Research at my Lab

Dr Filip Biljecki
Assistant Professor
Director / Principal Investigator

October 2022

NUS National University of Singapore

urban analytics lab

Nice to meet you 👋

Filip Biljecki

- Background: geomatic engineer, 3D GIScience
- MSc and PhD from TU Delft (Netherlands)
- Assistant professor at the:
  - Department of Architecture, NUS College of Design and Engineering
  - Department of Real Estate, NUS Business School
- Teaching at the Master of Urban Planning and MA of Urban Design
- Secondary activities — e.g. OGC, ISPRS

STARTING **OUT**

Founded in 1905 as a modest medical school with 23 students, NUS is today widely known for our innovative and rigorous education which has nurtured generations of leaders and luminaries across industries, professions and sectors in Singapore and beyond. Our singular focus on talent will be the cornerstone of a truly great university that is dedicated to quality education, influential research and visionary enterprise, in service of country and society.

3 campuses

17 schools

>70 double, joint and concurrent degree programmes with the world's top universities

12 NUS Overseas Colleges

>300 partner universities in 40+ countries for student exchange experiences

#10 in global employability of graduates

QS 2022 rank: #11 world, #1 in Asia

College of Design and Engineering

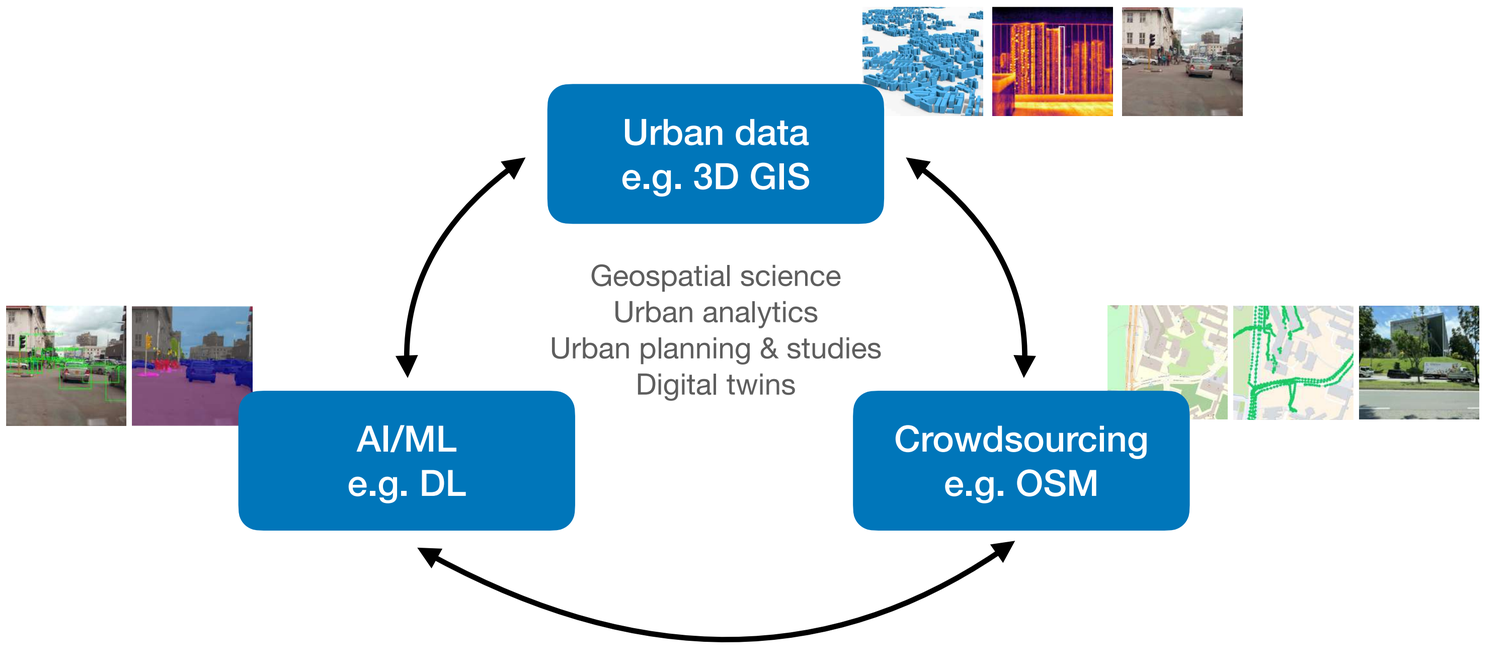
Education, research, innovation and enterprise in shaping a resilient future

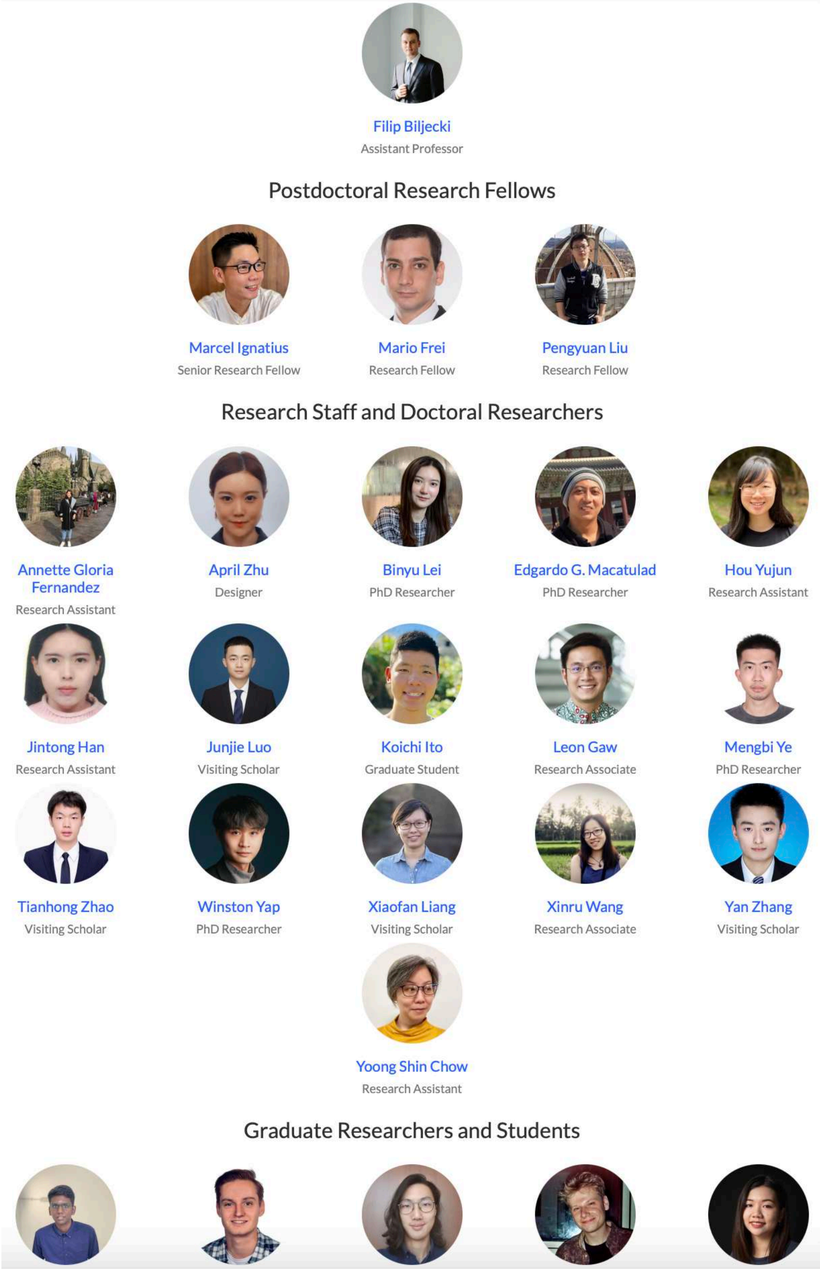
- Over the past 50 years, transforming Singapore into *An Endearing Home and a Distinctive Global City* (MND)
- Multidisciplinary faculty — architecture, engineering, industrial design, urban planning, economics, …
- SDE4 — First newly built net-zero energy building in Singapore and SE Asia ⚡ [even net positive]
    - 1st university building in the world to be WELL Certified Gold 🥇

Our research group

NUS Urban Analytics Lab

- Since 2019
- Urban data science & geospatial engineering. Breaking the silos between GIS and urbanism





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Content of the presentation

Our research

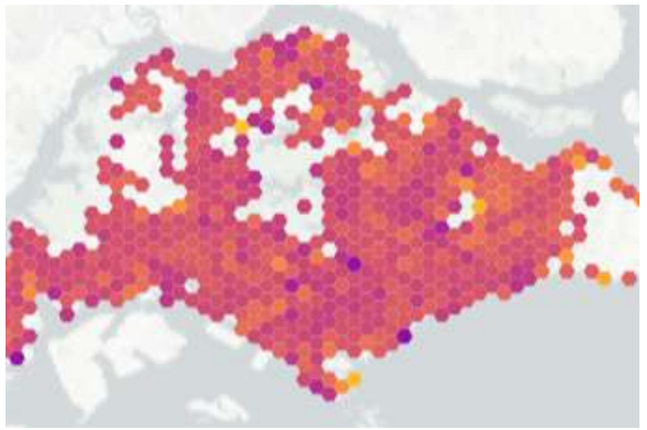
- Briefly on various (non-3D) projects
- Our 3D research
    - Brief examples of a few papers
    - Ongoing: generating 3D from OpenStreetMap
- Takeaways

Assessing bikeability from street view imagery

by Koichi Ito

Orchard Rd, Singapore from Mapillary

Bikeability



Published in Transportation Research Part C. Credit: Koichi Ito

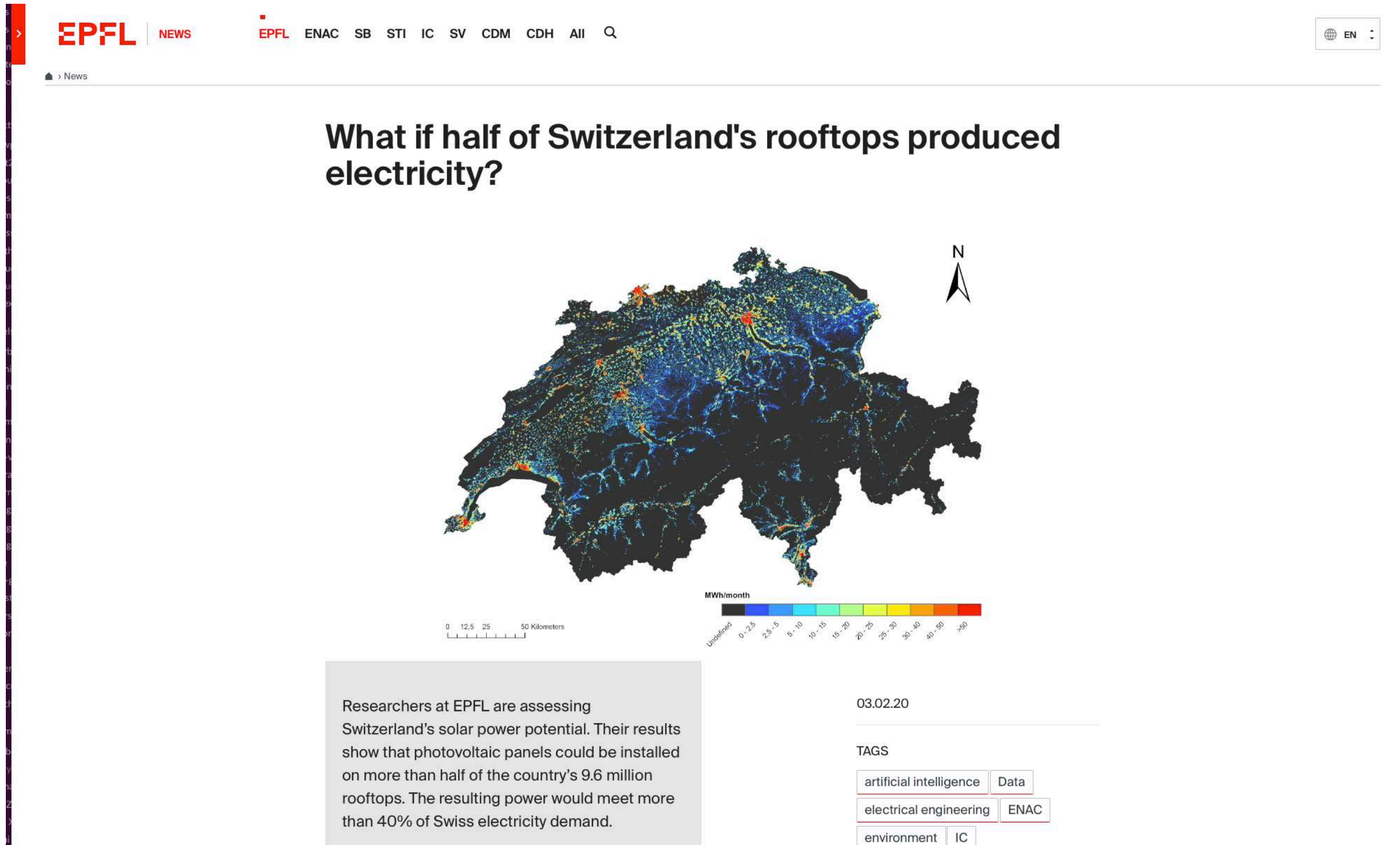
Unlocking rooftops is a hot topic

Potential for solar panels, green roofs, farms, …

Unlocking rooftops is a hot topic

Potential for solar panels, green roofs, farms, …

Mainstream research: (i) quantifying their potential; (ii) identifying the best locations



Cool, we know the potential in future. But what about the current situation and actual status *today*?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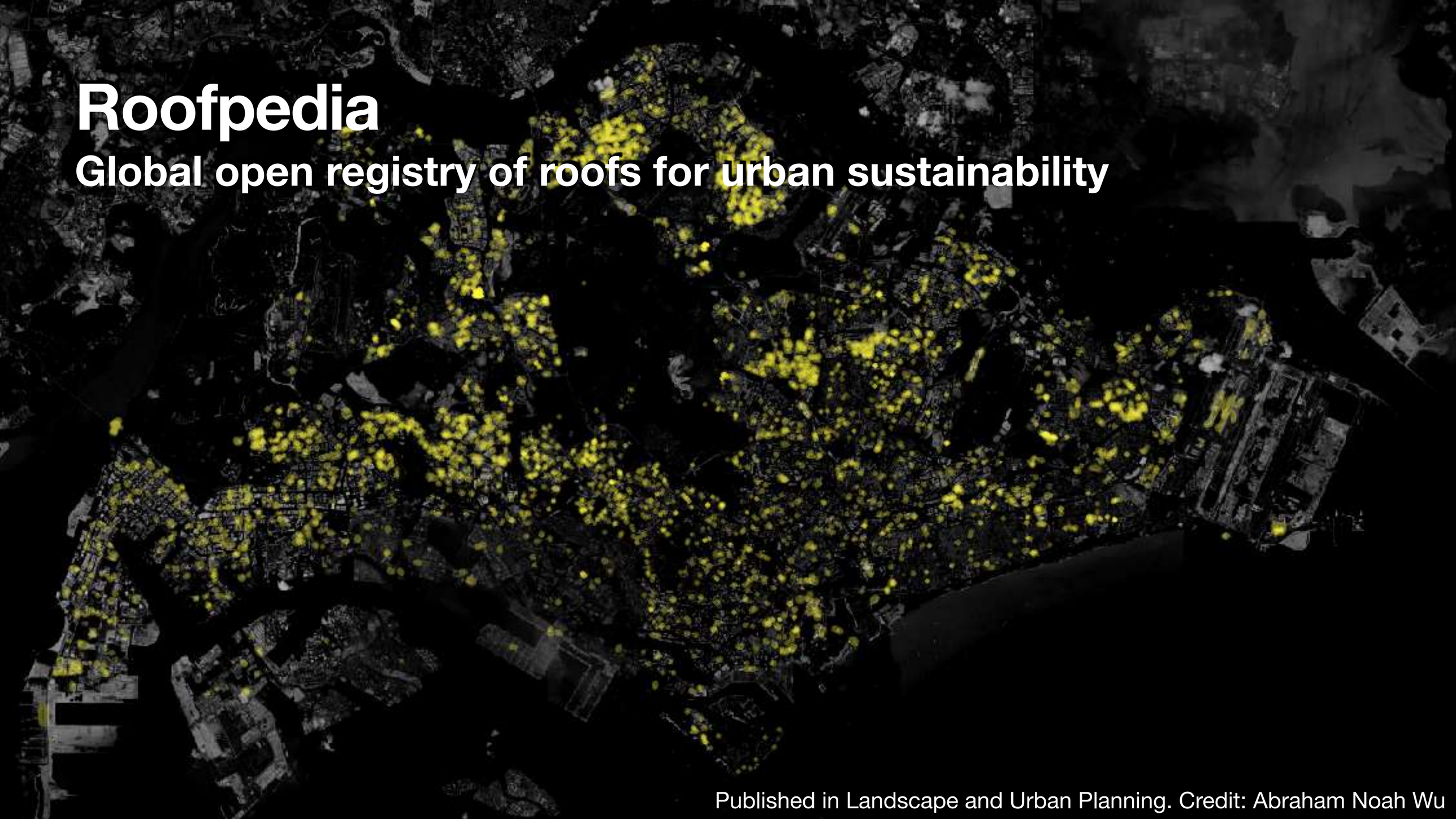

Roofpedia

Global open registry of roofs for urban sustainability

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

by Abraham Noah Wu

ROOFPEDIA

Automated Roof Mapping + Geospatial Roof Registry + Sustainable Roof Index

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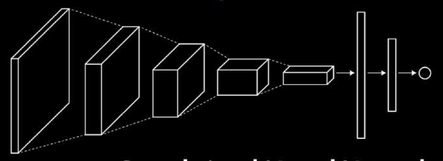
Automated Classification

Satellite Images



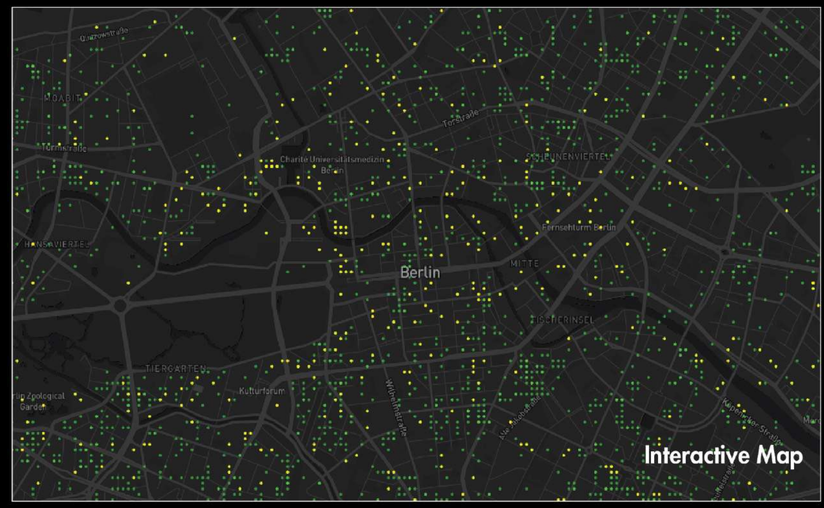
Convolutional Neural Network

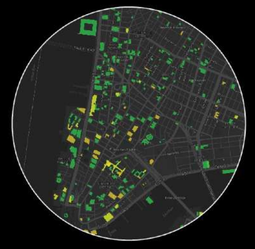
Rooftop Solar Panels | Rooftop Vegetation

GIS Processing

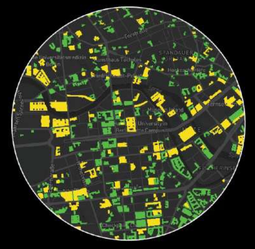
Solar Roofs | Green Roofs

Roofpedia Registry

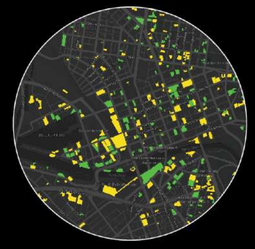




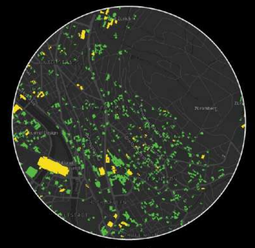
New York



Berlin

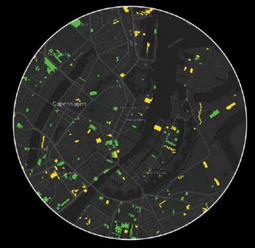


Melbourne



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

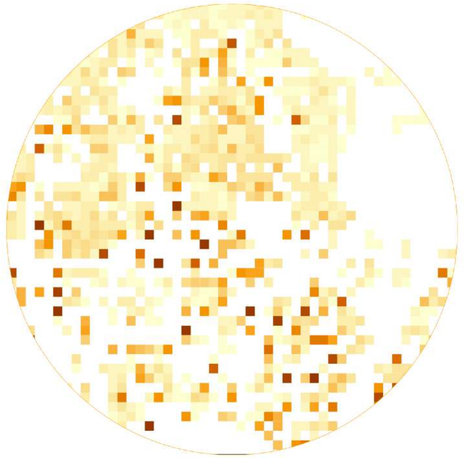
Green Roof Index

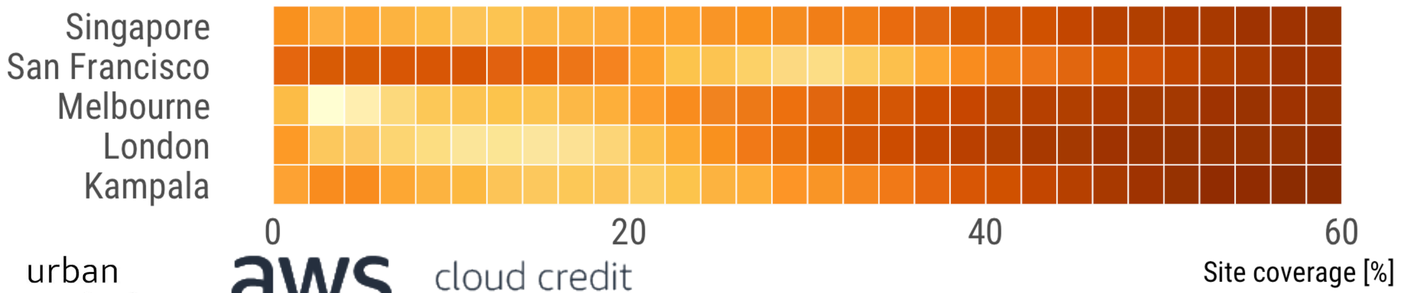
Zurich	100
Berlin	51
New York	28
Copenhagen	22
Paris	18
San Diego	14
San Jose	13
Phoenix	13
Melbourne	11
Las Vegas	9
Seattle	6
Los Angeles	6
Luxembourg City	4
Portland	3
San Francisco	2
Vancouver	0

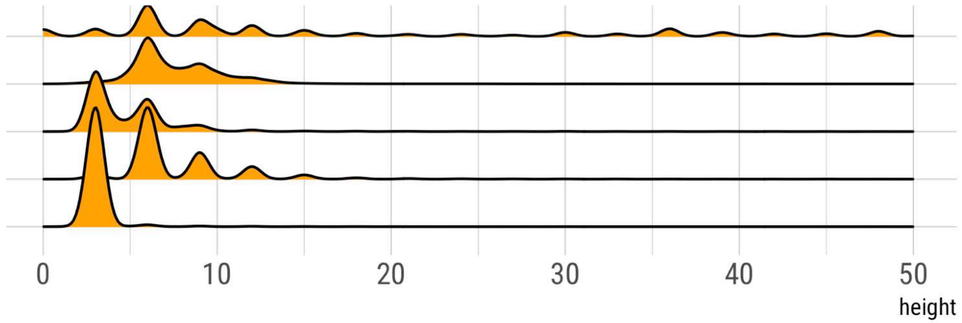
Data sources: Mapbox and OpenStreetMap contributors

Global Building Morphology Indicators

by Yoong Shin Chow







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aws cloud credit for research

Credit: Yoong Shin Chow

GBMI

- 1. Catalogue of metrics (~600)
  - e.g. site coverage,
    st. dev. of footprint complexity
- 2. Open-source tool to compute them
  - At any scale and anywhere
  - From OpenStreetMap
- 3. Open dataset
  - 20+ cities and a few countries

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

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

Global Building Morphology Indicators

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ABSTRACT

Characterising and analysing urban morphology is a continuous task in urban data science, environmental an-

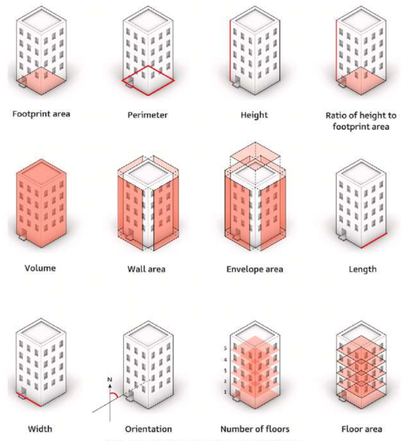
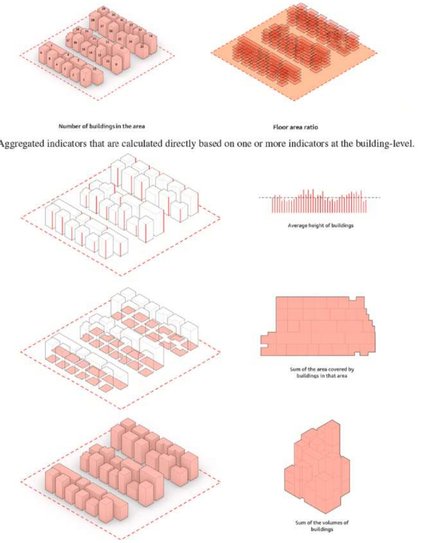


Fig. 1. Illustration of independent indicators at the building level.

Fig. 2. Illustration of contextual aspects computed at the building level based on its surroundings.



(a) Aggregated indicators that are calculated directly based on one or more indicators at the building-level.

(b) Examples of aggregated indicators that are based on summary statistics from an array of values such as building heights. Each of these indicators has several counterparts pertaining to the same array of values, such as minimum value and standard deviation.

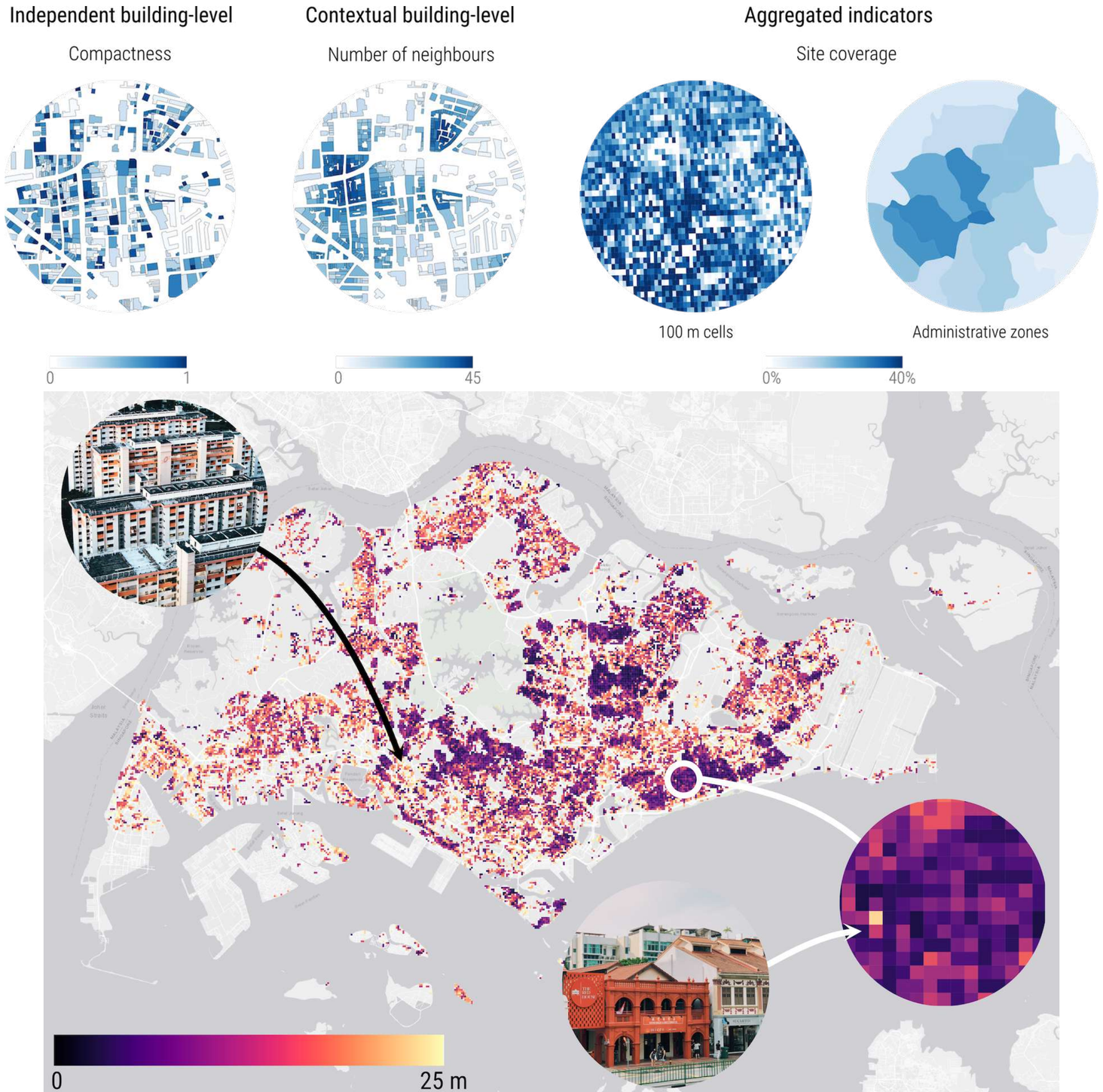
Fig. 3. Examples of aggregated indicators, divided in two groups.

Table 1
List of indicators at the building level (both the independent and contextual instances, together with their ranks at the corresponding zone).

Indicator	Data type	Unit
Footprint area	Decimal	m^2
Perimeter	Decimal	m
Height	Decimal	m
Height to footprint area ratio	Decimal	m^{-1}
Volume	Decimal	m^3
Wall area	Decimal	m^2
Envelope area	Decimal	m^2
Number of vertices	Integer	
Complexity	Decimal	
Compactness	Decimal	
Equivalent rectangular index	Decimal	
MBR[1] Length	Decimal	m
MBR[1] Width	Decimal	m
MBR[1] Area	Decimal	m^2

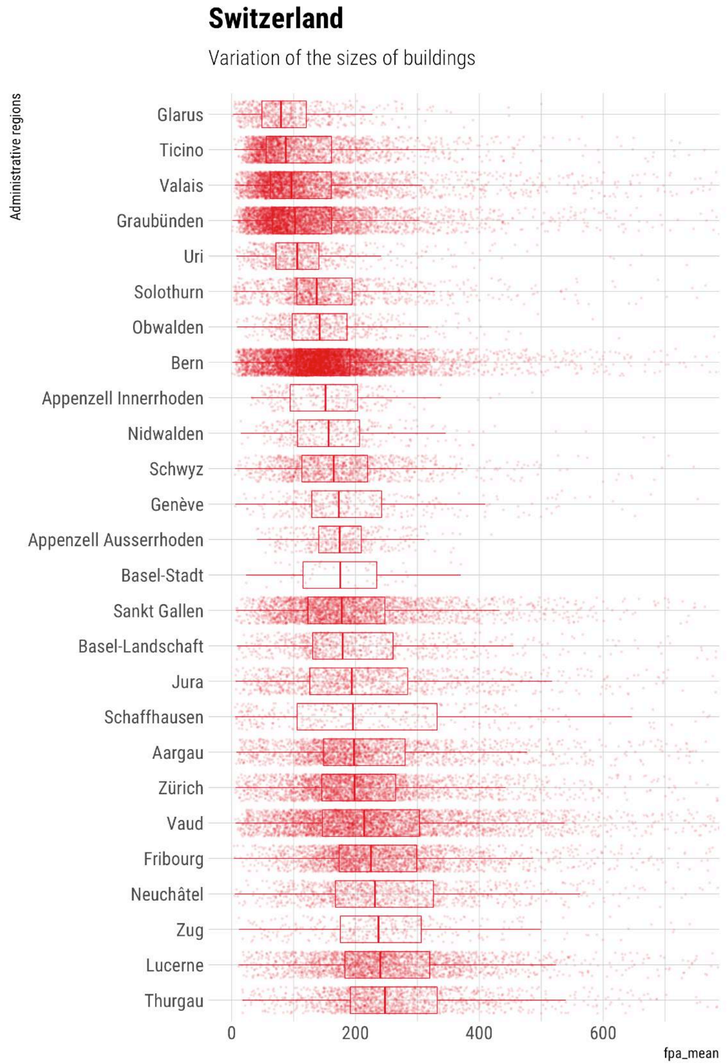
Table 2
Urban form measures at the aggregated level, derived from the indicators of the buildings in the corresponding area.

Building-level indicator	Summary statistics								
	Count	Min	Med	Mean	Max	Sum	SD	D	CV
Buildings	●								
Footprint area		●	●	●	●	●	●	●	●
Perimeter		●	●	●	●		●	●	●
Height		●	●	●	●		●	●	●
H/F[2]		●	●	●	●		●	●	●
Volume		●	●	●	●	●	●	●	●

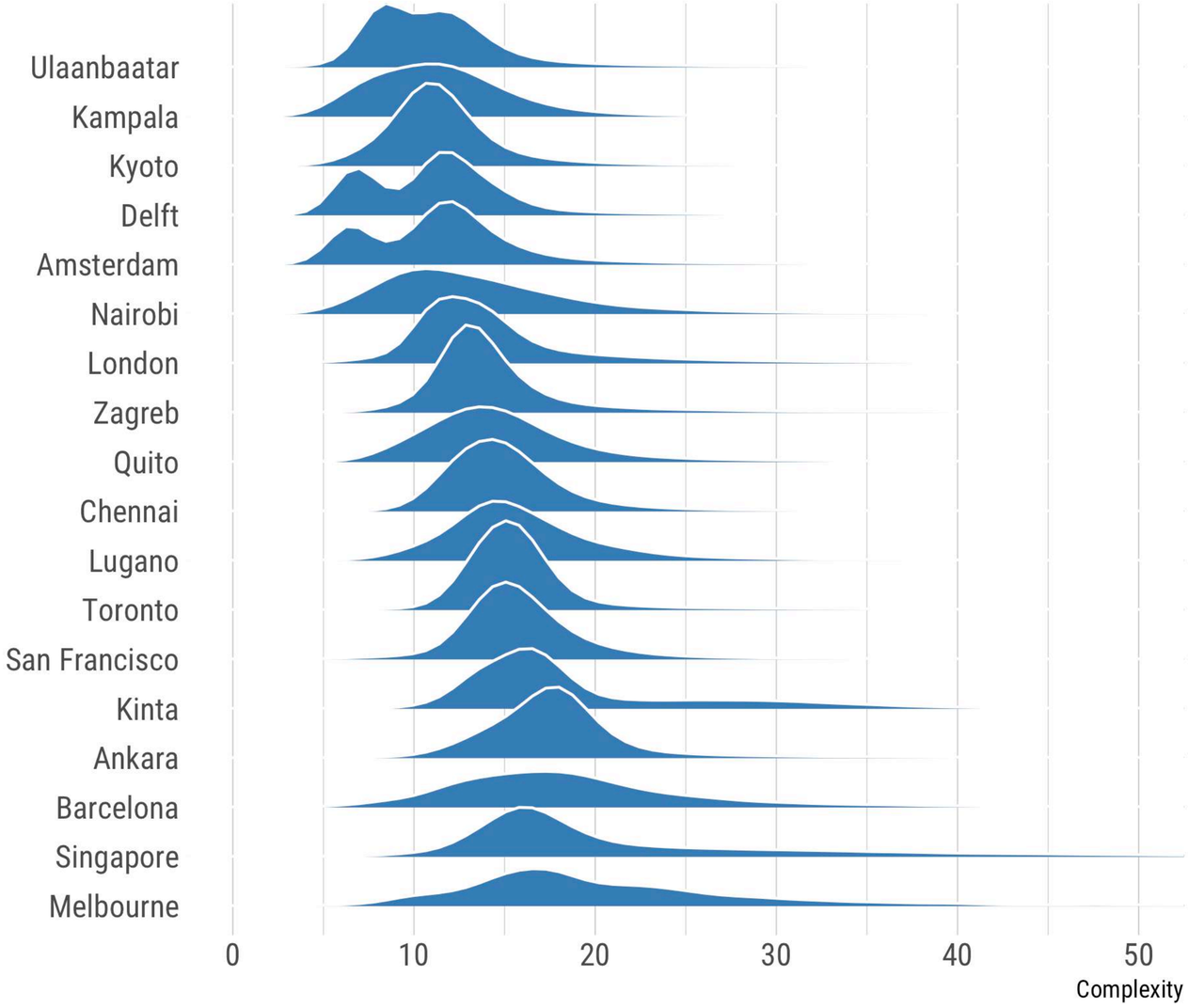

Independent building-level
Compactness
0
1
Contextual building-level
Number of neighbours
0
45
Aggregated indicators
Site coverage
100 m cells
Administrative zones
0%
40%
0
25 m

Building morphology around the world

Sizes of buildings within a country



Complexity of buildings around the world



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AWS Public Sector Blog

NUS Urban Analytics Lab scales research globally with AWS

by AWS Public Sector Blog Team | on 21 APR 2021 | in Analytics, Customer Solutions, Education, Government, Higher Education, Public Sector, Research | Permalink | Share

The Urban Analytics Lab at the National University of Singapore (NUS) spearheads research in geospatial data analysis and three-dimensional (3D) city modelling. The lab's work underpins the development of smart cities and provides scientists, architects, urban planners, and real estate developers with data insights. These insights help parties make informed decisions about projects ranging from energy modelling to urban farming. To meet rising global demand for

Resources

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Now more about 3D…

The core of our research agenda: buildings

Holistic research line on geospatial data on buildings

Acquisition | Harmonisation | Processing | Quality | Applications

- Mission: Use novel techniques, explore new data sources, and cut across multiple disciplines to make data on buildings…
  - Comprehensive and accessible
  - Interoperable
  - Maintained and reliable
  - More usable

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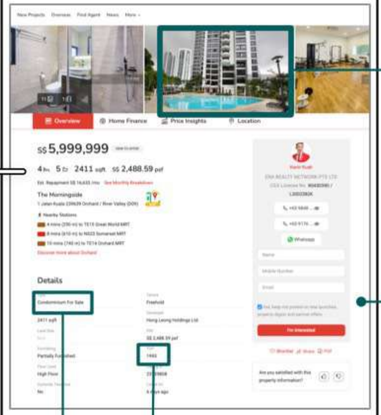
Exploiting real estate data to synchronise data on buildings

by Chen Xinyu

Situation

Real estate data

(1) Real estate ads



(2) Property transactions

Extracting relevant data

(A) Detecting features (computer vision)

(B) Collecting the location of a building

N1.295423, E103.8357

(C) Mining descriptions/characteristics

e.g. building type and year of construction

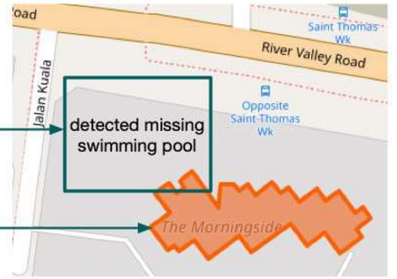
Type	TOP
Condominium For Sale	1993

e.g. height from address and floor area

#24-63	42
#23-65	97
#23-64	84
#23-63	42

Spatial database and downstream applications

(i) Quality control: revealing unmapped features



(ii) Sensing future buildings
(e.g. planned ones that are not yet mapped)

(iii) Quality control of existing attributes

type	condominium ✅
start_date	1997 ❌

(iv) Data enrichment: new attributes

levels	24
avg_floor_area	80

Example use cases: supporting energy simulations and 3D model generation

Floor area provides value for energy consumption estimations

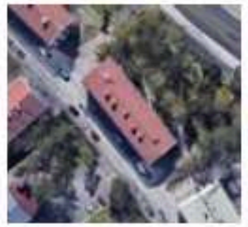
Number of floors, which can be inferred from corresponding property transactions, can be used to extrude existing footprints, resulting in 3D building models

3D reconstruction using single street view imagery

by Pang Hui En

SVI is plentiful but not always usable ➡️ often only 1 unobstructed image available

Imagery courtesy of Google Street View

ID	Input SVI	Output model	Actual top view	Inferred top view
1				
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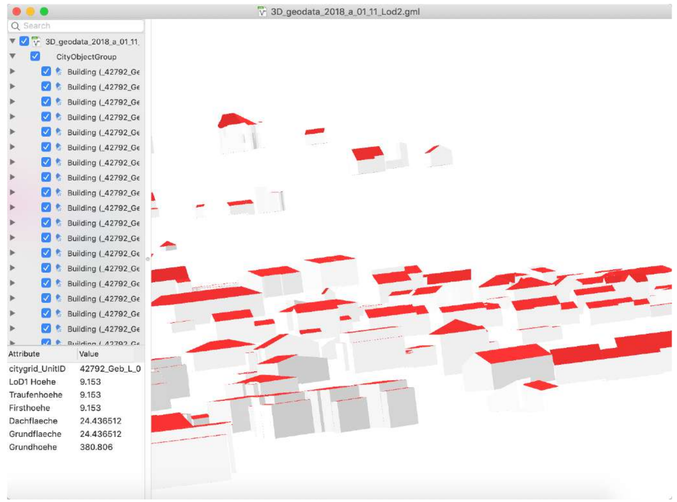
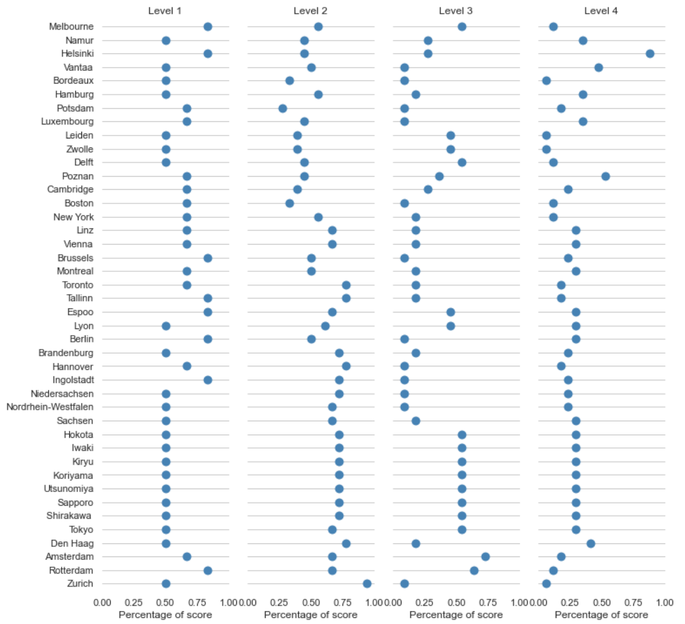
3				

Published in JAG

Assessing and benchmarking 3D city models

by Binyu Lei





- Gap: a formalised approach to assess (and compare) 3D city models (and DTs, by extension) holistically
- 3D City Index — an international benchmark and structured evaluative catalogue of 42 cities
  - 52 criteria at 4 levels — accessibility, properties (formats, LoD, thematic features, frequency of update), semantic content
  - Doubles as an inventory of openly available 3DCM

Accepted in IJGIS

Challenges to Digital Twins

by Binyu Lei

- Lots of people talk about potential of DTs, but not many talk about the challenges
  - What are the challenges encountered in adopting digital twins?
- Systematic literature review: about 30 papers found that talk about challenges
  - Helpful, but not that many
  - Only academia

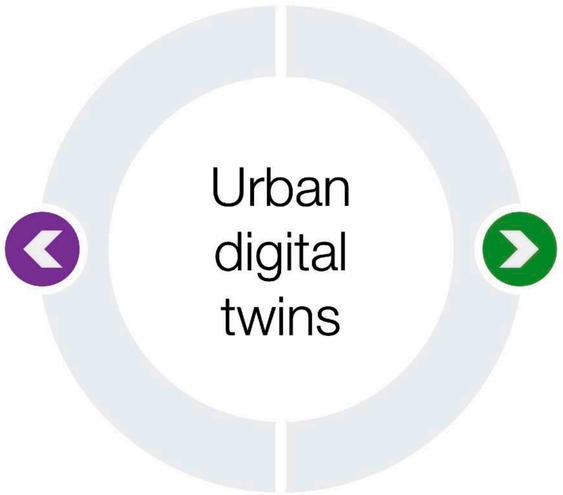
Challenges to Digital Twins (2)

- Delphi survey
  - A robust and scientific method to interview experts and reach a consensus
    - A consensus on challenges and their severity
    - Using multiple rounds
  - Conducted earlier this year — 52 experts
    - Benefit: also government and industry
    - 3 rounds

Challenges to Digital Twins (3)

Technical challenges

- Data
- Integration
- Interoperability
- Software
- Technical competency
- Standard
- Update
- Data creation
- Data complexity
- Architecture
- Data maintenance
- Hardware
- Reconstruction
- Visualisation

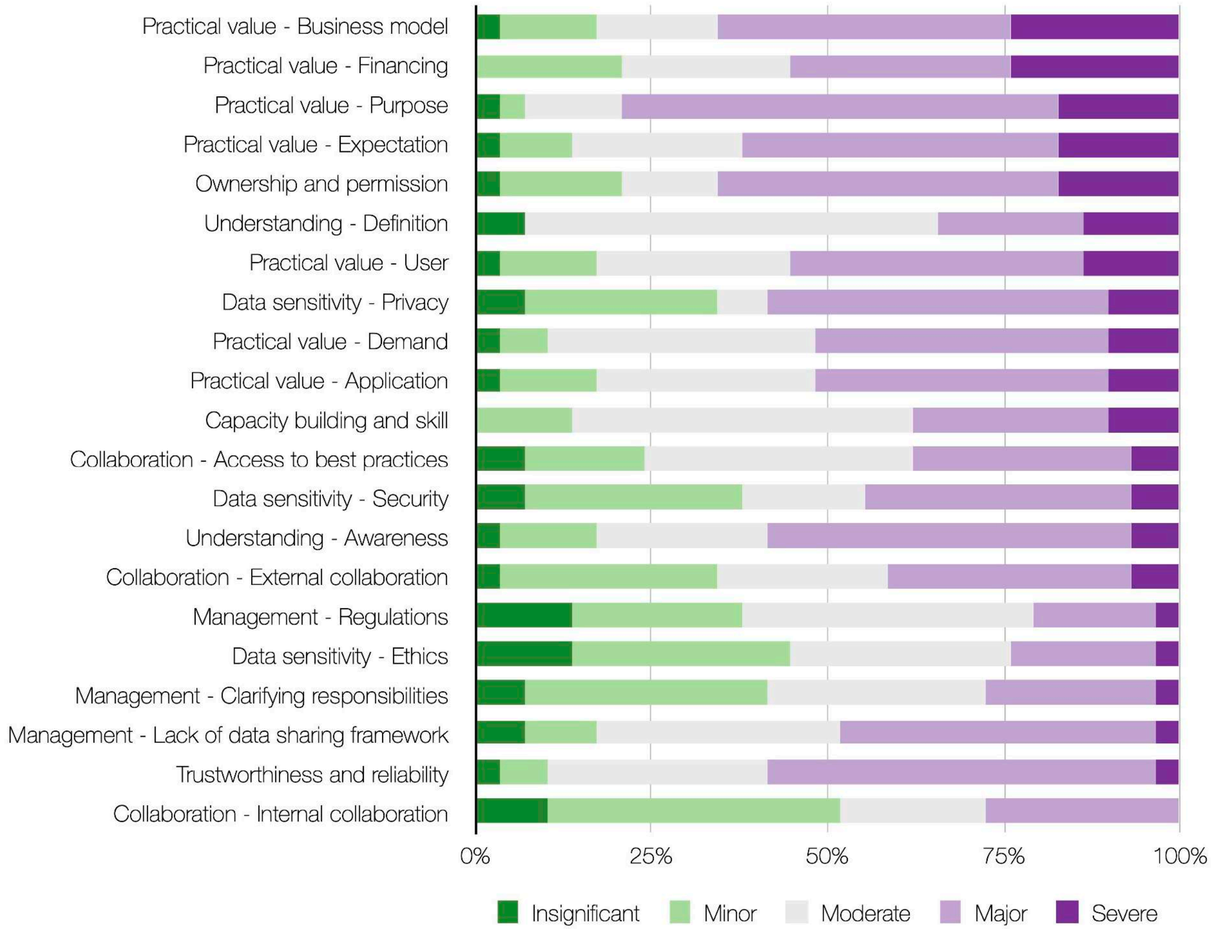


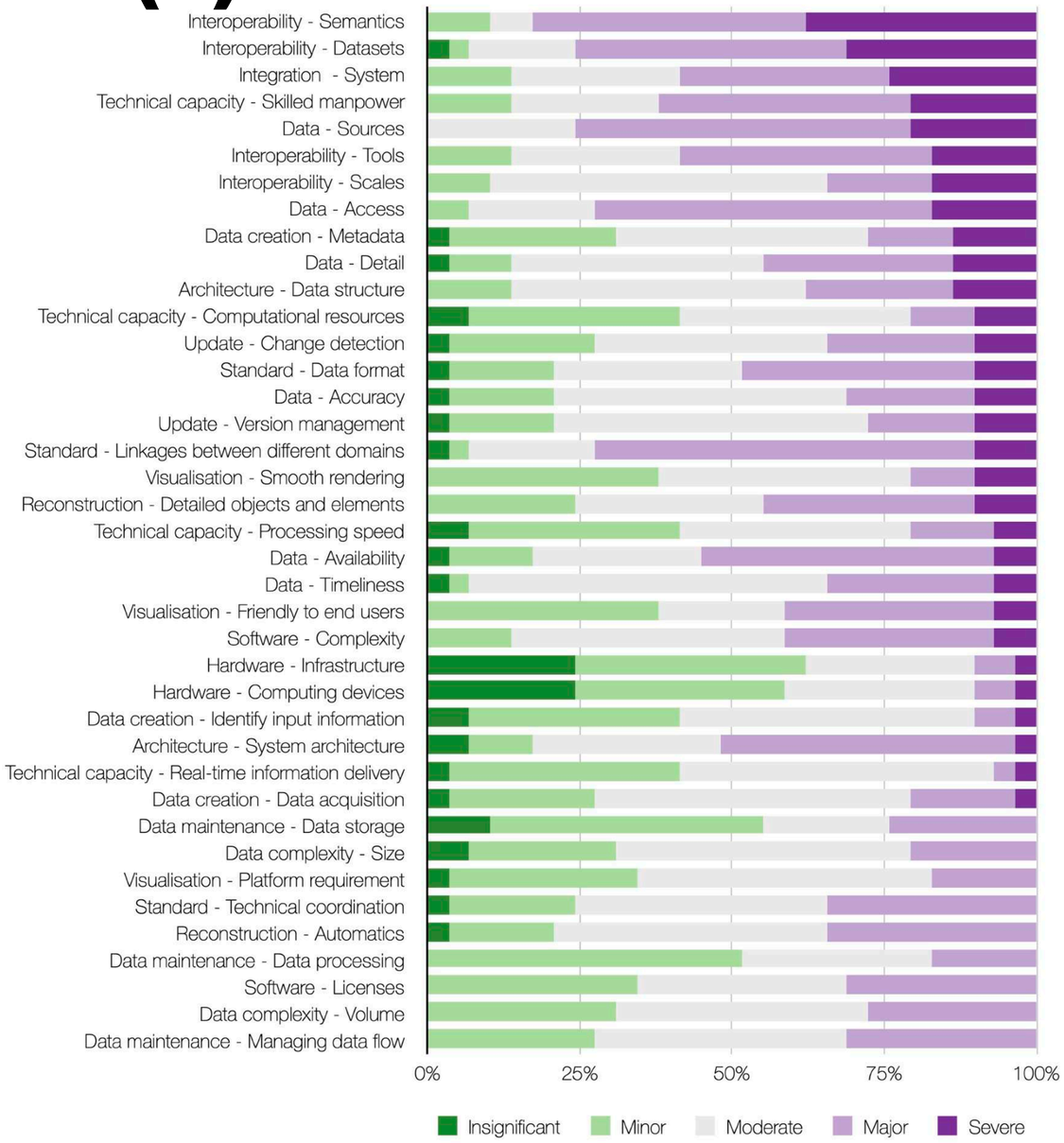
Non-technical challenges

- Understanding
- Practical value
- Collaboration
- Capacity building
- Management
- Data sensitivity
- Ownership
- Trustworthiness
- Participation

Challenges to Digital Twins (4)

Ranking challenges





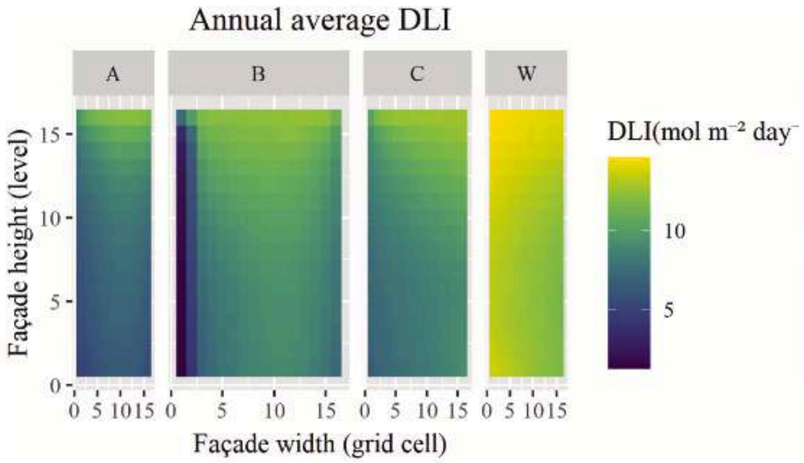
Geospatial technologies in urban farming

Supporting the 30 by 30 vision — Singapore's 30% of nutritional needs by 2030

Credit: Song Shuang

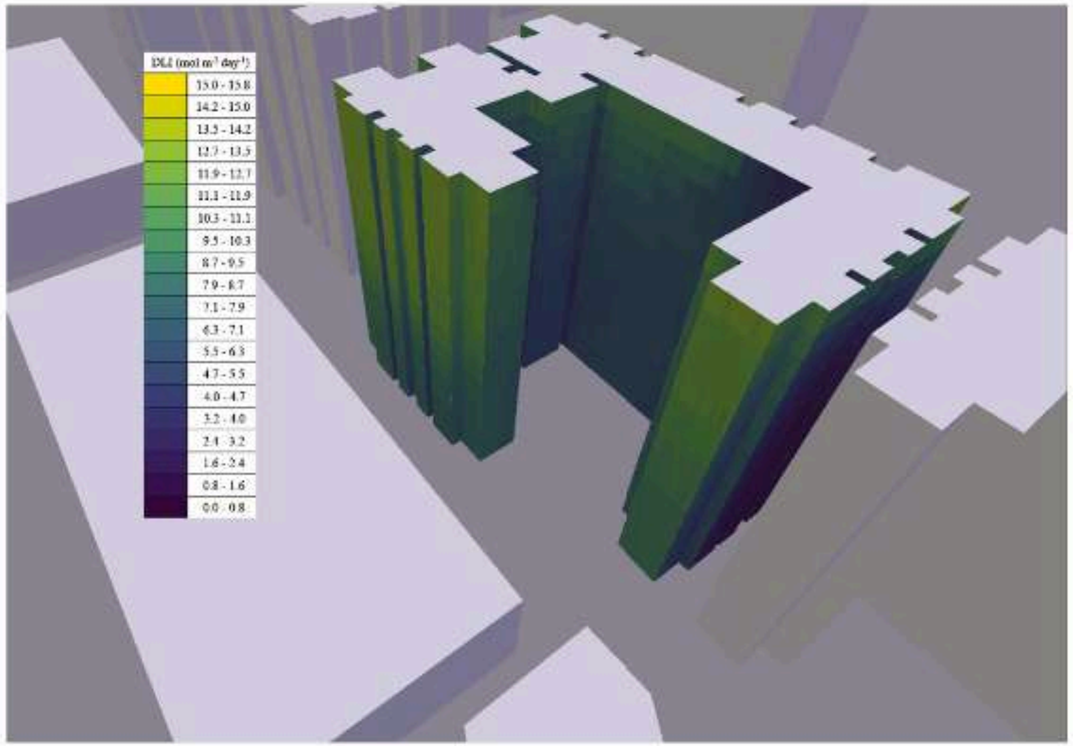
New 3D GIS use case: urban farming simulations

by Ankit Palliwal

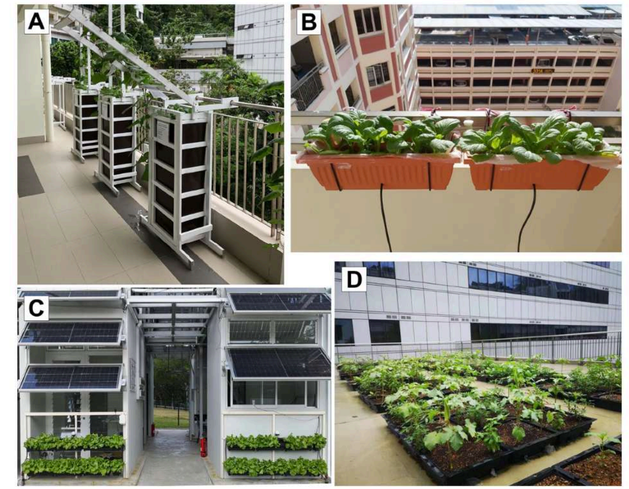


(a) PAR sensor placement along the corridors.

(b) PAR sensor placement on the window ledge.



Published in Computers, Environment and Urban Systems. Credit: Ankit Palliwal



Credit: Song Shuang

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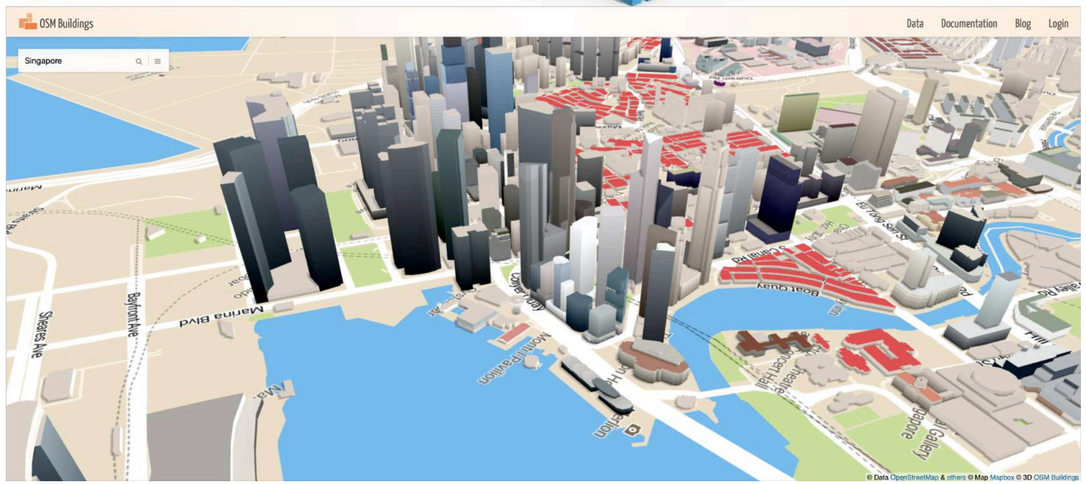
Ongoing research: crowdsourcing 3D models

Exploration of OSM data quality and potential

- Can VGI such as OpenStreetMap be used?
  - Simple — extrusion of footprints to the height (LoD1)
- Benefits to cities that don’t have any 3D data at all
- Part of our broader research on OSM data quality



OSM Buildings

3D cities / urban digital twins from open data

Singapore (CityJSON)

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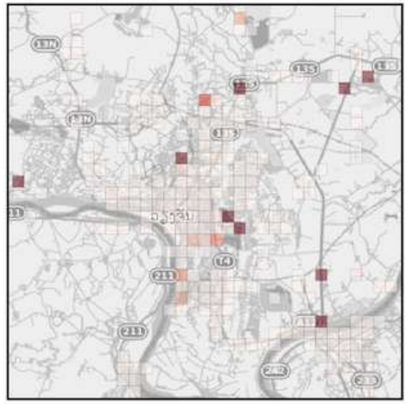
But OSM is very heterogeneous

Bandar Seri Begawan
Brunei

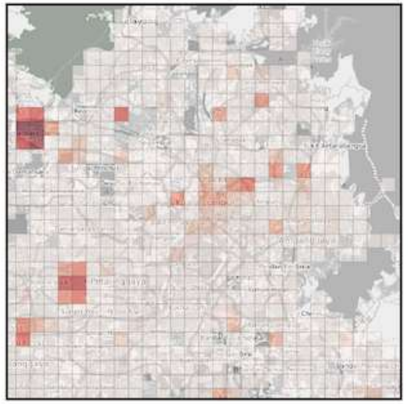
Phnom Penh
Cambodia

Jakarta
Indonesia

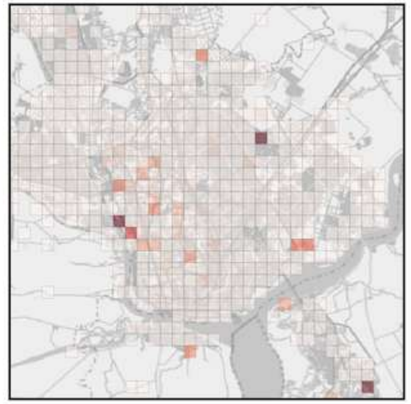
Vientiane
Laos



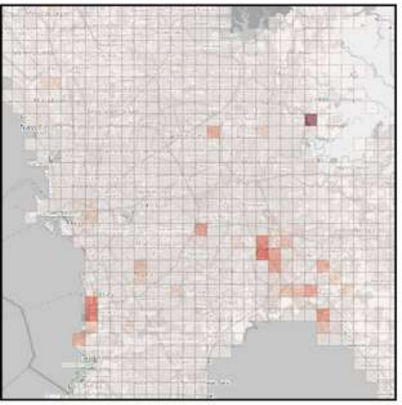
Kuala Lumpur
Malaysia



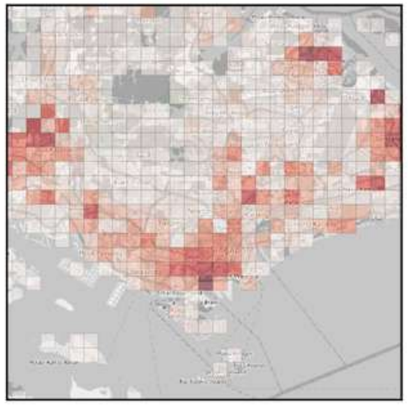
Yangon
Myanmar



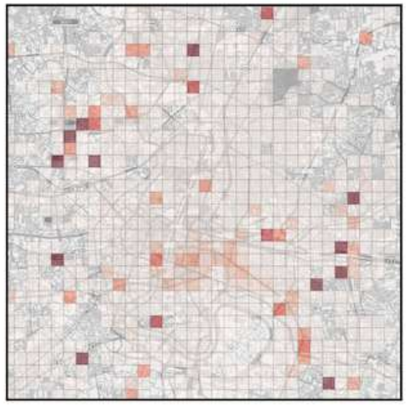
Manila / Quezon City
Philippines



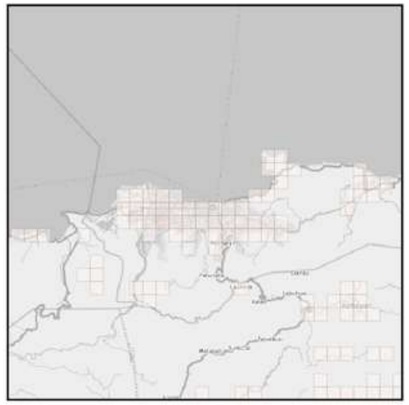
Singapore



Bangkok
Thailand



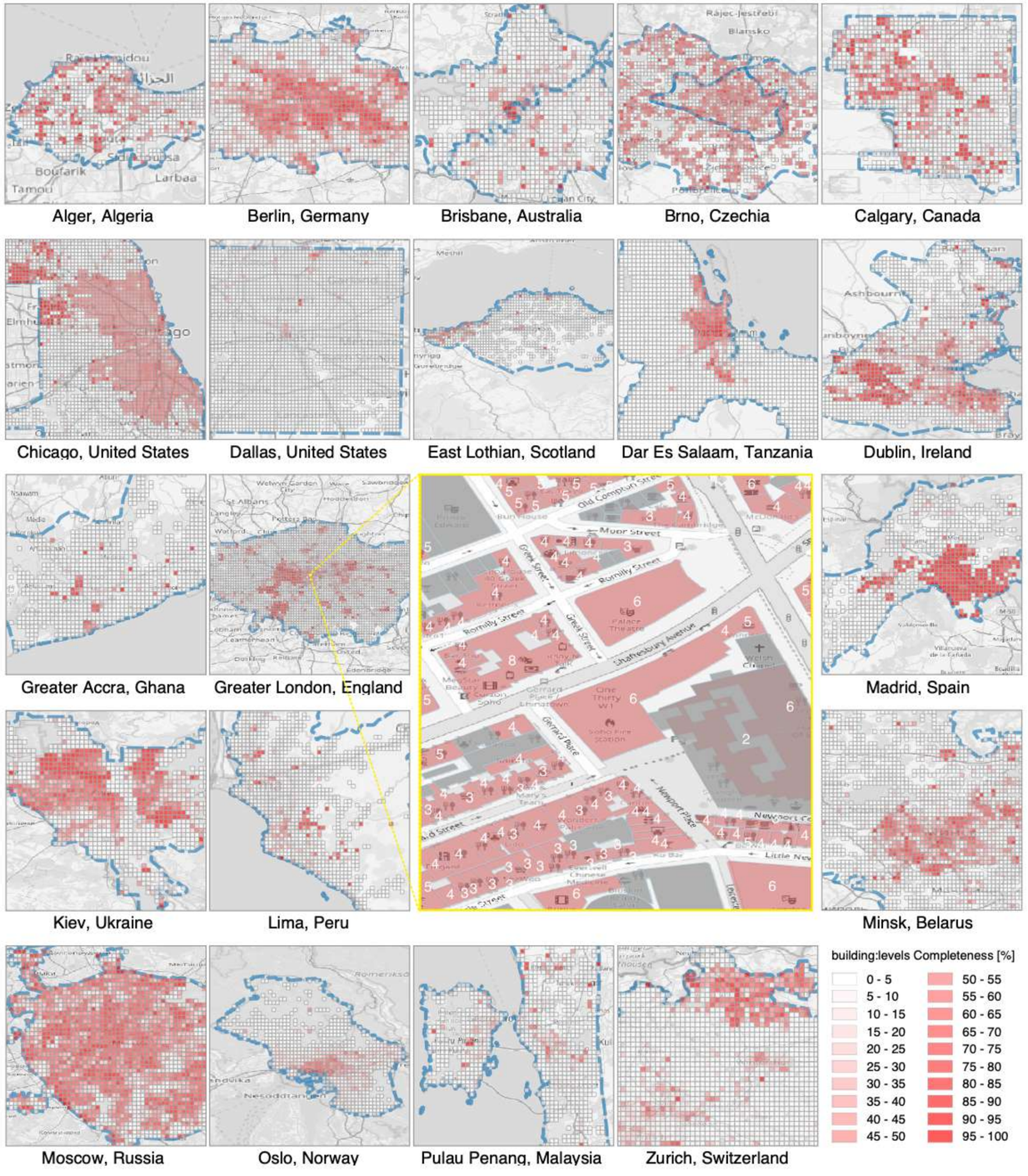
Dili
Timor-Leste

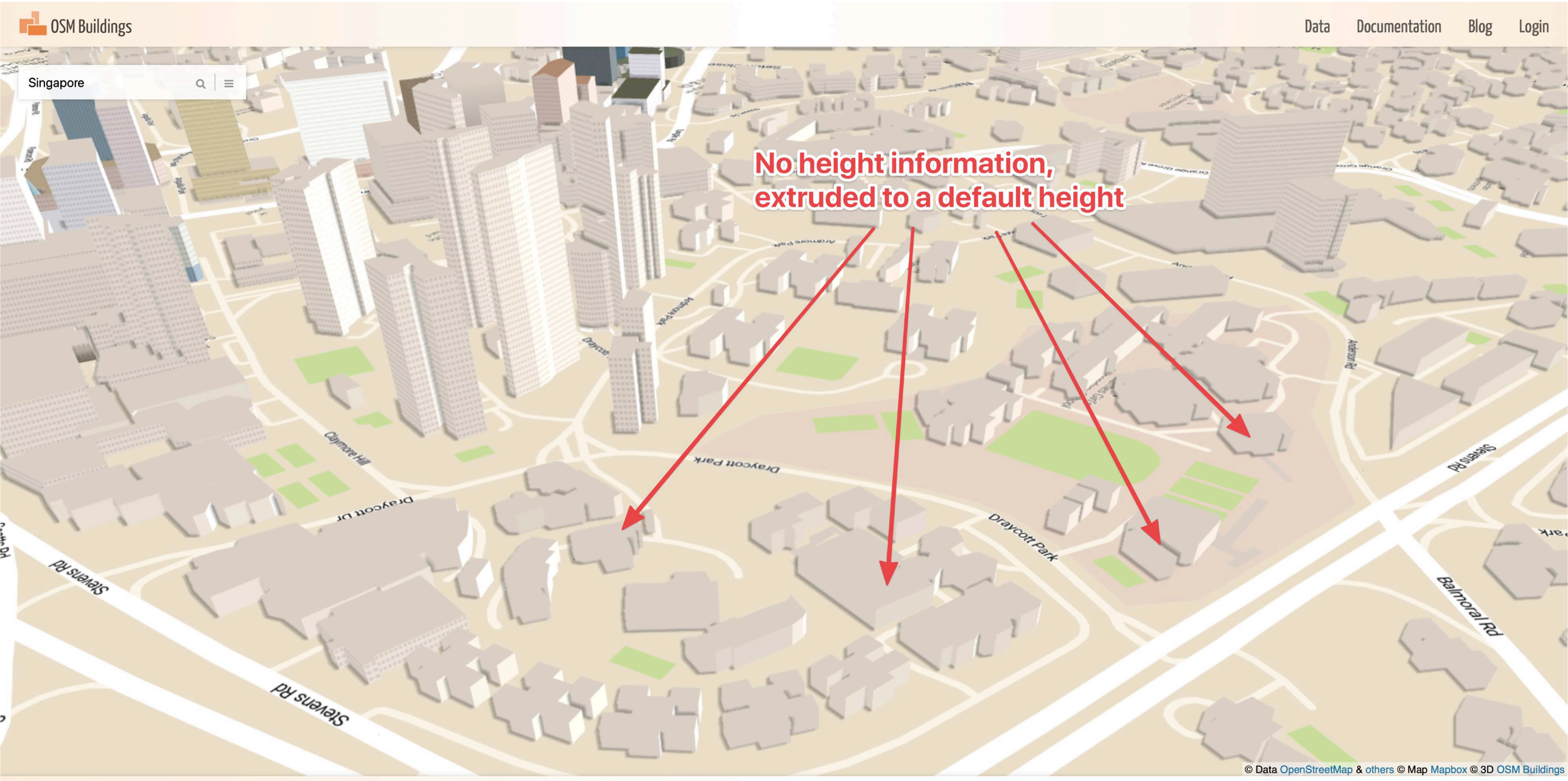


Ho Chi Minh City
Vietnam

Biljecki, F. Exploration of open data in Southeast Asia to generate 3D building models. ISPRS Ann Photogrammetry Remote Sens Spatial Information Sci VI-4/W1-2020, 37–44 (2020).

Country	Buildings (no.)	w/ height [%]	w/ storeys [%]
Brunei	27 545	0.0	8.2
Cambodia	321 810	0.0	0.1
Indonesia	26 924 178	0.0	0.4
Laos	386 802	0.0	0.1
Malaysia	261 918	0.4	4.4
Myanmar	2 539 579	0.0	1.6
Philippines	6 230 123	0.0	0.5
Singapore	100 491	1.0	15.5
Thailand	554 114	0.2	2.2
Timor-Leste	43 173	0.0	0.0
Vietnam	455 653	0.0	1.1
Southeast Asia	37 845 386	0.0	0.6


Alger, Algeria
Berlin, Germany
Brisbane, Australia
Brno, Czechia
Calgary, Canada
Chicago, United States
Dallas, United States
East Lothian, Scotland
Dar Es Salaam, Tanzania
Dublin, Ireland
Greater Accra, Ghana
Greater London, England
Madrid, Spain
Kiev, Ukraine
Lima, Peru
Minsk, Belarus
Moscow, Russia
Oslo, Norway
Pulau Penang, Malaysia
Zurich, Switzerland
building:levels Completeness [%]
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 75
75 - 80
80 - 85
85 - 90
90 - 95
95 - 100


OSM Buildings
Data
Documentation
Blog
Login
Singapore
No height information,
extruded to a default height
Claymore Hill
Draycott Dr
Draycott Park
Stevens Rd
Anderson Rd
Balmoral Rd
© Data OpenStreetMap & others © Map Mapbox © 3D OSM Buildings
© OSM Buildings
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Aspect 1: Change the scale of focus

Example of Kota Kediri, Indonesia

- Great quality in ‘pockets’ of completeness
- District scale is viable
- Lots of use cases focus at such scale
  - Solar, energy district simulations
  - Wind flow

Aspect 2: Filling data gaps

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Generating 3D city models without elevation data

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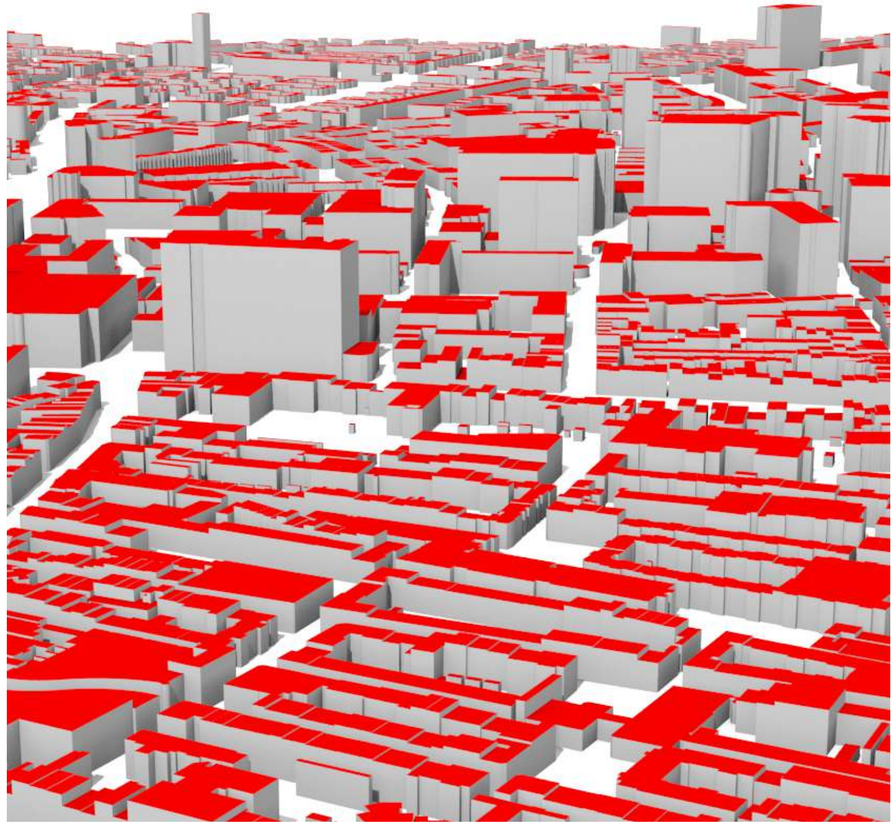
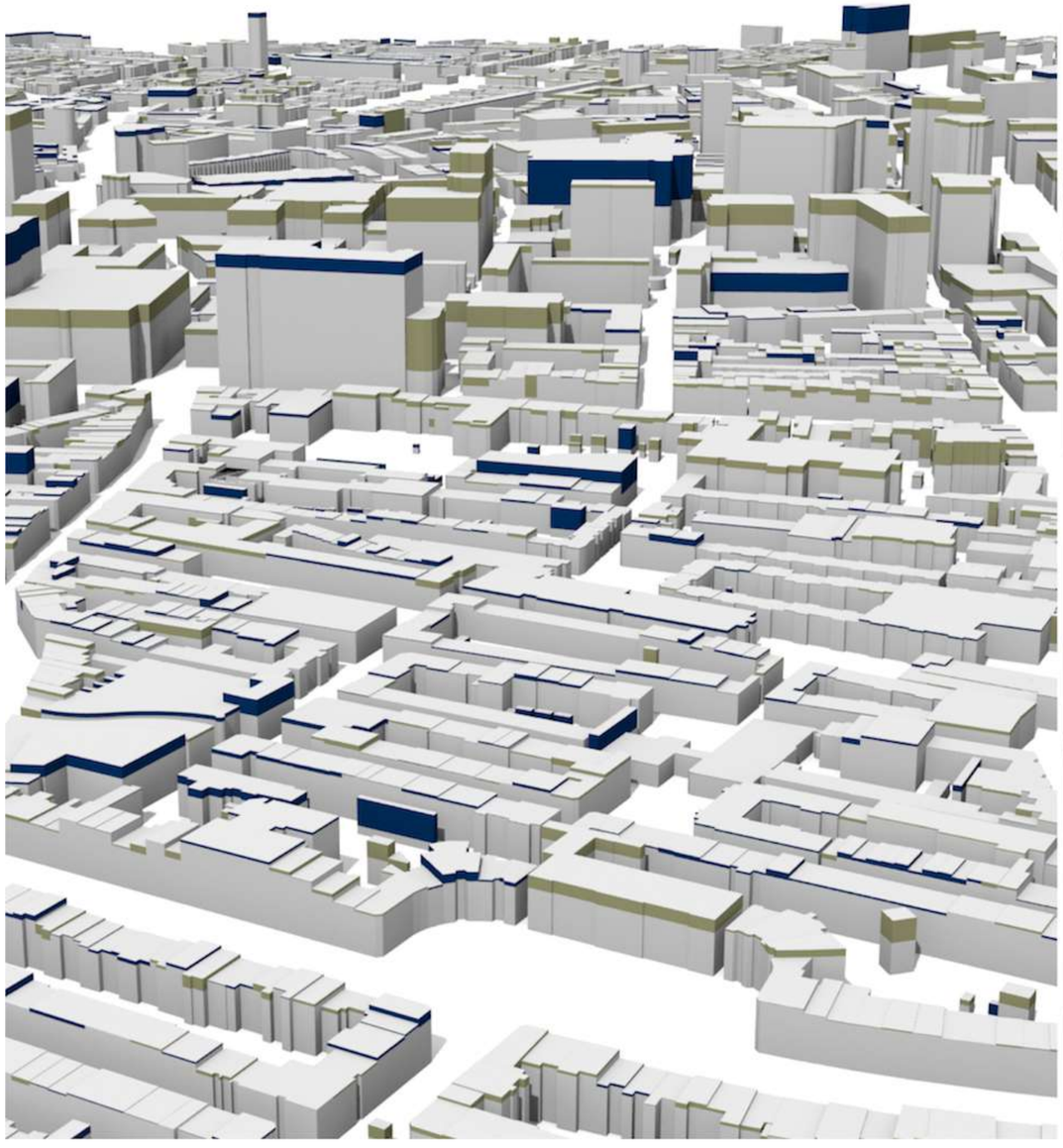
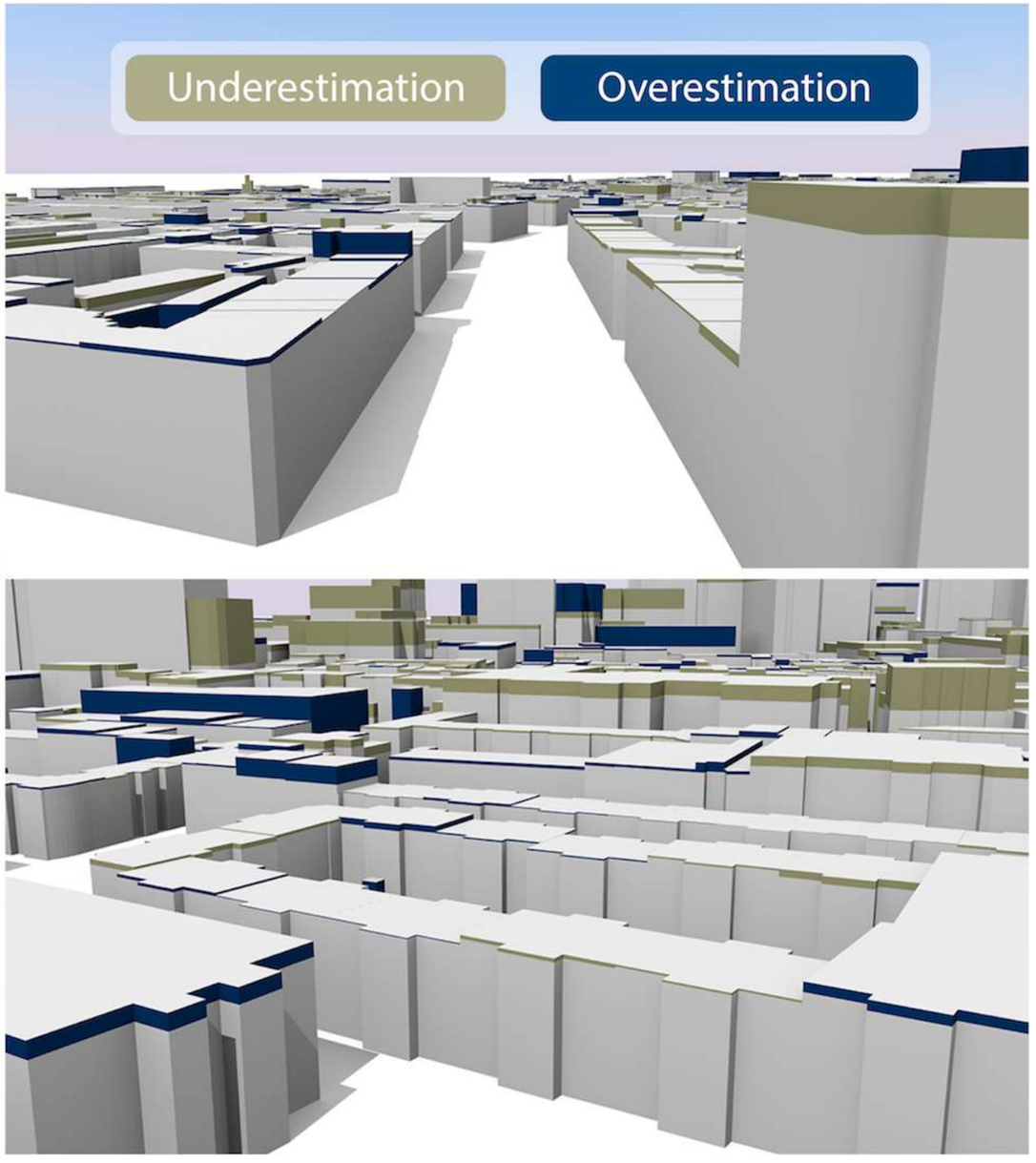
Random forest
CityGML
LOD1

ABSTRACT

Elevation datasets (e.g. point clouds) are an essential but often unavailable ingredient for the construction of 3D city models. We investigate in this paper to what extent can 3D city models be generated solely from 2D data without elevation measurements. We show that it is possible to predict the height of buildings from 2D data (their footprints and attributes available in volunteered geoinformation and cadastre), and then extrude their footprints to obtain 3D models suitable for a multitude of applications. The predictions have been carried out with machine learning techniques (random forests) using 10 different attributes and their combinations, which mirror different scenarios of completeness of real-world data. Some of the scenarios resulted in surprisingly good performance (given the circumstances): we have achieved a mean absolute error of 0.8m in the inferred heights, which satisfies the accuracy recommendations of CityGML for LOD1 models and the needs of several GIS analyses. We show that our method can be used in practice to generate 3D city models where there are no elevation data, and to supplement existing datasets with 3D models of newly constructed buildings to facilitate rapid update and maintenance of data.



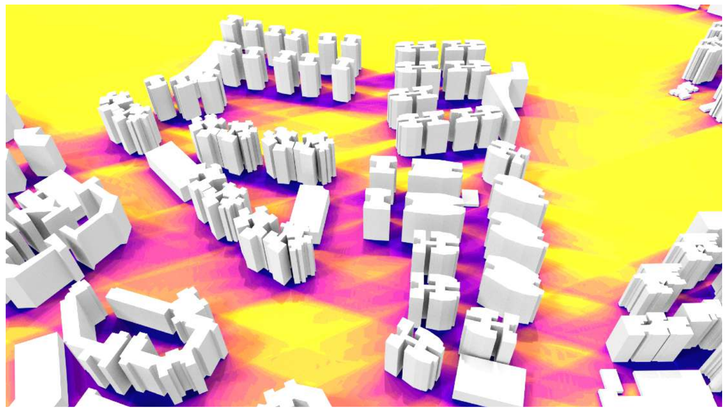



Underestimation
Overestimation

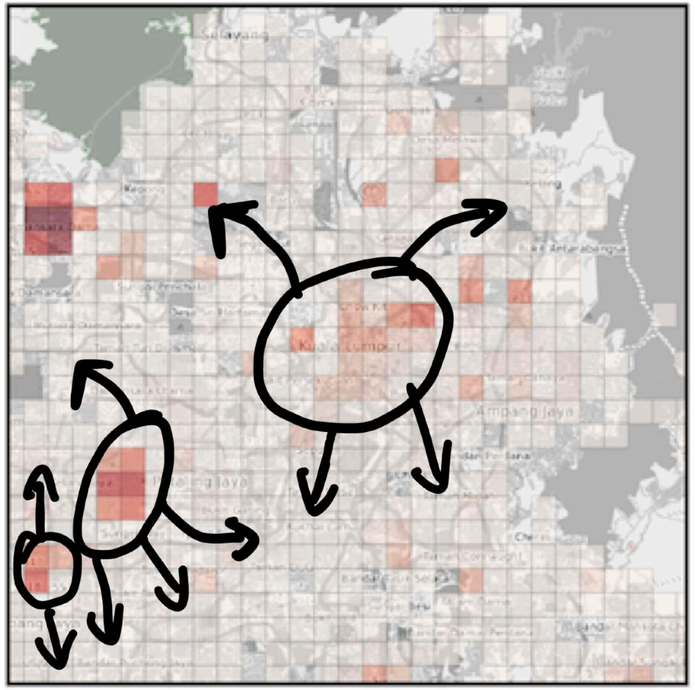
Training the method on precincts to be applied elsewhere

- Train city-specific (morphology-aware) predictive models from the available vertical information in each city, and apply it to the rest

- Not super accurate but good enough for many use cases

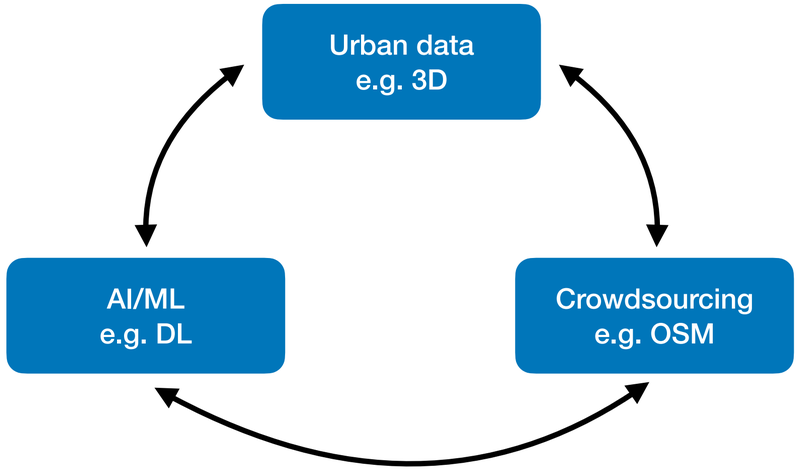


Kuala Lumpur
Malaysia



Looking ahead at our nexus…

What can the Lab do more in the future



- Our trifecta on urban data science and 3D:
  - Deep learning/GAN remain underused and offer lots of potential in GIScience. **Improving quality, completeness, and reliability.**
  - Thanks to 3D city models in regions that did not have any previously, **we may see novel use cases.**
  - With the growing geospatial data, it's important to set up means to benchmark them and assess their quality. Not a new topic, but much more can be done. **Urban data/analytics scientists tend to take data for granted.**

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