Quantifying Street View Factors of High-Density Urban Environments for Climatic Studies Using Google Street View

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Background

Fig. Examples of deep street canyons in the Mong Kok and Tsim Shi Tsui area in Hong Kong (Google, 2016)

- It’s difficult to quantify the street features (tree canopy, building overhangs, and shade structures) using model methods in complex street environments.

- An effective and accurate method for mapping the street features is crucial for studying its urban climate and assessing the relevant outdoor thermal comfort.
Question 1
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What’s is the spatial patterns of the sky, tree, and building features of street canyons in high-density urban environments?
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What’s is the spatial patterns of the sky, tree, and building features of street canyons in high-density urban environments?

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What’s the differences of GSV-based and 3D-GIS-model estimate methods?
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Question 3
What’s the differences of GSV-based and 3D-GIS-model estimate methods?

Research Objective
To develop an new approach for estimating and mapping sky, building, and tree features of street canyons in complex urban living environments.
Method | Study Area: Hong Kong

Fig. (a) Location of Hong Kong; (b) High-density urban areas of Hong Kong; (c) Building height density map.

- **High-rise compact building** blocks and **deep street canyons** with a high H/W ratio.
- Tall buildings of some **40-60 stories** with narrow streets.
Method | Data Collection: Google Street View (GSV)

- Google Street View serves millions of Google users daily with panorama images captured in hundreds of cities (Anguelov et al., 2010).

- All these panorama photographs are freely accessible on Google Maps by the Google Street View Application Program Interface (API).

**Fig.** Google Street View coverage map of Kowloon Area of Hong Kong ([Google, 2016](#)).
Method | View Factor Calculations using GSV images

<table>
<thead>
<tr>
<th>High-rise Area</th>
<th>Low-rise Area</th>
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<tbody>
<tr>
<td>(a) Panorama Image</td>
<td></td>
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<tr>
<td><img src="image1.png" alt="Panorama Image" /></td>
<td><img src="image2.png" alt="Panorama Image" /></td>
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<tr>
<td>(b) Features Extraction</td>
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<td><img src="image3.png" alt="Features Extraction" /></td>
<td><img src="image4.png" alt="Features Extraction" /></td>
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<td>(c) Fisheye Image</td>
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<td><img src="image5.png" alt="Fisheye Image" /></td>
<td><img src="image6.png" alt="Fisheye Image" /></td>
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<tr>
<td>[SVF, TVF, BVF]</td>
<td>[0.34, 0.00, 0.65]</td>
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</tbody>
</table>

- Panorama images from Google Street View
- Features extraction using deep-learning framework. Sky (in blue), tree (in green) and building (in grey) are extracted using the scene parsing method in a deep-learning framework.
- Fisheye images obtained by projecting the panorama images
- Based on the classified fisheye image, view factors for sky (SVF), tree (TVF), and building (BVF) are calculated using the classical photographic method.

**Fig.** Workflow procedure for calculation of view factors using Google Street View images
Method | Semantic Scene Parsing using PSPNet

Fig. Workflow of semantic scene parsing using Pyramid Scene Parsing Network (PSPNet).

➢ For a given input street view image in (a),
➢ the network extracts the feature map in (b),
➢ the pyramid parsing module is applied to form the final feature representation of the streetscape in (c).
➢ The pixel-wise classified output street view image with semantic categories in (d).


This assessment is implemented by using **100 randomly street points** (cover low-to-high building densities);

Comparing their calculated SVF, TVF, and BVF from sky, tree, and building features extracted using:

(1) Scene parsing deep learning technique;
(2) Manual delineation by eye inspection (as reference data).

**Fig.** Accuracy assessment of feature extraction using the PSPNet in a deep-learning framework.
Results | Tree View Factor (TVF)

**Fig.** Mapping of Tree View Factor (TVF) estimates of street canyons derived using 29,264 Google Street View images along the streets at 30-meter intervals;

<table>
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<th>Total</th>
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<th>HK Island</th>
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<tbody>
<tr>
<td>SVF</td>
<td>0.49</td>
<td>0.53</td>
<td>0.41</td>
</tr>
<tr>
<td>TVF</td>
<td>0.14</td>
<td>0.12</td>
<td>0.19</td>
</tr>
</tbody>
</table>

- The TVF is dominated by values **less than 0.1**, which is limited by the high building density and narrow street environment.
- **58%** of the study area, are dominated by low TVF (0.0–0.3), because of the high-density construction and narrow streets that limit space for greenery.
Results | Building View Factor (BVF)

Fig. Mapping of Building View Factor (BVF) estimates of street canyons derived using 29,264 Google Street View images along the streets at 30-meter intervals;

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- The coastline regions and low-rise areas, which cover about 20% of the study area, show much higher SVF (0.7–1.0), and lower BVF (0.0–0.3),
Results | Sky View Factor (SVF)

• The spatial patterns of GSV-based SVF estimates are similar and consistent with the corresponding building height and density in build-up areas.

• Areas with higher building density have higher BVF, lower SVF and TVF.

• Areas with higher tree canopy have higher TVF, lower SVF and BVF.

Fig. Mapping of GSV-based Sky View Factor (SVF) estimates of street canyons derived using 29,264 GSV images along the streets at 30-meter intervals;
The map of 3D-GIS-based SVF shows a similar pattern to that of GSV-based SVF estimates. They are correlated ($R^2 = 0.40$) and have a better agreement in high-building-density areas. The mean SVF value of 3D-GIS-based estimates (0.59) is about 0.11 (about 20%) higher than that of GSV-based estimates (0.49). There are large differences in the low-rise areas with large amount of street trees.
Fig. Examples of fisheye images from high-rise and low-rise street sample points from field surveys and Google Street View.

Reference data by fisheye photography from field surveys.

The sampling reference data include 20 in high-rise area and 20 in low-rise area.
Results | Verification of GSV-based View Factor Estimates

Fig. 1. Validation of TVF estimates in high and low-density areas using fisheye photography

Fig. 2. Validation of BVF estimates in high and low-density areas using fisheye photography

➢ GSV-based estimations is the effectiveness and high accuracy method to quantify the tree canopy and building density.
**Results | Verification of GSV-based View Factor Estimates**

- Scatter plot of SVF data from field survey and the corresponding GSV-based (in blue) and 3D-GIS-based (in red) SVF data.
- The sampling SVF data include 20 samples in Mong Kok within high-rise building area (in triangles), and 20 samples in Kowloon Tong within low-rise area (in circles).

**Fig. Validation of SVF estimates in high and low-density areas using hemispheric photography**

- Two SVF estimates have a better agreement in high-building-density areas;
- 3D-GIS SVF method overestimates as for not considering tree canopy.
Results | Difference between 3D-GIS and GSV-based SVF

Impact of Tree View Factor

![Histogram](image1)

**Fig. 1.** The bivariate histogram of GSV-based TVF estimates and difference between 3D GIS-based and GSV-based SVF

- The higher of the amount of street trees, the larger of the uncertainty of model simulation of SVF.

Impact of Building View Factor

![Histogram](image2)

**Fig. 2.** The bivariate histogram of GSV-based BVF estimates and difference between 3D GIS-based and GSV-based SVF

- The higher of the building density, the smaller of the uncertainty of model simulation of SVF.
Results | Tree View Factor (TVF) - Singapore

Fig. (a) Spatial distribution of Tree View Factor (TVF) estimates in Singapore; (b) Selected area in central Singapore.

➢ This mean Tree View Factor (TVF) of Hong Kong (0.14) is smaller compared with Singapore (0.26), a sub-tropical Asian city with high building and population densities.
Conclusions and Discussions

- The mean SVF, TVF, and BVF values in high-density areas of Hong Kong are 0.49, 0.14, and 0.33, respectively.

- A comparison between GSV-based and 3D-GIS-based SVFs show that the two SVF estimates are correlated ($R^2=0.40$) and have a better agreement in high-building-density areas. However, the 3D-GIS-based method overestimates SVF by 0.11 on average.

- The differences between the two methods are significantly correlated with street trees ($R^2=0.53$). The more street trees, the larger the difference. Street trees should be considered in model simulation of urban environment.

- Street tree canopy maps in Hong Kong areas are generated. The mean TVF values in the high-density areas of Hong Kong is 0.14. which is smaller compared with Singapore (0.26).

Thank you for your attention.

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