Digital Twins of Ecosystems

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Digital twins of natural environments have an enormous and largely unexplored potential [1, 2], due to their ability to explore alternatives in predictive ("what-may-happen") and prescriptive ("what-if") analyses. Bringing a natural system into a "virtual laboratory" enables us to perform experiments on the twin that would be impossible to perform on the real system: Digital twins could be used to explore the impact of temperature increase on fragile ecosystems. More generally, digital twins may be used to study the effects of climate-associated changes on fragile ecosystems or of interventions on pandemics [8], but also for digitalization and advanced automation in farming [10].

A digital twin turns a model of a natural system into a live replica by directly connecting the model to observations of the natural system in near real-time. Whereas digital twins play a major role in the on-going digital transformation in industry (e.g., [9]), they are criticized for being brittle, inflexible, monolithic, and difficult to both maintain and scale [6]. Our research targets flexible, modular and open-source digital twin solutions that couple heterogeneous models with streams of real-world observations, together with advanced analysis support: We develop digital twin architectures (e.g., [5]) that leverage domain knowledge, formalized using semantic technologies [4], with simulators and sensor data to explore hypothetical what-if scenarios. Currently, we also work on digital twins for resource management in, e.g., logistics [7] and cloud computing [3].

Currently, we develop digital twin technology in the context of ecosystems. For example, we conduct lab experiments on plants in an in-door greenhouse, where our digital twins connect data streams from sensors monitoring the environment, e.g., humidity, temperature. These streams, together with explicitly formulated domain knowledge, control actuators, such as water pumps, lamps, in order to study automated optimization and decision making. We also develop a digital twin of the Oslo Fjord, where we connect sensor data to a fjord circulation model and study the effects of climate change (e.g., extreme weather events) on the physical processes in the fjord and on its ecosystems. In this talk, we discuss our work on digital twin technologies that integrate models, domain knowledge and sensor data for decision making and what-if analyses. We will discuss the capture and use of knowledge about processes, interactions, and dynamics in the ecosystem, such as how plants interact with their environments. We further discuss the potential of this technology for monitoring and model-based analysis of ecosystems, illustrated by our current case studies.

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