University of Applied Sciences and Arts
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SUPSI Amenti

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SOLARCHITECTURE
sun as a building material

Data-Driven Assessment of Solar Potential for BIPV Feasibility in Early Design Stages

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Introduction

Building façades represent a considerable part of the urban surface and the solar energy they receive can significantly contribute to the whole urban solar potential. However, harnessing solar energy from vertical surfaces presents a major challenge due to the variability of solar availability, which is influenced by factors such as orientation, neighboring buildings, and vegetation.

Developing a simple, reliable, and robust method for assessing façade solar potential from the early stages of building design can support experts in integrating building-integrated photovoltaics (BIPV) more effectively. This study explores the relationship between the sky view factor (SVF)—which quantifies the visible portion of the sky from a given position—and the corresponding reduction in solar irradiation due to shading. By leveraging this relationship, it becomes possible to predict façade solar potential on a monthly basis using only orientation, SVF values, and geographical coordinates, significantly simplifying the analysis and eliminating the need for complex, time-intensive simulation tools.

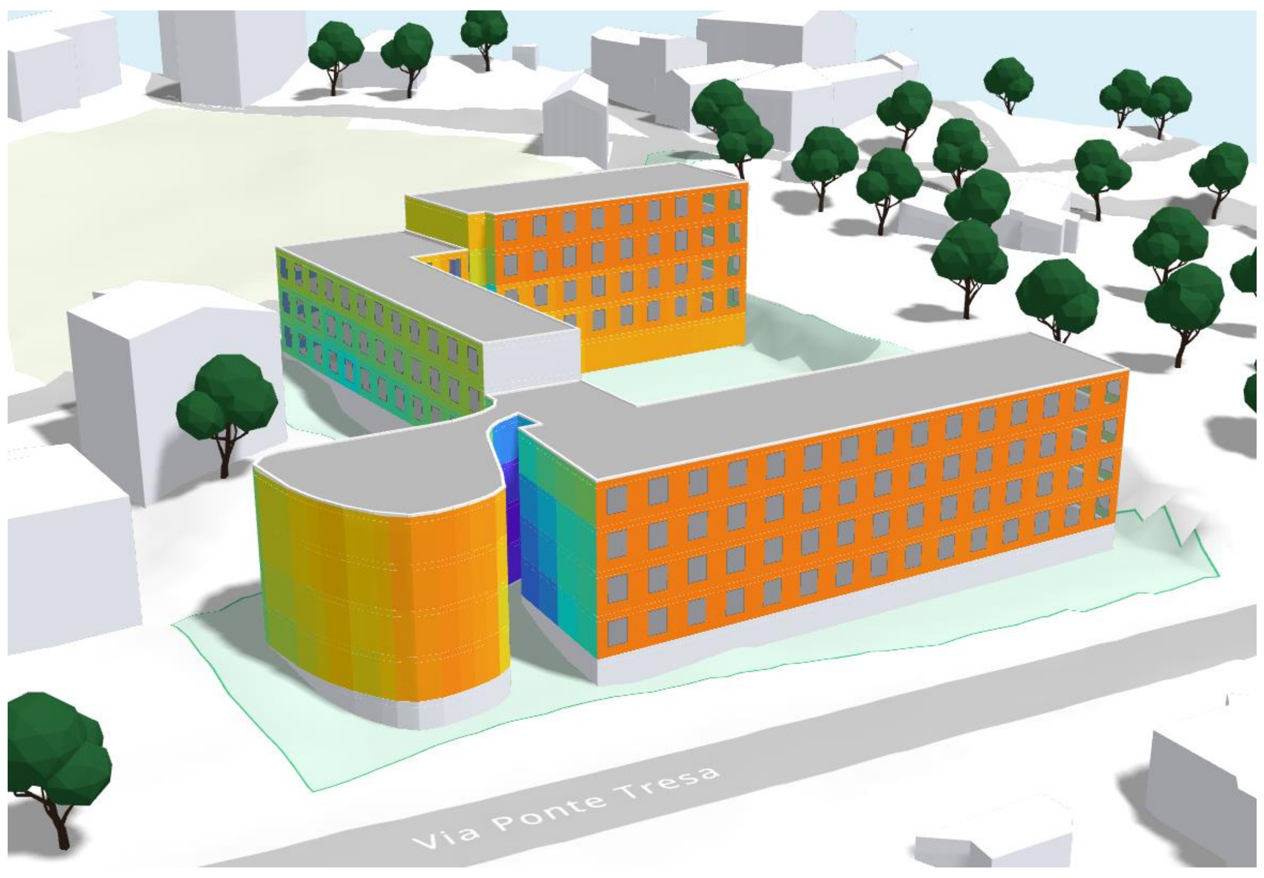

Figure 1. Solar simulation of the Franklin University College in Amenti AG.

Methodology

The methodology involves calibrating an Extreme Gradient Boosting (XGBoost) model to estimate the solar potential of building façades using easily accessible inputs. The model is trained on a dataset of 780’288 artificial observations, built using the parametric Rhinoceros plugins Grasshopper and Ladybug, analysing:

- 127 locations worldwide (longitude & latitude)
- 8 façade azimuths
- 4 urban density scenarios
- 16 points per façade

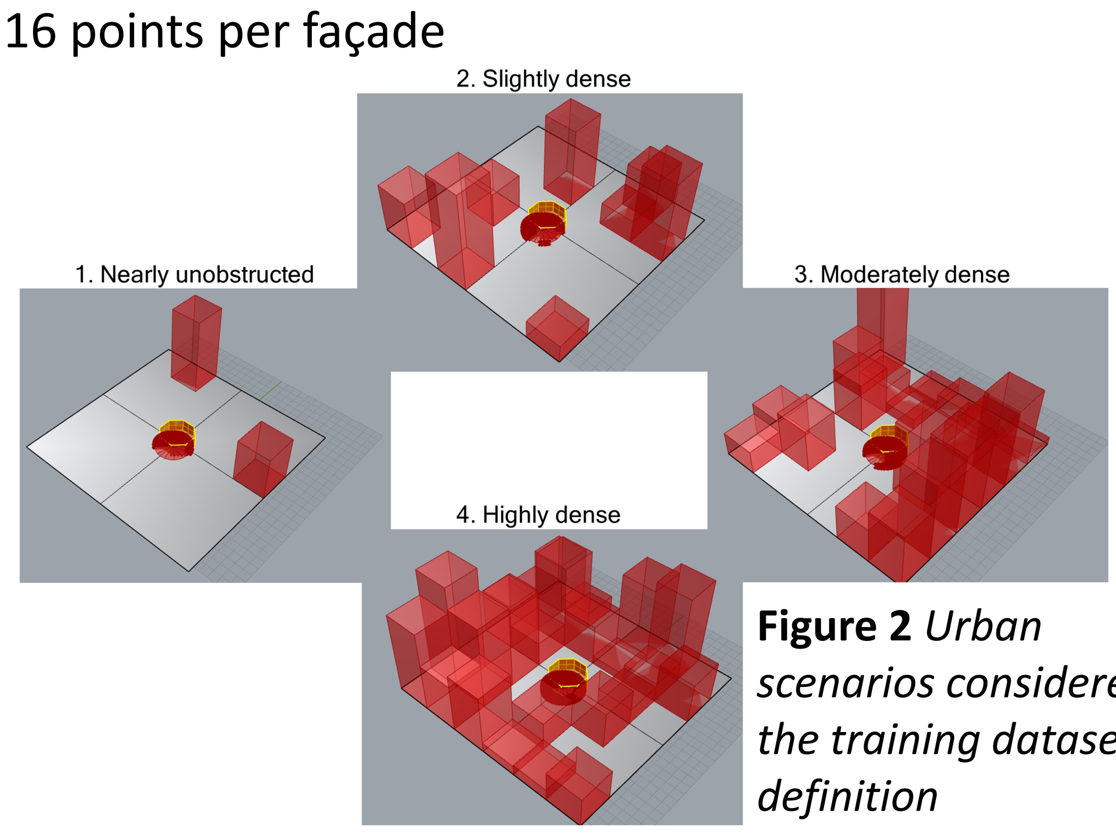

Figure 2 *Urban scenarios considered for the training dataset definition*

SVFs were computed for multiple façade points. In addition to the global SVF, twelve partial SVFs were calculated at each grid point, dividing the sky dome into twelve sections. This allows the metamodel to weight obstructions differently based on their direction.

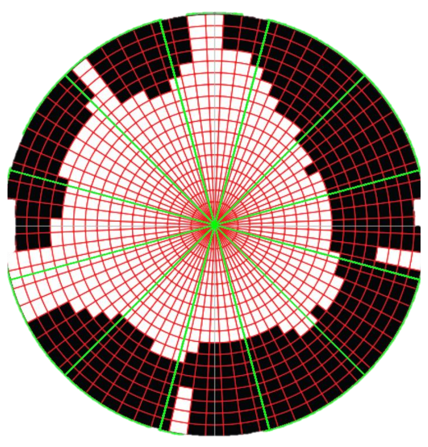

Figure 3 *Sky dome division to compute 12 partial SVFs*

The metamodel was calibrated using cross-validation combined with Bayesian optimization, yielding a robust and efficient model that takes a vector of inputs and outputs the percentage reduction in solar irradiation.

Results

An exploratory data analysis has been performed to validate the training dataset and extract relevant insights. Figure 4 shows the dispersion of the target variable as a function of SVF. This is maximum for intermediate values of the SVF until it reaches minimum values in the cases of complete shading (SVF=0) and completely free sky (SVF=0.5). Figure 4b highlights greater reductions in winter due to the sun’s lower position.

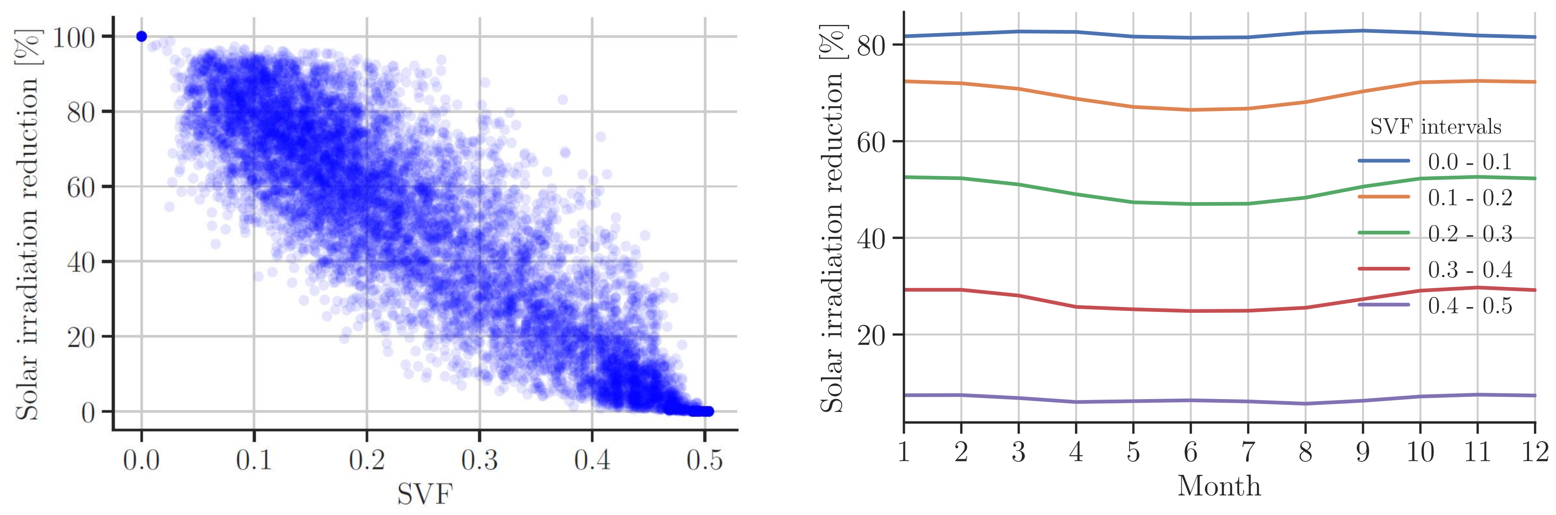

Figure 4 *[a] Scatter plot of a sample of SVF values with the corresponding solar irradiation reduction. [b] Median solar irradiation reduction per month and SVF interval*

The calibrated predictive model demonstrates high accuracy:

- Mean absolute error (MAE) of 1.4
- Mean squared error (MSE) of 5
- R^2 of 0.994.

Figure 5a compares the target variable with the model predictions for 50 observations, while Figure 5b shows the distribution of absolute residuals, with the 95th percentile below 5%.

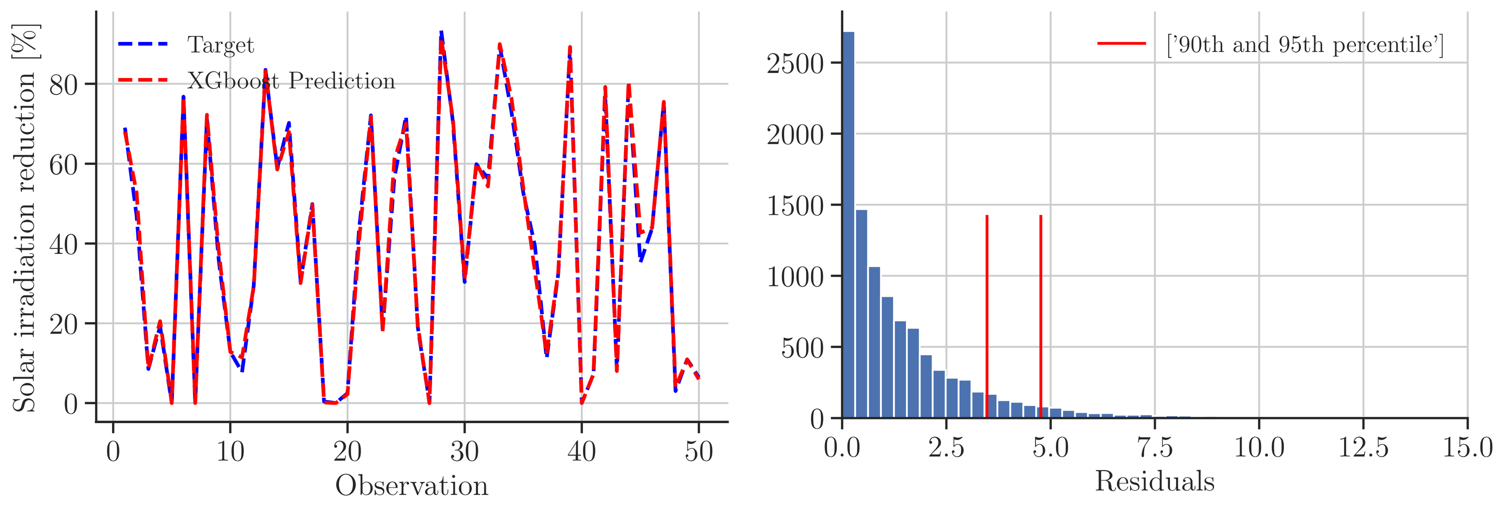

Figure 5 *[a] Comparison between the target variable and the model prediction for 50 observations. [b] Histogram of the residuals absolute value with the 90th and 95° percentiles indicated.*

The importance of input variables was assessed using SHAP (Shapley Additive Explanations) values (Figure 6). As expected, SVF is the most correlated with the target variable, followed by façade azimuth, while latitude plays a more significant role from a geographical perspective.

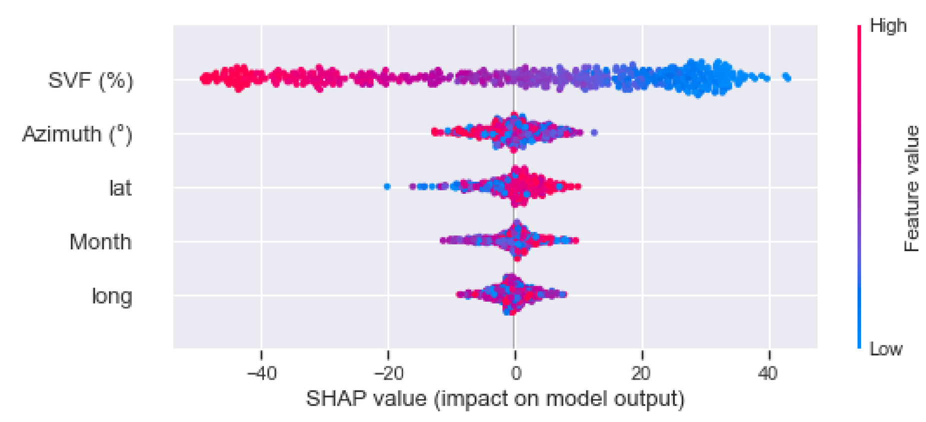

Figure 6 *SHAP values fort the model inputs*

References

- Altieri, Domenico, et al. "Predictive model of solar potential on building façades with the sky view factor as shading indicator." *Journal of Physics: Conference Series*. Vol. 2600. No. 4. IOP Publishing, 2023
- AMENTI AG: https://www.amenti.ch/en/

Conclusions

This study demonstrates the feasibility of a metamodel-based approach for estimating the solar potential of building façades, using SVF as a key predictor. The proposed method provides a simple and computationally efficient solution for assessing solar irradiation reductions due to shading in the early design stages. By addressing a gap in the literature, this work offers a comprehensive, generalized dataset and a more robust regression model. Future research should focus on developing simplified, non-linear regression equations to further streamline the process, enhancing model accessibility for a broader audience, including architects, investors, and building owners.