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Personalized Walkability Assessment for Pedestrian Paths

An As-built BIM Approach Using Ubiquitous Augmented Reality (AR) Smartphone and Deep Transfer Learning

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on behalf of
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Outline

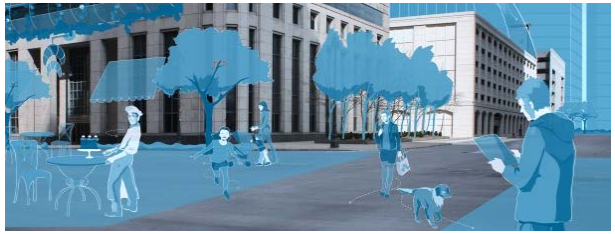
1. Introduction
2. An As-built BIM Approach
3. A Pilot Study
4. Discussion & Future Work

Section 1

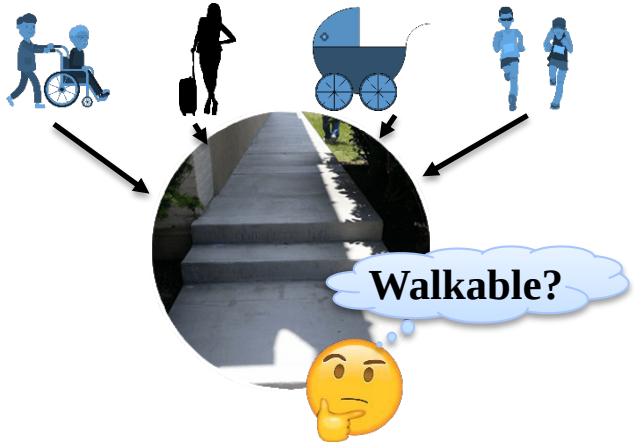
INTRODUCTION

1.1 Smart city, personalized walkability

- Smart city development
  - Settled by the government of many modern cities
  - Over 200 cities in China
- Smart living/ transportation
  - *Aims at making life more efficient, more controllable, economical, productive, integrated and sustainable* [1]
  - A pillar of smart city
- Personalized walkability
  - Meeting individual walking requirements of residents
  - Essential for smart living in smart cities
  - Demanding automatic (real-time, cheap) assessment
    - To handle the possible changes in paths



The rising of smart cities around the world
Photo source: siemens.com



Personalized walkability for smart living
Photo source: pixarba.com

1.2 Existing methods for Personalized Walkability Assessment (PWA)

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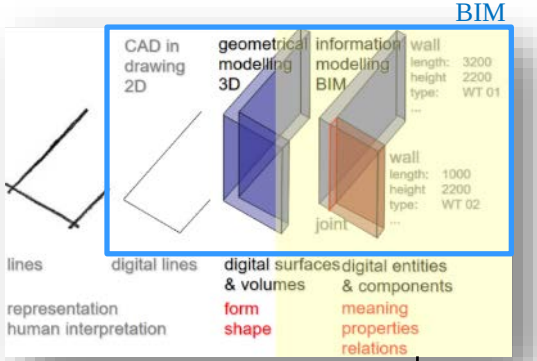
- Existing assessment methods suffers from (at least one)
  - Level of details
  - Automation of assessment
  - Personalized requirements
- So, we propose an as-built BIM approach for addressing the difficulties

Method	Input	Process by	Level of detail	Automation	Personalized	Example
Observational Audits	Walking Characteristics	Human experts	★★★★☆	★	☆	[2]
	StreetView (e.g., Google)	Human experts	★★★★☆	★★	☆	[3]
GIS-based	GPS records	Computers	★★	★★★★☆	★★	[4]
As-built BIM	*3D point clouds*	*Smartphone & computer*	★★★☆	★★★★☆	★★★★★	–

1.3 As-built BIM

- BIM (building information model/modeling)
  - *A digital representation* (“M”) *of physical & functional characteristics of a facility.* [5]
  - *A shared* (“I”) *… resource for information about a facility* (“B”)*, forming a reliable basis for decisions during its life cycle from inception onward.* [5]
  - Evolved from CAD (computer-aided design) [6]
- Why BIM, not GIS?
  - Semantically richer than GIS for PWA
- As-built (or as-is) BIM
  - As-designed → as-planned → *as-built* → as-demolished
  - Actual, current (real-time) conditions for PWA



An evolution view of CAD/BIM [6]

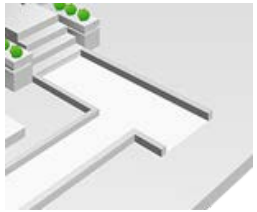
	Unit element	Emphasis
BIM	Component (3D, meanings, relations)	Temporal (Records, changes)
GIS	Data layer (mainly shapes)	Spatial (Fitting to the globe)

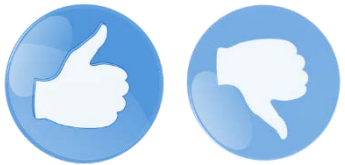
A quick comparison between BIM and GIS

Section 2

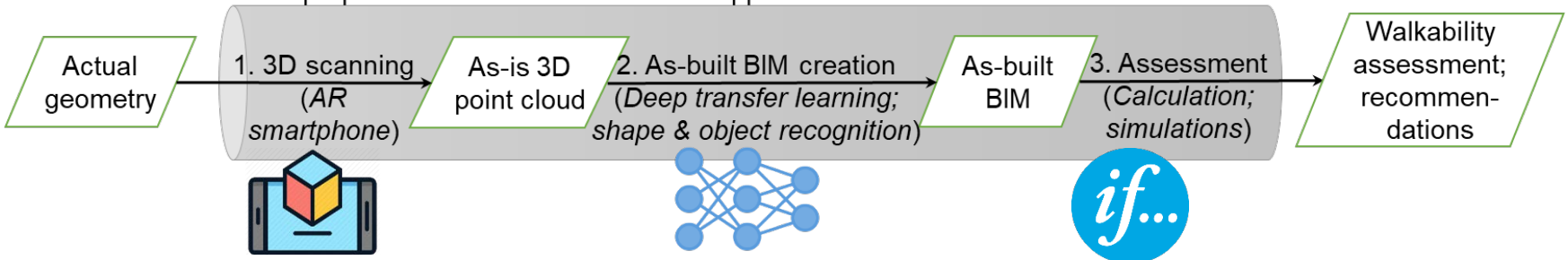
AN AS-BUILT BIM APPROACH

2.1 The conceptual framework





The proposed data-driven as-built BIM approach



- A three-step "pipeline"
  - 1. Actual path → As-is 3D point cloud
  - 2. As-is 3D point cloud → As-built BIM
  - 3. As-built BIM → PWA; recommendation

2.2 Technical details under the hood of Step 2

- Step 2: As-is 3D point cloud → As-built BIM
  - 2.1 Deep transfer learning [7-8]
    - As-is 3D point cloud → Semantically segmented points
    - *Method*: Pre-trained deep learning models (PointNet)
  - 2.2 Object modeling
    - Segmented points → 3D objects with meanings (semantic)
    - Data-driven shape fitting
    - *Method*: Improved RANSAC [9]
  - 2.3 As-built BIM creation
    - 3D objects → complete BIM with topology and relations
    - Model-driven
    - *Method*: Global optimization with constraints [10]

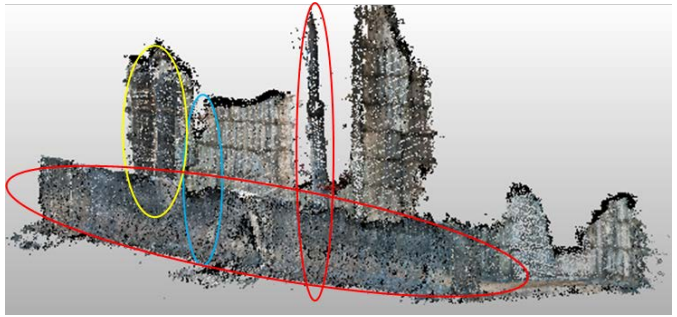
Section 3

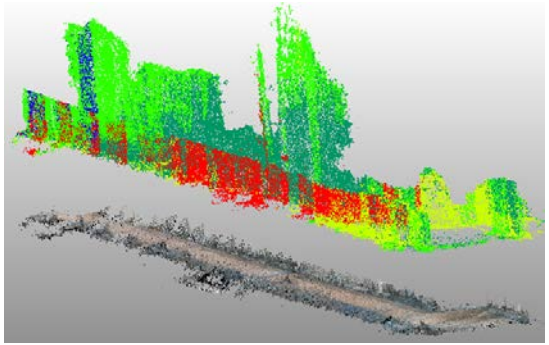
A PILOT STUDY

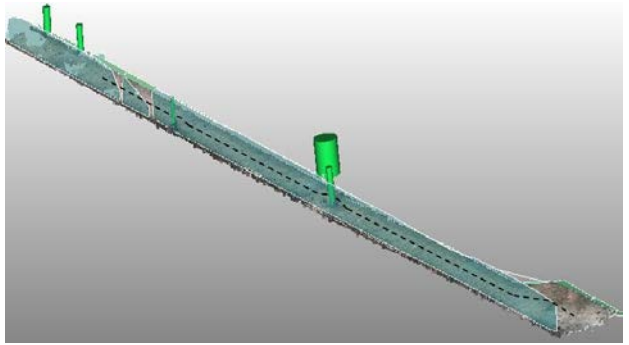
AROUND HKU

3.1 A street scene near HKU

(a) A scene of Bonham Road, Hong Kong

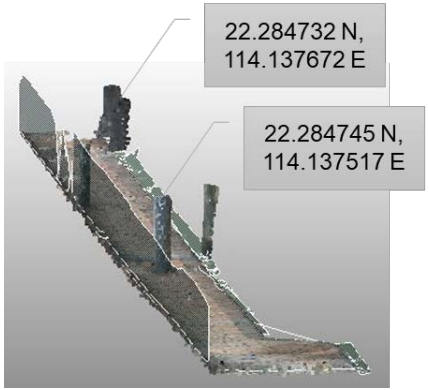

(b) As-is cloud of 569,344 points through AR scanning


(a) 3D point classification (*e.g.*, the points labeled as "manmade terrain" were detached as the pavement)

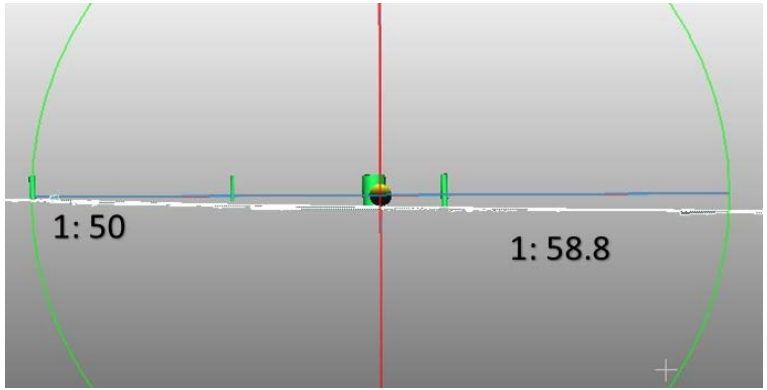

(b) As-built BIM consisting of semantic objects (walls omitted in this view)

- A narrow path
  - 1(a)
  - Guardrail
  - Obstacles
- 1: Phone scanning
  - 1(b) point cloud
- 2: As-built BIM
  - 2(a) segment
  - 2(b) modeling
  - 2(b) BIM

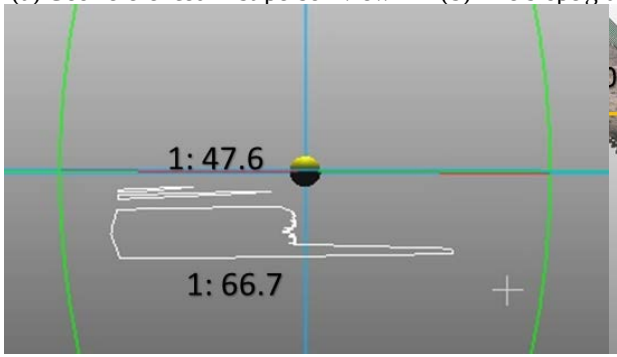
3.2 Analysis for PWA



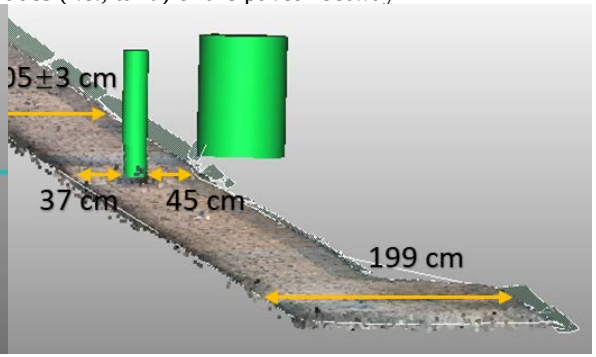
(a) Geo-referenced first-person view



(b) The slope grades (i.e., tanθ) of the paved footway



(c) The tilt grades of the paved footway



(d) The actual widths of the pavementwith obstacles

- 3: Assessment
  - 3(a) geo-referencing
  - 3(b) slope grade
  - 3(c) tilt grade
  - 3(d) footway width

3.3 PWA results and recommendations

- Examples of five types of pedestrians

Walking characteristic	Calculated value	Type of pedestrians				
		Wheelchair	Stroller	Luggage	Senior	Exercise
No. of steps	0	OK	OK	OK	OK	OK
Slope grade*	1:50.0~58.8	OK	OK	OK	OK	OK
Tilt grade†	1:47.6~66.7	OK	OK	OK	OK	OK
Footway width‡	45~199 cm	**Failed**	Limited	Limited	OK	OK
Clearance	Good	OK	OK	OK	OK	OK
Overall walkability (the worst)		**Failed**	Limited	Limited	OK	OK

*: Reference maximum slope grade: 1:8~12 (wheelchairs);
†: Reference maximum tilt grade of pavement: 1:15 (wheelchairs);
‡: Reference minimum width: 70~90 cm (wheelchairs), 40~70 cm (strollers), and 30~60 cm (baggage).

- Recommendation on possible obstacle removal

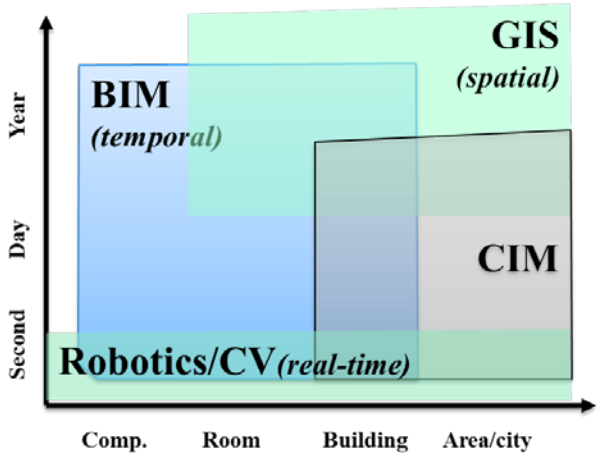
Major obstacles	Minor obstacles	Inoffensive obstacles
Light pole	(None)	Meter pole, drainage pipe #1, #2, and concrete trace on the wall

Section 4

DISCUSSION & FUTURE WORK

4.1 Discussion

- The proposed as-built BIM approach was confirmed
  - Can be automatic
    - Real-time
    - Inexpensive
  - Rich details
  - Personalized
  - Could be useful for other applications, too (see right)
- Yet still preliminary in
  - Test data set
  - Deep learning model
  - 3D object fine-tuning for better BIM
  - Completion and automation in PWA analysis



The spatial-temporal matrix of the interests of BIM, GIS, CIM. CV

4.2 On-going and future work

- Semantic prioritization
  - Identifying available urban semantics
  - Confirming most demanded semantics
- Data-driven 3D object modeling
  - Geometric regularity, e.g., symmetry
  - Interactive machine learning
- Model-driven as-built BIM creation
  - New semantic registration methods
  - More adaptive objects
- Everyday smartphone APP
  - To make an impact

References

- [1] European Commission (2014). Smart living. https://ec.europa.eu/docsroom/documents/13407/attachments/2/translations/en/renditions/native
- [2] Sun, G., Webster, C., and Chiaradia, A. (2017). Objective assessment of station approach routes: Development and reliability of an audit for walking environments around metro stations in China. Journal of Transport & Health, 4: 191-207.
- [3] Griew, P., Hillsdon, M., Foster, C., Coombes, E., Jones, A., and Wilkinson, P. (2013). Developing and testing a street audit tool using Google Street View to measure environmental supportiveness for physical activity. International Journal of Behavioral Nutrition and Physical Activity, 10(1): 103
- [4] Carlson, J. A., Saelens, B. E., Kerr, J., Schipperijn, J., Conway, T. L., Frank, L. D., Chapman, J. E., Glanz, K., Cain, K. L., and Sallis, J. F. (2015). Association between neighborhood walkability and GPS-measured walking, bicycling and vehicle time in adolescents. Health & Place, 32: 1-7.
- [5] National Institute of Building Sciences. (2015). National Building Information Modeling Standard. Version 3, Retrieved from https://www.nationalbimstandard.org/
- [6] Penttilä, H. (2007). Early architectural design and BIM. Computer-Aided Architectural Design Futures (CAADFutures 2007), 291-302.
- [7] Qi, C. R., Su, H., Mo, K., and Guibas, L. J. (2017). Pointnet: Deep learning on point sets for 3D classification and segmentation. Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition: 652-660. doi:10.1109/CVPR.2017.16
- [8] Hackel, T., Savinov, N., Ladicky, L., Wegner, J. D., Schindler, K., and Pollefeys, M. (2017). Semantic3D.Net: A new large-scale point cloud classification benchmark. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2017(IV-1-W1): 91-98.
- [9] Chen, K., Lu, W., Xue, F., Tang, P., and 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.
- [10] Xue, F., Lu, W., and Chen, K. (2018). Automatic generation of semantically rich as-built building information models using 2D images: A derivative-free optimization approach. Computer-Aided Civil and Infrastructure Engineering, in press, doi:10.1111/mice.12378.

- Chen, K., Lu, W., **Xue, F**., Tang, P., & Li, L. H. (2018a). Automatic building information model reconstruction in high-density urban areas: Augmenting multi-source data with architectural knowledge. Automation in Construction, 93, 22-34.
- Chen, K., Lu, W. S. ., **Xue, F**, Zheng, L. Z., & Liu, D. D. (2018b). Smart Gateway for Bridging BIM and Building. In Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate (pp. 1307-1316). Springer, Singapore.
- Harty, C., Goodier, C. I., Soetanto, R., Austin, S., Dainty, A. R., & Price, A. D. (2007). The futures of construction: a critical review of construction future studies. Construction Management and Economics, 25(5), 477-493.
- Gröger, G., Kolbe, T., & Czerwinski, A. (2007). Candidate OpenGIS CityGML Implementation Specification (City Geography Markup Language). Open Geospatial Consortium Inc, OGC.
- National Geographic Society. (2012). GIS (geographic information system). http://www.nationalgeographic.org/encyclopedia/geographic-information-system-gis/
- Niu, Y., Lu, W., **Xue, F**., Liu D., Chen, K., Fang, D., & Anumba, C. (2018). Towards the "Third Wave": An SCO-enabled occupational health and safety management system for construction. Safety Science. Under review
- Rowley, J. (2007). The wisdom hierarchy: representations of the DIKW hierarchy. Journal of information science, 33(2), 163-180.

Thank You !
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