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How to Use Haptic Technology in Interactive Digital Documentation of Heritage

Vladimír Hain, Roman Hajtmanek and Dušan Kočlík

Abstract

Virtual restoration of the extinct heritage is a method of reconstruction of an already destroyed work in a virtual environment. It represents a way and an opportunity to reenter the remodeled simulated space interactively and experience its contemporary atmosphere and former author expression. In addition to visual and acoustic experiences, haptic technologies represent the potential for expanding sensory perception, which is not yet sufficiently used in the architectural sector. This study focuses on defunct and endangered works of interior architecture and industrial heritage, which were significant at the time of their inception and shaped the direction of the industry. Especially in the case of cultural and spiritual heritage, we focus on interiors, which, by their short-term nature, are neither objective nor physically documentable. Selected extinct works for which there was enough data or there was still the possibility of consultation with a living author were experimentally virtually reconstructed. Using haptic technologies, we have expanded the observer's ability to interactively analyze space and its context through User Tracking of observers. The data obtained in this way continue to help the creators of the architecture set new starting points and limits for the current creation and design as well.

Keywords: architecture, heritage, digital documentation, haptic technology, user tracking

1. Introduction

Current digital technologies allow us to design, document, preserve, evaluate, and popularize cultural heritage and architectural heritage in many ways. However, their potential is not always fully exploited [1]. The chapter is aimed to explore form-forming factors of architectural space and theoretical research, between monument preservation, Haptic Technology, and architectural practice.

The study represents identified factors that affect the efficiency and quality of design process in the cooperation with modern technologies, documentation, and conservation process of heritage sites. It deals with the opportunities of transfer research results from the futuristic disciplines as well. In this case, the paper examines the study “Reconstruction of old industrial Power plant in Piestany” and describes one of the possible solutions based on the mixed reality (MR) application. The opportunity to experience this kind of an industrial object with multiple senses

(sight, hearing, smell, touch) in MR delivered a unique personalized haptic experience and immersive memories about lost heritage.

Developed presentations, mixed reality interactive models nowadays can create attractive interpretation of this rich source of experiences and knowledge. The interdisciplinary research team at the Slovak University of Technology in Bratislava Faculty of Architecture and Design focuses systematically their work on applications of virtual reality (VR) by merging different sensorial inputs from mixed reality and real environment. The article is focused to explore opportunities for incorporation of haptic technologies into monument preservation, research of virtual and mixed reality and architectural practice [2].

2. Theoretical scope

Haptic technology has excellent potential to help society in their daily lives, design, or education. In schools or museums of technology around the world, there are innovative creations of the human spirit, which are often presented in a way that is in comparison to other media less attractive for the contemporary audience. Therefore, the contemporary trend is the development of interactive kind of the presentation of physics laws and technology. These types are capable of making technology museums more inspiring and of enabling the interactive use of this plentiful source of knowledge. Too many historical buildings were destroyed, and they no longer exist, but historical archive documents, drawings, or photographs have been preserved. Some buildings remain in the living memory, or few physical fragments have been preserved. This technical documents and protected parts of the building may propose data for a digital presentation of the significant design or industrial monument. The interpretation of a hypothetical reconstruction by mixed reality can serve to better understand the culture, history, and technology by the public [3]. The virtual presentation of the model can serve as a haptic presentation of the extinct design, technical and cultural heritage as well.

Haptic technologies have been explored in virtual arts, such as sound synthesis or graphic design and animation [4]. The potential of their use is in the whole breadth of virtuality continuum (Figure 1). For the ordinary presentations in practice is used mainly augmented reality (AR) and virtual reality (VR) of displayed types of realities differ according to degree of reality.

The taxonomy of Milgram and Kishino provides a way of contrasting different types of mixed reality. This paper is focused on different fusions of other various sensorial inputs from real human life as smell, touch, and hearing with virtual or mixed environment [5].

The theory of didactics confirms that the senses are for people portals of information. Some people learn by sight, hearing, or by certain kind of activity (Figure 2). Each of us prefers a different method and way of teaching. The use of the combinations of senses is typical for “mixing learning styles” [7].

Figure 1. Virtuality continuum diagram by Milgram and Kishino (Steed, 2013) [5].

Figure 2.
Graph of sensory reception (M. Ganobjak, V. Hain, 2014) Picture of “Senzulator” was for the first time graphically illustrated by Prof. Robert Špaček in 1985. The term was created/used as a parallel by Modulor (authors: J. Keppl and R. Špaček, FAD STU, 1986) [6].

We receive a different percentage of information with every sense [6], and everyone remembers it differently. A difference needs to be created between receiving and remembering of the information. The most of the information we receive visually. By hearing, it is in comparison significantly less. We remember 20% of what we hear, 30% of what we see in visual form, and 90% of what we are actively doing [8].

Mixed reality actively uses mainly the first two human senses (sight and hearing) through which we receive the most of the information. Kinesthetic style of education uses activity of body and engages all senses (other three) without preference. It is proven that the best learning effectiveness is the way of learning through a combination of styles. Although the representation of other senses is negligible in receiving information, it appears that combinations of activating multiple senses are highly effective. This way, one can remember up to 80–90% of what one hears, sees, and does at once. It can be stated that the sensory overlap with which the information was captured creates stronger links between them for remembering. This is absent in the usual case of selective perceptions.

There are several cases of people with hearing, visual, or other disabilities that need to be kept in mind. In this case, one or more senses are missing, so they are replaced or compensated by another. Each situation is unique and different, it would be appropriate to pay special attention to each person with regard to their characteristics. However, it is not possible to set a specific tactile exposure for everyone. Universal design rules are offered as if they were the opposite of barrier-free design. It is a design for the widest possible range of users and not just for a narrowly specified group. Here it is important to create a quality exhibition that is inspiring and universal for everyone. One of the solutions to achieve such a balanced state is to create an exhibition and at the same time ensure that every single exhibit is perceived by several senses at the same time. This will provide the observer with fuller information. In addition, such an exposure to tactile or mixed reality allows a clearer situation to be understood and remembered not only by children but also by people with limited sensory abilities.

Such a prepared and focused presentation will bring visitors a new experience and allow them to perceive the laws of nature, often from a different perspective. The fun factor is also an integral and important part. It is usually a pleasant refreshment in the amount of informative information that comes to our attention.

The image of the Senszulator (Figure 3) shows the reach of our human senses. It shows the radius of the information we are able to receive in this sense. The eyes

Figure 3.

Inverse sensory orientation of exposure. Combinations of sensory perception affect the overall impression (scheme: M. Ganobjak, V. Hain, 2014) [6].

capture a lot of information, but at the same time we are overwhelmed with visual information. Therefore, it is possible to use the method of inverse engagement of the senses. There are not many educational presentations that are tactile, haptic, acoustically olfactory or by taste.

Just as we perceive the stimulus closer to the body, it may leave a larger memory footprint. The human being subconsciously prefers those stimuli and impulses from the environment that act closer to the body surface. This proximity leads to an approximately defined sequence of its sensory zones from the tactile zone through the olfactory zone, the thermal zone, the acoustic zone to the human most dominant visual zone. Irritation of human receptors affects the perception of the environment, behavior, and orientation in space as well as the overall relationship to our environment. The center of gravity is activated by the sensory organs to determine the size and character of the individual frameworks of human zones. This dependence is expressed by the *Senzulor*.

All of our senses provide information about the properties of the external environment. Different organized and developed sensory organs with different sensitivities and complexities can only receive the same information as well as several pieces of information at the same time. Similar combinations of our sensory perceptions affect a person's overall impression, feeling, or condition in multiple situations. These phenomena are positively or negatively reflected especially in the perception of presentations, and therefore, it is important to pay close attention to them during designing mixed reality as well.

By involving multiple sensory stimuli, the information flow is enriched, making it easier to compare the user experience with a real experiential situation [9] that is closer to innate learning and thus to collect relevant data on user perceptions. Such data are mainly used as feedback, which could improve the future designs of other installations and exhibitions. There are many techniques for processing spatial and haptic information. The space can be sketched, 3D scanned or measured using classic techniques, and compared with suitable project documentation. Then it is necessary to model it accordingly in the form of a virtual 3D model. The individual characteristic surfaces need to be arranged in order to create textures with suitable

qualities such as texture, reflection, color, etc. For obscure or unpreserved surfaces, it is possible to use photographs or retouched techniques or replace them with equivalent textures from similar objects.

3. Methodology

Haptic didactic tools educate “with an emphasis on the active and creative learning, not just passive reception of information.” Interactivity allows two-way communication, and the student thus has the opportunity to actively intervene in the operation through the user interface program and not just passively participate (receive) its content. This increases clarity, motivation, and desire of students to learn. The basic advantages of interactivity innovation are “activity pupil, increasing pupil attention, motivation and desire to learn, actively and creatively engage in educational activities, a positive attitude and interest in the curriculum, etc.”; ultimately better semantic connections and understanding of the curriculum.

Interactivity and immersiveness are important keys on exploration of virtual reality game. There is an issue involving haptic as part of stimulating interactivity between virtual characters and players in order to obtain more attention from players [10]. Haptic interfaces can create combinations of mechanical signals that do not have counterparts in real environments [11]. This allows creating haptic virtual environ in which entirely new haptic sensory experiences are possible (**Figure 4**).

The main goal of this research was to discuss the basics of effective use of haptic virtual environments in research of applications involving user sensory testing. To illustrate this intention, this chapter also discusses some recent discoveries in haptic perception, in which haptic presentation has played an important role in digital documentation of heritage; in this case, study of an industrial heritage.

Figure 4.
(a) Haptic perception in everyday environments. (b) In contrast, haptic perception in virtual environments (scheme: [11]).

4. Case study

Digital documentation and presentation by haptic technology in the old power plant in the Piešťany city

The presented case study presented in this chapter is an example of the implementation of the methodology of the previous research chapter. It focuses on the use of virtual and mixed reality as an analytical tool for the design of exhibition

space. In this way, a fuller exploration of new educational and simulation techniques in industrial spaces is ensured. The old power plant for heavy oil burning in Piešťany was built in 1906 as one of the first of its kind in the former Austro-Hungarian Empire. Later, the plant only provided distribution and energy transformation till the 1990s. The machinery hall originally had six diesel engines and generators. Now there is a multifunctional hall for scientific devices, exhibitions, and cultural events. Archival documents about the original state of the machinery hall allowed the exact appearance to be replicated through MR [12] (**Figure 5**).

After conversion, the building is now used as a technical science museum, which interactively educates about the energy and electricity sector (**Figure 6**). The building can currently be used for multifunctional common purposes, and at the same time, visitors can learn more additional information about the history of electricity in Slovakia. The exhibition is a hybrid of mixed reality, 3D haptic models, virtual reality, and physical industrial objects. These model solutions are defined according to the architectural value of the monuments [13]. The proportions, materials, and details for the 3D model were derived from preserved and functional historic diesel engines from the Technical Museum in Vienna. Photographic processes took 3 days through 3D scanning. Based on interdisciplinary cooperation and 3D animation of a historic engine MR exhibition was created.

The 3D model serves as a reference from which it was possible to analogously create proportions of details 1:1 (**Figures 7 and 8**) and draw them in a new complete 3D model of the building. Based on measurements on-site and archival research, it was found how the building was originally built according to plan in 1906. Further historical research identified all periods of building extensions and various stages of building outlook (1920–1945). For the purposes of this case study, it was decided to visualize just the first and oldest period of 1906 [12].

Figure 5. Archival documents of the building from the National Archive in Trnava from 1906 to 1938 (photo: V. Hain, M. Ganobjak, 2010).

Figure 6. Project of reconstruction of old power plant in Piešťany: M. Ganobjak, V. Hain, M. Paško, Z. Zacharová, 2014 (photo: P. Safko, 2014).

Figure 7.
Original diesel engine from Vienna Technical Museum compared with photogrammetry of 3D model via software Capture Reality and AGISoft (photo and 3D model: O. Virág, 2016).

Figure 8.
Final VR 3D model of the virtual presentation was presented by VR headset Oculus Rift in the Power Plant Piešťany, (3D model: O. Virág, 2016).

The user can experience the atmosphere of a characteristic industrial space design in original realistic quality, along with real-time sounds and animations. VR objects and a 3D model were prepared in Unreal Engine 4, which provides photorealistic images with high-quality surfaces, textures, and lighting. The outputs are suitable for all these selected tested devices: HTC Vive, Oculus Rift, Cyberith [2].

The VR scene for the power plant created in 1906 (**Figures 8 and 9**) is intended for education and visual communication of technical information, but it also builds on the diversity of educational and multisensory exposition, which is more universal. The target group is students, all visitors to the practical science center of the EP, but also experts in the field of electrical engineering, whom the exhibition created in this way can entertain but mainly teach the general public.

3D model of the engine room seeks to eliminate the extreme situations of negative emotions of the space; it is “phobia free.” MR respects the senses and aims to eliminate potential negative emotions. The space is becoming appropriate. MR and VR evoke feelings from original environment supplemented by authentic sounds and smell that invoke an industrial atmosphere. On the magic date of Friday, May 13, 2016, the virtual reality project was presented for the first time in the old power

Figure 9. 3D model of the original machine and mixed reality presentation with VR headset Oculus Rift in the power plant in Piešťany. For visitors it was possible to compare the current status and historical status—an overlay of physical and virtual reality (photo: O. Virág, V. Hain, L. Dait, M. Ganobjak, 2016).

plant in Piešťany through Oculus Rift glasses for VR (Video 1, <https://www.youtube.com/watch?v=Pk-8gCx03WM&feature=youtu.be>).

The presentation is fully animated with the possibility of synchronized human movement in space. The exhibition is thus interactive and creates a subjective experience. The audiovisual design in the original old machine hall of the old power plant sensually complements it with the historical scent of black oil (unrefined diesel). This greatly affects the imagination of the observer, allowing him to be better immersed in the experience for long-term storage of sensory information. At the same time, the MR presentation premises is a more advantageous form for a wider audience of all ages and for people with certain forms of disability. It's a so-called as a “window to the past.” This kind of mixed reality experience and visitors has proven that it is a suitable tool for commemorating the extinct heritage and reinterpreting its significance for the present (**Figure 10**).

The virtual Machinery Hall was tested by virtual tracking of the visitors. The mentioned motivation, inducing natural behavior, was taking photos of what they see. The reward system, which was linked to the real and also supported their natural behavior, was displaying their photographs and movements on the additional display. In addition, taking photos by the visitors marked the most interesting views and locations in the presented virtual space. Subsequently to the virtual

Figure 10. MR application testing by students of the University of the Third Age of the FAD STU in Bratislava (photo: V. Hain, 3D model: O. Virág, 2016).

exploration of the space, the brief questionnaire was given to them. This questionnaire concerned their feelings in the virtual environment and the overall quality of the virtual presentation [14].

Similar presentations using VR is appropriate and could be also adapted to people with different disabilities—the virtual movement through space for people with movement disabilities, visual space for people with hearing disabilities, brightness and contrast color scheme for people with seeing impairments, and rich sound experience for the blind people.

The virtual presentation is not limited by the visual or graphical style, it could be hyper-realistic, sketchy, or abstract, and it is also saving space and is very customizable. The currently unavailable spaces of the power plant in Piešťany are opened to public, and its past capabilities as circulation of fuel and cooling water through the past generators in the Machinery Hall are explained by the haptic diagrams. The authentic remaining equipment is complemented by educational presentation diagrams in various languages explaining its functioning by LCD touch panels.

On the wall and floor of the hall, the timeline with augmented reality presenting the electricity utilization is drawn. By focusing the tablets on the individual points of the timeline, the technology of the specific period is presented by the animation. The interactive installations are complemented by the Tesla coil, which is hanged on a steel rope above the heads of the observers, and it is throwing lighting above them. The turret room has also a stainless-steel ball in the middle, which is a Van der Graaf generator that bristles the hair of the visitors who are touching it (**Figure 11**).

The visitors reported that to move through virtual space without their avatar body was not comfortable experience. In the beginning of their virtual visits, they were a bit confused and disoriented, but in a short time, they adapted to that state and examined the space without obstructions. Use of the real environment as an anchor point for visitors' orientation and location in space showed to be very efficient for successful education, because the brain distinguishes the additionally given information in virtual reality, and it directly connects them with the real place. On the other hand, using mixed reality in this case study appeared to be a very practical tool for presentations at different places, outside of the original site of old power plant in Piešťany.

Here appeared the first hint and requirement of users for the implementation of additional haptic technologies, with which they would feel more anchored in space,

Figure 11. Mixed reality exhibition in the old power plant in Piešťany with augmented reality, virtual reality, and of original engine equipment (design and photo: V. Hain, M. Ganobjak).

more confident in understanding what is safe and what is risky. Acoustic or vibration signals would be appreciated by most users.

5. Visitor tracking and virtual exhibition evaluation

The virtually reconstructed machinery hall of power plant in Piešťany was also presented at the Night of European Researchers in Bratislava. At this event, the tracking of the visitors in this virtual installation was included. To induce natural behavior in visitors, we motivated them by the ability of taking photos of the virtual machinery. The second screen displayed the taken photos and their motions as reward system even more supporting the motivation of visitors. The photographs taken by users marked the most attractive places and motives of the virtual exhibition.

When the visitors finished their virtual observation, they answered a brief form containing questions about the comfort of VR and quality of this type of presentation.

Motions and gazes of the visitors in VR were noted every 0.3 second. These data were gathered with positions from which the photographs were taken, into the dense cloud of points to process them in the subsequent research. Visitors' motions were also noted via the heat map by the contrast trace. When visitors spent more time on a specific position, the trace became more contrast. These data notation enabled to visualize the attractiveness of certain places and to process them by supervised machine learning to create a prototype of an analytical instrument for evaluation of similarly designed virtual exhibitions (**Figure 12**).

The prototype of the analytical tool for such an evaluation is a statistical model based on the artificial neural network (ANN) trained by supervised learning. By the supervised learning, the ANN is learning the relations and links between the pairs of related input and output samples [15].

To teach the ANN, the planar heat map with visitors' motions was resampled to 40×66 pixels and sampled in 0.6 m, which is the size of human module, usually used in architectural design. Sampling the heat map, divided it to samples, each with four pixels. These samples were positioned in the original grid of 40 by 66 positions. In these positions, the 3D model of the exhibition was processed by the isovist tool, which is quantifying the spatial openness and visibility by measuring the distances from the certain positions to their surrounding objects.

Figure 12.

Users' tracking data: left—heat map of tracked users' motions in plan, right—point cloud of tracked users' view locations and positions, blue points are photographed views (R. Hajtmanek, 2019).

In this case, 24 distances from every location in the grid to the surrounding objects were measured. The sums of each 24 distances quantified the openness and visibility of the space in every location of the square grid. This analysis of the space openness was also noted via the planar heat map, equally sampled into four-pixel samples as the heat map of the tracked visitors' motions. The measured objects in the exhibition were also categorized via its significance. Categorization of the objects was made of three groups according to their significance: 1—windows and walls, 2—subsidiary hall's equipment, 3—the most important and attractive diesel machines in the hall. Every distance measure contained then also the information of significance of the measured object, which was visible from the certain location in the grid.

5.1 Results of the evaluation

The supervised learning of the ANN contains training and testing phases. In the testing phase, AAN is trained on the training set, consisting 80% of the total samples count. After the training phase, it is tested in the testing phase on the remaining 20% of the samples. The comparison between the test and original data then validates the learning of the ANN.

Based on the learning, the AAN generated the new heat maps of visitors' motions, from the input data of spatial openness and objects' importance. These newly generated maps were then compared with the original tracked data of the visitors' motions. The original and generated heat maps were colored and blurred to highlight the similarities or differences (Figure 13).

Graphical comparison of the heat maps validated the ANN learning in the training phase, as these parts of the images are similar. Comparison of the image parts generated during the training phase also shows similarities but with some inaccuracies. Still, it is possible to declare that some relations were learned by ANN as the

Figure 13. Comparison of the original and generated maps of the visitors' motions left—original blurred and recolored heat map, right—ANN generated blurred and recolored heat map. Area marked by the dashed rectangle was generated in the test phase (R. Hajtmanek, 2019).

recognition of the attractive space between the machines and windows and motions around the objects. With these outcomes, the prototype of this tool based on the ANN validated that it is possible to evaluate similar designs of the virtual exhibitions by predicting statistical response from its future visitors. Such an evaluation during the design process can then bring more attractive and better suited further virtual presentations.

6. Screening

The precisely modeled 3D representation of Machinery Hall in power plant in Piešťany was very captivating to the general public, but also to the energy professionals from Západoslovenská energetika a.s.—electricity supplier in the west of Slovakia. Together with iPartner and Živica—Center for Environmental and Ethical Education, an educative and interactive quiz game for primary schools was developed (Figure 14). Team from Faculty of Architecture and Design STU created an interactive application based on VR game, through which pupils solve tasks related to the subjects of physics, chemistry but especially electric energy. In addition to the classic haptic game with cables and a plasma lamp, they could also try themselves education virtually by visiting the Piešťany Power Station in 1906 via the VR application.

This application has already been tested at the Pavol Horov Primary School in Devínská Nová Ves—Bratislava. This quiz was tried by children from 12 to 15 years of age using the VR headsets. The screening in the schools showed that this way of education increased the interest of pupils strongly.

Pedagogues without VR experiences were interested by implementation of similar interactive methods in their future teaching process.

Experts in the field of industrial heritage and its pedagogy see the significance of presentation by virtual 3D models of lost historic objects in a few points:

- These installations are presenting the site to the wider public, and they serve as a reminder of local history.
- They are opening to the public, but also professional discussion about the site and its future image.
- They are reimagining the ideas about present and future.

Figure 14.

Testing of classical manual education and haptic-virtual via VR (authors: FA STU, Živica, ZSE, a.s., iPARTNER s.r.o., CRATE, 2017).

- They are efficient, bringing clear and quick comprehending of the lost historical objects by different tools as 3D printing, VR, AR, or holographic models.
- Efficient non-formal haptic learning.

The installations using synchronized movement in VR and animated virtual elements induce immersive and subjective experiences. The presentation in old power plant Machinery Hall used not only audiovisual elements, but also it was supplemented by the real oil and diesel smell.

Supplementing elements from the real environment improve visitor's immersion in virtual space and his imagination. His potential to create long-term memories is also increased. In addition, the installation, which is presenting historical objects and spaces by similar methods, is also more attractive to younger, but also to older audience and is universally accessible by everyone.

As the installations using VR are attractive to wide public of every age and also to a professional public, the knowledge about historical and cultural values of the historical buildings and monuments is easier transferred and communicated. These immersive technologies proved to be efficient and appropriate tool for memorialize objects of the lost heritage and to reinterpret its importance for today and for the future (**Figure 15**).

By the mixed reality, the visitor is teleported into the virtual space with the ability of moving and viewing the space in a natural way. VR also allows people for disabilities to move through and to explore the space, without barriers, which would be not possible or too expensive otherwise.

In the case of old power plant in Piešťany, the HTC Vive showed to be less usable by people with motion disabilities than Oculus. The virtual space is usually perceived from the first-person view. This point of view could be also modified by using different perspectives (frog's or bird's perspective) and scales (the observer could be smaller in comparison to the model and vice versa).

The VR presentations offer the opportunities to experience the past, future, different fictions, or visions. Visual stimulation is supplemented with textures or materials from the real world as dust and smell, present in the old, preserved spaces and buildings, as the smell of the oil in the Machinery Hall.

Visits of the lost interior from 1906 of Machinery Hall in the old power plant in Piešťany are possible from anywhere, as VR with motion synchronization allows it. Synchronization of the real movement with the virtual one is convincing and validates the application of mixed reality as a tool for presentation of the lost industrial heritage in the contrast with its contemporary design, comparing these often very different states of the space [16].

Figure 15.
Picture of the virtual machinery hall with machine equipment—at the first stage of the power plant in 1906 and the haptic presentation in former machinery hall (3D model: O. Virág, M. Ganobjak, V. Hain; photo: V. Hain, 2017).

Figure 16. *Planned addition of haptic technologies—Microsoft HoloLens 2, interactive tablets for AR in the old power plant in Piestany (scheme: V. Hain, 2021).*

7. Addition of new haptic technologies

Various studies researched the links between real and virtual by combination of various sensorial stimulations. To induce natural behavior in the spectator, the mixture of haptic and audio stimulations from real world and visual stimulations from virtual world was successfully used. The reason was that the spectator related the presented virtual space more easily to the real one.

The viewers perceived and comprehended the proportions and scale of the virtual elements more accurately as seeing them in the scaled physical 3D models or on the 2D displays as sketches or blueprints. In contrast, perception of scale was complicated, when visual stimulus from virtual environment was mixed together with visual and touch stimulus from the real environment on the scaled physical 3D model.

To achieve the more accurate perception of scale by the visitor in this combination of used stimulations from virtual and real environment, choosing a location in the scaled physical 3D model and then exploring it from that point of view in VR or by the camera would be more appropriate. This is implied in the described studies by the application of augmented haptic virtuality instead of using conventional augmented reality [17].

Therefore, the need arose to supplement the new available haptic technologies, which will be implemented in the premises of the Piešťany power plant in 2022 and subsequently their impact on users will be further tested (**Figure 16**).

The case study questions the relevance, meaningfulness, usability of VR, and its applications in entertainment. Some psychology researchers also indicate that improperly VR applications may lead to being isolated from the actual world that forced binocular imagery may cause brain disorder, and that its applications are not explored in the long-term view. In the described research, the VR is becoming a practical instrument for teaching wide public about lost historical objects. In comparison to various controversial applications of VR, this case study may be understood as appropriate and reasonable practical use of this technology [18].

8. Discussion

Using mixed reality (MR) as a tool for presentation and education of audience about industrial heritage is based on advanced technological skills in this area, but also to properly evaluate education level of the presentation. It requires to adapt the presentation to its targeted audience. The concept of using Haptic Technologies (HT) is not only the element of synergy, used in an organized complex design process, but in addition it is a crucial educational tool in MR.

Method that is trying to return the works to life can be called “virtual renewal.” There are similar projects in the world often appear as “digital reconstruction” [19]. Virtual method recovery was in collaboration with students successfully tested even during the last pandemics semesters. For distance reasons, teaching students are able to study architectural works within reach your site and if the situation so allows, students can also verify the current state of the object in-situ via the “Urban Walk—Interactive planning method” [20] or the “Industrial Walk” in conjunction with the “Before after method” [21]. Only time will tell how successful it will be, but the growing development of haptic technologies is an important aspect for the future education.

9. Conclusion

With HT, the described case study has reimagined the industrial heritage history and brought something what was not possible to create physically to a present viewer. Learning about our lost historical objects is now easier and more accessible to wide public with this applied interactive technology. By focusing gaze on specific targets in scene, the interactive elements can be activated, and thus the user is informed and learnt by more natural way.

Visitor tracking is also a good educational element in understanding how people perceive the local industrial heritage sites, as much as they are interested in them and how to attract as many new participants as possible through HT.

For each experimental study of education about historical remains, the precise study of the subject is required. For that reason, the described case study will be used as a foundation for subsequent research of the HT applications in the education and preservation of industrial cultural heritage.

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Author details

Vladimír Hain*, Roman Hajtmanek and Dušan Kočlík
Faculty of Architecture and Design, Slovak University of Technology in Bratislava, Slovakia

*Address all correspondence to: vladimir.hain@stuba.sk

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