Bridging Machine Learning and Real-World Experiments for Trustworthy Heat Transfer Coefficient Measurement

Thesis supervisors (dir): Julien Waeytens & Guillaume Perrin (Univ Gustave Eiffel)
Co-supervision: Sarah Juricic (CSTB)

Keywords: building energy performance, thermal building simulation, validation method, virtual testing or numerical benchmark or sequential design of experiments, sensitivity analysis**,** machine learning

Salary & Location: 30 k€ (gross annual) / CSTB & Univ. Gustave Eiffel, Champs sur Marne

Challenge: Create a framework of numerical experiments that both checks and diagnoses measurement biases in whole-building Heat Transfer Coefficient measurements

Change: Bring a systematic approach to method non-reproducibility diagnosis practices

Impact: Make Heat Transfer Coefficient measurement more reliable and bring methods closer to market

Context

The French building sector had a carbon footprint of 153 Mt CO2e in 2019, which represents 25% of France's annual footprint. Among other things, the efficient renovation of the real estate stock is essential to reduce its emissions and to act on energy poverty. In this context, on site performance measurement is identified as a lever to improve practices and make it possible to contractually ensure the achievement of performance during construction or after energy conservation measures.

The thermal performance of a building's fabric is evaluated by measuring its Heat Transfer Coefficient (HTC) which offers a reliable and comparable measurement. The HTC includes heat transfer through opaque walls, windows, thermal bridges, and heat transfer caused by infiltration or ventilation. Although HTC measurement methods have been the subject of international research for decades, they have not yet been widely adopted by the construction industry. One key challenge is the lack of reproducibility in the results. When tested under different conditions, the measurements can vary, and in some cases, the results may not match at all.

Reproducibility issues arise due to factors such as overly simplistic assumptions, oversimplified analyses, or inadequate consideration of uncertainties. Often, these errors are lumped together as "model error" without being explicitly addressed, making them difficult to identify and correct. Moreover, existing and heteroclite HTC validation protocols do not adequately address reproducibility. Instead, they focus primarily on testing how practically identifiable the estimates are, without fully considering the complexities of reproducibility.

Expected contribution of the PhD student

The PhD project aims at contributing to a consensual and exhaustive framework for measurement method validation. Considered that full field validation is infeasible in practice, because too costly, method validation could primarily be based on numerically mimicked experiments, in which a method is simulated and tested under variable conditions.

The PhD focus is on developing a framework for thorough validation and diagnosis of HTC measurement methods using a series of numerical experiments. These tests should be designed similarly to unit tests in computer science or similarly to the BESTEST framework, where direct comparisons between two tests help pinpoint the source of any observed errors.

The student is expected to:

- Conduct an extensive review of the sources of error in HTC measurement methods and evaluate how these sources interact. This will serve as the foundation for designing a numerical benchmark. The review should also identify which sources of error cannot be tested through simulations and must instead be examined through field experiments.
- Review computation-sober methods for sensitivity analysis and design of experiments.
- Design experiments that meet the benchmark requirements and create the set of simulations for the benchmark. The experiments should address methods with and without occupancy as well as methods in larger buildings. Sensitivity of the results to the choice of simulation model will be assessed.
- Define Key Performance Indicators (KPIs) to address the following questions: How close is the measurement to the expected reference value? When is a measurement considered satisfactory? How should the reference value be accurately calculated?
- Apply the numerical benchmark to third-party real-world HTC measurement methods to validate it and brand its credibility.

The outcomes will strongly benefit the IEA EBC annex 94 project, which aims at building a common framework for envelope performance measurement methods. Next to the usual conference and journal publications, the PhD candidate will be invited to participate and present their work to the annex 94 biannual meetings in different European countries. https://annex94.iea-ebc.org/

More generally, the outcomes of this work are expected to be fundamental to a future European standard for measurement method validation, which will benefit the entire building construction sector.

Expected candidate profile

The candidate should have a strong background in either building physics or applied statistics. Proficiency in English is expected (C1) and in French (B1, B2 preferable). Ability or interest in programming in Python is recommended.

Apply

Contact CSTB: sarah.juricic@cstb.fr
Contacts UGE: julien.waeytens@univ-eiffel.fr, guillaume.perrin@univ-eiffel.fr