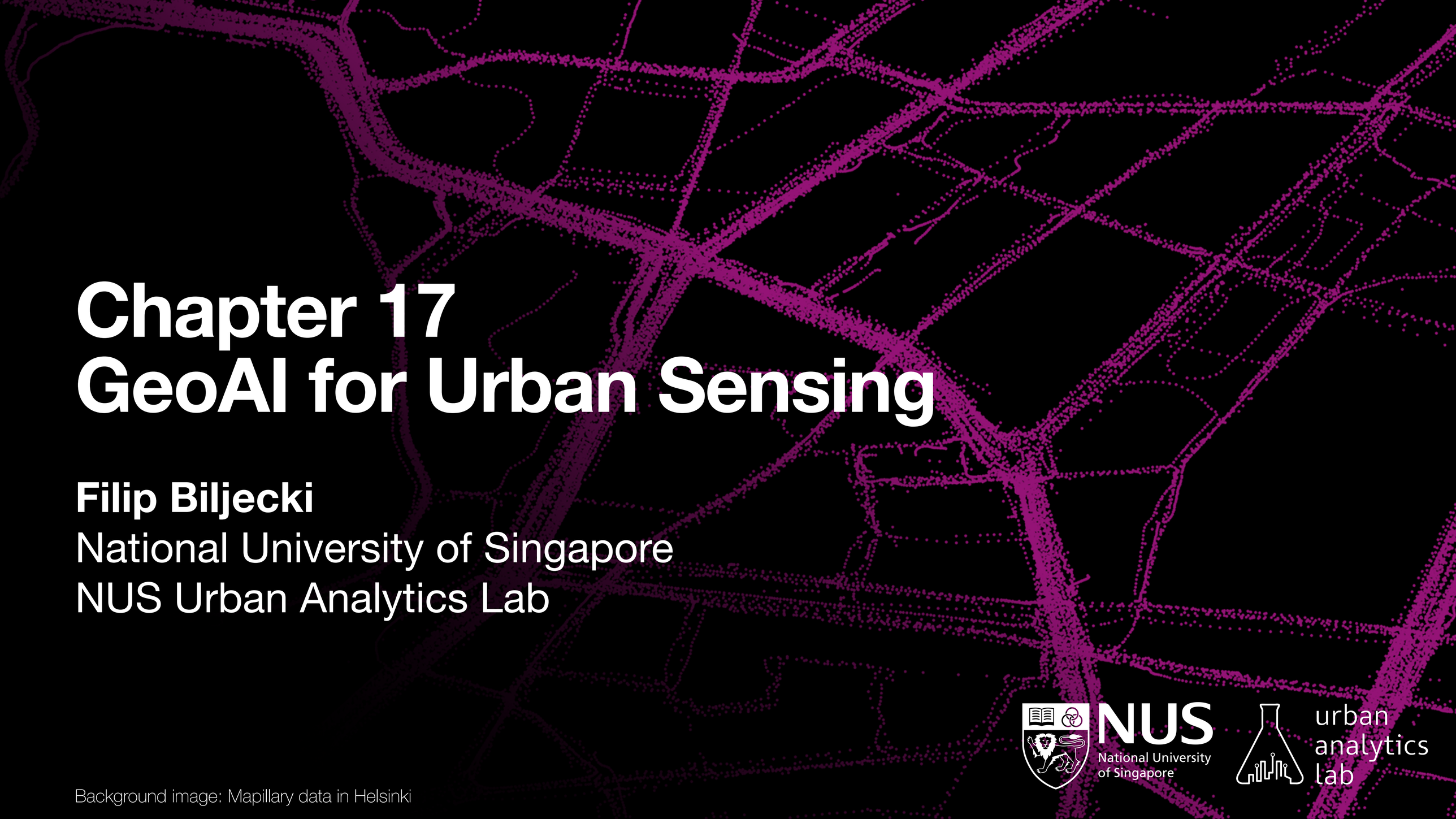


Chapter 17
GeoAI for Urban Sensing

Filip Biljecki
National University of Singapore
NUS Urban Analytics Lab

Background image: Mapillary data in Helsinki

Background and context

- Urban sensing can be defined as a collection of methods and techniques to sense and obtain information about the built environment and human activities in cities (Shi, 2021).
- It remains a vital topic in spatial information sciences and urban management.
- Huge growth in the past years due to the increased volume of existing data, proliferation of sensors and supporting platforms, increasing quality of existing data, emergence of new sources and types of data, the rise of citizen science and crowdsourcing, and greater computing power to process large amounts of data (Biljecki and Ito, 2021).

Examples of GeoAI for Urban Sensing

Recent case studies in Singapore

1. Sensing rooftops from high-resolution satellite images (Wu and Biljecki, 2021)

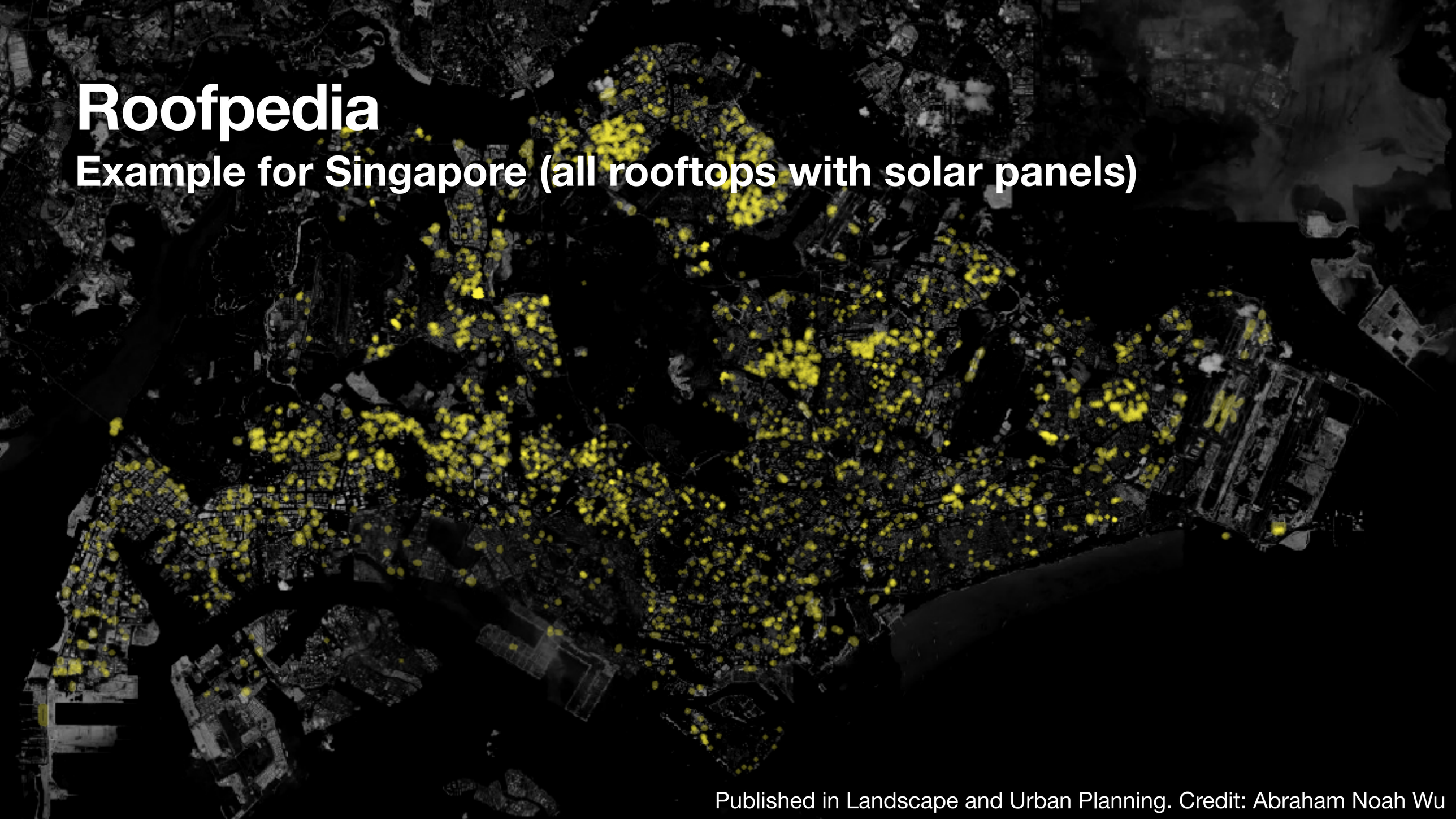
2. Sensing urban soundscapes from street view imagery (Zhao et al., 2023)

Sensing rooftops from high-resolution satellite images

Global open registry of roofs for urban sustainability

Roofpedia

Example for Singapore (all rooftops with solar panels)



Published in Landscape and Urban Planning. Credit: Abraham Noah Wu

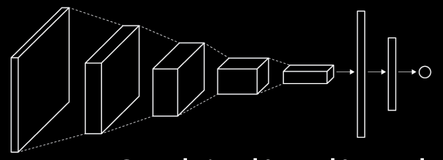
ROOFPEDIA

Automated Roof Mapping + Geospatial Roof Registry + Sustainable Roof Index

NUS National University of Singapore | urban analytics lab

Automated Classification

Satellite Images



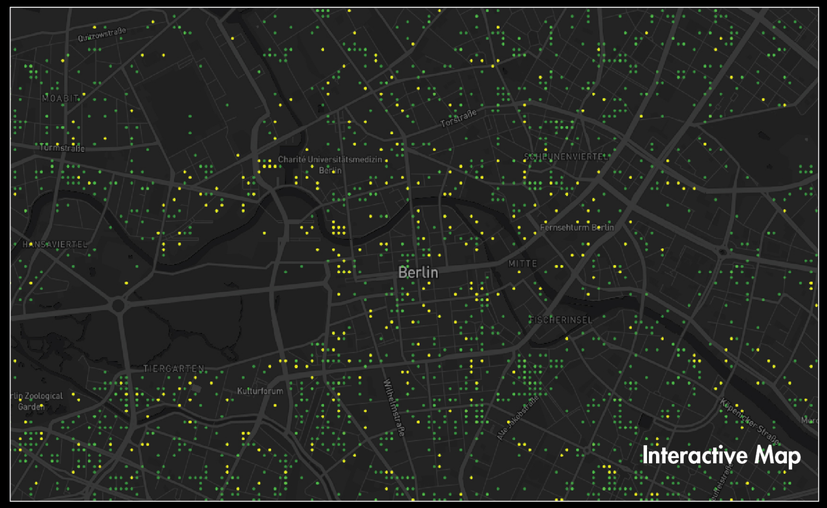
Convolutional Neural Network

Rooftop Solar Panels | Rooftop Vegetation

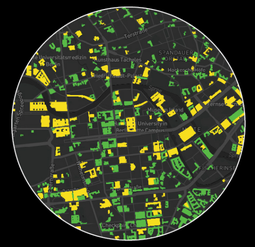
GIS Processing

Solar Roofs | Green Roofs

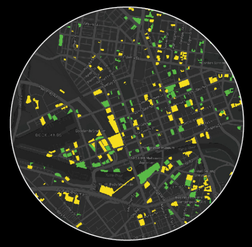
Roofpedia Registry



New York



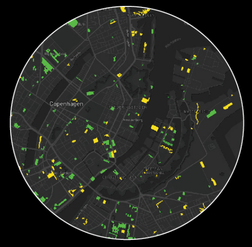
Berlin



Melbourne

Zurich

Las Vegas



Copenhagen

Roofpedia Indices

Solar Roof Index

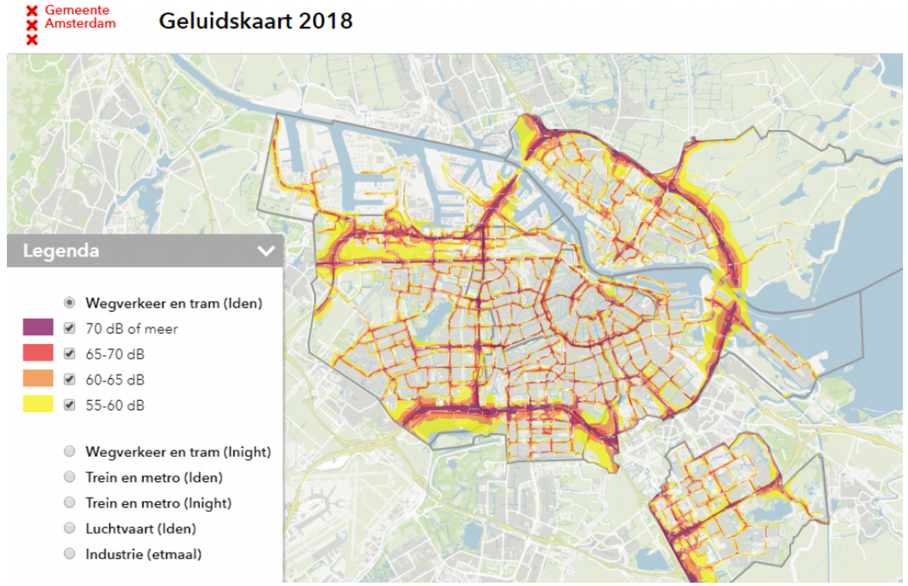
Las Vegas	86
Zurich	81
Singapore	75
Phoenix	75
Melbourne	74
Berlin	57
Copenhagen	45
New York	42
Paris	42
San Diego	24
Los Angeles	20
Seattle	13
San Jose	12
Portland	10
San Francisco	9
Luxembourg City	7
Vancouver	0

Green Roof Index

Zurich	100
Berlin	51
New York	28
Copenhagen	22
Paris	18
San Diego	14
San Jose	13
Phoenix	13
Melbourne	11
Las Vegas	9
Seattle	6
Los Angeles	6
Luxembourg City	4
Portland	3
San Francisco	2
Vancouver	0

Data sources: Mapbox and OpenStreetMap contributors

Sensing urban soundscapes from street view imagery

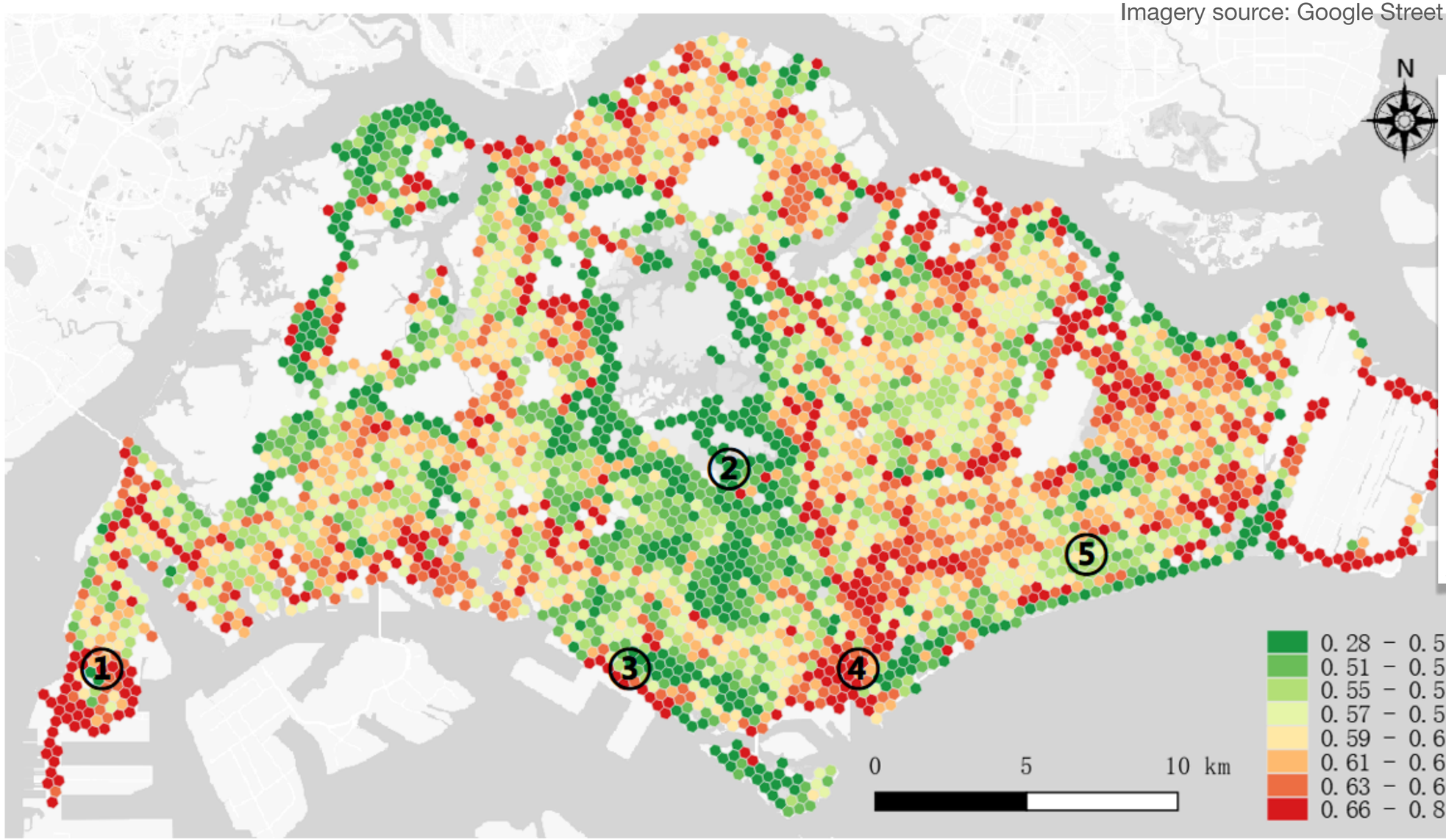


Sound map of Amsterdam 2018, Source: Sound map of Amsterdam 2018 / Topografische ondergrond © Gemeente Amsterdam

Street View Image in Singapore © Google Street View

- Creating noise maps is important but complex and tedious
- Street View Imagery (SVI) — a new instrument to sense noise?
  - Bypassing field measurements and an alternative to simulations
- Developing a model to predict sound intensity…
  - + also nature & quality of sound
    - Traffic, Nature, Human noise
    - Pleasant, annoying, …

Imagery source: Google Street View



Computers, Environment and Urban Systems 99 (2023) 101915

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

journal homepage: www.elsevier.com/locate/ceus

Sensing urban soundscapes from street view imagery

Tianhong Zhao [a,b], Xiucheng Liang [b], Wei Tu [a], Zhengdong Huang [a], Filip Biljecki [b,c,*]

[a] School of Architecture and Urban Planning, Shenzhen University, China
[b] Department of Architecture, National University of Singapore, Singapore
[c] Department of Real Estate, National University of Singapore, Singapore

ARTICLE INFO

Keywords:
Urban planning
GeoAI
Perception
Spatial analysis
Deep learning
Built environment

ABSTRACT

A healthy acoustic environment is an essential component of sustainable cities. Various noise monitoring and simulation techniques have been developed to measure and evaluate urban sounds. However, sensing large areas at a fine resolution remains a great challenge. Based on machine learning, we introduce a new application of street view imagery — estimating large-area high-resolution urban soundscapes, investigating the premise that we can predict and characterize soundscapes without laborious and expensive noise measurements. First, visual features are extracted from street-level imagery using computer vision. Second, fifteen soundscape indicators are identified and a survey is conducted to gauge them solely from images. Finally, a prediction model is constructed to infer the urban soundscape by modeling the non-linear relationship between them. The results are verified with extensive field surveys. Experiments conducted in Singapore and Shenzhen using half a million images affirm that street view imagery enables us to sense large-scale urban soundscapes with low cost but high accuracy and detail, and provides an alternative means to generate soundscape maps. R^2 reaches 0.48 by evaluating the predicted results with field data collection. Further novelties in this domain are revealing the contributing visual elements and spatial laws of soundscapes, underscoring the usability of crowdsourced data, and exposing international patterns in perception.

1. Introduction

Perception of urban environment is an essential task in urban informatics (Zhang et al., 2018; Zhang, Fan, Kang, Hu, & Ratti, 2021; Kruse, Kang, Liu, Zhang, & Gao, 2021), as it relates to urban design and planning (De Silva, Warusavitharana, & Ratnayake, 2017), public health (Harvey, Aultman-Hall, Hurley, & Troy, 2015), and living quality (Van Renterghem et al., 2020; Kang, Zhang, Gao, Peng, & Ratti, 2021). The acoustic environment is a critical component of the urban environment due to the direct impact on physical and mental health, e.g. a bad acoustic environment increases the risk of hypertension and heart attack (Stansfeld et al., 2005; Hoffmann et al., 2006) while pleasant sounds promote public health (Andringa & Lanser, 2013). Traditional assessments of the acoustic environment rely on the use of sound level meters, which describe sound in decibels (dB). Such an assessment focuses only on the negative aspects of sound but ignores the fact that some sounds (e.g., nature and bird sounds, etc.) have a positive impact on people's health (Nilsson & Berglund, 2006). The soundscape is proposed to involve how the acoustic environment affects the human perception of cities. According to the widely accepted definition given in the International Standard ISO, the soundscape is "acoustic environment as perceived or experienced and/or understood by a person or people, in context" (ISO/DIS 12913-1, 2014). This concept represents a paradigm shift in the field of acoustic environment evaluation, as it focuses on human perception rather than physical measurements. Brooks, Schulte-Fortkamp, Voigt, and Case (2014), Hasegawa and Lau (2022). Sensing soundscape helps to improve the perceived quality of the acoustic environment and — as a result — plays an essential role in health betterment.

A variety of research for sensing and evaluating soundscapes has been proposed, thereby improving the quality of soundscapes, e.g. placing noise sensors in locations such as airports and construction sites. However, these solutions are costly and cover a rather small area, inhibiting such implementation at the city-scale. Recently, researchers have begun to develop methods and multi-source data for assessing soundscapes that are both cheap and large-scale (Hsieh, Yen, & Li, 2015; Verma, Jana, & Ramamritham, 2019; Gasco et al., 2020). For example, Becker et al. (2013) proposed that patients participate in crowdsourcing

* Corresponding author at: Department of Architecture, National University of Singapore, Singapore.
E-mail addresses: zhaotianhong2016@email.szu.edu.cn (T. Zhao), xiucheng@u.nus.edu (X. Liang), tuwei@szu.edu.cn (W. Tu), zdhuang@szu.edu.cn (Z. Huang), filip@nus.edu.sg (F. Biljecki).

https://doi.org/10.1016/j.compenvurbsys.2022.101915
Received 5 April 2022; Received in revised form 4 September 2022; Accepted 7 November 2022
0198-9715/

Zhao T, Liang X, Tu W, Huang Z, Biljecki F (2023): Sensing urban soundscapes from street view imagery. Computers, Environment and Urban Systems 99: 101915

Conclusion

Challenges and opportunities

- GeoAI and urban sensing have made great strides in the past few years.
- But research rarely translates into actionable policies and adoption by policy makers.
- Further key challenges and opportunities are understanding the quality of data, emerging data streams, and ethical concerns & bias.

Urban Analytics Lab | Singapore

Connect with us

https://ual.sg **@urbanalyticslab**

Funding & support: NUS, Takenaka Corporation, NRF, FCL Global, AWS, Google

References

Biljecki, F. and Ito, K., 2021. Street view imagery in urban analytics and GIS: A review. Landscape and Urban Planning, 215, 104217.

Shi, W., 2021. Introduction to urban sensing. In: Urban Informatics. Springer Singapore, 311–314.

Wu, A.N. and Biljecki, F., 2021. Roofpedia: Automatic mapping of green and solar roofs for an open roofscape registry and evaluation of urban sustainability. Landscape and Urban Planning, 214, 104167.

Zhao, T., et al., 2023. Sensing urban soundscapes from street view imagery. Computers, Environment and Urban Systems, 99, 101915.