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Evaluating Urban Form Influence on Solar Exposure and Corresponding Building Energy Demands

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Urban areas are major contributors to climate change, accounting for 71 to 76% of CO_2 emissions from global final energy use [1]. Nevertheless, cities are growing in both size and number. By 2030, it is projected that 730 million people will live in megacities (cities with at least 10 million inhabitants) compared to 500 million people in 2016 [2]. The number of megacities will also increase from 29 to 43 [3]. On the other side, solar radiation is an important component in the energy balance of urban areas. Urban form impacts the production of building-integrated photovoltaics, solar heat gains and heating/cooling demand of buildings. Relevant urban form characteristics include urban layout, population density, and individual building characteristics, such as height, wall orientation, roof slope, and construction material. Optimization of the urban form design can contribute to better energy performance of buildings. However, optimization is a large multivariable problem that is computationally intensive. A good understanding of the urban form impact can guide the optimization. In this work, the influence of shadow from surrounding buildings on solar radiation incident on buildings is studied provided a three-dimensional (3D) model of an area.

Open Access 3D models for many cities are made available by local authorities. Standardized data formats for 3D modelling are well-established. The scientific community has been working towards understanding urban forms, their impact on energy demand, and the potential for realizing sustainable urban forms. So far, the available work relied on different tools to analyze the impact of urban form on space heating/cooling demand for a specific city making reproducibility difficult.

This work shows the advantage of using the standardized CityJSON format to establish an open-source Python-based framework to calculate hourly solar irradiance on building facades, considering the shadow of surrounding buildings, generate a thermal model of building envelopes, and calculate heat losses, gains, and the heating load of a building. The proposed methodology involves three phases. First is data collection and pre-processing. Second is the calculation of direct solar radiation on building facades and roofs. For that, hourly sun positions have been determined. Maximum shadow length is calculated for each sun position. The geometry of buildings is analyzed, shared walls are excluded, and exemplary window vertices are allocated on the free walls such that the window-to-wall ratio ranges between 15% and 25%. Orientations of walls and slopes of tilted roofs were identified. Hyper-points are deployed on each surface in a 0.5m grid. With that, shadow height at each hyper-point and direct solar radiation were calculated. Third is the estimation of the heating or cooling load.

An exemplary neighborhood in Munich is presented as a real case study. Preliminarily results confirm that urban form is influencing the energy performance of buildings. Less shadowing on a building implies higher solar exposure but not necessarily reduced heating demand despite identical thermal properties of buildings' envelope.

References:

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