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Title:
Predictive Digital Twins for Critical Infrastructure Protection: Simulation of Hazardous Gas Transport

The release of hazardous airborne substances in densely populated areas poses a significant threat to urban population as well as to critical infrastructures. In emergency situations, the prediction of the dispersion process of a gas contaminant in the atmosphere is a matter of paramount importance to put in place adequate counter-measures in a timely manner.

To this scope, an equivalent mathematical model describing the problem is formulated, where the incompressible Navier-Stokes equations are used to estimate the air flow in a built environment and the advection-diffusion equation models the pollutant's transport and dispersion itself.

In order to promptly obtain valid results, the solution procedure is split in two phases. In a first offline preparatory stage, computationally intensive wind flow simulations are carried out for various atmospheric conditions, leveraging on model order reduction techniques.

In a second online stage, the provided wind field is used as an input to model the dispersion process. The simulation combines a physics-driven model, i.e., the advection-diffusion equation, and sensor data gathered from the physical environment, this allowing also for the analysis of optimization strategies to improve the sensors location.

The final target of the workflow under consideration foresees its integration in a hybrid digital twin framework, a paradigm that has been proven to be a valid tool in the context of crisis management and useful to foster the resilience of critical infrastructures.