An IoT Device for the Predictive Maintenance of Book Heritage of Libraries

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I. INTRODUCTION

The preservation of cultural heritage is a matter of great importance, especially for countries with a rich and valuable cultural heritage, such as Italy. This country not only possesses significant cultural wealth but also bears the responsibility to protect it. Scientific literature has proposed various approaches and techniques for safeguarding movable properties, such as identifying defects in paintings and artworks, reconstructing such works, and protecting historical buildings. An area of growing interest is the protection of literary works, particularly through the use of artificial intelligence (AI) and deep learning techniques, which have enabled the design and implementation of systems for the safeguarding and reconstruction of ancient manuscripts [1] [2].

The degradation of materials that constitute literary works poses a threat, especially if these works are stored in unsuitable conditions that accelerate aging and deterioration. The preservation of library heritage is of interest to prominent actors, such as countries known for their ancient library heritage, as well as individual institutions, such as public, private, school, and university libraries. These institutions aim to maintain books in good condition and intervene preventively and promptly in case of incidents. Moreover, book monitoring is essential to ensure security against theft and fraud.

The advent of the fourth industrial revolution has led to the evolution and development of new paradigms that allow the automation and acceleration of these activities. Central to this revolution are the Internet of Things (IoT) and AI [2]. IoT has introduced new real-time monitoring and predictive maintenance approaches in various application domains, while AI has developed techniques capable of predicting the occurrence of future problems, thus enabling the implementation of preventive maintenance [3] [4].

II. METHODOLOGY

This study proposes an IoT device for the monitoring and preventive maintenance of library heritage within a library. The architecture of the proposed framework, illustrated in Figure 1, comprises a series of IoT devices for monitoring books, with a particular focus on ancient books. These devices are equipped with sensors to monitor various environmental characteristics, such as temperature and humidity, dust, and other necessary measurements. Each device is equipped with a communication module that allows communication with a central data layer, which collects data from the devices associated with each book in the library. The communication occurs through protocols typical of the IoT paradigm, such as MQTT.

The data collected in the data layer can be used for various purposes, and our framework includes the implementation of two main modules:

Analysis Engine: A module that implements approaches and techniques typical of AI models, such as machine learning and deep learning. These models analyze historical and recent data from IoT devices to make predictions that support the decisions of human operators, facilitating predictive and preventive maintenance of the library.

Application Layer: A module that implements services available to human operators of the proposed system, providing functionalities for data visualization, future predictions, and simulations of situations and events.

The collected data can be sent to a visualization module to provide human operators with an overview of the overall state of the monitored books, also allowing them to focus on data collected from a specific device. This information can be displayed through specific dashboards or with a 3D user interface.

The same data can also be sent to the Analysis Engine. This engine can preprocess the data to adapt it and make it usable by algorithms and models for analyzing and predicting possible future events. Preprocessing techniques typically aim to increase data quality in preparation for the operation of AI algorithms

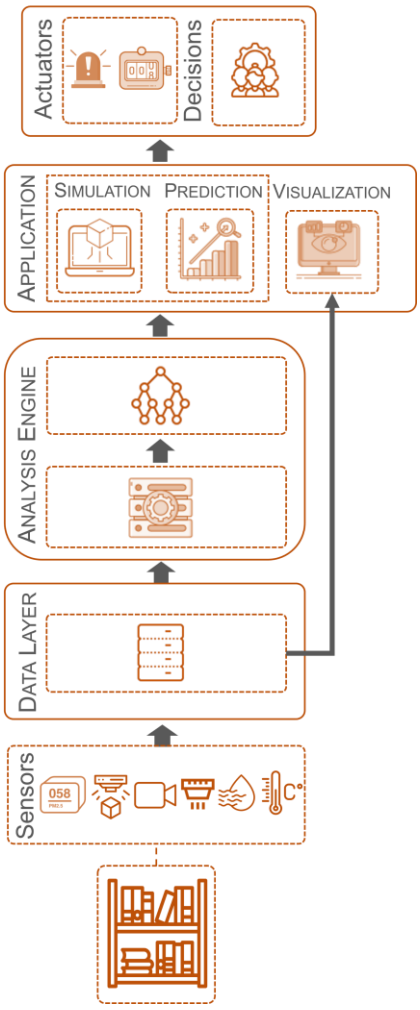

Fig.1 - IoT Library Predictive Maintenance Framework

used for predictive purposes. These techniques often also aim to identify features for feeding the AI algorithms, using traditional or neural network approaches for events and problems that can affect the books and, more generally, the libraries.

System users can leverage the output of the analysis engine using predictive functionalities, which alert users to problems with audible and visual alarms and through detailed reports. Using the analysis engine also allows the launch of simulations indicating how the system might behave in various situations to support user decisions.

III. Conclusions

This study proposes an IoT framework for the safeguarding and protection of library heritage. We have proposed an architecture with various modules, starting from the acquisition of different types of sensors directly from the books placed on the library's shelves. These sensors can be used for monitoring purposes to understand if the books' conditions are good or at risk, or for managing libraries, such as devices for ID scanning or tracking. The data acquired from the sensors are then sent to a database that stores the data from all the books in the library. Subsequently, these data can be processed by an analysis engine to make predictions on the data coming from the libraries. The information inferred by the Analysis Engine can be used to trigger certain actuators and actions and improve the decision-making performance of operators.

In addition to this framework, we also propose the design of an IoT-based device for monitoring books, which aims to acquire data related to a specific book and the actions that must be taken for each book. A prototype of the device has been implemented using a Raspberry Pi 4 and a series of sensors to acquire valuable data related to books. The data are sent to the Thingsboard Platform, which manages the collection, organization, and visualization of the data, creating useful dashboards.

The proposed framework and prototype represent the initial steps in developing a system for monitoring and predictive maintenance of books in a library. The results of the case study's experimental phase indicate that future developments will focus on implementing a compact device for monitoring all the essential features to understand the condition of the books. Other developments will include the integration of a predictive module to support the predictive maintenance of books.

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