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3D Printing Technology for Buildings' Accessibility: The Tactile Map for MTE Museum in Pavia

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Abstract: 3D printing technology is an innovative manufacturing technology used in several disciplines, whose number and diversity are growing day by day. The development of devices to improve the accessibility of buildings and urban spaces for people with disabilities through 3D printing technology is still not broadly explored. The present study is focused on filling this gap, with the realization of a tactile map of the MTE (Museum of Electrical Technology) of the University of Pavia (Italy) for blind and visually impaired people. The tactile map represents the building plan with all the information to guide the visit. The device is the result of a research process which is made by several steps and experimental tests, aimed at setting the best 3D printing profiles to meet all the requirements of the end-users. This paper describes methods and strategies applied to reach these goals: it underlines the social and technical approaches, the experimental phases and its possible future developments.

Key words: Accessibility, inclusive design, 3D printing technology, tactile maps, museums.

1. Introduction

1.1 Disability, Accessibility and Social Inclusion

Giving a numerical framework for "disability" is not easy because of the various conditions to consider. According to the United Nations, there are 650 million people with disabilities in the world, which corresponds to the 10% of the global population, that means the third world nation after China and India [1]. In addition, we have to consider the elderly, who are exponentially increasing: their welfare and inclusion represent a fundamental social challenge.

Thanks to the principles introduced by the ICF model—International Classification of Functioning (World Health OrganizationAssembly, 2001) and by the UN Convention on the Rights of Persons with disabilities (2006), the meaning of "disability" is now evolving: it is no more a permanent impairment deriving from a disease, but a "transient condition" resulting from the interaction between personal attitudes and environmental barriers that prevents the person's active and equal participation in society [2].

This new approach raises the need to design environments, urban spaces and buildings easily accessible and usable to as many users as possible.

An accessible world, which takes care of the special needs of people with disabilities, is surely a better world for everybody. Improving environments' and buildings' accessibility, with the design of inclusive solutions and devices, is a fundamental opportunity of progress and valorization.

If we decline this theme to the historical and cultural heritage, we can immediately understand how its accessibility is one of the primary goals to enhance its value and guarantee its conservation. The effort should include urban spaces, buildings, mobility systems and also the cultural activities and events. Also the UN Convention reaffirms the importance of the participation of people with disabilities "in the cultural life, recreation, leisure time and sport activities" [3].

The challenge of today is to pursue works and researches to develop inclusive solutions, with the aim of guaranteeing the best life's and social conditions to

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all people, following the principles of the universal design.

1.2 Accessible and Inclusive Museums

According to the ICOM (International Council Of Museums), a museum is "a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment" [4]. Museums have to be open to the public and to enrich people's culture. Thus, museums must be thought and designed for all people, regardless of their physical, sensorial or cognitive capabilities.

One of the main reference for the Italian regulations about museums, is the MiBAC Decree 10 May 2001. It underlines that all the public parts of museums "have to be accessible and usable to all the visitors" [5], including (1) the design of architectural solutions to overcome the differences in levels (at the entrances and inside the building); and (2) the devices and measures to let people with special needs understand and enjoy the visit (e.g., multisensorial sign systems and captions, easily usable reception desks and exhibitions elements, accessible paths, etc.).

It is important to underline that by saying "people with special needs", we refer to people with mobility, sensory or cognitive impairments, but also to children, elderly, dyslexic people and/or affected by learning problems, obese, cardiopathic, asthmatic people, etc. Making museums accessible to all these people means improving several aspects, e.g., the social and moral image, the museums' gains (because the number of visitors can increase) and the tourism in general. Designers have to apply the "inclusive design" principles and not only "for" people with disabilities.

One of the main solutions to reach this goal is to emphasize the use of all the five senses in a balanced way, being able to answer the needs of people with sensorial impairments, but also to enrich the visit for all. This result can be reached only putting the museum's visitor, with his/her different needs, curiosity and interests, at the center of the design process. Museums should be flexible and dynamic entities, able to change with the visitors and to answer their needs in interactive and innovative ways.

The main critical aspects about museums accessibility can be classified as following:

- container—accessibility of the building. The Italian law defines it as the possibility also for people with mobility or sensorial impairments to reach, enter and use spaces and parts in conditions of adequate safety and autonomy [6];
- contents—usability of exposed works. This means the right to acquire knowledge through the main senses (hearing, sight, touch). Visitors, regardless of their physical, sensory or cognitive capabilities, experience a handicap when the cultural message does not capture their interest [7];
- connections—information and symbolism. A precise, easily understandable, coherent and updated information system helps visitors to understand and enjoy spaces and the exhibitions. Different devices should be used, with proper interfaces and multisensorial solutions.

In the particular case of blind and visually impaired people, architects and engineers have to take care of the orientation and the spatial perception, together with the tactile and auditory consultation of the exposed works. Tactile maps, models, audio-guide and Braille captions—the tactile writing system based on an alpha-numeric code, invented by Louis Braille in 1825—strongly help reaching this goal. All these solutions improve the museum's offer and quality for all, not only for visitors with disabilities.

1.3 Tactile Illustrations, Models and Maps

Tactile aids specifically derive from educational needs. Their spread started thanks to the institutes for blind people, both in Italy and abroad, in the first half of the 19th century. The first examples were developed for didactic purposes and "for practicing of spatial orientation and movement" using "linear representation of everyday pathways for various users" (e.g., way from home to office and back, shopping, etc.) [8].

In order to make the comprehension easier, the tactile images should have the following features [9]:

- adequate thickness of the elements;
- easily identifiable graphic forms;
- resistance of the materials;
- identifiable textures and distinguishable elements;
- expressive clarity of figures;
- order of graphic elements and respect of their proportions;
- wholeness of the shapes;
- glued or properly fastened elements, not dangerous to the touch;
- non-prospective landscapes, backgrounds or figures;
- bright colors and strong contrast to facilitate reading to vision-impaired people.

In particular, the design of tactile images should guarantee adequate dimensions and materials, with net contours, precise details and touch-sensitive surfaces. The details should be realized considering that the tactile perception is up to 0.5 mm in thickness [10]. In two-dimensional reconstruction, like buildings' plans, the third dimension of thickness is aimed at the tactile perception: different heights can differentiate the elements' hierarchy.

This research deals with the realization of a special kind of tactile images: the "tactile maps". They are representations in relief, with colour contrasts, of buildings and spaces' plans, to help the orientation and the places' recognisability for blind and visually impaired people (an example is shown in Fig. 1). Tactile maps allow people to experience the environment in terms of dimension, proportion, shape and features and to acquire a mental reproduction of it, which is useful to live the space in more safety and autonomy conditions.

Tactile maps can be classified into two main types: "path maps" when they are related to tactile guides in the paving, also reported in the model; "place maps" when they represent the main reference points for orientation, such as streets, green areas, buildings walls, pillars, etc.

Fig. 1 Wooden tactile map of Avila Cathedral, Spain.

Table 1 Comparison of techniques to create tactile images.

Techniques	Costs	Realization	Relief
1. Embossing	High	Matrix	More levels
2. Thermoforming	High	Matrix	More levels
3. Dotted design	Cheap	Manual/printer	One level
4. Serigraphy	High	Viscosity ink	One level
5. Materic collage	High	Glued material	More levels
6. Microcapsule	Cheap	Oven printer	One level

The most used techniques to create tactile maps and images are: (1) embossing or "gaufrage"; (2) thermoforming; (3) dotted design; (4) serigraphy; (5) material collage; (6) microcapsule paper or "Minolta system" [9]. The main features of these techniques can be resumed in Table 1.

The main disadvantages of these techniques are related to the high costs (and work hours) to create the matrix of the object to be realized or to manually assemble the different pieces of materials. These processes are not easily flexible to future modifications.

In the cases of dotted design, serigraphy and microcapsule techniques, it is possible to create only one level of relief, and the tactile information is limited.

During the last years, another manufacturing solution has become available to create tactile images: 3DP (3D Printing Technology).

1.4 3D Printing Technology

AM (additive manufacturing)—also known as 3D printing—is an innovative and emerging technology for the production of 3D solid objects with a complex shape, starting from a 3D virtual model and obtained through a sequential deposition of layers of material.

Compared to more traditional manufacturing, 3DP changes technological production paradigms and it offers several benefits, such as mass customization (i.e., ability to create an unlimited spectrum of custom-built designs), improved flexibility (i.e., possibility of mass-producing complex products), shorter time-to-market (i.e., shorter design, process, and production cycles), simplified supply chain (i.e., production closer to final user), reduced waste of material (i.e., production of near-net-shape parts with almost no waste material) [11]. These advantages empower 3DP as a promising technology in various industrial fields such as automotive (with innovative designs and specialized components for engine production), aerospace (i.e., prototype of jet-engine parts), healthcare (with orthopedic implants, surgical guides, models for surgical planning and bio-printed tissues) and consumer (i.e., custom jewelery, goods and sport supplies).

Among all 3DP technologies, ASTM (American Society for Testing and Materials International) recognized seven main categories [12], based on different materials and curing systems.

Thanks to their flexibility, 3DP technologies are becoming increasing popular in many different fields of healthcare, including the production of aids/devices for people with disability.

As already mentioned, standard technologies for the production of tactile maps are mixed media, microencapsulation and thermoforming; all these techniques have several limitations, like high production times and costs, maps' low resistance, tactile degradation, low flexibility and the "monochrome bond". Some research groups started to work with 3D printed tactile maps, standardizing and comparing them to the ones produced through more traditional techniques, in order to overcome all these limitations. Voženílek et al. [8] aimed at evaluating all the aspects of interpretation and perception of geospace by new tactile maps produced through 3DP technologies.

During their research, they cooperated with final users (both blind and visual impaired people) and the organization Tyflocentrum Olomouc to determinate the most suitable and appropriate parameters and symbols to be used in this new type of tactile maps.

Gual et al. [13] compare multi-chrome 3D printed tactile maps and symbols with a classic microencapsulated paper, in order to determinate if there are significant differences in their use. Maps have been tested by several sighted, partially sighted and blind people, to define if these differences can depend on the different participants' profiles. Results showed a significant decrease both in time spent performing tasks and in discrimination errors to less than half for people using 3D printed tactile maps.

Moreover, an improvement in the process of memorizing tactile map legend and keys using 3D printed symbols is underlined [14]. Statistics were better especially for the blind people group, showing that 3DP technology can improve the use of tactile maps and reduce the time users spend to find them in an autonomous way.

Among the available 3DP solutions, we limited the evaluation to two technologies, according to the main requirements of the tactile map, i.e., durability, details accuracy, touch pleasing and possibility of managing different colors. These two technologies are:

- Binder jetting: it uses a base material, a powder base, which is distributed in equal layers, and a liquid binder, which is dropped through jet nozzles to "glue" the powder particles according to the 3D virtual model. It also allows to achieve a full color scale model;
- Material extrusion: it is the most widespread technology on the market; it involves the use of thermoplastic filaments, melted and deployed following a path that designs each slice of the 3D virtual model. The most common extrusion-based AM technology is the FDM (fused deposition modeling), trademarked terms by Stratasys Inc., or FFF (fused filament fabrication), exactly the equivalent open source term.

1.5 Research Question

From the considerations above, the importance of using the 3DP technology to develop solutions and devices for blind and visually impaired people is clear.

Thus, the research question we want to answer is: how to create tactile maps through 3DP technologies, which really meet the needs of blind and visually impaired people? In particular, our goal is to evaluate binder jetting and material extrusion technologies and produce a 3D printed tactile map with the most suitable technology and settings.

2. Materials and Methods

2.1 The Tactile Map for the MTE Museum in Pavia

Our first case study is the MTE (Museum of Electrical Technology) of the University of Pavia, Italy, directed by Prof. Michela Magliacani.

The museum is organized into five sections in temporal order and it is characterized by a one-level-structure of about 5,000 m^2, of which 3,200 m^2 for visitors. It is easily accessible for people with mobility impairments, but there are no devices for blind and visually impaired people.

The first step to increase MTE accessibility and usability is the realization of a tactile map, with information about the main elements of the museum and its exhibition path. The map is created and designed by Prof. Alessandro Greco and Dr. Valentina Giacometti and it is realized by Eng. Gianluca Alaimo, Dr. Stefania Marconi and Eng. Valeria Mauri, at the laboratory 3D@UniPV—Proto Lab of the Department of Civil Engineering and Architecture of the University of Pavia, coordinated by Prof. Ferdinando Auricchio.

The map, including descriptions in relief and Braille, is thought to be positioned at the entrance of the museum, near the ticket office. Its manufacturing should guarantee an adequate chromatic contrast between the base and the map's elements, and should

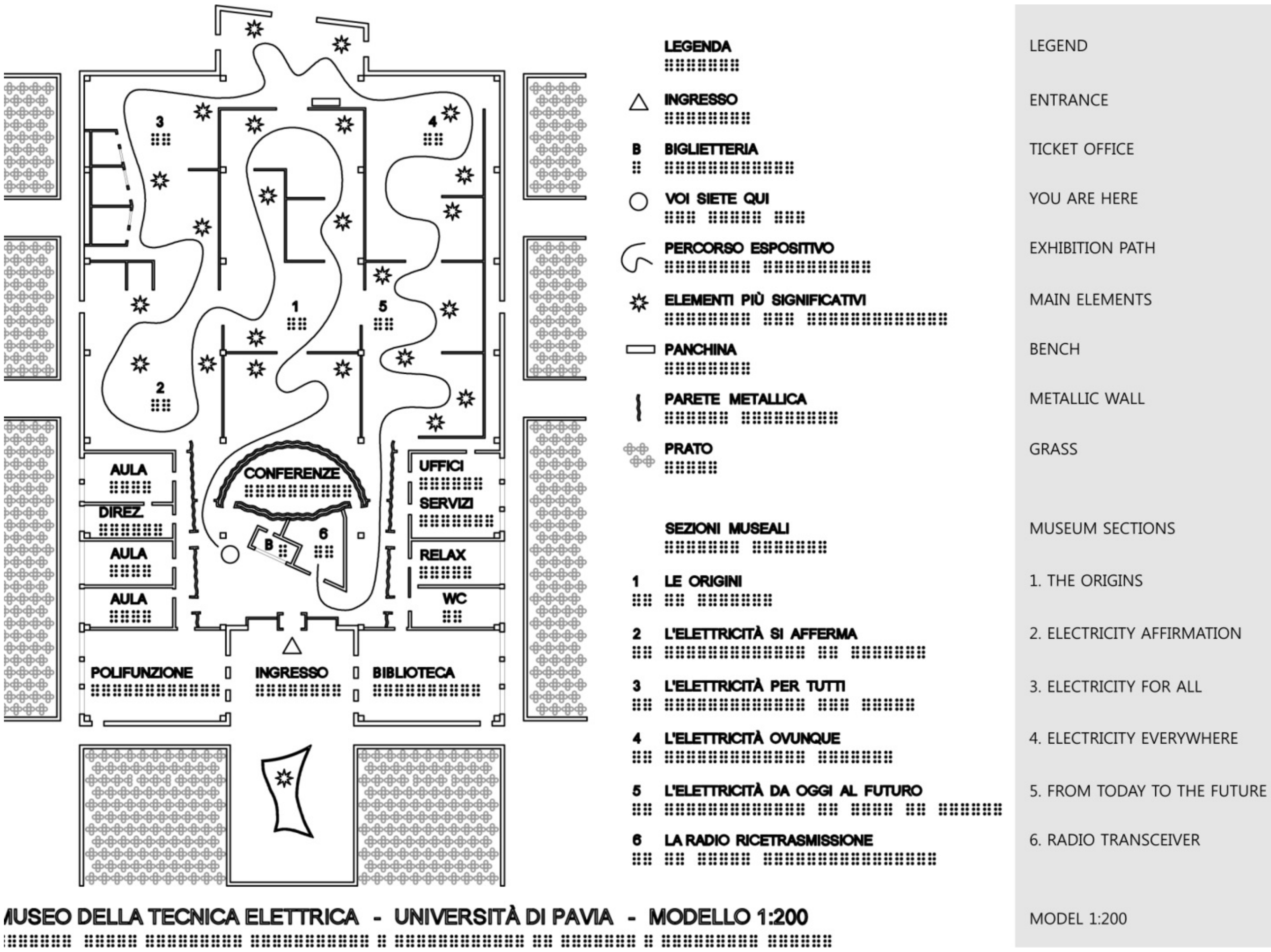

Fig. 2 Scheme of the tactile map for the MTE Museum.

result pleasant to the touch, resistant and durable.

According to the precious advice of Nicola Stilla, Italian Union of Blind and Visually Impaired People, different heights are included in the map to represent the main elements. In addition, specific surface textures are developed to better define the most significant elements.

The map is divided into two parts: on the left, there is the building's plan, in scale of 1:200, with the main museum objects and the exhibition path; on the right, there is the symbol legend, where each line of text in relief has its translation in Braille directly below (in Fig. 2).

2.2 Research Phases

The map is realized by applying an experimental process based on several testing steps. Three main iterative research phases can be identified:

- design: the tactile maps' contents are organized and a 3D virtual model in CAD (Computer Aided Design) is realized;
- realization: 3DP technologies are tested on this specific object to be realized;
- partial tests: to check and select the best materials, printer settings, shapes and dimensions of the single map's elements. In this phase, Nicola Stilla lets us understand the real needs of blind people and how they consult tactile devices.

Thanks to this iterative process, it is possible to identify the best materials, levels, heights, shapes,positions, dimensions and textures of the elements. One of the main efforts is focused on the translation of captions and texts into Braille: its dots code dimensions and distances are standard and the pleasantness to the touch must be guaranteed.

2.3 Partial Tests

As already mentioned above, two different 3DP technologies are tested for the realization of the tactile map for the MTE Museum: binder jetting and FDM. Four different tests are carried out:

- T1—binder jetting: a Projet 460 Plus by 3DSYSTEMS® company is used for the 3DP. The machine works using a chalk-like powder cured using glue and features a wide range of colors (up to 2.8 millions) along with short production times; on the other hand, due to the base material features, printed surfaces result rough and irregular, leading to a low touch pleasing. Moreover, the material fragility limits the durability of small details over time;
- T2—FDM 1 color: all the FDM tests involve the use of a 3NTR A4v3 FDM 3D printer (J-Deal Form® company) that is equipped with three extruders of 0.4 mm of nozzles' diameter, enabling the use of three different colors (or materials) at the same time. First, a single material is used to test the feasibility of the manufacturing and to assess the overall result. During this step, a preliminary set-up of the main printing parameters is carried out: an extrusion width of 0.5 mm is employed, along with a bed temperature of 120 °C and a printing environment temperature of 70 °C. Because of the printing area dimension, the tactile map (59.4 × 57.6 cm) is divided into 16 tiles (12 of 144 × 165 mm size and 4 of 99 × 144 mm size). Each tile requires about 3-4 hours of printing time, depending on the amount of details. 3D printed thermoplastic polymers are more touch pleasing and durable with respect to the previous test, resulting the most suitable printing materials for the realization of tactile maps. On the contrary, the use of a single color is not considered suitable for visual impaired people;
- T3—FDM 3 colors A: we preliminarily test the colors to identify the best combination to ensure an appropriate contrast among the different elements represented in the tactile map; the final choice is: blue for the map base, white for perimeter walls and internal partitions and yellow for texts and exhibited pieces. We still use the same printing parameters of T2. The use of different colors and, therefore, of various extruder changes during printing, leads to a significant increase in production times (about 20%~30%, up to 9 hours). Such an issue does not represent a limit for the manufacturing process;
- T4—FDM 3 colors B: we use the same printing setting of T3, but with a lower extrusion width of 0.4 mm: this change leads to a better manufacturing of fine details. Consequently, we achieve a better feedback from blind people in terms of touch pleasing, comprehension of Braille writing and details accuracy. The decrease in extrusion width involves a negligible increment (20-30 minutes per tile) of the printing time. The results of the partial tests are shown in the following Fig. 3.

3. Results and Discussions

3.1 Results Comparison

Each test (T1, T2, T3, T4) leads to partial results and considerations which are fundamental for the achievement of the final goal.

In order to report these partial results and learn from them, we elaborate a comparison table (Table 2) made up of the following criteria: details accuracy (C1), resistance and durability (C2), touch pleasing (C3), colors management (C4), and speed of realization (C5).

The details accuracy (C1) is validated by the experience of Nicola Stilla. According to him, tests T1, T2 and T3 guarantee proper details for the map symbols and surface textures (score 2), but only T4

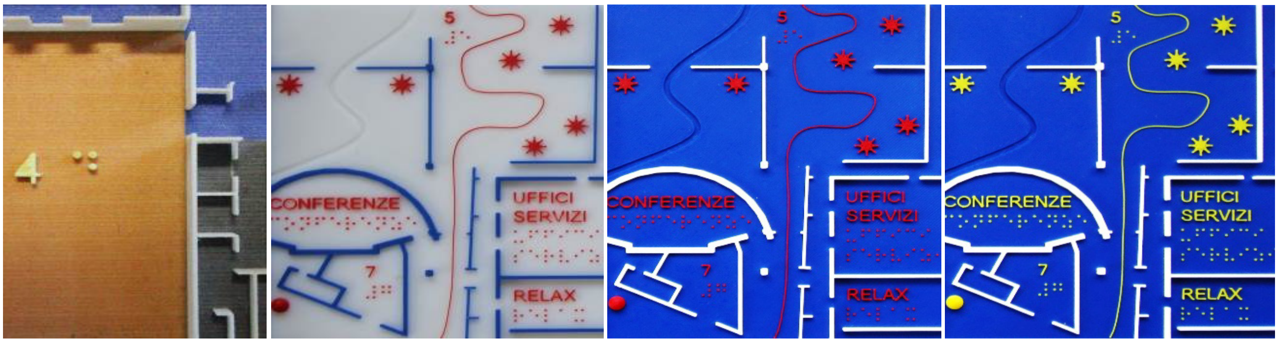

Fig. 3 Partial tests to identify the best 3DP technology and setting: T1 (binder jetting), T3 (FDM 3 colors A,with white base), T3 (FDM 3 colors A,with blue base), T4 (FDM 3 colors B: blue, white and yellow, with a lower extrusion width of 0.4 mm).

Table 2 Comparison of the partial tests according to the criteria.

Test type	Details accuracy C1	Durability C2	Touch pleasing C3	Colors C4	Speed C5	Total
T1—Binder Jetting	2	1	1	3	3	10—rejected
T2—FDM.1c	2	3	2	1	2	10—rejected
T3—FDM.3c.A	2	3	2	2	2	11—rejected
T4—FDM.3c.B	**3**	**3**	**3**	**2**	**2**	**13—approved**

Note: 1—bad, 2—mediocre, 3—good.

achieves successful results for texts in relief and Braille dots (score 3).

The durability parameter (C2) is evaluated according to the mechanical properties of the materials under analysis, i.e., the chalk powder (VisiJet PXL™) and ABS (acrylonitrile butadiene styrene). We preliminarily consider the elastic modulus, the elongation at break and the stress at break. The elastic modulus is a measure of the stiffness, the stress at break represents the strength of the material while the elongation at break is representative of its toughness. ABS shows an elastic modulus of about 2,000 MPa and a tensile strength in the range 25~35 MPa, while the VisiJet PXL™ exhibits a modulus of 9,450 MPa and its stress at break is equal to 14.2 MPa. Stiffness and strength of both VisiJet PXL™ and ABS are suitable for the realization of the tactile map, being the chalk powder the most stiffer and ABS the most resistant. Even though the map will not bear any structural load, it will be subjected to extensive manipulation in an unprotected environment, according to its final aim. Thus, we evaluate the capacity of the material of absorbing energy during impacts and of undergoing to unexpected loads, without failure or damage. This feature can be quantified by the strain at break property: a higher value of strain at break results in a more ductile behavior. Given such considerations, the scores are assigned only considering the value of the strain at break as follows: 1 up to 0.25%; 2 for values in the range 0.25%~1%; 3 for values higher than 1%. We retrieve a value of strain at break equal to 0.23% for the chalk powder[1] and in the range 1%~30% for 3D printed ABS [15], depending on fiber orientation and filament dimensions; we consequently assign the score 1 to VisiJet PXL™ and 3 to ABS.

The touch pleasing (C3) is again a qualitative evaluation by Nicola Stilla. It is based on the print finish degree and the feel of touch. Because reading and understanding only by touching takes blind people a long time, it is clear that the pleasantness to the touch is essential. The plaster used with binder jetting technology (T1) is too wrinkled to the touch (score 1); tests with FDM printers (T2 and T3) lead to mediocre results (score 2); only test with a lower extrusion

1 https://www.3dsystems.com/materials/visijet-pxl/tech-specs.

width (T4) completely satisfies the tactile requirements (score 3).

As concerns colors management (C4), binder jetting technology offers an extremely higher chromatic resolution with respect to FDM printers. We underline that binder jetting resolution is not fully exploited in the present application: actually, to ensure the usability by visually impaired people, few highly contrasted colors are sufficient. Accordingly, we assign scores as follows: 1 for monochrome prints; 2 up to 8 colors; 3 for values higher than 8.

The speed of realization (C5) for the entire map is very different for the two technologies. The Projet 460 Plus enables to realize the 16 tiles in one time, i.e., in the same building plate, for a total printing time of about 20 hours. Further, 20 hours are required for the cleaning and post-processing of each tile, for a total amount of time of 40 hours (2.5 h/tile). For FDM, the printing time depends on the number of extruders employed and on the specific printing parameters. Each time the printer has to change the extruder in use, a fixed amount of time is devoted to the extruders cooling/heating. With respect to a monochrome print, a 3-colors print involves a time increase of about 20%. The total amount of printing time with FDM ranges from 104 to 135 hours (6.5 hours/tile to 8.4 hours/tile) for monochrome and polychrome prints, respectively, considering also the post-processing required (about 6~7 hours for the whole map). Thus, we assign scores with respect to the total manufacturing time per tile: 1 if ≥ 10 hours/tile ; 2 if < 10 and ≥ 5 hours/tile ; 3 if < 5 hours/tile.

In Table 2, the assigned scores are summarized. The maximum level would be 15 (5 criteria × 3 maximum score): only the last test (T4—FDM.3c.B) exceeds the 80% of the assessment (12 points), reaching the total score of 13 points.

Accordingly, we opt for this choice: it results the best solution for our aims.

3.2 Technology Insights

As described above, the present research brings to select the FDM technology to create the tactile map for MTE: it is the most widespread, flexible and economic 3DP technology [16] and it answers the users' needs.

This technology involves the use of thermoplastic filaments, pushed through a heated extruder and a small nozzle by tractor wheels and deployed following a path that designs each slice of the 3D virtual model. The material curing is performed through a cooling process that enables the solidification of the deployed material. The trajectory of the printing head is driven by the "g-code", i.e., the standard language based on a series of coordinates, commonly used to handle industrial machineries.

The completely open-source nature of the FDM process allows the user to intervene directly on the machine code, controlling all the process parameters. FDM machines have the ability to process and combine large classes of materials, possibly locally changing infill patterns, density and all the other printing parameters: these features are not common to other 3DP technologies. Indeed, FDM covers a wide class of thermoplastic polymers, ranging from common ABS and PLA (poly-lactic acid) to biocompatible materials like PCL (polycaprolactone), to high-performance materials like PEEK (polyether ether ketone) and Ultem®, known for their recent "metal replacement" applications [17], to high-deformable materials as TPU (thermoplastic polyurethane).

The extreme flexibility of this technology opens several research paths and possibilities of application. As already mentioned, this work uses ABS in three different colours, in order to meet the special needs of blind and visually impaired people.

Fig. 4 Tactile map of the MTE museum.

3.3 Project Insights

The resulting 16 tiles of the tactile map are perfectly matched and fixed on a uniform base (see Fig. 4). In order to guarantee a reading hierarchy, the relief heights are different: 2.5 mm for the main walls, 1.25 mm for the internal walls and 1 mm for the texts, the symbols and the numbers. We create a specific corrugated shape to represent the metallic walls which separate the museum sections. The exhibition path is identified by a continuous yellow line, 0.5 mm height, which starts from the "you are here" point and links all the museum sections. The grass around the building is created by a specific texture, also reported in the symbol legend.

The whole map (59.4 × 57.6 cm) is put on a steel inclined lectern, with minimum height 80 cm, and maximum height 95 cm. The inclined position allows its easy tactile fruition for everybody, also for children and people on wheelchair.

4. Conclusions

The present research aims at realizing a tactile map for the MTE museum with the 3DP technology, in order to improve its accessibility for blind and visually impaired people. The study focuses on tactile maps' features and on the several techniques and applications of the 3DP technologies. From the combination of these studies and the comparisons of several tests, we find in the FDM technology with three extruders the best solution for our purposes. In fact, this technology lets obtain successful results about:

- details accuracy, fundamental to realize a tactile map with proper and clear information for blind people. In particular, the Braille language requires specific dimensions and features;
- durability, necessary to guarantee the tactile consultation by hundreds of visitors each day;

- touch pleasing, fundamental for blind people to use (and enjoy) the tactile map;
- colors combination, necessary to enlarge the use of the tactile map also for visually impaired people, children and all the interested visitors;
- time of realization, from the 3D model (CAD), the tactile map is realized into 16 different tiles, because of the dimensions of the printing area, in quite a short time (average of 9h for each tile).

Short time and flexibility of realization also mean lower costs than the maps realized with the mold matrix: the latter method is advantageous only for a great number of equal objects. 3DP technology means modelling only by 3D software, without matrices, so it is particularly indicated for unique objects, and it is easier to carry out partial tests. In addition, it guarantees flexibility in the future: each tile can be reprinted and replaced.

This work shows the application of 3DP technology to create successful tactile maps. Working on the map for the MTE Museum, we could improve our knowledge and hone printing technologies which can be exported to several cases. Our next steps will be focused on the realization of other tactile devices with 3DP technologies, to improve the quality of buildings and places, not only for people with disabilities but for all.

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