i-Wall: A Low-Cost Interactive Wall for Enhancing Visitor Experience and Promoting Industrial Heritage in Museums

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Abstract.

Interactive walls have been employed in many museums with the aim to enhance the visitor experience. These are usually large in size and expensive, while their typical use is to present generic content about the museum. As a result, they may not be easily set-up at multiple locations inside a museum and serve the purpose of presenting narratives about particular exhibits. This paper presents i-Wall, an affordable interactive wall system built from off-the-shelf components and technologies. i-Wall has been designed for the Syros Industrial Museum (Greece) and presents a narrative about a particular exhibit, the Enfield E8000, which is the first electric car that reached small-scale production (in 1973). i-Wall provides information to visitors about the concept, the design, the problems, the creators and the socio-political context related to the exhibit, in an interactive way. It also allows visitors to appreciate the interior of the car as well as its functions via augmented reality (AR) technology. The design of i-Wall combines interactive storytelling, animations, projection mapping, conductive paint, touchboard and AR.

Keywords: industrial cultural heritage; interactive wall; augmented reality; physical computing; off-the-shelf components; affordable technologies; iterative design; prototyping.

Fig. 1. Views of the interactive wall inside the industrial museum (on the left) and during use (on the right).

1 Introduction

Industrial heritage tourism refers to "the development of touristic activities and industries on man-made sites, buildings and landscapes that originated with industrial processes of earlier periods" [1]. Industrial museums are the major hosts of industrial cultural heritage and are attractive environments for heritage tourism [2], [3]. These museums affect people by connecting them with each other, amplify social inclusion and diversity and engage visitors with new and potentially inspiring experiences that combine heritage and tourism [4].

In many traditional museums, the perception of information about exhibits is relatively passive [5]. Visitors are only able to look at the exhibits from a safe distance and often have no basic guidance or information to connect the exhibits with other narratives related to the museum's collections [6], [7].

Over the past two decades, several museums introduced interactive installations (such as interactive walls, tables, boards, monitors, video projections etc.) in order to attract more visitors, spark their interest [8] and engage them in a unique social experience [9], [10]. While in the past, static imagery was enough, nowadays visitors seek more interactive elements, participation in the action and social engagement with others [11]. Current trends indicate that cultural organizations invest in sustaining the engagement of people with museums and raising connectedness between museum practices and the everyday personal experiences of the visitors [12].

Most of these interactive installations are costly and large in size, like the Van Gogh Alive[1] exhibition or the Gallery One interactive wall [13]. Therefore, they are not affordable for many small-sized museums. In addition, large installations pose restrictions about their positioning inside the museum. Furthermore, sizeable installations typically present generic information about the museum rather than stories or narratives about important exhibits.

This research explores the potential of interactive content presentation of industrial cultural heritage content in museums with the design, implementation and evaluation of a cost-effective, customizable interactive wall system. In addition, through an iterative approach of design and evaluation it explores the design of touch interactions with the i-Wall and AR (augmented reality) app content.

i-Wall aims at engaging visitors of an industrial museum to a storytelling interactive experience. i-Wall is adaptable to various sizes and it can present customized, exhibit-specific cultural content in a museum. It comprises affordable components and technologies: wooden surface, conductive paint, commodity sensors, microcontrollers and video projection. The system is accompanied by a marker-based augmented reality (AR) application which allows visitors to interact with a 3D model of the exhibit. An initial prototype has been designed and implemented for the industrial museum of Hermoupolis, in the island of Syros, Greece. It presents the story of a specific museum exhibit, the first electric car that as been produced worldwide [14] (in small scale), the Enfield E8000, which has been on display at the museum for the past few years.

[1] http://www.vangoghaliveuae.com/

Enfield E8000 is unique piece of industrial cultural heritage that has references to historical facts, engineering practices, social practices and the economic and political status of the time. The island of Syros faces a transformation towards a mix of cultural and tourist activities, while its capital city Hermoupolis is known for its rich industrial heritage [15], since it has been the primary harbour and industrial area in Greece for a period of about 60 years (1830-1890). The i-Wall project has been developed in the context of a graduate course on interactive systems design (studio).

2 Related Work

Several research works have focused on how to avoid the formal aspects of experiencing cultural heritage content in museums and cultural contexts. The aim was to involve the visitor more actively by engaging and motivating him to participate in an interactive interplay with tangible and intangible heritage.

In the past two decades a large number of interactive board technologies are used in museums and cultural heritage sites; multi-touch tables are the most popular among them, used to present interactive representations of the exhibits. Lately, large scale interactive walls and video projection technologies are also deployed for visualizing cultural content [16], [17]. In a parallel development, new methods are actively researched that combine different interaction techniques and styles in terms of visitor-exhibit interaction and social collaboration in the museum or public settings [18], [19].

Applications based on interactive walls in any form, either for the purpose of entertaining or informing, have been implemented in various museums and exhibitions, for the presentation of products, services or other exhibits.

The project "Living Walls" developed by the "High, Low technology" research group at MIT, is a series of interactive wallpapers able to record their environment, to reproduce sound, to control the lighting in the room and to send messages to a friend. Their purpose was strictly for display [20].

The interactive wall at the "100% Brisbane" exhibition, co-developed with Liquid Interactive [21] and the artist Sophie Blackhall-Cain, presents an interactive wall that explores data through touch, sight and sound within a collaborative environment where visitors co-experience information about the city in a playful and interactive way [22].

The Ferrari raising DNA Interactive touch Wall[2], developed by DigiMagic, has been created for Ferrari during the world championship Formula 1 in 2016 in Singapore. The "wall" served the purpose of informing users about the history of the Ferrari in an interactive way. This interactive wall uses conductive paint technology.

Another example of interactive wall is that of the "Retail Design Expo" in London in 2015. It had the form of a 'open-square' shaped projected surface and has been constructed by the office of "Dalziel and Pow"[3]. This interactive kiosk represents a fine example of a creative mixture of various technologies aiming at connecting visitors and providing useful content about an important event.

[2] https://www.youtube.com/watch?v=mpO0Q7u4Qg8
[3] https://www.youtube.com/watch?v=poA9bZ76iJk

With respect to AR, many systems have been implemented to provide cultural digital content to visitors, especially when the artefacts on display are not directly accessible [23], [24]. Touching the exhibits is normally forbitten in museums and therefore active interaction with (or examination of) any exhibited artefact is not possible. This can be resolved by using AR technology as it can present to the user additional interactive 2D or 3D content on top of markers or POIs (Points of Interest). The application of AR is widespread in the car industry.

McLaren has created an AR application[4] for the models of McLaren570S and McLarenP1. Users can install the apps on their phone or tablet and, by using a marker (available from the company's website) the car can be observed in a 3D form. The user can also see the car frame and receive information on the car's technology. AR technology is also widespread in museums, as in [25] which presents an AR app that allows users to change the colours of an artwork from the artist's palette.

3 Design and Prototyping

The i-Wall system has been developed following an iterative design process that involved incremental prototyping and technical testing of the main system components, i.e., the touch sensor, projection mapping, animation design, storytelling and AR application. This section outlines the design of the system components. The i-Wall setup is illustrated in Fig. 2.

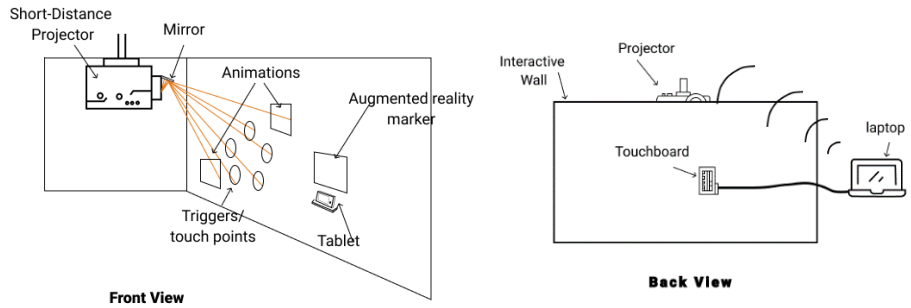

Fig. 2. The interactive wall setup. **On the left**: the front of the i-Wall consists of (a) the plywood surface, (a) touchpoints drawn with conductive ink, (c) an AR marker placed onto the surface, (d) a projector and (e) animations played upon the user touching the touchpoints. **On the right**: a touchboard (connected to a laptop) is mounted on the back of the i-Wall.

3.1 Touch Sensor

The touch interaction was implemented with TouchBoard technology, by Bare Conductive, which is compatible with the Arduino Genuino software. This board can enhance any surface with touch interaction. It comes with sensors that may respond when

[4] http://cars.mclaren.com/apps

they are connected (i.e. simply painted) with conductive paint. Each user touchpoint (trigger) is drawn onto a plywood surface in the form of an icon that relates to a story about the E-8000 electric car and is physically linked through the plywood via metallic nails to short wires onto the TouchBoard.

3.2 Projection Mapping

The layout of content projected on the interactive wall has been designed with the "Mad Mapper" software. Mad Mapper is installed on a laptop computer connected with the projector and the TouchBoard. Upon the user's touching a touchpoint/trigger, this event is identified by TouchBoard and, through MadMapper, it is matched to an animation/projection subsequently projected around/next to the touchpoint. The projections comprise short animations, edited in the context of this project.

3.3 Animation Design

On the i-Wall there are five triggers, each one corresponding to one part of the story:

1. The idea of the creation of the car
2. The sociopolitical context in Syros during the production of the car
3. The problems that arose during the production up to the closing of the factory.
4. The creator, John Goulandris
5. The materials and the method of construction

The style of the videos follows a simple line, the designs are flat and the colour pallete is neutral (white figures, light blue details, transparent background). For the creation of the animations, the software packages that were used are After Effects, Illustrator and Photoshop by Adobe.

3.4 Storytelling

Our main goal was to achieve an interactive storytelling experience via short videos. These have been designed with the minimum amount of text possible and their duration is around two and a half minutes. The touchpoints are placed in a circular arrangement on the surface of the wall so that the user is free to choose from which point they want to start the story of Enfield, and they are the master of the flow that unravels in front of them. However, we added some arrows connecting the touchpoints, indicating the "correct" line of selection, however without making it necessary that people had to follow this line of viewing. The AR app was also an aspect of the storytelling.

3.5 AR application

The AR application was the most suitable means to help the user understand the interior of the electric car. We accompanied the AR interaction with explanatory text, since the interior of the car is not actually visible to the museum visitors. A tablet was constantly

available next to the interactive wall and the user could pick it up to use the AR application. The AR application presents the information about the inside of the car in an interactive way, after the user has aimed the camera of the tablet on a marker that is onto the i-wall. Then the model of the car appears in a 3D form, on the screen of the tablet and the user can interact with it, by turning the model around, or selecting certain parts of it and reading the specific information.

For the creation of this application we used several software packages. The app was created using Unity, Vuforia and Android Studio. The model of the car was created with Cinema 4D by Maxon.

3.6 Prototype

Low fidelity prototype

A low fidelity prototype was developed in a canvas, with a long-distance projector mainly to check the lighting and the colour pallete of the animations, as well as the arrangement of the triggers and their connection to the TouchBoard.

High fidelity prototype

The high-fidelity prototype was created onto a light-coloured plywood (dimensions 1.20m x 2.40m) and a short-distance projector in order to avoid shadows during the use of the wall. The prototype was placed on a wall, half a meter high from the ground. The distance between the i-Wall and the projector was set to 1m.

Throughout the development of the second prototype, we tested several trial setups of the various system elements. The prototyping process helped us reach to the basic characteristics of the i-wall system:

- Simple and playful representation of the car's history
- Only touch operation
- Sound response from the system when someone touches a touchpoint
- Main use of white colour for the icons and animations
- Large projections with sufficient space between them
- Intuitive interaction through the AR app allowing the exploration of the car's interior.

4 Interaction Design

The interaction with the wall is deliberately kept simple, given the fact that it is part of a tour in an already rich in content museum. The aim was not to overload the visitor with intense visual stimuli. The function of the interactive wall starts from the touch of the user's hand on a touchpoint which triggers a series of actions. The basic steps are (see Fig. 3):

- Touch the desired video / trigger;
- Activate the touchboard via a circuit;
- Transfer the command to the laptop (which has projection mapping installed);

- Activate the video through the program;
- Project the video to a specific location (depending on the touchpoint).

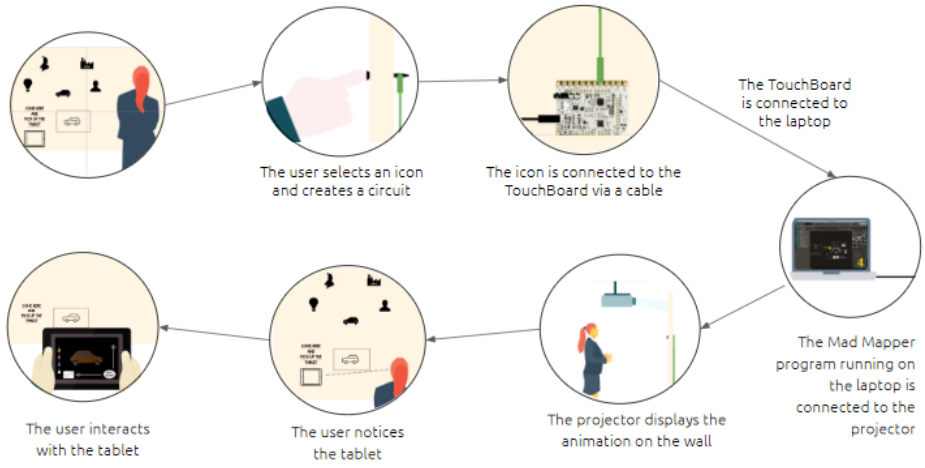

Fig. 3. The main workflow of the i-Wall triggered by user interactions.

System performance (i.e. the system's responsiveness to user actions) has been a key consideration, hence, we have ensured that the above procedure is executed in fractions of a second. In order for the user to realize that his touch is enough to activate the projections, the speed and sound have been adjusted to respond directly. By using one or even all the touchpoints at the same time the i-Wall can be controlled by one or more users simultaneously. Regarding the AR app, users may interact with a 3D model of the "Enfield E8000". Users can interact by:

- Applying basic transformations in order to view the different sides of the car;
- Reverting it back to its original position;
- Changing colour of the main body;
- Tapping on active areas on the model to view the relevant information;
- Exploring the different components that comprise the car model (car frame, main frame, wheels, electric engine etc).

5 Evaluation

We organized a formative user-centred evaluation in the design studio that took place in three distinct phases. After each evaluation phase, we made the necessary adjustments to improve the system to the extent possible. During the evaluation, the participants interacted with the i-Wall in an unguided fashion. Namely, they have not been provided with a specific usage scenario, so that we could monitor their reactions and responses.

5.1 Phase one

The participants were eight users; these were the supervisors of our interaction design studio course, who were familiar and informed about the subject and the technologies. We chose this group especially to get important information about the overall design and interactions. The main conclusions of the first round of evaluation included:

- To attract the attention of the visitor and intensify his curiosity was achieved with the element of surprise. The explanation under the title encouraged visitors to come up and touch one of the icons, but without explaining what exactly will happen when they touch one of the touch points!
- To amplify this transition, we added sound effects to every touch point so that users would understand that the icon has been activated.
- We also added background music, giving an exhilarating atmosphere to the environment.
- The title of the installation became more prominent: from a static image it was redesigned to blink so as to draw the attention of visitors.
- We placed the AR marker on a location that was easier to observe.
- Regarding the AR implementation, we noticed that the interaction did not fully correspond the user's instructions (i.e. it was not fully functional and comprehensible). Therefore the touchpoint icons were redesigned and the code was redesigned, for a better response to user moves.

5.2 Phase two

The participants were fourteen students who were familiar with the project but not with the technology in the form implemented. The main conclusions of his round of evaluation were:

- Participants were quickly acquainted with the technology and entertained with the interaction and sounds at touchpoints.
- Most of them did not manage to watch the videos, and specifically the flow of information, as videos had longer durations than required for that concept.
- Most of them were unable to control the projections of the animations due to the lack of controls, such as pause and start. This resulted in relatively tedious interaction and gradually losing interest in the animations.
- The implementation of AR seemed to have a greater appeal; the users spent time interacting with the car model and understood the function of the controls.
- A small percentage of users expressed the desire to navigate and discover their own functions in the AR app. Thus, we added user instructions in the beginning.

For the transition from the second to the third phase, we focused on the concept's functionality, such as improving the start time of the projections, as it was causing interaction problems. Also, we noticed for the first time the need of users to know the location of projection on the wall, as the attendance of several visitors at the same time led to some confusion. An animated line has been chosen to address this issue: as soon

as the user touched an icon, he listened to a sound, which was then followed by the animated line that framed the icon and continued its path until the video was viewed (illustrated in the video[5]).

5.3 Phase three

The participants were a mix of our supervisors and students. The aim of the third round of evaluation was to optimise performance and experience issues. The main conclusion was that i-wall was fully functional and it had great appeal to users, however:

- Some users would prefer a narration.
- Some users pointed out the need to switch language (between English and Greek).
- Additional indications suggesting the chronological order of the animations.
- The duration of some projections remained long enough, so additional visual indication of the duration of the projected clips was proposed.
- Regarding the AR app, some users would appreciate more possibilities and interaction affordances.

Fig. 4. On the left: the i-Wall with all animated content activated. On the right: a user interacting with the AR app.

6 Summary and Conclusions

This paper presented an interactive wall system (i-Wall) for engaging visitors of an industrial museum to a storytelling interactive experience. i-Wall comprises of affordable components and technologies: a wooden surface, conductive materials, wiring, touchboard and video projection. The AR application has proved a suitable tool to complement the main installation and offer a different perspective of the exhibit. The wall installation is adaptable to various sizes and it can present customized, exhibit-specific interpretive content in a museum. The i-Wall system has been developed for the industrial museum of Hermoupolis, in the island of Syros, Greece and it presents the story of a specific museum exhibit, the Enfield E8000, the first electric car manufactured worldwide.

[5] https://www.youtube.com/watch?v=YzJo9qQVy2s

Throughout the process of research, design and evaluation, we have found that there is a need for a different and more participatory approach to the design of interactive systems for museums. In particular, we have found that the i-Wall for Enfield E8000 contributes to a more experiential and entertaining experience while also promoting the industrial history of Syros island. A significant feature of the system is the combination of navigation, the sense of touch, sound and observation of the narration as it unfolds. The flow of storytelling directs users, without binding them to make specific choices, as the element of surprise remains throughout the interaction with the exhibit. Finally, i-Wall is flexible, as it can incorporate different means of interaction, while it can also be adapted to any space, when designed appropriately.

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