An Interactive Game Supported by IoT Devices to Improve Visiting Experiences of Cultural Sites

Fabrizio Balducci[1,*,†], Paolo Buono[1,†], Maria Francesca Costabile[1,†], Giuseppe Desolda[1,†], Rosa Lanzilotti[1,†], Nicole Novielli[1,†] and Antonio Piccinno[1,†]

[1]*University of Bari 'A. Moro' - Computer Science department, via E. Orabona 4, Bari (Italy)*

Abstract

This paper presents an IoT-based game for cultural sites, *Magic Torch*, which aims to improve the visitors User eXperiences. It enables tangible interaction with 'smart' artifacts that engage visitors and encourage their attention. In this paper, we focus on the design and development of the IoT devices involved in the games, illustrating the design choices that take into account the overall visiting experience to be offered, considering the technical and methodological aspects arising from the cultural stakeholders like curators and guides. Finally, we report some details on an experimental study we are going to perform to evaluate the impact of the game on the visitor User eXperience.

Keywords

IoT, smart objects, gaming

1. Introduction

Modern cultural sites such as museums, archaeological parks and art exhibitions aim to involve visitors in new and interesting ways, promoting interaction and differentiating themselves from the use of classic and static textual labels [1]. To provide engaging and captivating experiences, cultural sites integrate technologies like IoT (Internet of Things) devices, as already successfully done in domains like home automation [2] and production[3]: the basic idea is the pervasive presence of a variety of smart devices such as radio-frequency tags (RFID), QR codes, sensors, actuators, connections etc., which can interact with each other and with the users to achieve common goals [4]. In Cultural Heritage (CH) domain the IoT paradigm allows the development

EMPATHY: 3rd International Workshop on Empowering People in Dealing with Internet of Things Ecosystems. Workshop co-located with AVI 2022, June 06, 2022, Frascati, Rome, Italy.

*Corresponding author.

†These authors contributed equally.

fabrizio.balducci@uniba.it (F. Balducci); paolo.buono@uniba.it (P. Buono); maria.costabile@uniba.it (M. F. Costabile); giuseppe.desolda@uniba.it (G. Desolda); rosa.lanzilotti@uniba.it (R. Lanzilotti); nicole.novielli@uniba.it (N. Novielli); antonio.piccinno@uniba.it (A. Piccinno)

http://ivu.di.uniba.it/people/balducci.htm (F. Balducci); http://ivu.di.uniba.it/people/buono.htm (P. Buono); http://ivu.di.uniba.it/people/costabile.htm (M. F. Costabile); http://ivu.di.uniba.it/people/desolda.htm (G. Desolda); http://ivu.di.uniba.it/people/lanzilotti.htm (R. Lanzilotti); https://collab.di.uniba.it/nicole (N. Novielli); http://ivu.di.uniba.it/people/piccinno.htm (A. Piccinno)

0000-0003-1174-4323 (F. Balducci); 0000-0002-1421-3686 (P. Buono); 0000-0001-8554-0273 (M. F. Costabile); 0000-0001-9894-2116 (G. Desolda); 0000-0002-2039-8162 (R. Lanzilotti); 0000-0003-1160-2608 (N. Novielli); 0000-0003-1561-7073 (A. Piccinno)

of tangible interaction technologies [5] that can be used to augment cultural artifacts *smart* [6], for example by using RFID technology that accesses metadata or checks individual detected objects without any manual intervention [7]. The interaction with such objects favors emotions and involvement, improving the understanding and the appropriation of contents [8]; tangible thinking, or the ability to think through the physical manipulation of objects enhanced with digital information [9] can also favor *non-linear narration* [10], in which narrative paths can be contextualized through the environment and the user's interaction in physical locations.

Question-based gamification techniques have been used in CH to grab the attention of visitors, for example in the Caracol Museo de Ciencias [11] with challenges focused to solve escape room puzzles albeit lacking tangible components and interactions. The goal of this work is to present an interactive question-answer game called *Magic Torch*, which exploits IoT devices to foster tangible interaction with CH artifacts to engage visitors in a dynamic and challenging treasure hunt.

2. Game Scenario

To describe the Magic Torch game, let us consider the following scenario. Lauren is the is guide of the Natural Sciences Museum located in the University of Bari. She wants to increase the visitors interest by introducing an interactive game. Considering the passion of teens and young adults for adventurers like *Indiana Jones*, *Lara Croft* and *Nathan Drake*, Lauren designs a game as a treasure hunt in order to take advantage of the involvement coming from the presence of ancient utensils, animal bones and fossils.

The treasure hunt requires museum visitors to split into groups of 2/3 that have to reconstruct a secret key needed to open the lock of a Treasure Chest. At the beginning of the game, each group receives a 'Magic Torch' and a deck of smart cards, each capable of indicating to the torch the question printed on it; at the beginning of the experience, the guide presents to the players the educational content relating to the topics on which the questions have been designed. To reconstruct the secret key, the teams must collect some symbols interacting with tangible objects inside the museum and which represent the answer. In this way, the players move in the museum environment and, remembering the concepts expressed by the guide during the visit, for each card in the deck they have to identify the artifacts that answer the questions depicted on the cards (e.g., identify the tooth of the older prehistoric rhino). A confirmation of the answer is given by bringing the magic torch close to the artifact which answers the specific question: if the answer is correct, the torch flame will light up green, a sound will indicate the correct answer, and one of the secret keys symbols will appear in the sequence on the display. If you get a wrong answer, the torch glows red with a different sound to indicate the wrong answer. When a group correctly answers all questions and the secret key is complete, they can move to the IoT chest so that, typing the secret code, it opens providing them a prize.

3. Magic Torch smart device

The Magic Torch (Figure 1) is the main IoT device of the Smart Torch game. It has been designed considering the requirements and observations coming from exploratory studies carried out in the Natural Science Museum of the University of Bari, where the Magic Torch game will be played and evaluated.

Figure 1: The Magic Torch prototype with two smart cards for the gaming question configuration.

Through an iterative design, it was decided to eliminate the 'proximity' requirement since in an environment with showcase areas and narrow paths it would be difficult and technologically expensive triangulate the positions of all the torches also avoiding people moving disorderly when confused by distance signals. The torches, in fact, interact with *smart artifacts* used to answer the gaming questions and such objects could be placed in very close areas creating interferences; moreover, it is unthinkable to ask museum managers moving objects or cases to support the different interactions related to a treasure hunt gaming experience. Removing the proximity search from the design of the IoT device implies that it is not needed to manage the distance from an artifact to activate the feedback but radio-frequency solutions are exploited; in this way, a reader sensor is installed on the Smart Torch, the tangible interactions take place through RFID tags applied on museum artifacts (which turn into 'smart') and printed smart cards provided by the museum guide are used to configure the Smart Torches.

Particular considerations have been made on the data connections: it is useful to limit communication exchanges via Internet or WiFi networks since they may not always be available, they may require special permissions or it could not be adequate power to support all the communications in real time with multiple data streams in addition to those of the museum. In this sense, it has been planned to i) set and configure the visit through a .JSON file, which can be uploaded locally or downloaded from a remote server at the beginning of the visit ii) encode the session in a .json file to save the data locally in the Magic Torch memory and iii) send the data to a remote server only at the visit end.

The Magic Torch prototype is composed by: 1 RFID reader (MFRC522) compatible with MIFARE tags, 1 LCD screen with built-in I2C module, 3 RGB LEDs in parallel and a sound buzzer, all connected to 1 NodeMCU ESP8266 micro-controller. The ESP8266 is smaller than the classic Arduino and very cheap allowing faster IoT applications development while the firmware is preloaded on the SoC module featuring the advantage of being programmable also in the *Lua* language. Considering the various components, it was necessary to have more than 10 connection pins available so the *NodeMCU V2 module* has been chosen, also considering that in the use of an LCD screen this model offers an I2C module requiring only 4 connection pins on a breadboard instead of 16. The prototype diagram is shown in Figure 2.

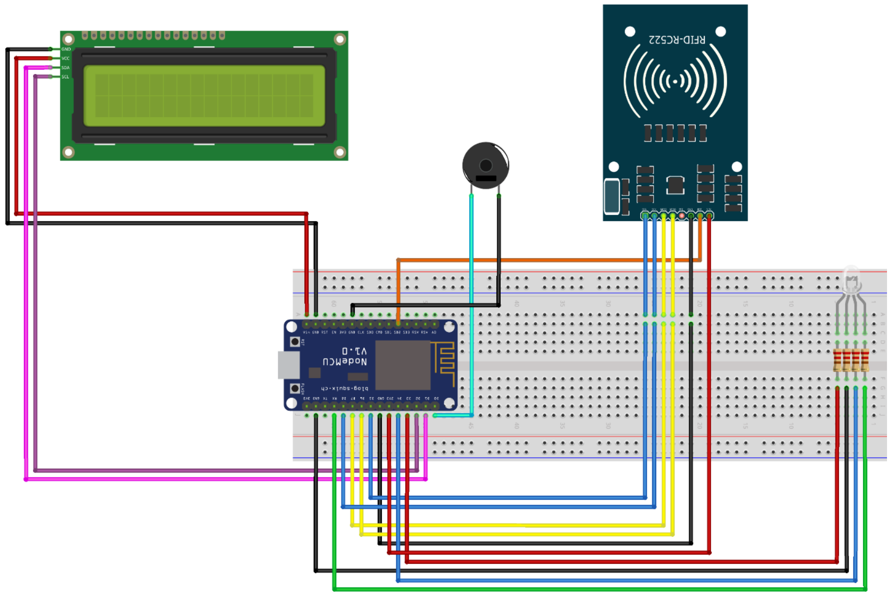

Figure 2: The Magic Torch diagram prototype featuring the five IoT components on a breadboard.

Exploiting the ESP8266 board and the Arduino IDE it has been created a sketch that allows to read an RFID tag and compare it with a .JSON file representing the structure of the game. The JSON file is located at a specific URL; as backup, in absence of an Internet connection, the .JSON file is recovered from the last file saved in the internal memory of the micro-controller. Instead of the MIFARE tag card it is also possible to use any object with an RFID tag such as BLE beacon. The switching on of the LED and the buzzer are used to return audio/visual feedback so that the green LED is used for the correct answer, red LED for a wrong one and blue LED stands for "waiting" and setup status; the LCD screen serves to keep track of the overall experience status.

4. Conclusion and Future Work

A technological test has been already carried out using a Magic Torch in a single room and verifying its interaction with 5 smart cards and 5 objects augmented via RFID tags. For the design of the interactive visit to be held in the Natural Science Museum of the University of Bari, 4 workshops have been performed with the curator and the professional guide of museum. We decided to recruit 30 participants to be that are divided into 3 groups of 10, and each group is scheduled on a different day. Each group is involved in a first tour of the museum, during which the guide shows the museum exhibits. This visit lasts around 20-25 minutes. At the end, the Smart Torch game starts. The visitors are divided into 5 sub-groups of two and each sub-group plays the game one at a time (the order is randomized). The game is played according to the scenario reported above. The sub-group that plays the game opens the box when it retrieves the secret key and wins a reward. All the group members are finally required to fill in the NASA-TLX questionnaire. To evaluate the visitor experience, we decided to measure their emotions, which are an important dimension of UX. To this aim, participants are also required to fill in the Self-Assessment Manikin (SAM) questionnaire after each interaction with a smart artifact filling a block-notes paper positioned near the RFID tag that can be easily ripped off [12]. At the end of the sessions of all the groups, a rank of the groups is made according to the number of correct answers and time they spent to complete the game; the first group wins another reward.

Acknowledgments

This work is partially supported by the Italian Ministry of University and Research (MIUR) under grant PRIN 2017 "EMPATHY: EMpowering People in deAling with internet of THings ecosYstems" and by the REsearch For INnovation (REFIN) grant, CUP:H94I20000410008 cod.F517D521 POR Puglia FESR FSE 2014-2020 "Gestione di oggetti intelligenti per migliorare le esperienze di visita di siti di interesse culturale". The authors thank Antonio Artal for his help in the prototypes implementation.

References

[1] M. T. Marshall, Interacting with heritage: On the use and potential of iot within the cultural heritage sector, in: 2018 Fifth International Conference on Internet of Things: Systems, Management and Security, 2018, pp. 15–22. doi:10.1109/IoTSMS.2018.8554899.

[2] P. Buono, F. Balducci, F. Cassano, A. Piccinno, Energyaware: a non-intrusive load monitoring system to improve the domestic energy consumption awareness, in: Proceedings of the 2nd ACM SIGSOFT International Workshop on Ensemble-Based Software Engineering for Modern Computing Platforms, 2019, pp. 1–8.

[3] F. Balducci, D. Fomarelli, D. Impedovo, A. Longo, G. Pirlo, Smart farms for a sustainable and optimized model of agriculture, in: 2018 AEIT International Annual Conference, IEEE, 2018, pp. 1–6.

[4] L. Atzori, A. Iera, G. Morabito, The internet of things: A survey, Computer Networks 54 (2010) 2787–2805. URL: https://www.sciencedirect.com/science/article/pii/S1389128610001568. doi:https://doi.org/10.1016/j.comnet.2010.05.010.

[5] E. Hornecker, J. Buur, Getting a grip on tangible interaction: A framework on physical space and social interaction, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '06, Association for Computing Machinery, New York, NY, USA, 2006, p. 437–446. URL: https://doi.org/10.1145/1124772.1124838. doi:10.1145/1124772.1124838.

[6] A. Chianese, F. Piccialli, Improving user experience of cultural environment through iot: The beauty or the truth case study, in: E. Damiani, R. J. Howlett, L. C. Jain, L. Gallo,

G. De Pietro (Eds.), Intelligent Interactive Multimedia Systems and Services, Springer International Publishing, Cham, 2015, pp. 11–20.

[7] C. Sun, Application of rfid technology for logistics on internet of things, AASRI Procedia 1 (2012) 106–111. URL: https://www.sciencedirect.com/science/article/pii/S2212671612000200. doi:https://doi.org/10.1016/j.aasri.2012.06.019, aASRI Conference on Computational Intelligence and Bioinformatics.

[8] D. Petrelli, E. Not, A. Damala, D. van Dijk, M. Lechner, mesch – material encounters with digital cultural heritage, in: M. Ioannides, N. Magnenat-Thalmann, E. Fink, R. Žarnić, A.-Y. Yen, E. Quak (Eds.), Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection, Springer International Publishing, Cham, 2014, pp. 536–545.

[9] H. Ishii, B. Ullmer, Tangible bits: Towards seamless interfaces between people, bits and atoms, in: Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems, CHI '97, Association for Computing Machinery, New York, NY, USA, 1997, p. 234–241. URL: https://doi.org/10.1145/258549.258715. doi:10.1145/258549.258715.

[10] M. Casillo, F. Colace, M. De Santo, S. Lemma, M. Lombardi, A. Pietrosanto, An ontological approach to digital storytelling, in: Proceedings of the The 3rd Multidisciplinary International Social Networks Conference on SocialInformatics 2016, Data Science 2016, MISNC, SI, DS 2016, Association for Computing Machinery, New York, NY, USA, 2016. URL: https://doi.org/10.1145/2955129.2955147. doi:10.1145/2955129.2955147.

[11] J. Cordova-Rangel, K. Caro, Designing a serious game to promote visitors' engagement in a science museum exhibition, in: 8th Mexican Conference on Human-Computer Interaction, MexIHC' 21, Association for Computing Machinery, New York, NY, USA, 2021. URL: https://doi.org/10.1145/3492724.3492732. doi:10.1145/3492724.3492732.

[12] D. Girardi, N. Novielli, D. Fucci, F. Lanubile, Recognizing developers' emotions while programming, in: Proceedings of the ACM/IEEE 42nd international conference on software engineering, 2020, pp. 666–677.