Workshops at Zhejiang University
of Finance & Economics

Demystifying BIM & Innovation

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Outline

解密 ① **What BIM is, really**

创新 ② **BIM innovations at iLab, HKU**

实践 ③ **Barriers to systematic BIM adoption**

Aim and scope

◈ Aim of this presentation   ***目的***

  ▣ To revisit the concepts about BIM   审视基础概念

  ▣ To discuss BIM innovations   探讨创新

  ▣ To identify practical barriers   识别现实阻力

  ▣ To share several recent studies   分享若干新进展

  ▣ To demystify & promote BIM   推广BIM

◈ Scope   ***范畴***

  ▣ Extension: BIM and stakeholders   外延：BIM及利益相关者

  ▣ Intention: Semantics and collaboration 内涵：语义及协作

Xue, F., & Tan, T. (2018). Demystifying BIM & innovation. (ZUFE Workshops-2018, Hangzhou, China)
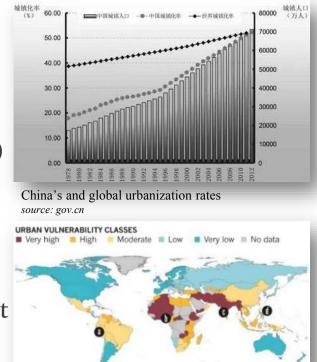
WHAT BIM IS, REALLY

1.1 Background

◈ Global urbanization 全球城镇化

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

◈ Leads to urban vulnerability (a.k.a. 'urban 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 decision supports 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*

1.1 Background (cont.)

iLab

◈ Construction is known as a "backward industry" 建筑业

  ▣ Low productivity, labor-intensive (*v.s.* aging workers)

  ▣ Fatality, occupational hazards, management (*e.g.*, cost overrun)

◈ A consensus of global research institutes (e.g., Harty et al., 2007)

  ▣ Effective (productive, automatic, age friendly) and efficient (safer, profitable, on-time, sustainable) industry

◈ Meets new *information communication tech.* (ICT) 机遇
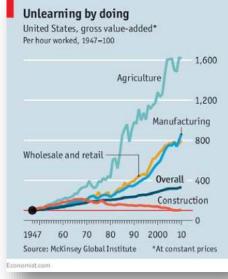
  ▣ Computing power

  ▣ *Urban big data*

      o BIM, RFID, LiDAR, GPS, UAV, CV, VR/AR, smart phones…

      o Three "V"s: Volume, velocity, & variety

◈ Calls for a collaboration data hub: BIM

Unlearning by doing
United States, gross value-added*
Per hour worked, 1947=100

USA's gross value-added by sectors
source: economist.com

Recent advances in ICT

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1.2 BIM

◈ BIM (building information model/modeling) 定义

■ *A digital representation of physical & functional characteristics of a facility.* (NIBS, 2015)
"M" ... "I"

■ *A shared … resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward.* (NIBS, 2015)
"B"

An evolution view of CAD/BIM (Penttilä, 2007)

◈ Evolved from CAD (computer-aided design) (Penttilä, 2007)
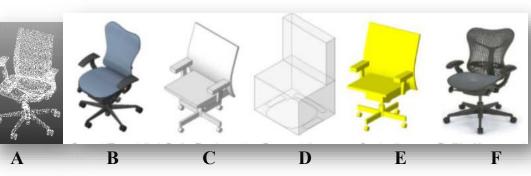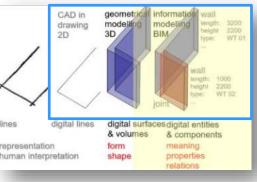
◈ Essence 本质

■ Urban semantics database ("**I**")

■ Component (unit facility) based

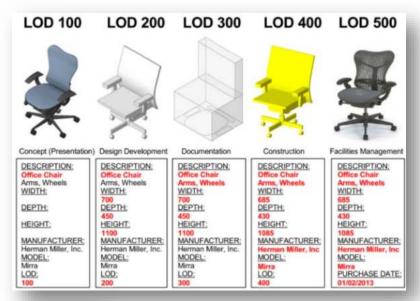 ○ "Family" and "instance"

◈ A quiz: Which is ***not*** BIM?

A   B   C   D   E   F

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1.2 Semantics focused in BIM

◈ BIM LOD (Level of Development)

   ▣ Previously "Level of Detail"

Arch.
↓

   ▣ LOD 100：For concept presentation

Eng.
↓

   ▣ LOD 200：For design development

   ▣ LOD 300：For 2D documentation

Const.
↓

      ○ LOD 350 construction 3D documents

O&M
↓

   ▣ LOD 400：For construction stage

   ▣ LOD 500：For facilities management

Demo.

◈ Focused semantics

   ▣ *Temporal* development 时间进展

   ▣ Abstracted family > exact geometry

What is called LOD
Source: PracticalBIM.net

No LOD : Data only
data, needs processing to info., then to BIM
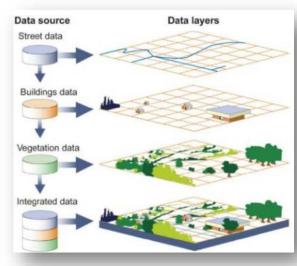
1.2 GIS – For comparison

◈ GIS (geographic information system)

- ▣ *A computer system for capturing, storing, checking, and displaying data related to <u>positions</u> on <u>Earth's surface</u>* (NGS, 2012)   "I"   "G"

- ▣ Evolved from DBMS (database management system)

◈ Essence

- ▣ Urban semantics database ("**I**")

- ▣ Data tables (layers) based

  - ○ *Independent objects (rows) in each table*
  - ○ *A few discussion on component-based GIS, too*

◈ A quiz: Which is ***not*** GIS?

   Which are ***not*** BIM?

Data source   Data layers
Street data

Buildings data

Vegetation data

Integrated data

GIS interpretation
Source: US Government Accountability Office

A   B   C   D   E   F

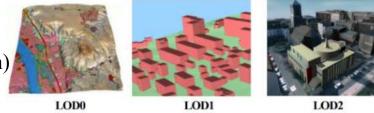# 1.2 Semantics focused in GIS – For comparison

◆ GIS LOD (Level of Detailing)

- ▣ Defined in CityGML (by Open GIS Consortium)
- ▣ LOD0 : Region and landscape
- ▣ LOD1 : + Prismatic buildings model (flat roof)
- ▣ LOD2 : + Roof and thematic surfaces
- ▣ LOD3 : + Detailed exterior (wall and roof)
- ▣ LOD4 : + Interior (indoor)

◆ Focused semantics

- ▣ *Spatial* details
- ▣ Exact geometry > abstracted concepts

◆ BIM/GIS integration

- ▣ In both academia and industry

GIS Level of Detailing (Gröger et al., 2007)

BIM-GIS integration   *Source: ESRI.com*

1.3 The "I": Information & semantics

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◈ Information is the meaning of data (Rowley & Hartley, 2017)

  ▣ *Abstracted*, inferred from data

  ▣ Answering interrogative questions (*what, who, where, when*)

  ▣ Semantics is a subset of information (Floridi, 2005) 语义是一种信息

◈ Urban semantics
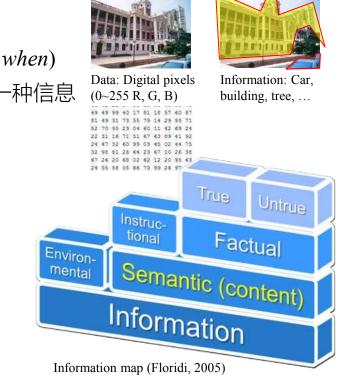
  ▣ Geometric / Non-geometric facts:

    ○ Size, location / function, materials, history, etc.

  ▣ Instructions (how-to):

    ○ Manufacturing, installation, access, etc.

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

Information: Car, building, tree, …

Information map (Floridi, 2005)

1.3 The "I": Target (factual) semantics (Chen et al., 2018b)

◈ "I" = 3D shapes? And textures?
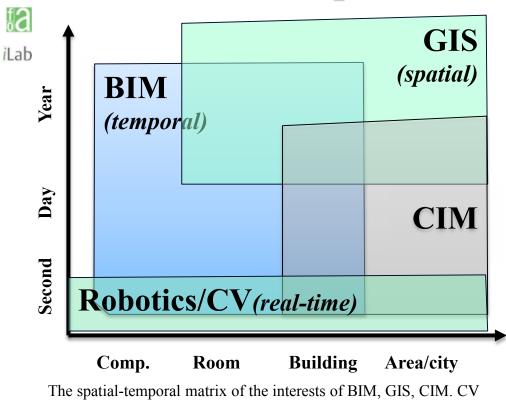
	Geometric	Non-geometric
Construction	• Site information (coordinate's data and layout) • Building spaces (floor, zones, rooms, openings) • Utility lines • Dimension of building components	• Construction materials (status, quality, category, manufacturer) • Precast elements (quality, category, manufacturer) • Equipment attributes (ID, type, status) • Financial data • Location of labor, materials, and machine • Project performance data • Construction schedule • Construction activity status • Site environment
Operation & maintenance (O&M)	• Building services (location, relationship) • Building spaces (floor, zones, rooms, openings) • Utility lines • Specification of exterior enclosure products • Furnishing	• Building services (identification number, manufacturer) • Status of mechanical, electrical, & plumbing equipment • Maintenance record • Indoor environment • Attributes of replaced components • Maintenance status • Maintenance schedule • Operation records

1.3 The "I": List of semantics standards (Wang et al., 2018)

Research/ industry	Application Scenario	Object Parameters
Pratt (2004)	BIM object contents exchange	Functional type; Geometry; Attributes; Relations between objects; Behavioural rules.
Belsky et al. (2016)	Semantic enrichment for BIM objects	Function; Geometry; Material; Identity; Aggregation relationships; Composition relationships.
Chen and Wu (2013)	Parametric BIM object modelling	Basic Object Data (Identification, Classification, Geometry, Quantities, and Phasing); Representation data (Material)
Open Geospatial Consortium (OGC, 2007)	Object data description in CityGML for virtual 3D city and landscape	Geometrical, Topological, Semantic, and Appearance properties.
Autodesk Revit (2017)	Modelling and professional analysis (e.g. thermal)	Identification (number, name, type, description); Classification (OmniClass code and description); Geometry; Material; Quantities; Manufacturer; Cost; Phasing; LEED, Thermal and Structural Properties, etc.
RIBA, UK (2014)	Object data description defined in NBS BIM Object Standard	Authorship, Identification (name, Uniclass code, and product link), Manufacturer, NBS description, and reference, etc.
NIBS, USA (2012)	Information Collection via Cobie to improve handover to owner-operator	Authorship, Identification (created by, category, Description, type, code, etc.) Manufacturer, Warranty, Geometry, Material
CIBSE, UK (2016)	Product description for manufacturer defined in Product Data Templates(PDTs)	Manufacturer, Construction, Application, Dimension, Performance, Electrical, Controls, Sustainability, Operations and Maintenance

1.3 The "I": Comparison to other technologies

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

◈ BIM, GIS, CIM, Robotics/CV
  ▣ Complementary and overlapping
  ▣ On the same urban objects
    ○ With focused semantics
◈ Integrated urban semantics is then
  ▣ Digital twin of the built environment
  ▣ Recognizable by machines
◈ For smarter city applications
  ▣ 4D, nD, temporal (building): BIM
  ▣ 4D, nD, temporal (area): CIM
  ▣ Spatial analysis (area): GIS
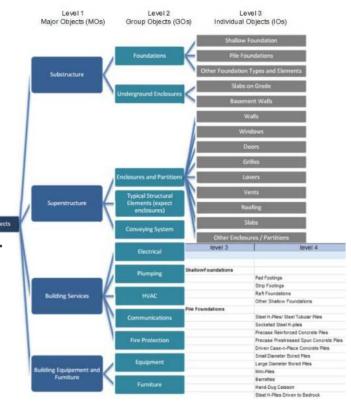 ▣ Real-time control: Robotics/CV

1.4 The "B": Universal vs. local

◈ Facilities in architecture is universal

- ▣ Substructure
- ▣ Superstructure
- ▣ Building services
- ▣ Equipment and furniture
- ▣ Site, etc.

◈ Building/BIM subjects to local regulations, e.g.

- ▣ Eurocode 3 - Design of steel structures - General rules and rules for buildings
- ▣ CPR 305/2011 Construction Products Regulation
- ▣ GB/T50002-2013 建筑模数协调标准

◈ 'One size does not fit all'

A taxonomy template for all BIM objects (Lu et al., 2017)

1.5 The "M": Model or modeling?

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◆ As "model" 模型

　　▣ A semantic database with a 3D/nD presentation

◆ As "modeling" 建模

　　▣ A more general process

◆ Life-cycle of "M"

　　▣ As-required BIM

　　▣ As-designed BIM

　　▣ As-planned BIM

　　▣ As-built (or as-is) BIM

　　▣ As-altered BIM

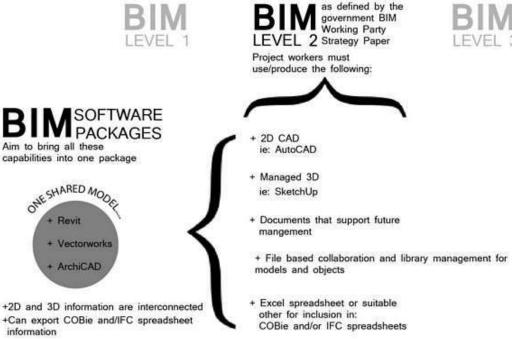　　▣ As-demolished BIM

Building & BIM

1.5 The "M": BIM software = Revit?

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◈ Semantics and files for BIM
- ▣ 2D CAD
- ▣ 3D structured objects
- ▣ PDF/Excel/IFC/ODBC DB

◈ Revit is a "glue" software

◈ Other "glue" includes
- ▣ ArchiCAD
- ▣ Vectorworks
- ▣ SketchUp
- ▣ Gloden

By 2016 any government funded projects or public projects over £5mil will have to comply to:

BIM LEVEL 1

BIM LEVEL 2 as defined by the government BIM Working Party Strategy Paper

Project workers must use/produce the following:

BIM LEVEL 3

BIM SOFTWARE PACKAGES
Aim to bring all these capabilities into one package

ONE SHARED MODEL...
- + Revit
- + Vectorworks
- + ArchiCAD

+2D and 3D information are interconnected
+Can export COBie and/IFC spreadsheet information

- + 2D CAD ie: AutoCAD
- + Managed 3D ie: SketchUp
- + Documents that support future mangement
- + File based collaboration and library management for models and objects
- + Excel spreadsheet or suitable other for inclusion in: COBie and/or IFC spreadsheets

Facets of the process of BIM *Source: thelandmarkpractice.com*

1.5 The "M": BIM Standards

◆ National standards

- ▣ NBIMS-US v3
- ▣ ISO 19650 Organization of information about construction works – Information management using building information modelling
- ▣ GB/T51212-2016 建筑工程信息模型应用统一标准

◆ Industry/stakeholder needs adapted standards

- ▣ Architectural design
- ▣ Engineering design
- ▣ Quantity surveying
- ▣ Construction
- ▣ Operation & Management

1.6 Recap of BIM demystification

◈ BIM

- ▣ Information infrastructure for construction & urbanization
- ▣ Foundation of collaborations
- ▣ More on concept/knowledge than on geometry
- ▣ Localization for each nation
- ▣ Localization for each stakeholder/industry
- ▣ Either a model or a process
- ▣ Variants in different stage of a building
- ▣ Many supporting software and formats
- ▣ Many standards
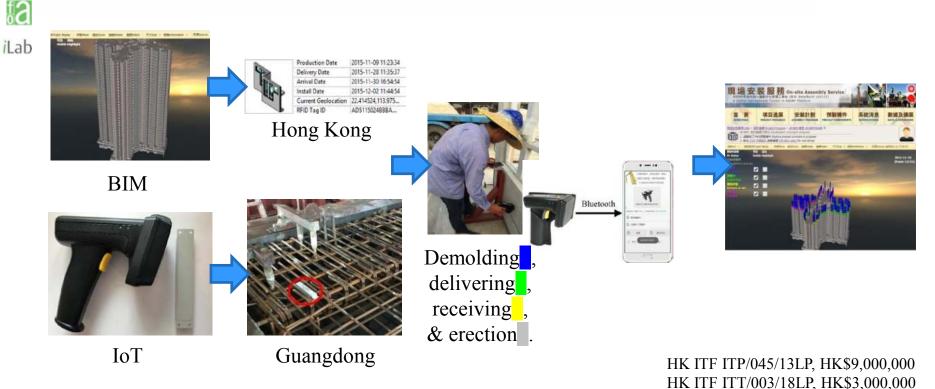
BIM INNOVATIONS AT ILAB, HKU

2.1 Innovation

◈ Innovation

   ▣ A buzzword that has over 40 definitions

   ▣ The essence, to me, it is combination

      ○ "There is nothing new under the sun." (Ecclesiastes 1:9)

   ▣ E.g., Swiss Army knife = knife + scissors + bottle opener + …

   ▣ E.g., Theory of relativity = Lorentz transformations + relative space & time

◈ For business, an innovation is

   ▣ Idea (brainstorming, many infeasible)

   ▣ Product (realized)

      ○ Most innovations go here

   ▣ Process (a systematic alternative comprising many new products)

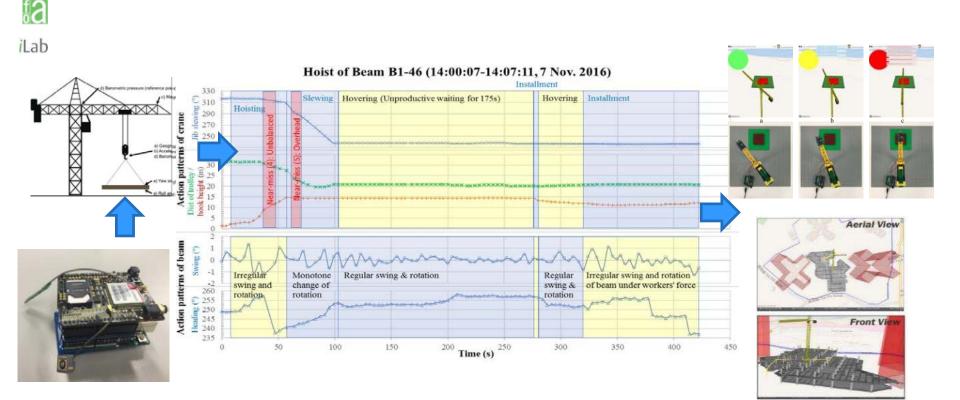   ○ Very difficult to make it happen, e.g., the overall BIM-centric business model

Swiss Army knife
Source: Wikipedia.org

2.1 Case 1: Progress monitoring = BIM + IoT

Hong Kong

BIM

IoT

Guangdong

Demolding ■,
delivering ■,
receiving ■,
& erection ■.

Bluetooth

HK ITF ITP/045/13LP, HK$9,000,000
HK ITF ITT/003/18LP, HK$3,000,000

Project video available at : https://www.youtube.com/watch?v=n8IRrweePIc

2.2 Case 1: Safety management = BIM + IoT (Niu et al., 2018)

Hoist of Beam B1-46 (14:00:07-14:07:11, 7 Nov. 2016)

2.3 Case 2: Semantic registration = BIM + PCD registration

◆ A dilemma of urban semantics in BIM/GIS

- ▣ *Inadequacy*: Poor semantics in the models
- ▣ *Overload*: Rich online open BIM/GIS resources
  - ○ With fact-nongeometric & instructional

◆ Semantic registration

- ▣ Registering semantics to low LOD models
- ▣ Input 1: Geometric measurement
- ▣ Input 2: Semantic components

◆ Performance metrics

- ▣ Computational time
- ▣ Precision = true positive / registered
- ▣ Recall = true positive / actual

Google Map/Earth? *~LOD2*
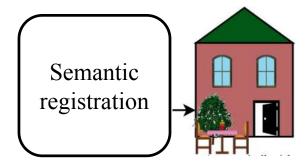
BIMobject.com has *>300,000* parametric BIM objects

Semantic registration

Semantic registration as a process

24

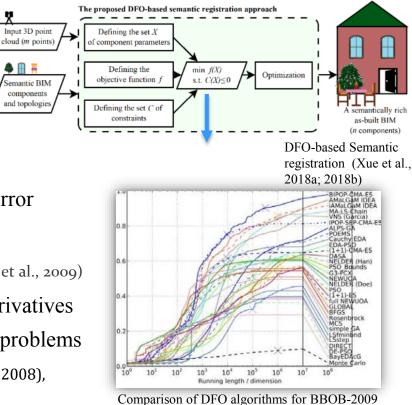# 2.4 Case 3: Automatic modeling = Case 2 + algorithm

- ◈ Semantic registration is a decision task
  - ▣ Can be automated through optimization
- ◈ Problem formulation (Xue et al., 2018a)
  - ▣ Input 1: E.g., 3D point cloud
  - ▣ *Variables* (*X*): transformation parameters
  - ▣ *Objective function* (*f*): minimum geometric error
  - ▣ *Constraints* (*C*): Topological regularity
- ◈ Derivative-free optimization (DFO) (Conn et al., 2009)
  - ▣ Solves problems comprising too complex derivatives
  - ▣ Succeeded in many science and engineering problems
    - ○ E.g., Protein folding (Nicosia & Stracquadanio, 2008), aircraft wing design (Lee, et al., 2008)

The proposed DFO-based semantic registration approach

DFO-based Semantic registration (Xue et al., 2018a; 2018b)

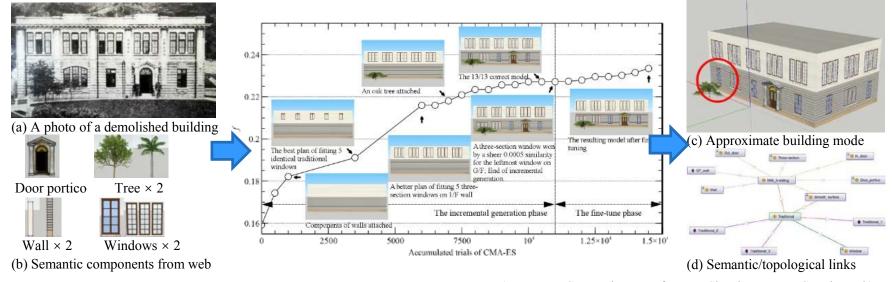Comparison of DFO algorithms for BBOB-2009 (Auger et al., 2010) *Source: Inria*

◈ 2D photo + free BIM objects → LOD3/300 3D models

- Automatic, error tolerant, recoverable from wrong objects
- Segmentation-free, topological relationships involved

- Time: 2.5h
- Precision: 0.92
- Recall: 0.92

(a) A photo of a demolished building

Door portico   Tree × 2

Wall × 2   Windows × 2

(b) Semantic components from web

(c) Approximate building mode

(d) Semantic/topological links

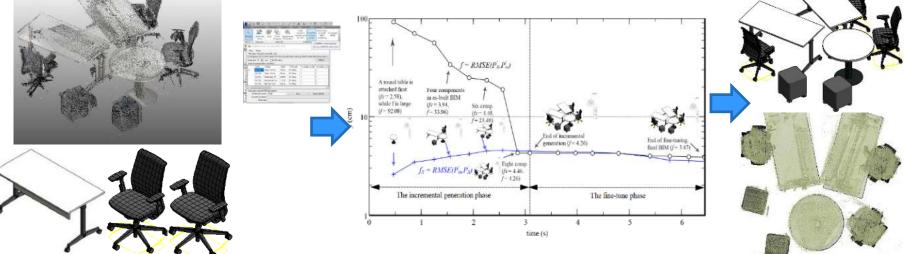(Language: C++, Ruby; Data formats: SketchUp, Bmp, Google earth) 26

2.4 An indoor case (Xue et al., 2018b)

◆ Point cloud + BIM objects → LOD 4/500 indoor model

- ▣ Automatic, saved 98% time from manual modeling
- ▣ *RMSE* = 3.87cm, equal to experienced modelers

▣ Time: 6.44s

▣ Precision: 1.0

▣ Recall: 1.0

(Language: C++, CLR; Data formats: Autodesk Revit, Stanford polygon)

Xue, F., & Tan, T. (2018). Demystifying BIM & innovation. (ZUFE Workshops-2018, Hangzhou, China)

2.4 A demo video

Xue, F., & Tan, H. (2018). Demystifying BIM & innovation. (EG-ICE Workshops 2018, Hangzhou, China)

2.5 Recap of innovation demystification

◈ Innovation

- ▣ Is combination, everywhere
- ▣ Concept, product, process (business perspective)
- ▣ BIM is an open urban semantic database
- ▣ BIM can connect to many construction hardware & software
  - ○ New sensors (e.g., IoT)
  - ○ New data processing (e.g., PCD registration)
  - ○ New algorithms (e.g., DFO)
- ▣ But, process innovation is very difficult

Xue, F., & Tan, T. (2018). Demystifying BIM & innovation. (ZUFE Workshops-2018, Hangzhou, China)

Section 3
PRACTICAL BARRIERS TO BIM

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THANK YOU !