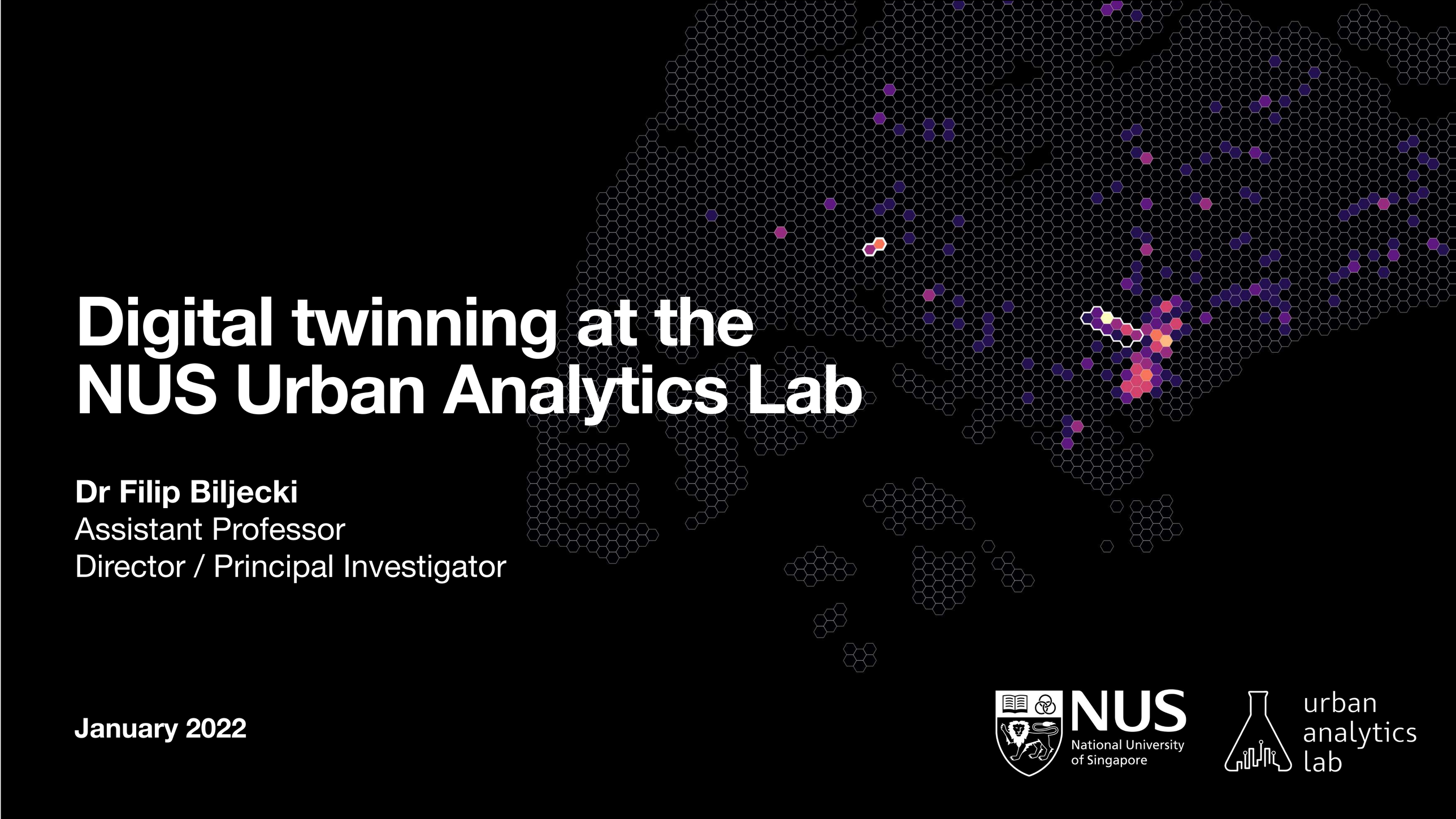


Digital twinning at the NUS Urban Analytics Lab

Dr Filip Biljecki
Assistant Professor
Director / Principal Investigator

January 2022

NUS National University of Singapore

urban analytics lab

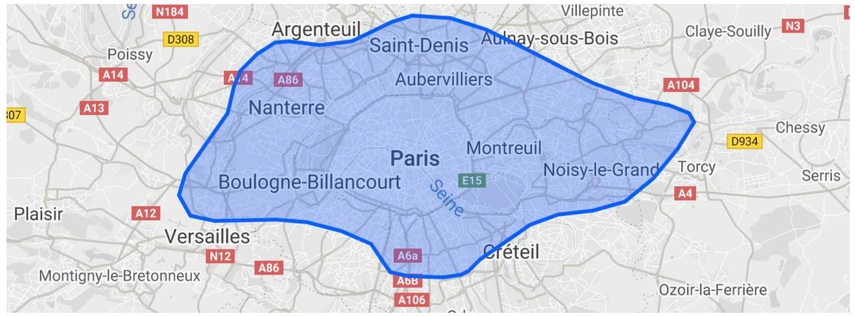
“A set of virtual information constructs that mimics the structure, context and behavior of an individual / unique physical asset, or a group of physical assets [city?], is dynamically updated with data from its physical twin throughout its life cycle and informs decisions that realize value.”

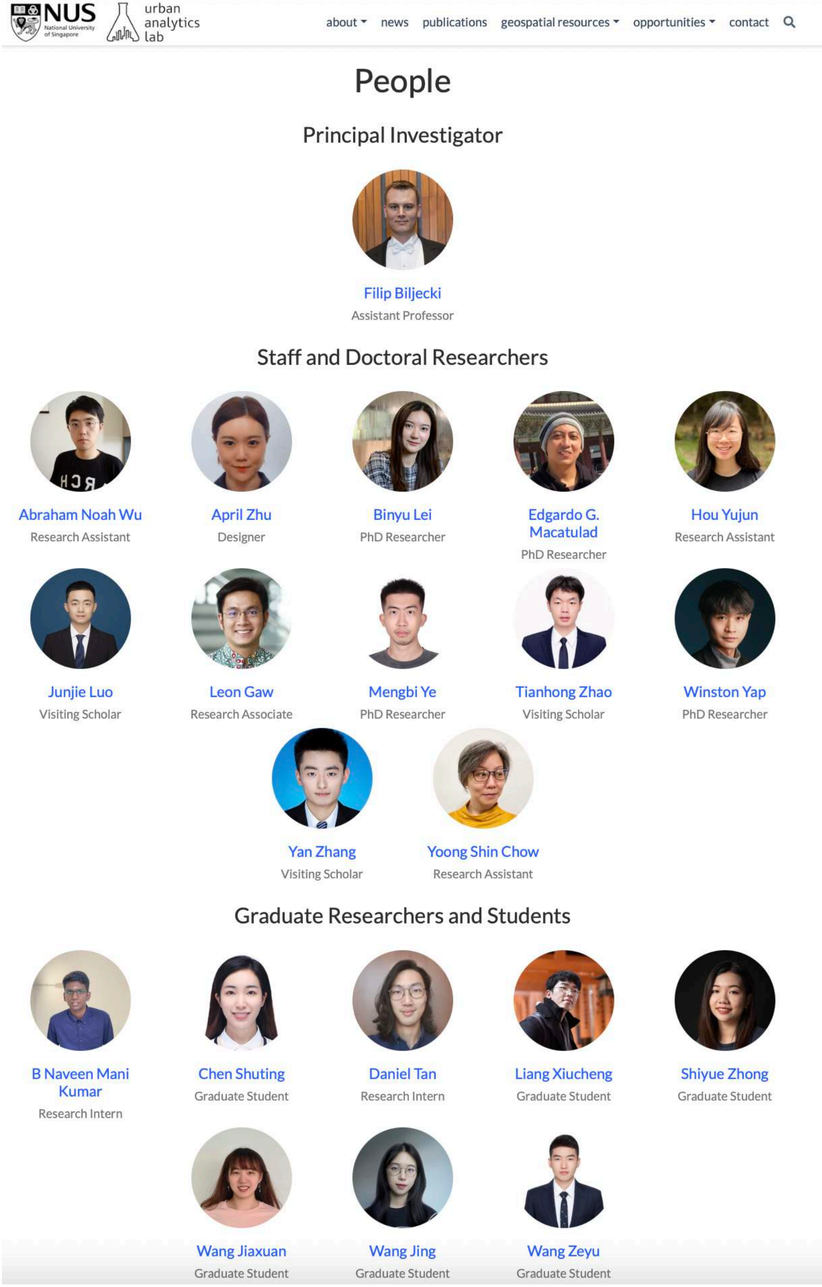
AIAA and AIA Position Paper Digital Twin: Definition & Value (December 2020)
American Institute of Aeronautics and Astronautics & Aerospace Industries Association

Our research group

NUS Urban Analytics Lab

- Since 2019
- Urban data science & geospatial engineering seasoning digital twins
- Singapore context 🇸🇬
  - Land scarce (city-state 🏙️)
    [space management, 3D, highly urbanised]
  - Tropical climate 🏝️
    [simulations]





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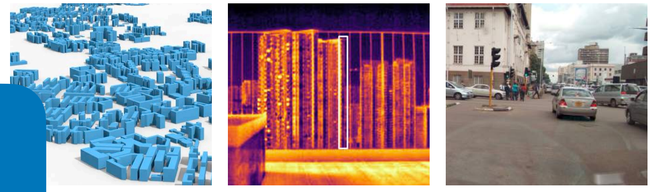
The focus of the Lab's research

Amplifying the nexus of three worlds



Urban data
e.g. 3D GIS

Geospatial science
Urban analytics
Urban studies
Digital twins 💫

AI/ML
e.g. DL

Crowdsourcing
e.g. OSM

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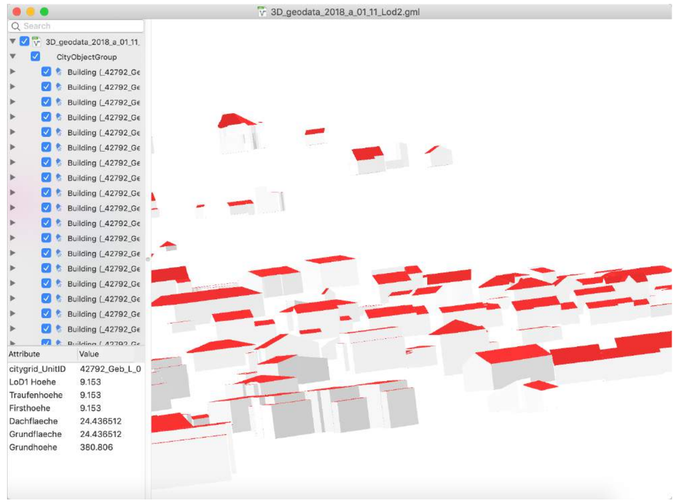
Content of this 15-min presentation:

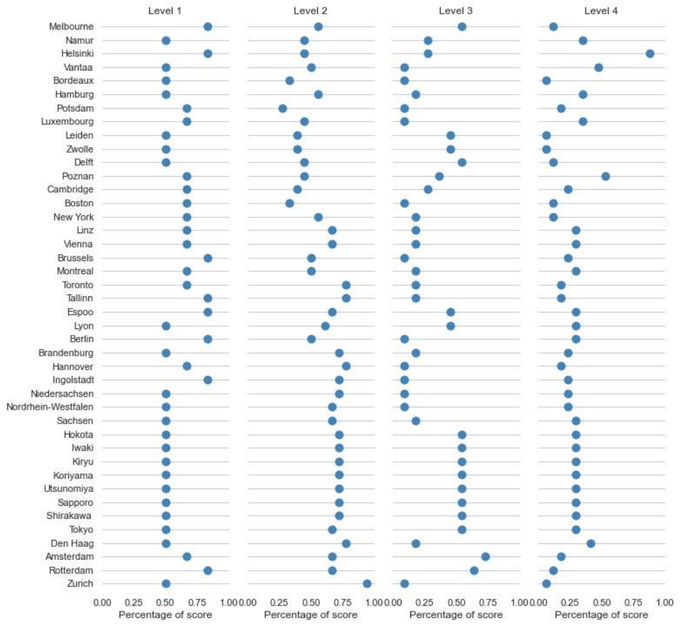
- Collection of our past and current research
- Next research: NUS Digital Twin project

Assessment and benchmarking 3D city models / DTs

by Binyu Lei

- Gap: a formalised approach to assess 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
    - Only open 3D data — doubles as an inventory of openly available 3DCM, assessed by their properties
    - Another benefit: looking for a dataset with specific properties (e.g. a LoD2 model containing tunnels and updated within the last 3 years)? — we know one ☑️





Binyu’s next step: challenges in the adoption of digital twins

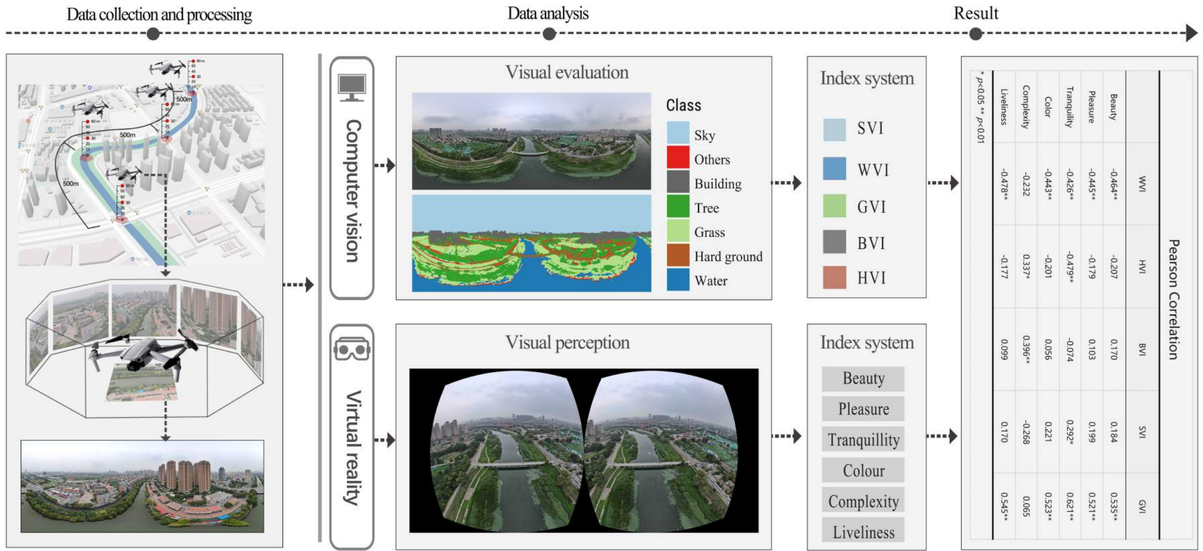
What are the issues that practitioners face and how severe they are?

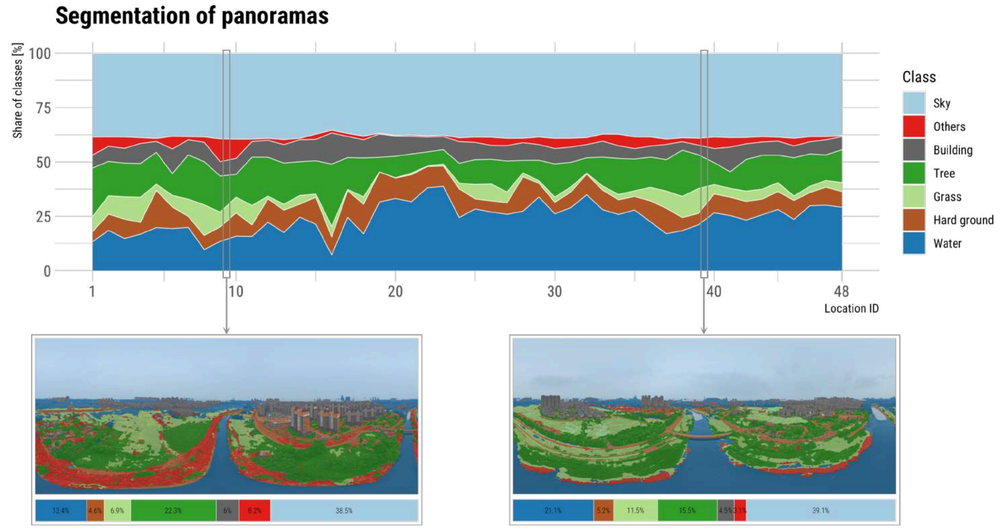
- Inventory of issues, challenges, and barriers ❌
  - Examples: software support, skillsets, interoperability, legislation, integrity
  - Longterm aspiration: solutions to overcome barriers to the adoption of 3D/DTs ✅
- Holistic method: systematic review (academia) + survey (NMAs, industry)
    - Delphi method
    - Ethics clearance by the NUS Institutional Review Board
- Please let us know if you want to participate in this research! Short surveys (5-10 min)

Infusing perception of landscapes into digital twins

by Junjie Luo

- Can we integrate perception as a dimension? Can we predict how people will react to a change in the landscape?
- Automated assessment of perception -> simulating changes to the landscape

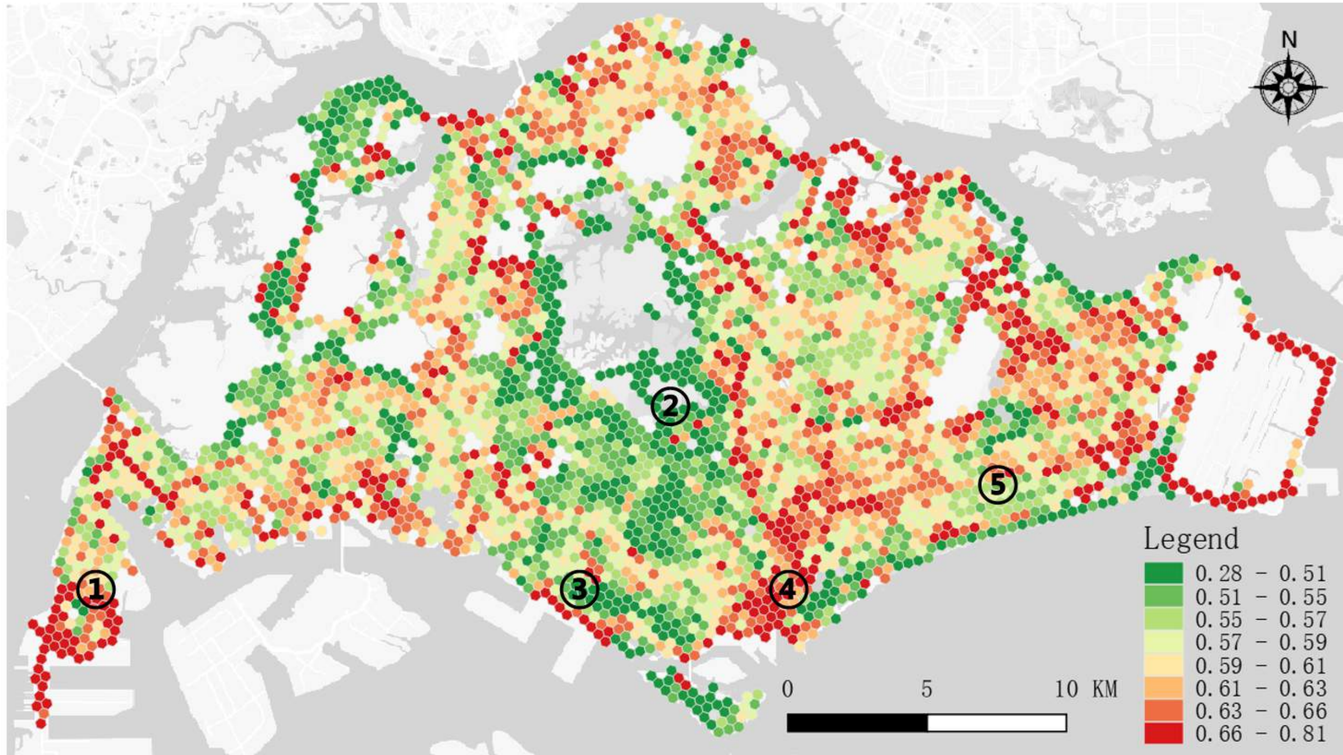




Urban soundscapes from images

by Tianhong Zhao & Xiucheng Liang

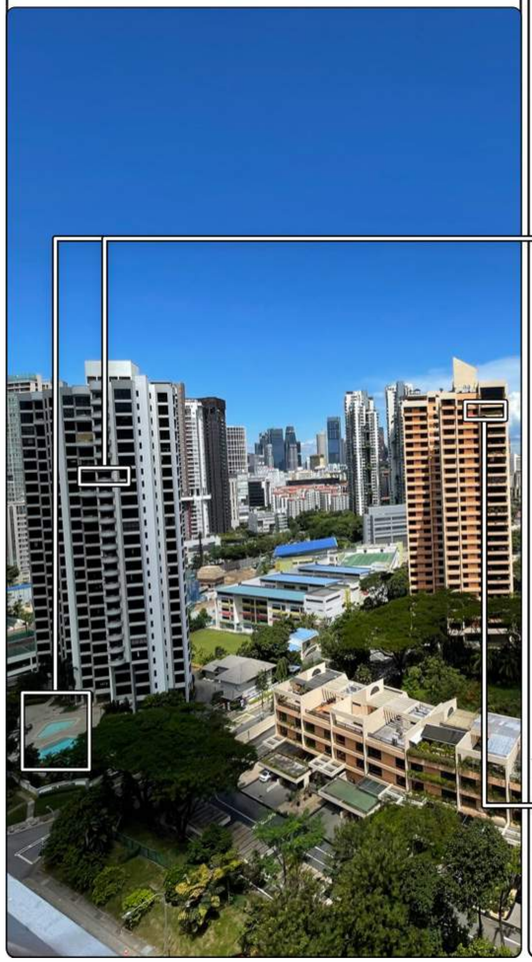
- 🌃➡️🔊 (images to sound)
- Large-scale hi-res soundscape map
- Intensity & nature (industrial noise, human noise, traffic noise, …)
- Integrating soundscapes in digital twins, and predicting changes based on redevelopment



Exploiting real estate data to synchronise data on buildings

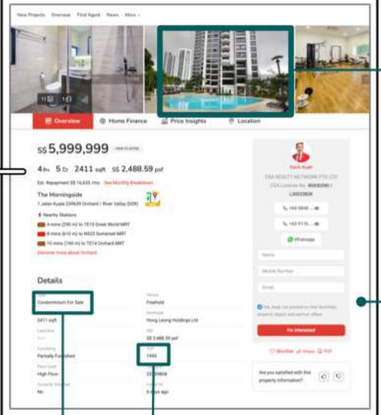
by Chen Xinyu

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

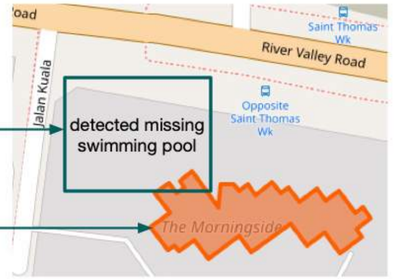
Type	TOP
Condominium For Sale	1993

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

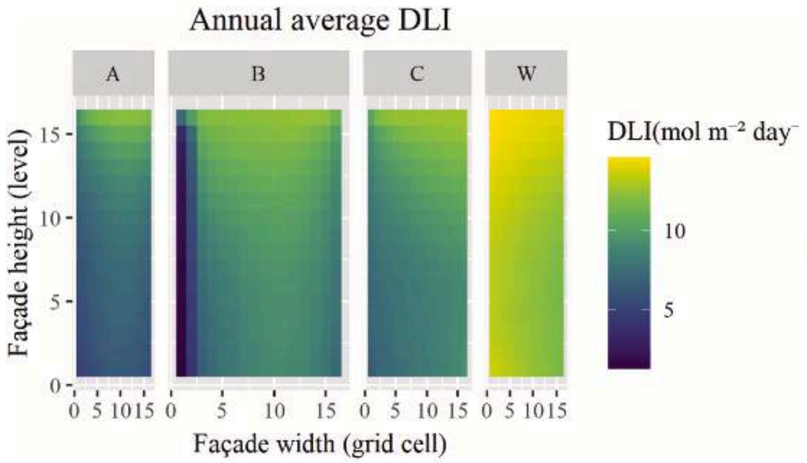
Geospatial technologies in urban farming

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

Credit: Song Shuang

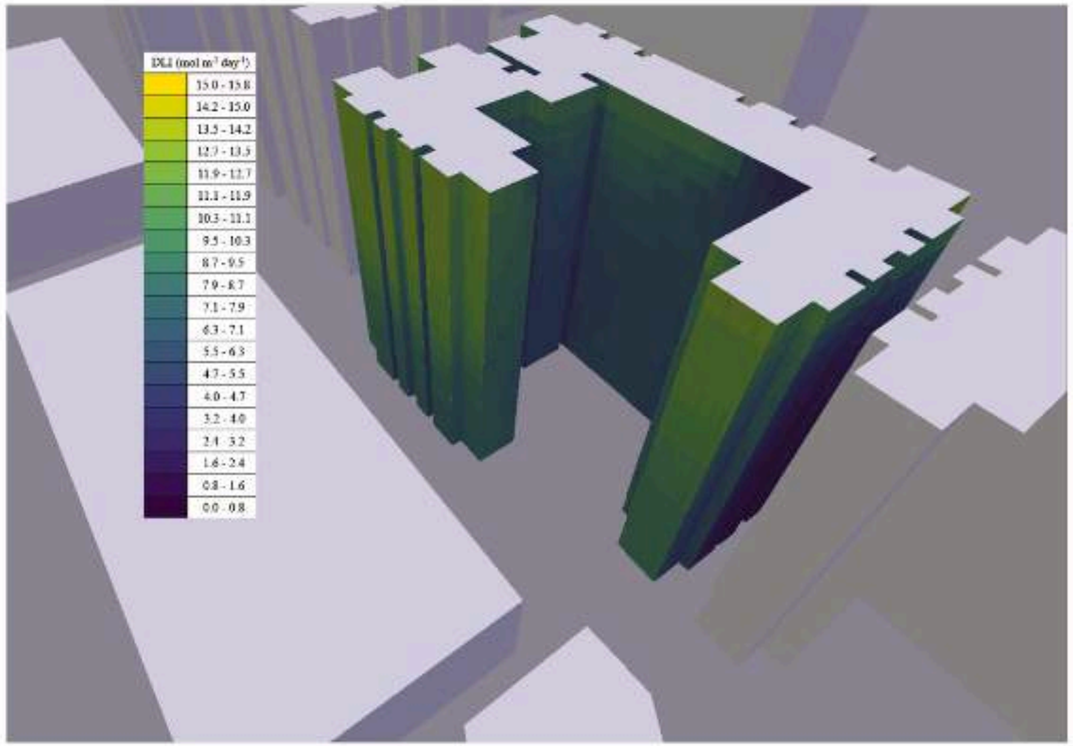
New 3D GIS use case: urban farming simulations

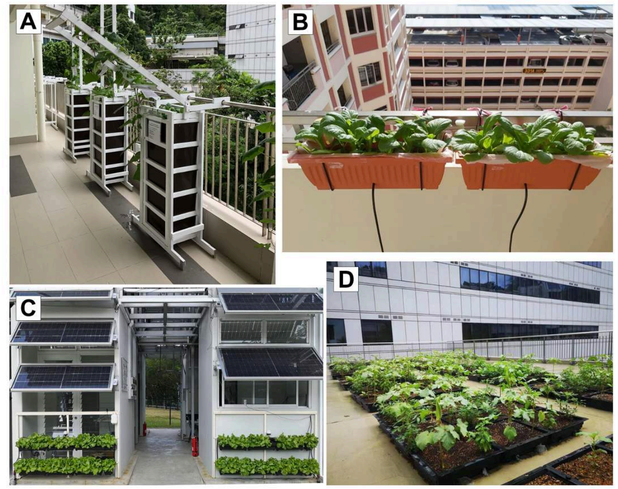
by Ankit Palliwal



(a) PAR sensor placement along the corridors.

(b) PAR sensor placement on the window ledge.





Credit: Song Shuang

Palliwal, A., Song, S., Tan, H. T. W. & Biljecki, F. 3D city models for urban farming site identification in buildings. Comput Environ Urban Syst 86, 101584 (2021).

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Generating 3D city models from open data

Maximising the coverage and outreach of 3D geoinformation

- Conflating 2D footprints + semantic information + heights
- Machine learning involved — prediction of heights where they are no available
- Two venues
    - Government data
    - Crowdsourced data: OpenStreetMap

OpenStreetMap content in Southeast Asia

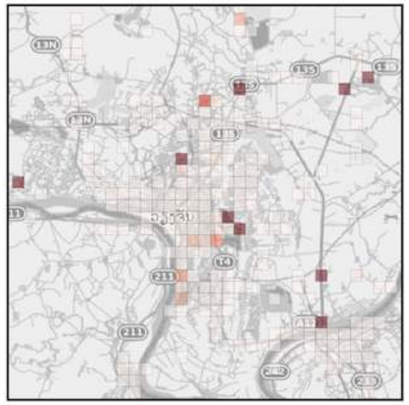
Potential of generating 3D city models from OSM

Bandar Seri Begawan
Brunei

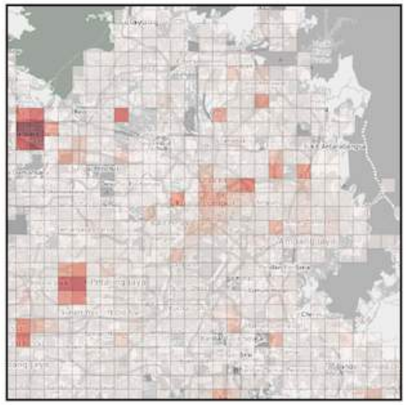
Phnom Penh
Cambodia

Jakarta
Indonesia

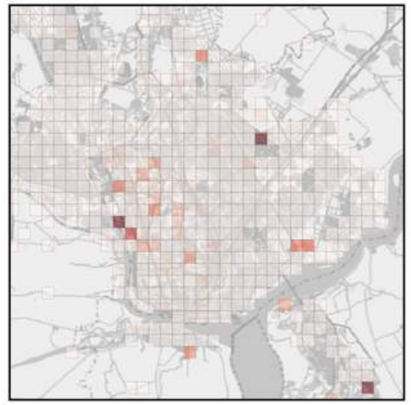
Vientiane
Laos



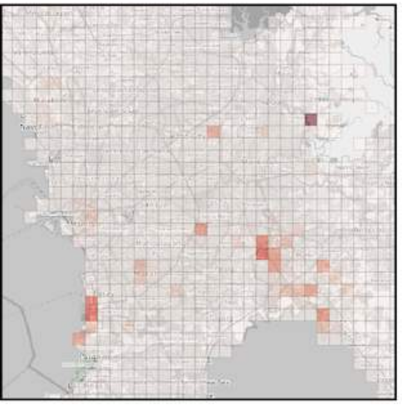
Kuala Lumpur
Malaysia



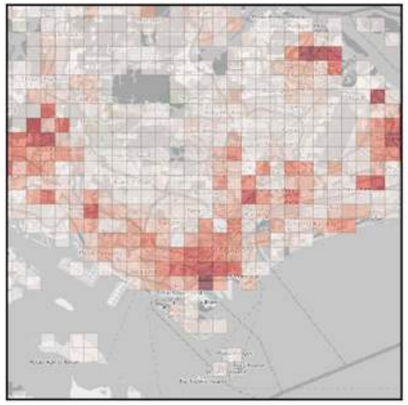
Yangon
Myanmar



Manila / Quezon City
Philippines

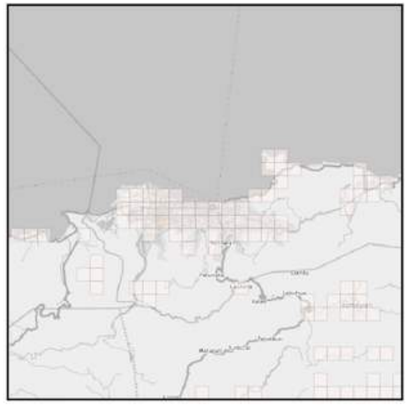


Singapore



Bangkok
Thailand

Dili
Timor-Leste



Ho Chi Minh City
Vietnam

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Building levels completeness

0% 100%

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).

3D cities / urban digital twins from open data

Singapore (CityJSON)

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Roofpedia

Global open registry of roofs for urban sustainability

Credit: Abraham Noah Wu

by 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

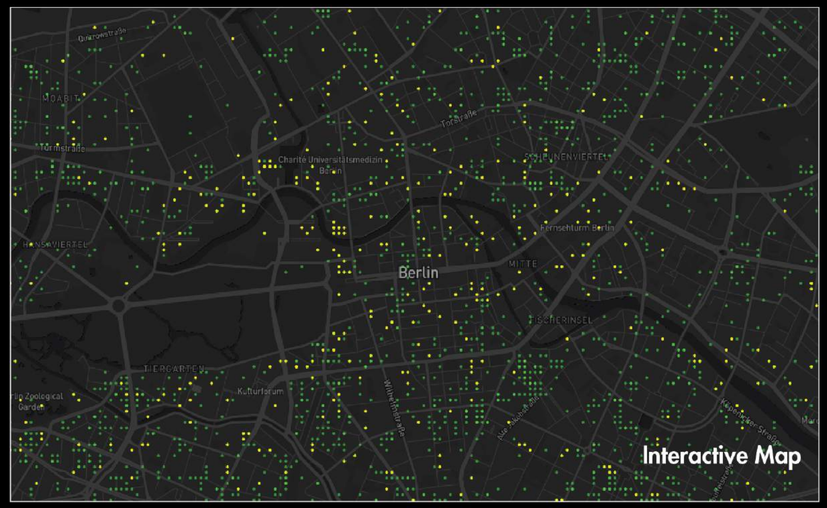
Convolutional Neural Network

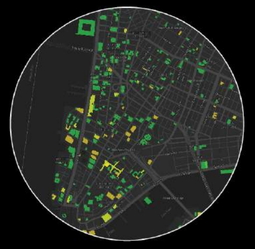
Rooftop Solar Panels | Rooftop Vegetation

GIS Processing

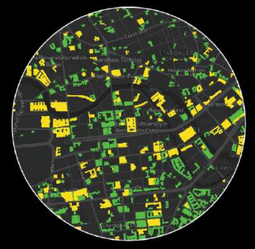
Solar Roofs | Green Roofs

Roofpedia Registry

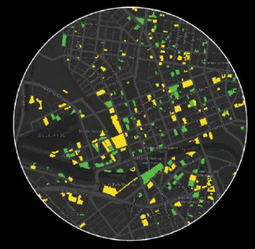




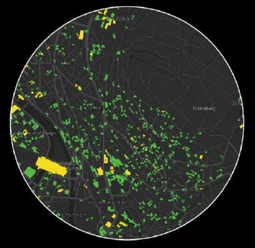
New York



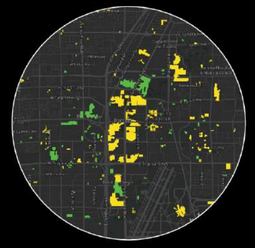
Berlin



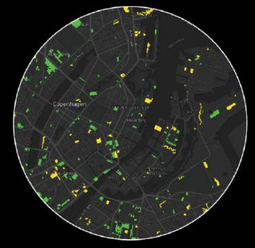
Melbourne



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

What’s next?

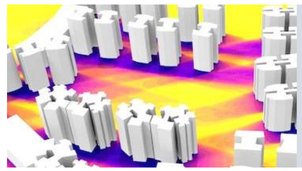
NUS Digital Twin Project

Cohesive, participatory, and integrated

NUS
National University
of Singapore

Goals of this project

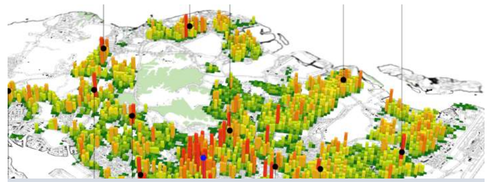
- Aims
  - Pronounce dynamic data in DTs
  - Investigate the role of crowdsourcing in DTs
  - Self-healing digital twins
  - Include underused forms of data (e.g. thermal)
  - Provide support to dynamic use cases
    - Liveable, healthy, and net-zero campus
      - Personal comfort, energy (indoor)
        - Sensors and robotic systems 🤖
      - Climate modelling (outdoor)



WP3. Participatory cohesive digital twins
Task 1. Spatial data infrastructure
Task 2. Data integration
Task 3. Participatory paradigm
Task 4. Breaking the silos

WP1. Advanced sensors and robotic systems for occupant-aware buildings
Task 1. Sensor development
Task 2. Occupant experiences
Task 3. IoT and edge computing
Task 4. Cognitive systems

Resiliency, sustainability, and wellness

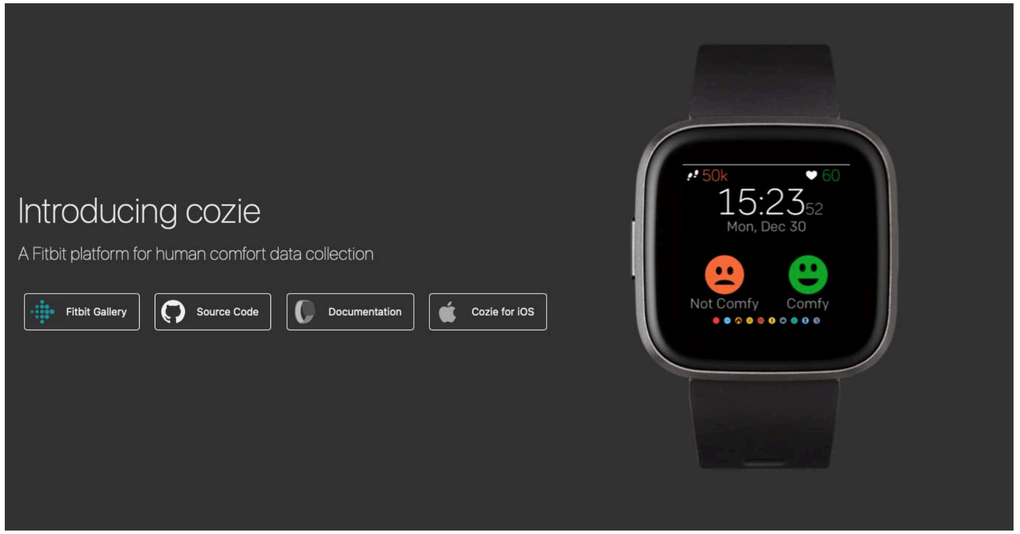


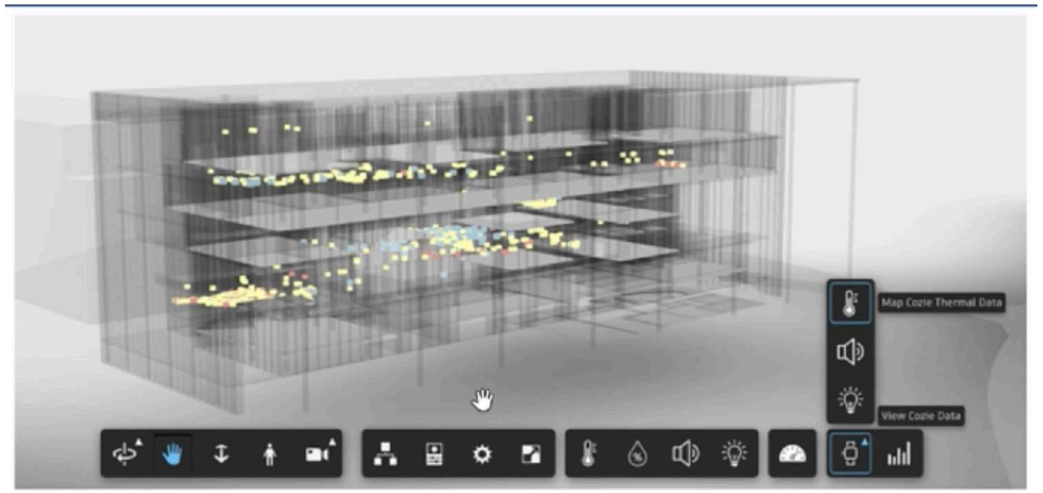
WP2. Climate modeling for pre-emptive design
Task 1. Climate change uncertainty
Task 2. Air quality & thermal comfort modeling
Task 3. Outdoor sensing
Task 4. Urban planning and design

Human and energy data in indoor environments

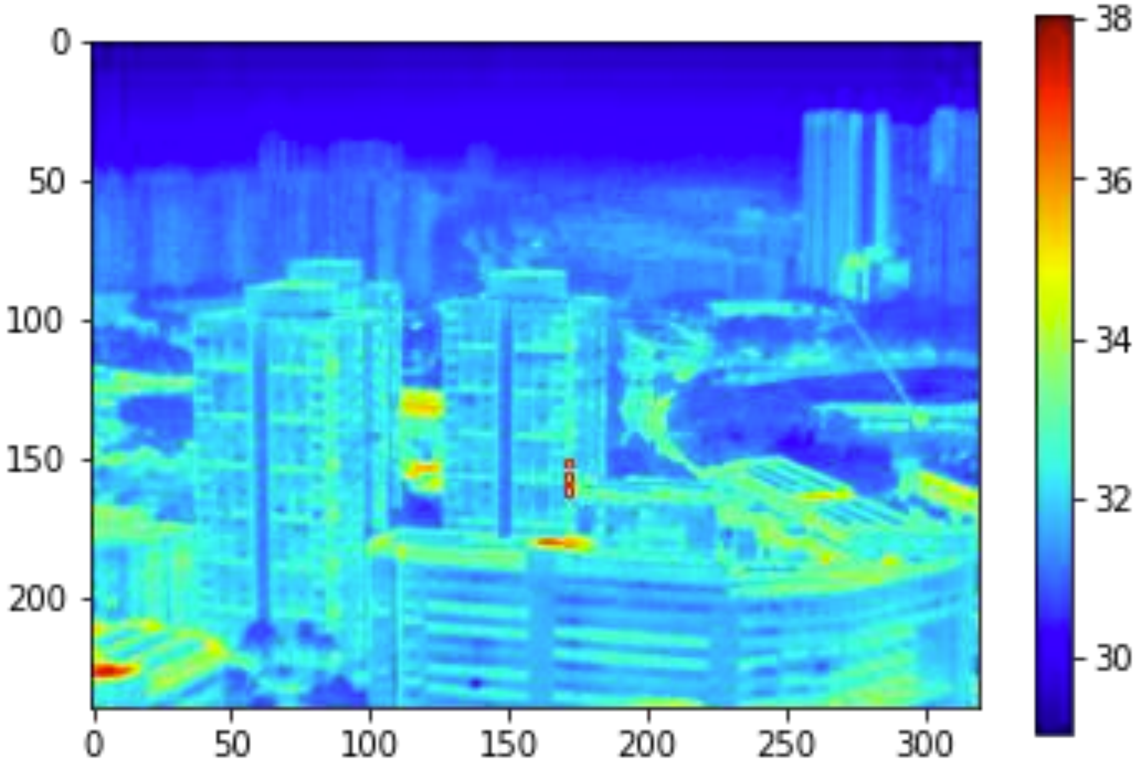
Work of our sister labs — Prof Clayton Miller and Prof Adrian Chong

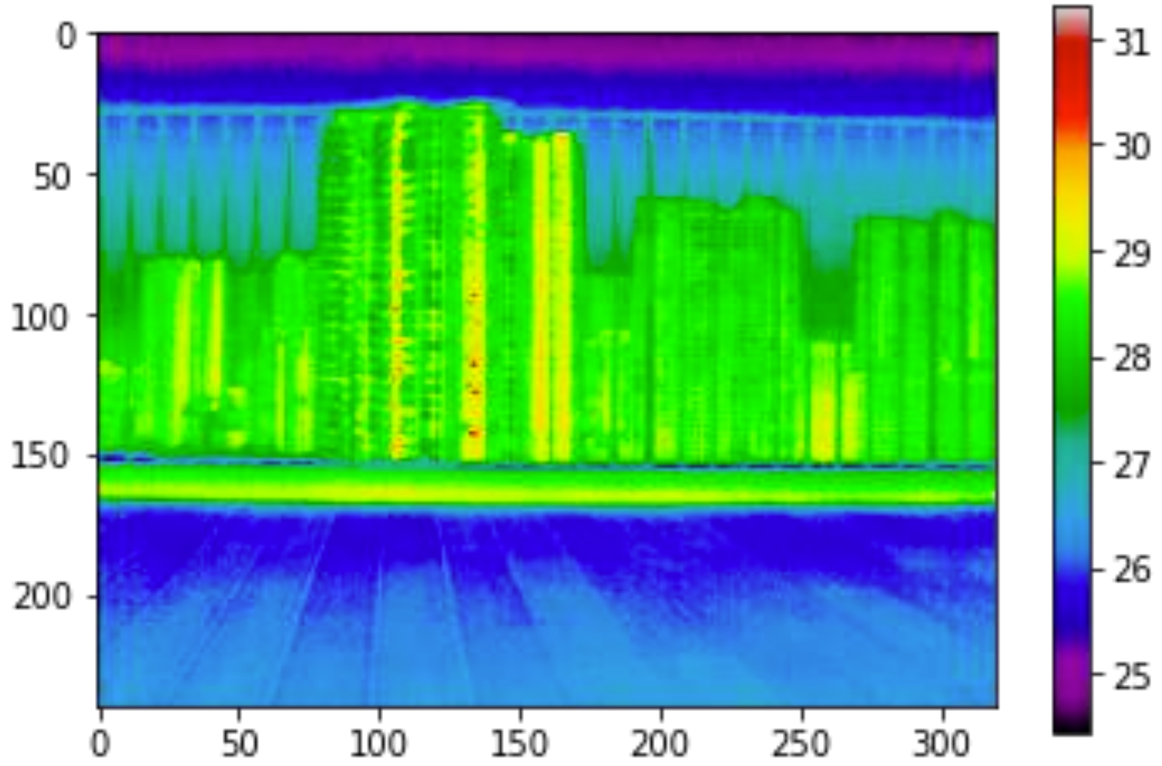
- Integration of dynamic and crowdsourced data in digital twins





Thermal imaging of the cityscape





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Acknowledgements

Team: Abraham Noah Wu, April Zhu, Binyu Lei, Edgardo G Macatulad, Hou Yujun, Junjie Luo, Leon Gaw, Mengbi Ye, Tianhong Zhao, Winston Yap, Yan Zhang, Yoong Shin Chow, B Naveen Mani Kumar, Chen Shuting, Daniel Tan, Liang Xiucheng, Zhong Shiyue, Wang Jiaxuan, Wang Jing, Wang Zeyu
Alumni: Pang Hui En, Ankit Palliwal, Ethan Chen, Lawrence Chew, Kay Lee, Koichi Ito, Chen Wangyang, Chen Xinyu

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