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"In-The-Wild" Observation and Evaluation of a Chinese Heritage VR Environment with HTC VIVE

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***Abstract*—Virtual Reality (VR) is an industry where heavy investments were made in recent years, it is also a revived research interest both internationally and within China due to the development of usable hardware by technology giants. In China, VR has seen an explosion of startups, and has attracted venture capital investments, but has also seen subsequent implosions and failures largely due to marketing hypes, mismanaged expectations, and definitely an unsustainable VR business model. There are presently over 100 types of VR devices, ranging from the low to the higher end equipment in the mass market which could potentially diversify application areas. However, a lack of developmental experience, usability studies, adjustments to social-cultural differences, and unsustainability in content generation and development may be seen as an issue within China's market. These observed issues are broad and challenging, which perhaps the VR academic community may have a stronger foothold from which the industry could benefit from. One aspect which may require immediate attention and active investigation is the two fronts of VR's core areas – user experience and content. In this paper, we conducted an 'in-the-wild' observation of a majority of participants experiencing VR for the first time in China. We observed more than 200 walk-in participants experiencing a virtual environment we reconstructed using the HTC VIVE during a four-day public exhibition at the 2017 China (Ningbo) Cultural Industries Fare. The observation outcomes are presented from three angles: user immersive experience; learnability; affective and emotional response. Our experience and findings demonstrated that VR application is effective in nurturing immersive experience and automated learning, establishing perception and intuition, and develop higher level of emotional engagement, which could benefit both the academia and the industry in heritage and cultural education.**

Keywords— VR, HTC VIVE, in-the-wild, user observation, user experience

I. INTRODUCTION

Since 2014, the Virtual Reality (VR) market has attracted numerous venture capital investments which contributed to significant growth. As a result, there are presently over 100 types of low and high-end VR devices in the mass market, including the commercially available VR headsets, such as the Oculus Rift and the HTC VIVE. Advances made to these headsets and the decrease in cost meant that adoption by the wider community and the diversification of application areas are now possible. Furthermore, imaginative contents, more engaging and immersive user experience are providing a highly motivating way of interaction. For the past decades, VR have been used in some industries, newer developments meant that the development of a broader category of concepts might have opportunities for revolutionising education. Within China's VR context, the China Electronics Standardization Institute (CESI) [1] suggests that the collaboration between VR developers and museums are developing virtual spaces where experiencing the physical collections of museums are now made possible. The report observes the adoption of VR by international museums – British Museum's first VR weekend and the American Museum of Natural History's VR collection and tours using Google Cardboard VR. These specific mentions by CESI may suggest that China is open for exploration of VR for cultural contents.

Over the past two years, the University of Nottingham's museum Masterclasses in collaboration with the V&A have attracted hundreds of museum delegates to our programmes in Ningbo, China. Our lectures on digital heritage and VR for cultural heritage have been particularly welcomed, attracting collaboration for VR and AR applications. This is indicative of the need of China's museums to apply advanced digital technologies for their collection.

Immersive virtual environments in the sense of 'virtual time travel' [2] can digitally revive the glories of a historical site by providing an experience that is far beyond the traditional museum displays, it can replicate the materiality of cultural artefacts, and assists visitors in the pedagogy of history and culture from a phenomenological aspect. Already, the diversity of technology used for heritage science is revolutionalising how heritage is accessed [3]. As it stands, within China's creative industries, a lack of developmental experience, usability studies, adjustments to social-and cultural differences, and unsustainability in content generation and development may be an issue. These issues require immediate attention from the VR academic community, include investigating the VR's core areas of user experience and content, for bringing benefit both the academia and the industry. Our "in-the-wild" study reported here will perhaps lend an insight into an aspect of the consumer market.

II. BACKGROUND

2017 China (Ningbo) Cultural Industries Fair was co-organised by Ningbo Municipal Government and Zhejiang Cultural Industries Promotion Society. It aims at demonstrating the progress of development in local products and services within the cultural industry, and providing a platform to facilitate exchanges between local and international companies and institutions. The exhibitors comprised of leading companies and institutions from a wide range of sub-sectors within the cultural industry, including intangible heritage, fine arts, technology, music, leisure etc. The NVIDIA Joint-Lab on Mixed Reality, an NVIDIA Technology Centre within the University of Nottingham Ningbo China, was invited by the Ningbo Productivity Promotion Centre to present our digital heritage technologies due to their relevance to the local cultural industry.

As pointed out by the China Electronics Standardization Institute, a subsidiary of Ministry of Industry and Information Technology of People's Republic of China [1], the limitations of technology and an unsustainable development model are key issues of VR's development in China. The white paper also reported a general lack in the application of VR in the cultural and educational domain – "the most salient shortage of Chinese VR industry is high-quality content" without which the development and prosperity of the VR industry cannot be realised. CESI also highlighted that the cultural heritage contents can be part of the VR education to approach the issues of sustainability and responsibility in the cultural industry, for preserving and promoting national culture and identity.

Embodied Interaction suggests that users create and communicate meaning in the process of interacting with emerging interface technologies. For instance, with the use of wearable computing, it provides a more tangible interaction and more emphasis on full-body interaction by conceptualising the haptic and kinesthetic [4], [5]. Hence, interface technologies are considered as the mediation in human communication rather than just a passive transmission channel. The empirical studies of students engaged in kinesthetically-enhanced learning activities with digital technologies has demonstrated that the concept of embodied interaction can increase student engagement and stimulate user-initiated actions, which can generate new value for them [5], [6], [7]. On the other hand, literature shows that more studies are still needed to further discover the experiential qualities about the notion of engaging experience in embodies interaction, such as the explorative nature of emergent meaning-making [4][8][9]. In line with this, we believe that the ability of recent VR technology to replicate natural physical interaction within a physically mapped virtual space will have grounds for users to create and communicate meaning, especially when the contents of our virtual environment are China's cultural heritage. The studies also suggest that by conducting observation in natural settings, more analyses can be done to identify how the user interactions can influence the affordances of learning.

III. DEVELOPING FOR A PUBLIC EXHIBITION

This section describes our setup for the public exhibition and our method of observation.

A. Hardware and Software Requirements

Interactive simulation and immersive virtual environment with cultural contents that provides a realistic experience for users require advanced computing system. Our professional workstation is built for performance, with core components matched with our NVIDIA Quadro M6000 (24GB). Our Workstation has an Intel i7 2.4GHz 12-core CPU, 64GB of RAM, and 2TB HDD.

Released in April 2016, HTC VIVE is a virtual reality headset developed by HTC and Valve Corporation for turning a room into virtual world with immersive experience via sensors. It enables users to navigate and walk more naturally, tracking both rotational and positional information in a minimum of $2.5m^2$ or $5m^2$ space using the motion tracked handheld controllers to interact with the objects more precisely, as well as interacting with the virtual scenes more vividly. HTC VIVE consists of 1) a headset that has a total resolution of 2160 x 1200 pixels, an aspect ratio of 9:5, a refresh rate of 90Hz, as well as a gyrosensor, an accelerometer and a laser position sensor for tracking the position of the users' head and providing a more natural and convincing image; 2) a pair of wireless and battery-powered controllers that come with a trigger button under each forefinger, a pressure-sensitive grip in each hand, a circular touchpad for providing a responsive and natural way to interact with a virtual environment; 3) a pair of base stations which placed in the corners of a room for following the headset's and controllers' sensors and providing accurate tracking when the user is moving freely in a room-scale VR area.

As the issues of health and safety are concerned at the public exhibition, the cleaning pad and sanitizing wipe were used to sterilize the surface of the headset and handheld controllers after every use. This practice is to maintain the cleanliness and prevent the possibility of cross infection at all time, for creating a hygienic and pleasant environment at this room-scale VR experiential area.

Other than hardware and equipment, various multimedia application software are used for developing the VR content. These include the use of Autodesk Maya for creating interactive 3D models, virtual scenes and visual effects; Blender 3D's features for producing UV unwrapping, texturing, raster, and particle simulation; Autodesk ReMake for converting multiple photos into high-definition 3D meshes that can be re-topologized, decimated, and aligned for creating VR asset for AR/VR with interactive experiences; Unreal Engine 4.15 that comes with a full Unreal editor that capable of building robust, feature complete and photo-real visualization in the VR environment (see Fig. 1).

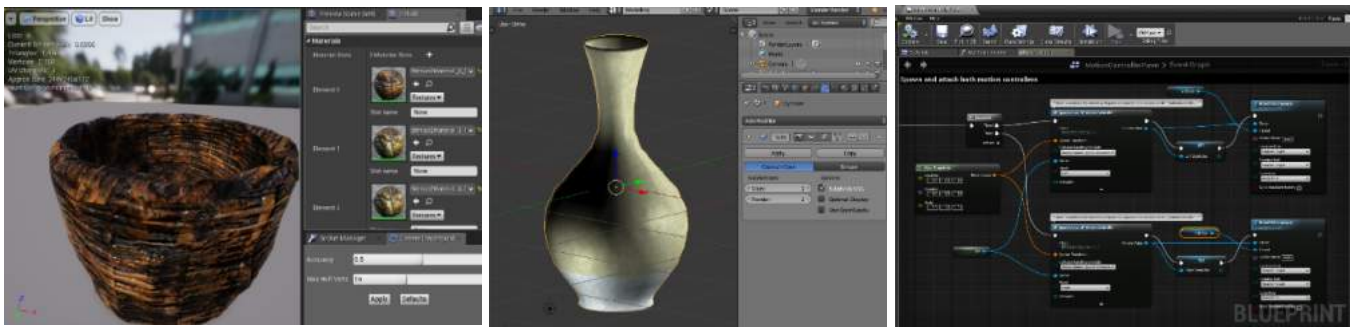

Fig 1. Content development process

B. Objects and Virtual Environment

We constructed a cultural heritage environment and included objects which are relatable to most of our visitors. As some of the NVIDIA Joint-Lab on Mixed Reality's projects relates to cultural heritage, we had immediate access to contents from our partners in cultural institutions. We set our virtual environment to a scenario ~800 years ago at the Yuan Dynasty (see Fig. 2). As the exhibition is held at a region (Ningbo) where the maritime Silk Road begins, the VR content acts as a natural interest for our participants. Our VR content development involves multiple procedures with the goal of realism in mind:

- Digital Capture – we used photogrammetry for capturing 3D architectural components and cultural objects.
- 3D Modelling – we reconstructed cultural environments and models which are no longer physically present, based on historical records, diagrams and literatures
- 3D Scene Setup – we reconstructed the virtual site (landscapes and water effects), and imported, setup and compiled objects as blueprint classes that are mapped to the events, physics engine and interactivity
- 3D interaction Setup – we created a parent Blueprint Actor with Interactable Actor Class for setting up some basic code before creating the Character Blueprint as a child actor to setup the variables (such as RightHandPickUp, TeleportHere) and functions (such as GetCurrentLocation, SetCurrentInteraction) that we need for the interaction.
- Lighting and Illumination – we created and adjusted lighting, fog and global illumination and re-rendered the scene after adjustments for realism.
- Testing – we tested and evaluated the scene, navigation, interactible objects, manipulation.
- Deployment – we deployed our VR application at the Ningbo International Exhibition Centre and tested the HTC VIVE's sensors for interference

Among these procedures, photogrammetry and 3D modelling are the two main procedures in developing the digital representations of the virtual environment. Photogrammetry requires good photo-shooting technique to capture photos of an object from different angles and heights. For a complex object, it involves several rounds of photo-shooting to capture fuller details and clearer texture. These photos were then imported into Autodesk ReMake, and we used the "feature detection" to recognise common points between any pair of overlapping pictures and join them together for creating a 3D model and fitting into the virtual environment. The 3D modelling was done in Blender to build the historical relics in the virtual environment, such as the vases, bowls and coins that were transported by merchant ships for foreign trade. In the modelling process, the photo samples collected from online resources and the archives of museums were used as our main reference.

Fig 2. Scenario views of participants interacting with the virtual environment

Fig 3. Our exhibition booth, showing a room-scale setting for participants to move around in with the HTC VIVE

IV. In-The-Wild Observation Method

A review of literature reveals that while many studies have evaluated user interaction in VR, most of the observations were conducted in formal, controlled settings. Very few studies have been 'in-the-wild'. Noticeable differences were detected between 'in-the-wild' settings (e.g. public exhibitions) and controlled settings (laboratory environments), and these relates to user experience and affective response. Although VR observations in natural and uncontrolled contexts are emerging, we still have very little knowledge on how user demographics perceive, adapts to, and reacts to unfamiliar technologies, particularly in walk-up-and-use scenarios in unpredictable settings [12], [14], [15]. We believe that "in-the-wild" observations are feasible for VR systems and are capable of yielding useful information for the future design of interactive virtual environments. These data therefore, increases the reliability of the evaluation of how interactive technologies can be further designed to accommodate larger groups of users and wider range of user expectations and experiences [13], [15]. In this study, our observation is purely "in-the-wild", also known as naturalistic observation that involve the study of participants' spontaneous behaviours, motivation, and experience. Our observation takes place from the moment when participants approach our exhibition booth and until they leave. The in-the-wild observation method records user engagement and responses, as well as the fluidity of behavior. We conducted the observation with these aims in mind: 1) participants' immersive experience, 2) the ability to learn and develop new meaning, 3) the affective and emotional response towards to virtual environment.

V. Venue and Participants

The observation was conducted during a four-day public exhibition at the '2017 China (Ningbo) Cultural Industries Fair', and evaluation is based on how interactions occur in relation to the objects of the environment. We calibrated a VR area measuring 2.5cm x 2.5cm with accurate tracking, for freedom of movement with the HTC VIVE. We observed more than 200 walk-in visitors. Depending on the level of comfort and individual interest, each participant was given 2 to 5 minutes on average of experience within the virtual environment. Our sample demographics consist of male and female of all ages, including working adults, the elderly, some international visitors, students, as well as children as young as 3 (see Fig. 3). Most of them arrive in small groups of families or friends. Others are accompanied by returning participants. The inclusion of a diverse group people with various backgrounds characterises our study. We had Chinese government officials, exhibition organisers, researchers, technologists, company managers, and institutional leaders (see Fig. 4). The officials and professional participants were made known to us via the exchange of name cards.

Fig 4. Physical view of participants using the HTC VIVE for interacting with virtual objectsObservation and Evaluation

VI. Observation and Evaluation

In this section, our observation and evaluation focus on the following angles.

A. Angle 1 - User Immersive Experience

We had no issues attracting a high rate of participants due to the popularity of VR within China as a result of heightened media reports in the past two years. In our observation, participants demonstrated motivation and acquired agility in managing the interactions, they

- expressed their interest to participate and showed no predisposition to give up when they have failed in an action. This includes making an appointment, spending time in the queue, returning in the off-peak hours to try out our VR demo, testing different control buttons to interact with the VR content.
- paid attention to visual information, VR devices (HTC VIVE headset and controllers) and virtual environment which was displayed at the monitor screen.
- perceived this virtual environment as a VR game environment. This could be influenced by mass market of VR within China that are largely associated with the gaming and video entertainment industry, where people are willing to spend money to gain the transformative and addictive experience in the illusory world. They *asked, "can the VR scene be changed?", "how do I collect game scores?"*
- demonstrated curiosity in exploring features within the virtual environment. This includes navigating the map while physically walking about and rotating their bodies at the VR area. They touched and felt the objects (broke the vases, rolled the large pots, turned the wooden boxes upside down).
- discovered their relationship with the virtual environment by using the handheld controllers to touch the objects which placed at the eye-level, followed by attempting to manipulate the object with the action of grabbing, pulling or pushing.

B. Angle 2 - Learnability

We observed with a closer inspection of the content interaction of our participants in the virtual environment and discovered interesting user patterns. Most of the users were interested and can:

- map real-life physical tasks and experiences to virtual tasks – opened the door as a means to leave the house, mess up the arrangement of the furnitures, tossed objects such as oranges to a maximum distance and breaking things as a result.
- adopt the perception of using the per-determined controls and settings to substitute physical movements and actions. This includes a deliberate perception of using the handheld controllers as a pair of human hands in the virtual environment, pressing the touchpad to 'jump' to other locations.

Develop new meanings and personal experiences through 1) performing tasks in the virtual environment, such as kept all oranges in the basket; 2) navigating their preferential pathways, such as found alternate ways to the seaport. Many participants expressed these statements *"I have been to an old house", "I helped to sell the oranges", "I broke the historical artefact for the first time", "…so they used a ceramic pot to cook?". These indicated that a highly personalised experience is possible with the right kinds of VR contents. Unlike VR games, real historical representation of virtual environments can induce such effects, and active role taking without the participants being formally assigned roles becomes a possibility.*

C. Angle 3 - Affective and Emotional response

We also observed that by immersing the participants in the virtual environment, it can influence participants' personal feelings and expressions, particularly,

- Unpredicted behaviours (such as vases are broken upon touching) attracted user attention to inspect the object and make a second attempt with an expectation of getting a dissimilar result
- Acquiring a sense of incompletion made participants feel responsible for and excited about completing it (such as keeping oranges scattered on the floor into a basket, pushing a box on the floor to the box stack)
- Replicating some real-world objects (such as artefacts in the museum) into the virtual environment stimulated participants' curiosity to take further action and anticipate new behaviours and discovery.
- Action in the virtual environments translates to physical emotional response by observers – an elderly man reprimanded us for breaking national heritage treasure after witnessing the breaking of a representation of an 800-year-old vase in our virtual environment.

VII. Discussions

In the study "in-the-wild" presented in this article, we have witnessed via an observation of 200 participants experiencing virtual representations of cultural heritage that first time users can be fully immersed with present VR technology due to high learnability. The positive consequence is that a high level emotional response become possible.

Our participants who experienced our virtual environment said that they were immersed and physically present within the virtual environment. We believe that their positive responses to the virtual environment were as a result of high interactivity, sensory and contextual experience. Our "in-the-wild" study observed that participants were not only able to adopt a more physical involvement within the virtual environment with present devices. The real-time feedback and realistic graphics of the VR experience provided a sense of control, allowing participants to be more focused with their actions and decisions without worrying about the controllers and headsets. This finding demonstrated that in cultural heritage education,

learning-by-making in an immersive VR application can be useful for transforming participants into autonomous learners who will be keen to discover relationships between themselves and their virtual environment and objects they were interacting with. Our observation supports the idea of embodied interaction whereby participants may meaningfully extend prior experience for creating new affordances, re-configuring their mental models of real-world actions, and building new reasoning skills. The capability of mimicking the reality for creating higher degree of familiarity is an important criterion in enhancing the learnability and usability in the virtual environment. As our VR application is natural designed to induce a process whereby perception and intuition will need to be reestablished, participants were positively motivated, they had imaginative and responsive towards it as if they were virtually transported back in time with the feeling of "being there".

This VR exhibition has taught us that by designing the virtual environment around full-body tasks or by allowing users to assume a role without formally assigning them one, affective engagement and emotional response towards the contents of the virtual environment – cultural heritage, can be stimulated. We found that the increase of positive emotional engagement can lead to the enhancement of a sense of presence, such as the intention and action to fix a problem in the virtual environment or the need to reconfirm possibilities with repeated actions. These become a stimulus which can evoke critical thinking in realistic virtual environments.

VIII. CONCLUSION

In conclusion, we think that VR as a popular technology has become quite ready for creating a truly immersive experience of a variety of contents. VR technology is accessible and can be applicable in a wide variety of areas. During the exhibition, , there were parallel VR exhibits on display in other booths. They were quite popular with visitors. However, the focus was the sale of VR hardware (e.g., hi-tech gaming chairs and structures) with downloaded VR demos and games meant for fun. For a China Cultural Fair, the contents were not quite cultural. We believe that cultural heritage contents can attract good attention. We were able to adequately acquire a large sample size for our study because of the appeal of our local cultural heritage contents.

In summary, our 'in-the-wild' observation highlighted three areas –user immersive experience, learnability, affective and emotional response. Through these, we confirmed three findings: real cultural heritage contents in VR is – effective in nurturing immersive experience and automated learning, appropriate for establishing perception and intuition, and is suitable for developing higher levels of emotional engagement.

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REFERENCES

[1] China Electronics Standardization Institute, The White Paper of the Development of Virtual Reality Industry 虚拟现实产业发展白皮书 (Own translation from the Chinese text). Available from: http://www.cesi.cn/201612/1698.html, 2016

[2] E. Ch'ng, "Experiential Archaeology: Is Virtual Time Travel Possible?" Journal of Cultural Heritage, 20(2009), pp. 458–470, 2009

[3] E. Ch'ng, V.L. Gaffney & H. P. Chapman, "Visual Heritage in the Digital Age," in E. Ch'ng, V. L. Gaffney, & H. P. Chapman, Eds., London: Springer Cultural Computing Series.

[4] P. Dourish, "Where the Action is: The Foundation of Embodied Interaction," MIT Press, Cambridge, MA, 2001.

[5] H. Zhang, C. Yu & L.B. Smith, "An Interactive Virtual Reality Platform for Studying Embodied Social Interaction," In: Proceedings of the CogSci06 Symposium Toward Social Mechanisms of Android Science, 2006

[6] M. Hobye & J. Löwgren, "Touching a stranger: Designing for engaging experience in embodied interaction," International Journal of Design, vol.5, no.3, 2011, pp.31-48.

[7] D. El-Zanfaly, "Imitation, Iteration and Improvisation: Embodied interaction in making and learning," Design Studies, vol. 41, pp.79-109. DOI: 10.1016/j.destud.2015.09.002

[8] R. Lindgren, M. Tscholl, S. Wang & E. Johnson,. "Enhancing learning and engagement through embodied interaction within a mixed reality simulation," Computers & Education, vol. 95, 2016, pp. 174-187. DOI: 10.1016/j.compedu.2016.01.001

[9] J.T. Stienstra, "Designing for respectful embodied interactions: towards a phenomenology and ecological psychology-inspired approach to designing for interactive systems," 2016. Eindhoven: Technische Universiteit Eindhoven

[10] J. Wu, "China's VR Industry Has Imploded - 90% Of Companies Go Bankrupt," 2017, Available from http://www.china.org.cn/business/2016-12/28/content_39999412.htm

[11] N. Yang and D. Wang, "Foreign Trade of Zhejiang in Yuan Dynasty元代浙江之海外贸易 (translated from the Chinese text)," Journal of Zhejiang Textile & Fashion Vocational College, vol. 2, pp.71-79. [Online]. Available from: http://www.cnki.com.cn/Article/CJFDTotal-NBFZ200802019.htm

[12] P. Marshall, R. Morris, Y. Rogers, S. Kreitmayer & M. Davies. "Rethinking 'Multi-user': An In-the-Wild Study of How Groups Approach a Walk-Up-and-Use Tabletop Interface," In: Proceedings of the SIGCHI conference on human factors in computing systems, CHI'11, ACM, New York, NY, USA, 2011, pp. 3033-3042. DOI: doi.acm.org/10.1145/1978942.1979392

[13] L. Anthony, K. A. Stofer, A. Luc & J.O. Wobbrock, "Gestures by Children and Adults on Touch Tables and Touch Walls in a Public Science Center," In: Proceedings of the The 15th International Conference on Interaction Design and Children, IDC'16, ACM, New York, NY, USA, 2016, pp. 344-355. DOI: 10.1145/2930674.2930682

[14] U. Hinrichs & S. Carpendale, "Gestures in the wild: studying multi-touch gesture sequences on interactive tabletop exhibits," In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI'11, ACM, New York, NY, USA, 2011, pp. 3023-3032. DOI: 10.1145/1978942.1979391

[15] A. Steed, S. Friston, Y. Pan, M.M.Lopez, D.Swapp, J. Drummond, "An 'In the Wild' Experiment on Presence and Embodiment using Consumer Virtual Reality Equipment," IEEE Transactions on Visualization and Computer Graphics , vol. 22, no. 4, 2016, pp. 1406 – 1414. DOI: 10.1109/TVCG.2016.2518135