

**Predictive digital twins of civil engineering structures
and adaptive planning to account for rare events**

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ABSTRACT

A digital twin is a virtualization of a physical asset built upon a set of computational models that dynamically update to persistently mirror a unique asset of interest throughout its operational lifespan, enabling informed decisions that realize value.

The talk covers the health monitoring, predictive maintenance, and management planning of civil structures [1], with a focus on railway bridges. The asset-twin coupled dynamical system is encoded using a probabilistic graphical model which provides a general framework for data assimilation, state estimation, prediction, planning, and learning while accounting for the associated uncertainty. The time-repeating observations-to-decisions flow is modeled using a dynamic Bayesian network. Real-time structural health diagnostics are provided by assimilating sensed data with deep learning models.

The framework is then extended to increase the robustness to rare events of digital twins modeled with graphical models. We incorporate probabilistic model-checking and linear programming into the Bayesian network to enable the construction of risk-averse digital twins [2]. The key idea is to model with a random variable the probability of the asset to transition from one state to another, thus defining a parametric Markov decision process. We refine the optimal policy at every time step resulting in a better trade off between operational costs and performances.

We showcase the capabilities of the proposed framework with a structural digital twin of a railway bridge and an unmanned aerial vehicle and its adaptive mission replanning.

REFERENCES

- [1] M. Torzoni, M. Tezzele, S. Mariani, A. Manzoni, and K. Willcox. A digital twin framework for civil engineering structures. *Computer Methods in Applied Mechanics and Engineering*, vol. 418, p. 116584, 2024. doi: 10.1016/j.cma.2023.116584
- [2] M. Tezzele, S. Carr, U. Topcu, and K. Willcox. Adaptive planning for risk-aware predictive digital twins. In *Physics-based and Data-driven Modeling for Digital Twins*, Eds. K. Cherifi and I.V. Gosea, SEMA SIMAI Springer Series, 2024. arXiv:2407.20490