The role of Augmented Reality and the Internet of Things in the Management of University Cultural Heritage. A Case Study: The Prat Collection

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***Abstract*—The integration of various technologies in a common goal is carried out in different branches of science. The management of the heritage found in university museums is of vital importance for the culture of students, teaching and the persistence of the historical memory of the institution. The aim of this work is to propose a system that integrates the Internet of Things (IoT) and Augmented Reality (AR) that allows specialists to manage this collection more efficiently with the use of these technologies. To achieve this goal, interviews and data collection on the collection, analysis of the state of the art on the application of these technologies in museums and the possible expected results and the innovative nature of the project have been shown.**

***Index Terms*—Augmented Reality, Internet of Things, Management of Cultural Heritage, University Museum**

I. Introduction

The use of New Information and Communication Technologies (NICT) can be applied in the sciences of cultural heritage. An important space where historical heritage elements are grouped are museums and the use of NICT has been evidenced in recent times, such is the case of the Internet of Things (IoT) and Machine Learning (ML) by Maksimovic et al, [1] in obtaining environmental values in museums, their processing and behavioral analysis. Similarly Augmented Reality (AR) is used to achieve greater visibility in disseminating heritage elements and creating digital experiences for museum visitors as done by Kadri et al [2].

The Universidad de Oriente, the second official university in Cuba and declared a National Monument, holds valuable assets in three university museums with collections. These university museums exhibit diverse patrimonial elements that contribute to the education and formation of new professionals in diverse university careers. One of these important collections is exhibited in the Francisco Prat Puig Cultural Center located in the historical center of the city of Santiago de Cuba.

This collection lacks a technological intervention that favors quality decision making for its preventive conservation and the objective of this research is a proposed IoT system with the integration of AR that allows knowing the environmental values and favors decision making regarding conservation actions and the presentation to the public of the cultural assets of the collection. From a mobile application, the specialist will be able to have different types of alerts depending on the sudden changes in environmental values that may occur and interact with each heritage element to send it to conservation or restoration as deemed appropriate. In this way, the use of new technologies is promoted in university museums and its viability can be evaluated in the future to be applied in all museums that need it.

II. Materials and Methods

For the selection of the collection, research techniques were applied to obtain the information to define the relevance of the different collections and thus allow us to argue the characteristics that distinguish the selected collection as well as its choice for the implementation of the proposal of this research.

- The interview with the Director of the Heritage Department of the Universidad de Oriente made it possible to define that the Francisco Prat Puig Art and Archaeology collection would be the one selected for the research due to its relevance for teaching and research as well as the accessibility of the goods to the visiting public.
- Interviews with the specialists and curators of the collection that allowed to know how they are managed and the actions they carry out for their conversation.
- Preliminary documentary review of the inventories and technical data sheets of the collection that made it possible to know the different types of materials of each heritage element.
- Observation and tour of the different rooms where the elements of the collection are located.
- For the selection of the IoT and AR technologies applied in the research, a bibliographic analysis was carried out in order to know how these technologies are being applied in museums and heritage collections. Section IV presents more details of such technologies and proposed system.

These methods and techniques applied allowed to diagnose the Francisco Prat Puig collection has some particularities, an important detail is that it presents a better accessibility by both domestic and foreign external visitors because it is located outside the University. In addition, among other aspects to be highlighted are the following deficiencies:

- Presents damages caused by the incidence of environmental variables or biological attacks of xylophagous in the patrimonial goods that are in exhibition or in the warehouse. Mainly for those made of materials such as paper, leather, fabric and wood.
- Impossibility of knowing or controlling the state of conservation of heritage elements in real time.
- There is no technology implemented in the collection for specialists or for the visiting public.
- Insufficient environmental control, security and prevention of possible future damage to the collection.
- Contains 9 showcases and 3 pedestals and each of them contains an uncontrolled microclimate.

III. Related Works

The most important microclimatic conditions to be taken into account according to Thomson [3] and are temperature, relative humidity, lighting, noise and vibrations and their values should be found as shown in the following Table I according to the following authors:

TABLE I
RECOMMENDED MICROCLIMATIC VARIABLES

Variables	***Recommended Values***	***Materials***	***Authors***
Temperature Humidity Lighting	$18-25°C$ 40 - 65 % 50 - 250 lux	Glass, Ceramics	Buys et al. Heras et al. y Koob et al. [4]–[6]
Temperature Humidity	$10-25°C$ 30 - 50%	Paper, Fabric, Metal and Stone	Álvaro [7]

All these environmental phenomena can be detected and measured using IoT and there are different works where these measurements are performed using this technology, such is the case of what is proposed by Maksimović et al [1] and Fornari et al [8] to measure temperature and humidity in museums.

Another technology used in museums is Augmented Reality (AR). A bibliographic analysis shows different scientific results where the use of AR is put into practice, Mohammed-Amin, Amakawa et al. [9], [10] explores it as a tool to represent and document the historical heritage and its applications by representing 3D models of buildings, archaeological sites in ruins or contemporary sites partially modified and that are represented with this technology as they were originally. Similarly, Geigel et al. [11] uses it to tell stories to visitors and create narratives to enhance the user experience during their visits.

Both technologies are used separately in museums, IoT is used to obtain environmental values and process them and it is assumed that they are focused on museum specialists mainly, AR for visitors, specifically in the dissemination of information that allows to improve the user experience in their visits. However, if we analyze the relationship of these two technologies with a common goal in the literature we can find authors such as Agrawal et al. [12] applied in the detection of human heart beats and sampling of the information collected with a 3D design for studies in the science of medicine.

In the Cuban context, so far there is only reference to a scientific article published in Cuba by Mengana de la Fe [13] in the Emilio Bacardi Museum in the city of Santiago de Cuba with the use of AR, without integration with other technologies, but the interest in inserting this technology within the Cuban people is demonstrated since there are references of projects focused on education and video games in news or events organized by Cuban institutions. For its part, the use of IoT is evidenced in tourism as analyzed by Franco [14] in the protection of the environment, but no evidence of its application in Cuban museums has been found.

IV. Proposal and Partial Results

The selection of the sensors to obtain the environmental variables demanded a study of the different sensors that exist, taking into account their availability, economic feasibility, the climate where they will be exposed and the materials of the collection. It is proposed to take as a reference the proposal of the author Maksimović et al. [1] where he makes different measurements but in this case other environmental values are added to be measured such as: Pollution, Luminosity, Carbon Dioxide and Saltpeter, mainly due to the variety of materials that the collection has and the location of the collection in the historical center of the city, near the Bay of Santiago de Cuba in consensus with the specialists.

Table II summarizes the environmental variables to be measured with their respective sensors. These sensors were also chosen mainly for their high range of measurements, since they allow different minimum and maximum to be measured, which allow detecting any inconvenience that can be corrected by software without the need for constant calibration in the laboratories and keeping the system in constant operation. It should be noted that no sensor was found to measure the possible attack of xylophages and saltpetre in the environment, so to announce the presence of this type of anomaly the remaining sensors will be analyzed and by correlation of data it will be possible to take it into account as well.

TABLE II
RECOMMENDED MICROCLIMATIC VARIABLES

Variables to Measure	***Sensor***
Temperature and Humidity	*DHT22*
Pollution	*SDS011*
Brightness	*BH1750*
Carbon Dioxide	*MH-Z19C*
Vibrations	*M0168 (OEM)*

In order to obtain some preliminary information to correlate the data and demonstrate the need for the implementation of this research, a first proof of concept was carried out with the sensors that were available at the experimentation time, specifically to obtain the environmental values of temperature and humidity. It should be noted that this a work in progress since it is still necessary to obtain the remaining sensors needed to obtain the other environmental variables proposed.

However, this proof of concept allows the researchers to obtain actionable information that will allow them to improve the system if necessary.

As shown in Figure 1 on the right, the proof of concept was divided into 3 submodules. In submodule 1 is the main microcontroller, in this case a NODEMCU that will have interconnected in turn a DS3231 shield which is a real time clock to store the date and time of each measurement that is performed and stored on an SD card by a reader shield of this type of card, in addition to having an internal backup system of 2 lithium batteries for continuous operation even if there are power failures, plus the locations of the showcases are located away from an electrical switch. However, for extreme energy cases, submodule 2 was added, which is a 20,000 mHA power bank battery that is also connected to submodule 1 and can be recharged simultaneously. Submodule 3 contains 2 sensors to measure temperature and humidity (DHT22). The submodules were installed in a single showcase and separately at the convenience of researchers and museum specialists, submodules 1 and 2 were placed in the lower part of the showcase to protect them from the visibility of visitors and at the same time not to break the artistic atmosphere of the collection, practically invisible to the human eye and only recognizable by specialists who know the location of each node, and submodule 3 would be installed in the upper part of the showcase to collect as much information as possible with greater relevance in the temperature and relative humidity inside the showcase from the highest point, once installed some tests were performed to verify the correct operation of each one as shown in Figure 1 on the left.

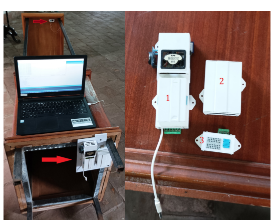

Fig. 1. Proof of Concept Analysis

The experiment is still in execution, and its duration is intended to be for 3 consecutive months in order to obtain a considerable amount of information, but it was decided to obtain a month of preliminary measurements to analyze the behavior of the proof of concept, these first measurements were made to the environmental variables of Temperature and Humidity expressed in °C and %. It is important to note that the maximum and minimum values were plotted for each day of July since the measurement was made every 5 minutes for each type of variable and the variations were very few in those measurement intervals. In the showcase where the proof of concept is carried out, there are heritage elements made of glass and porcelain. For this reason, the preliminary data obtained in the measurement is correlated with the recommended temperature and humidity values proposed by the authors of the Table I and it can be seen that the temperature

TABLE III
VARIABLE MEASUREMENTS

Enviromental Variables	Recommended Value	Averaged Measured Value					
		June		July		August	
		Max	Min	Max	Min	Max	Min
Temperature	18 - 25	34	30	33	29	33	29
Humidity	40 - 65	42	34	41	31	43	30

measurements both in minimum and maximum exceed them and the maximum and minimum humidity are below those recommended by the authors previously studied as shown in Table III. And as the specialists of the collection comment the high temperatures in the glass can cause breakage and deterioration in the heritage elements, and analyzing that the showcase of the proof of concept maintains these values it is likely that the remaining ones have similar values, so the study of these values should be continued. It is important to mention that in the first days of the experiment the display case was located very close to the center of the exhibition room and high humidity values were observed, but after energy failures in the museum it had to be moved closer to an electrical switch to keep the system in operation and therefore was located very close to the wall of the room, this resulted in lower humidity values and higher temperature values mainly because the wall radiates heat from the outside area to the inside of the room at noon.

These first results allow the authors to improve and perfect the proposal of this research. As would be the case of perfecting the nodes of each display case since the proof of concept is mostly a NODEMCU type plate and two main deficiencies were detected in this plate which are:

- A single analog input makes it impossible to connect sensors that require this type of connection, although this can be corrected by adding a multiplexer, but it would be one more component to add to each node and when searching, it was not possible to find the specific type needed at the time.
- The voltage regulator that has the board has a high Dropout voltage, which causes more demand on power consumption with the system operating at minimum conditions and then this enables the battery charge connected to the NODEMCU to be depleted very quickly, this is in turn deficient because it requires that the different nodes work independently of continuous access to electricity as the showcases can be separated from an electrical switch.

Therefore, as soon as the proposed measurement time of the prototype with the NODEMCU board currently being measured is finished, it is intended to print a custom board that will allow correcting the deficiencies found, this electronic board will be as generic as possible and will contain more analog inputs in case they are needed and its regulator will have lower Dropout voltage. As a summary, the proposed system is under development, see Figure 2, contains a Rasbperry Pi model 3 as the main concentrator to process and store the information collected by the different Nodes that are based on the ESP8266 chip of each display case with its energy backup system, in this case lithium batteries. The concentrator has an MQTT server to keep the values constantly updated and they will be sent instantaneously via Internet to the web platform of university heritage that is available in the servers of the Universidad de Oriente and was implemented by the authors Morejón et al. [15] using an API and also multicriteria algorithms can be applied to analyze the data and provide the specialists with different actions to perform depending on the historical environmental variables stored or alarms if necessary, due to any abrupt variation in the measurements. To visualize the information it will be possible to use two available ways, the university platform via web and an AR application developed using the Vuforia SDK due to the features it provides, the greater number of compatible devices it supports and the improvements it has presented in recent years with respect to the competition. Each display case will have a QR code that, when scanned by the application, will allow the specialist to access in real time to the information of the environmental variables for each display case, as well as to obtain alerts on the system if necessary, as shown in the Figures. All the information will be available both remotely and inside the museum, since the information will be replicated on the Universidad de Oriente platform and on the museum's main hub. The tests carried out with the AR application and the proposed final result are shown in Figure 3.

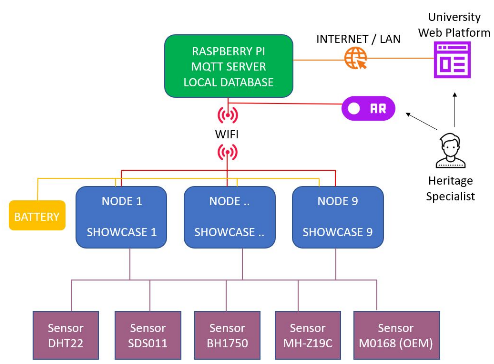

Fig. 2. Proposed Architecture

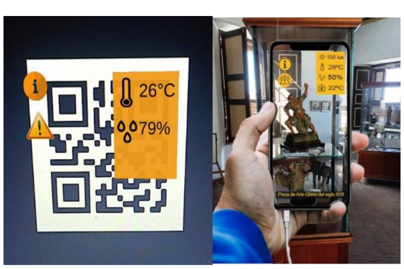

Fig. 3. AR App Testing and Proposal

V. Conclusions

The possibility of using different technologies in a common objective is demonstrated and an IoT system is proposed to the Universidad de Oriente that integrates AR within its layers to help in the conservation of the heritage elements of the university collection, something new to date and that can be implemented in a museum collection and has not been done in the literature consulted. Some preliminary measurements were made that allowed the researchers to analyze adjustments in the proposed system that allow a greater energetic and modular scalable efficiency since it can be applied in other museums with equal or similar conditions and it is an approach of the use of technology in Cuba with the historical-cultural patrimony.

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