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The « Internet of Things » within the « Special Exhibition of the Internet of Things »

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ABSTRACT: Along with the development of the Internet of Things and its related technologies, various industries, especially the service industry, have evolved from being «informatized» to being «intelligentized». This trend has also brought changes to various services offered by museums in Taiwan. Indeed, the Internet of Things, big data, artificial intelligence, and robotics have brought museums the opportunity to develop innovative exhibitions, enhance their educational function, and realize their vision statements. In relation to the Intelligent Museum Project, the National Science and Technology Museum launched the Special Exhibition on Exploring the Internet of Things. In the Exhibition, technology education is integrated with research on information and communications technology, as well as daily life, via an interactive narrative on information and communications technology that grows by leaps and bounds. «Online to Onsite visitor behavior system» was also constructed to capture visitors' behavior in a real-time manner, and to create the Internet of Things within the Special Exhibition of the Internet of Things. The challenges include: determining how to present the «virtual» internet world in the «real» Exhibition, conversion of the content of interactive exhibits, selection of narrative approaches, and construction of a database system.

When the Special Exhibition was launched in the National Science and Technology Museum during 2016-2017, the data were collected via the system constructed in the exhibition hall. An analysis of 14,960 entries of visitors' behavior found that 98.4% of visitors were highly satisfied with the Exhibition; average time on site per visitor was 92 minutes; general performance of visitors' behavior was 22.35 points, which falls into «high-level participation»; there was no «low-level participation». Judging from the comments and feedback provided by visitors, most of them are positive about the Exhibition. As such, it can be said that the educational function of the Special Exhibition on Exploring the Internet of Things has been realized.

KEYWORDS: Internet of Things, Museum exhibition, Interactive narrative.

1 INTRODUCTION

In 1999, Kevin Ashton coined the term "Internet of Things" to describe "a system where the Internet is connected to the physical world via ubiquitous sensors." Since then, the term "Internet of Things" became the most important keyword in the twenty-first century. In 2015, the Taiwan government began implementing new science and technology development policies and initiated a four-year "Smart Museum Project" across the museum community, hoping to promote the world's latest technological applications and developments by utilizing the museums' abundant resources and innovative practices. Therefore, the National Science and Technology Museum (NSTM) engaged in the strategic planning of a special exhibition called "Explore IoT Exhibition", using diverse exhibition methods to translate the concept of Internet of Things (IoT) into physical exhibitions that provide physical experiences for the general public. In addition, an "Online to Onsite Visitor Behavior System" (hereafter as "OOVBS") was set up within the Explore IoT Exhibition to record visitor behaviors in real time. In planning the Explore IoT Exhibition, the most important task was found to be integrating knowledge on IoT technologies and linking it to science education, research on information and communication technology, and activities of daily living. One of the challenges in planning the Explore IoT Exhibition was determining how to liven up a theme by using interactive storytelling methods so that the theme becomes interesting enough to elicit visitor curiosity. Humans generally exhibit a model of behavior in which they are more receptive and understanding of "stories". Thus, using storytelling methods allows for easier communication, which enables visitors to become easily immersed in an exhibition, thereby understanding the story content.

2 THE DEVELOPMENT OF INTERNET OF THINGS

Bill Gates outlined his ambitions of building a smart home in his 1995 book *The Road Ahead,* giving rise to the concept of IoT. In 1999, the co-founder of the Auto-ID Center at the Massachusetts Institute of Technology, Kevin Ashton coined the term IoT. IoT is a global network of infrastructures that connect physical objects and virtual data through data acquisition and communication capabilities to achieve various types of control, detection, identification, and services. Since then, this term has been widely used. IoT represents the technological revolution of logical

calculation and communication. This is also attributable to the invention of computers, which actualized the integration of electronics, semiconductor, information, optoelectronics, communication, and biotechnology industries, thereby constructing the "Internet of Things" that encompass everything in the world. IoT is also considered to be the next wave of digital era.

Based on a computer's Internet, IoT uses radio frequency identification (RFID), infrared sensor, global positioning system, and laser scanners, among other sensing equipment and follows different network protocols to connect any objects and networks for the purpose of exchanging and communicating information to realize smart identification, positioning, tracking, monitoring, and management. In recent years, the development of IoT and related technologies led to the Fourth Industrial Revolution or Industry 4.0 – Smart Technological Revolution, plunging countries around the world into a frenzy as they develop relevant technologies and cultivate visionary and interdisciplinary talents to bolster their nation's competitiveness. This trend also instigated the evolution of museum services from information-based services to smart services.

For this reason, the Taiwan government established the vision of using intelligent technology to create a prosperous society and achieve sustainable growth in its 2015 new science and technology development policy. To realize this vision, the government developed a four-year "Smart Museum Project" (2017–2020), using museums as the site for promoting digital intelligence and innovative mobile applications. By incorporating 5G network, mobile cloud-based services, smart sensing, big data, IoT, augmented reality (AR), virtual reality (VR), and wearable devices, among other cutting-edge information and communication technologies, the project provides innovative user-friendly services from the perspective of museum visitors and users. It also uses diverse applications for imparting general knowledge, enhances people's understanding of and identification with the latest smart technologies, reshapes a new-generation museum, and develops museums into a comprehensive smart learning site integrating cultural, science and technology, and everyday activities. The "Explore IoT Exhibition" investigated in this study was one of the subprojects of the "Smart Museum Project" in 2017. It was aimed at using diverse exhibition techniques to educate visitors on the everyday applications and development of IoT technologies and their impact on the future.

3 EXPLAINING INTERNET OF THINGS WITH PHYSICAL AND VIRTUAL INTEGRATION

Everyone knows that IoT is the "product" of countless technological evolutions and developments. The rise of IoT represents human advancement toward a digital or information age in which smart applications and different disciplines and subjects are embraced. In a manner of speaking, IoT not only signifies the rise of new technologies, but it also tells the history of human civilization. In this context, IoT provides a very good narrative for the Explore IoT Exhibition. In recent years, designing museum spaces with storytelling elements is a popular approach in contemporary museum designs. An exhibition can be a story or a play, unfolding in space with twists and turns, each exuding different atmospheres that follow the structure of a typical narrative: introduction, development, twist, and conclusion [1]. A narrative is focused on enhancing observers' experience and the way they interpret a work. As stories are being incorporated into museum space designs, contemporary museum designs place more emphasis on "how to exhibit" instead of "what to exhibit", taking stories in an exhibit to the next level. In other words, museums are now designed to elicit "understanding of things" rather than "appreciation of objects" [2]. Most people perceive IoT as a means of "responding to needs after analysis and calculation by using mobile devices to connect to everything and transmit data via cloud." The "actions" of IoT are invisible to the naked eye, indicative of a "virtual" process; therefore, we must find ways to use physical exhibition to build a bridge of communication with the virtual world, to display an IoT-themed exhibition, and to tell stories about this technology that are comprehensible to the public. For this reason, an important task in telling a story about IoT is using different storytelling methods. In this study, interactive storytelling was used to deconstruct the storytelling methods used in the Explore IoT Exhibition. Interactive storytelling is a novel method that contemporary museums adopt to display artworks in a way that prompts visitors to engage in an interactive relationship with the exhibit. Such direct and active involvement enables visitors to understand the story the exhibit is trying to tell [3].

3.1 STORY IN THE EXHIBIT

While children can understand the world by listening to stories, people can understand the unknowns through storytelling, using the existing knowledge structure in their brain to piece together all the imagined unknowns [4]. Based on the above discussion, the story context of the Explore IoT Exhibition in technological development was dissected by following the development trajectory: "I"—the self, "IT"—information technology, "ICT"—information and communication technology, to "IOT"—Internet of Things and Industry 1.0–4.0. The core principle of the exhibition was defined as building a future world in which people and people, people and things, and things and things communicate and interconnect with one another to embody the spirit of IoT. Subsequently, two stories were used to discuss the topic, Online and Onsite: The "Internet of Things" within the "Special Exhibition of the Internet of Things".

3.1.1 REDEEMING "PHYSICAL" PRODUCTS WITH "VIRTUAL" COINS

A smart city is constructed using an online to onsite (O2O) exhibition method. The basic architecture of IoT is composed of three layers: perception, network, and application. The stories in the Explore IoT Exhibition were established using this architecture. Specifically, visitors look at exhibits while using an exhibition app (network) —the "online" setting—on a mobile device that is connected to sensing nodes (perception) deployed at the exhibition; they play online games designed for a physical exhibition—the "onsite" setting—to understand what is IoT; they can build up their tour experience by using the exhibition app to earn virtual coins, which can then be used to redeem any commodities (application) of their choice from a vending machine at the exhibition (Figure 1). In this process, visitors purchase "physical" commodities with "virtual" currency, thus experiencing the machine-to-machine or man-to-machine (M2M) IoT application.

3.1.2 TRACKING "ONSITE" VISITOR BEHAVIOR BY "VIRTUAL" AND "PHYSICAL" INTEGRATION

The ultimate goal of IoT is to analyze data collected by sensing components and conduct predictions for precision marketing and decision making. To achieve this exhibition's goal and ensure the accuracy of the Explore IoT Exhibition, the NSTM has set up an OOVBS at the exhibition site to track visitor behaviors. Based on a beacon micro-positioning sensing technology, the OOVBS adopts information technology, mobile device, and human-machine interface app, coupled with the exhibition's onsite interactive units, to record visitors' cognition and understanding of the exhibited content, their needs, and learning patterns. These data are used to establish the visitors' learning process as they tour around the exhibition. Through behavioral analysis, the methods used to tell stories of an exhibit can be organized to determine whether the storytelling methods are appropriate and to analyze them for further improvements. Such analysis also helps the museum to build up its big database on visitor behaviors, which can then be provided to museum operators as reference for various activity and service planning.

3.2 EXHIBITION STRUCTURE AND ARRANGEMENT

In the fifteenth century, oral storytelling was the prototype of museum exhibitions in which stories of exhibits were told orally. At the beginning of the nineteenth century, the narratives and essence of museum exhibits were based on scientific knowledge and theory; the public viewed cabinets of displays as they filed into an exhibition space, following the chronologically ordered arrows. During this period, museum exhibits provided only single narratives. At the beginning of the twentieth century, contemporary museum exhibits were changed to people-oriented, showcasing artworks in a manner most suitable for people, psychologically and physiologically. Various materials, lighting, multimedia systems, and other contemporary science technologies fill the interior of the museum hall as visitors continuously explore the exhibition space [4].

3.2.1 EXHIBITION STRUCTURE

The above discussion shows how the storytelling activities of museum exhibitions have slowly changed from straightforward oral storytelling to communicating with the public through use of media and other techniques. An exhibit's messenger—research personnel or curator—is the one behind the curtain using various techniques to effectively deliver messages to viewers [1]. The structure and arrangement of the Explore IoT Exhibition are described below. Table 1 summarizes the structure of the exhibition.

Table 1. Structure of the Explore IoT Exhibition

Area A: Now is the Future	Schematic of exhibit name		APP
	Launch the Fourth Industrial Revolution		PFID
			Knowledge points (I-coin)
			Empirical value (I-point)
Area B: 0 and 1 Overturn the World	Famous characters in the 20th century	Finger counting	
	A world of 0 and 1	Mechanical algorithm	
	From analog to digital	Era of vacuum tube	
	History of computer development	Transistor	
	The development of integrated circuit	Integrated circuit	
			Nanotechnology
			System on a Chip (SoC)
Area C: Virtual Neighbors	Network connections	Transmission media and information exchange	
	From Cable to Wireless > Infinity	Wireless networks distinguished by distance, such as IR, Bluetooth, Zigbee, WiFi, NFC, RFID, 4G, 5G	
	Wireless		
	Mobile, 3C integration	Application and principle of wireless transmission	
		Revolution of mobile devices	
Area D: Transboundary "Languag	From computers, Internet to IoT		
	The architecture of IoT		
	Core technologies	Perception/network/application layers	
	Cloud computing	Sensor/Actuator	
	Visions and Opportunities	Embedded technology/Microelectromechanical systems (MEMS)	
		SaaS PaaS IaaS	
Area E: Smart City	Application of IoT	Family	Smart grid
	Experiencing Area	Transportation	Smart car
		Health	Wearable technologies, etc.
		Factory Logistics	Industry 4.0
		Consumption and retail	Shopping on mobile device
Area F: Infinite Potential of IoT	The whole exhibition is my IoT		OOVBS
	Human? Machine?		
	Vending Machine		Vending machine
		I-coin	Using "virtual" coins to redeem "physical"
		I-point	commodities

3.2.2 EXHIBITION ARRANGEMENT

Regarding the arrangement of the exhibition, the Explore IoT Exhibition was divided into six areas. Starting with the launching of the Fourth Industrial Revolution, Area A "Now is the Future" showcased a play about robots, educating viewers on the history of technological advances from the use of steam as substitute for manual labor, the start of the electricity era, the rise of automated production following the development of information technology, to the development of smart technologies. Without computers, the works we are doing now would require more than 400 billion people to complete. Next, Area B "0 and 1 Overturn the World" explored the digital to analog process, showing how humans have learnt to communicate with computers and "challenge binary numbers". The world's first general-purpose computer ENIAC was at the time as big as a whole classroom, but thanks to the development of integrated circuit technology, ENIAC's entire circuit can now be installed on a single phone card. The computer artefacts collected by NSTM not only tell the impact of computer technologies on human lifestyle, but also show how they differ from products used today, revealing the trajectory of technological developments.

The integration of computers and networks in the twentieth century highlights humans' glorious achievements in the history of communication. Computers connected to brain power are able to circulate information, enabling knowledge to exert power with exponential leverage. In Area C "Virtual Neighbors", which displayed the development of cable and wireless networks to infinite possibilities, visitors learn how computer users in different areas are able to share network resources so that using the Internet is made as easy as breathing and enables users to know everything without even stepping a foot outside their door. Area C also featured the "Maker Network Cable", an activity for making your own network, so that visitors can understand the technical difficulty of network connections. We believe that "connecting to the Internet connects you to the future". The continuous exploration and innovation of technologies ranging from computers, the Internet to IoT suggest that humans must create communication among people and objects and among objects so as to increase information transparency and provide the correct instant response. In Area D "Transboundary Language", "Understanding the Architecture of IoT" deconstructed the perception layer, network layer, and application layer. If IoT is personified, the perception layer represents the skin and five senses, which are stimulated by external factors, sending out signals that are transmitted through the neural network, which is the task of the network layer. The application layer represents the cerebrum in the central nervous system; specifically, in this layer, the cloud server receives large amount of data, provides a response after big data analysis, and gives instructions to each device accordingly.

When all objects are rendered readable, identifiable, locatable, searchable, and controllable through the network, becoming seamlessly integrated into the virtual world where connections can be made anytime and anywhere, visitors were welcomed into Area E "Smart City", which is the key site for actualizing the applications of IoT. We simulated behavioral changes in everyday activities (e.g., food, clothing, housing, transportation, education, and entertainment) when smart devices penetrated the daily lives of the general public. Visitors were also invited to experience how they should embrace the digital age. Area E is a realization of the life that Bill Gates had envisioned in his book *The Road Ahead*. The development and advancement of every technology are all aimed at improving societies. After experiencing "The Infinite Potential of IoT" in Area F, do you think IoT is as good as scientists claim it to be? Will it be a beautiful new world? Or a prison cell under constant surveillance? Have you ever thought about who you should trust when robots start coexisting with humans? When human intelligence encounters artificial intelligence (AI), the "I" among all things may have its own advantage, it may even replace humans to perform computational tasks, but do not forget that what makes humans unique is their ability to love, and this ability is the most difficult program for scientists to crack at this stage.

4 THE "INTERNET OF THINGS" WITHIN THE SPECIAL EXHIBITION OF INTERNET OF THINGS

To achieve "IoT" within the special exhibition, the OOVBS setup used a beacon technology and program nodes embedded in multimedia interactive software to actively, rather than passively, extract data by following the rules of automation and transform these collected data into useful information. An information feedback system was employed to establish two-way interactions between the museum and visitors, creating a platform for visitors and the museum to engage in dialogue in real time. This system was installed within the interactive units at the exhibition. Subsequently, a micro-positioning and interactive program design using 73 beacons was adopted to incorporate the four indicators of Bitgood's [6] behavior observation scale—degree of involvement, state of operations, degree of reading, and content of discussion—in the interactive exhibit software. Visitors were required to download the exhibition app and enter an ID code to activate the app and use the interactive units. In summary, the OOVBS system was used to collect every visitor's information and behaviors, including basic information, opinions and feedback, and overall behavioral performance.

The exhibits and goals of each interactive unit were compiled and designed according to the plans made for the Explore IoT Exhibition. Subsequently, the methods of interaction and the desired learning performance were examined to classify the indicators of visitor behavior. Each behavioral indicator was given scores of 3, 2, or 1 when the level of a visitor's behavior was high, moderate, or low, respectively (Table 2). These level scoring criteria were also incorporated in the interactive software program design to implement judgment nodes. Participation records for a total of 11 units were collected for the special exhibition. The calculation formula was as follows: 2X3+2X3+6X3+1X3=33. Therefore, the scores for the level of visitor behavior can be a maximum of 33 and minimum of 11, ranging from 1–11 (low level of participation), 11–22 (moderate level of participation), and 22–33 (high level of participation) [7].

Table 2. Goals of interactive units in the Explore IoT Exhibition and level scoring scale of OOVBS

OOVBS Assessment Indicator	Exhibition Goal	Corresponding Interactive Unit	Unit No.	Level Scoring Criteria	Total Score
Reading	To understand computers and the development of Internet, IoT, and relevant technologies.	1. IoT Class 2. Understanding the Perception Layer – Audio Guide app	2	Level 1: None of the questions were answered (heard) correctly Level 2 Half of the questions were answered (heard) correctly Level 3: All the questions were answered (heard) correctly	6
Involvement	To understand the history of computer development and evolution of Internet technologies.	1. Challenge Binary Numbers 2. Make Your Own Smartphone	2	Level 1: 30 sec Level 2: 60 sec Level 3: 90 sec	6
Operation	Smart City is the key site for experiencing IoT applications. The exhibit provided simulation of how smart devices have changed the everyday activities (food, clothing, housing, transportation, education, and entertainment) of the general public.	1. Understanding the Architecture of IoT 2.Maker Network Cable 3. Experience a Smart Car 4. Cycling Health Test 5. Be a Logistic Operator 6. Virtual Shopping with Joy	6	Level 1: Started a unit Level 2: Completed halfway Level 3: Completed the whole unit	18
Discussion	To understand the impact of technological development on IoT and Industry 4.0, change perspective of self, and understand the impact of technology on humans and society.	Share tour experiences and post photos or feedback on social media websites.	1	Level 1: 1 to 2 posts Level 2: 3 to 4 posts Level 3: 5 to 7 posts	3

The OOVBS collected 14,960 sets of data between November 10, 2017 (the exhibition's opening day) and February 28, 2018. Essentially, a set of data is meaningful only after it is analyzed. Therefore, an analysis of the collected data revealed that 98.4% of the visitors were satisfied with the exhibition (57.2% were extremely satisfied and 41.2% were satisfied). The visitors' most favorite interactive unit was "Maker Network Cable" (32.6%), followed by "Experience a Smart Car" (22.5%) which is an interactive unit designed using VR technology, and "Virtual Shopping with Joy" (14.4%). Visitors' overall behavioral performance was assessed using the viewing time and behavior level as recorded by the OOVBS. The visitors spent a total of 92 minutes on average viewing exhibits at the special exhibition and according to the beacon-recorded data, the visitors spent 8.36 minutes on each unit. Visitors' trajectory did not show specific movement line. Visitor behavior level based on a statistic of the 14,960 datasets showed that the lowest score was 15 points and highest score was 29 points, averaging 22.35 points, which indicate high level of participation. None of the visitors showed low level of participation, suggesting that the visitors at the special exhibition were all willing to view the exhibits closely, participate in the interactive units, and understand an exhibit's content, instead of simply playing with a few buttons or toying with the exhibit.

5 CONCLUSION

The Explore IoT Exhibition was a part of the four-year "Smart Museum Project" implemented in accordance with Taiwan's science and technology development policy. It was also a special exhibition celebrating the NSTM's 20th anniversary. Technological development has taken a quantum leap over the past 20 years, as evident by global competitions in the development of nanotechnologies, how the Internet has connected the world, Taiwan's massive involvement in technological research and development, the advent of telecommunication liberalization in Taiwan, and the development of Apple mobile phones. These advances signify the linking of the past with the future. Therefore, while planning this special exhibition, we made use of this opportunity and attempted to construct an innovative exhibition model, in which a database of visitor behavior is integrated into the exhibition. We proposed a physically and virtually integrated smart museum exhibition model that embeds IoT within the special exhibition of IoT. This model was then put into practice and a visitor database for this exhibition was established, documenting and assessing visitors' behaviors and learning models as they tour around the exhibits.

A museum's exhibition and educational activities have inherently been the paradigm of innovation. In future, museums must lean toward smart management, customizing exhibition activities according to different age groups and occupations. Smart management enables museums to accurately pinpoint the preference of their target audiences and organize cultural events suitable for them, so that visitors can not only view exhibits but also participate in the museum's innovative cultural activities. Using big data application facilitates the acquisition of accurate data, including the characteristics of museum visitors, their preference, end goals, and how they like to experience things, thereby helping museums to make decisions in advance, such as how to organize activities, how to plan exhibits to people's liking, how to engage in precision marketing for further research, and how to predict future markets [8]. This is also the ultimate goals of an IoT-dominated world.

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