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Cultural Intelligence-Investigation of Different Systems for Heritage Sustainable Preservation

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ABSTRACT

Cultural heritage protection is a multidisciplinary subject. An intelligent decision-making mechanism, combined with multi-criteria assessment, is required to lead to compatible and sustainable decision making concerning conservation works. Decision making is a complex process that takes into account a wide range of parameters, from qualitative (such as the historical or cultural value of the building) to quantified data (such as the properties of its materials) and involves the following tasks: monitoring, inspection, diagnosis, intervention study, interventions, and evaluation of interventions. It should be based on specific specifications, criteria, and methodology to ensure the sustainability of the construction and require the availability of data of a different nature and of high quality. In this work, different artificial intelligent systems are investigated and tested—UTASTAR methodology based on linear regression, unsupervised non-linear classifiers (feed-forward neural networks), and clustering methodologies (fuzzy c-means algorithm)—in order to develop a decision.

KEYWORDS

Artificial Intelligent Systems, Conservation, Cultural Heritage, Data Mining, Decision Support, Multi-Criteria Analysis

1. INTRODUCTION

1.1. Cultural Heritage Conservation Decision Making

During the past, decisions on conservation interventions regarding cultural heritage were mainly based on prior experience and practices. In many cases the valuable data deriving from scientific diagnosis and decision making were disregarded, resulting this way to irreversible damaging actions for the structure itself as well as for its values. However, in real practice, conservation actions are multidimensional aspects that require the adoption of an integrated scientific methodology that can ensure high and stable quality and performativity of the final proposed solution. The process of decision making is rather complicated, taking into consideration a great variety of parameters, ranging from numerical data such as materials' properties to qualitative parameters like an asset's historical or cultural value(Kioussi, Labropoulos, Karoglou, Moropoulou & Zarnic, 2011).

The recent advances of ICT technology, especially in the area of Artificial Intelligence (AI) and Machine Learning (ML), has enabled the more effective organization and management of existing

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experience and data, allowing thus, the systematic support for decision-making in conservation interventions in monuments and buildings. The critical parameters and criteria should conform to specific quality standards covering the heritage asset's life-time documentation (Kioussi, Labropoulos, Karoglou, Moropoulou & Zarnic, 2011).

Several works have been proposed in the literature towards a scientific-based decision support system, mostly regarding modern buildings and cultural heritage assets as well. The majority of works focuses on building construction, as it is well revealed in the "A review from a Portuguese user's perspective", by Ferreira et al. (2013) and even more often at the energy performance aspect, seeking for energy efficiency solutions and retrofitting. It is obvious that such kind of system reviews and analyzes specific parameters, oriented to the particular needs of the building construction and its individual's energy requirements, often disregarding the particularities of cultural heritage buildings.

In the cases of decision support processes designed for historic buildings and cultural assets, their basic concern is reuse, prioritization or budget allocation: Sanna et al. (Sanna, Atzeni & Spanu, 2008) propose the creation of a rehabilitation projects hierarchy based on ranking by exploring the contribution of fuzzy logic and mathematics to meet the needs of qualitative and quantified criteria. Ascione et al. (Ascione, Cheche, De Masi, Minichiello & Vanoli, 2015) attempt to evaluate the possibility of renovating historic buildings in order to achieve low energy efficiency from an economic point of view, by applying the cost-benefit methodology (EPBD Directive 2010/31/EU) and by adopting the macroeconomic approach to take into account the environmental and economic impacts of energy efficiency. Silva et al. (Silva & Henriques, 2005) investigate the hydrothermal behavior of a historic building without heating in the temperate climate of Lisbon using long-term monitoring and applying risk-based climate analysis following the limitations for historic buildings and targets set by different standards. They thus define a classification to support decision-making. The research team of Yung et al. (Yung, Lai & Philip, 2006) seeks the objective factors that determine decision-making for the maintenance of the structured heritage. A probability regression model is used to evaluate 155 cultural data in Hong Kong, which questions the allegations of other researchers that decision-making on cultural heritage conservation is based on economic criteria only. Finally, the purpose of Stefani et al. (Stefani, Brunetaud, Janvier-Badosa, Beck, Luca & Al-Mukhtar, 2012) work is to provide the scientific community with a system that will assist in the scientific monitoring and control of monuments as well as in decision-making concerning the planning of conservation actions.

The main focus of these works is to exploit certain criteria and parametric values, according to the specific needs each time, in order to achieve a scientific decision upon a conservation treatment on a cultural heritage structure. Integrated conservation that depends on holistic documentation able to assess and combine different types of parameters involved in conservation decision making, does not seem to be the objective of any on the aforementioned cases. Nevertheless, it is obvious that cultural heritage conservation issues regard a wide range of variable critical parameters and therefore all decisions can actually be resolved with multi-criteria analysis.

On the other hand, the last years there is a boom in ML community with the introduction of novel deep structured models which can resemble the way that humans think and process data more effectively than other conventional shallow learning approaches. Humans receive innumerable sensory inputs but they are able to draw meaningful conclusions in a concise manner(Arel, Rose & Karnowski, 2010). The main difficulty in implementing such complex humans' operations on a computer machine is the so called "curse of dimensionality", i.e., the learning complexity exponentially grows with linear increase in the dimensionality of the data. To overcome this "curse", we need to pre-process the data in a manner that would reduce their dimensionality by extracting features that are able to be effectively processed by an engine. However, a human-centric feature extraction process is challenging and usually application-dependent. Moreover, if incomplete or erroneous features are extracted, the classification process is inherently limited in performance. In addition, the mathematical models used for feature extraction mainly capture low-level properties, while high-level concepts that humans often use to perceive visual content, are hardly represented (Yu & Deng, 2011).