Architectural Models for Tactile Perception

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Abstract

The article discusses the role that physical models play in the process of incorporating and breaking down perceptual and cognitive barriers in the communication and representation of historic-architectural heritage, also in relation to what international conventions and more recent regulatory guidelines indicate.
In addition to the historically well-established purposes of the model as a design aid, other purposes have been added, such as providing a better understanding of spaces within orientation systems.
In the field of cultural heritage enhancement, the use of the physical model is cited by several guidelines as a useful element in improving accessibility conditions for different types of users.
The analog model can address both the 'haptic narrative' of the state of affairs and the narrative of hypothetical reconstructions of the same, thus being able to 'speak' not only to people with visual or cognitive disabilities, but to the totality of users.
In this regard, the article illustrates a series of case studies that use the analogous model of architecture to overcome the role historically assigned to these artifacts, which involved an exclusively visual perception, by opening them up to a new level of sensory perception capable of increasing the degree of inclusiveness.

Keywords: accessibility, cultural heritage, perceptual barriers, communication, universal design.

Introduction

Cognitive and perceptual accessibility is a fundamental building block for the effective and inclusive communication of cultural heritage. In fact, it aims to remove the barriers that hinder the understanding and enjoyment of heritage by people with disabilities, the latter understood as the set of conditions that hinder people's participation in society due to the presence of barriers of various kinds [Menchetelli, Melloni 2023].
There are several conventions and regulations that address the issue of eliminating physical, sensory and cognitive barriers within cultural venues. For example, the *United Nations Convention on the Rights of Persons with Disabilities* (Law 18/2009) [1] recognizes the right of persons with disabilities to participate in cultural and leisure activities on an equal basis with others (article 30) and obliges States to take measures to make cultural facilities accessible (article 9); or the *Faro Convention on the Value of Cultural Heritage for Society*, which emphasizes "the promotion of measures to improve access to cultural heritage, especially for young and disadvantaged people, in order to increase awareness of its value, the need to conserve and preserve it, and the benefits that can be derived from it" (article 12) [2].
In Italy, the Ministerial Decree of 28 March 2008 named *Linee guida per il superamento delle barriere architettoniche nei luoghi di interesse culturale* [Ministero per i Beni e le Attività Culturali 2008] establishes the minimum requirements for the physical, sensory and

cognitive accessibility of cultural places according to the principles of Universal Design, while the Guidelines for the preparation of the *Linee Guida per la redazione del Piano di Eliminazione delle barriere architettoniche* (P.E.B.A.) [Direzione Generale dei Musei 2018] and the subsequent *Piano Strategico per l'Eliminazione delle Barriere Architettoniche* (Ministerial Decree No. 534, 19 May 2022) [Direzione Generale dei Musei 2022] aim to adapt museums and institutes to achieve the widest possible physical, cognitive, sensory and cultural accessibility.
Planned actions include the elimination of physical barriers through interventions to adapt spaces according to the principles of inclusive and universal design, and the elimination of cognitive barriers through interventions to facilitate the understanding of spaces and the communication of cultural artifacts through translation into simple language or the use of visual and tactile aids. In this area, physical models play an important role in the communication and inclusion process, providing a tangible three-dimensional representation that allows people of all abilities to explore and understand sites and monuments in a more complete and immersive way.
In fact, the analog model can facilitate the understanding of spatial relationships between different parts of a building or monumental complex, addressing not only people with disabilities, but the totality of users.
Physical models support the 'reading' of complex architectural and spatial concepts and consequently the creation of a mental representation of them, allowing to "visualize" the structure, the arrangement of rooms and the relationship with the surroundings; they also allow to explore architecture through touch, providing information about shapes, volumes, textures and materials, even showing details that are not always perceptible through sight; finally, they can be used for educational and awareness-raising activities, encouraging interaction with heritage and its history.
The scientific literature suggests several studies on the uses and purposes of tactile models of architecture, which may be focused on informing and orienting users [Caddeo et al. 2006], or may have as their goal the enhancement of cultural heritage. In these cases, the models may represent the building in its full volumes, either as ruins or as reconstructive hypotheses [Caldarone 2018; Empler, Fusinetti 2021; Empler, Caldarone, Fusinetti 2023], the environment on which it insists,

Fig. 1. Hagia Sophia, Istanbul, mosaic of the southern vestibule (11th century). On line source: <https://rb.gy/cjf8q5> (accessed 21 February 2024).

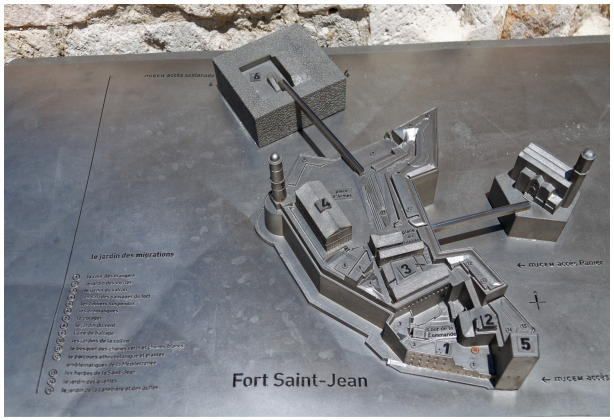
Fig. 2. Brunelleschi and Ghiberti present Cosimo the Elder with the model of the Church of San Lorenzo, executed by Marco da Faenza after a design by Vasari (1556). On line source:: <https://rb.gy/21bnrb> (accessed 21 February 2024).

the details and particularities of its external conformation or its interiors [Balletti et al. 2012; Sdegno, Riavis 2020], even the three-dimensional reconstruction of Renaissance paintings with the desire to narrate the perspective scan, a fundamental element for understanding and recognizing the value of the painting [Ansaldi 2023]. This extensive documentation is then complemented by contributions related to the conferences Il Disegno per l'Accessibilità e l'Inclusione - DAI 2022 [Càndito, Meloni 2022] and DAI 2023 [Sdegno, Riavis 2023] both sponsored by UID, proving the topicality of accessibility and inclusion issues within the discipline of drawing.

Architectural models over time

The evolution of the use of architectural models is historically documented, and it is possible to show how the purposes of use have changed over time, moving from an initial symbolic and religious use to a design use.
In the Greek world, for example, the physical models of architecture could represent the synthesis of the building, constituting themselves as *ex votos* to be given to the deity [Bigi 2017], as similarly happened in the Egyptian or Byzantine periods. An example of the latter is the mosaic inside the Hagia Sophia in Istanbul, in which two emperors are depicted, each holding a physical model presented to the Virgin Mary with Jesus. Emperor Justinian holds a model of the basilica he rebuilt in the 6th century, while Emperor Constantine holds a model of Constantinople, the city he founded, named after him, and which houses the basilica itself. The use of the model, both of the city and of the church, is valued here as a homage to the god whose grace and protection they invoke [Whittemore 1938] (fig. 1).
In the Renaissance, the physical model began to take on new meanings, playing a fundamental role in the architectural design process due to its ability to communicate the building under construction to the patron. In the painting by Marco da Faenza, commissioned by Vasari, *Brunelleschi and Ghiberti Present the Model of the Church of San Lorenzo to Cosimo il Vecchio*, it is the figure of the patron who emphasizes and at the same time points out the correspondence between the model shown and the building site under construction in the background [Limoncelli 2023] (fig. 2).

Fig. 3. Wooden model of the dome and apses of Santa Maria del Fiore attributed to Filippo Brunelleschi (Florence 1377-1446). Museo dell'Opera del Duomo, Florence. On line source: <https://rb.gy/31wr59> (accessed 21 February 2024).



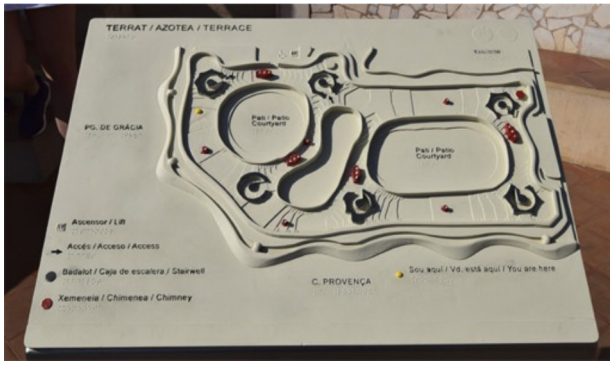


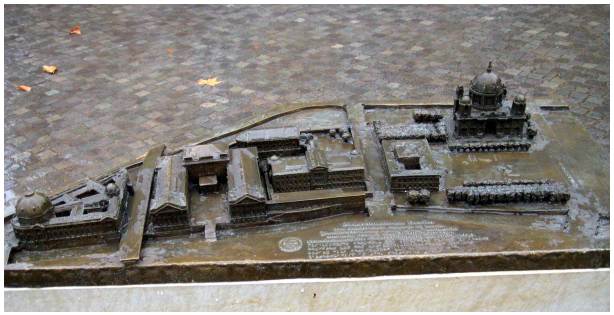
Fig. 4. Bronze model of Fort San-Jean, Marseille. On line source: <https://rb.gy/f7fduy> (accessed 21 February 2024).

Fig. 5. Casa Milà, Gaudi, aluminum tactile model of the terrace at the top of the building. On line source: <https://rb.gy/mg00tu> (accessed 21 February 2024).

In this period, the analog model was used to illustrate the grandeur of the work, innovative engineering solutions, or simply the distribution of space and construction details for the workers, as well as to serve as a useful design reference in the event of the designer's death, which was not uncommon given the long construction periods of the works. Few records of these models remain to this day, due to the fact that they were quickly disposed of at the end of the work in order to salvage the material. Extremely significant, and preserved because of the importance of the subject they represented, are the models of Antonio da Sangallo's design for St. Peter's Basilica (never realized due to the architect's sudden death) and of the dome of the Basilica of Santa Maria del Fiore in Florence, presumably by Brunelleschi (fig. 3).
The use of the model then evolved over time, first through the detailed wooden models of the Baroque period, and then through the small cork reproductions of the eighteenth century, used as travel souvenirs and designed for the Grand Tour market.
Today, the model still supports the development of the design idea and is used as a three-dimensional representation to illustrate the project to the client, but the historically established purposes have been supplemented by others, such as providing a better understanding of the spaces within the orientation systems.

Tactile models for communication

Physical models, whether related to individual buildings (fig. 4), a specific level (fig. 5), or depicting a small part of a city (figs. 6, 7), are often used in wayfinding systems, the set of strategies aimed at conveying environmental information to users through the use of wayfinding signs and other communication methods [Empler 2012].
The creation of these three-dimensional models, which are necessarily to scale, promotes orientation for all visitors, including those with vision-related sensory disabilities, who can explore the model by touch. Haptic reading allows for comparison and understanding of the spatial distribution of buildings, but for the information conveyed to be clear and effective, the processing must follow certain guidelines to meet the principles of legibility.



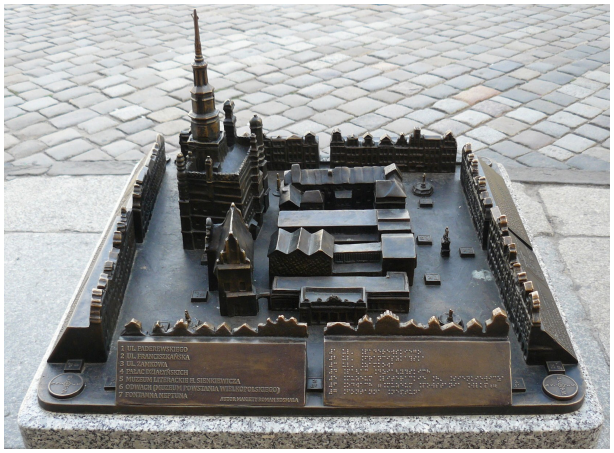


Fig. 6.: Bronze model of the Museum Island in Berlin, representing the cultural district of five Berlin museums; a UNESCO World Heritage Site. On line source:: <https://rb.gy/fw0lwt> (accessed 21 February 2024).

Fig. 7. Bronze model of the Market Square in Poznan, Poland. On line source: <https://rb.gy/od3dy> (accessed 21 February 2024).

Like two-dimensional tactile maps, three-dimensional models require a simplification of information because haptic exploration does not allow for the distinction of fine details. Haptic reading occurs through sequential exploration of the model with fingers and palms, and the perception of the whole is the result of organizing this partial information [Empler, Fusinetti 2019].
The size and materials used depend on the scale of the representation, whether urban or detailed, the final location of the model, whether interior or exterior, and the quality of the execution, which can be handmade or three-dimensional printing.
The processing of these types of models, which also have complex shapes, involves the use of digital technologies that, starting from integrated surveying methods for data acquisition and subsequent modeling, allow the model to be printed by additive or subtractive prototyping [Empler, Fusinetti 2021; Montusiewicz et al. 2022].
However, the digital processing of data for model processing must be subject to certain representational guidelines that allow the recognition of shapes to ensure proper understanding of the object by the user.
For this reason, the size of the replica should not exceed the size –ideally the width of the movement of the arms– and should be elaborated in such a way that all the elements can be distinguished, even through the use of textures or numbers to be recalled later in the legend.
The example shown in fig. 08 is the tactile model prepared for the communication of the Fortress of Marciana on the Island of Elba. The model was created from the acquisition of the current state of the fortress by aerial photogrammetry; the mesh obtained from the point cloud was then simplified with the aim of obtaining a model that would allow a correct understanding of the artifact, taking care to close or fill in the areas that could have represented a danger during tactile exploration (such as the spaces inside the four lateral walls); before production, numerical references in black and braille were added to the legend on the base to which the model is attached, allowing the various parts of the fortress to be understood. To support this reading, a brief description of the fortress in Italian, English and Braille has also been added to the base plate. The plastic was produced by an additive printing process, the volume of which was used to create the silicone matrix in which the resin was poured to obtain the final model.

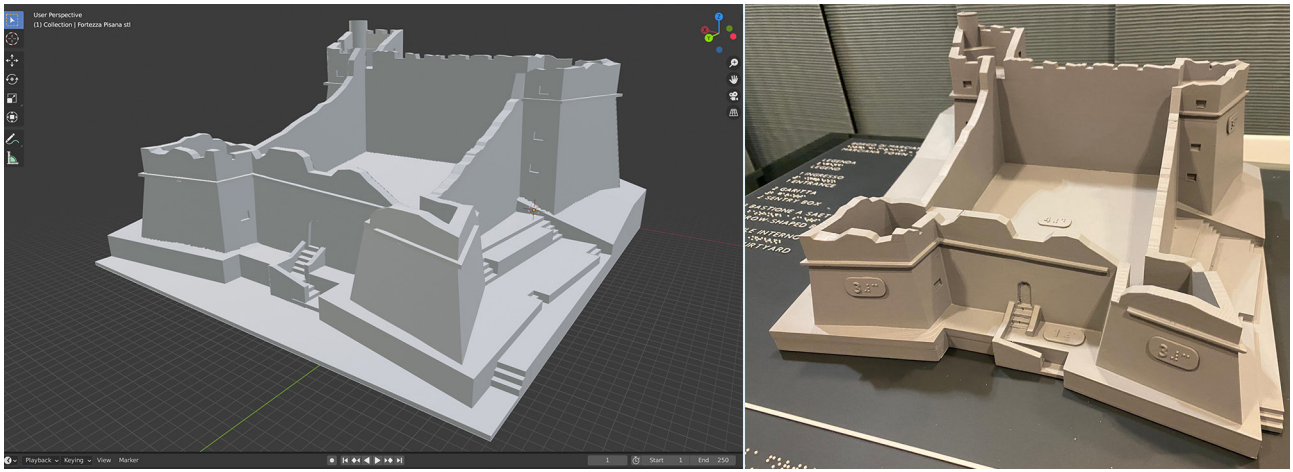


Fig. 8. Tactile model of the fortress of Marciana, Island of Elba. On the left,the model processed from survey operations; on the right, the printed model. (graphic elaboration by the author).

When preparing the models, it is also necessary to take into account the spacing of graphic marks, such as lines or textures, which, when used as textures, must be at least 2 mm apart to be correctly perceived, while the distance between individual objects, especially if they have similar heights, must be placed at a distance of more than 5 mm [Simmonet et al. 2018]. These arrangements may lead to a partial change in the proportions of the model elements, but they are useful variations to achieve correct and effective communication.
The possibility of tactile exploration of the physical model allows the transmission of architectural and spatial information, which, in the case of wayfinding systems, is translated into models whose main function is orientation. These types of models, called directories, help the user to identify the destination to be reached, facilitate the correct perception of the spaces to be traversed, and allow greater autonomy of movement, even for people with visual or cognitive disabilities in general.
In the field of cultural heritage promotion, the use of the physical model is considered by the above-mentioned guidelines as a useful element to improve the accessibility conditions for different types of users. This peculiar typology allows both a correct understanding of the spaces, facilitating the orientation even inside the cultural institutions and consequently promoting the autonomy of the user, and an effective interpretation and perception of the architectural object, through haptic exploration, within an inclusive path of valorization of the good.
The analog model of an architectural cultural artifact can be reduced to different scales, depending on the information to be communicated to the users.
At the urban scale, it can represent an area of particular value, as in the case of the tactile model of the Luma Arles cultural center in France. The complex, designed by Gehry, covers an area of eleven hectares and is described by two tactile panels characterized by the use of different colors and textures that help distinguish the different buildings in the area. The classification of the elements through the use of color is then reduced in the orientation system of the area, thus implementing an inclusive approach to the enjoyment of the site (fig. 9). In this sense, the tactile model can be used by blind people to create their own mental map of the area through touch, which is useful for safe movement and autonomous orientation in space.
It is also possible to communicate a particular urban form, as in the case of the German town of Nordlingen:

Figure 9. Tactile model of the Luma Cultural Center in Arles, France. On line source: <https://rb.gy/gk0xxi> (accessed 21 February 2024).

Fig. 10. Bronze map of the city of Nordlingen, Germany. Author: Andrew-M-Whitman. On line source: <https://rb.gy/a9xaek> (accessed 21 February 2024).

a tactile bronze model, accompanied by Braille texts, emphasizes the unique circular shape of the settlement, due to the inhabited development of the core within a meteoritic crater (fig. 10).
Architectural models of individual buildings or parts of buildings can illustrate the different elements that make them up in more detail and highlight construction details, such as the bronze model of the *Golden Gate Bridge* included as part of the *Bridge Enhancement Staging Project*, in which it is possible to tactilely explore one of the two towers to better understand its shape and proportions [Anagnos et al. 2013] (fig. 11).
Finally, one of the most important features of the use of physical models is that they can illustrate both the 'haptic narrative' of current status of a cultural object and the narrative of its hypothetical reconstructions [Caldarone 2018; Empler, Fusinetti 2021; Barvir et al. 2021]. The possibility for the blind to independently explore tactile representations of cultural artifacts is therefore a challenge that requires the adaptation of the meaningful content of the cultural object to the specific characteristics of tactile exploration [Souradi et al. 2020], although the use of these models allows them to 'speak' not only to people with visual or cognitive disabilities, to whom they are primarily addressed, but to the totality of users.

Conclusions

Developments in the use of these models in the field of heritage communication are now directed towards the implementation of new sensory levels through the use of information technologies.
The *Unesco4All* project presents an innovative approach that aims to create sensory pathways around some World Heritage sites, specifically designed for a blind audience. Users are provided with a ring equipped with NFC technology [D'Agnano et al. 2015], which, with the support of an app, is able to 'read' the pattern after haptic exploration and provide a real-time audio description.
It uses a similar approach to the research carried out for the enhancement of the Olomuc Castle, Czech Republic. Here, user-model interaction is achieved by printing model elements corresponding to points of interest with a conductive material that 'responds' to

Fig 11. Bronze model of one of the towers of the Golden Gate Bridge. On line source: <https://rb.gy/8mofb3> (accessed 21 February 2024).

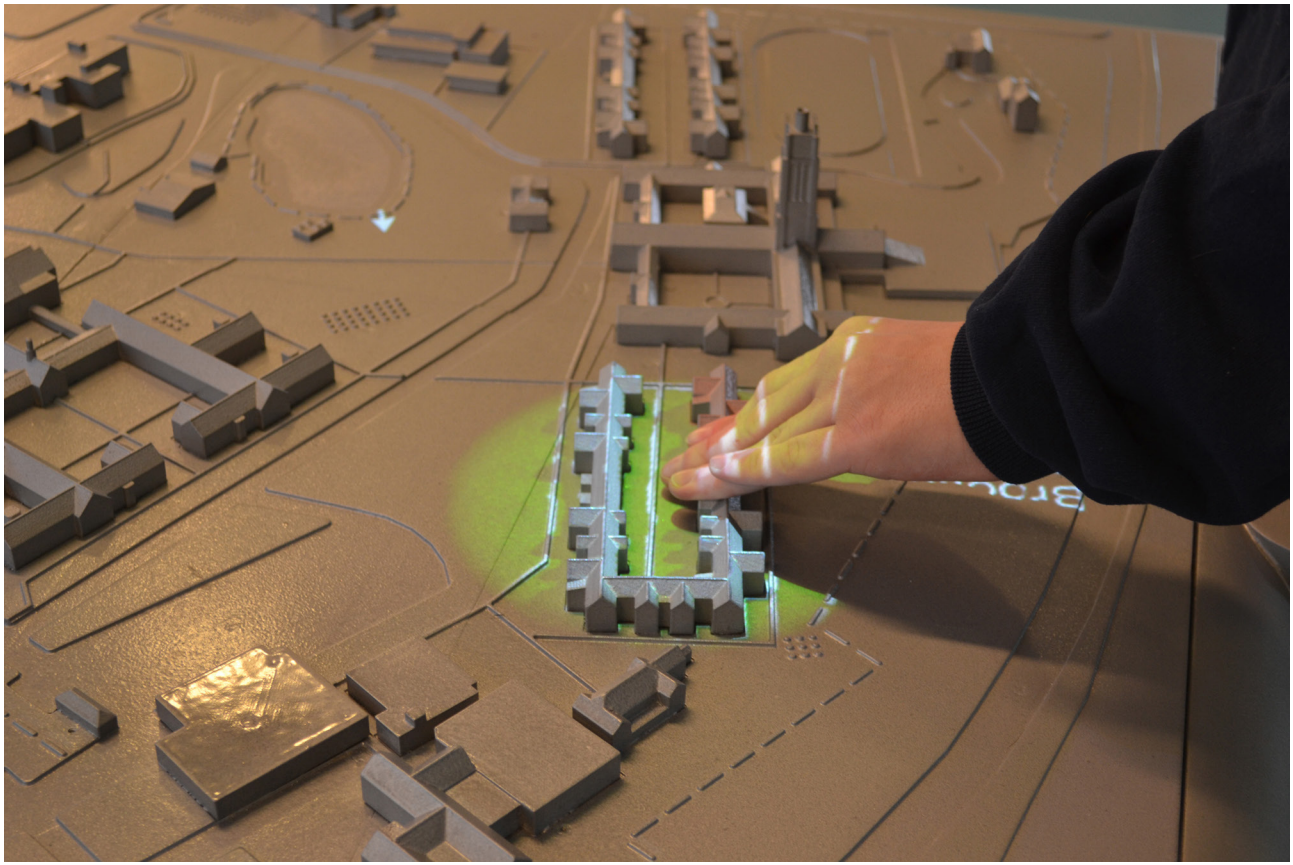


Fig. 12. Perkins School's multisensory model, which offers audio, tactile and visual cues for inclusive interaction. Credit: University at Buffalo IDeA Center. On line source: <https://rb.gy/bfj1sp> (accessed 9 April 2024).

touch. Activation of the connections by touch results in the display of detailed information on the tablet next to the 3D model and an audio description of the elements [Lazna et al., 2002].
Research by the *IDEA Center* at the University at Buffalo proposes an interactive wayfinding system. Three-e-dimensional maps were printed and then painted with conductive paint: when touched, a light projection illuminates the building and information about it is communicated to the user, along with directions on how to reach it, all through an audio system (fig. 12).
Today, the role historically assigned to physical models, which were exclusively visual, is being replaced by models that support new levels of sensory perception, capable of increasing the degree of inclusiveness and responding effectively to regulations requiring interventions in accordance with the principles of design-for-all.

Notes

[1] In this regard, consult the document of the *Ministero del Lavoro, della Salute e delle Politiche Sociali* (2009) regarding the *Convenzione delle Nazioni Unite sui diritti delle persone con disabilità*, in particular article 30 refers to participation in cultural and recreational life, leisure and sports, and article 9 concerns accessibility:<https://www.lavoro.gov.it/temi-e-priorita/disabilita-e-non-autosufficienza/focus-on/Convenzione-ONU/Documents/Convenzione%20ONU.pdf> (accessed 20 February 2024).

[2] Article 12 of the *Convenzione di Faro* specifically refers to access to cultural heritage and democratic participation: <https://www.journalchc.com/wp-content/uploads/2020/08/Convenzione-di-Faro.pdf> (accessed 20 February 2024).

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