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LEVERAGING SENSOR DATA TO ENHANCE MULTI-PHYSICS SIMULATIONS FOR PEDESTRIAN FLOW IN A DIGITAL TWIN FRAMEWORK

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ABSTRACT

As urban population keeps growing, its safeguarding against potentially disruptive events related to the failure of critical infrastructures is a matter of utmost importance. This includes the scenario of a sudden release of hazardous airborne contaminants. In this context, real-time prediction of gas diffusion processes is the core part of the early phase decision-making process of an evacuation scheme.

For this purpose, a mathematical model describing the problem is formulated, where the incompressible Navier-Stokes (INS) equations are used to model the atmospheric wind flow while the advection-diffusion equation is employed to simulate the contaminant dispersal. Concurrently, an evacuation process is simulated via a distributed macroscopic pedestrian flow model [1], where the crowd is supposed to be continuously informed about the contaminant presence, thus enforcing a one-way coupling between its navigation field and the instantaneous gas concentration field. This simulation setup strongly resembles the real-world scenario of the presence of so-called *agents* within the crowd, i.e., informed entities embodied, for example, by emergency first responders.

To satisfy computational efficiency, the workflow is divided into two main stages. In a first offline phase, the computationally intensive wind field evaluation is performed, for different atmospheric conditions, by solving the INS equations with the aid of model order reduction techniques. In a second online phase, the coupled problem of contaminant dispersion and crowd movement is addressed. Here, environmental sensor data is leveraged to improve the accuracy of the evaluation of the diffusion process via the implementation of a data assimilation strategy in the form of an ensemble Kalman filter [2].

The implementation of this model within a digital twin framework will help to increase the situational awareness and to formulate possible system prognosis states during crises events.

REFERENCES

[1] Herzog, R., Pietschmann, JF., and Winkler, M. (2023). Optimal Control of Hughes' Model for Pedestrian Flow via Local Attraction. *Appl Math Optim*, *88*(87).

[2] Carrassi, A., Bocquet, M., Bertino, L., and Evensen, G. (2018). Data assimilation in the geosciences: An overview of methods, issues, and perspectives. *Wiley Interdiscip Rev Clim Change*, *9*(5).