Dam’s predictive maintenance system based on it’s twin-model development

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1 Introduction

Since ancient times, the availability of water has been crucial for the development of settlements. Dams, built mainly of stone or reinforced concrete, are essential for regulating river flows and creating reservoirs. However, their construction and maintenance entail significant risks, such as overflows, seepage and structural problems, which can have serious consequences if not properly managed.

Dams age and require constant maintenance to ensure their operation and avoid catastrophes. The proposed work focuses on developing an innovative and cost-effective predictive maintenance system for gravity dams, monitoring problems such as seepage, movement and deformation to ensure their integrity and safe operation.

2 Methods

Within the field of dam management and conservation, it’s necessary to develop advanced technological solutions. This initiative proposes a novel combination of hardware and software developed with the purpose of monitoring and foreseeing possible failures in dam structures, ensuring their safety and efficiency.

2.1 Hardware

Catastrophes and incidents due to dam failures have underscored the importance of implementing proper safety practices. Systems are in place to measure parameters that affect the stability of a dam, such as seepage, movement and stress-strain.

- Seepage occurs mainly at the foundation and can be detected with piezometers, which are accurate, continuously monitor and specifically.

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- Coordinometers, tiltmeters and 4K cameras, which are accurate, continuously monitor and provide early warnings, are used to measure movement.
- Accelerometers, which measure acceleration forces, are sensitive, non invasive and provide continuous monitoring.

These instruments are strategically installed in the dams to detect and respond to any structural problems, ensuring the safetty and proper functioning of the dams. This work focuses on developing a predictive maintenance system using these technologies for existing gravity dams.

2.2 Software

Develop all the necessary algorithms to apply predictive maintenance techniques to the dam. It will first be necessary to develop an algorithm that obtains the established parameters to be used as an input in AI techniques that will achieve the predictive nature of the system. The algorithms to be developed are initially the following:

- <u>Movement measurement</u>: An algorithm capable of successively comparing the data from the installed sensors and the images collected by the 4K high-resolution camera will be applied.
- <u>Vibrations treatment</u>: The objective is to establish stress-strain relationships using a finite element model (FEM) of the dam and its surroundings.
- <u>Location of leaks</u>: An algorithm will be developed to compare the piezometer's measurements to determine any substantial variations in the pressure values, indicating the approximate location where it was taking place. To locate the crack through which the leakage occurs, data from the vibration analysis will be used to detect the structural problem out of which it results.

As a result of the algorithms a status indicator will be obtained for each parameter which will serve as input data for a Neural Network, thus having 3 input values. As output data, it will offer a prediction of the evolution of the characteristic structural parameters of the dam and the maintenance needed

3 Results

The piezometer is a device used to measure the water pressure in the soil pores, essential for determining the water table and the stability of structures such as dams [1]. This instrument detects the interstitial pressure, which varies according to the depth of the reservoir or drainage channel. There are two main types of piezometers : piezo-resistive piezometers, which provide fast and accurate response to pressure changes, and vibrating-wire piezometers, which provide reliable data but require protection against transient voltages [2].

Interstitial pressure is influened by reservoir level, increasing with higher water levels. Seepage can alter this pressure, weakening the dam and affecting the water supply. Adequate monitoring by piezometers is important to detect seepage and ensure dam stability, especially considering that the interstitial pressure must correlate with the reservoir water level to avoid structural risks.

In the field of dams, the hydraulic structures built in the cross section of the water course with the purpose of permanently or variably raising the water level for its subsequent conduction, as well as the storage of water to supply it in times of scarcity, stand out. The hydrostatic pressure generated by the stored water plays a fundamental role in the stability of the dam, being resisted by the wall of the structure.

The horizontal and angular displacement of a gravity dam, for example, can be accurately measured through the use of pendulum and tiltmeters respectively. The implementation of coordinometers becomes essential to monitor dam movements in detail and take timely corrective measures in case anomalies are detected [3].

In addition, the application of state-of-the-art technologies such as high-resolution cameras with image stabilization and advanced connectivity allow early detection of possible damage to the structure, thus improving the safety and stability of the dams. The entire monitoring process is based on the collection and analysis of accurate data to assess the dam’s behavior and ensure its proper functioning over time.

Dams, as structures exposed to external forces such as water flow and terrain changes, are susceptible to vibrations that can compromise their stability. These vibrations, generated by various causes such as wind, changes in water pressure or seismic movements, can be monitored through the use of accelerometers.

These devices, especially the triaxial ones, allow to evaluate the acceleration in all possible directions, being crucial to guarantee the structural integrity of the dam. In addition, it is essential to consider how the water level of the reservoir influences the dynamic response of the dam, varying its natural frequencies of vibration [4].

During an earthquake, seismic forces can compromise the integrity of the dam, highlighting the importance of continuous monitoring by means of accelerometers resistant to adverse conditions. These devices are key to detecting cracks, the presence of which can be necessary to the stability of the structure.

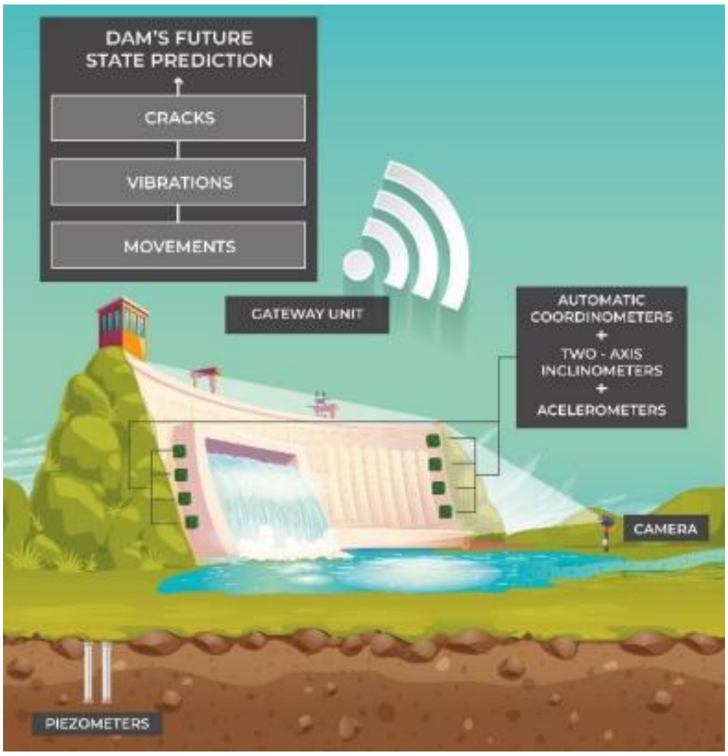

Figure 1: Operation of the proposed solution. Source: Own elaboration.

4 Conclusions

The construction and maintenance of these dams entail significant risks, necessitating advanced technological solutions for predictive maintenance to ensure their safety and efficiency. The proposed system integrates hardware such as piezometers, coordinometers, tiltmeters, 4K cameras, and accelerometers with sophisticated algorithms to monitor parameters affecting dam stability, detect structural problems, and predict maintenance needs. By employing state-of-the-art technologies and continuous monitoring, including during seismic events, the system aims to mitigate risks associated with dam failures, ensuring the integrity and functionality of these critical hydraulic structures.

This state-of-the-art technology integration and constant monitoring not only seeks to prevent catastrophic dam failures, but also to ensure water supply and the protection of downstream communities. Ultimately, this approach promotes the resilience of water infrastructure in the face of changing environmental challenges, thus safeguarding the well-being and safety of the populations that depend on it.

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