Deflection-based bridge damage characterization harnessing the power of Machine Learning

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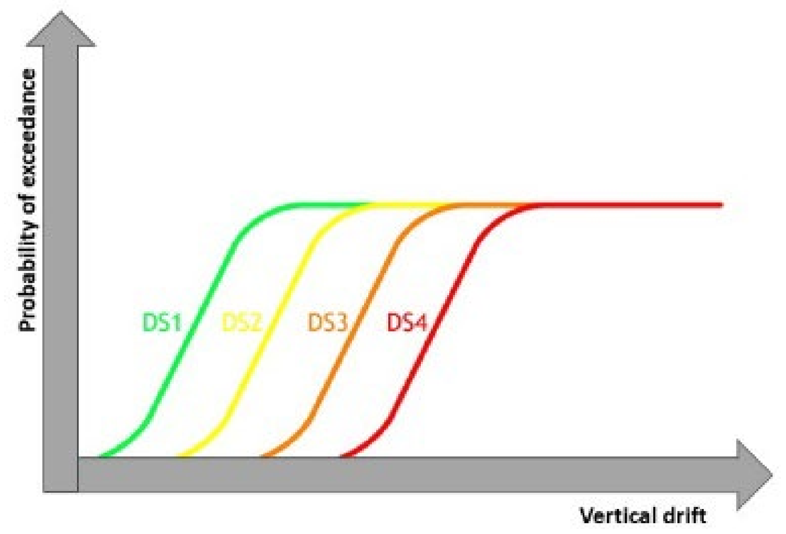
Aims and Objectives

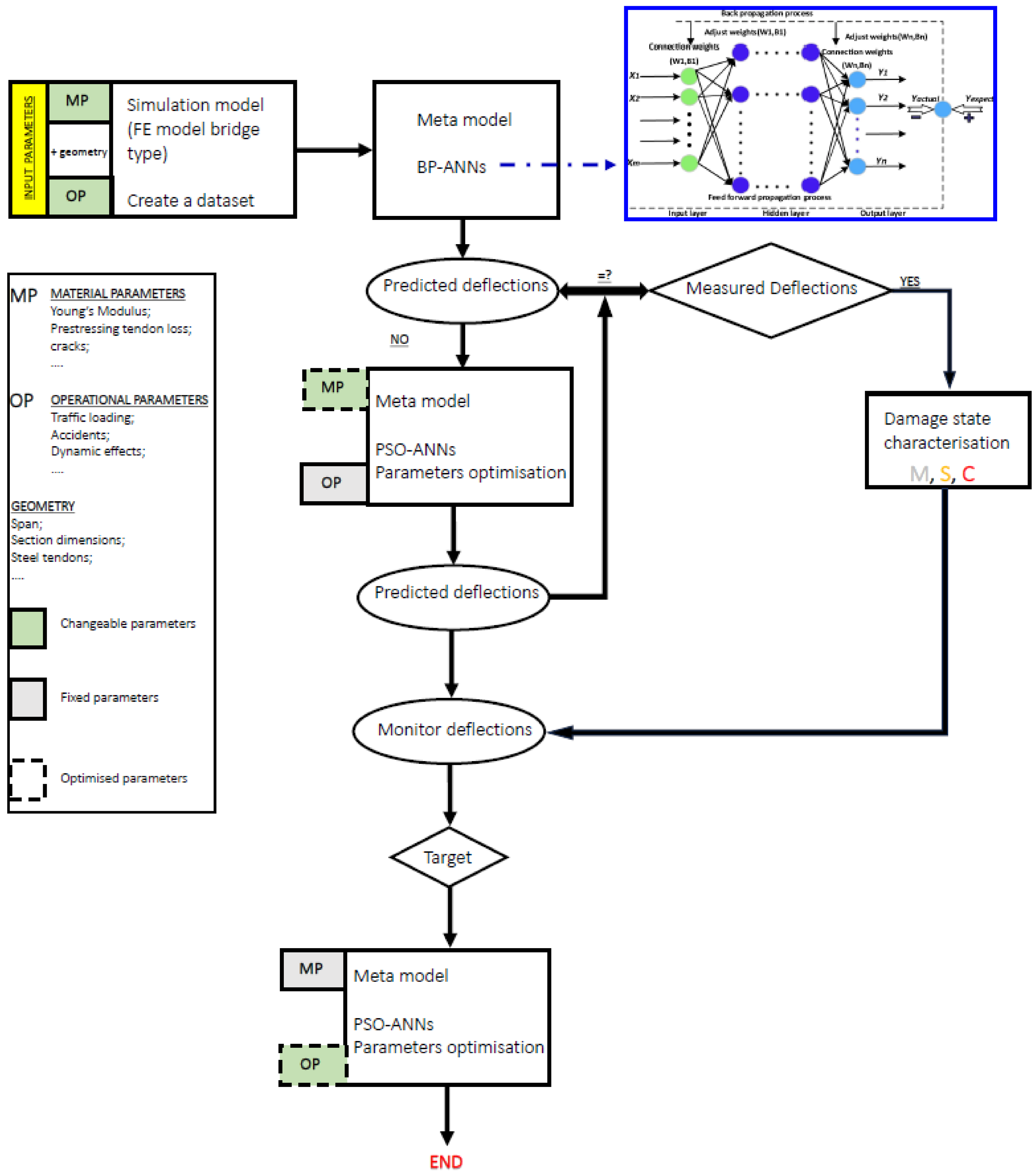
-Develop a novel, streamlined and cost-effective methodology to identify damage states in different types of concrete bridges by exploiting Machine Learning and observed deflections.

- Develop drift-based fragility curves for each bridge type (balanced cantilever, cast-in situ slabs, I-beam, continuous box-girder)



Contextual Background

Bridge deflection is a crucial indicator of potential bridge failure and deterioration, yet there is a lack of guidelines linking deflection to damage states in bridges. This absence hampers the development of effective restoration strategies, as understanding the extent of damage is essential for repairs. The complexity of factors contributing to deflection, such as creep, shrinkage, tendon corrosion, overloading, cracking, and settlements, poses challenges in using deflection to assess damage. Uncertainties in the causes of deflection and limitations in current prediction methods further complicate structural health assessment after years of service. Machine Learning offers a promising solution by analyzing extensive structural data to identify patterns and trends indicating damage levels.

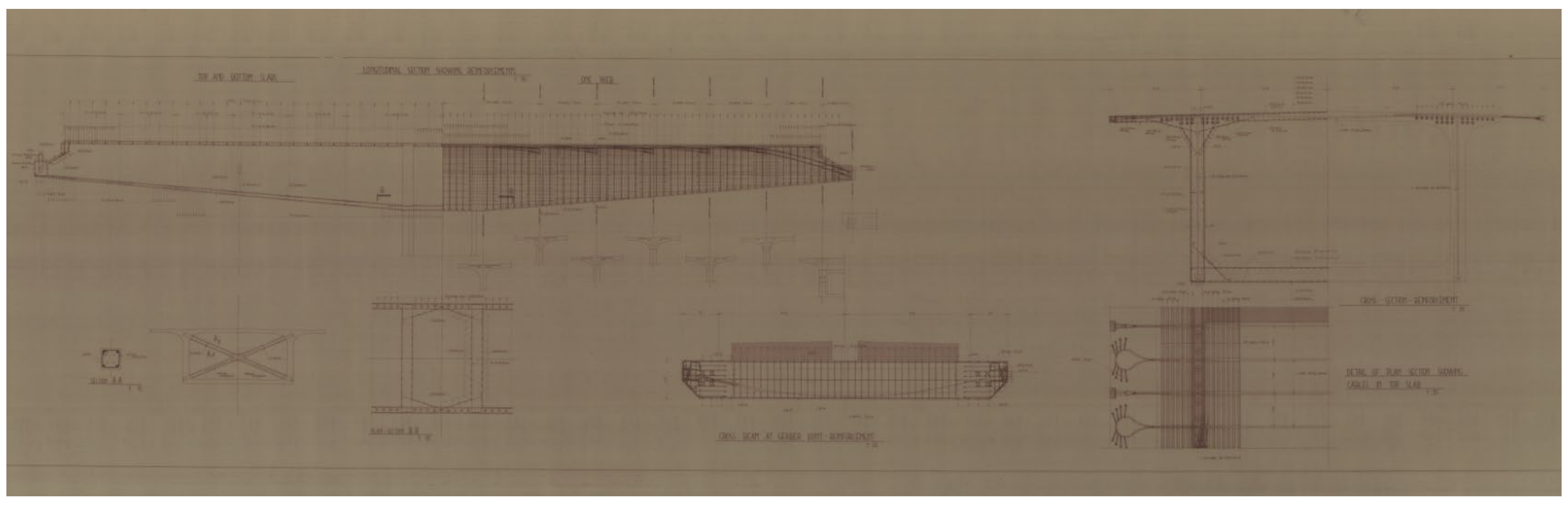


Methods

The flowchart herein presented, shows the proposed methodology for bridge damage characterisation exploiting machine learning and deflections in concrete bridges. A meta model (surrogate model) of a specific bridge type is established. In order to create a meta model of the bridge type, a computational model is generated first which contains information on material parameters, geometry and operational parameters. A priori sensitivity analysis should be conducted to determine the set of important parameters that are sensitive to the objective output of the model, which is deflections in this case. Material parameters, geometry and operational parameters constitute the data set to train the BP-ANN meta model which will predict deflections as an output. The optimal model obtained from the previous step is the new meta model which is able to fully substitute and represent the computationally demanding finite element model. If, in-situ deflection measurements differ from the predicted meta model deflection, it means that the model parameters do not accurately represent the real condition of the bridge and must be updated. An optimisation algorithm, PSO, is therefore used for parameter identification. In particular, in the optimisation process, the operational parameters are kept fixed and the material parameters are calibrated such that they return deflection values that match the in-situ deflection measurements. Having obtained an updated meta model that fully represent the condition of the bridge, damage state levels could be defined based on the material parameters such as tendon prestressing loss, Young's Modulus etc. Furthermore, the updated model is exploited for prediction of the operational parameters, i.e. traffic loading, such that target levels of deflection are not exceeded. The methodology is developed for a specific bridge type but can be extended to other bridges by exploiting transfer learning techniques.

Future work

The landmark Polyfytos Bridge will be adopted in this research as a case study. Built in 1975 in the Municipality of Western Macedonia, Kozani, Greece, the bridge spans a total length of 1371m, thus holding the record for the largest overall length in Greece at the time of its construction. The Polyfytos bridge has a mixed structural system, consisting of simply supported I-beams and cantilevers with variable cross-sections and variable pier sections.



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