CAA
2017

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http://dx.doi.org/10.15496/publikation-43153

Mixed Reality, 3D Printing, and Storytelling: Methodologies for the Creation of Multi-Sensory Scenarios in the Field of Cultural Heritage

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Abstract

In the last years there has been a revolution in the use of cultural heritage from a communicative and interactive point of view: the user looks for exciting experiences and a new "contact" with the site. So, we have to propose innovative means of communication and learning to meet these changing needs. The field of archeology and historical reconstruction of buildings, provides new ideas for research in this field: the three-dimensional reconstruction of historical and cultural buildings involves the ludic sector, and it is also effective for the diffusion of the historical sites. The paper aims to promote a methodology that begins from the reconstruction of documentary sources and archaeological excavation, it shapes a three dimensional model and prints a real prototype. Printed object can be perceived better and offers both a visual and a tactile approach. The possibility of integrating the physical object with augmented reality systems, appears to be today the innovative field of research of this methodology. Also, this system makes possible an immersive perception of the site. Dissemination moves from the bidimensional area into the three-dimensional reality of space that surrounds the "user".

Keywords: 3D printing, mixed reality, communication, dissemination, cultural heritage

Introduction

Today, it still happens too often to see confused and bewildered visitors in a museum hall or an archaeological park. If you ask them to describe their experience, many reply they have seen, metaphorically speaking, a "cemetery of stones". It is therefore still difficult to communicate what sites represent. Teaching materials, when present, are most often unclear and seemingly designed for specialists. Other groups of visitors are just allowed to watch in uncritical contemplation (De Felice and Volpe 2014). In order to overcome this gap, technological aspects are often emphasized, while the true issue is methodological and cultural. Today, it seems indeed almost impossible not to use the new technologies in the field of archeology as well as in the survey step, post production of data step, study of reconstructive hypotheses starting from survey data. Daly and Evans defined "Digital archaeology" as follows: "Digital Archaeology explores the basic relationships that archaeologists have with Information and Communication Technology (ICT) and digital technology to assess the impact that such innovations have had on the very basic ways that archaeology is performed and considered" (Daly and Evans 2006)

At present, the aim and evolution of archaeology is not to keep popularizing the digital technologies; it is necessary to develop a procedural path to realize effective virtual platforms for users to enjoy an immersive and learning experience. If the aim is to disseminate scientific knowledge, scientific data should be the starting point. Historical research, onsite survey, the acquisition of point clouds through laser scanner and photogrammetry, the subsequent critical elaboration of data, represent the foundation to accurately interpreting and reconstructing an object in the digital space from historical, metric and geometrical viewpoints.

Scientific research is now gearing toward the virtual migration of reality and the creation of 3D shapes that can be experienced as real spaces (Bercigli, Parrinello, & Picchio 2016). Graphical solutions should transmit historical and scientific knowledge while creating different forms of communication giving rise to multiple feelings and reactions among users. However, access to virtual and augmented reality is generally based on devices like viewers or tablets and smartphones. This is why many believe that a multimedia, interactive museum should be based only on sophisticated interfaces and on the man-machine interaction.

The use of virtual reality through viewers or mobile devices entails several issues. Different by their nature, they are due to the human perception system. First, users tend to concentrate solely on what is defined by experiential marketing as the "wow factor". This results from the use of the technology itself, and the information content is left in the background. Second, facilitated access to virtual reality, regardless of where the user is located, may decrease the level of empathy with the archaeological site and the artifact, with the perception of the historical context or with the material-based texture of finds. Finally, the issues related to the image and the "short circuit" that is created are quite evident. This stems from the contrast between the visual signals and the perception of movement, creating the so-called "motion sickness" (Chardonnet, Mirzaei, & Merienne 2015)

However, if the communication interface was a physical model, the user would have a direct emotional, unfiltered relationship. The physical quality of an object can be easily perceived. This happens because senses are predisposed to seize the relevant signals, with no sensory "short circuit." The ease of understanding a stimulus implies a higher rate of response on the part of the user (Empler 2015). Obviously, this uses traditional media that does not provide any added value to the new communication techniques. Therefore, the integration between physical models and digital interfaces could give rise to a global exploratory system based on audio-visual and tactile sensations. This process creates a rapprochement between the physical and virtual space and amplifies the values of each.

Recent Solutions: Some Examples of Integration Between 3D Printing and Multi-Sensory Experiencess

Here, I analyze some international experiences that are based on the integration between the physical object and digital communication technologies:

1. University of Camerino and the "Santuario della santa casa di Loreto";

2. Hitachi Digital Imaging Systems Project and the "Uffizi Gallery in Tokyo";

3. "Glass Beacon Museum" in the Trajan's Market.

In the first case, the researchers set up a space consisting of a multimedia table, with a scale physical model of the Basilica of Loreto obtained through 3D printing. This model can be "queried"; it works like an interface in order to access contents concerning the Shrine. To enable the interactive mode, "proximity sensors" were placed in certain areas of the 3D printed model. The interaction is managed by the Arduino technology: this is a hardware platform that, through its software, allows for the connection of proximity sensors to an electronic screen. The informative content is automatically activated once the user taps or touches a region of interest. Moreover, the touch screen allows the user to access more information. Finally, 3D viewers and game engine technologies create an immersive experience: the user is catapulted into the virtual and three-dimensional reconstruction of the Shrine as it existed in the seventeenth century. It makes use of a VR viewer and a binocular projection system. Visitors enjoy the virtual space through a motion simulation system. (Feriozzi, Meschini, & Rossi 2016). The model acts as mediator between the real world and virtual reality, and it becomes a three-dimensional interactive platform to access historical, metric and geometrical information. It is therefore an object of interaction and a means of access, while virtual reality comes about separately and later. From a perceptual point of view, this is a stand-alone interaction system, based on visual sensations. Still, users have a limited possibility to move; they are bound to a screen and to the virtual reality system, which necessarily implies for visitors to hold a fixed position.

The second example, "The Uffizi Gallery in Tokyo", fits into the category of the 2D digitization of cultural heritage. The Exhibition features real size copies of some of the most famous paintings from Uffizi Gallery. The interactive screens, placed next to each painting, not only allowed the user to access the information content but, thanks to them, the work could be appreciated in its smallest details. The data base offered images acquired at very high resolution (1200 pixels per inch) or gigapixel with accurate colors and without any geometrical distortions. By zooming on the painting area of interest, the user could see details virtually indistinguishable to the naked eye, in addition to capturing details concerning the pouncing or the engravings in the initial drawing. This can be described as augmented reality. This type of digitization represents a valuable aid also to scholars. They can carefully examine every detail or the techniques of "construction" of the painting itself. From a perceptual point of view, it enables an interaction stimulating visual and tactile sensations, in so far as it was possible to touch the works themselves and feel the texture of a brush stroke or an incision. Paradoxically, although they are not original works, this exhibition allows users to appreciate the artistic perfection of such art. In addition, these tools provide complete and accurate information on multiple levels of communication and interaction and involve as many users as possible. While the direct experience of an object or artifact remains important, the example described above allows developing new forms of entertainment and communication and a procedure that can be replicated in places and situations where gaining access to a cultural asset proves to be difficult.

In the experimental project of the Glass Beacon Museum at the Trajan's Market in Rome, the Google glasses, augmented reality viewers, were put at the disposal of visitors. During the exhibition, visitors followed a pre-established path across the exhibit. The path was established by the distribution of beacons, namely low frequency bluetooth repeaters. These detected the user's position and automatically activated the informative content displayed on the viewer. In this way, visitors could access text, images and video directly from their display. In particular, some sculptural elements underwent a virtual reconstruction and were enriched with the reconstruction of decorations and chromatic spectra. Such reconstruction (loaded into the database to which viewers were connected) was overlapped to the real object thanks to the Google glasses; therefore, the user could appreciate the virtual decorations, now lost, on a physical and real element. In this way, the displayed object is not a means to access the information content but becomes itself the subject of interaction. You would define this as mixed reality; visitors enjoy the real space in a shared manner by overlapping virtual elements either in a stand-alone mode or on-demand. The user has a richer experience thanks to audiovisual content; however, they do not have a tactile experience because these are original fragments and works that cannot be touched.

The mixed reality (MR), contrary to VR and AR, seems to be the ideal solution to integrate the physical object and advanced communication technologies. MR allows overcoming and increasing the information received through perceptive data only. Contrary to virtual reality, it does not cause motion sickness and does not alter the context perception. You can offer to visitor a tactile and material experience, audio-visual content, as well as innovative communication and learning tools. The difficulties related to augmented reality have to do with the perfect overlap between the real and virtual image, in addition to the user traceability. The superimposition of a virtual content on a physical element has been based, until now, on systems that can be defined as "passive." ARTag, or geometrical markers in augmented reality, monitor the user and the camera in the viewer, tracking its position and direction, and once you know the real position of the camera and viewers, optical collimation and 3D digital models are projected into the real marker. In this way, the point of view and the center of projection, are constrained and preferential. The systems of interaction between the user and virtual elements, are also based on technologies borrowed from game engines like Kinect and Leap Motion 3D (Empler and Fabrizi 2016), which in turn may be defined as "passive," since they track, from the outside, movements on the basis of the user's position.

In order to overcome such a restricted point of view, a viewer called HoloLens exploits the principle of the hologram: the image projection system is internal and does not need any external marker. The recognition of the surrounding environment takes place by means of an internal digital camera. This system can be defined as "active." In this case the camera tracks the environment and not the reverse. A hologram is "drawn" internally, in real time, on tracked objects whose position is known to the viewer. An infrared sensor, still inside the viewer, deriving from Kinect technology, detects movements and guides the virtual man-object interaction. However, the user cannot freely move in the three-dimensional space because the processor must reprocess and re-map the environment in order to project a new image.

A recent technology called Project Tango developed by Google (currently only available for smartphone and soon for viewers too), however, has revolutionized the Mixed Reality system. It was designed as a mobile device, tracking the morphology of the space around the observer thanks to a depth sensor. The three-dimensional space is mapped and recorded in an integrated points cloud with RGB values in real time. The device, therefore, returns a three-dimensional digital model, contained in the internal memory, where it inserts the virtual objects where the user is located. The user can move into the surrounding space where virtual objects are inserted; at the same time, they can interact with projected items whose perspective varies with the user's position. This can happen because the digital objects are inserted into the three-dimensional model of the real environment and the overall projected image.

Proposed Solution to Offer Multi-Sensory Experiences: Between Virtual Reality and Reality Reproduction

If the goal is to make the public understand an archaeological artifact and its history while creating multi-sensory learning scenarios, it is necessary to go through a process of analysis, synthesis, recording, reconstruction, and communication following a workflow consisting of these steps:

1. Data acquisition via integrated techniques of laser scanner, photogrammetry, direct survey GPS, and topography;

Figure 1. 3D printing and virtual model are overlaid by using mixed reality.

2. Reprocessing and interpretation of data and construction of a NURBS (Non Uniform Rational Basis-Splines. It is a mathematical model for generating and representing curves and surfaces) or polygonal model;

3. Archeological reconstruction and interpretative hypotheses on the basis of geometrical properties and historical analyses;

4. Retopology and transition from a hi-poly to a low-poly mesh model to lighten the software upload required to generate real time applications;

5. Texturing of the resulting three-dimensional model;

6. Design and print a real prototype with a 3D printer in the most appropriate scale;

7. Processing of virtual platforms for communication.

Thanks to the many technologies available on the market, partly presented above, it is possible to integrate the tactile properties of the printed prototype with the visual ones to create multi-sensory museums.

For example, when framing a scale model through mobile devices or viewers, you may virtually visualize the three-dimensional model characterized by accurately reconstructed decorations (Figure 1) (Aliperta and Gira 2015). The overlap between the virtual and physical representation is possible because the virtual model and the prototype are obtained from the same initial data, based on the accuracy of

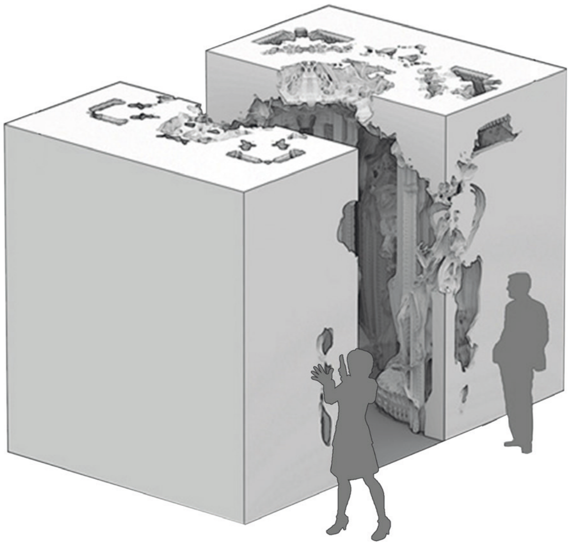

Figure 2a.

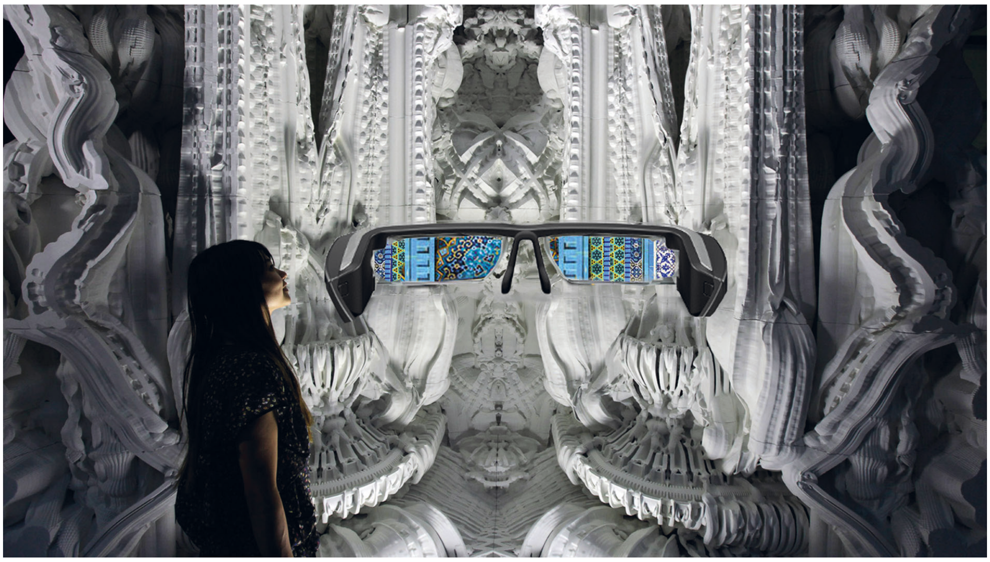

Figure 2. An object printed on a larger scale increases the immersive effect (2a), 3D printing and mixed reality help stimulate visual and tactile sensations (2b).

the survey and the exact geometric reconstruction. The three-dimensional digital image is stored in a cloud database, which loads data on viewers or devices when it recognizes the geometric marker previously recorded on the prototype. The prototype should be printed in the most appropriate scale in terms of both overall dimensions and details. When the staging space is larger, the perceptual impact can be increased by printing the object or part of it at a larger scale. In this way, thanks to the use of viewers like Google Tango and mixed reality, instead of a summary image, a more detailed, immersive image is returned; the user can interact with the object and interpret it seamlessly (Figures 2a-2b). It is possible to recreate real environments in which the visitor can enjoy the entire space available. Viewers allow tracking and creating a three-dimensional model of the environment in which it moves and project images, objects and elements onto it. The mode of interaction is not a virtual space; it is real and dynamic (Bercigli et al. 2016)

However, the multi-sensory scenario is not complete yet. “Storytelling” plays a fundamental role in conveying information, stimulates curiosity and generates a better learning environment. User surveys show that narration and interaction are their main expectations: by customizing their own experience, they want to enter into the stories and interact with the characters (Pescarin et al. 2012).

An archaeological object is made of tangible and intangible properties. Archaeology deals not only with the collection, analysis, and interpretation of

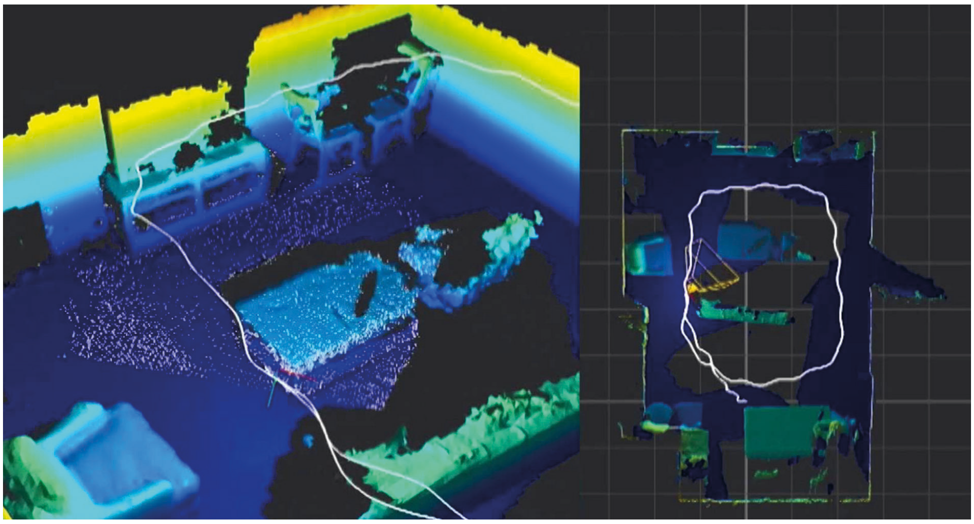

Figure 3. Google Tango tracks space in real-time and creates a point cloud. The numerical model is stored on the device memory, and it will update as the real environment changes.

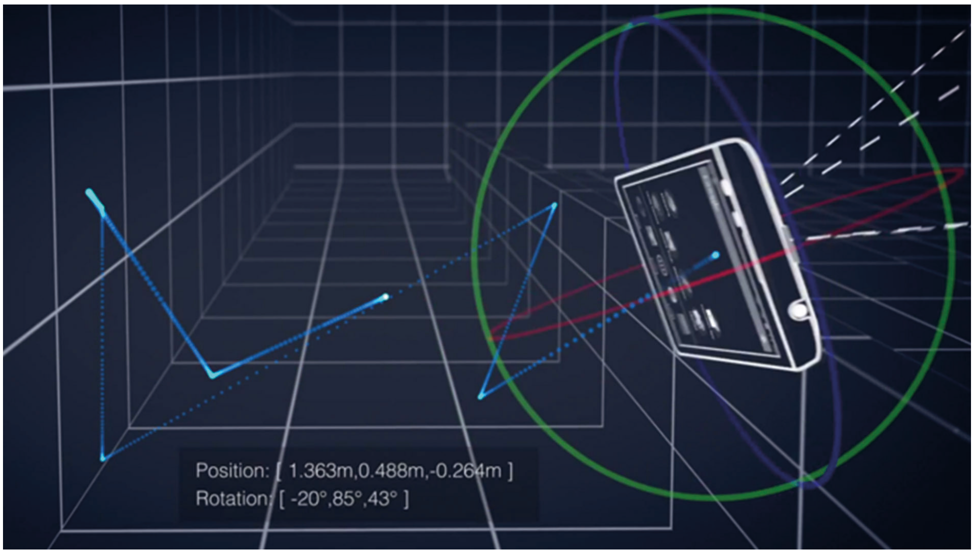

Figure 4. Point cloud has its own coordinate system x, y, and z. Virtual objects are placed in the point cloud's coordinate system and the viewer's position is drawn in the same coordinate system. Users and objects interact in virtual space.

data; it tries to reconstruct stories, cultures, events (De Felice and Volpe 2014). In one of his famous books, Umberto Eco said: "…the past must be recognizable, but there is a need for real characters, like ordinary people….they make us understand everyday life and their behavior tells us a lot more about their time than history" (Eco 2012 as cited in Ferdani et al. 2016). It is therefore desirable and possible to "populate" the static images loaded on the cloud of reconstructions with virtual characters, i.e. archetypes adapted to the specific context, thanks to mixed reality.

The real printed prototype becomes the scenery of a virtual "show": images and stories involving visitors are projected onto it. The physical object expresses itself and the archaeological artifact it represents, through the characters and their culture. This is how the overall nature and complexity of an archaeological find are communicated, and how participation and sharing of a museum space are stimulated.

Once again, mixed reality can help us thanks to the use of Google Tango technology, which creates a three-dimensional and digital model of the space surrounding the visitor and the printed prototype is part of it (Figure 3). This digital model, inserted into the device memory, has its own system of three-dimensional coordinates, where the position of the observer is plotted (Figure 4). In such digital space, both the virtual representation of the archaeological artifact and characters, in the form of avatars, are projected. User, physical model, reconstructions, and virtual objects belong to the same reference system. Visitors can therefore interact with them thanks to the device-embedded leap motion systems (Figure 5). The interaction system makes these figures selectable and queryable: they can communicate the scientific and the historical content in relation to the character played. Different narrative paths can be developed for the different types of site users (Figure 6).

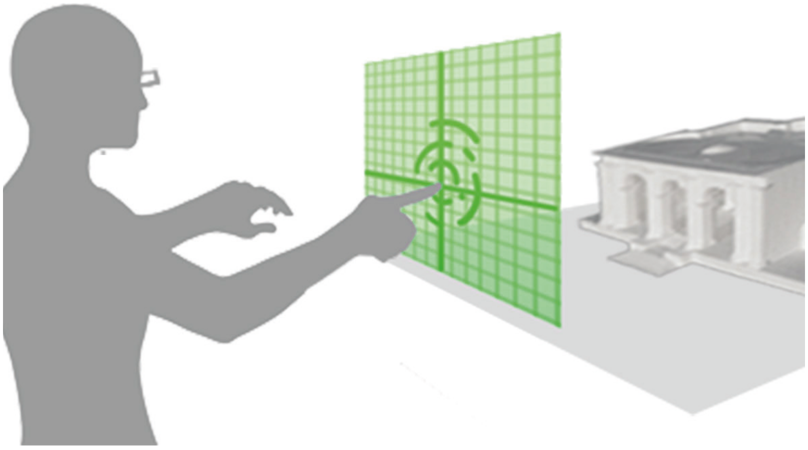

Figure 5. Users, real objects, and digitized objects interact virtually in the space thanks to a specific system, like leap motion, integrated into the device.

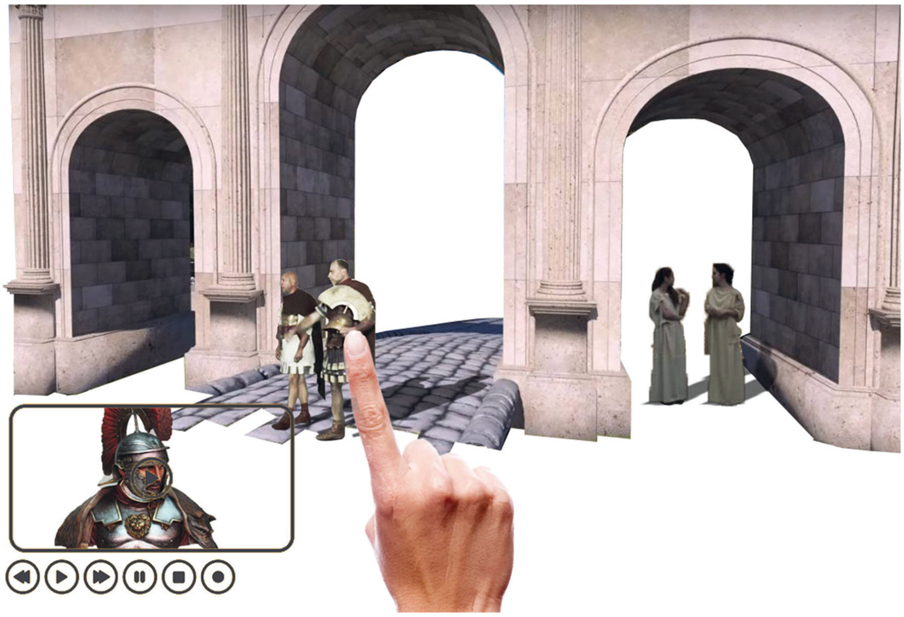

Figure 6. Characters and avatars are delectable and queryable. You can assume different narratives, in relation to the different site's users.

Space becomes dynamic. It includes real objects, reconstructions, stories, and relations; the perception of digital space varies thanks to the physical model generating a new spatial awareness, a reality where users can find their own narrative and empathize with the context.

Conclusions

Analysis, documentation and interpretation connecting to digital technologies, computer graphics and 3D printing, contribute to the dissemination of scientific knowledge while involving the user. Playful, interactive, immersive aspects contribute to experimental, new forms of communication. The physical model is an "analog" interaction system. It exploits the user's internalized perceptions by leveraging previously learned codes of conduct to approach a different environmental situation (Empler 2015). In the proposed system here, the prototype becomes the container and its contents, and acts as a liaison to access a system of "digital" interaction based on mixed reality. New standards of information and experience are established for the mental, virtual, and real spaces. "Multi-sensory" museums have the potential to become containers of multicultural and interconnected information going beyond the divide between researchers and the public, thus creating an increasingly participative construction of knowledge.

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