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Quantifying street view factors of high-density urban environments for climatic studies using Google Street View

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Abstract Text:

The urban thermal environment has practical implications for energy consumption, human comfort and productivity, air pollution at street level, and urban ecology. It is influenced by the geometry of street canyons, street trees, building blocks and impervious ground covers. Street view factors for sky (SVF), tree (TVF), and building (BVF) are three important parameters of the urban outdoor environment that describe the geometrical relation between different surfaces from the perspective of radiative energy transfer, which plays a key role in the urban thermal environment.

However, the previous study areas mainly focus on the cities where streetscape features are relatively simple with well-defined building and street structures. The feasibility and uncertainty of accurately estimating view factors at large-scale in such high-density urban areas as Hong Kong, with much more complex streetscape structures, are still not clear. A typical street in high-density urban areas of Hong Kong is characterized by large overhanging signboards, narrow lanes, heavy traffic, and high-rise buildings that block sunlight and air paths and provide very limited openness to the sky. An effective and accurate method for mapping the sky, tree, and building view factors

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of street canyon in Hong Kong is therefore crucial for studying its urban climate and assessing the relevant outdoor thermal comfort.

This study aims on (1) developing an approach for automatically and accurately deriving sky, tree, and building view factors of street canyons in the high-density urban environment of Hong Kong using the publicly available Google Street View (GSV) images and a deep-learning feature extraction algorithm for extraction of street features (sky, tree, and building) (see **Fig. 1** and **Fig. 2**); (2) verifying the accuracy of the developed GSV-based method using reference data of hemispheric photography from field survey; and (3) comparing the GSV-based with 3D-GIS-based view factors estimates and investigating the impact factors for the discrepancies between them.

As a result, maps of SVF, TVF, and BVF of street canyon in high-density urban areas of Hong Kong are generated. Validation using reference data of hemispheric photography from field surveys in compact high-rise and low-rise areas shows that the GSV-based view factor estimates have satisfying agreements (all with R^2 >0.95) with the reference data, suggesting the effectiveness and high accuracy of the developed method. This is the first reported use of hemispheric photography for direct verification in a GSV-based streetscape study. Furthermore, a comparison between GSV-based and 3D-GIS-based SVFs shows that (1) the two SVF estimates are significantly correlated (R^2=0.40, $p<0.01$), and show better agreement in high-density areas. However, the latter overestimates SVF by 0.11 on average; (2) the differences between them are significantly correlated with street trees (R^2=0.53): the more street trees, the larger the difference. This suggests that a misrepresentation of street trees in a 3D-GIS model of a street environment is the dominant factor contributing to the large discrepancies between the two datasets.

The developed GSV-based method for analyzing view factors in a 3D street environment makes large-scale sky, tree, building view factors estimation possible. This will be playing an important role in relating science-based evidence for urban climatic studies and decision making in urban planning and design processes. A thorough quantification and understanding of the physical streetscape using view factors, including its features and dynamics, would offer great utility to urban planners and climatologists investigating the urban environment.

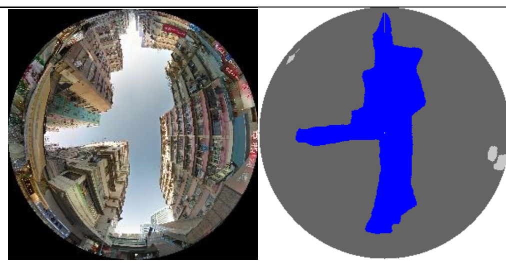
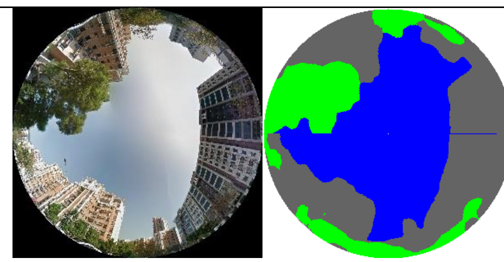
	Example of high-rise area	Example of low-rise area
[Lat, Lon]	[22.3224, 114.1708]	[22.3328, 114.1747]
(a) Panorama image		
(b) Features extraction		
(c) Fisheye image		
[SVF,TVF, BVF]	[0.34, 0.00, 0.65]	[0.64, 0.16, 0.20]

Fig. 1. Workflow procedure for VF calculations using GSV images proposed by Gong et al. (2018). It illustrated by taking two examples from high-rise and low-rise areas. **(a)** Panorama images downloaded from Google servers using coordinates of sampling street points as inputs. **(b)** Extraction of sky (in blue), trees (in green), and buildings (in grey) using the scene parsing deep-learning technique (Zhao, Shi, Qi, Wang, & Jia, 2016). **(c)** Fisheye images obtained by projecting the panorama images from cylindrical projection to azimuthal projection. Based on the fisheye image of extracted features, SVF, TVF, and BVF are calculated using the classical photographic method developed by Johnson & Watson (1984). The resulted VF estimates are also indicated.

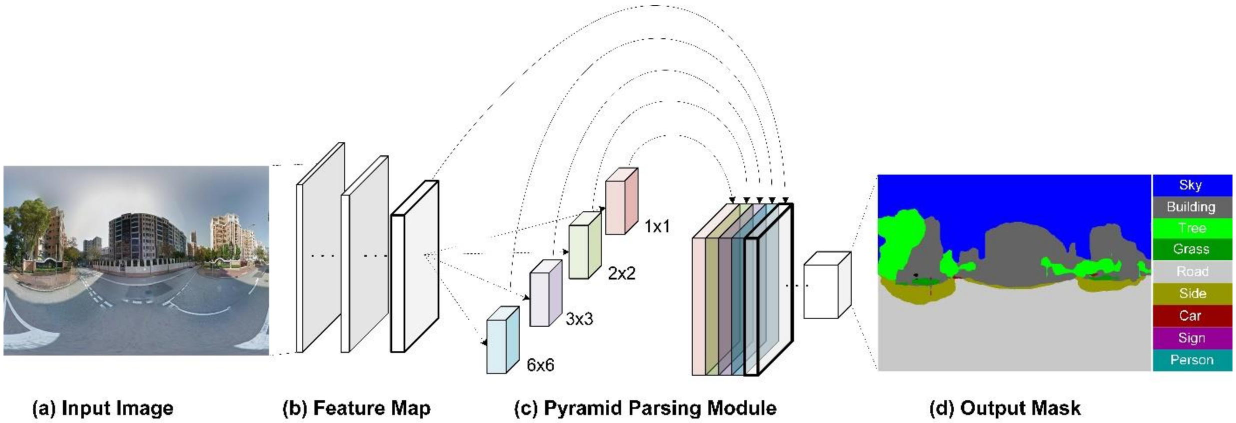


Fig. 2. Workflow of semantic scene parsing using PSPNet. For a given input street view image in **(a)**, the network extracts the feature map in **(b)**, and then the pyramid parsing module is applied to form the final feature representation of the streetscape in **(c)**. Finally, a pixel-wise classified output street view image with semantic categories in **(d)** is produced by feeding the feature representation into a convolution layer.