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A conceptual framework for developing digital twins of human-environmental systems

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Abstract: Human-environmental systems (HES) are incredibly intricate and interlinked structures. They are influenced by a wide range of variables that can affect each other in countless ways, which makes them challenging to study, comprehend, and forecast. This research presents a ground-breaking approach to developing digital twins for HES using artificial intelligence. A digital twin is a virtual replica of a physical entity or system, which can be manipulated and tested in various ways to better understand and predict the behaviour of its real-world counterpart. This innovative digital framework untangles complicated correlations, enhances predictive capabilities, and aids in making decisions that are environmentally sustainable.

The proposed framework goes beyond traditional system models by creating a digital duplicate of the HES that accurately reflects the dynamic behaviour of the system in the real world. The key innovation lies in the use of machine learning algorithms and causal inference methods. These are integrated to allow for detailed simulations, accurate predictions, and the provision of decision support.

In the first stage of the framework, data is collected from a variety of sources, including satellite imagery, environmental sensors, and socio-economic indicators. This step is followed by data pre-processing and quality control to ensure the data is appropriate for building accurate digital twins. The second stage involves the actual construction of the digital twin. Machine learning algorithms, such as deep learning and reinforcement learning, are used to train the model. These algorithms learn from the collected data, grasping the complex interconnections between various factors, and can forecast future states of the HES under various scenarios. The third stage is the innovative application of causal inference, which we argue is essential in HES due to the complex interlinkages between many variables. Causal inference refers to determining what effects come from specific causes. We use methods like instrumental variable techniques, counterfactual analysis, and propensity score matching to uncover causal relationships. These can then be utilized to anticipate the impacts of interventions or policy changes. The framework also has a feedback loop for continuous model refinement. As more real-world data becomes available, the model can be updated, increasing the accuracy of its predictions over time.

The suggested framework can serve as an effective tool for participatory planning and collective decision-making. Stakeholders can interact with the digital twin, comprehend the potential outcomes of different decisions, and thus participate in more informed, democratic, and sustainable decision-making processes. Our research contribution is threefold. Firstly, we advance the current state of knowledge by integrating machine learning and causal inference in the development of digital twins for HES. Secondly, we provide a new application of these digital twins as decision-support tools and as facilitators of participatory planning. Lastly, our framework is versatile and can be adapted to a range of HES, including urban systems, agricultural systems, and natural ecosystems. As we continue to refine this framework, we aim to usher in a new era of sustainable planning and decision-making, informed by a comprehensive understanding of the complex dynamics of human-environmental systems.

REFERENCES

Zheng, Y., Yang, S., & Cheng, H. (2019). An application framework of digital twin and its case study. *Journal of Ambient Intelligence and Humanized Computing*, *10*, 1141-1153.

Onaji, I., Tiwari, D., Soulatiantork, P., Song, B., & Tiwari, A. (2022). Digital twin in manufacturing: conceptual framework and case studies. *International journal of computer integrated manufacturing*, *35*(8), 831-858.

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