An IoT and AI Based Framework for Predictive Analysis in Urban Area: A Case Study

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I. Introduction

Italy is a country with a thousand cultural and natural resources, but it is characterized by numerous problems related to its geomorphological structure. These problems are mainly related to the geological conformation of the territory, the presence of mountain ranges, seismicity, and hydraulic vulnerability. Landslides, floods, and subsidence are among the most common problems affecting several regions. Heavy rainfall, often concentrated in short periods, can cause rapid and destructive floods. Land management and uncontrolled urbanization amplify these risks. One of the most peculiar and lesser-known hydrogeological phenomena is bradyseism, a phenomenon characterized by a slow, cyclical raising or lowering of the ground, often linked to variations in the underlying magmatic pressure. Bradyseism is particularly evident in the Campi Flegrei area. This active volcanic area is subject to periods of ground uplift and subsidence that can last for years or decades. Monitoring bradyseism is essential for the safety of local populations. Understanding bradyseism and its effects is crucial to mitigate the risks associated with this unique natural phenomenon and to protect the communities living in these vulnerable areas.

Considering that the Internet of Things (IoT) has revolutionized our ability to collect data in real-time and then use it to make 'informed' decisions, it makes sense to think about the design and implementation of frameworks based on this operational paradigm to carry out real-time monitoring of structures of public interest in areas affected by the bradyseism phenomenon. Thanks to the adoption of artificial intelligence techniques, moreover, it is possible to implement, starting from the data collected and designing digital twins, an environment capable of giving rise to predictive monitoring processes. Such approaches offer new added-value services both to those who have the task of managing and protecting the public good and to citizens who can be better informed about what is happening in their area. The final objective is to realize a significant contribution to improving the quality of life in those areas that suffer from such complex problems as those introduced above.

In this scenario, the article intends to describe the main phases that characterized the design, implementation, and experimentation of an IoT-based platform for monitoring, including predictive monitoring, of the state of 'health' of public facilities (schools, civil protection premises, municipality) in the city of Quarto Flegreo. This platform, through the definition of digital twins and the positioning of sensors to feed an appropriate structural reference model, can monitor the main parameters of interest and trigger alarms in the event of criticality.

It was therefore intended to create a real Structural Health Monitoring System (SHMS) customized to the needs of the reference context. An SHMS is a set of tools and procedures designed to monitor and assess, even in real-time, the condition of a structure. Such a system includes sensors, data acquisition hardware, BIM, IoT Platform for data analysis and interpretation, and strategies for making decisions based on the acquired data. These systems are fundamental for ensuring safety, identifying structural problems, and planning maintenance activities [1-4].

Its main components are as follows:
- sensors: these are the fundamental elements of a structural monitoring system. They may include accelerometers, inclinometers, deformation sensors, temperature sensors, humidity sensors, and many others. These sensors detect and record various physical parameters that may indicate changes in the condition of the structure and feed into structural reference models.
- Data acquisition hardware: this component collects data from the sensors and transmits it to the data processing system. This may include data acquisition modules, data transmission systems, and other devices.
- data processing software: this is the heart of the structural monitoring system. This module receives data from the data acquisition hardware, processes it, and produces useful results. These results can include graphs, diagrams, tables, and other visualizations that make the data easy to understand. It is also possible to design and implement dashboards to supplement this.
- Data interpretation models: these are algorithms or procedures used to interpret the collected data. These models

can help identify trends, detect anomalies, and predict possible future problems.

- alarm management protocols: these are action plans that are implemented when the structural monitoring system detects a problem. These may include maintenance procedures, evacuation, or other interventions.

The general architecture is schematized in Figure 1

As mentioned above, the experimentation of the implemented platform was conducted at the Quarto Flegreo Municipality and highlighted some of its strengths, among which it is worth mentioning

- Cost reduction: The collection of data and their analysis in real time allowed more efficient use of resources while minimizing waste. In particular, the use of human resources has been optimized by identifying possible problems more precisely and on time.
- Improved security: The continuous surveillance of public sites has helped to improve the security felt by citizens and, at the same time, has enabled emergency situations to be identified and prevented.
- Improvement of public services: The collection and analysis of data enables more accurate planning for the maintenance of public buildings, resulting in cost savings.

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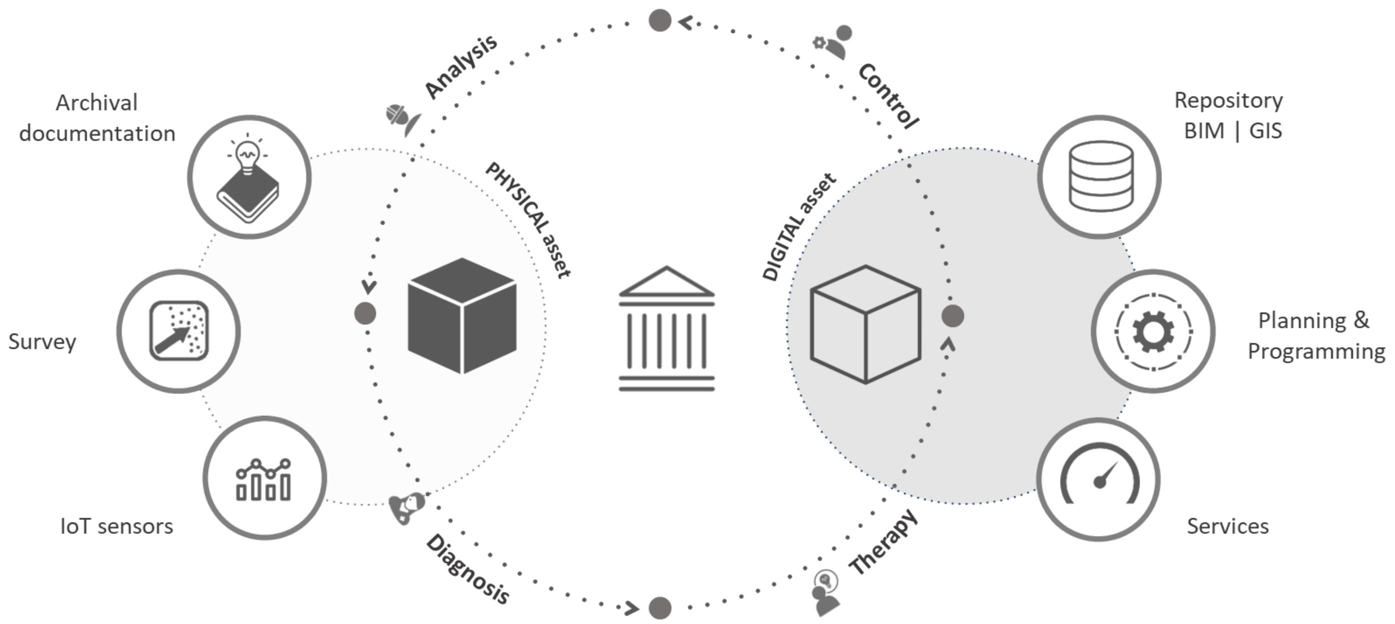

Figure 1 System Architecture