An intelligent platform for the management of underwater cultural heritage

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Abstract. Conservation of Underwater Cultural Heritage is crucial to preserving society's history. This research proposal aims to study and develop Artificial Intelligence techniques for the management of submerged archaeological complexes, serving as a supporting tool for decision making.

Keywords: Underwater Cultural Heritage, Artificial Intelligence, Underwater Internet of Things, Edge Computing.

1 Introduction

The documentation and conservation of Underwater Cultural Heritage (UCH) are crucial to preserving society's identity and memory, ensuring its accessibility to present and future generations. Conservation methods and processes, from the evaluation and analysis of the state of the heritage to restoration activities, still present multiple challenges, including the complexity of operating underwater, the lack of regulation, policies and resources to cope with the effects of climate change, ineffective protection of cultural heritage (unsustainable tourism) or the elevated costs. To overcome these obstacles, the UNESCO created a treaty, *The Convention on the Protection of Cultural Heritage Underwater 2001*, which establishes basic principles for protection, rules for heritage treatment and a system of international cooperation. So far, only 63 countries have ratified or accepted this document [1].

The conservation of submerged archaeological complexes requires the adoption of innovative and sustainable solutions that aim not only at preserving them in-situ but also at using the available information for decision-making. The use of sensors could be one of the most cost-effective practices for assessing the state of tangible heritage, facilitating the monitoring of environmental changes. The Internet of Things (IoT) refers to the connection of multiple and heterogeneous objects (buildings, machinery, vehicles, etc.) with electronic devices (sensors and actuators) through different communications to collect and provide data. This new technology has grown rapidly, finding applications in multiple sectors such as energy efficiency, health care, industry 4.0, security and public protection logistics and transport, etc.

The concept of IoT adapted to marine environments is known as the Internet of Underwater Things (IoUT) [2-5] and consists of a network of interconnected and intelligent underwater objects, such as sensors, probes or autonomous vehicles. To support the IoUT, the Underwater Wireless Sensor Networks (UWSN) [6-7] are considered a promising network system. Since the technologies of communication and waterproofing of equipment are in a mature phase, it is an appropriate time to investigate in this field.

2 Proposed research plan

This PhD project aims to research on Artificial Intelligence (AI) techniques that support coordination and management of UCH. These algorithms and models, capable of generating knowledge, will be incorporated into a platform based on IoUT technologies and the Edge Computing paradigm. The platform will integrate information stored in databases with data acquired in real time. The different stages of the data are displayed in the figure below (Fig. 1).

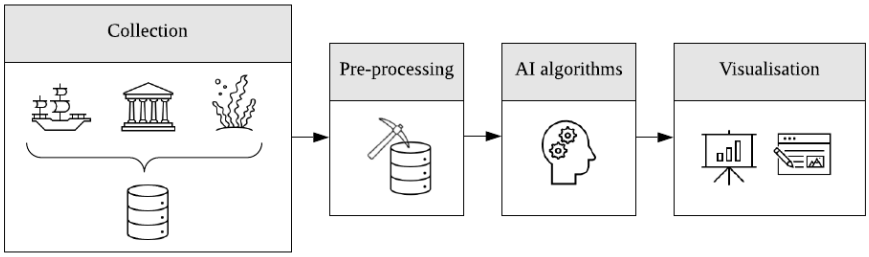

Fig. 1. Proposed data stages for Underwater Cultural Heritage management.

The general objective is divided into the following specific objectives:

- To design a database containing environmental factors and parameters involved in the deterioration of UCH (temperature, pH, salinity, conductivity, marine currents, biological growth, etc.), including existing databases and information measured on-site.
- To study the application of IoUT in cultural heritage conservation.
- To research on AI algorithms, and to develop predictive models capable of quantifying UCH degradation phenomena in a changing environment.
- To develop a platform integrating a Service-Oriented Architecture (SOA) on underwater networks of IoUT sensors.

This research is linked to the project *Technological Consortium TO develop sustainability of underwater cultural heritage (TECTONIC)*, which started in February 2020 [8]. Funded by the European Union's Horizon 2020 programme, its main objective is the implementation, improvement and evaluation of innovative materials, techniques, instruments and methodologies for conservation, restoration and management of UCH.

For the obtention of the PhD degree, the modality initially chosen is "Thesis by Compendium of Articles/Publications", in which the student must submit at least three articles or chapters published or accepted in journals in the field of research chosen. The estimated duration of this research is three years. An Action Plan is being defined to ensure compliance with the objectives on time, and a Quality Plan will be prepared for the monitoring and evaluation of the research.

During the first year, a literature review will be conducted on the following topics: UCH degradation phenomena, AI techniques, IoUT, UWSN, SOA and Multi-Agent Systems (MAS), the Edge Computing paradigm, norms and standards for UCH conservation. Additionally, a database including critical environmental factors in UCH degradation phenomena will be created. Participation in 2-month research exchanges (as part of the secondment plan of the TECTONIC project) are planned for the whole PhD duration. The first year these will be dedicated to the collection of data at the TECTONIC's pilot sites: Italy, Greece and Argentina. During the second year, AI algorithms (classification, clustering and regression, initially) will be studied for predicting the status of the underwater environment. Moreover, the UCH management platform proposed will be designed. The third year will be dedicated to implement and evaluate the platform at the pilot sites.

Several resources will be available for the development of the proposed platform. On the one hand, the existing resources in the BISITE Research Group, which count with an extensive research career in IoT and its applications in different fields [9-14]. On the other hand, the connection of this PhD research with the TECTONIC project will allow access to its resources, the possibility of implementing the proposed platform in the pilot sites, and the access to educational and training activities.

3 The role of CBR in UCH management

The seabed is a giant museum. Underwater Cultural Heritage includes three million shipwrecks, cities and ruins, and thousands of prehistoric sites [15]. Conservation methods and restoration activities are still complex and expensive, making almost impossible to individually analyse the vast number of submerged historical items/sites. In addition, the increasing impacts of climate change continuously threat submerged heritage.

To cope with these challenges, the Case-Based Reasoning (CBR) methodology is proposed as a sustainable approach. When a new UCH case is found, it will be compared with a UCH *case base* of global items/sites previously analysed and restored.

The most similar cases will be *retrieved* from the UCH *case base*, and the conservation approach and restoration treatment will be *reuse* for the new UCH case discovered (after *revision*).

4 Progress to date

This research is at a very early stage. The past few months have been dedicated to reviewing the literature, although several more months will be needed to complete this phase. The first research exchange was programmed for the summer of 2020. However, due to the health crisis caused by the COVID-19, the secondment plan of the TECTONIC project will change, affecting the PhD timing schedule.

So far, dissemination activities include the submission of a paper for the 17th International Conference on Distributed Computing and Artificial Intelligence (DCAI); and the preparation of two Doctoral Consortiums (DCAI and ICCBR).

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References

1. UNESCO: LEGAL INSTRUMENTS, Convention on the Protection of the Underwater Cultural Heritage, last accessed 2020/06/03.
2. Kao, C-C.; Lin, Y-S.; Wu, G-D. and Huang, C-J.: A Comprehensive Study on the Internet of Underwater Things: Applications, Challenges, and Channel Models, Sensors, 17(7), 1477 (2017).
3. Nordrum, A.: A language for the internet of underwater things [News]. IEEE Spectrum, vol. 54, no. 9, pp. 9-10 (2017).
4. Liou, E.; Kao, C.; Chang, C.; Lin, Y. and Huang, C.: Internet of underwater things: Challenges and routing protocols, 2018 IEEE International Conference on Applied System Invention (ICASI), Chiba, pp. 1171-1174 (2018).
5. Xu, G.; Shi, Y.; Sun, X. and Shen, W.: Internet of Things in Marine Environment Monitoring: A Review. Sensors, vol 19, issue 7, 1711 (2019).
6. Jouhari, M.; Ibrahimi, K.; Tembine, H. and Ben-Othman, J.: Underwater Wireless Sensor Networks: A Survey on Enabling Technologies, Localization Protocols, and Internet of Underwater Things. IEEE Access, vol. 7, pp. 96879-96899 (2019).
7. Urunov, K.; Shin, S.; Namgung, J. and Park, S.: High-Level Architectural Design of Management System for the Internet of Underwater Things. 2018 Tenth International Conference on Ubiquitous and Future Networks (ICUFN), Prague, pp. 326-331 (2018).
8. TECTONIC, https://www.tectonicproject.eu/, last accessed 27/04/2020
9. Sittón-Candanedo, I.; Alonso, R.S.; Corchado, J.M.; Rodríguez, S.; Casado-Vara, R.: A review of edge computing reference architectures and a new global edge proposal. Future Generation Computer Systems, vol 99, pp. 278-294 (2019)

10. Sittón-Candanedo, I.; Hernández-Nieves, E.; Rodríguez-González, S.; Santos-Martín, M.T.; González-Briones, A.: Machine learning predictive model for industry 4.0. International Conference on Knowledge Management in Organizations, Springer, pp. 501–510 (2018).
11. Tapia, D. I., Fraile, J. A., Rodríguez, S., Alonso, R. S., & Corchado, J. M.: Integrating hardware agents into an enhanced multi-agent architecture for Ambient Intelligence systems. Information Sciences, 222, 47-65 (2013).
12. De la Prieta, F.; Bajo, J.; Rodríguez, S. and Corchado, J.M.: MAS-based self-adaptive architecture for controlling and monitoring Cloud platforms. Journal of Ambient Intelligence and Humanized Computing, vol 8, no 2, pp. 213-221 (2017).
13. Alonso, R.S.; Tapia, D.I.; Bajo, J.; García, O.; de Paz, J.F.; Corchado, J.M. (2013) Implementing a hardware-embedded reactive agents platform based on a service-oriented architecture over heterogeneous wireless sensor networks. Ad Hoc Networks, 11, 151–166 (2013).
14. González-Briones, A.; De La Prieta, F.; Mohamad, M.; Omatu, S.; Corchado, J.M. Multi-agent systems applications in energy optimization problems: A state-of-the-art review. Energies, 11, 1928 (2018).
15. UNESCO, The World's Underwater Cultural Heritage, http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/underwater-cultural-heritage/, last accessed 2020/06/03.