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AI-driven digital twin framework for handling coupled multi-domain problems in building performance simulation. Application to adaptative façade towards flexible and positive energy / carbon buildings

It is well known that buildings are responsible for 40 % of global energy demand and generate roughly 30 % of energy-related CO_2. Decreasing these figures need to develop new efficient and innovative products but meanwhile, also on reliable tools to follow, scrutinize and simulate their behavior, for instance with building energy simulation and monitoring interfaces. Advanced Building Envelopes (ABE) aimed at proposing to tackle these issues by permitting a dynamic and controllable adaptation of the façades to both the external environmental conditions and the indoor comfort requirements. Through the use of innovative configurations or combinations of products, e.g., three glazing units with various fluids, phase change material, variable glazing, passive radiative cooling, green walls, etc., ABE present a huge interest for fostering and promoting flexibility in buildings and to help in converging towards positive energy buildings (PEB). Such an approach could be used for both new buildings but also for retrofitting or upgrading existing buildings. However, the practical use of ABE remains challenging, mainly because few validated data sets or open-source solvers exist that can track such multiphysics interactions at practical time-steps, leaving designers to rely on oversimplified assumptions and empirical safety factors. In addition, their implementation in facility management tools is still scarce and hamper their consideration by experts in refurbishment projects.

This Ph.D. subject proposes a more user-friendly and generic methodology to evaluate the ABE performance at different scales (components and buildings), by enhancing the communication and interactions between building energy simulation (BES) and building information modeling (BIM) for multi-physics domains (thermal, radiative, optical…), relying on the use of artificial intelligence and specifically large-language models (LLM) to develop bi-directional links between physical assets and their digital twins.
The plan work is summarized as follows:

- Develop and validate a framework to handle all retained technologies in a coupled simulation tool, improving an existing Python framework already connecting coupled optical and thermal external model libraries (python-based R-C models and three-phase method in Radiance) to EnergyPlus, and considering in the same time real-time metrics to capture the occupant comfort feelings.
- Develop a series of test-cases with several ABE solutions and various control strategies.
- Develop an ontology for the AI-based assistant that will connect all tools and the related files formats for an ABE.

- Generate an LLM embedding the previous features, and validate it on at least three configurations. The key performance indicators for this validation will be define a priori.
- Test the final methodology and the associated tool for real-time co-simulation-based control on a building or a living lab.

Finally, let us mention that this Ph.D. is part of a larger collaboration with Politecnico di Torino where and with which exchanges could be feasible

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