The Use of RFID Technology for the Collection Management in the Archaeological Museum of Thessaloniki

Maria Dermenoudi
Archaelogical Museum of Thessaloniki
Thessaloniki, Greece
mariadermenoudi@hotmail.com

Dimitris Karolidis
Archaelogical Museum of Thessaloniki
Thessaloniki, Greece
dkarolidis@culture.gr

Aggeliki Moneda
Archaelogical Museum of Thessaloniki
Thessaloniki, Greece
amoneda@culture.gr

Vasiliki Drakaki
Archaelogical Museum of Thessaloniki
Thessaloniki, Greece
drvasilikh@gmail.com

Antonis Dimitriou
School of ECE, AUTH
Thessaloniki, Greece
antodimi@ece.auth.gr

***Abstract*—This paper presents our preliminary approach for implementing radio frequency identification (RFID) technology in the full artifact collection of the Archaeological Museum of Thessaloniki, one of the biggest museums in Greece that houses more than fifty thousand artifacts. For selecting the most cost-effective RFID tags, we develop a standard procedure for use in museums. This involves the measurement of the read ranges of various tags attached on different substrates and the study of the relationship between tag range and tag price. Our tests indicate that wet inlay tags represent the most cost-effective solution; even for attachment to conductive artifacts with the use of insulating material. Taking into account the experimental results and the need for safeguarding the antiquities in general, we propose various methods of attachment of the tags to the artifacts. Our study contributes to current cultural heritage practices since this is the first time that the development of a standard-practice for using RFID technology in a full museum collection is attempted.**

***Index Terms*—RFID, Museum, Internet of Things**

I. Introduction

This work is part of our project CultureID [1], where we aim to embed RFID technology inside the Archaeological Museum of Thessaloniki, in order to enable new interactions with the exhibits. In this context, we aim to tag more than 50000 antiquities, the museum's personnel-cards and the visitors' tickets. A dense network of RFID readers will allow: *i)* monitoring of the entire collection, including movement of the artifacts for restoration and time-stamped digital storing of all actions related to each artifact, safeguarding cultural heritage [2], *ii)* monitoring of the interests of the visitors, creating statistics on the time-spent on each exhibit in the exhibition area [3], *iii)* interactions and games [5] with our prototype RFID-capable social robot, *iv)* interactions and games with our prototype localization-capable portable RFID reader, *v)* location-aware guided-tours offered in the mobile device of the visitors [4] and *vi)* security-monitoring of the collection [6]. In this paper, we present our preliminary approach on tagging the antiquities, constrained by the proper cultural heritage practices.

This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code:T2EDK-02000).

The use of RFID technologies has been mostly used in the museum sector for enhancing visitors' interaction with exhibits [7] and for improving and facilitating the employed collection management systems (CMS) [8]- [9]. Our work echoes the second approach, by adopting and applying existing RFID technologies for more efficient management of the Archaeological Museum of Thessaloniki (AMTh) collections, both in storage and on display.

The Archaeological Museum of Thessaloniki occupies a distinct place on the Greek cultural map. According to the Hellenic Statistical Authority, the AMTh was the sixth most visited museum in Greece for 2019 with more than 140.000 visitors. Also, the same year, the museum scored the eighth-highest revenue on the Greek national level. The museum collections include more than 50000 artifacts dating from the Prehistoric era to the end of antiquity. They come from excavations all over Macedonia, Greece since 1912, along with handed over antiquities and acquisitions. The ceramics, metalworks, and crafts collection comprises more than 10,000 artifacts, which cover all aspects of ancient Greek life, from daily activities and house equipment, entertainment and adornment, to religion and cult practices, beliefs on the afterlife, and burial customs. The "lithics" collection comprises approximately 4,500 antiquities produced by local workshops and includes statues and votive reliefs from sanctuaries within the city and its adjacent areas [10].

Tagging of the artifacts in a non-destructive manner is identified as a key milestone for the success of the project. The use of RFID technology poses several challenges while high reading reliability is crucial. Tag reading depends on both the features of the tags themselves and the tagged item. This includes size, composition, and volume of materials, and tag placement [11]. Tag reading is affected by multipath, detuning of the antenna in the neighborhood of conductors, shading and absorption. For example, metals couple undesirably with the tag's antenna and insulation separating the tag from the metallic-artifact can improve reading. Decoupling may also occur when many tags are placed very close to one another; under such circumstances, the tag antennas may fail to activate the chip, decreasing the overall performance [11].

The importance of the project ”CultureID” [1] is threefold: a) this is the first time that RFID technology is implemented in an archaeological museum, that is, a museum whose collections exclusively include antiquities, b) this is also the first time that RFID tags are going to be attached to a full museum collection with more than 50000 artifacts, and c) this is the first time that the establishment of a standard (i.e., prototype) technique and method of tag attachment on antiquities is attempted. This is a laborious and arduous task since a) it addresses the several challenges posed by the use of RFID technology, b) it involves the use of different artifact-manufacturing materials (e.g., metal, clay, stone), varying surface morphologies (e.g., shapes, volumes, rough, smooth, flat, etc), varying states of object preservation (e.g., from completely deteriorated to perfectly preserved), and very fragile objects (e.g., restored thin-walled glass vessels). Finally, the attachment approach should follow the internationally adopted guidelines for the restoration and preservation of antiquities according to which “every intervention should be non-intrusive and reversible”.

This paper presents our preliminary approach for implementing RFID technology in the collections of the Archaeological Museum of Thessaloniki and for developing a standard procedure for the use of tags on antiquities. First, we selected various RFID tags as possible candidates. Then, we attached these tags to two different substrates, one metallic and one non-metallic, since metals affect tag readings. Next, we measured the read ranges of the RFID tags on both substrates. Following this, we studied the relationship between tag range and tag price, since the tags are going to be attached to thousands of objects. This leads us to choose two wet inlay tags as the most cost-effective ones. Although not designed for use with metals, the two “winning” tags gave the best results on the metal substrate as well but with the use of insulating material. Finally, taking into account the experimental results and the need for safeguarding the antiquities, we propose various methods of attachment of the tags to antiquities.

II. Tags' Performance when Attached on Different Materials

A. Methodology

Amongst the scopes of this project is the achievement of economies of scale: decreasing the purchase cost per unit while reaching the best possible performance since the tags are going to be attached to more than 50000 objects, and, also, achieving a lower per-tag buying cost when they are purchased in large quantities. We start our endeavor by selecting 24 RFID commercially, readily available, and affordable tags to test for performance. These include 16 wet inlays, 4 ceramic, and 4 plastic ones, as shown in Fig. 1. We strive to read their ranges when they are attached to two different substrates, a metal (copper), shown in Fig. 2, and a non-metal (cardboard) one since metal substrates and accordingly metal objects affect RFID readings. Finally, we compare the readings and we choose the tags with the best cost-effectiveness to attach to the antiquities of the museum collection. For our field testing, we install an MTI Wireless Edge, (MT-242032/NRH) (circular) antenna, and we use the Impinj Speedway Revolution R420 UHF RFID Reader to measure the power backscattered by each tag. We also place markings on the floor in 0,5-meter intervals to acquire and document the readings. The setup is shown in Fig. 3.

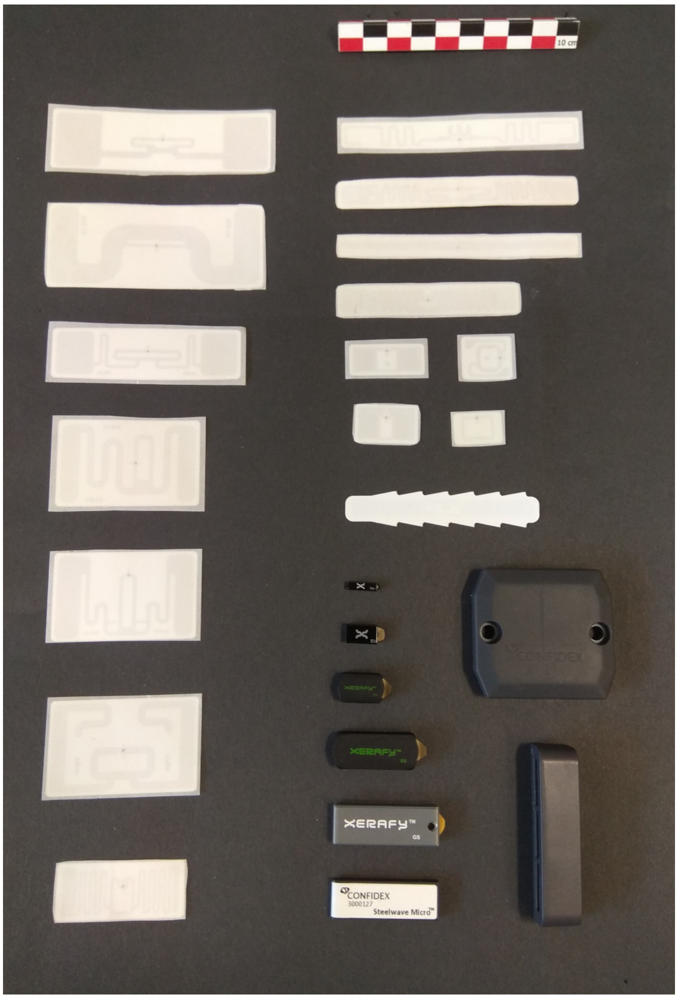

Fig. 1. Commercial passive UHF RFID tags that were measured.

B. Measurements

The results of the readings taken from the 24 tags that were attached on both cardboard and a copper sheet substrate are

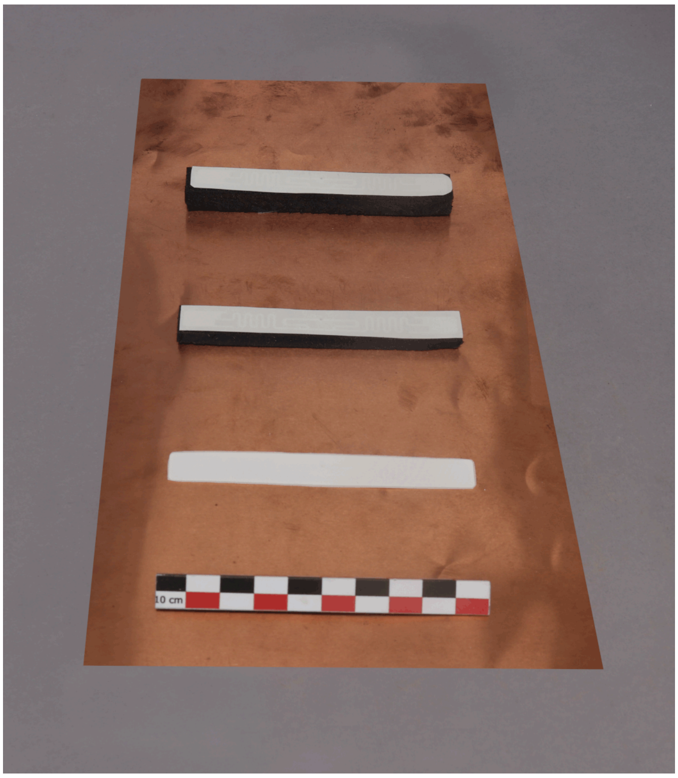

Fig. 2. Low-cost UHF RFID tags with substrate of different thickness on top of copper.

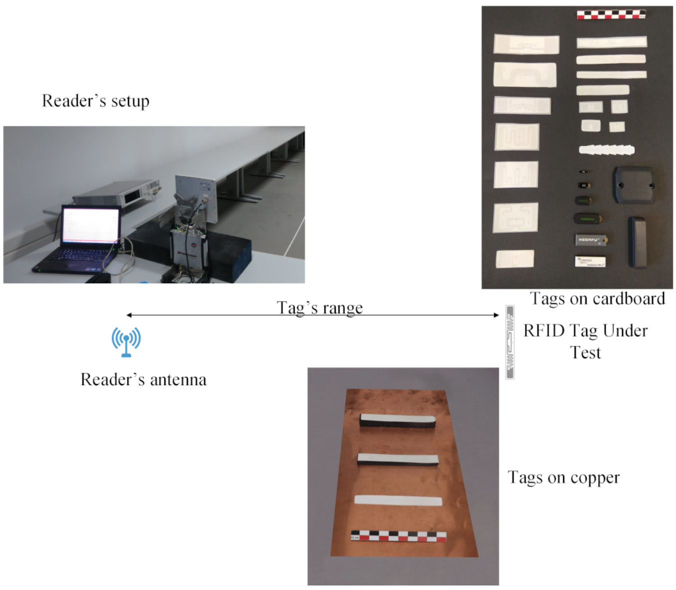

Fig. 3. Commercial passive UHF RFID tags that were measured.

presented in Table I. As expected, all wet inlay tags produced no signal when attached over a copper sheet. The ceramic and plastic tags produce a zero to low range signal when they are attached on cardboard while they perform the best by giving a maximum range when they are attached on the copper plate since they are designed for use with metals. The reading range of all tags is dependent on their size, in proportion to their equivalent effective antenna surface (the bigger, the better).

TABLE I
READ RANGE OF RFID TAGS ON DIFFERENT SUBSTRATES

Tag	**Range on Cardboard (m)**	**Range on Copper (m)**
ALN-9716 'Pearl'	1.6	0
ALN-9715 'Glint'	1.6	0
ALN- 9713 'SIT'	0.1	0
ALN-9770 'Bat'	7.5	0
ALN-9368 'Wonder Dog'	≥8.0	0
ALN-9714 'Bio'	0.7	0
ALN-9720 'HiScan'	4.3	0
ALN-9726 'Spider 360'	6.8	0
ALN-9728-35 'GT-35'	6	0
ALN-9741 'Doc'	6.5	0
ALN-9740 'Squiggle'	≥8.0	0
ALN-9730 'Squigglette'	7.5	0
ALN-9962 'Short'	7.8	0
Xerafy Dash-On XS	0	1.5
Xerafy Pico-iN Plus	0	1.8
Xerafy PicoX II Plus	0.2	1.8
Xerafy NanoX II	0.45	4.8
Xerafy Global Trak I	0.5	3
Confidex Steelwave Micro	0.7	2.3
Confidex 3000392 Pino	6.8	0
Confidex Halo	0.1	5.5
Confidex Ironside	1.0	6.5

The two most cost-effective tags are the white wet inlays ALN 'Squiggle' and ALN 'Short'. Their reading range over cardboard reaches 7,8 meters while they average a 0,10€ per piece when bought in large quantities (> 10.000 pieces). The downside is that they produce no signal at all when attached over a copper sheet. Additionally, the museum collection houses a very large number of metal objects (> 5.000) that need to be tagged. The use of ceramic or plastic tags that work well on metals is not a favorable option since these tags average a cost of 3€ per piece and their implementation would shoot up the overall budget of the project which is against the objective of the CultureID programme. For this reason, we decided to test the two best performing white wet inlays ALN 'Squiggle' and ALN 'Short' (with the Higgs 4 IC) over a copper-sheet with the use of an insulating film to check whether their performance could be improved so that they can be used on ancient metal antiquities, as suggested in [12]. This is shown in Fig. 2. We used sheets of low-density, closed-cell polyethylene foam (Plastazote LD45®) in 8 different thicknesses from 0,1cm to 2cm and at the same size with the tags, as insulators. Plastazote is inert material that has been used in the prevented conservation of antiquities and works of art for the past two decades [13]. The reading ranges of the two white wet inlays are affected positively by the thickness of the insulating film (i.e., the thicker the film the bigger the reading range) up to a certain thickness over which there is no additional beneficial effect. The results for the two tags are shown in Figs. 4 and 5. The maximum range of 7m is limited by the dimensions of the measurements' area. The resulted reading ranges of the two white wet inlays on the copper sheet with the use of an insulator is bigger compared to the ceramic or plastic tags that are designed for use with metals. This finding is suggestive that the wet inlays ALN 'Squiggle' and ALN 'Short' are way more cost-effective compared to the ceramic or plastic tags.

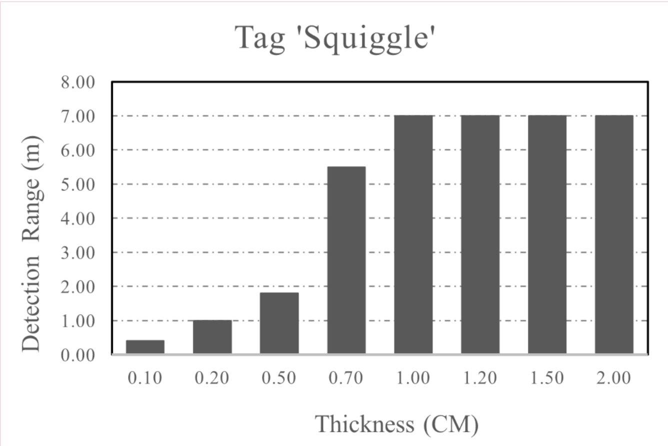

Fig. 4. Low-cost UHF RFID tags with substrate of different thickness on top of copper.

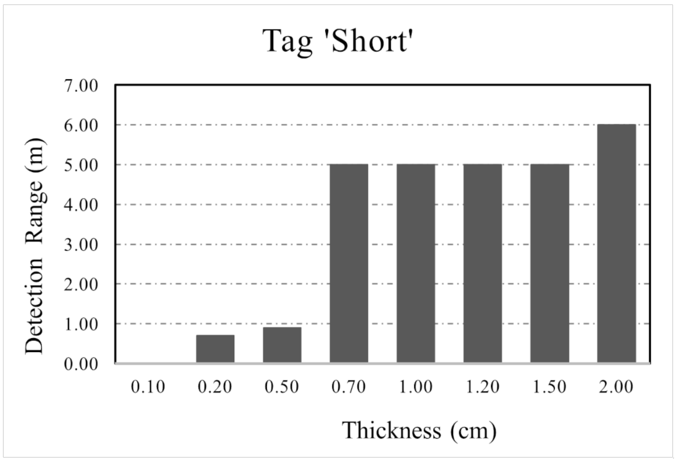

Fig. 5. Low-cost UHF RFID tags with substrate of different thickness on top of copper.

III. Attachment of RFID Tags on the Artifacts

Taking into account the results of the empirical tests along with the internationally adopted policies and practices for the restoration and preservation of antiquities, we suggest the following guidelines for attaching the two most cost-effective ALN 'Squiggle' and ALN 'Short' tags on antiquities.

Fig. 6. RFID tags are hidden in the exhibition.

The guidelines are compiled in relevance to the raw material that was used for the manufacturing of an ancient artefact (metal, nonmetal), their volume, and morphology. Also, these guidelines are written for the objects in museum storage and not the ones on display; for this last category, the tags are going to be placed in such a way that they will not be visible to visitors (Fig. 6). This is a whole new task that is going to commence at a subsequent stage of the CultureID project.

A. Objects with handles (e.g., vases) or with a decorative/ construction element where the tag could be tied or fasten with a knot

The following procedure is proposed and shown in Fig. 7:

- Laminate the RFID tag with a plastic sheet or pouch so that it can become more damage-proof.
- Adhere the RFID tag on a hard substrate of about the same size (e.g., plastic sheet).
- Place the laminated RFID tag inside a transparent self-sealing flat polyethylene bag.
- Tie or fasten the bag on a decorative/ construction element (i.e., handle) with the use of an adjustable plastic cable tie clamp (Fig. 7)

Fig. 7. Tagging objects with handles.

B. *Objects without handles (e.g., flat stone slab inscription) or without a decorative/ construction element where the tag could be tied or fasten with a knot*

The following procedure is proposed:

- On large, voluminous objects without a decorative/ construction element where the tag could be tied or fasten with a knot, build a custom made substrate on the surface of the object with the use of a molding material (e.g., dow, putty) and at about the same size as the tag, as demonstrated in Fig. 8. The molding material is used because it can follow the morphology of the rough surface on the interface with the object, while the upper, exposed side can be shaped flatbed.
- Cover the molding material with a primer (e.g., polymer solution) so that the tag could adhere more easily.
- Laminate the RFID tag with a plastic sheet or pouch so that it can become more damage-proof
- Adhere the RFID tag on the flat custom-made substrate.

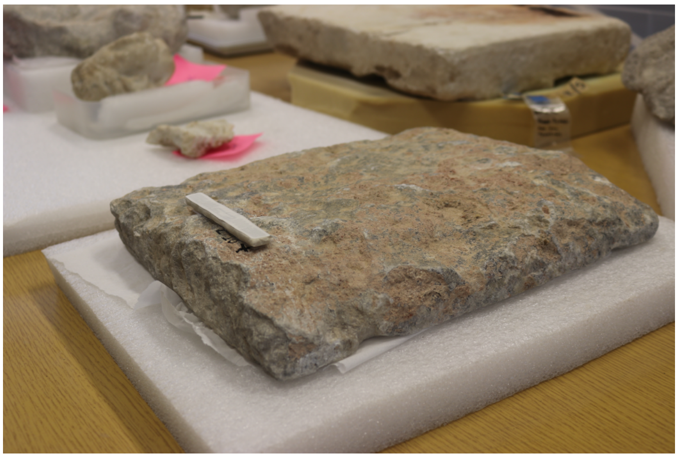

Fig. 8. Tagging objects without handles.

C. *Small-sized objects (<10cm) that can be stored inside self-sealing bags*

The following procedure is proposed, as shown in Fig. 9:

- Laminate the RFID tag with a plastic sheet or pouch so that it can become more damage-proof.
- Place the RFID tag inside the transparent self-sealing flat polyethylene bag that houses the object.

Fig. 9. Tagging small objects.

D. *Metal Objects*

1) Objects with handles or with a decorative/ construction element where the tag could be tied or fasten with a knot: The following procedure is proposed:

- Laminate the RFID tag with a plastic sheet or pouch so that it can become more damage-proof
- Adhere the RFID tag on a piece of a low-density, closed-cell polyethylene foam (Plastazote LD45®) at the same size with the tags
- Place the laminated RFID tag inside a transparent self-sealing flat polyethylene bag
- Tie or fasten the bag on a decorative/ construction element (i.e., handle) with the use of an adjustable plastic cable tie clamp

2) Small-sized objects (<10cm) that can be stored inside self-sealing bags: The following procedure is proposed:

- Laminate the RFID tag with a plastic sheet or pouch so that it can become more damage-proof
- Adhere the RFID tag on a piece of a low-density, closed-cell polyethylene foam (Plastazote LD45®) at the same size with the tags
- Place the RFID tag inside the transparent self-sealing flat polyethylene bag that houses the object.

IV. Conclusions

The current technological approach in the cultural heritage sector embraces the use of RFID technology for collection management that includes digital documentation and archiving, and web applications and networking. The importance

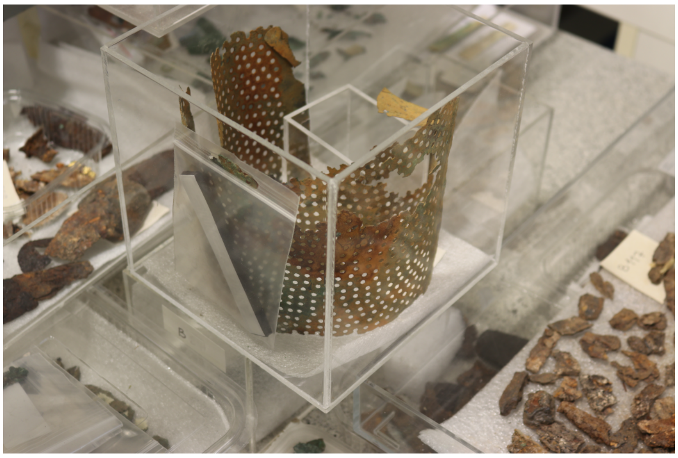

Fig. 10. For metallic objects, the tag is originally attached on top of a polyethylene foam with a width >0.8cm.

of the CultureID programme lies in the fact that it involves the implementation and use of RFID technology for tagging an entire collection within an antiquities museum. This involves the empirical testing of the performance of readily available tags in the market, and the development of a standardized procedure for attaching the tags on antiquities. The last one takes into account the characteristics of the objects themselves (manufacturing technique and morphology) and the internationally adopted guidelines for the protection of cultural heritage. In this project, we also attempted to achieve economies of scale by decreasing the purchase cost per unit while reaching the best possible tag performance since we plan to attach tags to more than 50000 objects. Our work is part of the research stream that submits to the use of RFID technologies as a unique and helpful way to improve the management of collections within museums as well as other heritage and educational settings.

REFERENCES

[1] CultureID. The Internet of Culture. Embedding RFID Technology in the Museum. Accessed Apr. 16, 2021 [Online]. Available: https://cultureid.web.auth.gr/?page_id=216&lang=en.

[2] M. Buzzi, C. Senette, "RFID Sensors and Artifact Tracking," In: Masini N., Soldovieri F. (eds) Sensing the Past. Geotechnologies and the Environment, vol 16. Springer, Cham. https://doi.org/10.1007/978-3-319-50518-3_21

[3] L. Kovavisaruch, V. Sornleardlumvanich, T. Chalernporn, P. Kamolvej and N. Iamrahong, "Evaluating and collecting museum visitor behavior via RFID," 2012 Proceedings of PICMET '12: Technology Management for Emerging Technologies, 2012, pp. 1099-1101.

[4] Y. Huang, S. Wang and F. E. Sandnes, "RFID-Based Guide Gives Museum Visitors More Freedom," in IT Professional, vol. 13, no. 2, pp. 25-29, March-April 2011, doi: 10.1109/MITP.2011.33.

[5] O. Miglino, A. Di Ferdinando, R. Di Fuccio, A. Rega, C. Ricci, "Bridging Digital and Physical Educational Games Using RFID/NFC Technologies," *Journal of e-Learning and Knowledge Society*, vol. 10, no 3, Sep. 30, 2014.

[6] Z. Liu, M. Wang, S. Qi and C. Yang, "Study on the Anti-Theft Technology of Museum Cultural Relics Based on Internet of Things," *IEEE Access*, vol. 7, pp. 111387-111395, 2019, doi: 10.1109/ACCESS.2019.2933236.

[7] S. Hsi and H. Fait, "RFID enhances visitors' museum experience at the Exploratorium," Communications of the ACM, Sept. 2005, doi: https://doi.org/10.1145/1081992.1082021

[8] F. Sahba, "Museum automation with RFID," 2014 World Automation Congress (WAC), 2014, pp. 19-22, doi: 10.1109/WAC.2014.6935643.

[9] L. Ciofi, I. Zappia, R. Balleri, and M. Gherardelli, "RFID applied to the cataloguing of a collection of historical plaster moulds," *Journal of Cultural Heritage*, vol. 21, pp. 910-914, https://doi.org/10.1016/j.culher.2016.05.003.

[10] Archaeological Museum of Thessaloniki. A museum for all, Accessed Apr. 16, 2021 [Online]. Available:https://www.amth.gr/en.

[11] M. Buzzi and G. Marchesini, *Applying UHF RFID Technology to Archaeology*. Accessed Apr. 16, 2021 [Online]. Available:Applying UHF RFID Technology to Archaeology. Available:https://www.academia.edu/4234719/Applying UHF RFID Technology to Archaeology.

[12] C. R. Park and K. H. Eom, "RFID Label Tag Design for Metallic Surface Environments," *Sensors*, vol 11, no 1, pp. 938-948, Jan. 2011, doi: https://doi.org/10.3390/s110100938.

[13] C. Margariti and P. Loukopoulou, "Storage solutions for excavated textiles: tending to their recalcitrant behaviour,"*Journal of the Institute of Conservation*, vol. 39, no 2, pp. 145-157, Aug. 2016, DOI: 10.1080/19455224.2016.1212718.