Machine-aided Bridge Vulnerability and Condition Management

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Bridge safety has been a longstanding priority for civil engineers. Engineers and researchers devote significant effort toward establishing the ability to detect and monitor damage and to manage the performance of our bridges over their lifecycle. However, current practices, heavily reliant on manual involvement, still present challenges in efficiency and effectiveness. For instance, rapid bridge vulnerability assessment methods are being developed, but these methods normally require information about the bridge, e.g., substructure type, which is not readily available in most current bridge databases (e.g., National Bridge Inventory). Manually collecting the necessary information for each bridge is time-consuming and would influence the use of those rapid bridge vulnerability assessment methods. Similarly, routine bridge inspection, mandated every two years in the United States, requires organizing inspection photos, evaluating bridge condition, etc., which are also time-consuming tasks. A two-year inspection cycle may be overly cautious, especially in the early stages of its life when there is typically little degradation. Furthermore, when conducting an inspection there is no reference for when to use advanced inspection techniques, so visual inspection, the simplest method, is adopted for most bridges. Given these challenges in bridge asset management, the integration of machine learning to use the data from historical records of bridge performance can aid in and serve to expedite the above tasks.

The objective of this research is to develop machine learning-based methods that can assist humans in completing certain tasks associated with bridge asset management. Towards this objective, the following research tasks are carried out. In Task 1, a CNN-based bridge substructure identifier is developed to automatically recognize the bridge substructure type from an inspection image. A method is developed to set a rational budget for this work based on risk tolerance. In Task 2, the automated bridge inspection image organization tool (ABIRT) is developed to automate the process of organizing inspection images and generating an inspection report. In Task 3, a technique for machine-assisted bridge damage analysis using visual data is developed and validated. Additionally, a decision-making method is established to assist bridge inspectors in adopting this technique, with a focus on managing costs and minimizing risks. And in Task 4, reinforcement learning-based approach is developed to manage the bridge inspection process. Through this research, several key machine learning techniques are explored to assist bridge managers with the more tedious steps involved in the seismic vulnerability analysis and condition management tasks, allowing the engineer to dedicate more time to making decisions. This highly cross-disciplinary research is scalable and expandable to many other applications and will serve to improve the future safety and reliability of our infrastructure.