Valmarana, section [drawings of Elisa Bortolan and Martina Vanucci].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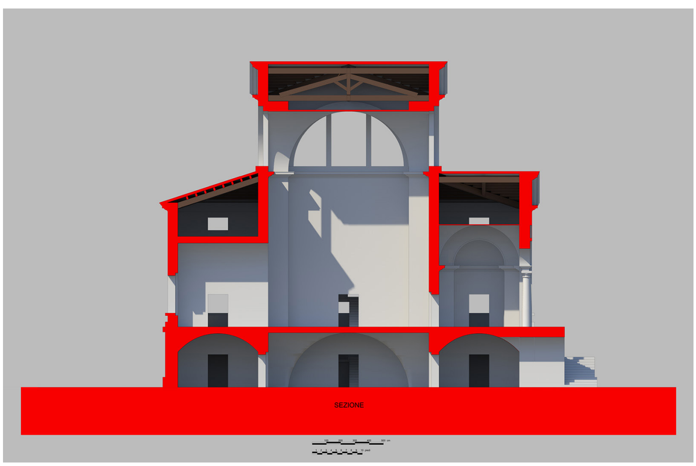
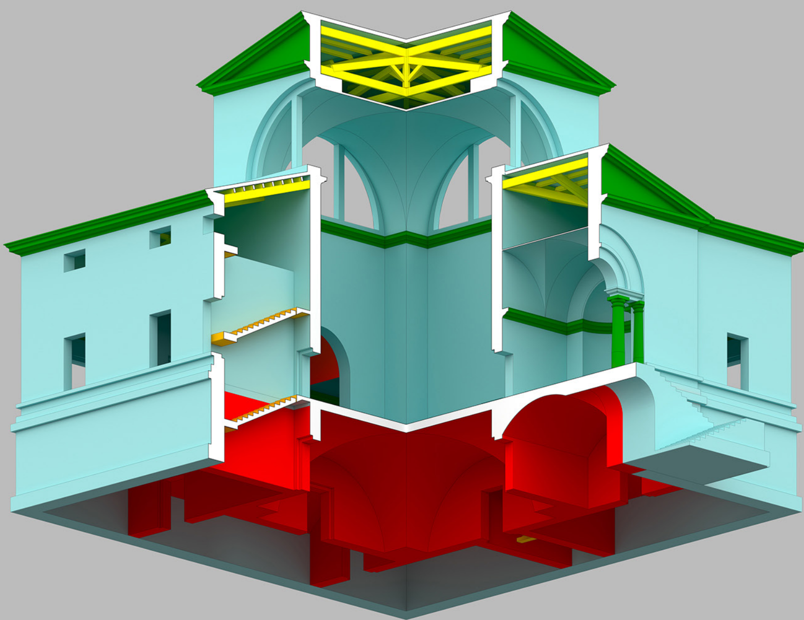
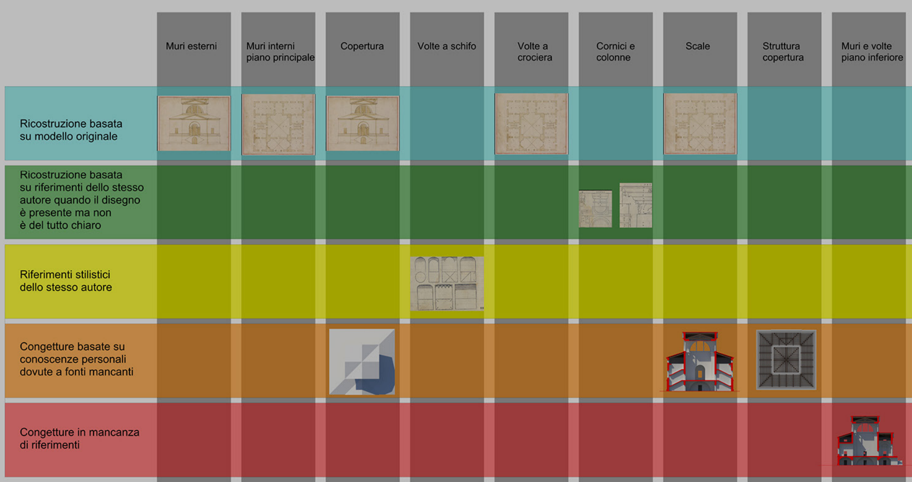

SEZIONE

one – students, teachers, or general users – will be able to autonomously print out accessible architectural models, in different scales and materials, using different types of printing machines.

3. *In-VisIBLe Image Captioning Dataset&System*: an Artificial Intelligence based on visual information to recognize building types and describe architectural images with captions. In ensuring the inclusiveness of also visually impaired people in the didactic process, one of the most important challenges is to transform the images used to describe the courses contents in a format that can be understandable by the visually impaired [Ahsan, Bhalla, Bhatt, Shah 2021]. Indeed, using text-to-speech technology, transforming the text into a modality that can be understood by the visually impaired is already done by multiple software platforms, while the auditory description of images tailored to a didactic lecture is missing currently. In the case of History of Architecture lectures, every image should be able to provide information about the type of building(s) described and at the same time give a detailed description about its content.
4. Developing an online platform that is accessible to visually impaired people is an important step towards creating a more inclusive teaching&learning tool [Ferati, Vogel, Kurti, Raufi, & Astals 2016]. For this reason, IDMs, Guidelines, and digital files to print 3D models, together with the links to the Captioning Dataset&System and MOOCs, will be uploaded on the *In-VisIBLe Teaching & Learning Web Platform*: a free-access, VIB-accessible online database. In this way, these tools will be available and freely accessible also to every user not directly involved in the project.
5. *Massive Open Online Courses (MOOC)* of History of Architecture accessible to VIB. To make the Inclusive Didactic Modules of History of Architecture available to the widest possible audience, they can also be used remotely, in the form of *In-VisiBLe MOOCs*, which are equipped with features that make them accessible to visually impaired and blind users [Marques, Escudeiro, Barata, Carvalho, de Sousa, Queirós 2019].
6. *Guidelines to make architecture and visual arts accessible to VIB*, which have the objective of promoting the dissem-

Fig. 04
The 3D digital mathematical model of Villa Valmarana, uncertainty scale table [drawings of Elisa Bortolan and Martina Vanucci].





Muri esterni
Muri interni piano principale
Copertura
Volte a schifo
Volte a crociera
Cornici e colonne
Scale
Struttura copertura
Muri e volte piano inferiore
Ricostruzione basata su modello originale
Ricostruzione basata su riferimenti dello stesso autore quando il disegno è presente ma non è del tutto chiaro
Riferimenti stilistici dello stesso autore
Congetture basate su conoscenze personali dovute a fonti mancanti
Congetture in mancanza di riferimenti

ination and use of the tools and methodologies developed for HE courses of History of Architecture in the activities related to visual arts of museums, cultural/educational institutions, high schools.

Cultural accessibility can play a pivotal role as one of the most strategic and effective tools in forging a genuinely inclusive society. *In-VisIBLe* project outcomes are expected to have a significant impact on educational institutions, including schools and universities, as well as museums and cultural establishments that play vital roles in the education and integration of visually impaired and blind people, who often lack the necessary resources for this purpose. This initiative will enable the implementation of an effective pedagogical model in educational settings ranging from secondary schools to universities and in the educational and exhibition programs offered by museums and cultural venues [Friso, Marchesani 2022]. Furthermore, the project is expected to have a considerable influence on sighted individuals, enriching their aesthetic and learning experiences and heightening their awareness of tactile perception and VIB learning methods. We aim at sharing the challenges of our project, in order to promote accessibility to culture and improve HE teaching and learning quality and innovation. In doing so, cultural accessibility can fulfil its role and become one of the most strategic and effective tools for creating a truly inclusive society.

Fig. 05
3D print model in 1:200 scale.

Fig. 06
3D print model in 1:100 scale of the sectional first floor plan; printed in two pieces.

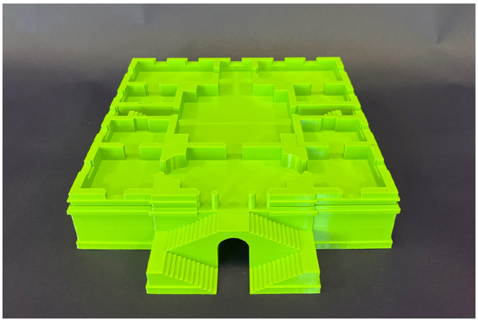
Fig. 07
3D print model in 1:100 scale of the sectional first floor plan; first part of the main entrance.

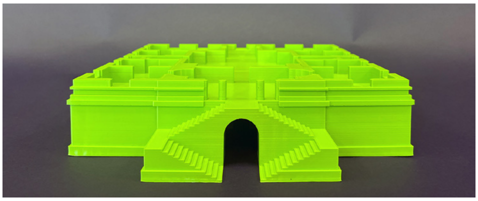
Fig. 08
3D print model in 1:100 scale of the sectional first floor plan; second part.

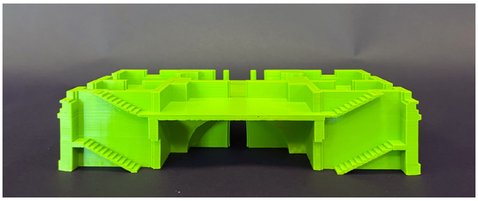
3D architectural models as HE inclusive educational tools

For the second objective (Guidelines for the design and realization of 3D architectural models accessible to VIB) some case studies have been developed which are currently in the final 3D printing phase (Fig. 2 and Fig. 3). These case studies (Palladian villas, the Tempietto of San Pietro in Montorio by Bramante, and some projects by Claude-Nicolas Ledoux) were selected and developed in collaboration with the CoVHer project (Computer-based Visualization of Architectural Cultural Heritage, 2021-1 -IT02-KA220-HED-000031190), an Erasmus + project started in parallel with the *In-VisIBLe* project [2].

The two Erasmus+ projects have different objectives but have one common issue: the construction of 3D models of his-







torical architectures. This made collaboration and exchange of some methodologies possible. Part of the know-how developed within the *CoVHer* project was used to create the 3D models of *In-VisIBLe*. Indeed, digital model with specific characteristics are necessary to carry out a 3D print. These characteristics concern some aspects of the model's construction: the semantic division of the architectural elements, the correct use of the methods and techniques of digital representation, the standard of the file produced and the interoperability of the 3D model, the 3D printing phase, and the subsequent postproduction.

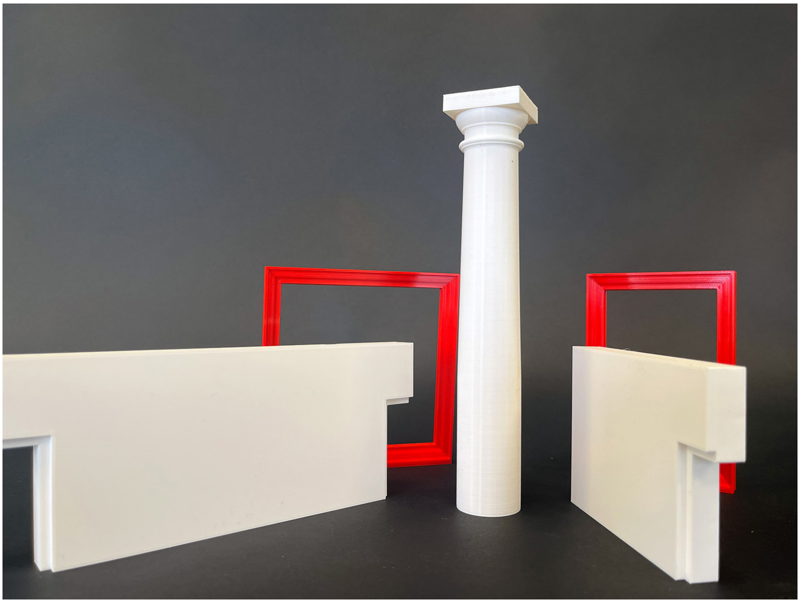
Here are presented some of the case studies (Villa Valmarana by Andrea Palladio) created within the Unibo *Architectural Drawing Laboratory (C.I.)* course [3] and partly reworked by intern students of the In-VisIBLe project (the 3D models were created within the course of professors Fabrizio I. Apollonio and Federico Fallavollita, the student authors of the models are Elisa Bortolan and Martina Vanucci; the intern students are Wessal Akrar and Alberto Angeletti). During the three-month course, digital critical 3D models of architecture that were never built or have been lost are studied and created [Apollonio et al. 2021]. The representation scale adopted is approximately 1:50, with some details that can reach the 1:10/5 scale (such as some frames or moldings of the architectural order).

The first important feature is the semantic division of the 3D model. The model is built according to the elements of the architecture which are identified and built separately (Fig. 4). The architectural elements can be either the wall, the window, the roof, or the column composed of the base, the shaft, and the capital, etc. The construction of the architecture by parts allows the user to read and represent the 3D model in a rational way. Furthermore, digital modelling techniques easily allow the organization of the model by levels and sublevels.

The second important issue is the choice of digital representation methods and modelling techniques. For this project it was decided to adopt the method of mathematical representation for the construction of 3D digital models, using the hand modelling technique. This allowed us to accurately control the geometry of the models and at the same time allowed the experimentation of this methodology within the Labora-

Fig. 09
3D print model in scale 1:50 and 1:50: different architectural elements.

Fig. 10
Two blind people exploring 3D model prototypes during *In-VisiBLe* Multiplier Event in Thessaloniki, July 2023 [Photo: Micaela Antonucci].



tory of Architecture Drawing C.I course of the Single Cycle Degree/Combined Bachelor and Master in Architecture at the University of Bologna.

The continuous digital representation method allows an accurate control of the modelling process because it describes the geometry through parametric mathematical equations. The 3D objects described in this way can be easily checked: for example, it is possible to check whether the 3D elements are closed with all manifold edges. This issue is very important from both theoretical and practical points of view. From a theoretical point of view, it is important because it allows us to imagine and build 3D models in a semantically and technically rational way; the 3D elements shall not self-intersect and shall be designed in scale with realistic joints and supports. From a practical point of view, it is important because the composition of the 3D model for closed watertight elements allows us to produce renderings without artifacts and transform the NURBS model into a watertight mesh without problems.

The tessellation phase of the 3D model, i.e., the transformation of the mathematical model into a polygonal model, takes place in a mathematical environment, making us able to control the geometric transformation. Before being exported for 3D printing, the file is exported as a standard sharing file (ICF, Industry Foundation Classes, is an exchange open file format aimed at the

interchange of 3D models, produced with a BIM based workflow, with the minimum loss of geometrical data, metadata and paradata). This format allows you to preserve some digital and structural characteristics of the original 3D model: the semantic and object division, the mathematical or polygonal geometric nature, etc. This is the format that will be freely shared on the *In-ViSIBLe teaching&Learning platform* as a source model for 3D prints. In fact, one of the shared objectives of the CoVHer and the In-VisIBLe projects is the creation of a 3D repository where every user can search in the future for other elaboration.

The 3D architectural models were developed with features (size, materials, scale, etc.) suitable for tactile exploration, that make them also accessible to visually impaired and blind people [Celani, Milan 2007; Watanabe, Sato 2019].

The 3D printing part is divided into various phases. The models are printed in the *Architectural Model Laboratory* of the Department of Architecture of the University of Bologna (responsible prof. Francesco Gulinello), with the collaboration of architect Davide Giaffreda. The first phase consists in the choice of the cut and the portion of the 3D model to print. In this first phase the model is analysed and sectioned to best communicate the main features of the architecture to be represented. In the case study of a Palladian villa, various 3D digital models were developed at different scales: a first 3D model at 1:200 scale (Fig. 5); a second 1:100 scale 3D model of the main plan (Figs. 6-7-8); a third sectional model of a quarter of the entire model in 1:50 scale and some details in 1:5 scale (Fig. 9). The different scales models were further developed in a second phase to be correctly printed: the 1:200 scale volumetric model was simplified by reducing and eliminating the internal structure of the model and simplifying some frames; the 1:50 scale model was modified by designing some joints of the architectural elements to facilitate the semantic reading of the object and its assembly by elements.

Furthermore, the different architectural parts have been printed with different colors to allow visually impaired people to better perceive the differences. The printed elements were processed with the open sources UltiMaker Cura program and created with the UltiMaker S5 3D printer. A study was carried out to test the best orientation of the elements to be printed in the 3D printing chamber to reduce and eliminate any printing defects. These study and indications can have general validity because they are linked to the type of printing technology adopted. The final print quality of course also depends on the type of the 3D printer used. The idea of the project is to provide, together with the example 3D models, the Guidelines for building and printing the models with different technologies and printer machines.

Conclusions

Both the two projects are still ongoing and at the end of 2023 the first finished results of this experimental phase will be presented. The goal is to produce some 3D models for HE visually impaired students, which were tested by visually impaired people in *In-VisIBLe* first Multiplier Event in July 2023 in Thessaloniki (Fig. 10).

The feedback was generally positive, especially regarding the scale of the models and the section cut chosen to communicate the spatial and geometric characteristics of the architecture. Among the critical issues is the printing material adopted: the plastic often has edges that are too sharp and can be unpleasant to the touch.

Furthermore, the characteristics of the layered 3D printing technique produce the jagged effect which can be mistaken for a surface feature of the 3D model. For these reasons, in some case studies post-production techniques will eliminate these problems: for example, the sharp edges will be filed down and the curved surfaces made smooth to allow correct reading by touch. The exploration of these models within HE courses will be assisted by a teacher/expert who will guide the visually impaired students in reading the architectural space and its superficial and formal characteristics.

Credits

This study was carried out together by the authors, who have discussed every aspect; yet, for merely academic reasons we attest that Chapter 1 was written by Micaela Antonucci and Chapter 2 by Federico Fallavollita; Conclusion was written by both the authors.

Note

[1] <https://site.unibo.it/invisible-eplus/en>

[2] The project is coordinated by Federico Fallavollita of the University of Bologna and involves five European countries; its main objective is the development of shared standards for the construction and validation of digital 3D models of architectures that were never built or have been lost. <https://covher.eu/>

[3] <https://www.unibo.it/it/didattica/insegnamenti/insegnamento/2023/458533>

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