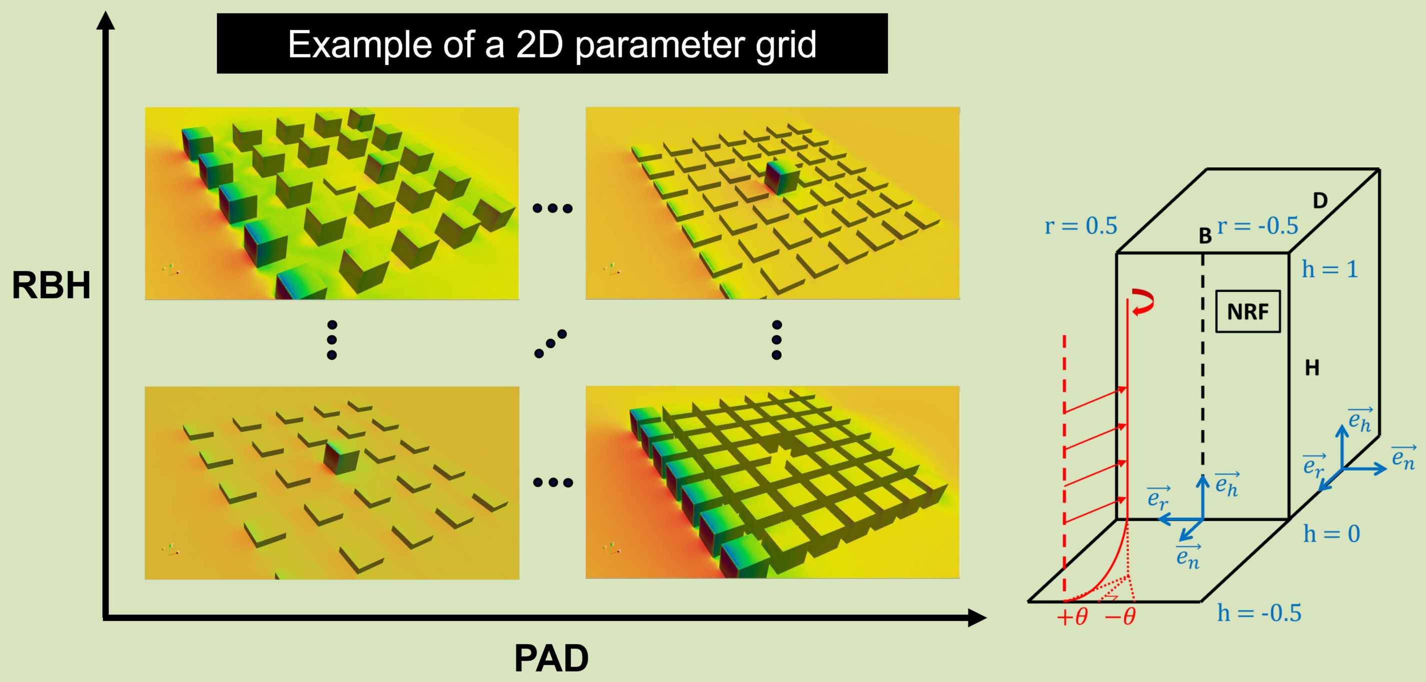
PREDICTION OF WIND PRESSURE COEFFICIENT DISTRIBUTIONS ON BUILDING FAÇADES COUPLING NEURAL NETWORK AND CFD DATABASE

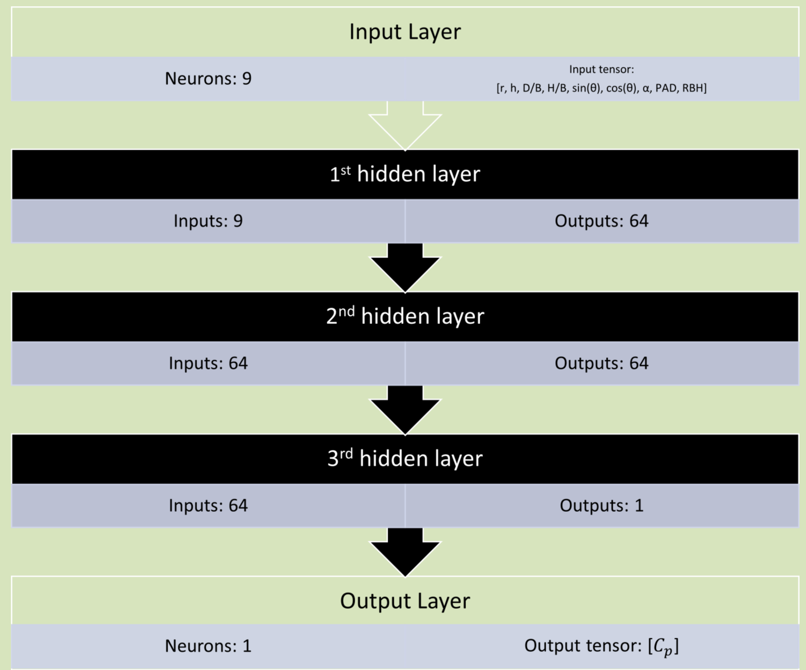
Xiasu Yang, Maxime Nibart

SUEZ ARIA Technologies, 92000 Nanterre, France

Geometric and Deep-learning Models



Generation of a rich CFD training database with Code_Saturne



Neural network diagram for the CpCalc_nn model

CpCalc_nn predictors:

- **(r, h):** position in the local coordinate system defined on a normalized reference façade (NRF)
- **D/B:** depth-to-breadth ratio
- **H/B:** height-to-breadth ratio
- $\boldsymbol{\theta}$**:** relative wind direction with respect to the NRF
- $\boldsymbol{\alpha}$: power law wind profile exponent characterizing the terrain roughness
- **PAD:** Plan area density for a group of buildings
- **RBH:** Relative building height

Training of the CpCalc_nn model:

- A multilayer perceptron (**MLP**) neural network built with **PyTorch**
- A **CFD training database** computed with **Code_Saturne**
- First validation using a **CFD validation database** excluded from the training database
- Second validation using **wind tunnel datasets** provided by **Tokyo Polytechnic University (TPU)** [1]
- **Mini-batch gradient descent** algorithm is used for faster convergence and avoiding overfitting

Validation and Prediction Results

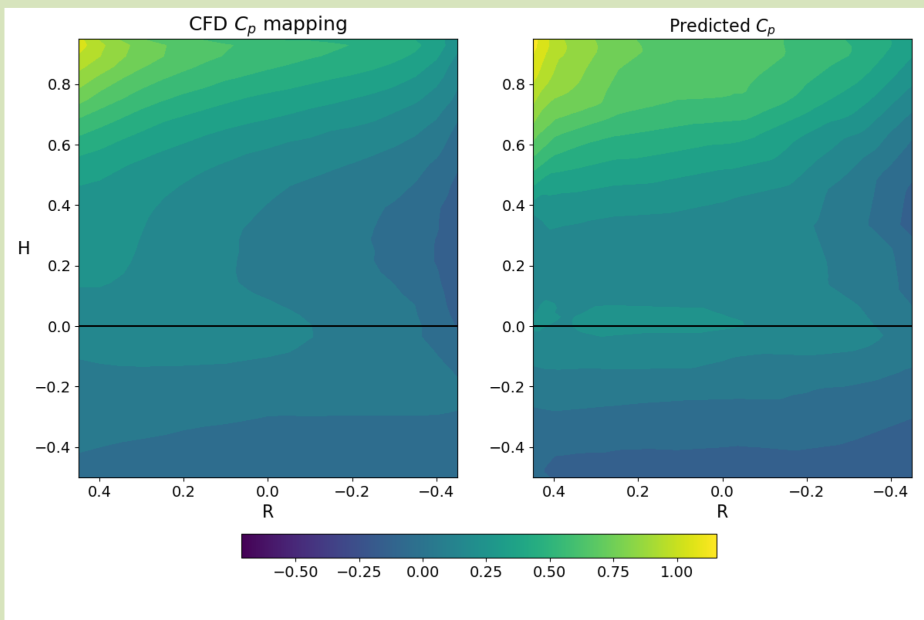
Validation Result (with reference data):

- **Against the CFD validation database:** CpCalc_nn shows a R^2 score of 0.95 for all heights, and a R^2 score of 0.93 for $h < 0.1$ (crawl spaces and floor-mounted air vents).
- **Against the wind tunnel database:** clear improvement over the existing polynomial-based model CpCalc+ [2] in all situations.
- The best validation scores are obtained for isolated buildings, while the worst are found for densely surrounded buildings with tall neighbors.

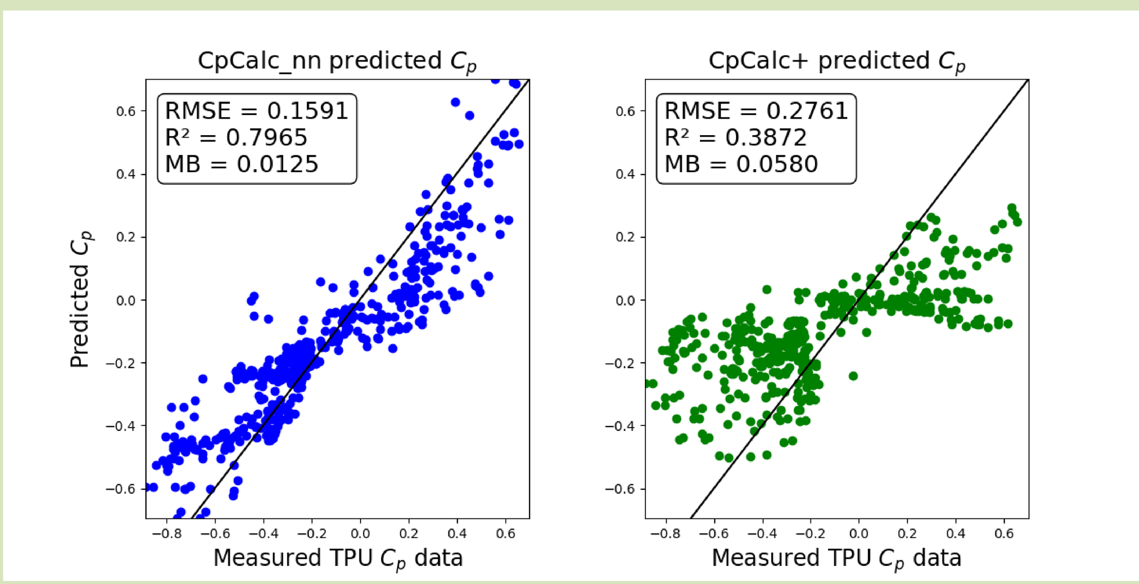
Prediction Result (no reference data):

The predictions of **CpCalc_nn** exhibit a high degree of **physical consistency** with CFD results, while significantly extending the applicable parameter range and improving accuracy over the existing polynomial-based model.

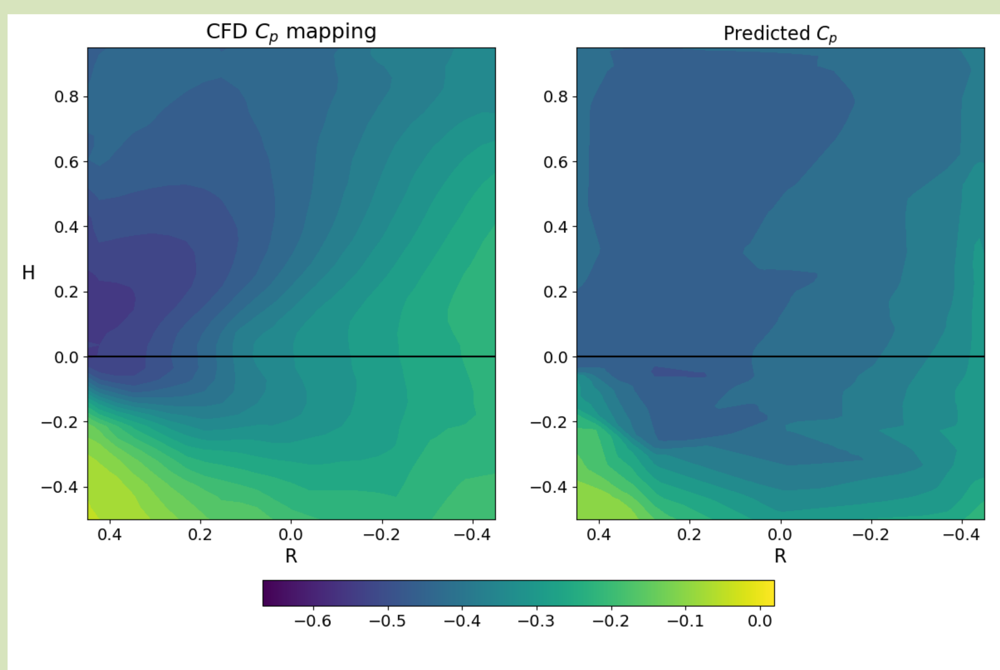
Prediction on a windward angle



Validation Result CpCalc_nn vs CpCalc+



Prediction on a leeward angle



Conclusion

A deep-learning model, **CpCalc_nn***, is developed in the present project to predict the spatially varying wind pressure coefficient (C_p) maps on flat-roofed building façades. The trained model is validated against multiple validation datasets, including a state-of-the-art wind tunnel campaign, demonstrating both satisfactory **accuracy** and strong **generalizability**. By constructing the training database from CFD simulations, the cost of data acquisition is drastically reduced compared with wind-tunnel-dependent databases.

*Download **CpCalc_nn** at `gitlab.com/xyang_suez/cpcalc_nn` (MIT License)

References

[1]. Tokyo Polytechnic University, TPU aerodynamic database. https://wind.arch.t-kougei.ac.jp/system/eng/contents/code/tpu.

[2]. Grosso M., 1992, Wind pressure distribution around buildings: a parametrical model. Energy and Buildings. Vol 18, 101-131.