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Validation of Machine Learning Models for Structural Dam Behaviour Interpretation and Prediction

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Abstract: The main aim of structural safety control is the multiple assessments of the expected dam behaviour based on models and the measurements and parameters that characterise the dam's response and condition. In recent years, there is an increase in the use of data-based models for the analysis and interpretation of the structural behaviour of dams. Multiple Linear Regression is the conventional, widely used approach in dam engineering, although interesting results have been published based on machine learning algorithms such as artificial neural networks, support vector machines, random forest, and boosted regression trees. However, these models need to be carefully developed and properly assessed before their application in practice. This is even more relevant when an increase in users of machine learning models is expected. For this reason, this paper presents extensive work regarding the verification and validation of data-based models for the analysis and interpretation of observed dam's behaviour. This is presented by means of the development of several machine learning models to interpret horizontal displacements in an arch dam in operation. Several validation techniques are applied, including historical data validation, sensitivity analysis, and predictive validation. The results are discussed and conclusions are drawn regarding the practical application of data-based models.

Keywords: concrete dam; machine learning methods; structural behaviour; sensitivity analysis; model validation

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1. Introduction

Dam safety is a continuous requirement due to the potential risk of environmental, social, and economic disasters. In ICOLD's bulletin number 138 [1] the assurance of the safety of a dam or any other retaining structure is considered to require "a series of concomitant, well-directed, and reasonably organised activities. The activities must: (i) be complementary in a chain of successive actions leading to an assurance of safety, (ii) contain redundancies to a certain extent so as to provide guarantees that go beyond operational risks" [1]. Continuous dam safety control must be done at various levels. It must include an individual assessment (dam body, its foundation, appurtenant works, adjacent slopes, and downstream zones) and, as a whole, in the various areas of dam safety: environmental, structural, and hydraulic/operational [2].

Structural safety can be understood as the dam's capacity to satisfy the structural design requirements, avoiding accidents and incidents during the service life. Structural safety includes all activities, decisions, and interventions necessary to ensure the adequate structural performance of the dam. The activities performed for the structural safety control of large dams are usually aided by simulation models. According to Lombardi [3]: "the difference between the predicted value and the actual reading is indeed the true criteria to judge the behaviour of the dam". Such predictions can be based on deterministic models, such as finite element models or data-based models. Most large dams have an essential