CERIS Civil Engineering Research and Innovation for Sustainability

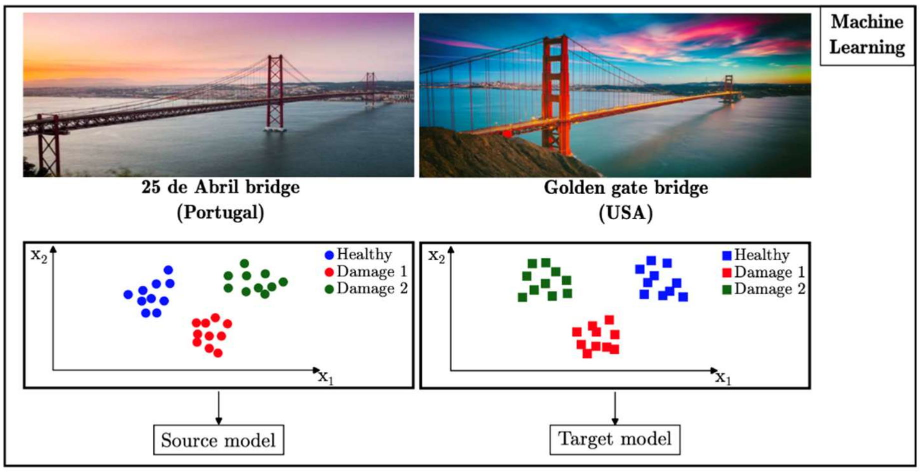
Transfer learning for structural health monitoring

Summary

Structural Health Monitoring (SHM) proposes the continuous assessment of the structural integrity to ensure the safety operation and increase the lifespan of structures from several areas, including civil infrastructures, aeronautical, energy industry, and others. The traditional methodology relies on the application of machine learning methods to investigate the data sets measured using a monitoring system installed in the structures. However, this methodology still have generalization difficulties among structures, even when structures are nominally and topologically similar. The data sets present divergences between their underlying distributions that do not allow the generalization of the model estimated to different situations. In the last years, transfer learning has gained relevance due to extending the SHM concept to investigate different structures, while minimizing costs with monitoring systems and time associated with data acquisition. This methodology can revolutionize how SHM is currently proposed by leveraging knowledge gained from a well-monitored structure to improve the integrity assessment of other structures under unknown conditions. The main idea is to reuse the relevant knowledge from a labelled structure (source domain) to investigate another one (target domain) with limited data. This thesis intends to lay down the foundations of transfer learning for SHM by describing the motivations that led to its application in the analysis of structures, the main questions to decide the necessity for knowledge transfer, the definitions of the main terms that provide the particularities of transfer learning, and the main approaches proposed according to the type of knowledge to be transferred. This work highlights the benefits of using transfer learning in the context of SHM for damage identification. At first, transfer learning is applied to overcome difficulties inherent in the complexity of estimating an accurate finite element model, and unsupervised damage detection of a real bridge is performed using knowledge of its model. Then, transfer learning is combined with a stochastic model for damage detection in an experimental application and its underestimated numerical model, and the quantification of damage levels in the structure is carried out based on a requirement imposed by the transfer learning methodology. Finally, a comprehensive analysis using transfer learning is proposed to investigate the structural conditions of three different real bridges subjected to environmental and operational conditions, and the importance of the quality of knowledge transferred across different bridges for damage detection is highlighted. The transfer learning methodology indicated satisfactory results in all investigated cases and demonstrates the attractive benefits of its application, which can result in significant progress in the damage identification process considering different structures.

Keywords

Transfer learning, domain adaptation, transfer component analysis, joint distribution adaptation, max independence domain adaptation, structural health monitoring, damage identification.



Comparison between traditional machine learning and transfer learning methodologies in the SHM context.

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