PHYSICS MEETS DATA: MACHINE LEARNING FRAMEWORKS FOR STRUCTURAL ENGINEERING

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Structural engineering increasingly requires models that are both data-driven and physically consistent, especially when real-world measurements are sparse, noisy, and heterogeneous. This thesis develops physics-informed machine learning (PIML) frameworks that combine physical knowledge with observations to address three key challenges. First, it enables the identification of unknown loads in tunnel linings from limited displacement measurements. Second, it supports real-time prediction of tunneling-induced ground settlement by integrating simulations with monitoring data. Third, it improves concrete damage classification in structural health monitoring by transferring knowledge from synthetic data to real experiments. Across these applications, the proposed approaches enhance accuracy, efficiency, and robustness, demonstrating the potential of PIML for more reliable structural analysis, monitoring, and maintenance.
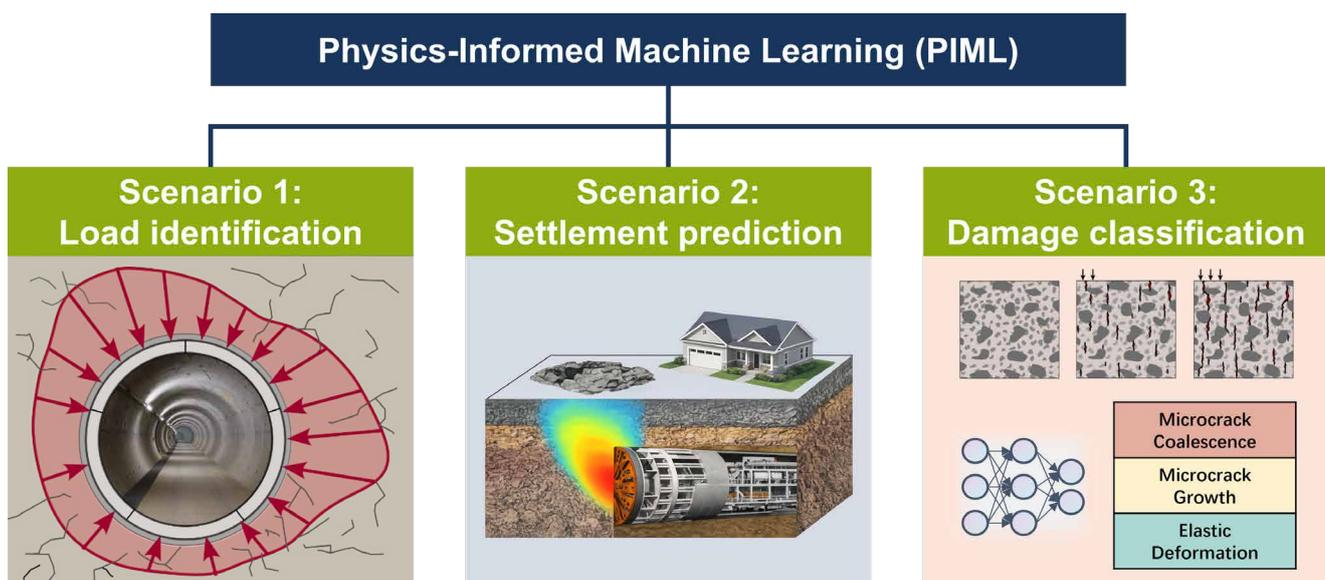
Figure: Overview of the three application scenarios of the thesis.