



THE UNIVERSITY OF HONG KONG 香港大學
faculty of architecture 建築學院



iLab | @HKURBAN
the urban big data lab

ICSBS 2019

Semantic enrichment of city information models with LiDAR-based rooftop albedo

26 October 2019

Xue, F.*, Lu, W., Tan, T., & Chen, K.,

Assistant Professor
Dept. of REC / iLab
FoA, HKU, HKSAR, PRC





iLab

Outline



Background



Semantic Enrichment using LiDAR



Discussion

Section 1

BACKGROUND



1.1 Background



iLab

◆ Global urbanization

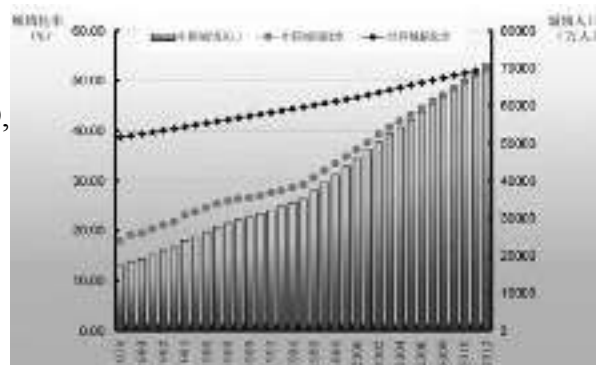
- ▣ By 2050, 65% world's population will live in cities (WHO, 2015)
- ▣ Irreversible; Even faster in China

◆ Leads to urban vulnerability (a.k.a. 'city diseases')

- ▣ 'Dead' space/landscape, low familiarity with surroundings,
- ▣ Poor waste treatment, environment (air, water) pollution,
- ▣ Heritage destruction, aging town blocks, inefficient traffic,
- ▣ Disasters (earthquake, climate change), resource crisis, ...

◆ Demands smarter and more resilient development

- ▣ (a) Smarter analysis and decisions in multiple disciplines
- ▣ (b) On basis of accurate, timely urban semantics



China's and global urbanization rates

source: gov.cn



Global urban vulnerability level (Birkmann et al, 2016) source: nature.com



1.2 Urban semantics

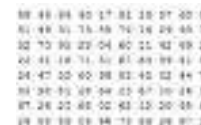


iLab

- ◆ Why semantics from signals? (Rowley & Hartley, 2017)
 - ▣ Answering interrogative questions (*what, who, where, when*)
 - ▣ Enabling automated reasoning / checking
 - ▣ Abstracted, processed from data and signals
- ◆ Types of urban semantics
 - ▣ Geometric: Dimension, location, rotation, color, ...
 - ▣ Non-geometric facts: Function, materials, history, owner, ...
 - ▣ Instructions (how-to): Manufacturing, installation, access, ...
- ◆ Common databases / interfaces
 - ▣ BIM/CIM: building/city information model
 - ▣ GIS: geographic information system



Data: Digital pixels
(0~255 R, G, B)



Semantics: Car,
building, tree, ...



1.3 Roofs



iLab

◆ Considerable in typical metropolises

- ▣ 20~25% urban surfaces (Rose et al. 2003)

◆ Rooftop albedo

- ▣ Reflected (other than absorbed) solar radiation by coatings

- → Negative radiative forcing

- ▣ At a worldwide level, every year (Akbari et al. 2009)

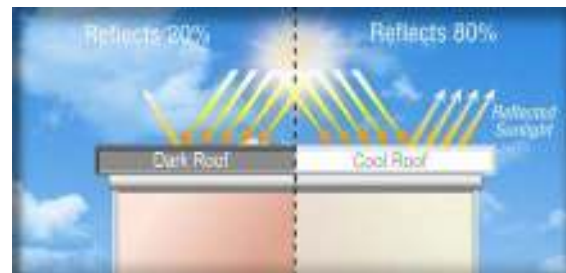
- Offsets billions of tons of CO₂ emissions
 - billions of dollars of energy bills

- ▣ Became mandated in certain areas

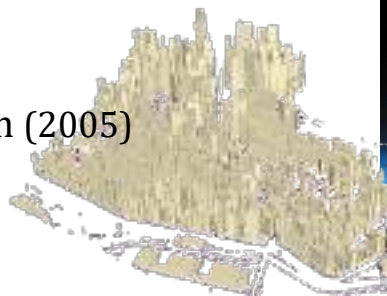
- E.g., California Energy Commission (2005)

◆ Problems in CIM roofs

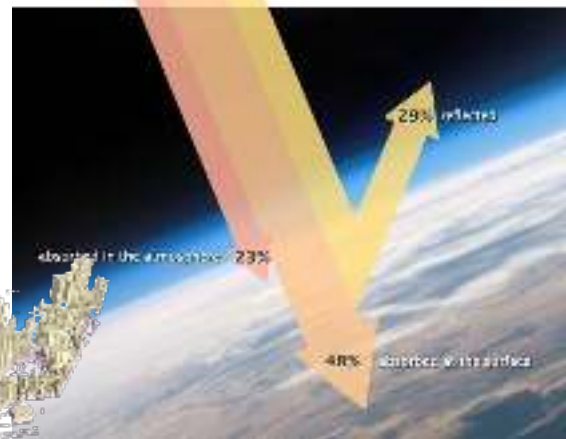
- ▣ No albedo, even not accurate in 3D



“Cool” roofs (Source: Lawrence Berkeley Laboratory)



2.5D “block” city map



Radiative forcing (Source: Wikipedia)

1.4 Opportunity and aims

- ◆ LiDAR data (infrared laser)

▣ Light Detection and Ranging

- Different devices: total station, vehicle-borne, drone

▣ Aerial LiDAR from drones / fixed-wing aircraft

- Large-scale
- Uniform point density (4~1,000 pts/m²)
- Laser reflectance (almost *linear* to albedo) (Levinson et al. 2014)
- Rooftop details

◆ Semantic enrichment using LiDAR ?

Geometry

- Non-geometric, e.g., albedo, green roof

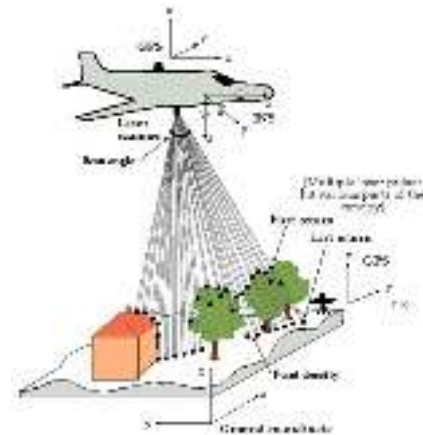
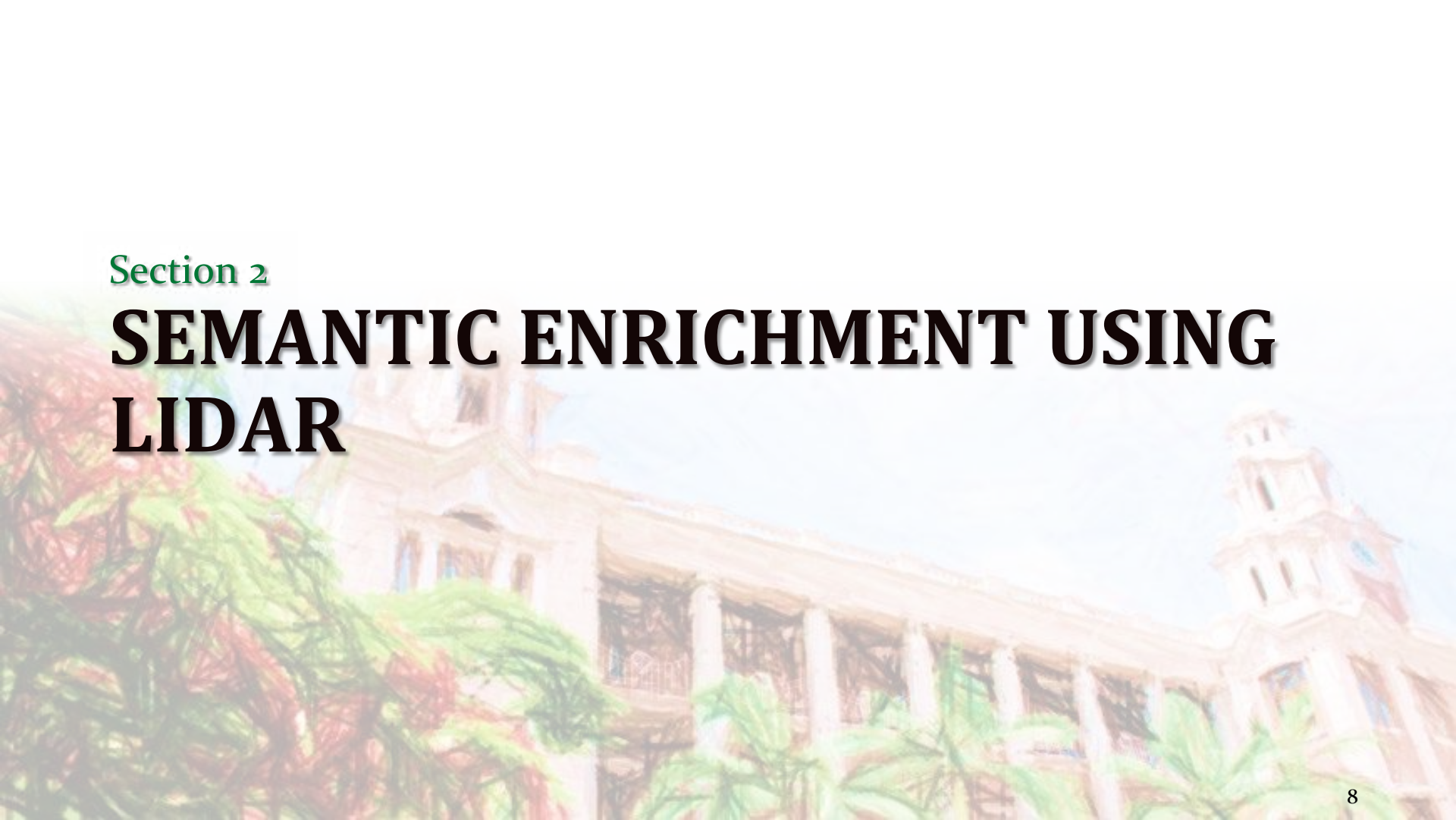


Illustration of aerial LiDAR



Infrared laser reflectance
(warmer color = less received) 7

The background of the slide is a photograph of a large, ornate building with a clock tower, likely a university or government building. The building is light-colored with many windows and columns. In the foreground, there are lush green palm trees and other tropical foliage. The sky is a clear, pale blue.

Section 2

SEMANTIC ENRICHMENT USING LIDAR

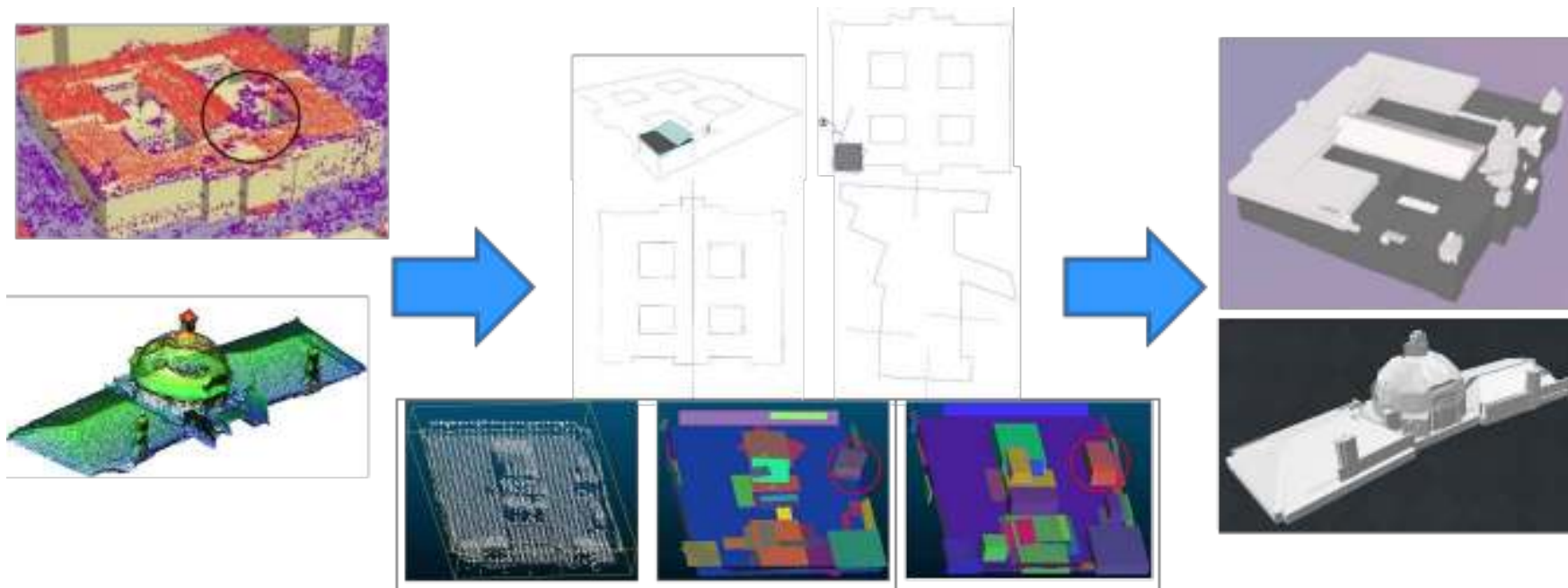


2.1 Semantic enrichment: Geometry



iLab

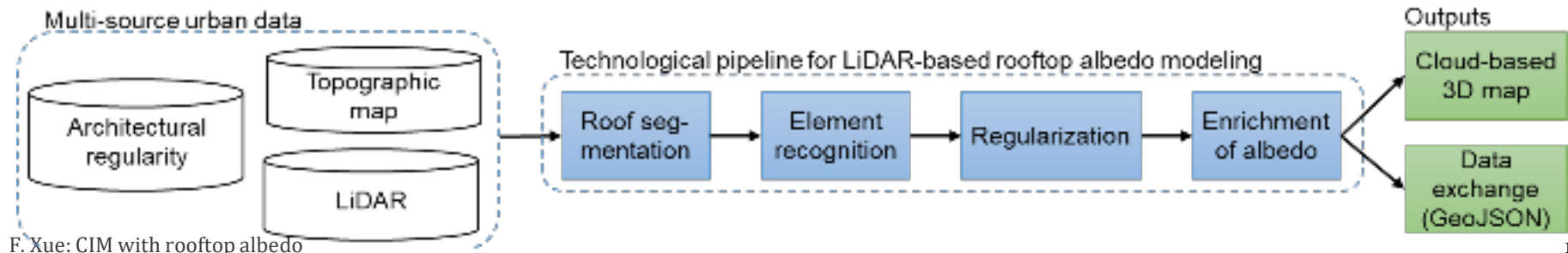
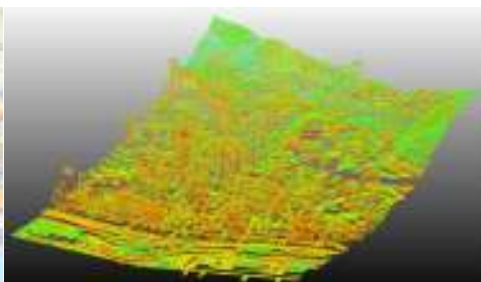
◇ LiDAR → RANSAC → rectification → LoD2 model (Chen et al. 2018)





iLab

2.2 Semantic enrichment: Rooftop albedo





2.2 Semantic enrichment: Green roofs prediction



◇ Geometry + albedo → material prediction, e.g., green roofs (Tan et al. 2019)

iLab



Generated rooftop
objects from point clouds



Identified green roof areas
by machine learning



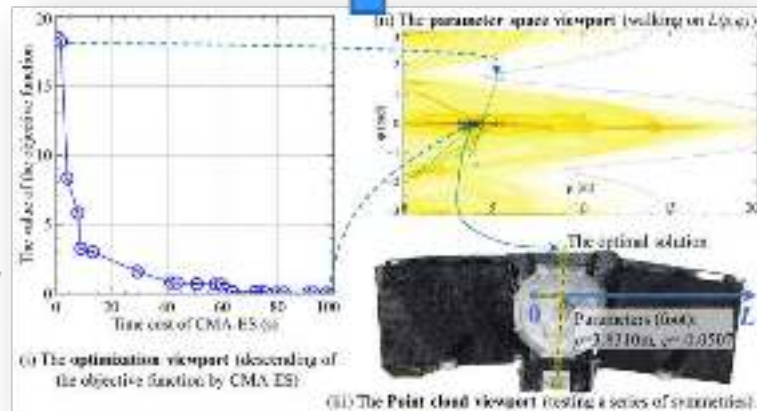
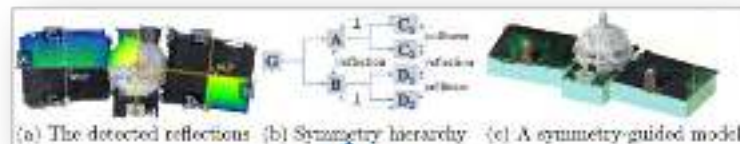
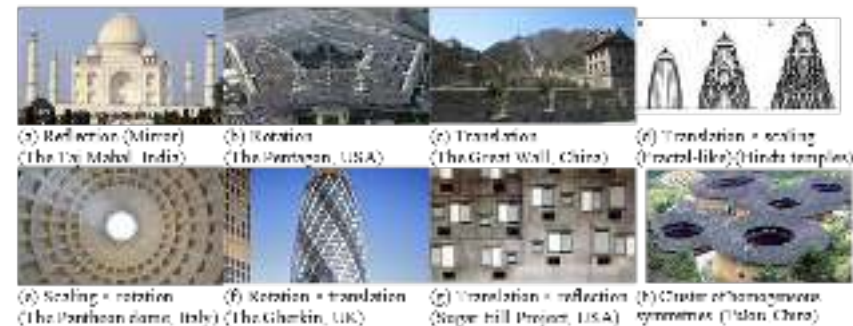
2.3 Semantic enrichment: Symmetry

◇ 3D point cloud $\rightarrow$ symmetry hierarchy (Xue et al., 2019)

▣ A knowledge discovery tool for further 3D modeling

▣ Time = 98.6s

▣ PCR = 93.7%



Section 3

DISCUSSION





3.1 Discussion



iLab

◆ A pilot study of rooftop albedo and materials prediction

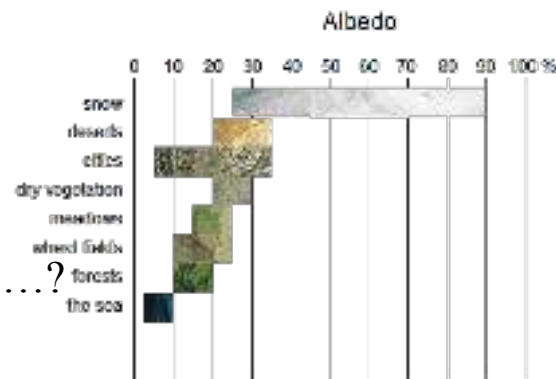
- ▣ From LiDAR point clouds
 - Using geometric features (from LiDAR)
 - Using laser reflectance (from LiDAR)
- ▣ For smart city applications
 - Simulations, heat island, micro climate, etc.

◆ Limitations

- ▣ A small-scale test
- ▣ No benchmarking against other methods

◆ In terms of excessive heat on roofs / micro climate

- ▣ Which is the best, green roof, PV panel, or simple white paint ...?
- ▣ “One size fits all ?” What are the trade-off ?





References



iLab

- ◆ Akbari, H., Menon, S. & Rosenfeld, A. 2009. Global cooling: Increasing world-wide urban albedos to offset CO₂. *Climatic Change*, 94(3-4): 275-286. doi:10.1007/s10584-008-9515-9
- ◆ Birkmann, J., Welle, T., Solecki, W., Lwasa, S., & Garschagen, M. (2016). Boost resilience of small and mid-sized cities. *Nature News*, 537(7622), 605.
- ◆ California Energy Commission. 2005. *California Energy Commission Building Energy Efficiency Standards, For Residential and Nonresidential*. Publication No. CEC-400-2006-015. Sacramento, CA, USA: California Energy Commission.
- ◆ Chen, K., Lu, W., **Xue, F.**, Tang, P., & Li, L. H. (2018). Automatic building information model reconstruction in high-density urban areas: Augmenting multi-source data with architectural knowledge. *Automation in Construction*, 93, 22-34.
- ◆ Levinson, R., Chen, S., Berdahl, P., Rosado, P. & Medina, L. A. 2014. Reflectometer measurement of roofing aggregate albedo. *Solar Energy*, 100: 159-171. doi:10.1016/j.solener.2013.11.006
- ◆ Rose, L. S., Akbari, H. & Taha, H. 2003. *Characterizing the fabric of the urban environment: a case study of Greater Houston, Texas*. Berkeley, CA, USA: Lawrence Berkeley National Laboratory.
- ◆ Rowley, J., & Hartley, R. (2017). *Organizing knowledge: an introduction to managing access to information*. Routledge.
- ◆ Tan, T., Chen, K., Lu, W., & **Xue, F.** (2019). Semantic Enrichment for Rooftop Modeling using Aerial LiDAR Reflectance. In *Proceedings of the 2019 IEEE International Conference on Signal Processing, Communications and Computing*.
- ◆ World Health Organization. (2015). *Global Report on Urban Health—Executive Summary*. http://www.who.int/kobe_centre/measuring/urban-global-report/en/
- ◆ **Xue, F.**, Chen, K., & Lu, W. (2019). Architectural symmetry detection from 3D urban point clouds: A derivative-free optimization (DFO) approach. In *Advances in Informatics and Computing in Civil and Construction Engineering* (pp. 513-519). Springer, Cham.



Thank you !

Q&A time

